Large Scale Demonstration Desalination Feasibility Study

Corpus Christi, Texas

City of Corpus Christi

Texas Water Development Board

Turner Collie & Braden

BHP Engineering & Construction, Inc.
LBG-Guyton Associates • LNV Engineering
Metcalf & Eddy • Olivarri & Associates, Inc.
RVE, Inc. • George Ward, PhD

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Executive Summary

EXECUTIVE SUMMARY

1 INTRODUCTION

The State of Texas has experienced significant population growth over the last 50 years in recognition of its scenic beauty, robust economy, recreational opportunities, and desirable living conditions. This growth has led to increased pressure to develop additional water resources to meet the growing demand. In addition, there is an increasing concentration of population in coastal areas throughout the United States, and the establishment of desalination facilities in coastal communities has the potential for providing new resources already located in fast growing areas. There is legislation in the United States Congress to establish subsidies for seawater desalination projects as a benefit to the nation as a whole.

Governor Perry, in recognizing the need to develop additional water resources for Texas, has established a desalination initiative to determine whether those needed resources can be obtained from desalination of seawater. Three projects were funded by the Texas Water Development Board (TWDB) in the upper, middle, and lower coast regions of Texas to explore this possibility. This summary details the investigation of a potential desalination facility in the Corpus Christi area and discusses elemental factors and benefits involved.

Corpus Christi has a number of factors that make it an optimum location for a seawater desalination project. Those factors are as follows:

- Largest Texas Gulf Coast city with strategic port
- Largest industrial city in attainment status for air quality
- Progressive history of long-range water planning
  - Garwood water supply/Bay City-Mary Rhodes Pipeline
  - Texana water supply/Mary Rhodes Pipeline
  - Water demands met through 2052
- Regional water system
- Proximity to users
- Local and regional support
- Potential to supply future customers
- Prime coastal desalination site

As noted above, the City of Corpus Christi has developed sufficient water supplies to meet its needs and the needs of its customers for the next 50 years. However, those water supplies are obtained from distant multiple surrounding watersheds and not from within the City or its service area. See *Corpus Christi Regional Water System* map attached. If seawater desalination is a feasible alternative to provide increased supply to the City of Corpus Christi, then other water-short regions of the State could potentially benefit from the diversion of some of Corpus Christi's existing supplies to those locations.

2 SCOPE

The scope of the *Large Scale Demonstration Desalination Feasibility Study* comprises the following:

- Takes the initial first step in determining the overall parameters under which a desalination plant might operate
- Explains the processes, costs involved, and decisions applied in determining alternatives
- Ultimately determines whether any fatal flaws exist which would make the project not feasible

Several specific scope tasks were examined and completed during the study and are listed below.

Scope tasks:

1. Site Requirements and Selection
2. Treatment
3. Source Water Blending
4. Potential Partners
5. Potential Customers
6. Power Sources
7. Project Funding and Development
8. Cost Model Development
9. Report

2.1 Task 1 – Site Requirements and Selection

An alternative site and process selection matrix was used to determine the best location of the proposed plant as well as the type of treatment that would be required. Industrial sites in the Corpus Christi area were screened using several criteria such as available land area, interest in an on-site large scale desalination facility, existing seawater or baywater intake structure and associated withdrawal permit, and proximity to potential users of the finished product water or byproduct disposal area.

The initial screening of sites identified five sites that could potentially accommodate a large scale desalination facility. Interviews were conducted with the property owners and plant management and staff to verify the site availability and to discuss the viability and interest in co-locating a large scale desalination plant on the properties.

Based on this research, the Barney Davis Power Plant site appeared to have the greatest potential for siting the desalination facility. The site is located close to the Gulf of Mexico, and it has a large capacity intake into Laguna Madre, available land area, and an outfall facility with cooling ponds discharging into Oso Bay. However, the owners of the Barney Davis Power Plant were in the process of selling this facility as well as several other power generating facilities, and they did not want to encumber the site with commitments or restrictions that could impact the potential sale.

Because of the available land area and the beneficial location of the Barney Davis site, this site was retained for detailed evaluation. However, because of the uncertainty of the long-term future viability of the site as a power generation facility, the resources on the site, such as the intake and the outfall facilities, were not considered to be available to the desalination facility. The initial analysis of the Barney Davis site was based on developing a desalination facility that would supply all of its own resources and not rely on shared uses with the Barney Davis Power Plant.

The uncertainty of the long-term use of the Barney Davis Power Plant resulted in the retention of the second ranked site for detailed evaluation for the potential development of a large scale desalination facility. Two sites that were retained for detailed evaluations are the DuPont-Oxychem site and the Barney Davis Power Plant site.

Within days of the conclusion of the study, the evaluation team received confirmation that the sale of the Barney Davis site was consummated and that the new owners of the facility were interested in co-locating a large scale desalination facility on the property. They also indicated a willingness to allow shared use of their on-site resources such as the intake facilities and the outfall system. A quick review indicated that this shared use of resources could eliminate the cost of the open sea intake, the raw water pipeline, the raw water pump station and the byproduct outfall facilities—potentially saving as much as $80 million in construction costs. Optimized alternatives of the Barney Davis site using the shared resources were then developed and included in *Chapter 4, Section 6.1* of the Report. Additional research is required to fully develop the benefits of the optimized alternatives. Therefore, the optimized alternatives are not identified as official alternatives but are presented for consideration for future analysis and possible significant cost reductions.

2.2 Task 2 – Treatment and Byproduct Management

Introduction

The initial screening produced five sites that met the minimum criteria, which were then narrowed to two, the Oxychem site on the north side of Corpus Christi Bay and the Barney Davis Power Plant located south of Corpus Christi Bay and between Laguna Madre and Oso Bay. Four alternatives were developed for each site that included different combinations of intakes, raw water sources, pre-treatment options, byproduct management, and pipeline costs. A detailed, weighted decision matrix evaluation technique was used to compare each of the eight alternatives. The following paragraphs describe the options that were considered for each of the facility components for the Intake, Pre-Treatment, Primary Treatment, and Byproduct Management.

Intakes

The intake selection must be based on the raw water source location and must consider quality, environmental impacts, intake technology, and costs. Therefore, the intake selection is only a component of the entire alternative of which it is a part. No single intake option is optimum for all alternatives.

Considering the above intake factors, three intake concepts were evaluated for this project. The optimized alternatives used the existing intake structure at the Barney Davis Power Plant. See *The Barney Davis Power Plant Pipelines* figure attached. Other intake concepts considered included open sea intakes and infiltration intakes. All intake options must allow transport of raw water to the treatment plant site. For any option that uses the Gulf of Mexico as the raw water source, the raw water line must cross Padre Island and either Corpus Christi Bay, Red Fish Bay, or the Laguna Madre. Construction of raw water lines through environmentally sensitive areas greatly increases the cost and complexity of the project.

i. Existing Barney Davis Intake

The primary alternative developed for the project did not initially include the use of the existing intake at the Barney Davis Power Plant because of the uncertainty regarding ownership of the facility. The original owner was attempting to sell the power plant and did not want to encumber the site with any commitments that might inhibit the sale of the property. Also, the long-term operation of the Barney Davis Power Plant was in question.

In addition to the questions regarding ownership, the design team had developed a desired baseline water quality of 35,000 mg/l as a target for raw water to be treated. The Laguna Madre water used at the Barney Davis Power Plant for cooling has extended periods of time when salinities are above 35,000 mg/l; therefore, efforts were directed at determining the availability of brackish groundwater to blend with the Laguna Madre water to meet the 35,000 mg/l salinity limitation. These efforts were unsuccessful due to the lack of availability of groundwater with appropriate levels of total dissolved solids.

For all of the reasons noted above, the primary alternatives were developed based on not using the existing intake at the Barney Davis Power Plant.

Several days before the project was finalized, it was learned that the sale of the Barney Davis Power Plant had been consummated and the new owners intended to be cooperative with the concept of co-locating a desalination facility onsite including use of the existing intake facilities. As a result of the change in ownership status, the recommended Barney Davis site alternative was optimized to include the use of the existing intake facilities. For the optimized alternatives, all modifications necessary to obtain raw water were included in other on-site facilities, and no changes or modifications are anticipated for the intake. The benefits of using the existing intake are somewhat offset by the necessity of increasing the plant size to handle the higher salinities during dry weather conditions.

ii. Open Sea Intake

The open sea intake consists of an onshore fine screen and a pipeline from the shore to the appropriate intake location terminating at the open sea inlet structure.

The open sea inlet structure has coarse screens with very low screen velocities, debris intake, and impingement, and it is constructed of concrete. This structure will be located on the sea floor and extend vertically to rise above the height of vegetation in the area. A 7-foot structure height was chosen for the analysis.

The pipeline between the open sea intake and the onshore fine screens uses high density polyethylene (HDPE) pipe. The sea bottom floor will be wet dredged to a sufficient depth to fully bury the pipe. A granular bedding and backfill will be provided to support the pipe, and a protective rock barrier and anchor will be placed over the top of the pipe. After construction, the finished grade of the sea floor will be returned to its original grade with the rock protective barrier as the finished grade material.

A fine screen assembly will be located onshore to screen finer particles from the intake stream. Multiple isolated screen assemblies will be used to allow periodic maintenance of these screens without affecting intake operations. Periodically these fine screens will be purged with a violent blast of air. The purged material will then be drained and the solid material removed from the purge stream. The cleansed purge stream will be returned to the open sea. The fine screens are located in a structure onshore to facilitate maintenance operations and shield the violent purging operations from sea traffic. If uncontained, the magnitude of the air blast could cause harm to small boats. Also, locating the fine screen onshore eliminates the need to design the raw water pipeline to withstand the high pressures required to deliver the air purge.

iii. Infiltration Intakes

Infiltration Galleries

Infiltration gallery intakes generally consist of drawing water through the existing or constructed soils to an onshore receptor, then pumping the water to the point of use. Infiltration gallery intakes, use the soils surrounding the collector pipes which act as the screening device. The passageways through the soils have very small openings that remove nearly all of the particulate matter from the seawater, thus producing a relatively high quality raw water stream. The alternatives that use the infiltration gallery intake concept have a greatly reduced pre-treatment requirement because of the high degree of filtering. Three types of infiltration gallery intakes were considered: caissons, linear collection wells, and Ranney collectors and are described in more detail below.

- ***Caissons***

Caisson infiltration galleries, also called vertical beach wells, are vertical shafts constructed as close to the shore as feasible to be close to the water source. These shafts could be 60 feet or more in depth with a spacing of 300 or more feet. The number of vertical beach wells would need to be developed based on the soils structure in the area, but it is estimated that at least 40 wells would be required. The 55-mgd intake capacity required for this desalination facility is more than twice the capacity of the largest known vertical beach well plant intake system in the world. This intake concept was not used in the development of any alternatives because of questionable long-term reliability, cost, high maintenance requirements, and large onshore land area requirements.

- ***Linear Collection Wells***

Linear collection wells are an enhanced version of the vertical beach well. Vertical caissons are constructed, but the collection system is enhanced by horizontal collector pipes buried parallel to the shoreline. All construction is performed onshore. Water is still drawn through the indigenous soils, and the system capacity is dependent on the structure of the soils. This option requires six caissons and 39,000 linear feet of horizontal collector pipes. This intake concept was not used in the development of any alternatives because of questionable long-term reliability, cost, high maintenance requirements, and large on-shore land area requirements.

- ***Ranney Collectors***

The Ranney collector infiltration gallery is an enhanced version of the linear collection well. Caissons are constructed onshore and horizontal collector pipes are constructed under the seabed. Each caisson can accommodate multiple collection legs to reduce the number of caissons. The Ranney collector configuration was used in the alternatives because it significantly reduced the amount of shoreline required to be dedicated to the intake system. The collector pipes could either be constructed by jacking techniques or could be wet dredged in a manner described in the open sea intake. If the collector pipes are jacked into place, the permeability of the existing soils would be the limiting factor on the number as well as the size and length of the collector pipes. If the collector pipes are installed with wet dredging techniques, the backfill and bedding materials could be manufactured and constructed to optimize intake performance. The alternatives that used infiltration galleries for the type of intake are based on using the Ranney collector infiltration gallery. The size and length of the collector pipes are based on using the jacking techniques for installation. The costs for a Ranney intake system were estimated using 39,000 linear feet of collector pipe.

Intake Options Summary

The intake options used in the development of alternatives included the existing Barney Davis intake, the open sea intake, and the Ranney collector intake. The vertical beach well and linear infiltration wells were eliminated for reasons previously stated.

Pros

The existing Barney Davis intake is the optimal intake choice for the following reasons:

- Intake already exists.
- Site is permitted.
- Configuration is compatible with the desalination facility.
- No construction of an expensive raw water line through Laguna Madre and Padre Island or into the Gulf of Mexico is required.

Cons

The existing Barney Davis intake would not make a good intake choice for the following reasons:

- The source of water available at this location is from Laguna Madre and is hypersaline.
- The hypersalinity of the water increases the capital and operating costs of the system, which partially offsets the savings from using the existing facilities.

However, even accounting for these offsetting factors, the use of the existing Barney Davis intake is the recommended intake concept if a final agreement can be reached with the property owners and the project is determined to be feasible from an environmental standpoint.

Conclusion

The open sea intake is considered the next most viable intake primarily because of the long-term reliability compared to the Ranney collector system. The cost of the open sea intake is less than the cost of constructing the Ranney collector, but the reduction in pre-treatment requirements makes the Ranney collector less costly on a total life cycle basis for the evaluation of a complete alternative.

Pre-Treatment

The reverse osmosis (RO) process requires a high quality feedwater to minimize fouling, maximize membrane life, and provide efficient treatment.

Initially, nine candidate pre-treatment options were identified for consideration including:

1. Direct filtration (eliminated prior to pre-screening as not applicable)
2. Conventional flocculation, sedimentation, and filtration
3. Solids contact clarification (Accelator) and filtration
4. Plate or tube settler clarification and filtration

5. Pulsator or Superpulsator clarification and filtration
6. Dissolved air flotation (DAF) clarification and filtration
7. Micro-sand enhanced clarification and filtration
8. Ultrafiltration using immersed membranes (Zenon)
9. Infiltration galleries

After the pre-screening process, which is described in detail in the feasibility report, to achieve the required feedwater quality, four pre-treatment options were considered for detailed evaluation:

Option 1 – Plate or tube settler clarification with filtration

Option 2 – Dissolved air flotation clarification with filtration

Option 3 – Ultrafiltration using immersed membranes (Zenon)

Option 4 – Infiltration galleries using the Ranney collector

Option 4 is more precisely referred to as an intake system, but the screening process inherent to the system greatly reduces the pre-treatment requirements on the plant site.

Each of these options is described in more detail below.

Option 1 – Plate or Tube Settlers Clarification and Filtration

Plate or tube settlers followed by granular media filtration are well proven in drinking water treatment. These systems have been effectively used in seawater reverse osmosis and can be considered as a baseline approach capable of treating worst-case water quality. For this reason, they are included in the feasibility analysis as a “baseline” alternative of accepted practice.

Pros

- The enhancements of the tube or plate settlers result in a much smaller process footprint than for conventional sedimentation.
- Clarified turbidity may be slightly higher than for conventional sedimentation, but low turbidities are still achieved through subsequent filtration.
- Residuals concentrations are in an acceptable range of 0.1 to 0.5 percent solids.

Cons

- Susceptible to rapid changes in water temperature.
- Limited in treating high turbidity and algae.
- The tube openings in tube settlers can become blocked with algae and solids which creates short-circuiting and deterioration in clarifier performance.

Conclusion

Plate and tube settlers are being replaced with more advanced and innovative technologies as described in Options 2 through 4 below.

Option 2 – Dissolved Air Flotation (DAF) Clarification and Filtration

Pros

DAF offers several pre-treatment advantages:

- Achieves very low clarifier effluent turbidities of less than 0.5 NTU and a high level of performance even without using a polymer, which can be an advantage in pre-treatment ahead of RO.
- Not susceptible to thermal variation and has demonstrated significant advantages in treating very cold (dense) water, thus DAF may be very effective in treating high density seawater.
- Proven premier clarifier for treating large concentrations of algae, which are notoriously difficult to settle. This may be a distinct advantage in treatment of seawater where red tides or algae may be of concern.
- DAF followed by granular media filtration can easily treat the expected worst-case raw seawater quality.

Potentially important advantages include:

- Can produce a residual concentration of up to 2 percent solids when mechanical extraction is used. This sludge concentration is about four times the maximum solids concentration achievable with plate, tube, Accelator, or sludge blanket clarifiers.
- Mechanically extracted DAF residuals can be fed directly to dewatering processes such as belt filter presses or centrifuges without further thickening.

DAF is extremely well proven from pilot tests conducted for large plants as indicated by designs for Boston, Massachusetts, at 450 mgd and the New York City Croton Water Treatment Plant at

290 mgd. When the DAF is located above the filtration units, the maximum surface loading rate of both the DAF and the filter must be limited to less than 5 gpm/sf.

Conclusions

For the reasons above, DAF clarification followed by granular media filtration is included as the most robust and favorable high-rate clarification technology to be considered in this analysis. The "stacked" DAF is the most advantageous configuration for reducing plant footprint and is evaluated in detail in the feasibility report.

Option 3 – Ultrafiltration Using Immersed Membranes

Membrane microfiltration (MF) and ultrafiltration (UF) (low pressure hollow fiber membrane treatment) technologies have developed rapidly over the last 5 years. In immersed UF systems, the membrane fibers are immersed in raw or coagulated water, and a vacuum is applied to the lumen of the fibers to draw the water through the membrane and into the lumen.

Pros

- UF membranes provide physical removal of solids, particles, algae, and physical disinfection by removal of pathogens such as *Giardia*, *Cryptosporidium*, and some viruses.

- MF and UF have demonstrated effectiveness for providing low silt density indices (SDI) ahead of high-pressure membrane processes such as nanofiltration (NF) and RO resulting in greater NF and RO process efficiency.

Cons

- Unless a coagulant is used, UF membranes do not remove color or organics.

There is some limited experience for MF and UF in seawater pre-treatment.

Conclusions

Because of the high degree of benefit that can be realized by using the Zeeweed process as a full replacement for both clarification and filtration and the proven robustness of the process, the Zenon Zeeweed 500D UF was selected for analysis as the immersed ultrafiltration process for comparison to the conventional pre-treatment approach using tube settler clarification and filtration and DAF filtration. Other approaches using other types of UF as a "filtration" replacement may be considered in the future when the plant is sited, water quality is confirmed, and residuals disposal options are known.

Option 4 – Infiltration Galleries

Bank filtration without pre-treatment was included in this feasibility study to capture the potential least cost process alternative with assumed worst-case water quality. A bank infiltration system is conceptualized to provide "physical" pre-treatment ahead of the RO. The infiltration galleries considerations are presented in *Section 2.2* under the *Intakes* heading. An ultraviolet radiation disinfection system is included on the plant site to assist in the removal of pathogens that are likely to pass through the infiltration galleries.

Summary of Pre-Treatment Options

Four alternatives for each treatment site were developed based on selecting compatible combinations of intakes, off-site pipeline, pre-treatment, and common elements (including RO components). A weighted prioritization method was used to evaluate the alternatives using the following factors as the decision criteria:

- Total life cycle cost
- Reliability
- Complexity of implementation

The intake pre-treatment combination using infiltration galleries was the least cost alternative, but this option received low marks for reliability and complexity of implementation. Tube and plate settlers and the DAF system have similar life cycle costs, but the DAF pre-treatment was determined to be more reliable than the tube and plate settler option. The immersed UF membrane was the most costly of the pre-treatment options, but it scored favorably in the reliability of treatment and complexity of implementation.

Conclusions

Based on the information available, the alternatives using DAF appeared to be the optimum pre-treatment options for the Corpus Christi Desalination project. It should be noted that in view of the cost competitive nature of this application and the long-term trend of decreasing costs of micro- and ultra-filtration membranes, the immersible membrane should also be considered for any future developments.

Treatment

RO is a state-of-the-art technology used in processing large scale desalination for raw waters containing a total dissolved solids concentration higher than 3,000 mg/l. Other technologies using thermal techniques, electrodialysis reversal, and other treatment processes have significant drawbacks for use with the raw water sources available in the Corpus Christi area and are only applicable in niche applications; therefore, RO is the only primary treatment process considered in this feasibility analysis.

Byproduct Management

Several potential options for byproduct disposal were considered including:

- Deep well injection
- Evaporative lagoons
- Offshore discharge
- Discharge to a wastewater treatment plant
- Membrane-thermal zero liquid discharge
- Beneficial reuse
- Dilution and discharge to Oso Bay

Deep Well Injection

Deep well injection required the construction of a minimum of 25 to 30 widely spaced wells with an estimated capacity of 1 mgd each. In addition to the wells, well distribution lines and high pressure injection pumps operating at approximately 1,000 psi are required. The cost of this byproduct disposal option was very high and was therefore eliminated from further consideration.

Evaporative Lagoons

In this option, large lagoons are constructed to contain the water until it is evaporated to atmosphere leaving only the salts behind. To evaporate 25 to 30 mgd of byproduct water would require a land area of 38,000 acres. Although evaporative lagoons were considered, the estimated cost for purchasing the land and constructing a lined lagoon system is over $2 billion and, therefore, is not considered a feasible solution.

Offshore Discharge

Offshore discharge is considered the most straightforward and reliable method of byproduct disposal. The byproduct stream will have a TDS concentration of twice the ambient conditions, but proper design of diffusion outfalls should minimize environmental impacts. The final location of the outfall will require further investigation.

The design of the outfall is important to assure that environmental impacts are minimized and that the discharged material does not migrate back to the intake area at concentrations higher than normal ambient conditions. To accomplish these features, the outfall needs to be located at the proper depth and distance from shore and sufficiently remote from the intake. To minimize cost, most of the discharge outfall pipe is constructed in the same trench as the intake line, but diverges at the appropriate location to attain the proper separation distances.

The relative locations of the outfall and discharge pipes must be determined by detailed hydraulic modeling during subsequent design phases. For this assessment, an estimate of a 0.25-mile (1,400 feet) separation distance was determined to be reasonable for planning purposes.

The byproduct outfall needs to be located in water deep enough to avoid conflicts with marine traffic but also shallow enough to benefit from mixing that results from surface wave action. For mixing and diffusion, a maximum water depth of 40 feet was chosen.

Two types of currents predominate in the Gulf of Mexico in this area, riptides and wind-driven currents. Riptides predominate along the coast and are generally contained within one-half mile of the shoreline. Riptides close to shore must be avoided to prevent the discharge from recirculating and possibly concentrating toward the shore. The wind-driven current in the area is known as the Texas Coastal Current. The Texas Coastal Current will aid in the mixing and dispersion of the byproduct stream and prevent the discharge from reaching the intake structure.

The 2.0-mile offshore distance was chosen as the optimum location in consideration of depth and currents in the area, as described above, and to ensure that riptides do not interfere.

Pros

Although significant and important environmental concerns would have to be addressed, it appears that discharging to the Gulf of Mexico offers the greatest opportunity for environmental support.

Cons

The byproduct stream would have a TDS concentration of twice the ambient conditions, but proper design of diffusion outfalls should minimize environmental impacts. The final location of the outfall requires further investigation.

Conclusion

Option 3 involves pumping the desalination byproduct stream approximately 2 miles offshore. Because the result is a diffused discharge that minimizes environmental impacts, offshore disposal was the selected byproduct disposal method.

A 2.0-mile offshore distance was chosen as the optimum location in consideration of depth and currents in the area as described above and to ensure that riptides do not interfere.

Discharge to a Wastewater Treatment Plant

Discharging the byproduct to a wastewater treatment plant was considered but quickly determined not to be viable. The byproduct stream would have a flow of approximately 25 mgd and a TDS concentration of 70,000 mg/l. The largest wastewater plant in the area, the Oso Treatment Plant, has a rated capacity of 16.2 mgd, and the effluent is used to dilute the hypersaline conditions in the bay. If the plant could be made to accommodate the proposed byproduct stream, the resultant dissolved solids concentration would be approximately 49,000 mg/l and would negatively impact Oso Bay's salinity.

Conclusion

This option was determined not to be feasible due to the negative salinity impact and, therefore, was eliminated.

Membrane-Thermal Zero Liquid Discharge (ZLD)

Zero liquid discharge technologies involve concentrating the byproduct stream to essentially dry salts and disposal of the dried cake residue. Research indicates that this technology is the most expensive of all byproduct disposal options and is only considered viable when a valuable byproduct can be recovered.

Conclusion

Due to the cost of this option and the lack of a reliable, long-term customer for the byproduct salts, this option was eliminated.

Beneficial Reuse

During the site selection investigations, a potential customer for seawater salts was found near the Oxychem site. The customer is currently trucking in saltwater at a concentration of 300,000 mg/l to use as a feedstock for their manufacturing facility. The processes to concentrate the byproduct to the desired concentration are similar to but not as extensive as the previously mentioned ZLD technology.

Cons

- High cost
- Entire desalination facility operations would be dependent on the economic viability of the product being manufactured by the byproduct customer.

Conclusion

This option was determined not to have satisfactory reliability as the sole disposal method for the byproduct stream and, therefore, was eliminated from consideration.

Dilution and Discharge to Oso Bay

The Barney Davis Power Plant currently has the ability and permits to withdraw over 500 mgd of water from Laguna Madre for cooling and then discharge the warmed water through cooling ponds and release it into Oso Bay. Oso Bay is a flow limited body of water, and the continued circulating flow from the cooling tower operations is considered highly beneficial, even though the salinity of the discharge is higher than background conditions in Oso Bay. The byproduct stream from the desalination facility is approximately 25 mgd with a salinity of 70,000 mg/l. Combining the cooling water discharge with the byproduct stream would increase the salinity of the discharge to Oso Bay by approximately 5 percent.

Conclusion

This option represents a significant cost savings from all other options and should be considered in all future discussions and evaluations.

Byproduct Management Summary

Of all the options for byproduct stream disposal, the open sea outfall is determined to be the most reliable. Diluting the byproduct stream with the cooling water and discharging the blended stream to Oso Bay offers a potentially significant cost savings but involves environmental issues that must be addressed. Both of these options are carried forward in the detailed evaluations and cost modeling performed for the *Large Scale Demonstration Desalination Feasibility Study*.

Service Area

Water from the proposed treatment facility would be post treated after both pre-treatment and RO to make it compatible with existing City of Corpus Christi water and would be tied directly into the distribution system. The existing City demand is significantly greater than the 25 mgd that the plant would produce, allowing the desalination plant to operate in a constant flow condition for maximum economy.

Conclusion

The connection to the Corpus Christi distribution system is nearby, minimizing the cost of connection and maximizing the potential economic benefit.

2.3 Task 3 – Source Water Blending and Byproduct Management

Source Water Blending

The quality of the feedwater to a desalination facility has a significant impact on the cost of treating the water. The higher the total dissolved solids (TDS) concentration, the greater the cost to treat. Similarly, the desalination facility produces a byproduct water that is approximately twice the concentration of the influent feedwater to the plant. The TDS concentration of the byproduct is of concern to the environment. For these reasons, the possibility of using brackish groundwater to make significant reductions in the TDS concentration of either the feedwater or the byproduct was investigated as a part of this study.

There is significant brackish groundwater in the Corpus Christi area, but the closer to the coast a facility is, the higher the concentration of dissolved solids that are found in the water. The higher the TDS concentration, the greater the volume that must be pumped to make a significant difference in the quality of the blended water. For the Barney Davis Plant site, the average TDS concentration of the Laguna Madre source for the cooling water pumps at the plant was over 41,000 mg/l. If the area groundwater has a TDS of 10,000 mg/l, it would take 10 million gallons per day (mgd) of brackish groundwater to blend with 45 mgd of Laguna Madre water to reach the 35,000 mg/l desired feedwater quality. The electric logs available indicated that production of these groundwater quantities is unlikely and would potentially have consequences related to land subsidence. In addition, the test well that was drilled as a part of the Padre Island Desalination Project (a separate study funded by the City of Corpus Christi to determine feasibility of a small desalination plant on Padre Island) showed rapid deterioration of quality as the well was pumped. If wells were drilled and water quality deteriorated, it would require increasing quantities of groundwater to make the same dilution.

Byproduct Management with Blending

The same situation exists with efforts to blend brackish groundwater to dilute the concentration of the byproduct water. Reducing the blended concentration to the same concentration as the Laguna Madre would require approximately 25 mgd of brackish groundwater to blend with the 25 mgd of byproduct water. In addition, the brackish groundwater may contain constituents that are harmful to the marine environment.

Conclusion

TDS results from a previous desalination study, existing log data, and the interpretation of a professional hydrogeologist provided the facts needed to determine that using brackish groundwater for blending is not cost effective. This same result was determined with blending with either the feedwater or the byproduct water.

2.4 Task 4 – Potential Partners

The City is committed to a public process for the development of a seawater desalination facility. As a part of that process, there is a great likelihood that a public private partnership could be developed if legislation is passed permitting such an arrangement for municipalities in Texas. However, the City wants to have maximum competition in the development of such partnerships, which can only come after development of a Request for Qualifications leading to the selection of qualified firms who will be given an opportunity to respond to a Request for Proposal to design, build, and potentially operate a desalination facility for a firm fixed price.

Conclusion

For the reasons noted above, the City has not formed any alliances with private firms at this time.

Contacts have been made with universities in the area to coordinate on research and data collection needs, but no sources of funding are anticipated from those efforts. The universities are supportive of the City’s efforts and have expertise in data collection and analysis that will be crucial to the long-term development of facilities.

2.5 Task 5 – Potential Customers

Files from the 2001 regional plans submitted to the TWDB were analyzed to determine potential customers for water that would become surplus to the City with the advent of a desalination facility. Demands in the aggregate of 10 mgd or more were located and the current strategies reviewed. However, the 2006 regional plans are in the process of being prepared, and there has been increased emphasis placed on the development and movement of groundwater, at least partially in response to the junior water rights provision in Senate Bill 1. The change in senior rights to junior rights for surface water involved in interbasin transfers has created less interest in surface water transfers and more interest in groundwater transfers. Several likely customers for City water have become involved in projects to determine the cost of groundwater, as well as one of the City's regional customers. The City has entered into an agreement with the San Antonio Water System (SAWS) to investigate cooperative ventures in the Nueces Basin through a U.S. Army Corps of Engineers Feasibility Study. This study was recently signed by all parties and will examine the potential for further cooperative efforts by the parties, including efforts related to desalination.

Conclusion

For the reasons noted above, no firm negotiations on price were possible, and potential revenue streams from sale of surplus water were estimated based on raw water costs statewide.

2.6 Task 6 – Power Sources

Both conventional and alternative power sources were investigated during the course of this feasibility study. Conventional power sources are referred to as the purchase of retail power at competitive rates from the electric power grid. Alternative energy sources consist of developing a power source using wind or solar energy specifically designed to meet the power requirements of the desalination facility.

Costs for conventional power were derived from conventional grid-based power sources estimated at $0.065 per kilowatt hour based on available supplies and a retail power cost. The results of the study indicate that conventional power is likely to be the most viable option for the desalination facility.

Pros

- All costs to obtain the power are readily definable.
- Cost projections for the next 30 years indicate relatively stable power costs are anticipated.
- Recent correspondence from Topaz Power Partners has indicated the potential for lower cost power if a retail electric provider can be developed to retail the power from the Barney Davis Plant to the desalination facility.

Cons

Wind-generated power appears to be close in cost for the desalination plant. However, it is necessary to consider the following disadvantages:

- Wind power is dependent on a noncontrollable resource.
- Only marginally cost-effective at the available power rate structure.
- Additionally, uncertainties about a potential suitable location, the cost of the land for a wind generation facility, and the cost of transmission to the desalination facility represent significant unknown costs at this point.

Conclusion

Solar power was considered, but the conceptual costs for solar power on the scale needed for the large scale desalination facility were an order of magnitude higher than either conventional power or wind-generated power.

2.7 Task 7 – Project Funding and Development

As noted previously, the concept of public private partnerships and some method of design/build/own/operate/transfer have been used in other states as a means of reducing costs and delivering projects in a timely fashion. Current Texas law does not permit Corpus Christi to avail itself of this option. However, this project did perform a review of the different project funding and development methods and that information is contained in the report. Costs as presented in *Task 8, Cost Model Development*, below were estimated based on conventional design, bid, and build practice as normally practiced by cities in Texas.

Conclusion

Analysis of project descriptions in other areas leads to an assumption that costs could be 10 percent to 20 percent less if estimated using an alternative delivery method.

2.8 Task 8 – Cost Model Development

A spreadsheet cost model was developed (see *Appendix F* in the report) to compare the cost of City operations with and without a desalination facility. For the purposes of this cost model, it was assumed that the expenses for the construction of a pipeline to bring water from the Colorado River to the intake pump station at Lake Texana would be avoided if a desalination facility were to be constructed. All other City expenses for upgrades to the O. N. Stevens Plant were assumed to be needed, although operations costs were lessened by the reduction in flow through the plant. Costs were brought back to a present worth in a 2004 comparison, and the amount of subsidy was adjusted until the present worth of the no-desalination option was the same as the present worth of the desalination option. The subsidy required under this analysis was $874 per acre-foot. The primary reason for the size of the subsidy is the past performance of the City of Corpus Christi in developing lower cost water supplies for future needs. The subsidy would be in addition to an estimated revenue of $5,000,000 annually from the sales of surplus City water supplies.

Governor's Desalination Initiative Cost Comparison

To facilitate comparison of various studies being performed in Texas under the Governor's Desalination Initiative, the following summary of costs is presented.

Projected Costs	
Projected Cost of Water (Current System – No-Desal)	$1.78 / 1,000 gallons
	$580 / Acre-Foot
Projected Cost of Desalted Water	$3.51 / 1,000 gallons
	$1,142 / Acre-Foot
Project Cost of Combined System	$2.61 / 1,000 gallons
	$851 / 1,000 gallons
Projected Subsidies Required	
Equivalent Annual Subsidy	$24.5 million
Equivalent Unit Subsidy ($ / 1,000 gallons)	$2.69 / 1,000 gallons
Equivalent Unit Subsidy ($ / Acre-Foot)	$876 / Acre-Foot
Capital and O&M Costs Summary (2004 Present Worth)	
Capital Cost	$196.6 million
Annual O&M Cost	$17.5 million

Cost Analysis Summary

The above cost analysis was performed under worst-case conditions. Despite the many data collection programs taking place under State, Federal, and university programs, much of the specific data needed to optimize a desalination treatment facility does not currently exist. This fact points to the importance of pilot plant testing and data gathering as key components of the process in gaining further insight into the cost of treatment and residuals management. Corpus Christi is ideally situated to be a participant in this process and is looking forward to continuing to work with the Governor's Office and the TWDB to make desalination of seawater a reality in Texas.

2.9 Task 9 – Report

The draft *Large Scale Demonstration Desalination Feasibility Study* was prepared in accordance with the guidelines and schedules contained in the Research and Planning Fund Regional Facility Planning Contract between the City of Corpus Christi, Texas, and the TWDB, and as modified during the development of the Study.

A draft of the findings of the Study was presented to the City of Corpus Christi City Council at their regular meeting on August 24, 2004. After approval of the Draft Report by the City of Corpus Christi, the Draft Report was submitted to the TWDB on August 31, 2004, and simultaneously made available for public review at five public locations in Corpus Christi and the surrounding service area.. A summary presentation of the Draft Report was made to the Region N Planning Group on September 9, 2004. A public meeting was held on September 9, 2004, at the Corpus Christi Main Public Library. A public comment period was open through September 16, 2004. No public comments were received. Comments from the TWDB, Texas Parks & Wildlife Department, and the United States Bureau of Reclamation were received on September 30, 2004.

Draft responses to the comments were returned to the TWDB on November 1, 2004. Revisions to the Draft Report necessitated by the written comments were developed during November 2004. The final *Large Scale Demonstration Desalination Feasibility Study* was submitted to the TWDB on November 30, 2004.

3 RESULTS AND CONCLUSIONS

The results of the *Large Scale Demonstration Desalination Feasibility Study* in the Corpus Christi area are as follows:

- There are no significant technical issues that would prevent such a facility from being constructed. The processes that were investigated are available for application to this facility and all have some amount of experience with applications to seawater.

- There are significant environmental issues that need further investigation. The issue of sea grass beds is of great concern, and routing studies are needed to determine the routing that provides the least disturbance of these areas. This is of such significant concern since the availability of suitable mitigation areas is limited. Identification of such areas is also needed as a part of the investigation of the impacts of these pipeline routings. In addition, there are environmental concerns with the discharge of the desalination byproduct with the Barney Davis Plant cooling water into Oso Bay. This alternative would eliminate the disturbance of the sea grass beds noted above, but would have environmental consequences of its own. These areas need further study to better define the relative merits of each.

- There are institutional concerns with the method that is used to build large scale desalination facilities. Such facilities throughout the world are generally being constructed through alternative delivery methods, which include some modification of the design, build, own, operate, and ultimately transfer of the facilities to a municipal owner. Currently, Texas law does not allow municipalities to procure such facilities through alternative delivery methods. It is estimated that a savings of 10 to 20 percent is possible from the cost reported in this report if alternative delivery methods could be used.

- Finally, the report indicated that substantial subsidies are required to make the facilities comparable in costs to other potential water sources. There is recognition that desalinated seawater has higher reliability and higher quality than most conventional sources, but it is difficult to quantify the value added for this water.

4 CONCLUSIONS

The following conclusions were reached as a result of this study.

- Seawater desalination produces a truly drought-proof supply with added value.
- Pilot scale investigation and data gathering studies are needed to further define the costs of the facilities to provide additional insight into the viability of desalination along the Texas coastline.
- The viability of desalination of seawater is primarily a question of timing. The technology exists currently if funding can be provided to build plants which will provide a valuable contribution to the expansion of the current water supply.
- Support of the TWDB, the Governor's Office, and many interested State Legislators has been invaluable in achieving the results to date.
- Costs for desalination facilities and environmental challenges that are faced in siting and operating such facilities are highly site specific.
- Subsidies will be needed for the foreseeable future to spur development of such facilities.
- The size of the subsidy needed for Corpus Christi is a direct result of the City's proactive procurement of water supplies to meet their needs from less costly sources. Corpus Christi has shown the resolve to move forward with large projects to ensure their long-term water supplies. This same resolve is a key element in moving forward in the investigation of desalination as a further augmentation of their supply.

5 BENEFITS OF CONTINUED INVESTIGATIONS

The development of additional water supplies is crucial to a continued healthy economy in Texas and to proper management of the growth that is occurring. The major ports of the coastal cities like Houston, Galveston, Corpus Christi, and Brownsville play a significant role in attracting business investment in Texas. Desalination of seawater for potable water supply is a quantum leap in technology and in development of truly drought-proof supplies for a thirsty nation.

The three demonstration projects that have been partially funded by the TWDB through Governor Perry's desalination initiative have brought positive benefits to Texas. These efforts have brought attention from the Federal level as Federal officials realize that the potential for providing additional drinking water supplies is becoming just as crucial to Texas as it is to California and other more arid regions. Growth along the nation's coastline is proceeding rapidly and additional supplies of quality drinking water are needed now and in the future to properly manage that growth.

As all of the projects have demonstrated, there are no serious technical impediments to the treatment of seawater and production of potable water. However, there are significant environmental issues that must be addressed to be sure that desalination of seawater is managed to minimize any negative effects and maximize the positive effects. In addition, there are questions concerning the cost of such facilities. It is difficult to compare the costs of producing a water which comes from a drought-proof source whose quality can be specifically engineered to nearly any desired level of dissolved minerals, versus the cost of conventionally obtained surface water that is treated with more conventional treatment technology and whose quantity is subject to current and future droughts of record. There is added value to desalinated water from the reliability of the supply and the quality of the product, and the determination of that incremental value has yet to be quantified.

Continuation of the demonstration projects through the pilot plant and data gathering phases is in the best interest of Texas for the following reasons:

- The more widespread and potential applications of membrane processes there are, the more incentive there is for membrane manufacturers to continue to fund research into newer, better, and more energy efficient membranes.

- Membrane technology improvements are applicable to the entire State, as many areas have supplies of brackish groundwater that are now being investigated for conversion to potable supplies through desalination technology. Improvements in membrane life, durability, and susceptibility to fouling and scaling are just as applicable to groundwater desalination as they are to seawater desalination.

- Development of large scale seawater desalination projects at the coast provides a ready source of supply to growing coastal areas, many of which encompass significant industrial capacity that contributes heavily to the economy of the State.

- Development of water supplies at the coast relieves some of the pressure on inland sources of water, both for growth farther inland as well as for environmental flow needs.

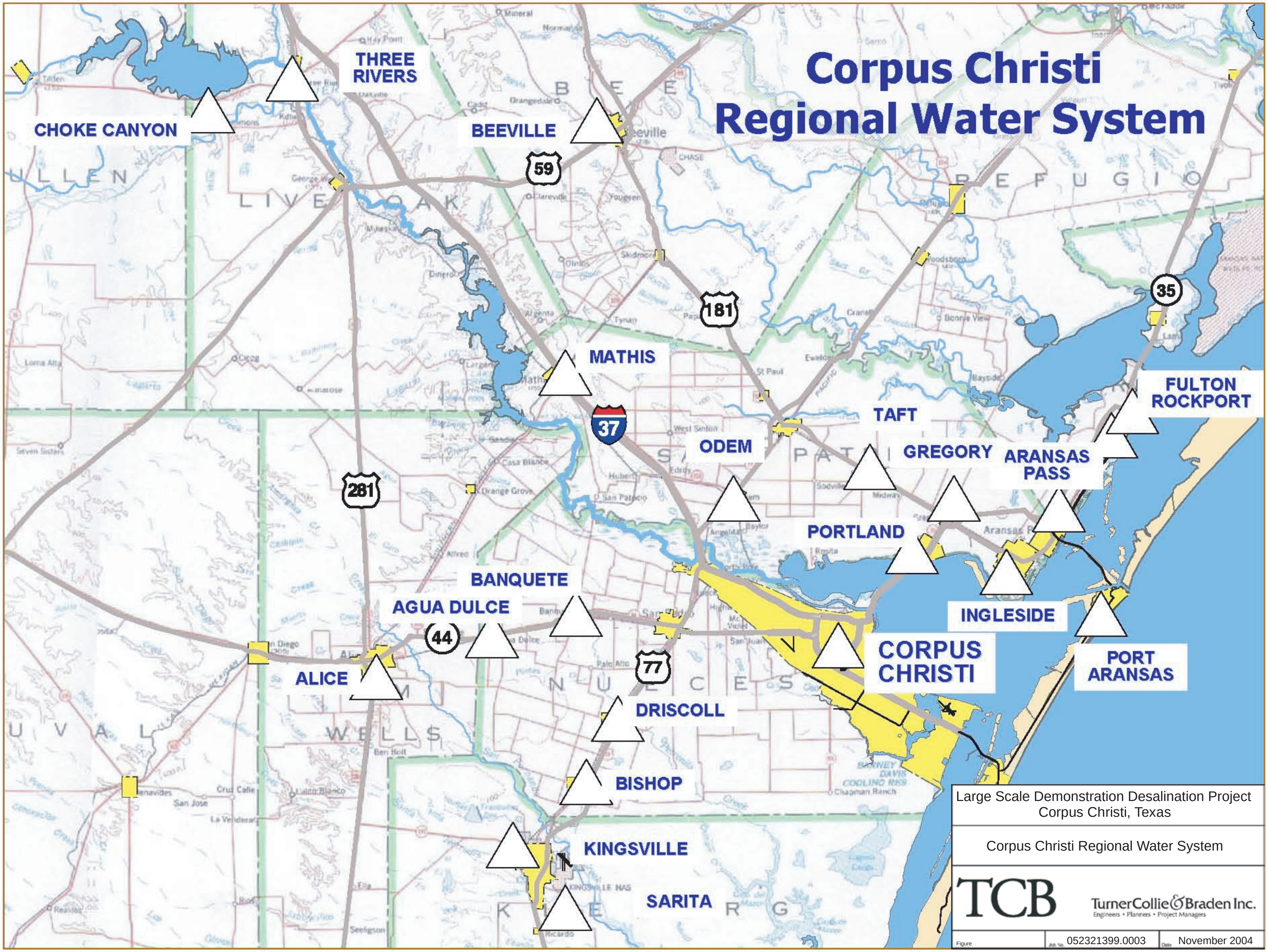
- All of the demonstration project investigations had to rely to some extent on worst-case assumptions. These assumptions have resulted in high costs and potential subsidy levels. Pilot plant investigations and direct data gathering provide a means of refining those costs and potentially reducing the subsidy amounts needed.

- An active process of investigation of desalination in Texas helps make the case for Federal funding to support desalination activities throughout the United States with a variety of source water quality.

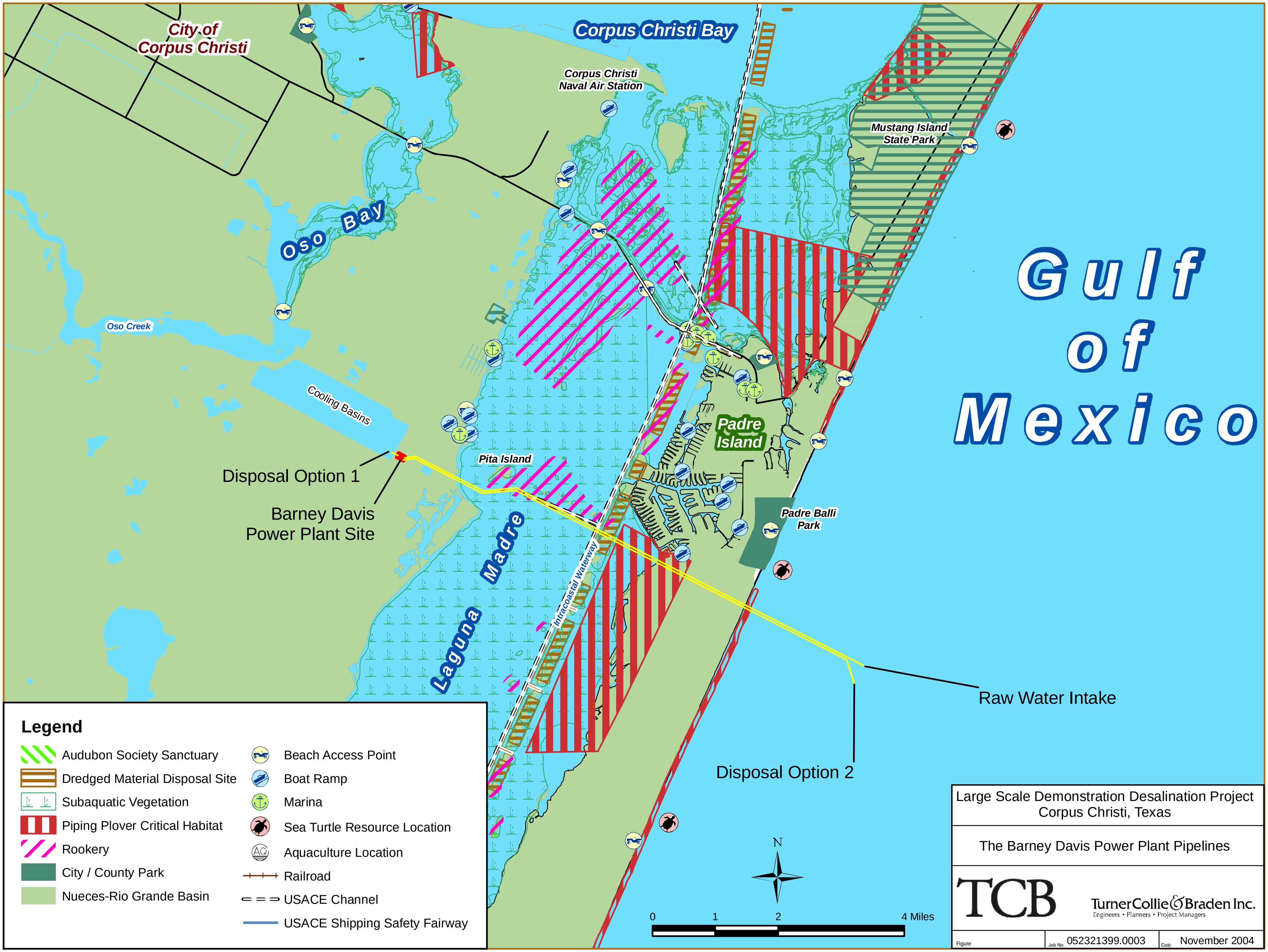
- Continuation of the demonstration process allows continued debate on the added value of water from a desalination facility.

- The pilot plant and data gathering phase will better define the environmental issues that will be faced and help to gather information on impacts and potential mitigation strategies to minimize those impacts.

- The pilot plants will provide a focal point for public attention and education efforts in desalination technology. Nothing informs the public better than something that can be seen in operation, and the greater the number of pilot facilities that are in operation, the greater the number of members of the general public who will have the opportunity to view them.



Corpus Christi
Regional Water System
CHOKE CANYON
THREE RIVERS
BEEVILLE
MATHIS
ODEM
TAFT
GREGORY
ARANSAS PASS
FULTON ROCKPORT
PORTLAND
INGLESIDE
PORT ARANSAS
CORPUS CHRISTI
BANQUETE
AGUA DULCE
ALICE
DRISCOLL
BISHOP
KINGSVILLE
SARITA
Large Scale Demonstration Desalination Project
Corpus Christi, Texas
Corpus Christi Regional Water System
TCB
TurnerCollie&Braden Inc.
Engineers • Planners • Project Managers
Figure
Job No. 052321399.0003
Date November 2004



City of Corpus Christi
Corpus Christi Bay
Corpus Christi Naval Air Station
Mustang Island State Park
Oso Bay
Oso Creek
Cooling Basins
Gulf of Mexico
Padre Island
Pita Island
Padre Balli Park
Disposal Option 1
Barney Davis Power Plant Site
Laguna Madre
Intracoastal Waterway
Raw Water Intake
Disposal Option 2
Legend
Audubon Society Sanctuary
Dredged Material Disposal Site
Subaquatic Vegetation
Piping Plover Critical Habitat
Rookery
City / County Park
Nueces-Rio Grande Basin
Beach Access Point
Boat Ramp
Marina
Sea Turtle Resource Location
Aquaculture Location
Railroad
USACE Channel
USACE Shipping Safety Fairway
N
0
1
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4 Miles
Large Scale Demonstration Desalination Project
Corpus Christi, Texas
The Barney Davis Power Plant Pipelines
TCB
TurnerCollie&Braden Inc.
Engineers • Planners • Project Managers
Figure
Job No. 052321399.0003
Date November 2004

Chapter 1

Introduction and Project Background

CHAPTER 1 – INTRODUCTION AND PROJECT BACKGROUND
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CHAPTER 1 – INTRODUCTION AND PROJECT BACKGROUND

1 INTRODUCTION

This report covers the feasibility analysis of a desalination facility for the City of Corpus Christi, Texas. The project is an outgrowth of a request for Statements of Interest published by the Texas Water Development Board (TWDB) at the request of the Governor's office. The City of Corpus Christi responded to the publication of the requests for Statements of Interest, and the City's response was selected, along with two other responses, for further study. The Texas Water Development Board provided a $500,000 grant to the City, and the City provided another $240,000 for in-kind services to perform the analysis.

2 BACKGROUND

The City of Corpus Christi is a medium size city located on the Gulf Coast of Texas. The City has a progressive background in developing its drinking water supplies, both for its own needs and the needs of its regional system. The 2002 State Water Plan shows that the City of Corpus Christi serves 75 percent of the total municipal and manufacturing water needs in the 11-county Region N Regional Water Planning Area.

The City currently obtains its water supplies from two different basins. Water is obtained from both Choke Canyon Reservoir and Lake Corpus Christi, which flows into the Nueces River and is picked up and treated at the O. N. Stevens Water Treatment Plant. The City of Corpus Christi owns the rights to water from these two reservoirs. In addition, the City also obtains water from the Navidad River Basin through a contract for raw surface water with the Lavaca-Navidad River Authority (LNRA). This contract includes 41,841 acre-feet of firm yield water, as well as 12,000 acre-feet of interruptible yield water that has a reasonably high reliability. This water flows from Lake Texana in Jackson County through the 101-mile Mary Rhodes Pipeline to the O. N. Stevens Water Treatment Plant.

It is interesting to note that in 1996 the City of Corpus Christi and the Nueces Basin were in drought conditions, and an additional source of water was needed. The City evaluated potential options, including desalination, and decided to construct the Mary Rhodes Pipeline. At approximately the same time, Tampa Bay decided to construct a desalination facility. The Mary Rhodes Pipeline was constructed and placed in service in 1998 and has provided a reliable source of supply for the City since that time. The desalination plant for Tampa Bay Water was completed in 2003 and is still having difficulties in meeting its contractual requirements. However, Tampa Bay Water implemented other improvements through alternative delivery methods which provided sufficient additional supply to its system so that the lack of desalination water has not been a major problem.

Despite the above-noted comparison, the City of Corpus Christi remains vitally interested in desalination, believing that it is just a matter of time until desalination does become cost effective. The City is ideally situated to provide the necessary proving ground for a desalination facility, being located directly on the Gulf Coast of Texas. It is also an attainment area for air quality under the Federal Clean Air Act. In addition, it has a large service area that includes a number of smaller municipalities and a significant amount of manufacturing demand. There is also a basic belief among area residents that desalination offers a reliable source of drought-proof water that is becoming more cost-effective as advancements are made to the membranes, energy recovery, and other factors. The City has secured supplies of water for itself and its regional service area beyond 2050. Corpus Christi's interest in desalination is for its much longer term needs, as well as a desire to assist in expanding the available water supply throughout the State of Texas to benefit those entities with shorter term needs.

3 EXISTING SERVICE AREA DESCRIPTION

The existing service area of the City of Corpus Christi includes all or portions of the majority of the Coastal Bend Regional Water Planning Group counties: Aransas, Bee, Jim Wells, Kleberg, Live Oak, McMullen, Nueces, and San Patricio (*Figure 1-3-1*).

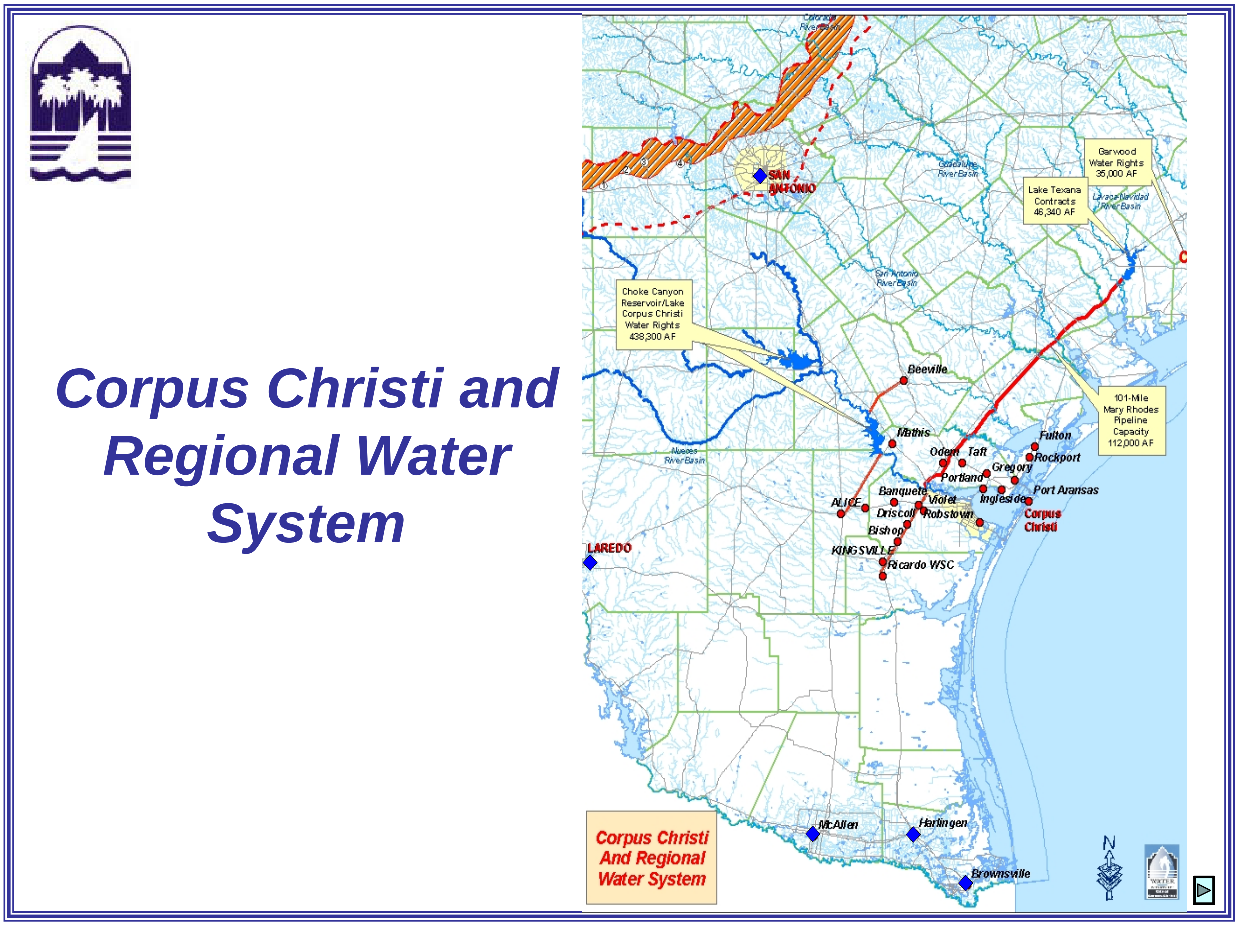
The City of Corpus Christi is the largest of the three regional water providers in Region N, and it sells water to the remaining two regional water providers—South Texas Water Authority (STWA) and San Patricio Municipal Water District (SPMWD). STWA provides water to cities and water supply corporations that supply both residential and commercial customers within the western portion of Nueces County as well as Kleberg County. SPMWD distributes water to cities, water districts, and water supply corporations providing water to residential, commercial, and industrial customers throughout the eastern half of San Patricio and southern Aransas Counties. The major water demand areas are primarily municipal systems in the greater Corpus Christi area, as well as large industrial (manufacturing, steam-electric, and mining) users primarily located along the Corpus Christi and La Quinta Ship Channels. Based on State surveys (TWDB 1993) of industrial water use, industries in the Coastal Bend area are very efficient in their use of water. For example, petroleum refineries in the Coastal Bend area use on the average 60 percent less water to produce a barrel of refined crude oil than refineries in the Houston/Beaumont area.

4 RAW WATER SUPPLIES

The Coastal Bend Region depends mostly on surface water sources for municipal and industrial water supply use. The three major surface water resources include the Choke Canyon Reservoir/Lake Corpus Christi System (CCR/LCC System) in the Nueces River Basin and Lake Texana on the Navidad River in Jackson County. The water quality of these sources is generally good. However, there are some areas of concern, specifically within the Lower Nueces River and the Calallen Reservoir Pool, where the bulk of the region's water supply intakes are located.

There are some areas in the region that are dependent on groundwater. There are two major aquifers that lie beneath the region—the Carrizo-Wilcox and Gulf Coast aquifers. The Gulf Coast aquifer underlies all counties within the Coastal Bend Region and yields moderate to large amounts of both fresh and slightly saline water. The Carrizo-Wilcox aquifer only underlies parts of McMullen, Live Oak, and Bee Counties and contains moderate to large amounts of either fresh or slightly saline water.

Figure 1-3-1 Existing City of Corpus Christi Water Service Area



5 GROWTH PROJECTIONS

Population projections for the City of Corpus Christi were recently completed and posted to the Texas Water Development Board website. Those projections are shown below in *Table 1-5-1*. The service area population for the City of Corpus Christi is projected to increase from 277,450, shown in 2000, to approximately 470,523 in 2060.

Table 1-5-1 Service Area Population Growth Projections

Year	2000	2010	2020	2030	2040	2050	2060
Population	277,450	316,058	356,123	391,077	421,761	448,879	470,523

According to the 2001 Regional Plan for Region N, the City of Corpus Christi has adequate supplies to meet its own needs through the 2050 planning horizon in the 2001 Regional Plans. The only reason for developing strategies for the City of Corpus Christi is to provide for the manufacturing and municipal demands of its regional system.

6 EXISTING WATER RATE STRUCTURE

CH2MHill, Urban Engineering, and Collier, Johnson & Woods undertook an extensive study of the Corpus Christi utility department in 1990. As a result, a rate schedule for water service was developed based on cost of service. A two-part rate schedule was implemented consisting of (1) monthly minimum customer charge based on customer class and meter size and (2) a volume charge based on water use. Customers are charged a minimum base rate and extra capacity cost, based on water usage above the base amount. In 1997, with the inclusion of water from Lake Texana as part of the region's supply system, the rate schedule was modified to include a Raw Water Cost Adjustment (RWCA). The RWCA is calculated monthly and, basically, is the total monthly expenditure associated with the acquisition and delivery of raw water to the treatment plant divided by the total number of gallons sold the previous month to establish a rate. The previously calculated monthly minimums and volume charges were adjusted to remove that portion of the rate associated with raw water.

A copy of the City's current water rate ordinance is attached in *Appendix A.*

Note: All of the above information on the water rate structure is taken directly from the City's Water Conservation Plan, which was adopted by the City Council on August 24, 1999.

7 REGIONAL PLANS

As noted previously, the City of Corpus Christi and its extended service area for both treated and raw water are located wholly within the confines of Region N Regional Water Planning Area. As also noted, the City of Corpus Christi has adequate water resources to meet its own supply needs throughout the 2050 planning horizon established in the 2001 Regional Plan. However, the City has continued to plan to meet the needs for surface water for the SPMWD and STWA, as well as to meet the manufacturing and steam-electric water needs in both Nueces and San Patricio Counties. The management strategies, which were proposed for meeting these needs, included extending the current contract with LNRA, seeking additional interruptible yield supplies from the LNRA, investigating Aquifer Storage and Recovery for additional supplies, and completing the infrastructure for the connection of the Garwood water to the Mary Rhodes Pipeline.

8 DESALINATION ACTIVITIES IN THE CORPUS CHRISTI AREA

Corpus Christi's prime coastal location has led to several investigations of desalination as a source of water over the years. Desalination was proposed as the answer in lieu of the Mary Rhodes Pipeline in 1996 when the City of Corpus Christi was in need of immediate new water supplies. The economic analysis both then and now showed that the pipeline was the better and faster route to obtain the additional water the City needed.

Another desalination effort has been underway concurrently with this study, and that is the Padre Island Desalination Feasibility Study. This study examined the feasibility of a brackish groundwater desalination facility potentially combined with an Aquifer Storage and Recovery project. The primary motivation behind this study is the need to increase the reliability of potable water service to Padre Island. This area is served by a single, aging line that is submerged in a harsh environment. The cost of a second line to Padre Island has specific and significant environmental challenges, and the purpose of this study was to determine whether water could be produced on the Island at a lesser cost than completing a second pipeline.

Brackish groundwater desalination is generally much less costly than seawater desalination because of the difference in dissolved solids concentration of the two sources. This study, however, found that after a short period of pumping, the water quality increased in total dissolved solids concentration to such an extent that the treatment costs were more similar to those for seawater desalination. As a result, the City has determined that it is not cost effective to construct such a plant at the present time. Information learned from the draft results of the Padre Island study were passed along to the consultant team for this project, particularly with regard to the quality of brackish groundwater in the area.

9 PUBLIC INVOLVEMENT

Local residents in the Corpus Christi area have shown an interest in desalination activities of all types. The City was conducting studies on a smaller brackish groundwater desalination facility on Padre Island at the same time as this large scale desalination study was being carried out. The public involvement portion of the Padre Island study was more extensive, at least partially because of the imminence of the project. At least a portion of the public involvement activities for the Large Scale Demonstration Desalination Feasibility Study was devoted to distinguishing between the two projects. . Public meetings were held to kickoff the project, and at approximately the 50 percent and 90 percent completion milestones. In addition, much the same information was presented to the City Council in open session, and to the Region N Regional Water Planning Group either on the same dates or a day following the public meeting presentations. Extensive use was also made of the City's website to post project summaries, briefing documents, presentations, and the draft report. *Appendix G c*ontains the summaries of the public meetings and any public comments that were received, along with a sampling of related newspaper clippings.

Chapter 2

Customer Base Determination

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CHAPTER 2 – CUSTOMER BASE DETERMINATION

1 INTRODUCTION

As noted in *Chapter 1*, the City of Corpus Christi already serves a large, multi-county service area with water for municipal, manufacturing, and steam-electric power generation needs. The City also has sources of water from the Nueces, Lavaca, and Colorado Basins, with only the water from the Colorado Basin not currently connected with infrastructure to the City's O. N. Stevens Water Treatment Plant.

2 ALTERNATIVE SERVICE AREAS

A major portion of the feasibility of a desalination facility is the cost of providing service. Although costs of membrane treatment and, to some extent, the pre-treatment required to provide desalination through membranes have come down in recent years, there is still a need to economize to the greatest extent feasible in making use of a desalination facility.

The area that would receive water directly from the desalination facility would be within the City's current water distribution system. Connection to the City's system provides the lowest cost of service by reducing that portion of the overall cost. As succeeding chapters of this report indicate, there are two different locations in the Corpus Christi area being evaluated for the location of the desalination facility. The Barney Davis Plant is in an area that serves predominantly municipal demands, and is located at the opposite end of the City's system from the O. N. Stevens Water Treatment Plant. This provides a synergy with the O. N. Stevens Plant's distribution pumping facilities by establishing another entry point with the ability to feed the interior of the City system from two directions. The City has recently built a distribution pump station in that general quadrant of the system for the same purpose. This additional supply from that area reinforces the value of the pumping plant with additional backup supply.

A second benefit derived from a desalination plant at this location relates to system reliability for the City. The current system configuration has all water coming to the City through the O.N. Stevens Plant. For reliability purposes, plant personnel desire to have at least 20 percent of the total plant flow satisfied by Nueces River water with higher percentages required during high demand conditions in the system. This operational plan is being followed to prevent a shutdown of the O.N. Stevens Plant in the event of a disruption of the supply in the Mary Rhodes Pipeline. If there is no flow in the Nueces River of stored water from Lake Corpus Christi, then it takes several days for that water to reach the plant, once it is released from the dam. This situation causes difficulty for the City in maximizing use of resources from Lake Texana and potentially from Garwood. A 25 million-gallons-per-day (mgd) supply from a desalination facility would represent less than 25 percent of the City's current peak day demand and may assist in maximizing the use of the City's other available resources.

The other desalination plant location being considered is on the northern side of Corpus Christi Bay and east of the O.N. Stevens Plant. This location would provide water service primarily to manufacturers in the area. The interconnection would be made to a nearby City's treated water line. Although some discussion has been held concerning a possible high purity water utility to capitalize on the highly treated water available, discussions with industries in the area as a part of the San Patricio Municipal Water District's proposed desalination facility indicated little support for such higher priced water.

No other alternative service areas were explored in this investigation, primarily because of the ability of the City of Corpus Christi to wheel other water resources to entities in need from sources that are closer to those needs. This reduces the overall cost significantly if a water demand in the greater San Antonio area can be served with water from the Choke Canyon Reservoir, which is only 60 miles away, instead of piping water over 100 miles from the coast to the San Antonio area.

3 RECOMMENDED SERVICE AREA

The recommended service area for the desalinated water is the current distribution area of the City's water distribution system. As noted above, this provides the lowest overall cost for the desalination treatment facility.

4 DESCRIPTION OF NEED FOR THE PROJECT

As noted previously, the City has provided for its water supply needs with water that is significantly less expensive than water from a desalination facility. However, there are other communities that are not as fortunate. The City recognizes that finding new sources of water is a benefit for the entire State and not just the Coastal communities. The City further recognizes that much of the population of Texas is located within 100 to 150 miles from the coastline, and the development of proven desalination technology could provide additional supplies of drought-proof water with potentially fewer environmental impacts than the development of surface water supplies inland.

The City has significant customer support with both its retail customers at the City level as well as its wholesale customers in its extended regional service area. At the same time, however, the City's customers, both wholesale and retail, are interested in paying the lowest possible cost for raw and treated water. Once again, it is recognized that the City is interested in providing the technology for its much longer term best interests, but it cannot come at the expense of City rate payers, either retail or wholesale. Copies of letters of support were provided by most of the City's wholesale customers, and desalination continues to be a topic of favorable discussion among City Council members and their constituents.

Chapter 3

Site Selection

CHAPTER 3 – SITE SELECTION
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CHAPTER 3 – SITE SELECTION

1 INTRODUCTION

Selection of potential sites for the Large Scale Desalination Facility is the first step in developing the overall concepts and costs for the facility. A capacity of 25 million gallons per day (mgd) is chosen as the target capacity. However, depending on the feasibility and success of this initial phase, it may be desirable to increase the capacity by adding a second phase to the site, such as an additional 25-mgd treatment module.

Site sizing requirements are dependent on the treatment processes and process loading criteria for both the pre-treatment and desalination processes. These loading rates are dependent not only on the selected processes but also on the quality of the raw water being provided to the facility.

Preliminary investigations indicate that the raw seawater quality in the vicinity of Corpus Christi, Texas can vary significantly in terms of both total dissolved and total suspended solids. As an example, the total dissolved solids in Laguna Madre can be highly variable and can approach a concentration that is nearly double the dissolved solids concentrations in the main Gulf of Mexico. Similarly, suspended solids can be significantly higher near the gulf coast shorelines and in the bays due to runoff and activities of man.

Variability of total suspended solids and other particulate constituents can have a significant impact on the pre-treatment processes selected and the sizing of these units. As has been demonstrated at other desalination facilities in the country, the quality of the water from the pre-treatment processes can have a significant impact on the long-term operations and costs of the desalination facility. Likewise, the concentration and characterization of the dissolved solids could have a similar effect on the desalination process. Final process selections, loading criteria, and process sizing cannot be made until a final site is selected. Conversely, the site cannot be selected until the size requirements are determined.

To overcome this apparent paradox, certain assumptions regarding water quality are required and worst-case plant site requirements can be determined from these assumptions. This chapter develops the site requirements and selects specific sites for further evaluation based on these assumptions and criteria. Because a combination worst-case and average condition approach is used, the resultant site criteria should provide a site that is reasonably sized to accommodate the design capacity of the proposed facility without excessive conservatism or redundant factors of safety in the estimates.

At this stage of the project, it is not possible to commit to potential site owners on the specific benefits that may be realized from the development of the desalination facility. In return, potential site owners cannot render firm commitments regarding the co-use of the site and facilities. Therefore, it is evident that this site requirements determination and the site selection process must be kept at the conceptual level until the development of the project is more firm.

2 SITE SELECTION CRITERIA

In identifying and selecting a site for a desalination facility, several factors must be evaluated. An internal workshop was held among the engineering team to identify and discuss several factors that could influence the selection of the appropriate site. Two categorical types of sites were considered for evaluation: green field sites and co-location with industrial sites.

Green field sites, by definition, are not developed. As a categorical concept, green field sites do not have infrastructure associated with them. The development of a green field site would require the development of both on-site and off-site infrastructure such as transportation systems, power supply, intake, and distribution facilities. Development of a green field site would not be constrained by existing on-site development. Green field sites do not provide any advantages other than flexibility of the on-site development process, which was not considered to have significant economic value. Green field sites would only be considered if other sites were determined to be unavailable.

Conceptually, co-locating the desalination facility with an industrial site offers potential cost saving advantages. The following potential advantages were identified as possible enhancements for co-locating with an industrial facility.

- Industrial sites may already have intake or discharge permits. A permit modification to allow the co-use with the desalination facility is potentially easier than obtaining new permits. The existence of an intake or discharge permit could be a significant factor in the viability of a particular site.
- Many industrial sites apply reverse osmosis treatment to potable water sources to improve the water for their industrial use. These industries may be interested in purchasing water in a condition that does not require additional treatment.
- Heated cooling water may be available from the industrial processes on the site potentially providing a warm water supply to the desalination facility. A warm water supply could reduce pressure requirements thus lower overall energy costs of the desalination facility. The water quality tradeoffs between reduced pressures and treated water quality would require additional study.
- Industrialized areas will have transportation infrastructure onsite or relatively close to the proposed facility. Delivery of treatment plant chemicals would not be a problem.
- Industrialized areas will likely have power infrastructure available in the vicinity.
- Industrialized areas are sites already in a disturbed condition. Archeological investigation requirements would be reduced for such sites.

The following criteria were identified for inclusion in the identification, evaluation, and selection of sites for the desalination facility.

- Available land area
- Salt water intake permit
- Proximity to potential byproduct discharge location
- Proximity to customers
- Owner's level of interest in co-siting a desalination facility

These criteria were used in both identifying and selecting sites for further consideration. Development of land area requirements is presented in *Section 2.1.4*, and the remaining considerations are presented in *Section 2.2* of this chapter.

2.1 Conceptual Facility Sizing

A first step in identifying potential sites for the proposed 25-mgd desalination facility was determining the overall size of the site needed to accommodate the proposed facility. To meet this goal, general water quality data in the region was identified, or assumed, if necessary. Treatment processes were then identified to meet anticipated treatment goals and unit processes were sized on a preliminary and conceptual basis to determine overall land area requirements. The remaining paragraphs of this section document the assumptions, criteria, and analysis used for the determination of the land area requirements for the proposed desalination facility.

As part of this "Large Scale Desalination Demonstration Project Feasibility Study," conceptual site layouts were prepared for a desalination facility with a finished water capacity of 25 mgd. The conceptual layouts are based on "preliminary" design criteria that were developed from assumed water quality data and industry standards for process component sizing. This information is provided as the worst-case basis for identifying and selecting potential sites, developing facility support requirements for power supply, site access, and site development issues and environmental constraints. Following this task, design criteria and site requirements for specific candidate processes were refined in subsequent chapters.

2.1.1 Assumptions and Criteria

Preliminary site requirements and design criteria were based on the following assumptions:

- The desalination plant will be designed to produce 25 mgd of potable water from a seawater source high in total dissolved solids. This will require the use of a desalination process, as well as appropriate pre-treatment steps.

- Reverse osmosis (RO) was the only desalination process considered. Mechanical, charge-based, or heat-based methods of desalination have not been considered.

- The reverse osmosis process will reject about 50 percent of the feed stream to the desalination facility as byproduct. To achieve 25 mgd of product water, the feed stream to the reverse osmosis unit must be at 50 mgd.

- Pre-treatment process will produce a waste stream of approximately 5 to 10 percent of the total plant flow through sedimentation basin sludge removal and filter backwashes. To achieve the required 50 mgd to the desalination process, the feed stream to the pre-treatment process is estimated to be 55 mgd.

Because a site has not been determined, and because the plant feedwater supply has not been quantified, a data set of feedwater quality has been assumed for the initial design calculations. The total dissolved solids (TDS) in the raw water has been assumed to be 35,000 mg/l or less. If the local water supply cannot be found that meets this TDS level, then locating or manufacturing the required water quality is recommended. Blending of seawater with groundwater to achieve 35,000 mg/l or lower may be possible. Alternatively, if the feedwater supply cannot be reduced to 35,000 mg/l, it is assumed that it will be brought in from the Gulf to maintain the maximum TDS level at 35,000 mg/l. TDS concentrations above this level will have a significant impact on the cost of treatment. Raw water quality requirements and seawater-groundwater blending are addressed in *Chapter 4 – Water Production*.

No information on raw water quality for sparingly soluble salts such as barium, strontium, or silica was available. Sparingly soluble salts can cause scaling problems with reverse osmosis systems. The initial analysis has assumed negligible concentrations of these constituents.

2.1.2 Treatment Process Considerations

Pre-treatment processes were selected to handle anticipated worst-case water quality. As a worst-case (largest site area requirement) process, a conventional treatment train consisting of flash mix, four-stage flocculation, sedimentation and multimedia filtration was selected to provide pre-treatment to the RO process. Still considering worst-case water quality and a multiple barrier treatment approach, high-rate clarification processes could be used to reduce land requirements. Many of these high-rate processes, although relatively untested in seawater, are generally well proven in the water treatment industry. Dissolved air flotation (DAF) has generally proven to out-perform conventional flocculation, sedimentation, and tube or plate settling. DAF has been selected and designed for large water treatment plants for both Boston, Massachusetts at 450 mgd, and New York City Croton Water Treatment Plant at 290 mgd.

To estimate possible reduction in plant component footprints, DAF and multimedia filtration were considered. In addition, DAF can be combined with filtration in a “stacked” configuration that would further reduce area requirements. Further project implementation steps will consider membrane ultra-filtration and bank filtration, which may have smaller component footprints. Also, with additional water quality data, it may be possible to reduce the amount of pre-treatment, thereby reducing footprint and cost.

2.1.3 *Byproduct Management Considerations*

Residuals will be generated from both the pre-treatment processes and the RO process (byproduct). Depending on how these residual streams are handled, they can have a significant impact on the plant process footprint.

It is assumed that pre-treatment residuals from the sedimentation basins and filters will be handled by on-site thickening, dewatering, and off-site disposal. For DAF, it is assumed that the residuals do not have to be thickened and that they can be dewatered onsite.

Sludge lagoons are also an option; however, it is estimated that they could require between 7 and 10 acres to process both the sludge and the filter waste washwater residual streams. If lagoons are ultimately selected, after sufficient accumulation of sludge, it would be dried and hauled away in solid form to an appropriate disposal location. Lagoons for processing pre-treatment residuals are very land intensive and typically not viable for treatment systems in this size range. Lagoons are not furthered considered in the development of the site sizing requirements.

Typically, the greatest challenge in developing a desalination facility is the disposal of large quantities of the byproduct water. This water is rich in dissolved solids and must be disposed in an environmentally sensitive manner. Several options are considered for the management of the byproduct stream.

- On-site evaporation
- Discharge to a wastewater treatment plant
- Zero liquid discharge
- Deep well injection
- Local industries using brine as a raw product
- Offshore disposal

On-site Evaporation. Initial calculations indicate that discharge of the RO byproduct water to on-site evaporation ponds is infeasible due to the significant land required. Including a 20 percent contingency area, over 33,000 acres of pond surface area are required for evaporative lagoons for the anticipated required capacity in the Corpus Christi, Texas region. Evaporative lagoons are not further considered for this application.

Discharge to Wastewater Treatment. Discharging the byproduct to a local POTW is also infeasible. The largest wastewater treatment plant identified in the area has a capacity of 16 mgd. The byproduct stream from the 25-mgd reverse osmosis plant will be approximately 25 mgd and will overwhelm the available wastewater treatment plant.

Zero Liquid Discharge. “Zero liquid discharge” (ZLD) technologies include mechanical or heat drying of the byproduct, multiple desalination concentrators in series, or a combination of these processes to greatly reduce the volume of byproduct. ZLD technologies are extremely energy intensive and suffer from reduced efficiencies and diminishing returns as the byproduct becomes more concentrated. Processes required for zero liquid discharge will not be considered for the development of this preliminary site sizing criteria. The cost of these technologies renders them unlikely to be cost-effective for a 25-mgd reverse osmosis facility.

Deep Well Injection. Deep well injection is sometimes considered for disposal of the byproduct stream from a reverse osmosis facility. The estimated quantity of byproduct to be disposed of is 25 mgd from this facility. It is estimated that several possible dozens of widely spaced deep wells would be required for this application. Although deep well injection of the byproduct stream may be viable, most of the wells would be located off-site. If a well were located on the treatment plant site, it would have a negligible impact on the site land area requirement.

Discharge to Industry. There are industries in the Corpus Christi area that use highly concentrated brine with a total dissolved solids concentration of 300,000 mg/l as a raw product stream. Potentially, these industries could use the entire byproduct stream from the desalination facility. However, initial contacts with these potential customers indicate that the product needs to be 300,000 mg/l, substantially higher than the 70,000 mg/l estimated concentration of the RO byproduct stream. The additional capital and O&M costs required to concentrate the byproduct stream would be extremely expensive. Furthermore, the reliability of this disposal method would be subject to the demands and schedules of the industrial user and potentially not reliable under all scenarios.

Offshore Disposal. Offshore disposal of the byproduct stream, though expensive, provides the greatest degree of reliability to the disposal of the byproduct stream. For purposes of site criteria development, offshore disposal is the preferred process for byproduct management.

2.1.4 Unit Sizing and Site Layouts

Based on the above assumptions, preliminary design criteria was developed and a footprint required for each unit process within each pre-treatment alternative (conventional and DAF) was estimated. These estimates, along with support facilities and a contingency for miscellaneous site features, are developed and shown in the following paragraphs and in *Tables 3-2.1.4-1* and *3-2.1.4-2*.

Using the conventional pre-treatment layout, the worst-case total estimated area for a 25-mgd facility is approximately 12 acres. The conventional processes used in this analysis include flocculation, sedimentation, and filtration as pre-treatment for the reverse osmosis units. Sizing for the individual components within the site is presented in *Table 3-2.1.4-2*. Support documentation including the criteria used, a summary of the calculations, and a preliminary site plan are included in *Appendix B-1*.

Table 3-2.1.4-1 Estimate of Site Requirements for a 25-mgd Conventional Pre-Treatment Facility

Facility	Length (ft)	Width (ft)	Diameter (ft)	Footprint (sq ft)
Seawater Intake[1]				
Seawater Screening[1]				
Seawater Low-Lift Pump Station[1]				
Metering and Rapid Mix	40	40		1,600
Flocculation	250	120		30,000
High-Rate Sedimentation	530	250		132,500
Filtration	240	70		16,800
Pre-Treatment Chemical Building	70	50		3,500
Intermediate Pump Station/wet well	200	200		40,000
RO Building	280	170		47,600
Degasifier	40	60		2,400
Disinfection Contactor/Clearwell	200	180		36,000
High Service Pump Station[2]				
FWW EQ Tank			72	4,069
Sludge Thickening and Dewatering	150	100		15,000
Administrative Building includes:	70	100		7,000
On-Site Laboratory				
Maintenance Shop				
Locker Room/Restroom/Showers				
Small Meeting Room				
Control Room				
Subtotal				336,469
Unaccounted for Site Usage	50%			168,235
Total				**504,704**
			Total (acres)	**11.6**

1 – Assume off-site location

2 – Included in the finished water clear-well footprint.

Table 3-2.1.4-2 Estimate of Site Requirements for 25-mgd Facility Using DAF Pre-Treatment

Facility	Length (ft)	Width (ft)	Diameter (ft)	Footprint (sq ft)
Seawater Intake[1]				
Seawater Screening[1]				
Seawater Low-Lift Pump Station[1]				
Metering and Rapid Mix	40	40		1,600
Flocculation	250	60		15,000
Dissolved Air Flotation	250	60		15,000
Filtration	240	70		16,800
Pre-Treatment Chemical Building	70	50		3,500
Intermediate Pump Station/wet well	200	200		40,000
RO Building	280	170		47,600
Degasifier	40	60		2,400
Disinfection Contactor/Clearwell	200	180		36,000
High Service Pump Station[2]				
FWW EQ Tank			72	4,069
Sludge Thickening and Dewatering	100	50		5,000
Administrative Building includes:	70	100		7,000
On-Site Laboratory				
Maintenance Shop				
Locker Room/ Restroom/Showers				
Small Meeting Room				
Control Room				
Subtotal				193,969
Unaccounted for Site Usage	50%			96,985
Total				**290,954**
			Total (acres)	**6.7**

1 – Assumes off-site location

2 – Included in the finished water clear-well footprint

It is estimated that the total site required for an ultimate capacity of 50 mgd would be approximately 23 acres based on the same design criteria, with efficiencies in site space gained in parking, roads, administration building, and the finished water pump station.

Using high-rate DAF to replace conventional sedimentation in front of the reverse osmosis units, it is estimated that the overall site requirements would be substantially reduced. Under this alternate design concept, the estimated plant site requirements are estimated to be approximately 7 acres. Support documentation including criteria used, a summary of calculations, and a preliminary site plan is included in *Appendix B-1*.

Footprints have been assumed for support facilities such as an administrative building, maintenance shop, and laboratory space. These are only placeholders based on typical industry requirements and are subject to change in future adjustment. In addition to footprint estimates of identified spaces on the site, a contingency has been factored into the overall site requirements to account for roadways, yard piping, sidewalks, landscaping, utilities, and miscellaneous facilities not yet identified. The areas reserved for these components are considered a worst-case scenario so that site size requirements established herein are conservative. The preliminary land area requirements determined in this analysis are based on a finished water capacity of 25 mgd. If a future expansion of the plant to 50 mgd finished water production is considered, it has been assumed that the treatment processes and process support facilities would be mirrored.

Under the high rate pre-treatment option, it is estimated that the total site required for an ultimate capacity of 50 mgd would be approximately 12 acres with efficiencies in on-site space gained in parking, roads, administration building, and the finished water pump station.

If plant capacity is expanded to 50 mgd in the future, the high rate pre-treatment options are much more land-area efficient than the conventional pre-treatment process. Using the high-rate DAF pre-treatment option in front of the reverse osmosis system, approximately 50 mgd of capacity can be placed in the same area required for a 25-mgd conventional pre-treatment reverse osmosis plant.

2.1.5 Power Requirements

Power requirements have been estimated for major components of the treatment process. The highest power consumption would be from the RO feed pumps, which pump 50 mgd of water to a pressure of 800 to 1,200 psi.

Based on the estimated raw water quality, finished water quality goals, and treatment process design criteria, a preliminary estimate of required power supply was developed for a conventional 25-mgd facility. Summary information is shown in *Table 3-2.1.5-1*. The initial 25-mgd plant is estimated to require approximately 20 MW of power supply with a 100 percent demand factor, and the power requirements for a facility using DAF pre-treatment would be comparable. If the plant were expanded to an ultimate capacity of 50 mgd, the power load would approximately double. An energy recovery system will be installed that could recover a significant portion of the energy used to desalinate seawater; however, for the development of site area requirements, the power recovery feature is not included, and a full capacity substation is used in the sizing analysis. These issues are more fully developed in *Chapter 4 – Water Production*.

Table 3-2.1.5-1 Summary of Estimated Required Power

System	kW	kW/yr	Cost/yr[1]
Pre-Treatment System	1,430	10,890,000	$708,000
Desalination System	16,550	144,020,000	$9,362,000
Dewatering	300	2,000,000	$130,000
Chemical Dosing	110	890,000	$58,000
Distribution	770	6,710,000	$436,000
Misc.	500	4,380,000	$285,000
Total	**19,660**	**168,890,000**	**$10,979,000**

1 Assume $0.065/kW-hr

2.2 Site Identification, Analysis, and Selection

2.2.1 Site Identification

With the identified site criteria established in *Section 2.1.1* and the specific site size requirements identified in *Section 2.1.4*, comprehensive research of the industrial areas in and around the Corpus Christi area, including Nueces and San Patricio Counties was conducted. (See *Appendix B-2*.) This research revealed five potential sites for the proposed desalination facility.

Elementis Chromium	84,200 ac-ft/yr	Nueces County
Flint Hill Resources East (Koch)	9,331 ac-ft/yr	Nueces County
Qualitech Steel	161,300 ac-ft/yr	Nueces County
DuPont	4,000 ac-ft/yr	San Patricio County
Barney Davis Power Plant (AEP)	560,000 ac-ft/yr	Nueces County

The five identified industrial sites are holders of saltwater rights permits in San Patricio and Nueces Counties. The criteria were chosen as a differentiator from other potential industrial sites because of the potential infrastructure that would likely already be in place and that, if necessary, additional water rights permits could possibly be easier to obtain. The required water rights for the proposed first phase of the Large Scale Desalination Project are a minimum of 62,000 acre-feet/year (ac-ft/yr), which is equivalent to a continuous flow rate of 55 mgd.

2.2.2 Preliminary Screening Analysis

Elementis Chromium Site. A preliminary contact was made with Jaime Garcia, Plant Manager of Elementis Chromium. It was determined that saltwater intake was currently being used by Calpine for cooling water for the cogeneration facility which is located adjacent to the Elementis facility. The interest level for co-locating a desalination facility at this site was very low. For this reason, this site was eliminated from further consideration.

Flint Hills Resources East. A preliminary contact was made with Dave Allen, Facilities Manager and Mike Wilkes, Manufacturing Manager. It was determined that the existing saltwater intake was not currently in use and was scheduled for removal. The water rights at this facility are not sufficient for the desalination facility, and the capacity of the intake was not determined during these initial preliminary screening discussions. The interest level was very strong for this site and they are willing to develop further discussions. They have sufficient land available and are willing to consider an arrangement for co-siting at this facility. They are currently at the end of the City water main and are very interested in developing an alternate feed of water to the refinery in the event of disruption of service with the current main. It is recommended that this site be considered for further follow-up.

Qualitech Steel. It was difficult to determine the present status of ownership of this facility and preliminary contact attempts were unsuccessful. However, it was determined that this site is currently involved in bankruptcy proceedings. The site has a currently unused large saltwater intake with water rights of 161,000 ac-ft/yr, which would be adequate for the desalination facility. However, with the current status of the ownership of this plant and those involved in the bankruptcy proceeding, it is not recommended for further follow-up. In the future and prior to selecting a final site for subsequent project phases, the status of this site should be reconsidered.

DuPont. A preliminary contact was made with Corky Neischwietz, Unit Manager, and Bob Blaschke, Environmental Coordinator, for this facility. It was determined that the saltwater intake is owned by DuPont and is currently not in use. The process that it had been used for has been shut down and removed from service. The saltwater rights are only 4,000 ac-ft/yr and are not sufficient for the desalination facility. There was some interest in cooperating with the desalination effort, but there was no compelling need for the water at the DuPont site. They do have sufficient land available for siting the facility and would be willing to be considered for locating the facility and negotiating for the necessary land. Because of the lack of a compelling need for the facility at this site, it is not recommended for follow-up.

Adjacent to the DuPont site is the Oxychem site. The Oxychem site was not identified in the original site pre-screening, but was discovered for possible consideration through discussions with DuPont personnel. The Oxychem site was originally built as a Caustic/Chlorine facility by DuPont and is contiguous to the DuPont plant. It was acquired several years ago by Oxychem and uses high concentration saltwater as its primary feedstock. There was some uncertainty as to whether DuPont or Oxychem had the saltwater intake permit when our investigation began. It was eventually resolved that the DuPont plant had the water rights permit. The possibility of utilizing the reject byproduct from the desalination facility as a plant feedstock presented some unique opportunities for this project; therefore, it was decided to further investigate the Oxychem site as a potential prospective site.

Oxychem. Contact was made with Tom Feeney, Plant Manager; Dennis Biggs, Project Engineering Superintendent; Brian Rapp, Cogen Technical Superintendent; and Ray Gritte, Manager of Diaphragm Cell Technology. There was a very strong interest in co-siting a desalination plant with their facilities. They use a feed stream of saltwater for their process and stated that some of their plants use a concentrated seawater feed. Pros and cons and specific requirements will be addressed later in the report, but the possibility of their using the desalination reverse osmosis byproduct stream as a feedstock seemed viable. Oxychem has sufficient land for the proposed site and also has a cogeneration facility that has excess generating capacity at this time. There are many good synergies for considering this site, and it is recommended for follow-up.

Barney M. Davis Power Plant. The Barney M. Davis Power Plant is located in Nueces County, Texas, adjacent to the south side of the City of Corpus Christi. The plant is located on approximately 1,992 acres of land (after separation of generation and transmission & distribution), between the Laguna Madre and Oso Bay.

The Barney M. Davis site has long been considered strongly as a viable location for the desalination facility. The existing intake and saltwater rights are sufficient for the desalination facility. However, the intake is located in Laguna Madre, which has a highly variable salinity content that can reach concentrations as high as 70,000 mg/l. This could be a significant problem for the desalination process. The site discharges cooling water into Oso Bay, and there may be a possibility that the desalination byproduct stream could be commingled with the cooling water resulting in low cost byproduct disposal. Locating the desalination facility at this site would also provide a large base power demand for the power plant, and a beneficial power rate structure may be negotiated.

Just prior to publication of this report, a contact was made with the new owners for this site, Topaz Power Partners. This contact revealed that the new owners are interested in co-siting the desalination facility. In addition, the new owners provided a draft letter of their willingness to provide a site for the desalination plant and to allow discharge of the byproduct water into their cooling ponds, if a discharge to Oso Bay proves to be feasible.

2.2.3 Site Selection Recommendations

As a result of the site investigations, two sites were chosen for more detailed analyses in this feasibility study—the Barney Davis Power Plant site and the Oxychem/DuPont site. Of these two sites, the Barney Davis site is probably the most feasible site from technical considerations. The Barney Davis site has potentially useable infrastructure in place, is closer to the Gulf of Mexico if an open sea intake or open sea byproduct disposal is required, has significant land area available for a desalination facility, is co-located with a potential power source, has the necessary transportation infrastructure nearby, is in close proximity to major water system infrastructure, and is situated at the opposite end of the City's distribution system from their existing treatment plant.

The Oxychem site is also potentially viable based on the preliminary screening conducted. However, in comparison to the Barney Davis site, the Oxychem site is located farther from the Gulf of Mexico if an open sea intake or byproduct disposal is required, the available land area is smaller, and the delivery point to potential users of the finished product water is more distant.

On an intuitive basis, it appears that the Barney Davis site is technically the strongest site. However, including both the Oxychem and Barney Davis sites in the detailed feasibility analysis makes contrasting conditions and cost sensitivity analyses more readily available. Also, at this early stage of the project, neither the desalination facility nor the site owners can make a firm commitment to the other party, and further analyses must be finalized and administrative and legal issues resolved. Therefore, bringing at least two sites forward in the evaluation process allows additional negotiating during future project phases.

For this screening of potential sites, two sites are recommended for the detailed analyses in the subsequent sections of this report. As the feasibility study progresses, other site selection criteria may become more apparent and some of the assumptions used in this preliminary screening may change in relative priority. Therefore, selection of the appropriate site should be considered an ongoing activity and should be included as a detailed task in any subsequent project phase that results from this feasibility study.

Chapter 4

Water Production

CHAPTER 4 – WATER PRODUCTION
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CHAPTER 4 – WATER PRODUCTION

1 INTRODUCTION

In *Chapter 3*, preliminary estimates of the treatment requirements were made to allow for development of plant site requirements and for pre-screening potential sites. By identifying the general site requirements early in the process, the evaluation team was able to simultaneously screen potential sites and develop the detailed evaluations presented in this chapter.

Chapter 4 provides a detailed review and evaluation of each major function and process required to obtain raw water supplies, treat the water to drinking water standards, and deliver potable water to the Corpus Christi water system. Detailed criteria and sizing of all major components have been prepared and presented, and cost estimates for capital costs, operations and maintenance costs, and total life cycle costs have been made.

During the identification, screening, development, and evaluation of alternatives, a significant emphasis is placed on the long-term reliability of performance. By emphasizing reliability, the resultant cost estimates will present a reasonable expectation of the total project cost while minimizing risk associated with marginally acceptable processes. When the project proceeds to preliminary engineering, additional water quality, treatability, and pilot studies should be performed to validate the assumptions used in this report and to potentially identify cost-effective solutions that may not have been available or were eliminated from detailed evaluation through the course of this feasibility study.

2 DEVELOPMENT OF SEAWATER SOURCE

The required product water flow-rate of the project is 25 mgd as defined in the Request for Statements of Interest. However, to produce 25 mgd of finished water, a larger portion of raw water is required to account for waste streams for the water treatment plant. These waste streams can include filter washwater, clarifier residuals streams, and concentrated dissolved solids in the reverse osmosis byproduct stream.

For a seawater membrane desalination plant, the largest component of the waste stream is the membrane system byproduct concentrate. This stream will typically comprise over 90 percent of the total waste for a seawater membrane desalination plant.

The ultimate recovery of a seawater membrane system is typically a factor of the maximum permissible operating pressure and the solubility of sparingly soluble salts such as calcium sulfate. Each is discussed below in further detail.

Maximum Permissible Operating Pressure. The maximum operating pressure is generally a limit set by the safety factors developed. When two water volumes are separated by a semi-permeable membrane, water will flow from the side of low solute concentration, to the side of high solute concentration via the process of osmosis, until equilibrium is reached. The flow may be stopped, or even reversed, by applying external pressure on the side of higher concentration. The phenomenon resulting from reverse flow through the application of pressure is commonly referred to as reverse osmosis. The thermodynamic energy that provides the driving force for osmosis is referred to as the osmotic pressure.

The osmotic pressure p, may be determined using the van't Hoff formula:

$$p = cRT \qquad \text{- Equation 1}$$

where,

c is the molar solute concentration,
R is the gas constant, and
T is the absolute temperature.

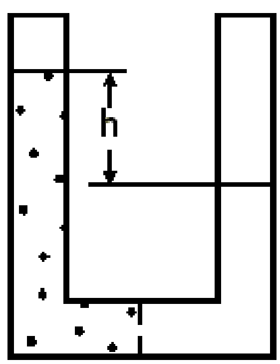
Figure 4-2-1 shows connected vessels separated by a semi-permeable membrane. If there is only water in the device, the level will be the same at both sides. When solute molecules are added to one side, water will start to flow into it, so that its level will go up at this side, and down at the other side. The system will stabilize when the osmotic pressure is balanced by the hydrostatic pressure generated by the difference in the water levels, as indicated in Equation 2.

$$cRT = rh \qquad \text{- Equation 2}$$

where,

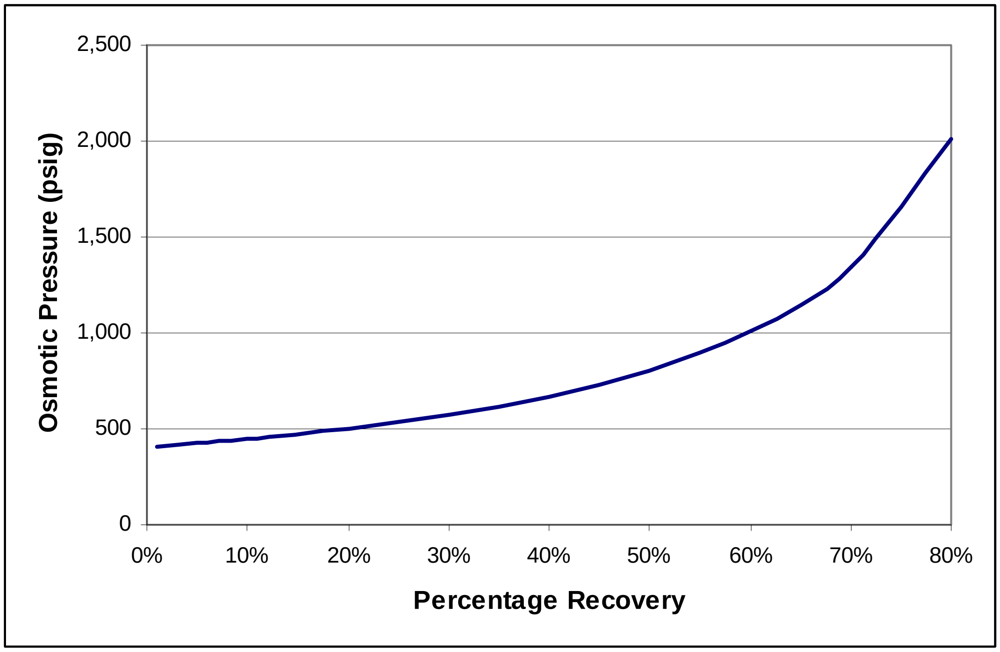
r is the water specific gravity.

Figure 4-2-1   Explanation of Osmosis



The osmotic pressure may be estimated using the relation 0.0115 psig/ppm. For a typical seawater (TDS = 35,000 mg/l), *Figure 4-2-2* was constructed to illustrate the effect of increasing recovery on the osmotic pressure of the concentrate.

Figure 4-2-2   Effect of System Recovery on Concentrate Osmotic Pressure for Standard Seawater



Most systems are designed to operate at a maximum pressure of less than 1,000 psig, although some systems have been designed to operate as high as 1,200 psig. Based upon *Figure 4-2-1* and *Figure 4-2-2,* the osmotic pressure of concentrate at 60 percent recovery is approximately 1,000 psig. To produce permeate; the operating pressure must exceed the osmotic pressure. For seawater reverse osmosis (SWRO), the practical limit for recovery is typically 50 percent. Most operating plants today operate with between 35 and 50 percent recovery depending upon the salinity of the water and the type of membrane utilized.

Although mass transfer theories have recently superseded the reverse osmosis theories when describing hyper-filtration, reverse osmosis remains the simplest explanation used to describe the function of hyper-filtration membranes.

Sparingly Soluble Salts. Reverse osmosis seawater desalination systems utilize the differing rates of mass transfer of water and salts through a semi-permeable membrane to produce high quality permeate from seawater. Since the membranes reject high percentages of salts (>99 percent), an accumulation of salts occurs on the feed side of the membrane. At some juncture, the solubility of sparingly soluble salts such as calcium sulfate, barium sulfate, strontium sulfate, or calcium carbonate may occur, resulting in precipitation of these salts on the membrane. Precipitation of these salts can increase pressure drop, requiring higher feed pressures and resulting in higher operating costs, or can result in increased salt concentrations in the permeate stream. Both of these consequences are undesirable.

Reverse osmosis system operators and designers can control the concentration of sparingly soluble salts in the concentrate stream by controlling the system recovery. Reducing the recovery also reduces the concentration of sparingly soluble salts in the concentrate. Chemical conditioning of the feedwater using scale inhibitors and dispersants can result in supersaturation of sparingly soluble salts with minimal precipitation. Generally, for seawater desalination, the residence time of the supersaturated water in the membrane vessels is very short–far shorter than the kinetics of precipitation. As a result, many seawater installations have been shown to operate with no scale potential at recoveries on the order of 50 percent with sparingly soluble salts concentrations exceeding solubility by as high as 300 percent. As a result, the ultimate recovery of seawater reverse osmosis units is generally determined by operating pressure and salt passage.

Based upon the limits imposed by osmotic pressure and sparingly soluble salts, it is predicted that the reverse osmosis system recovery will be approximately 50 percent. Detailed modeling using the membrane manufacturer's proprietary software can be performed to confirm recovery. This determination is discussed in detail in *Section 3.2*.

In summary, to produce 25 mgd of finished water for this application, the raw water supply must be on the order of 50 to 55 mgd to account for concentrate discharge and pre-treatment waste streams. The final raw water requirement depends on the specific pre-treatment and residual handling process selected and is, therefore, addressed in further detail in *Section 3.2*.

2.1 Groundwater Sources for Raw Water Blending

Brackish groundwater can be used to blend with a saline water source to manufacture a consistent feedwater to the reverse osmosis (RO) desalination system. This section reviews available literature concerning the existence, availability, and anticipated quality of groundwater in the study area to determine if groundwater blending is a viable process for the Corpus Christi Demonstration Desalination Facility.

The study area of Nueces and San Patricio Counties is located in South Texas in the Coastal Bend region of the West Gulf Coastal Plain and encompasses the City of Corpus Christi, the county seat of Nueces County. The Nueces River is the boundary between the two counties, which have a land area of 1,518 square miles.

Located on the coast of the Gulf of Mexico, Corpus Christi lies directly to the southeast of Corpus Christi Bay and Nueces Bay. Both bays are relatively shallow with significant freshwater flows from the estuary of the Nueces River. The entrance to Corpus Christi Bay is protected from the Gulf of Mexico by a series of sandbars and low-lying islands extending parallel to the coast. Between these low-lying islands and the mainland, there exist shallow regions of frequently hypersaline water, such as that in Laguna Madre.

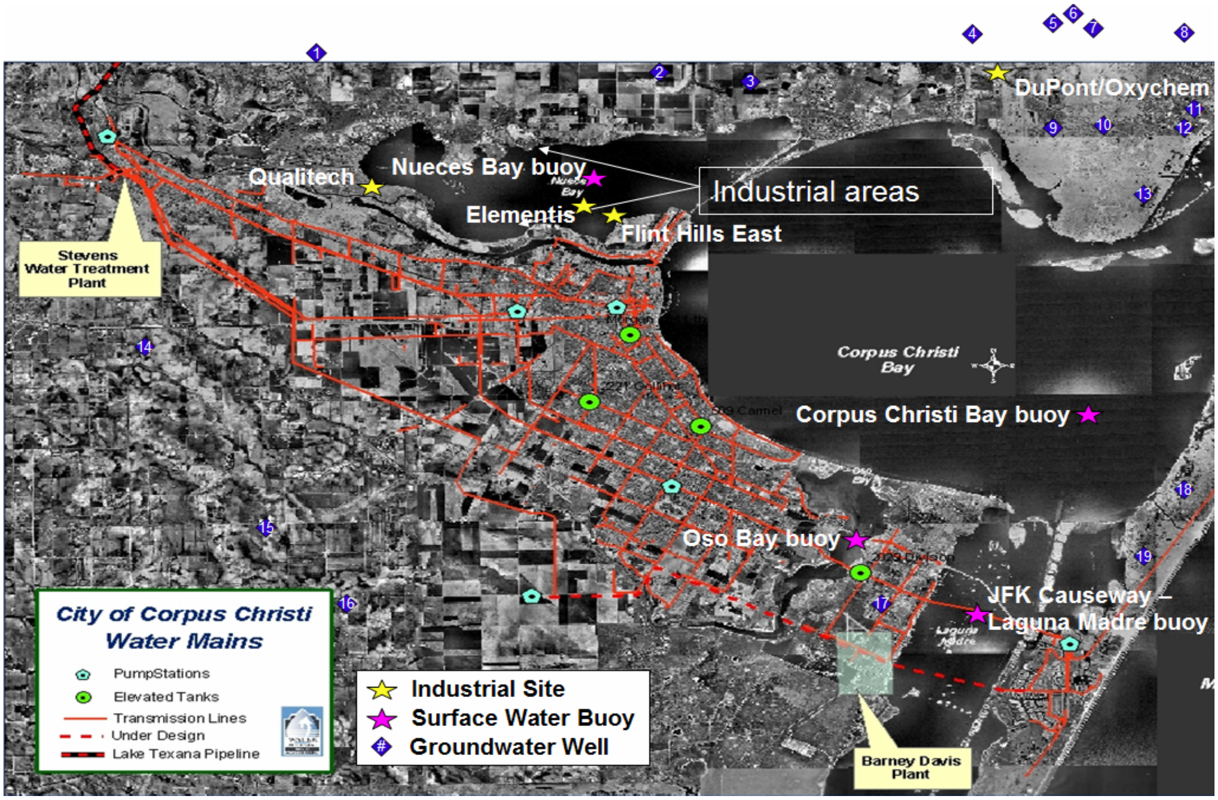
Groundwater occurs under water table and artesian conditions. Under water table conditions, the water is unconfined and does not rise above the level at which it is first encountered in a well. Under artesian conditions, the aquifer is overlain by relatively impermeable beds, and the water is confined under hydrostatic pressure. Where the elevation of the land surface at a well is considerably lower than the level of the outcrop of the aquifer, the pressure may be sufficient to cause the water to flow at the surface. Although the terms “water table” and “piezometric surface” are synonymous in the area of outcrop of an aquifer, the term piezometric surface, as used in this report, is applied only to the artesian parts of the aquifers. In the areas where the beds of permeable material in the Gulf Coast aquifer crop out, groundwater is unconfined and is therefore under water table conditions. Down dip from the outcrop areas, the permeable beds may be overlain by less permeable material, and the water is, therefore, confined or under artesian conditions.

TWDB reports that groundwater in the two counties moves southeastwardly from the areas of recharge to areas of discharge. Several communities use groundwater for public supply, but the largest public supplies are obtained from the Nueces River. TWDB reports that small additional supplies of groundwater, perhaps on the order of a few million gallons per day, are probably available for development in the two-county area without depleting the aquifer. The aquifers cannot support large-scale withdrawals of groundwater without depletion.

According to TDWB (1968), moderate saline water is available for development in the area. The stratigraphic units that contain fresh to slightly saline or moderately saline water in Nueces and San Patricio Counties are, from oldest to youngest, the Goliad Sand of Pliocene age, the Lissie Formation and Beaumont Clay of Pleistocene age, and the alluvium and beach and dune sands of Pleistocene or Recent age. The Goliad Sand, Lissie Formation, and Beaumont Clay crop out in belts that trend roughly northeast, parallel to the coast). The Goliad Sand is farthest from the coast, and the Beaumont Clay is nearest the coast.

Limited well water quality data for the Corpus Christi area was obtained from a local publication (USGS 1968), from a database on the TWDB website (TWDB 2004) and from a review of electric logs of oil and gas test wells and of studies on the brackish to saline resources performed for the San Patricio Municipal Water District. From this data, wells in the vicinity of the five locations under consideration for the desalination facility were reviewed. *Figure 4-2.1-1* illustrates the relative positions of the wells to the five locations originally identified as sites for the demonstration desalination facility.

Figure 4-2.1-1 Well Locations Used for Groundwater Quality Determination in the Vicinity of Corpus Christi

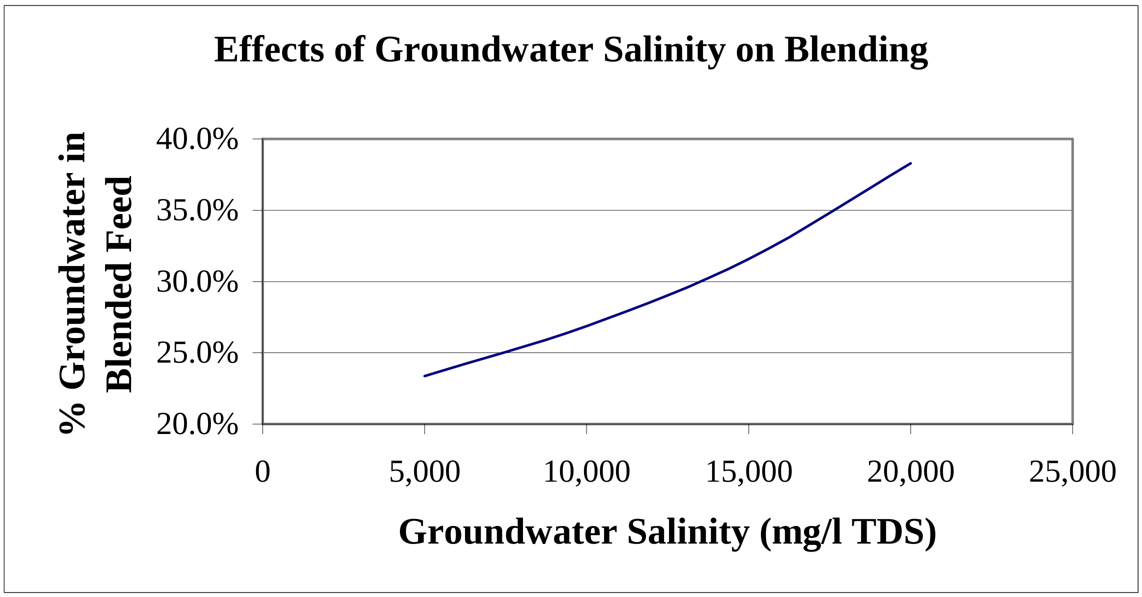


Water quality of relatively shallow wells varies widely with well depths ranging from 40 feet to 406 feet in depth. Much of the data is also very dated, with collection ranging from 1938 to 1966. Total dissolved solids in the reported data range from 305 mg/l to 9,580 mg/l. The overall confidence in the current validity of the data is low, given well publicized reports of seawater intrusion in the Gulf Coast region.

It is assumed that groundwater sources possessing total dissolved solids of less than 500 mg/l would be suitable for potable water with no additional treatment. These sources were eliminated when evaluating a "design" groundwater analysis for blending purposes. Additionally, it was assumed that groundwaters possessing between 500 mg/l and 1,000 mg/l of total dissolved solids could economically be used for other applications (irrigation, industrial) with substantially lower cost than the equivalent product water from a desalination facility. Therefore, the target groundwater quality data for use as a blending agent with seawater has a total dissolved solids concentration of greater than 1,000 mg/l of total dissolved solids.

From a mass balance perspective, as the TDS concentration of the groundwater increases, the use of groundwater as a seawater blending agent becomes less valuable. With a fixed saline concentration from the primary source, as the groundwater salinity increases, greater quantities of groundwater are required to bring the manufactured blend of water to the desired TDS level. As the percentage of groundwater in the blended stream increases, the number of wells is increased, well collection lines become more expensive, and the likelihood of increasing saltwater intrusion is increased either from the nearby seawater source or by raising deep brines in the aquifer. *Figure 4-2.1-2* indicates the efficacy of using groundwater at varying TDS concentrations when blending with a fixed saline source. The fixed saline source is 43,500 mg/l TDS, which is taken from water quality data from Laguna Madre adjacent to the Barney Davis Power Plant site.

Figure 4-2.1-2 Blending Groundwater With Saline Water



With a total blended stream flow of 55 mgd, every 2 percent rise in the groundwater contribution corresponds to approximately 1 million gallons per day. From *Figure 4-2.1-2*, if the groundwater TDS concentration is 15,000 mg/l, a 32 percent groundwater contribution to the blend is required, which is approximately 17 million gallons per day. For estimating purposes, it is reasonable to assume that the cost of developing a 1 mgd well, including well collection lines and related appurtenances, is $1.25 million. The analysis of well information in the area of each of the two treatment plant sites (selected in the pre-screening process in the previous chapter) is presented in the following paragraphs.

2.1.1 General Groundwater Aquifer Descriptions

The aquifers that have a potential of providing water at the Barney Davis Plant site or Oxychem Plant site are the Chicot and Evangeline units that compose part of the overall Gulf Coast Aquifer System. The units are composed of lenticular and alternating beds of sand, silt, clay, and shale. The sand beds vary in thickness from a few feet to about 40 feet with a few beds up to about 70 to 100 feet.

The sands vary in grain size from very fine to medium. If there are any coarse grained sands, normally they occur in the Chicot unit. It is difficult to distinguish between the Chicot and Evangeline units as they are composed of the same general types of material. In some locations, there can be a change in color of the sand with sands of the Chicot unit normally being buff to tan and sands of the Evangeline unit grading to a gray color. Sands of the Evangeline unit normally are finer grained than sands of the Chicot unit. At the Oxychem Plant site area, review of electric logs shows that for the Chicot unit which extended from approximately land surface to a depth of about 750 feet, the section had about 25 percent sand and about 75 percent clay. Review of electric logs spanning the Evangeline unit in the depth interval about 750 to about 2,200 feet, shows the Evangeline is composed of about 35 percent sand and about 65 percent clay. Individual sand beds were at a maximum thickness of about 100 feet with some sand beds being no more than about 5 feet thick. Thus, the units are composed of many alternating beds of sand and clay.

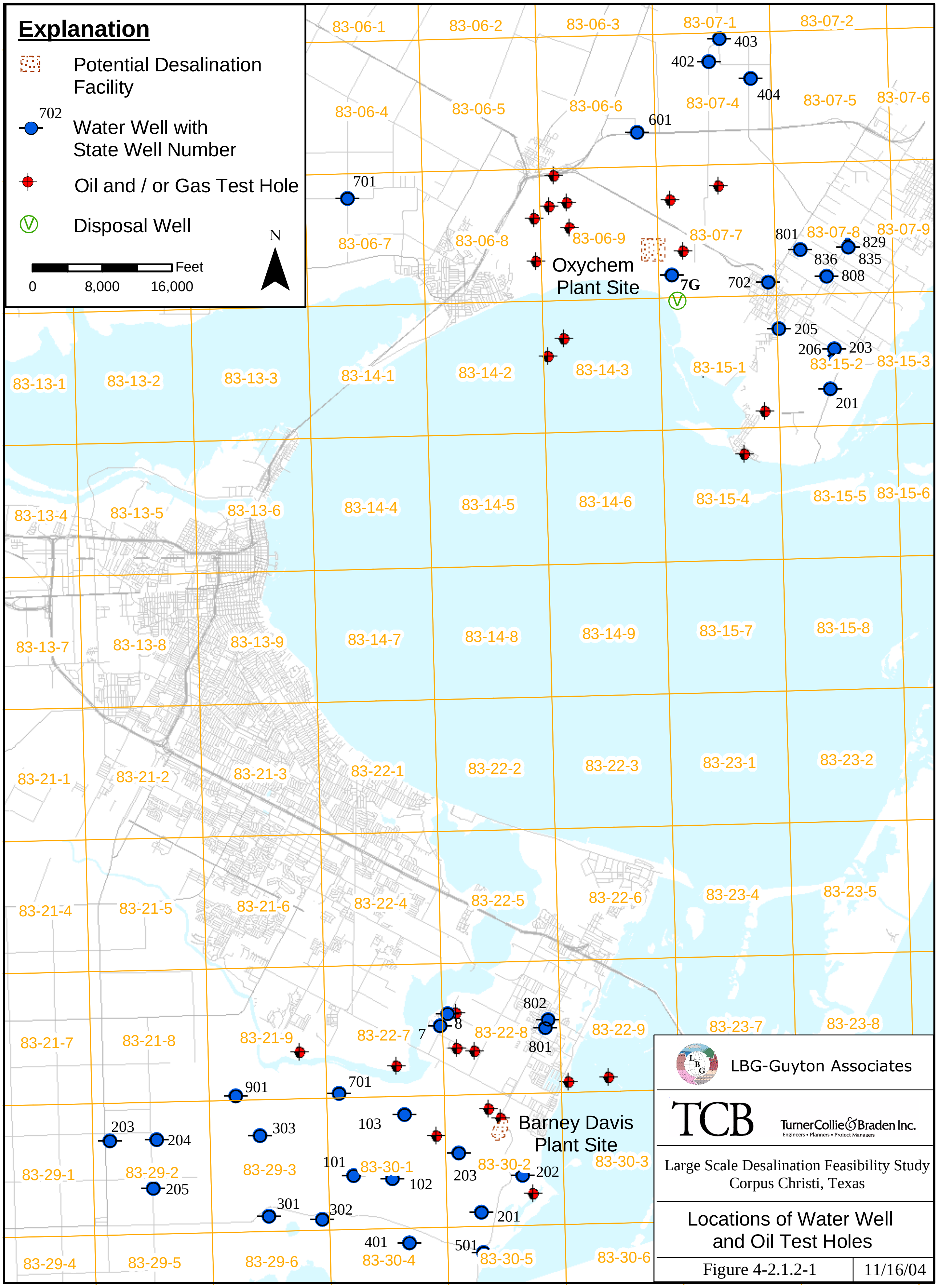
The aquifer units dip toward the coast at a rate greater than the slope of land surface. The dip of the Chicot unit is about 30 feet per mile and the dip of the Evangeline unit is about 50 to 60 feet per mile. The aquifer units thicken toward the coast and extend on past the coastline in the subsurface below the Gulf of Mexico.

Numerous groundwater reports were collected and reviewed for the purposes of investigating geologic and hydrogeologic conditions for the study and are listed in the references of the report.

2.1.2 Water Well and Water Quality Data

Oxychem Plant Site

As part of the study, data were collected regarding water wells drilled in the area and the quality of the water obtained from them. Records available from TWDB, previous reports, and private sources show that wells are primarily drilled for domestic and stock purposes and for public supply in a limited part of the City of Aransas Pass. In Aransas Pass a small amount of groundwater has been provided for public supply. Well locations from the TWDB database are shown in *Figure 4-2.1.2-1*. Records for the wells are given in *Table 4-2.1.2-1* and water quality data are provided in *Table 4-2.1.2-2*. In general the data show that wells that are completed to depths of about 150 to 210 feet can provide water with TDS in the range of 2,000 to 4,500 mg/l. The data also show that the sands available for screening are limited in thickness and that the wells normally provide small quantities of water. As examples, one abandoned well (83-06-701) is located to the west of the Oxychem Plant site about 7 miles and is completed to a depth of 210 feet. A sample from the well had TDS of 2,254 mg/l. Another well (83-07-702), located on the west side of the City of Ingleside, was sampled in 1965, and had TDS of 1,928 mg/l with the well completed to a depth of 150 feet. A domestic well (83-07-404), located approximately 3 miles north of the City of Ingleside, was sampled in 1965, 1975, and 1981. This well screens the Chicot unit in the depth interval from 182 to 192 feet and had TDS values of 4,556 mg/l, 4,631 mg/l, and 3,836 mg/l, respectively. It also is reported at one industrial facility near Corpus Christi Bay and in close proximity to the Oxychem Plant site, that at a depth of about 40 feet the groundwater contained about 8,000 mg/l of TDS.


Explanation
Potential Desalination Facility
702
Water Well with State Well Number
Oil and / or Gas Test Hole
Disposal Well
N
Feet
0
8,000
16,000
Oxychem Plant Site
Barney Davis Plant Site
83-06-1
83-06-2
83-06-3
83-07-1
83-07-2
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LBG-Guyton Associates
TCB
Turner Collie & Braden Inc.
Engineers • Planners • Project Managers
Large Scale Desalination Feasibility Study
Corpus Christi, Texas
Locations of Water Well and Oil Test Holes
Figure 4-2.1.2-1
11/16/04

Table 4-2.1.2-1 Groundwater Quality Data

State Well Number	Well Owner	Screened Interval or Total Depth (feet)	Sample Type or Source	Lab	Sample Date	Iron	Manganese	Calcium	Magnesium	Sodium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Dissolved Solids	Total Hardness	Specific Conductance (micromhos/ cm at 25oC)	pH
WW-83-06-601	W. W. Tolan	220	Water Well	TWDB	10/08/38													--	--
			Water Well	TWDB	05/28/69	--	--	88	27	1620	351	117	2500	1.1	<0.4	4545	330	9432	7.6
WW-83-06-701	M. Crites	210	Water Well	TWDB	11/02/38	--	--	--	--	--	397	48	1190	--	--	2250	--	--	--
WW-83-07-402	Porterfield Estate	175	Water Well	TWDB	09/19/38	--	--	53	27	1632	134	54	2570	--	--	4400	242	--	--
WW-83-07-403	J. S. McCampbell	280	Water Well	TWDB	09/19/38	--	--	54	18	1493	329	<1	2260	--	--	3990	211	--	--
WW-83-07-404	R. F. McCampbell	182-192	Water Well	TWDB	06/04/65	--	--	44	35	1670	540	328	2200	--	--	4560	254	8000	8.1
			Water Well	TWDB	08/17/75	--	--	69	23	1670	536	305	2280	0.7	<0.4	4631	266	9240	7.9
			Water Well	TWDB	06/23/81	--	--	40	31	1350	406	470	1714	0.7	<0.1	3836	227	7840	8.5
WW-83-07-702	City of Ingleside Well 3	140-150	Water Well	TWDB	07/08/65	--	--	28	22	687	376	86	890	--	1	1928	160	3480	7.5
WW-83-07-801	Leon Contreras	84	Water Well	TWDB	06/23/38	--	--	35	22	332	421	54	355	--	--	1005	177	--	--
			Water Well	TWDB	07/08/65	--	--	14	15	555	554	107	520	1.5	0.5	1515	96	2650	7.8
WW-83-07-808	A. E. Murphy	90	Water Well	TWDB	06/22/38	--	--	108	25	196	329	45	340	--	--	875	372	--	--
			Water Well	TWDB	05/28/69	--	--	97	17	202	332	44	311	0.5	<0.4	862	311	1694	7.5
WW-83-15-201	Ingleside Land Co.	41	Water Well	Dept. Health	05/28/69	--	--	48	8	150	224	5	208	0.1	0.4	570	152	1080	7.7
UB-83-22-801	Flour Bluff School	151-181	Water Well	TWDB	01/05/66	--	--	18	8	305	492	72	200	--	0	875	77	1460	7.5
			Water Well	TWDB	06/19/81	--	--	24	11	270	419	49	207	1	<0.1	806	104	1467	8.5
			Water Well	TWDB	12/06/91	--	--	36	15	227	360	43	209	0.9	0.7	744	152	1240	7.7

Table 4-2.1.2-2 Records of Wells

State Well Number	Well Owner, Well Name/ Number	Year Com-pleted	Drilling Firm	Aquifer (1)	Well Elevation (feet) (2)	Total Depth of Well (feet)	Screened Interval & Total Screen (feet)	Casing & [Screen] Diameter/s (inches)	Specific Capacity (gpm/ft)	Pumping Rate (gpm)	Static Water Level Depth (feet) (3)	Date	Use of Water (4)
WW-83-06-601	W. W. Tolan	1927	E. T. Elwood	Ch	25	220	–	3	–	–	14.3	2/25/65	D, S
							–	[3]					
WW-83-06-701	M. Crites	1919	–	Ch	–	210	–	–	–	–	–	–	(U)
							–	–					
WW-83-07-402	Porterfield Estate	1921	–	Ch	–	175	–	–	–	–	90	1938	(U)
							–	–					
WW-83-07-403	J. S. McCampbell	1927	–	Ch	–	280	–	2	–	–	–	–	(U)
							–	[2]					
WW-83-07-404	R. F. McCampbell	1960	Martin Well Service	Ch	12	192	182-192	4	–	–	8.8	6/4/1965	D
							–	[4]					
WW-83-07-7G	E.I DuPont de Nemours Co.	1984	Layne-Western	Ev	–	1,750	1,180-1,720	12	–	1,500	Flows	Aug-84	(U)
							175	[12]					
WW-83-07-702	City of Ingleside	1947	J. R. Burns	Ch	–	150	140-150	6	–	–	–	–	Irr
	Well 3						10	[6]					
WW-83-07-801	Leon Contreras	1931	–	Ch	12	84	–	4	–	–	17.1	6/23/38	D
							–	[4]			13.3	11/19/59	
WW-83-07-808	Murphy	1920	–	Ch	15	90	–	4	–	–	14.9	6/22/38	D, S
							–	[4]			16.3	2/25/65	
WW-83-07-829	Humble Oil & Refining Co.	1938	Layne Texas Co.	Ch	18	182	50-182	8	–	120	–	8/20/39	(U)
							132	[8]					
WW-83-07-835	McCampbell	1939	Humble Oil	Ch	18	–	–	–	–	–	20	Aug-39	(U)
							–	–					
WW-83-07-836	McCampbell	1939	Humble Oil	Ch	18	–	–	–	–	–	21	1939	(U)
							–	–					

Table 4-2.1.2-2 *(continued)*

State Well Number	Well Owner, Well Name/ Number	Year Com-pleted	Drilling Firm	Aquifer (1)	Well Elevation (feet) (2)	Total Depth of Well (feet)	Screened Interval & Total Screen (feet)	Casing & [Screen] Diameter/s (inches)	Specific Capacity (gpm/ft)	Pumping Rate (gpm)	Static Water Level Depth (feet) (3)	Date	Use of Water (4)
WW-83-15-201	Ingleside Land Co.	–	–	Ch	13	41	–	4	–	–	7.33	12/16/80	(U)
							–	[4]					
WW-83-15-203	H. A. Stevens	1913	–	Ch	11.96	50	–	4	–	–	8.13	3/17/64	D
							–	[4]					
WW-83-15-205	V. A. Kirkpatrick	1938	–	Ch	13	92	–	–	–	–	17.42	11/21/47	D, S
							–	–					
WW-83-15-206	W. T. Harris	1936	–	Ch	9.57	51	–	1.5	–	–	6.91	11/19/59	S
							–	[1.5]					
UB-83-21-901	King Ranch	1958	Carl Vickers	Ch	15	140	119-140	5	–	–	12.2	11/10/65	S
							21	[5]					
UB-83-22-701	King Ranch	–	Carl Vickers	Ch	20	146	125-146	5	–	–	13.3	11/10/65	S
							21	[5]					
UB-83-22-801	Flour Bluff School	1953	Martin Well Service	Ch	15	181	151-181	6	–	–	16.1	2/18/04	Irr, P
							30	[6]					
UB-83-22-802	Flour Bluff School	1953	Carl Vickers	Ch	15	172	151-172	6	–	–	24	1965	(U)
							21	[6]					
UB-83-22-7	S. Overley	2003	Martin Water Wells	Ch	–	165	125-165	4	–	–	25	5/13/03	D
							40	[4]					
UB-83-22-8	F. Cabral	2003	Martin Water Wells	Ch	–	165	125-165	4	–	–	18	5/12/03	D
							40	[4]					
UB-83-29-203	Ruth Cowles Estate	1947	Carl Vickers	Ev	19	1,035	1,015-1,035	6	–	–	66	1965	D, S
							20	[4]					

Table 4-2.1.2-2 *(continued)*

State Well Number	Well Owner, Well Name/ Number	Year Com- pleted	Drilling Firm	Aquifer (1)	Well Elevation (feet) (2)	Total Depth of Well (feet)	Screened Interval & Total Screen (feet)	Casing & [Screen] Diameter/s (inches)	Specific Capacity (gpm/ft)	Pumping Rate (gpm)	Static Water Level Depth (feet) (3)	Date	Use of Water (4)
UB-83-29-204	Ruth Cowles Estate	1926	A. C. Downs	Ch	18	197	–	4	–	–	–	–	(U)
							–	[4]					
UB-83-29-205	B. Cunningham Estate	1926	A. C. Downs	Ch	19	190	170-190	4	–	–	–	–	(U)
							20	[4]					
UB-83-29-301	King Ranch	–	–	Ch	18	63	–	5	–	–	8.2	7/28/60	S
							–	[5]			12.5	11/10/65	
UB-83-29-302	King Ranch	1963	Humble Oil	Ch	20	246	222-246	5	–	–	17	11/10/65	S
							24	[5]					
UB-83-29-303	King Ranch	–	Carl Vickers	Ch	17	155	134-155	5	–	–	18.3	11/10/65	S
							21	[5]					
UB-83-30-101	King Ranch	–	King Ranch Corp.	Ch	20	50	45-50	6	–	–	22.7	11/10/65	S
							5	[6]					
UB-83-30-102	King Ranch	1960	Carl Vickers	Ch	20	114	94-114	5	–	–	19.9	11/10/65	S
							20	[5]					
UB-83-30-103	King Ranch	1962	Carl Vickers	Ch	18	117	97-117	5	–	–	18.7	11/10/65	S
							20	[5]					
UB-83-30-201	King Ranch	–	King Ranch Corp.	Ch	15	90	80-90	6	–	–	7.7	11/10/65	S
							10	[6]					
UB-83-30-202	King Ranch	–	King Ranch Corp.	Ch	8	65	60-65	5	–	–	6.5	11/10/65	S
							5	[5]					
UB-83-30-203	King Ranch	–	–	Ch	20	50	45-50	5	–	–	5.8	11/10/65	S
							5	[5]					
UB-83-30-401	King Ranch	–	King Ranch Corp.	Ch	23	50	45-50	6	–	–	33.3	11/10/65	S
							5	[6]					
UB-83-30-501	King Ranch	–	King Ranch Corp.	Ch	5	65	60-65	6	–	–	5.3	11/10/65	S

EXPLANATION

(1) Aquifer: Ch = Chicot aquifer Ev = Evangeline aquifer

(2) Approximate well elevations from USGS and/or Texas Water Development Board (TWDB) data and/or maps. USGS and/or TWDB reported well elevations are not the same for some wells.

(3) Static water level depths shown are reported depths to water below the measuring point datum for the wells, which are generally about 2 to 3 feet above the land surface elevation. USGS, TWDB and other reported water-level data may not be the same as shown if the water-level datum is different.

(4) Use of Water: D = Domestic supply P = Public water supply S = Livestock
Irr = Irrigation supply U = Unused I = Industrial

About a mile west of the Oxychem Plant site it also is reported that a water well drilled to a depth of about 600 feet produced water that contained about 12,000 mg/l of TDS. In summary, water well and water quality data show that the limited sands of the Chicot unit contain water that increases in its TDS content with depth and at one location was 12,000 mg/l at a depth of about 600 feet.

One large-capacity water well was constructed at the DuPont facility in 1984 in proximity to the Oxychem Plant site. The well screened sands of the Evangeline unit in the depth interval from about 1,180 to 1,720 feet and is reported to have been pumped at a rate of about 1,500 gpm. The well was constructed to provide water on an emergency basis for treatment using the reserve osmosis process. It is reported that the TDS content of the water was high enough so that its use for providing influent to a reverse osmosis facility was not within the guidelines established for the project.

Barney Davis Plant Site

Data and records from the TWDB show that there are a limited number of domestic and stock wells and a few small irrigation wells at a public school that have been drilled in the vicinity of the Barney Davis Plant site. The water wells in the immediate area of the Barney Davis Plant are less than 200 feet deep and screen sands of the Chicot unit.

One small irrigation well (83-22-801) is located approximately 3 miles north of the Barney Davis Plant site. The well was drilled to a depth of 181 feet and water samples collected show TDS values that range from about 875 to 744 mg/l with the samples collected over the period from 1966 to 1991. The well locations are shown in *Exhibit 4-2.1.2-1*, and well data are given in *Table 4-2.1.2-1* and *Table 4-2.1.2-2*.

A number of domestic and stock wells are shown in the area to the west of the Barney Davis Plant site and the wells normally are constructed at depths that range from about 50 to about 246 feet and produce small quantities of water for domestic and stock purposes. The wells normally are constructed with 4- to 6-inch-diameter casing.

2.1.3 Estimate of Total Dissolved Solids Content of Groundwater

Numerous electric logs of oil or gas test holes or injection wells were collected and analyzed to estimate the TDS content of the groundwater and to estimate if there were any significant vertical and/or lateral variation in TDS in the two study areas. An objective was to select oil or gas test hole logs that started at a shallow depth so that as much of the subsurface geology as possible could be reviewed. Many oil or gas test hole electric logs do not start until a depth of 1,000 feet. The estimating of TDS values was based on the correlations of electric log resistivity values to groundwater quality and on information developed by the San Patricio Municipal Water District as it studied the brackish water resources in San Patricio County. General relationships were developed between the resistivity values shown on electric logs and the TDS content of groundwater. Those relationships indicate that with a resistivity of 8 ohmmeters, the approximate TDS content of the groundwater is about 3,000 mg/l; at 4 ohmmeters, TDS is estimated at about 10,000 mg/l; at 2 ohmmeters about 20,000 mg/l; and at 1.5 ohmmeters, greater than 20,000 mg/l of TDS.

Oxychem Plant Site

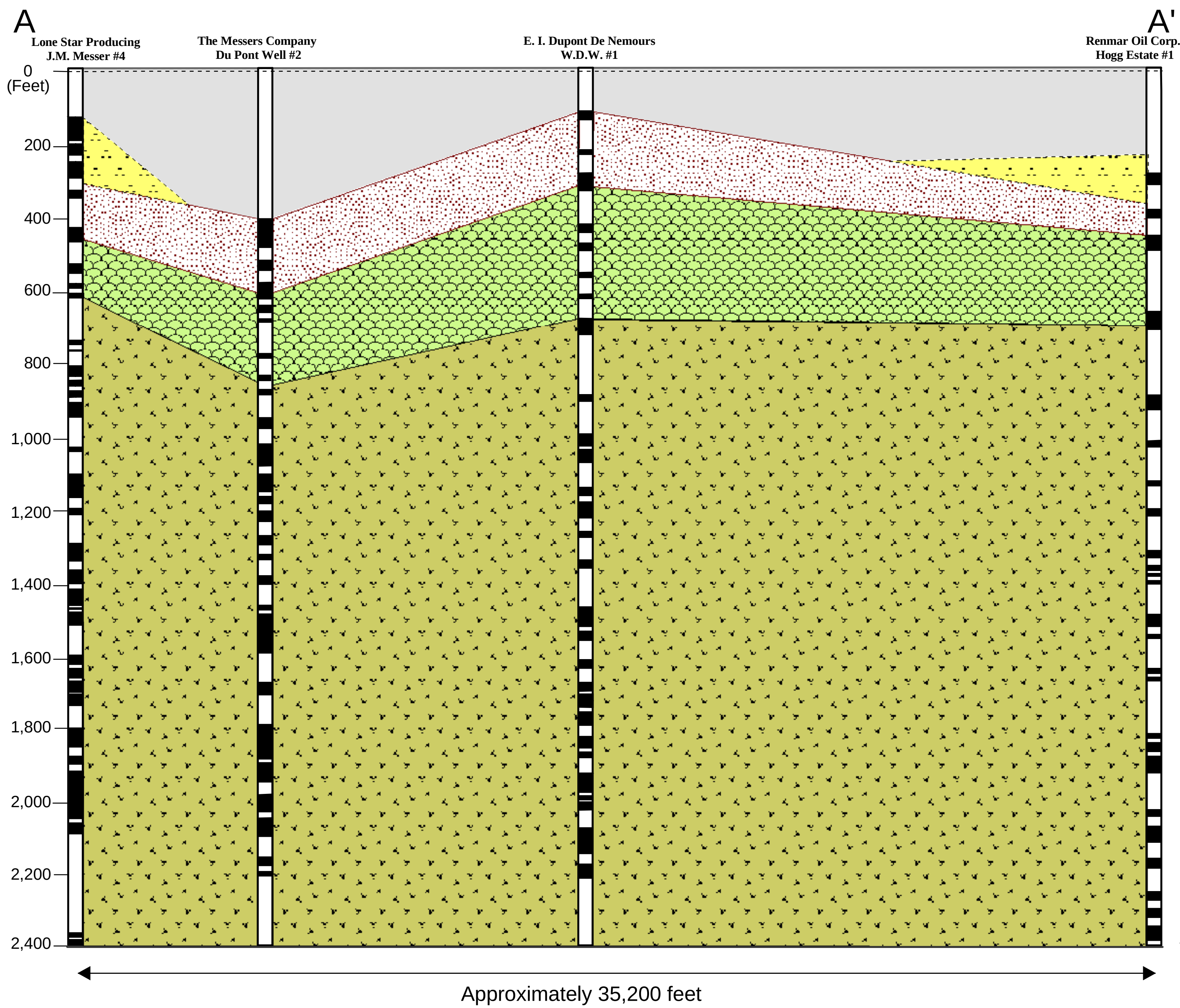
Electric logs, as stated previously, were collected for a number of oil and gas test holes or injection wells with the locations of those test holes or wells shown in *Figure 4-2.1.2-1*. The electric logs show that as depth increases, the resistivity values decrease which indicates an increase in the TDS content of the groundwater. Cross sections showing resistivity values from electric logs and estimates of depths of sands are shown in *Figure 4-2.1.3-1* and *Figure 4-2.1.3-2*. In the area in proximity to the Oxychem Plant site, the electric log data show that the groundwater could contain TDS in the range of about 10,000 to 20,000 mg/l in the depth interval from about 400 to 700 feet. Below 700 to 750 feet, the TDS content of the groundwater increases to 20,000 to potentially 30,000 or more mg/l. The cross section also shows a variation in the thickness of sands, and it appears that the sand thickness is greater in proximity to the Oxychem Plant site than farther to the southeast toward the Gulf of Mexico.

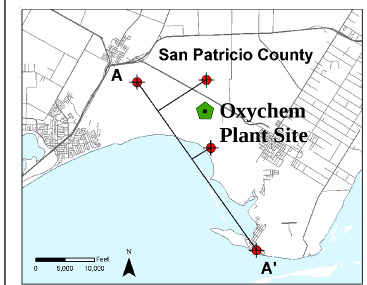
Barney Davis Plant Site

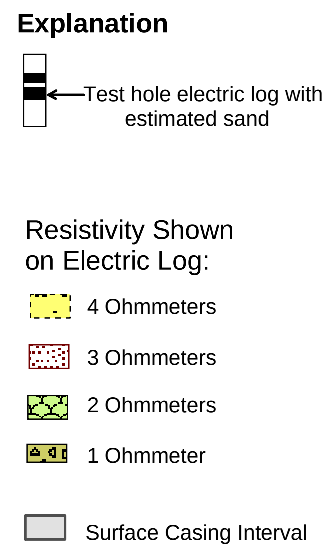
The electric log data in proximity to the Barney Davis Plant show that water with potentially 10,000 to 20,000 mg/l TDS occurs in the depth interval from about 250 feet down to a depth of about 900 to 1,000 feet. The data also show that below this depth the water quality changes with increasing TDS down to a depth of 3,000 feet as the resistivity values are about 1 ohmmeter. The electric log cross section information also shows a limited thickness of sand in the depth interval from about 700 feet to about 1,200 feet that could be considered for screening by any well. In proximity to the Barney Davis Plant site, a greater thickness of sand in the Evangeline unit is evident in the depth interval from about 1,200 down to 2,800 to 3,000 feet.

2.1.4 Estimates of Aquifers Ability to Provide Water

The ability of an aquifer to provide or transmit water is gauged by a number of parameters and one is called aquifer transmissivity. Aquifers with higher transmissivity values normally can provide larger quantities of water, and aquifers with lowers transmissivity values normally have the ability to provide less water. The Texas Water Development Board recently developed a groundwater flow model for the Gulf Coast aquifer and that model has layers equivalent to the Chicot and Evangeline units. The model is referred to as the Central Gulf Coast Groundwater Availability Model (GAM). Unfortunately the Evangeline unit is not represented in the model in the area of the Barney Davis Plant site and the Oxychem Plant site probably partly due to the salinity of the groundwater in those areas. The United States Geological Survey (USGS) developed a groundwater flow model that did include the Evangeline and Chicot units of the Gulf Coast aquifer in the present area of this study. The TWDB published Report 289 for the USGS model in about 1985 titled *Digital Model for Simulation of Groundwater Hydrology in the Chicot and Evangeline Aquifers along the Texas Gulf Coast*. Transmissivity values from that model were utilized to help estimate the effects of developing groundwater from the Chicot and Evangeline units in the area of study. In proximity to the Barney Davis Plant site, it is estimated that the transmissivity of the Evangeline unit could be about 27,000 gallons per day per foot (gpd/ft) and that in proximity to the Oxychem Plant site that the transmissivity of the Evangeline unit could be about 44,000 gpd/ft. Aquifer conditions are a







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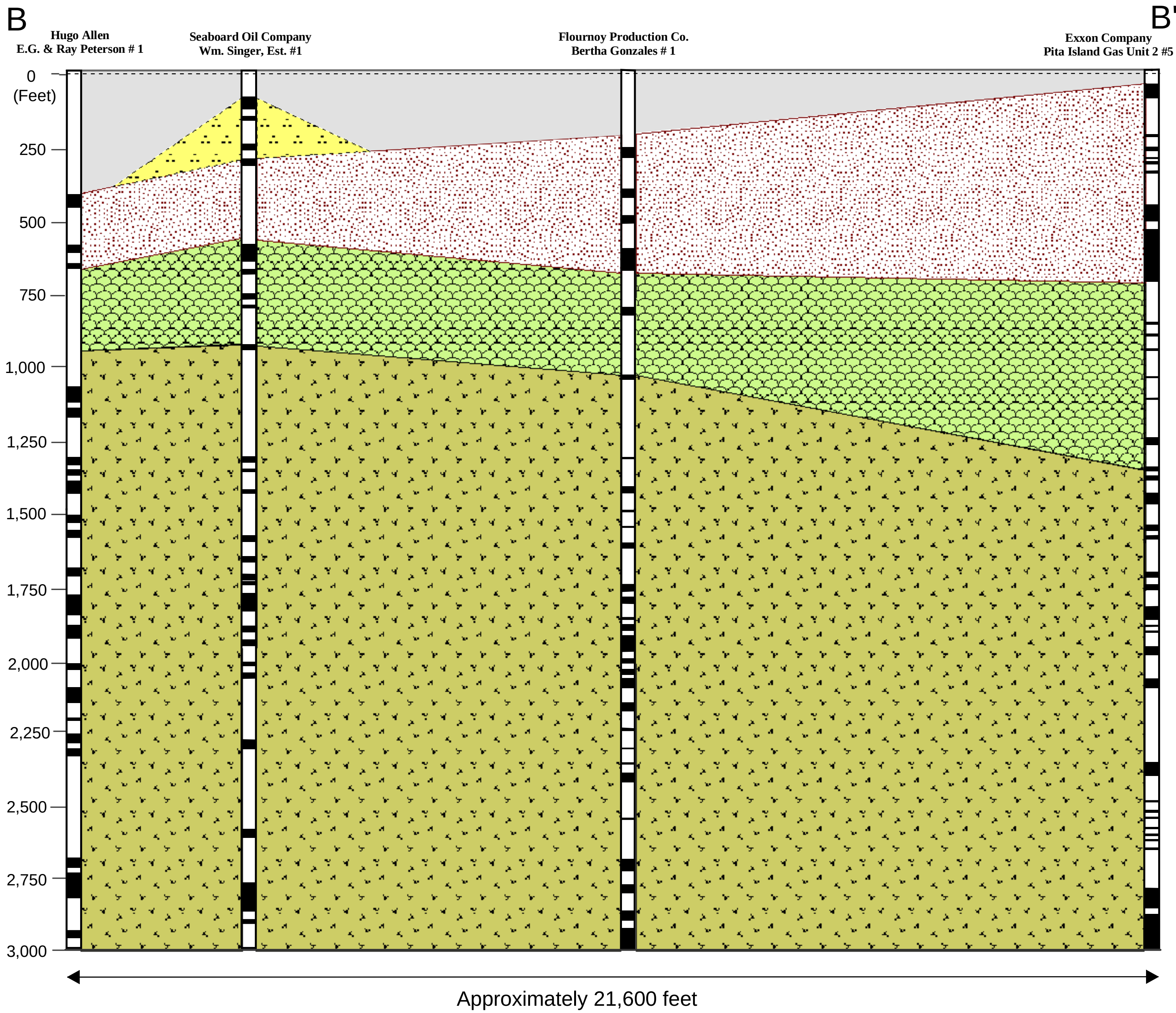
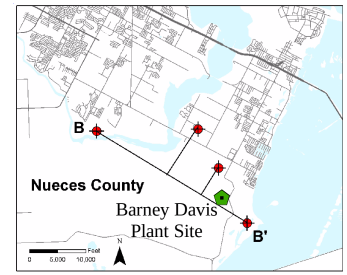
Cross Section A - A'
near Oxychem Plant Site

Large Scale Desalination Feasibility Study
Corpus Christi, Texas

Figure 4-2.1.3-1 | 11/16/04





Explanation

Test hole electric log with estimated sand

Resistivity Shown on Electric Log:

- 3-10 Ohmmeters
- 2-3 Ohmmeters
- 1-2 Ohmmeters
- 1 Ohmmeter
- Surface Casing Interval

LBG-Guyton Associates

TCB Turner Collie & Braden Inc.
Engineers • Planners • Project Managers

Cross Section B - B'
near Barney Davis Plant Site

Large Scale Desalination Feasibility Study
Corpus Christi, Texas

Figure 4-2.1.3-2 | 11/16/04

degree better at the Oxychem Plant site than at the Barney Davis Plant site based on the aforementioned groundwater flow modeling report published by TWDB.

The Barney Davis Plant site and the Oxychem Plant site data or information from Report 289 indicates that the transmissivity of the Chicot unit could be about 18,000 gpd/ft. At the Barney Davis Plant site, the estimated depth to the base of the Chicot unit is about 900 feet and at the Oxychem Plant site, about 750 feet. The total transmissivity of the aquifer probably would not be utilized if wells were constructed because some of the sands are located within 200 feet of land surface where the water quality is significantly better in terms of lower TDS than with deeper sands within the Chicot unit. At the Barney Davis Plant site, limited electric log data show about 50 feet of sand can occur in the depth interval above 300 feet that potentially could be screened in small capacity production wells.

Pumping test data are available for Well 83-07-829 located in Aransas Pass. The well screens sand of the Chicot unit in the depth interval from approximately 50 to 182 feet. The well was pumped at a rate of about 120 gpm and testing indicated an aquifer transmissivity of about 3,000 to 3,700 gpd/ft. The test was performed using two observation wells that screened the same depth interval. The well is located about four miles to the east of the Oxychem Plant site. The results of the testing show that the shallow sands of the Chicot unit have a limited capacity for providing water to wells.

2.1.5 Groundwater Availability in the Vicinity of the Oxychem Plant Site

Groundwater is available from the Gulf Coast aquifer in proximity to the proposed location for the desalination facility. The major sands available for screening generally occur in the Evangeline unit below a depth of about 750 feet extending to a depth of about 2,100 feet. The TDS content of water in this depth interval is estimated to be in the range of about 20,000 to 30,000 mg/l or possibly a small amount higher. This conclusion is based on review of groundwater quality data and of electric logs and on data from studies of the brackish to saline resources in San Patricio County performed by the San Patricio Municipal Water District.

Available data and the study indicate that it may be possible to develop a groundwater supply of about 15 mgd from a series of wells located in proximity to the plant site and spaced about 0.5 miles apart. It is estimated that each well could provide about 1,000 gallons per minute (gpm). Pumping this quantity of water is estimated to lower the pressure or potentiometric head in the Evangeline aquifer about 130 to 200 feet in the near proximity of the well field. If the wells are located in a single line, that line of wells would be approximately 5 1/2 miles long. The estimate of aquifer pressure decline was developed using aquifer transmissivity data from TWDB Report 289. It also is estimated that the pressure decline in the aquifer will result in a limited amount of land surface subsidence. Further site specific studies are needed to refine these estimates as there has been a very limited amount of groundwater pumpage in San Patricio County to help establish a relationship between pumpage, aquifer pressure decline or potentiometric head decline, and subsidence. Based on the relationship between potentiometric head decline and subsidence that has been developed for the Evangeline unit in Harris County (the Houston area), it is estimated that land surface subsidence in the range of 0.5 to 1.5 feet or slightly more could result in the well field area. If the need for groundwater for the project is intermittent and thus pumpage is intermittent, the amount of subsidence estimated also would be less due to the periodic lowering of the pressure in the aquifer during pumping but also recovery in the pressure in the aquifer during times of non-pumping.

It is estimated that the cost of a production well constructed to a depth of about 2,100 feet screening sands in the depth interval from about 700 to 2,100 feet, and equipped with a pump and motor to provide 1,000 gpm could be in the range of $700,000 to $850,000. The well would be constructed with stainless steel screen and blank liner and potentially some of the pump components would be made of stainless steel. If electrical starters and controls, SCADA equipment, discharge piping, and well site access driveway and fencing are included, the cost of a well unit could be about $1 million.

The potential for constructing shallow wells also was considered in the vicinity of the Oxychem Plant site. Based on available data, it is estimated that production wells providing potentially a few to several hundred gpm each could be constructed screening sands in the depth interval from about 250 to 750 feet in the Chicot unit. It is estimated that the water could contain TDS in the range of about 10,000 to 20,000 mg/l. If a small capacity well (less than 200 gpm) is constructed screening sands only above a depth of about 350 feet, it is possible that the water might contain about 10,000 mg/l of TDS. As mentioned previously, one production well drilled in the area to a depth of 600 feet provided water with 12,000 mg/l of TDS.

A limited number of electric logs are available for oil or gas test holes or injection wells in the area that encompass sands above a depth of about 750 feet. Those logs show about 70 to 100 feet of sand in the interval from 300 to 750 feet. The limited sand thickness influences and limits the pumping rate that can be obtained from a well, particularly if it only screens sands above a depth of 750 feet. The pumping of several wells is estimated to cause an aquifer pressure decline that would have the potential of causing a limited amount of land surface subsidence. The amount of subsidence that would occur would depend on the quantity of groundwater pumped and the amount of pressure or potentiometric head decline that is caused in the Chicot unit.

Additional study in the area of interest would provide data to improve estimates of the amount of groundwater available and the effects that pumping would have on the Chicot and Evangeline units in terms of pressure declines and potential land surface subsidence.

2.1.6 Groundwater Availability in the Vicinity of the Barney Davis Plant Site

Groundwater is available from the Chicot unit and deeper Evangeline units of the Gulf Coast aquifer in proximity to the proposed desalination facility at the Barney Davis Power Plant site. For the Evangeline unit, significant thicknesses of sand occur in the depth interval below about 1,200 feet down to a depth of about 2,200 feet. The estimated TDS content of the water in this depth interval ranges from about 25,000 to 40,000 mg/l. Between the depths of about 700 to 1,200 feet, electric logs show limited sand thickness available for screening in a well as shown in *Exhibit 4-2.1.3-2*. These conclusions are based on the review of electric logs of oil or gas test holes and on studies of brackish to saline groundwater resources in Nueces and San Patricio Counties.

Available data indicate that it may be possible to develop a supply of about 10 mgd from a series of wells pumping an estimated 1,000 gpm per well and spaced about 0.5 miles apart. As stated previously, aquifer conditions do not appear to be quite as good at this site as at the Oxychem Plant site. Pumping about 10 mgd is estimated to lower the pressure or potentiometric head in the Evangeline unit about 150 to 200 feet in the vicinity of the wells. The estimate of the pressure or potentiometric head decline is based on transmissivity data for the Evangeline unit included in TWDB Report 289. It also is estimated that the lowering of the pressure or potentiometric head in the aquifer has the potential to cause a limited amount of land surface subsidence. Based on empirical data for the Harris County area where large quantities of groundwater have been pumped from the Evangeline unit and some land surface subsidence has resulted, it is estimated that in the range of about 0.5 to 1.5 feet or slightly more subsidence could occur in the well field area. The amount of subsidence that could occur should decrease with distance away from the well field, as does the aquifer pressure or potentiometric head reduction. Further site specific studies are needed to refine these estimates, as a substantial amount of pumpage from the Evangeline unit has not occurred in the area so that relationships could be developed between pumpage, aquifer pressure decline, and land surface subsidence. If the need for water by the desalination facility is intermittent, and pumping from the well field is intermittent, the amount of pressure decline that could occur should be less and the amount of subsidence that could result from the aquifer pressure decline also should be less.

As stated previously, it is estimated that wells could a screen sands in the depth interval from about 1,200 to 2,200 feet. A well would be constructed with stainless steel screen and blank liner and potentially some components of the pumping equipment could be constructed of stainless steel or some other metal that is resistant to the corrosion that can occur when pumping water with high levels of TDS.

It is estimated that the cost of a production well constructed to a depth of about 2,200 feet and equipped with a pump and motor could provide 1,000 gpm could be in the range of $700,000 to $850,000. Total well cost, including electrical starter and controls and SCADA equipment, discharge piping and site development, could be in the range of $1 million per well.

For the deeper wells in this area, the water quality is unsuitable for blending. The estimated water quality of 25,000 to 40,000 mg/l is at or slightly above the target water quality goal. Although this water could be used, it would be necessary to consider this water a sole source and not a blending source. At 1,000 gpm per well, approximately 40 wells would be required to meet the project quantity requirement of 55 mgd. Based on the information available, this withdrawal rate probably is not sustainable without continual degradation of water quality and objectionable levels of land surface subsidence.

The potential for wells screening sands above a depth of about 700 feet also was considered for the Barney Davis Plant site. Based on available data, it is estimated that production wells potentially providing a few to several hundred gallons per minute could be constructed screening sands in the depth interval from about 300 to 700 feet. It also is estimated that the water could contain total dissolved solids in the range of about 5,000 to 15,000 mg/l but probably closer to 15,000 mg/l. A limited thickness of sand of probably no more than 50 feet occurs above a depth of 300 feet where the groundwater could contain TDS of possibly 3,000 mg/l. The pumping of multiple wells at rates of a few to several hundred gallons per minute per well will cause an aquifer pressure or potentiometric head decline that would have the potential of causing a small amount of land surface subsidence. Depending on the sustainable water quality (5,000 to 15,000 mg/l TDS), 23 percent (12.6 mgd), to 30 percent (17.6 mgd) of the total supply would have to be provided through the shallow, small capacity wells. Long-term withdrawal of groundwater at these rates probably is not sustainable and would cause additional subsidence and water quality degradation.

2.2 Coastal Region Seawater Salinities, Temperature, pH

Prior to selecting the conceptual process design criteria for the demonstration plant pre-treatment and desalination processes, characterization of the feedwater is required. Representative water quality data is used as the basis for the desalination system process design because actual water quality data relative to the desalination process is very limited.

Five possible sites for the proposed demonstration facility were identified, including one power plant and four industrial sites. A database search for seawater quality for each of the potential locations was conducted. A limited amount of seawater quality data was obtained through the Texas Water Development Board.

The Texas Water Development Board maintains water quality monitoring buoys in the vicinity of Corpus Christi. Four of these buoys are in the immediate vicinity of Corpus Christi, providing data of value during the water quality analysis. GPS coordinates of the proposed sites for the desalination demonstration plant were cross referenced with the known locations of water quality monitoring buoys to determine the most applicable buoy for each site.

Figure 4-2.2-1 shows the four potential plant sites (yellow stars) as well as the locations of the available sampling buoys for Corpus Christi (pink stars). A fifth site, the Barney Davis Power Plant, is also under consideration. All of the potential plant sites will rely on data from the Nueces Bay buoy, except for DuPont/Oxychem that will likely rely on data from the Corpus Christi Bay buoy and the Barney Davis Power Plant, which withdraws cooling water from Laguna Madre.

Table 4-2.2-1 details the coordinates of each potential plant location as well as the data availability and coordinates of the associated buoy. The raw water quality data as well as information about the sampling program can be found at URL: http://hyper20.twdb.state.tx.us/data/bays_estuaries/sondpage.html.

Data are available for each site either in one-hour or one-hour-and-a-half time steps and the parameters sampled include temperature, pH, conductivity, salinity and DO.

Figure 4-2.2-2 presents the salinity data available from the TWDB water quality monitoring buoy for the period from December 1986 to August 1990. The data indicates wide variations in the salinity. It appears likely that some of the outliers in the data may be a result of probe failure in the buoy. TWDB does not provide an indication of data quality, preventing a more representative analysis of the other data. Most of the salinity readings range from 30 to 40 g/kg for the period from December 1986 to September 1989.

Figure 4-2.2-1 Water Quality Monitoring Buoy and Proposed Demonstration Plant Locations

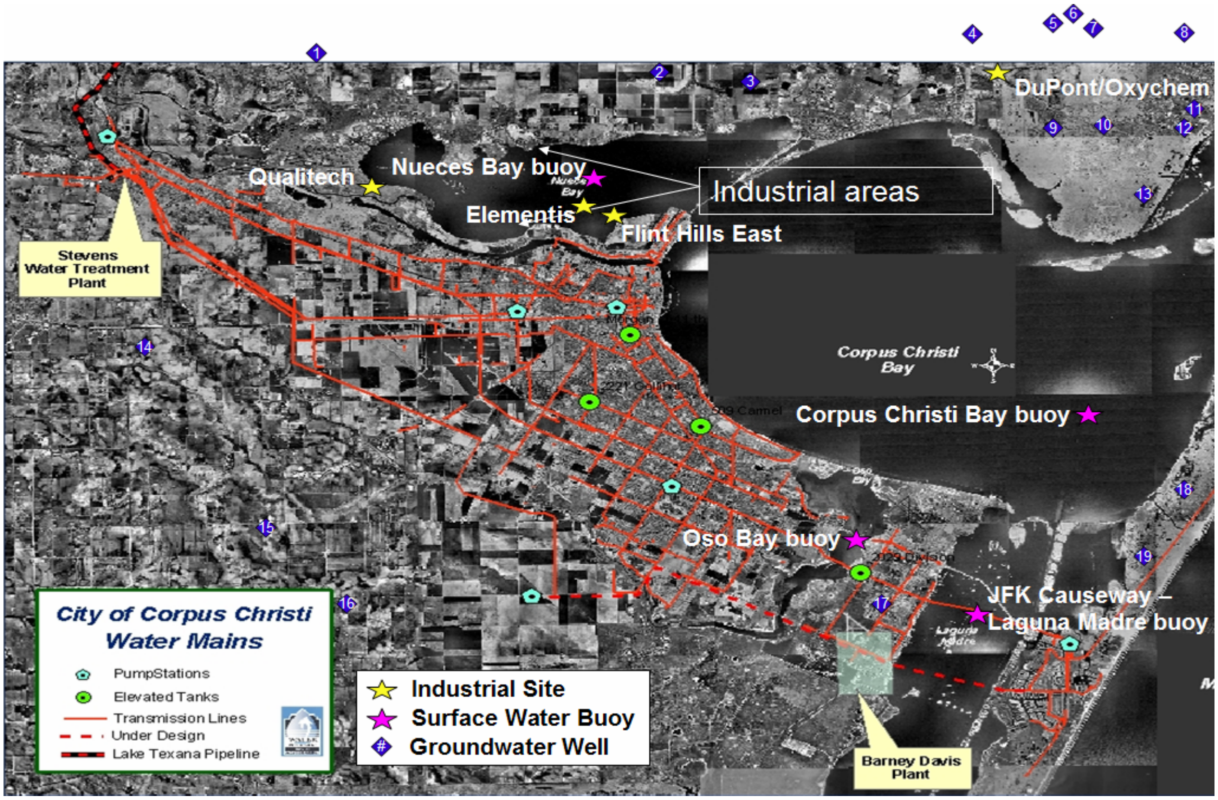


Table 4-2.2-1 Proposed Industrial Site and Water Quality Monitoring Buoy Locations

Site	Latitude	Longitude	Buoy	Latitude	Longitude	Available Data
Qualitech	27° 51' 11.08"	97° 31' 25.32"	Nueces Bay	27° 50' 56"	97° 25' 26"	Dec. 1986 to Aug. 1990
Elementis	27° 50' 24.23"	97° 25' 29.33"	Nueces Bay	27° 50' 56"	97° 25' 26"	Dec. 1986 to Aug. 1990
Flint Hills East	27° 50' 7.63"	97° 24" 43.65"	Nueces Bay	27° 50' 56"	97° 25' 26"	Dec. 1986 to Aug.1990
DuPont/ Oxychem	27° 53' 26.75"	97° 14' 23.31"	Corpus Christi Bay	27° 44' 30"	97° 13' 00"	Dec. 1986 to July 2003
Barney Davis Power Plant			Laguna Madre/JFK Causeway	27° 38' 04"	97° 14' 22"	Feb. 1991 to Oct. 2002

To indicate the probability of a given salinity for the data set, a cumulative distribution curve was compiled using the data illustrated in *Figure 4-2.2-2*. Completion of a cumulative distribution curve for the water quality data indicates that median salinity is approximately 34,000 mg/l, with the 10^{th} percentile and 90^{th} percentile approximately 12 g/kg and 38 g/kg, respectively. The cumulative distribution is illustrated in *Figure 4-2.2-3*.

Based upon the analysis above, it was determined that a median seawater salinity of 35,000 mg/l was appropriate for the design seawater analysis. To determine the level of pre-treatment required and to adequately select the design criteria for the reverse osmosis desalination system, individual water quality parameters are required.

Figure 4-2.2-2 Time Series Salinity Data for Nueces Bay

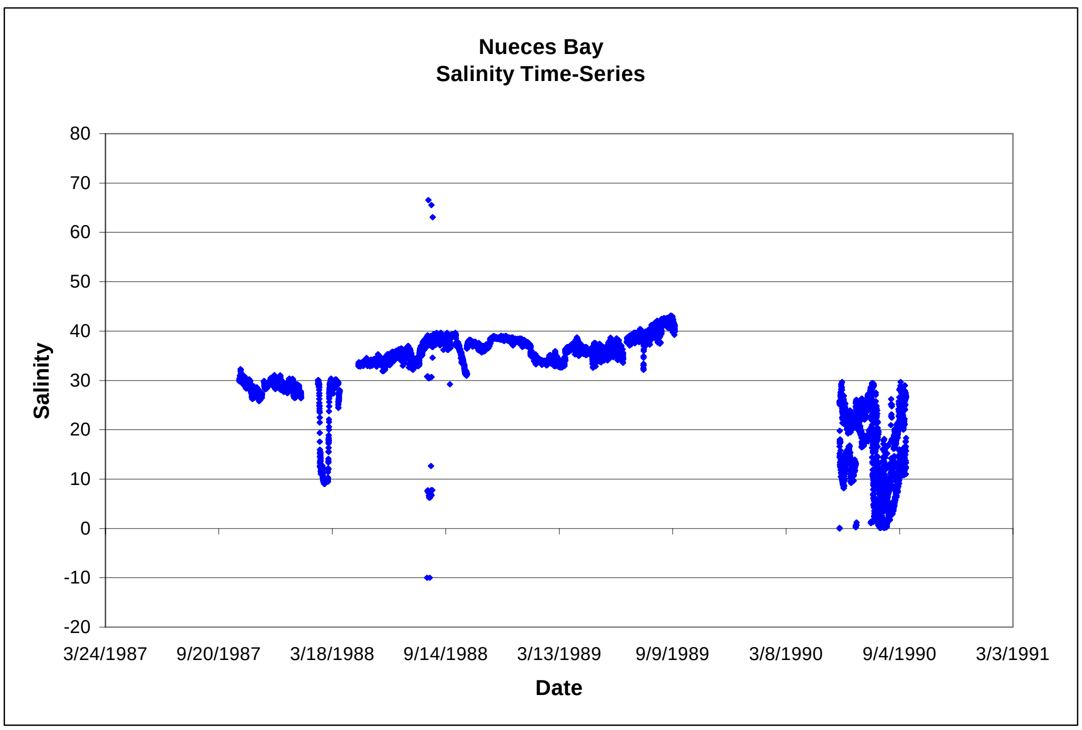
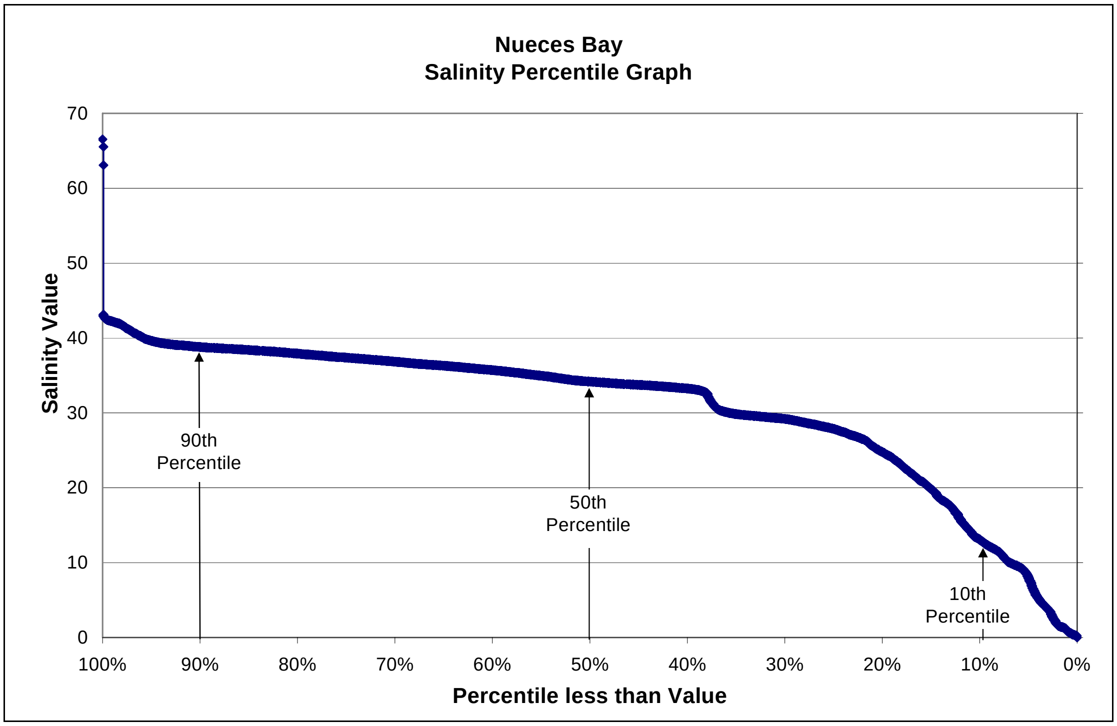


Figure 4-2.2-3 Cumulative Distribution of Nueces Bay Salinity



A similar analysis was completed for salinity data obtained for Corpus Christi Bay. *Figure 4-2.2-4* presents the salinity data available from the TWDB water quality monitoring buoy for the period from December 1986 to July 2003. The data indicates wide variations in the salinity, along with rapid changes in the seawater salinity.

To indicate the probability of a given salinity for the data set, a cumulative distribution curve was compiled using the data illustrated in *Figure 4-2.2-4.* Completion of a cumulative distribution curve for the water quality data indicates that median salinity is approximately 28 g/kg, with the 10^{th} percentile and 90^{th} percentile approximately 18,000 mg/l and 37,000 mg/l, respectively. The cumulative distribution is illustrated in *Figure 4-2.2-5.*

Limited water quality data for Laguna Madre was also available through the TWDB monitoring program, providing data for a potential site at the Barney Davis Power Plant. *Figure 4-2.2-6* presents the salinity data available from the TWDB water quality monitoring buoy for the period from November 1999 to October 2002. The data indicates wide variations in the salinity, with observed hypersaline conditions approaching 50,000 mg/l.

Figure 4-2.2-4 Time Series Salinity Data for Corpus Christi Bay

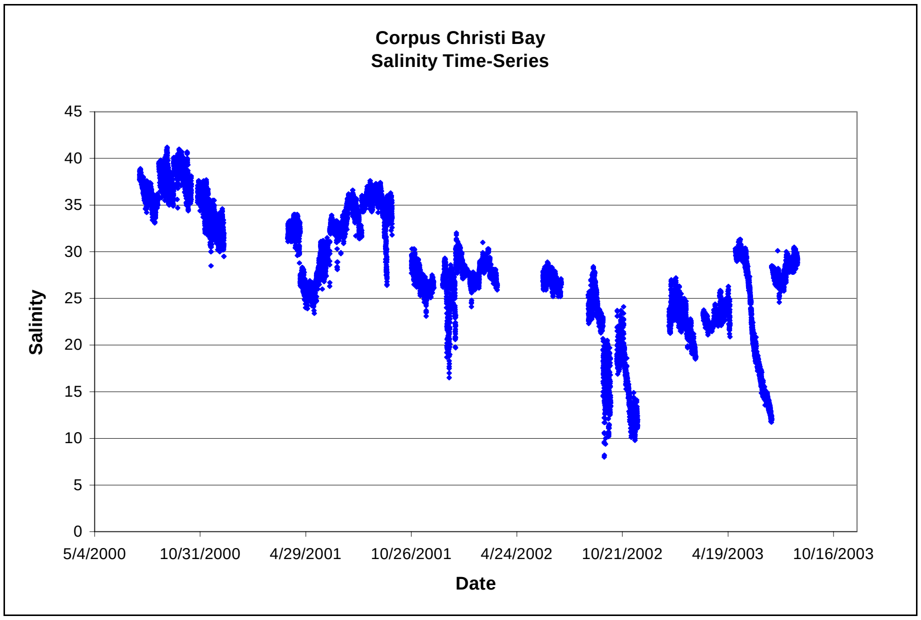


Figure 4-2.2-5 Cumulative Distribution for Corpus Christi Bay Salinity

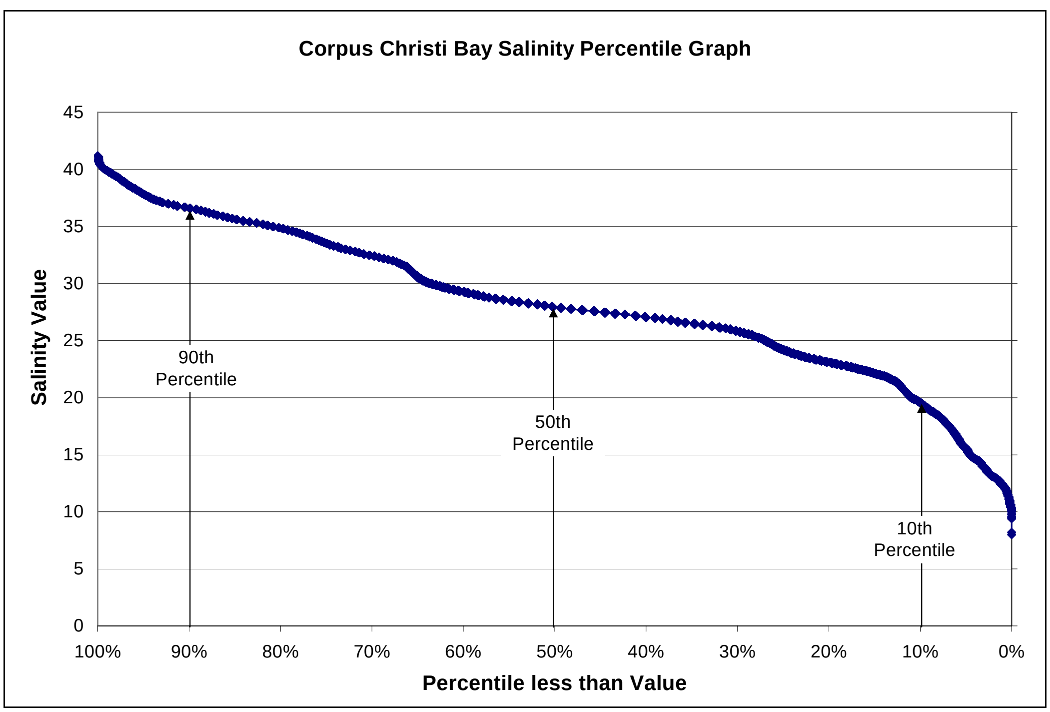
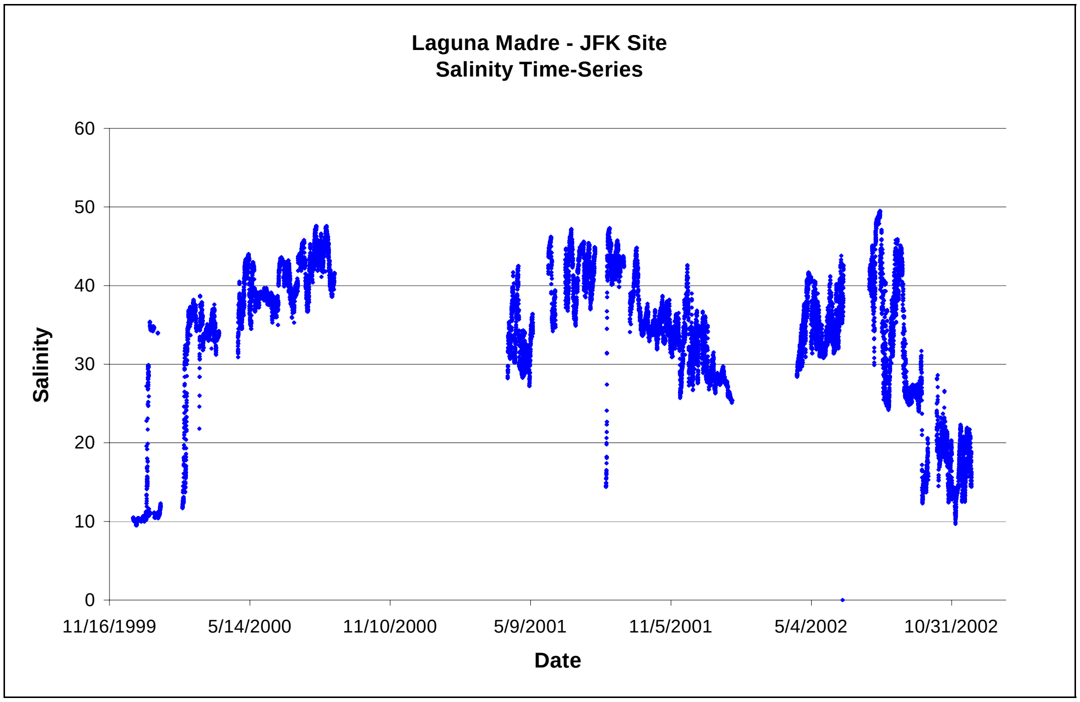


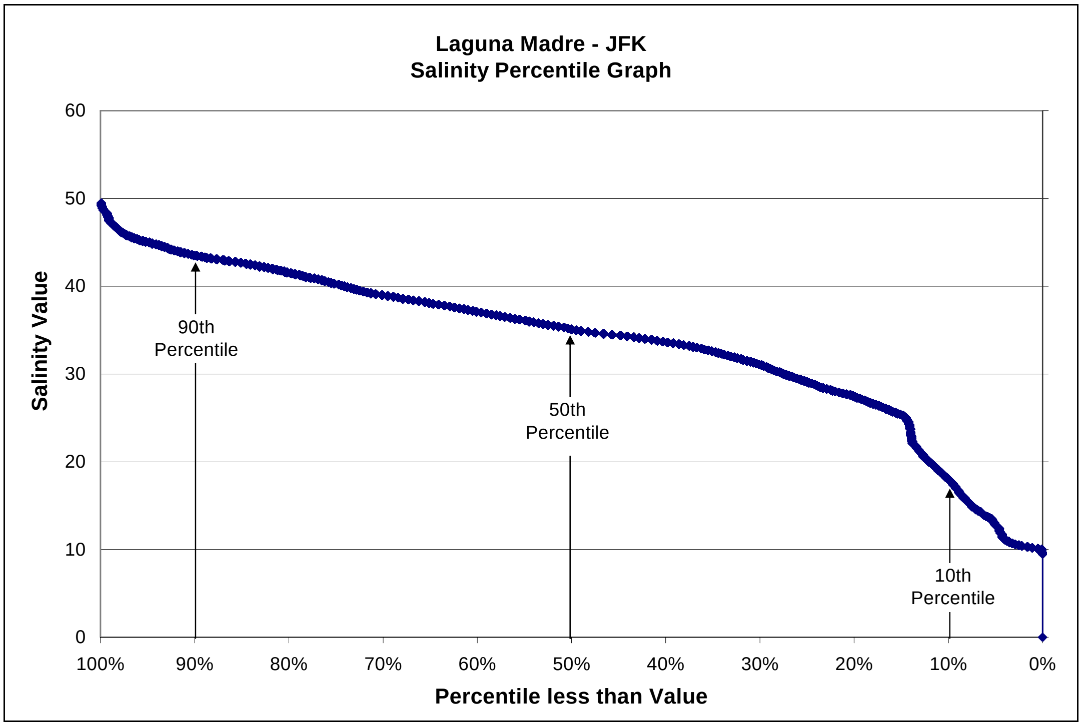
Figure 4-2.2-6 Time Series Salinity Data for Laguna Madre



To indicate the probability of a given salinity for the data set, a cumulative distribution curve was compiled using the data illustrated in *Figure 4-2.2-6.* Completion of a cumulative distribution curve for the water quality data indicates that median salinity is approximately 35,000 mg/l, with the 10^{th} percentile and 90^{th} percentile approximately 17,000 mg/l and 43,000 mg/l, respectively. The cumulative distribution is illustrated in *Figure 4-2.2-7.*

Based upon the analysis shown below, it was determined that a median seawater salinity of 35,000 mg/l was appropriate for the design seawater analysis. To determine the level of pre-treatment required and to adequately select the design criteria for the reverse osmosis desalination system, individual water quality parameters are required.

Figure 4-2.2-7 Cumulative Distribution of Salinity Data for Laguna Madre



A concise summary of the salinity data presented in *Figures 4-2.2-2* through *4-2.2-7* is presented in *Table 4-2.2-2.*

Table 4-2.2-2 Summary of Salinity Data (g/kg) From Monitoring Buoys

Description	Nueces Bay	Corpus Christi Bay	Laguna Madre	Oso Bay
Average	31.7	28.2	33.4	33.4
Maximum	66.5	41.2	49.5	54.8
Minimum	5.0	8.0	10.1	5.0
10th percentile	12.0	19.5	17.9	23.0
25th percentile	28.7	24.2	29.0	27.4
50th percentile	34.4	27.9	35.0	34.6
75th percentile	37.5	33.5	40.2	37.6
90th percentile	38.8	36.6	43.5	42.7

2.2.1 Seawater Temperature Variation in the Corpus Christi Region

Detailed understanding of the water temperature range is required to evaluate the performance of the desalination system. Temperature impacts the diffusion of water and salt through RO membranes and the solubility of sparingly soluble salts that can result in membrane scaling. The data collected from the monitoring buoys was analyzed for each source to determine the mean, maximum, and minimum values. Additional percentile data corresponding to the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile were extracted from the data set to provide additional understanding of the data distribution.

The greatest temperature variations occurred in Nueces Bay. The temperature varied widely throughout the data set, with an average temperature of 24.3°C. The minimum temperature observed was 3.2°C with a maximum temperature of 42°C. Eighty percent of the entire data set was between 14.6°C and 30.2°C. The least amount of temperature variation occurred in Corpus Christi Bay, with a minimum temperature of 9.4°C and a maximum temperature of 32.0°C. The average temperature for the data set was 23.9°C. Eighty percent of the data points were bracketed by 14.3°C and 30°C. Laguna Madre and Oso Bay possessed temperature data distributions bracketed by those of Nueces Bay and Corpus Christi Bay. A summary of the temperature data for all of the monitoring buoys is presented in *Table 4-2.2.1-1*.

Table 4-2.2.1-1 Summary of Temperature Data (°C) From Monitoring Buoys

Description	Nueces Bay	Corpus Christi Bay	Laguna Madre	Oso Bay
Average	24.3	23.9	25.2	24.1
Maximum	42.0	32.0	33.4	34.7
Minimum	3.2	9.4	5.5	6.0
10th percentile	14.7	14.3	17.3	14.5
25th percentile	19.8	17.9	22.2	19.4
50th percentile	26.8	26.2	27.0	25.2
75th percentile	29.2	29.3	29.4	29.5
90th percentile	30.2	30.0	30.4	31.5

Due to temperature extremes and shallow water in the Corpus Christi area, wide fluctuations in seawater temperature must be accounted for in the reverse osmosis system design.

2.2.2 Seawater pH Variation in the Corpus Christi Region

Water pH variations can affect the carbonate equilibrium and impact the solubility of sparingly soluble salts that can result in membrane scaling. The data collected from the monitoring buoys were analyzed for each source to determine the mean, maximum, and minimum values.

Additional percentile data corresponding to the 10th, 25th, 50th, 75th, and 90th percentile were extracted from the data set to provide additional understanding of the data distribution.

The pH in all water bodies studied varied little. The 10th percentile and 90th percentile for Nueces Bay was 7.8 and 8.3, respectively. Examination of the data set indicates some missing or erroneous data, rendering the maximum and minimum measurements as questionable outliers. As a result, the maximum and minimum were not evaluated for pH. Similarly, the pH in Corpus Christi varied from a 10th percentile of 7.1 to a 90th percentile value of 8.5. The average pH in Corpus Christi Bay for the data set was 8.0. The average pH levels in Laguna Madre and Oso Bay were measured as 8.4 for both sources, higher than the average pHs for Nueces Bay and Corpus Christi Bay. A summary of the pH data for all four buoys is presented in *Table 4-2.2.2-1*.

Table 4-2.2.2-1 Summary of pH Data From Monitoring Buoys

Description	Nueces Bay	Corpus Christi Bay	Laguna Madre	Oso Bay
Average	8.1	8.0	8.4	8.4
10th percentile	7.8	7.1	7.5	8.1
25th percentile	7.9	7.8	8.1	8.2
50th percentile	8.1	8.3	8.5	8.4
75th percentile	8.2	8.4	8.7	8.6
90th percentile	8.3	8.5	8.9	8.7

In the absence of comprehensive, site-specific water quality data, a search of published literature was conducted to determine typical water quality parameters for a 35,000 mg/l seawater. The results of the search, and the references utilized to establish the water quality data are summarized in *Table 4-2.2.2-2*

Historical experience in the design and operation of seawater desalination facilities indicates that the typical recovery of systems desalinating seawater of 35,000 mg/l is approximately 50 percent. Successful long-term operation with seawater concentrations exceeding 35,000 mg/l may necessitate a reduction in the reverse osmosis unit recovery, which increases the overall size and cost of pre-treatment equipment. A groundwater blending option was studied to determine if blending could be practiced to maintain the seawater total dissolved solids at less than or equal to 35,000 mg/l.

Table 4-2.2.2-2 Design Seawater Analysis

General		Unit	Average
Turbidity	-	NTU	<20
Conductivity	-	µS/cm	48,000
Total Dissolved Solids	TDS	mg/l	35,323[+]
Alkalinty (calculated)	Alk	mg/l as $CaCO_3$	117.3[#]
Total Hardness (calculated)	TH	mg/l as $CaCO_3$	6,392[#]
Temperature	T(°C)	°C	10 - 30[##]
pH	-	-	8[+]
Chloride	Cl^-	mg/l	19,441[+]
Sulfate	SO_4^-	mg/l	2,713[+]
Bromide	Br^{--}	mg/l	66.2[+]
Bicarbonate (calculated)	HCO_3^-	mg/l	143.1[+]
Carbonate (calculated)		mg/l	0[#]
Hydroxide (calculated)	OH^-	mg/l	0[#]
Carbon Dioxide (calculated)	CO_2	mg/l	0[#]
Fluoride	F^-	mg/l	1.3[+]
Iodide	I^-	mg/l	22.4[+]
Nitrate	NO_3^-	mg/l as N	0.5[++]
Nitrite	NO_2^{--}	mg/l as N	0.01[++]
Phosphate	PO_4^{--}	mg/l	0.01[++]
Sodium	Na^+	mg/l	10,812[+]
Magnesium	Mg^{++}	mg/l	1,302[+]
Calcium	Ca^{++}	mg/l	409.8[+]
Potassium	K^+	mg/l	389.2[+]
Iron (dissolved)	Fe^{+++}	mg/l	<0.3[*]
Manganese (dissolved)	Mn^{++}	mg/l	<0.05[*]
Boron	B^{+++}	mg/l	5[++]
Barium	Ba^{++}	mg/l	0.03[++]
Strontium	Sr^{++}	mg/l	13.6[+]
Silica (total)	SiO_2	mg/l	2.1[+]
Hydrogen Sulfide	H_2S	mg/l	n.d.
Silt Density Index	SDI	-	>5
True Color	TCU	-	<15[*]
Total Organic Carbon	TOC	mg/l	4[++]
UV254	UV254	cm^{-1}	0.05[++]
Chlorophyll A	-	mg/l	n.d.
Algae	-	#/ml	n.d.
Dissolved Oxygen	-	mg/l	4 - 8[##]
Ammonium	NH_4^+	mg/l	n.d.
Bacterial Counts	-	#/ml	1,000[++]
Free Chlorine	HOCl	mg/l	n.d.
Specific Gravity	-	-	1.0243[+]

[+] Pankratz, T., J. Tonner (2003) *desalination.com an environmental primer*
[++] Personal Communication - Lisa Henthorne
[#] Calculated Value
[##] Texas Water Development Board Bay & Estuary Water Quality Monitoring Program
* EPA Secondary Drinking Water Quality Standards (40CFR143)
n.d. - not determined

2.3 Source Options

2.3.1 Seawater

Three potential sources of seawater supply are being considered for supplying the Corpus Christi Desalination Plant: (1) use of an existing intake, (2) construction of a new intake, and (3) construction of bank filters along a coastline. A variation of the first option is to use once-through cooling water at an elevated temperature to reduce the required transmembrane pressure across the reverse osmosis membrane. Bank filtration provides an advantage over direct intakes of improved plant feedwater quality. Filtration of the seawater through the natural beach sand and other sediments reduces turbidity and the Silt Density Index (SDI), in many cases, eliminates additional desalination pre-treatment unit processes for further turbidity and organics removal.

Two bank filtration construction alternatives were analyzed: vertical beach wells and horizontal infiltration galleries. Based on existing literature, there are a number of limitations to the application of bank filtration for seawater desalination facilities. Also, little is known about the subsurface conditions along the coastline at this time. To determine the efficacy of bank filtration for a particular site, exploratory drilling to determine the aquifer characteristics (depth, strata) and pump tests on boreholes should be conducted. Initial design concepts for required depth, potential discharge, and number of required beach wells or length of horizontal laterals in the site area have been developed based on assumed existing conditions. Spacing between wells at proposed withdrawal rates is another important factor in design. Conditions could vary based on the final site selected. Initial design parameters have been assumed.

2.3.1.1 Open Sea Intake

Two types of open sea intakes are commonly in use. The first, which consists of an open channel dredged from the shore to the inlet works, is no longer in common use due to permitting issues and poor water quality achieved. The second consists of a submerged pipe extended out into the raw water body. This type of intake system is common where shallow water and concentrations of weeds are present near the shoreline. The controlling factors of the offshore distance are:

- Topography of the floor of the water body
- Geotechnical information of the intake site of both of its onshore and offshore segments
- Size of waves and depth of wave disturbances
- Weed concentration and movement patterns
- Navigable water requirements of the U.S. Army Corps of Engineers
- Tide characteristics

A topographic representation of the seabed (includes the slope of the bottom, the depth at selected distances), geotechnical information, and wave motion must be made available to design engineers.

The presence of dead weeds poses challenges to the design of open water intake structures. The buoyancy of weeds varies according to ambient and atmospheric conditions. Dead weeds travel over the whole range of water depth. Therefore, the prediction of their movement patterns is challenging, since the submarine current conditions in some locations vary with water depth. Weeds can travel in any direction, according to the prevailing currents. An offshore intake head can be located in a seaweed-free area, but then it is usually only a matter of time, months or perhaps years, before the weeds move in. Screens are fixed on intake head inlets to stop weed and fish flow into the pipeline.

With offshore systems, the problems involved are similar to those of the open channel, but with less severity and lower frequency. Traveling screens in the settling basin onshore are still required and intake head cleaning has to be performed regularly.

A sea intake is the conventional approach to a seawater source (*Figure 4-2.3.1.1-1*). The intake pipe should be buried and protected with heavy armor stone. At the end of the intake pipe, a riser pipe bearing the intake screen will protrude above the sea floor. It is desirable to have a minimum of twenty five to thirty feet of water depth, as this will provide some damping of bottom wave surge and minimize the suspended sediments. The intake itself should be placed out beyond the surf zone to avoid suspended bottom sediments (*Figure 4-2.3.1.1-2*). The surf zone has been estimated to be 1,000 to 1,250 feet from shore. Available bathometric survey data indicates that the required depth of water is approximately two miles from the shoreline, which is well beyond the surf zone. Current measurements and a fathometer survey must be performed at the proposed intake zone for the selected desalination plant sites to determine the bottom topography and the exact distance from the shore. For this study, the intake location is presented at two miles from the shoreline.

The following are design criteria for the sea intake:

- Wave effects and depth: Approximately 25 to 30 feet of water depth is required to reduce impacts of bottom surge and scour.

- Location from shore: The intake must be located beyond the surf zone, which is expected to be approximately two miles offshore.

- Screened intake: This should consist of two high-capacity intake screens, each flanged to a riser that leads to an intake pipe. These intake screens will have coarse openings designed to meet the impingement and entrainment requirements of large capacity intakes. This coarse screen will be located approximately two miles offshore.

- A fine screen will be located in a structure on the shoreline and adjacent to the raw water pump station. The fine screen will be equipped with a high-pressure air-burst backwash system. The compressor, tank, and accumulator will be housed in the pumping station, as are the controls that activate the system when screen head loss exceeds a predetermined value. Residuals retained on these screens will be returned to the sea.

- Intake Pipe Installation: A minimum 12-foot-deep trench dredged in the seabed and beach is required. Armor rock protection will be placed over the pipe and will not project above the level of the seafloor, to avoid creating any scouring turbulence above the pipe.

- Face velocities at the screen will be less than 0.5 fps to minimize impingement of fish and other organisms.

Schematics of the onshore intake structure and raw water pump station are presented in *Figures 4-2.3.1.1-3* and *4-2.3.1.1-4*, respectively.

2.3.1.2 Vertical Beach Wells

The use of vertical beach wells is limited, especially in the United States. There are no known vertical seawater beach wells operating continuously in the United States (serving plant capacities over 0.8 mgd). The largest plant in the world served by beach wells is in Mallorca, Spain, with a well field capacity of 24.4 mgd (WDTF 2003). Individual well capacities at this installation are 1.5 mgd. Assuming that a yield of 1.5 mgd is realistic for individual wells in Corpus Christi, approximately 37 wells would be required to supply the 55 mgd of feedwater required. The O&M of this large number of individual wells would be extremely onerous and costly.

Although the beach wells would be drilled to the seawater aquifer, extraction of 55 mgd of water could further exacerbate the delicate balance between intruded seawater and freshwater discharge and raises the question of potential upcoming of deeper brines.

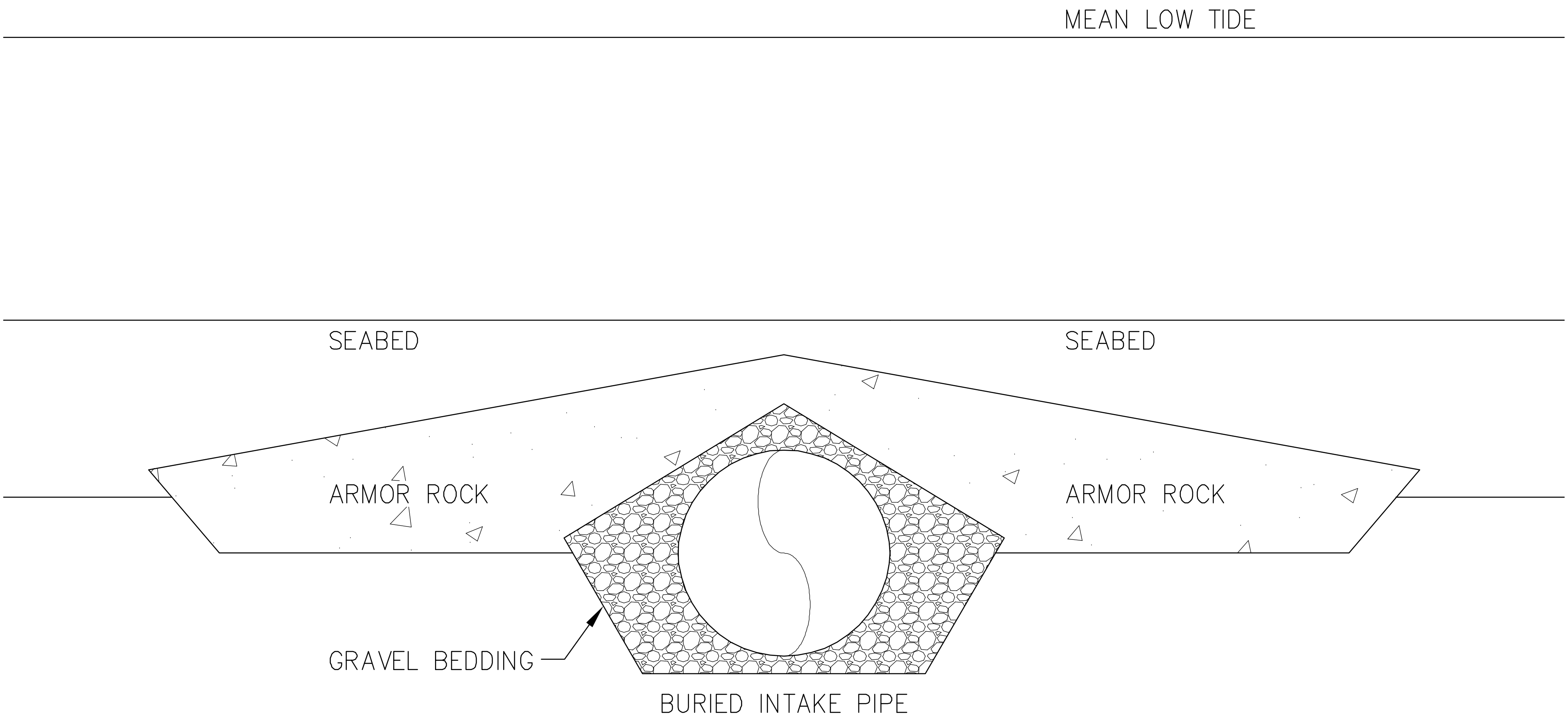
The assessment of vertical beach wells is based on the following assumptions:

- Well depths of approximately 60 feet (*Figure 4-2.3.1.2-1*)

- Distance between each well of 300 feet

- Geotechnical investigation required for locating test wells

- Transmissivities of aquifer beneath the beach being sufficient to allow production of at least 1.5 mgd from individual wells



NOTES:
1. ARMOR ROCK MIN. 5 FT THICK
2. CAPACITY 55 MGD REQ'D
3. SCREEN INTAKE VELOCITY < 0.5 FT/S

NOT TO SCALE

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Figure 4-2.3.1.1-1
Sea Intake Pipe Section

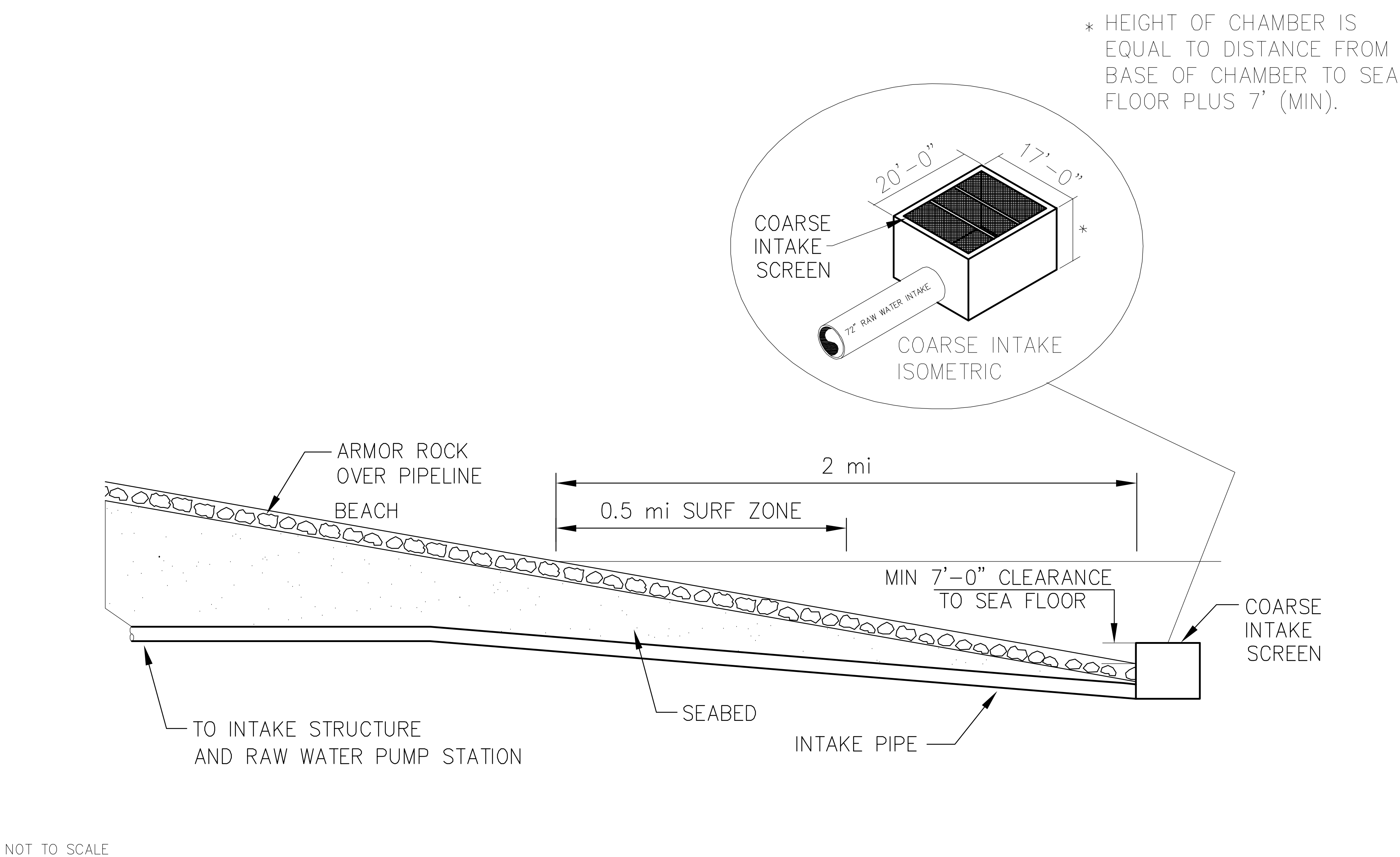

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Figure 4-2.3.1.1-2
Profile of Sea Intake

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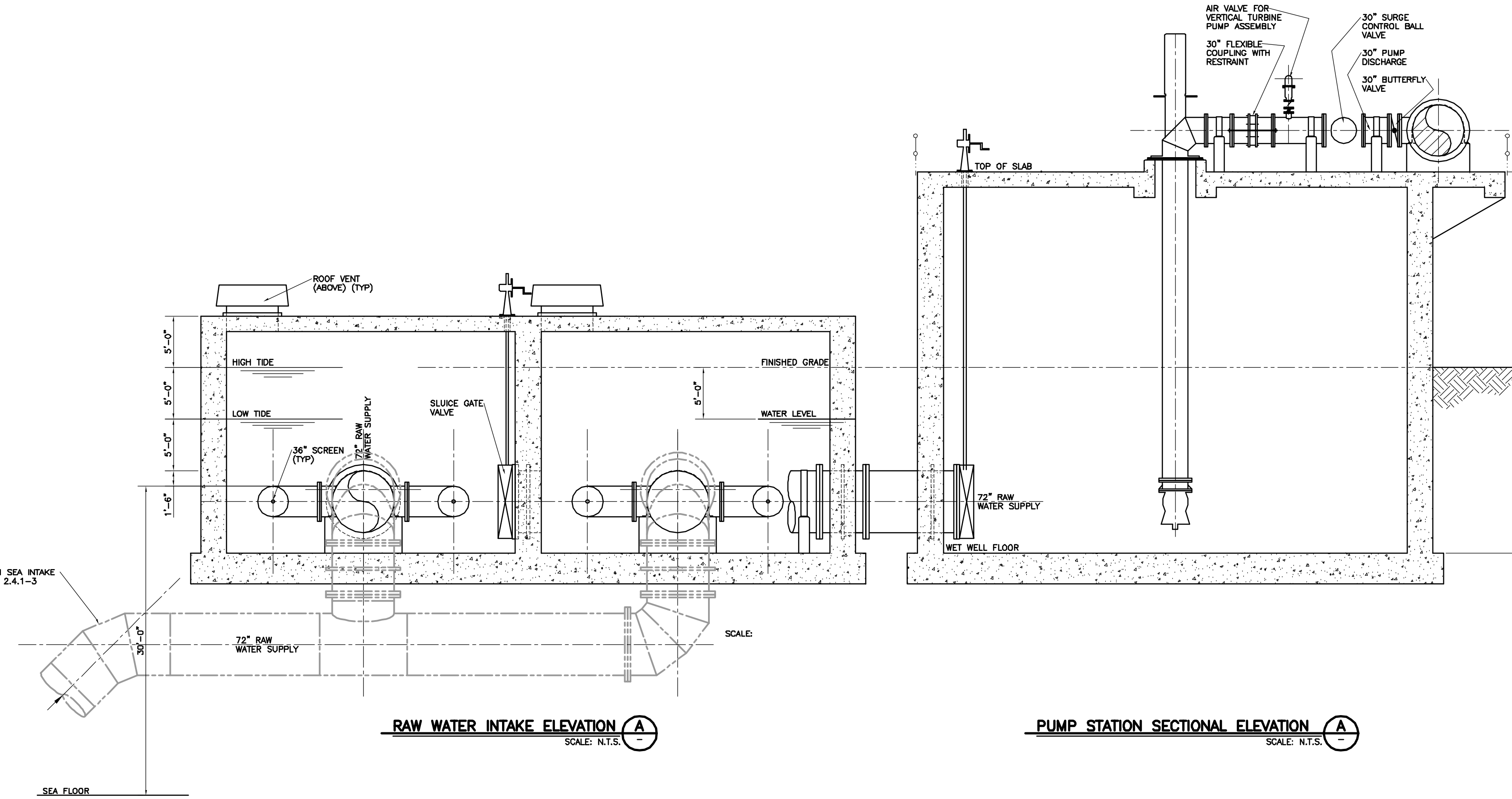

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Large Scale Demonstration Desalination Project
Corpus Christi, Texas

RAW WATER PUMP STATION
TYPICAL SECTION
FIGURE 4-2.3.1.1-3

Exhibit 4	Project No. 052321399.0003	Date JUNE, 2004

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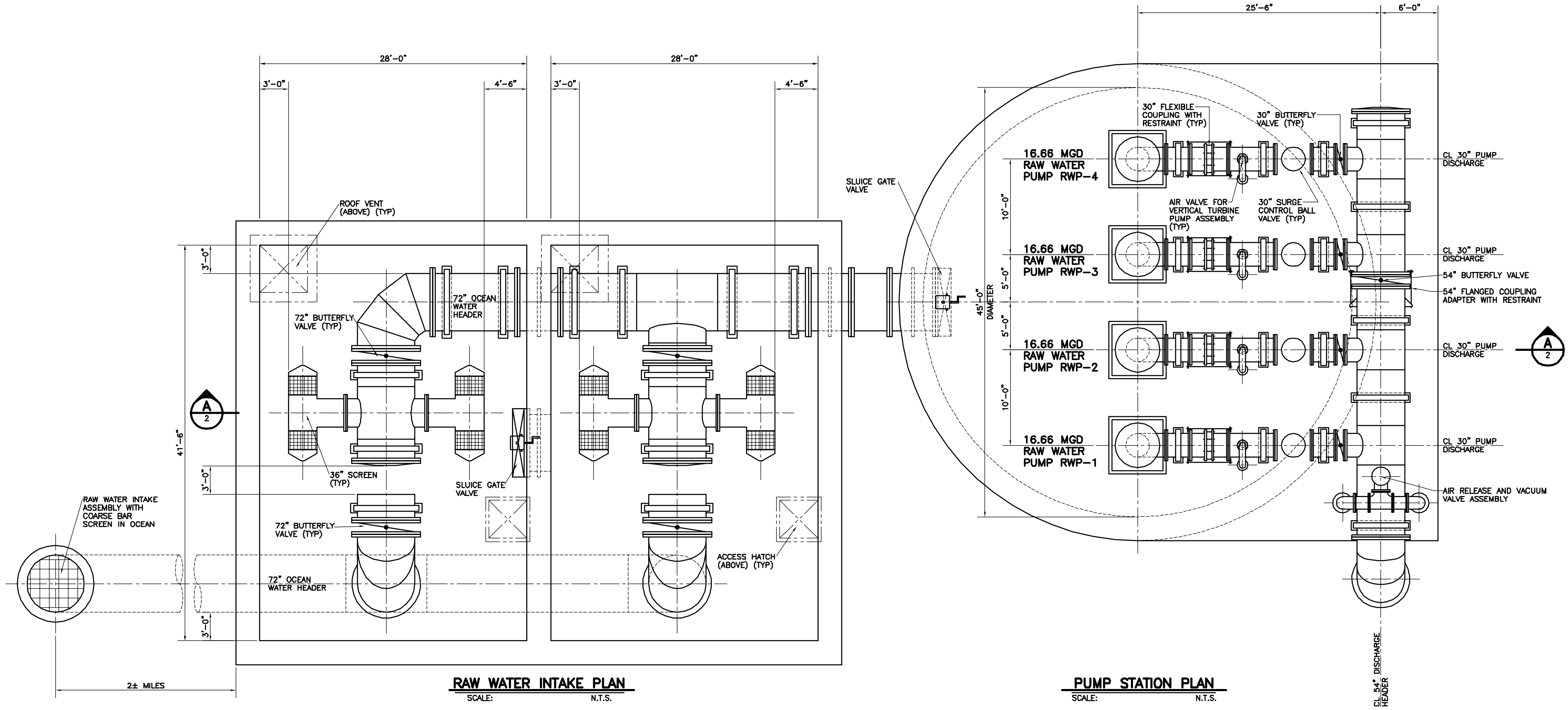

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Large Scale Demonstration Desalination Project
Corpus Christi, Texas

RAW WATER PUMP STATION PLAN
FIGURE 4-2.3.1.1-4

Exhibit 3	Project No. 052321399.0003	Date JUNE, 2004

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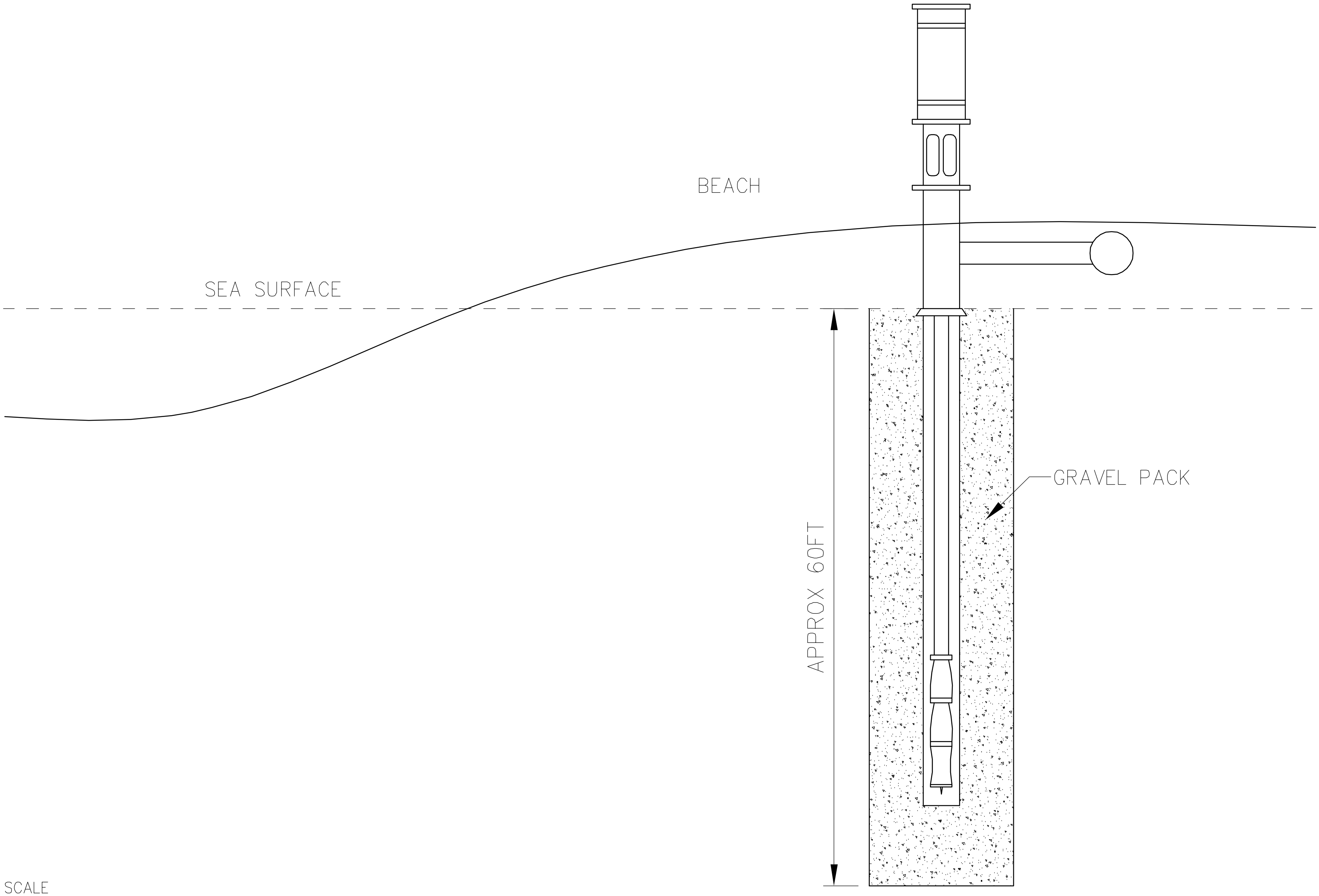

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Figure 4-2.3.1.2-1
Beach Well

In general, well fields have historically not been determined to be practical or economically feasible for large seawater desalination plants. This is due to the relatively large number of wells required and acquisition of coastal land, which can prove difficult and costly.

2.3.1.3 Infiltration Galleries

Two types of infiltration galleries were considered. The first type is a linear gallery that would lie parallel to the coast, drain from each end to a central sump, and drain into a pumping station just off the beach (*Figures 4-2.3.1.3-1* and *4-2.3.1.3-2*). Without specific hydrogeologic information, the linear gallery was sized at 1 gpm per linear foot of pipe, based on discussions with Henry Hunt of Collector Wells International, an expert in horizontal and Ranney type collector wells. This results in an infiltration gallery that is 39,000 linear feet, or 7.2 miles of beach length. Four pump stations with 0.9 mile laterals in each direction parallel to the coastline would be constructed to limit pipe sizes required. This would result in each lateral being sized to carry up to 6.9 mgd of flow continuously. At 3 feet per second, this would require a 24-inch-diameter perforated pipe.

The second type of infiltration system consists of two or more long screens jacked out under the seabed from an onshore caisson, sometimes called a Ranney Well (*Figure 4-2.3.1.3-3*). Depending on the hydraulic conductivity of the surrounding seabed, it is expected that approximately seven caissons would be required. The caissons would each contain a pump station conveying water to a common header connecting to the plant site. It should be noted that design of the actual linear infiltration gallery or Ranney well field is highly dependent on local geology, and therefore the design criteria contained in this document are subject to change.

The assessment of infiltration galleries is based on the following assumptions:

- Geotechnical investigation of seabed and beach is needed.
- Entire system is buried. Caisson tops are protected with riprap.
- Earth retention would be required to open cut the linear-type gallery.
- Landward groundwater discharge intercepted will be minimal for the linear system.
- Caisson and horizontal wells will draw only seawater filtered by the seabed.
- Beach over the linear gallery will be protected with riprap.

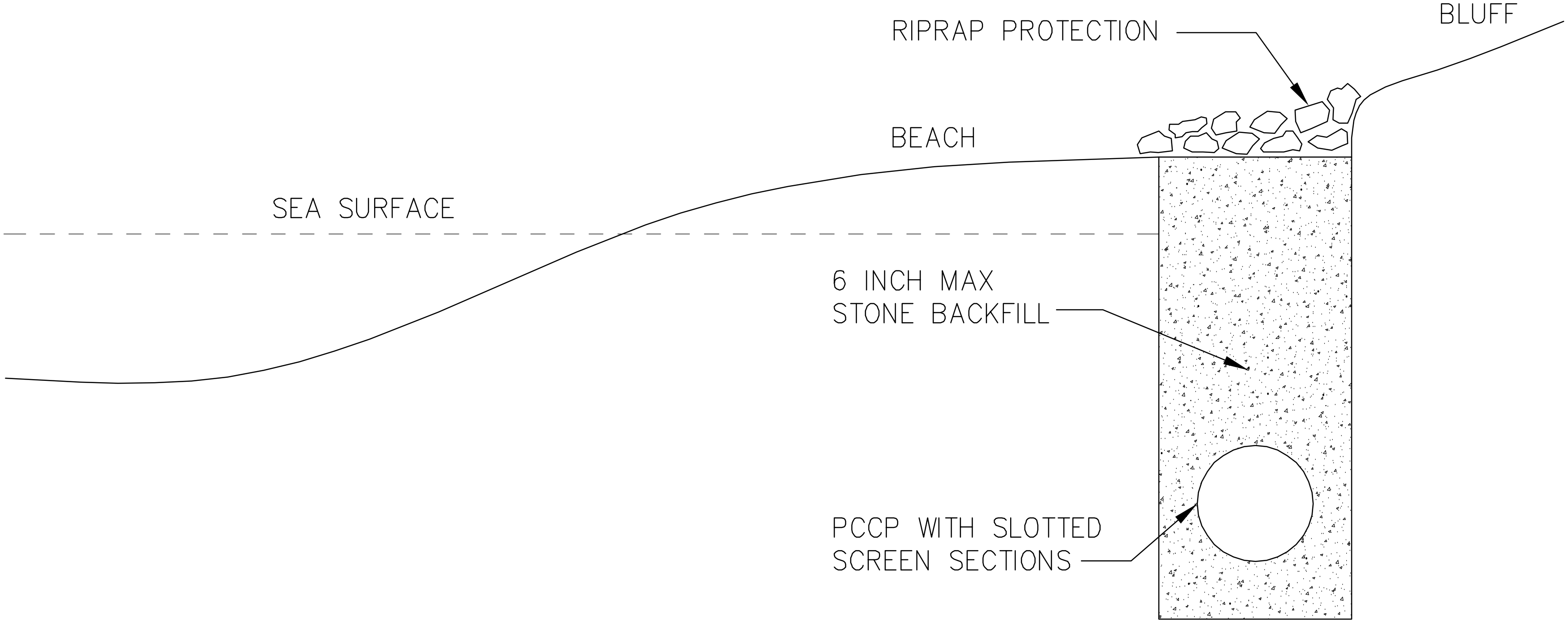

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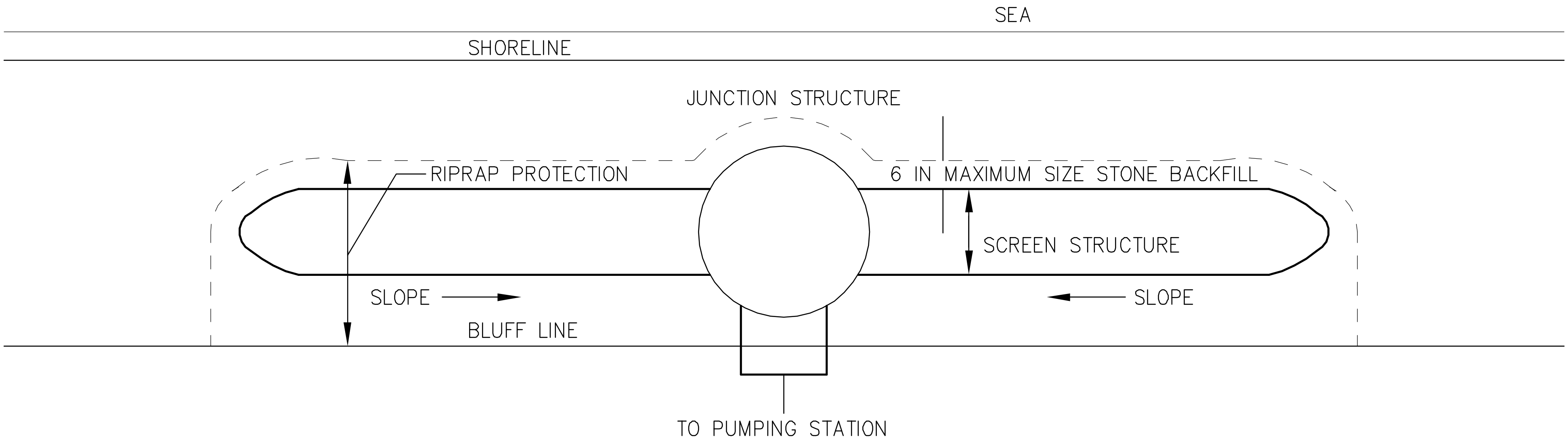
Figure 4-2.3.1.3-1
Infiltration Gallery



NOTE:

1. LENGTH OF INFILTRATION GALLERY IS DEPENDENT ON HYDRAULIC CONDUCTIVITY, THICKNESS OF THE BEACH AQUIFER AND PROXIMITY TO THE SHORELINE.

2. PERFORATED PIPE COULD BE SUBSTITUTED FOR SCREENED STRUCTURE.

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Figure 4-2.3.1.3-2
Plan of Linear Infiltration Gallery

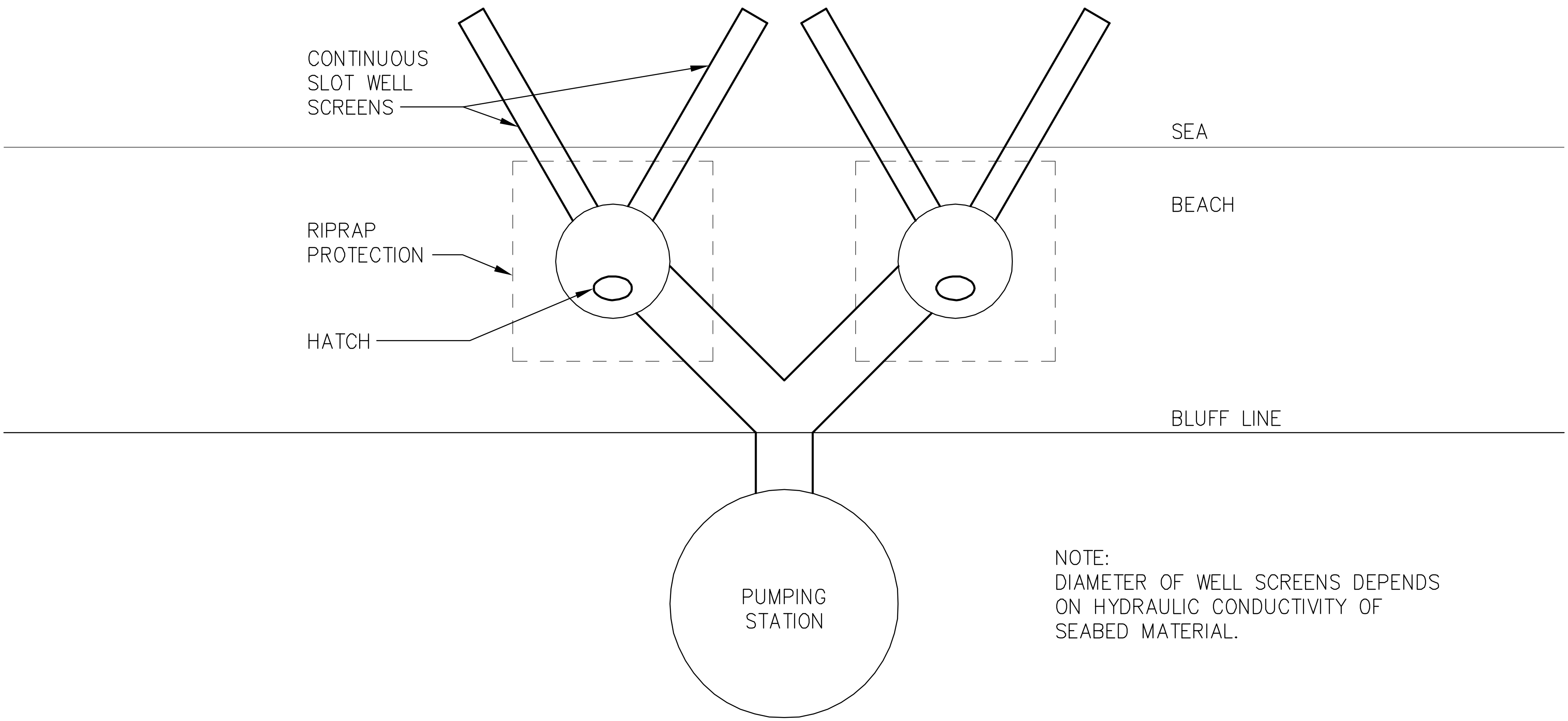

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Figure 4-2.3.1.3-3
Infiltration Ranney Wells

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2.3.2 *Intake Alternatives Evaluation*

The three alternatives for retrieving seawater are evaluated in *Table 4-2.3.2-1*. They were compared on yield, reliability, contamination potential, capital costs, operating costs, operations, environmental, implementation in land and permitting.

Table 4-2.3.2-1 Evaluation of Alternatives

Item	Vertical Wells	Infiltration Galleries	Sea Intake
Reliability	37 wells, poor reliability	Long length required/ Fair to poor reliability	Unlimited/Excellent
Temperature	Constant	Constant	Variable
Silt Density Index	Low	Moderate	High
Installation Cost	High	High	Moderate
Contamination Potential	Low	Moderate	High
Land Requirements	High	High for Infiltration Gallery Moderate for Ranney Well	Low
Permitting Requirements	Moderate	Moderate	Heavy

2.3.2.1 *Yield, Reliability, and Contamination Potential*

Vertical beach wells have been assumed to produce a maximum of 1.5 mgd, which would require approximately 37 wells plus additional spares. The wells would be drilled in a staggered pattern along the beach at about 150-foot intervals on each side of the pump station. The reliability of this large number of wells is poor and would require constant maintenance and a very large inventory of spare parts. The risk of contamination of vertical beach wells from seaward spills is considered low, since seawater is not being directly infiltrated. Landward contamination can be controlled by proper land use upgradient from the wells. However, the risk of eventually degrading the water quality by reducing the pressure on underlying aquifers and thus causing the upcoming of brines at depth is moderate to high.

The yield from infiltration galleries, either the linear type of long buried well screen or Ranney type wells consisting of horizontal well screens jacked from a caisson, depends on the permeability and thickness of the surrounding water bearing materials. The linear type is estimated to require 7.2 miles of length to extract the required 55 mgd. Infiltration galleries are moderately reliable, but do require cleaning and flushing periodically to prevent plugging of the screens and build-up of deposits of fine-grained materials, which reduce the yield. Contamination of infiltration galleries has similar sources as the beach wells, but the risk is higher because galleries can directly infiltrate near-surface groundwater. The risk of causing upcoming of deeper brines is less than vertical wells because a larger portion of the yield will be direct seawater and the galleries are much shallower.

The seawater intake yield is unlimited since seawater is taken directly into the intake through a screen placed on a riser that leads to the buried intake pipe to the pumping station. The sea intake is subject to plugging by marine growth, which is controlled by an airburst system that cleans the screen automatically when there is a change in headloss. There is also a potential for damage to the screen, from entanglement by fishing nets or ships' anchors although it is easily repaired or replaced. The sea intake is ranked highest in terms of yield and reliability. The risk of contamination from seawater intake is from petroleum products on the sea surface.

2.3.2.2 Capital Costs

The initial cost of vertical beach wells includes drilling the wells, installing the screens, placing seals, installing the submersible pumps, bringing in power, and providing 10,000 feet of manifold piping to collect the raw water for the pumping station. Approximately 37 wells with 5 spares or a total of 42 wells would be required to keep 37 wells in operation. The cost of exploration and design of the system would be included in the final capital cost. Planning-level estimates of construction costs are available for vertical beach wells for plants up to 10 mgd production capacity. At this capacity, it is estimated that beach wells would cost approximately $13.2 million in year 2004 dollars, with an *Engineering News Record* (ENR) Construction Cost Index of 6825.

The cost includes construction of the well, collector piping, lateral piping, wellhouse, pumping equipment, electrical, and controls. The cost does not include land acquisition or delivery of water to the treatment plant site. These two costs are site-specific and have, therefore, not been included in the estimate. Because the cost trend is linear, an estimate of cost for a well field for a 25-mgd facility can be extrapolated. Estimated cost for a well field to support a 25-mgd production plant would be approximately $30 million (USBR 2003). The anticipated high capital cost of vertical beach wells, when coupled with the high costs of operating and maintaining 37 well pump stations, makes this option economically unfeasible, and therefore it has not been considered further.

The initial cost of installation of the linear type infiltration system is also high. This is due to the length and the earth support necessary to keep the trenches open below the water table during construction of the system. The greatest material cost is the large diameter sections of screen. The Ranney type well construction cost may be less than the previous two options, since based on the assumptions stated previously, seven caissons would need to be drilled compared to at least 37 with vertical wells, and the radial pattern of the horizontal collectors would require much less beach length compared to the infiltration gallery option. However, this option is more dependent on specific beach hydrogeology than the other options, making cost estimation difficult. It is estimated that construction of each Ranney type well would cost approximately $2.5 million. With seven wells, a total construction cost of approximately $17.5 million is estimated. As with other options, this does not include the cost of land acquisition or a conveyance pipeline to the plant site.

Capital costs of the sea intake are estimated to be the lowest of the three intake systems depending on how far out the intake pipe must be installed beyond the surf zone to have sufficient depth water that is low in suspended sediments. The sea intake is a straightforward, conventional marine pipe placement in shallow water. The intake screens are bolted to risers that penetrate the sea floor to the buried intake pipe. The materials, with the exception of the screens are common construction materials i.e., HDPE pipe, crushed rock bedding, and riprap. Construction cost for an intake to provide 55 mgd of raw seawater to the plant is estimated at approximately $5 million, not including land acquisition, which should be minimal compared to the alternatives, or conveyance pipeline to the plant.

2.3.2.3 Operating Costs

Vertical beach wells have the highest operating cost with a large number of continuously operating pumps. It is estimated that full-time maintenance may be required for this system alone. All pumps are electrically powered and standby power should be included. Vertical wells have the highest operating cost in comparison to the other two raw water systems, which use a central piping station.

Infiltration galleries operate under low head and flow to a smaller number of central pump stations, where the raw water is pumped to the desalination plant. The major operating cost is periodic maintenance of the screens, which tend to plug, and removal of fine-grained deposits that build up in the pipe. An added benefit of these alternatives is that the raw water is filtered by the material surrounding the collection pipe and therefore would not require pre-treatment at the plant.

The sea intake operates by gravity and has only a small power requirement during periodic maintenance to operate a compressor at the central raw water pumping station to clear marine growth from the screen. Sea intake has the lowest operating cost.

2.3.2.4 Operations

Operation of the 37 vertical beach wells may require a full-time operator in addition to the maintenance and repair staff to monitor the functioning of each well. Monitoring water levels to determine the drawdown of the well field versus seawater recharge would also be necessary.

Operation of the infiltration gallery system or Ranney well system requires monitoring headlosses to determine any plugging or deposit build-up in this long linear gallery. Periodic maintenance and monitoring of the amount of drawdown and recharge occurring is required. There are no moving parts and no power requirements.

The sea intake requires little in the way of operation. A change in headloss at the screen automatically triggers the airburst cleaning of the screen. A seasonal check of the screen by divers for damage or encrustation would be prudent. No other monitoring is necessary. The sea intake should have the lowest operations oversight and cost.

2.3.2.5 Environmental

The vertical wells occupy a large section of beach and although well heads, power cables, and piping can be buried, each well head would have to be in a small structure for security. Wellhead protection zones would also have to be established for each well. The vertical wells, by their nature, draw water deeper than the other two systems, thereby risking changing the salt/fresh balance in lower aquifers. Daily maintenance and operation of the well field will interfere with use of the beach.

The infiltration gallery installation has the greatest construction impact on the beach since the gallery is long and runs parallel to the coastline and will take a long time to construct. Due to potential contamination from activities at the beach, the infiltration gallery should have a large buffer zone for water supply protection. The gallery requires a large concrete sump midway that feeds collected water into the raw water pump station (see *Figure 4-2.3.1-4*). There will also be some access points to the gallery for maintenance, probably in the form of manholes.

The Ranney type well system may have the least environmental impact of the bank filtration options. There are significantly fewer wells required compared to the vertical well option, limiting land requirements, and the horizontal laterals are buried and therefore do not require open-trench construction techniques as with the infiltration gallery alternative.

Construction of the sea intake will have a short impact on marine life while the pipe is laid. The intake screen has an intake velocity less than 0.5 ft/sec, so marine life moving by the intake will be impacted minimally. The construction of the sea intake will have a short impact on the beach since it is confined to a narrow corridor crossing the beach perpendicular to the coastline. Riprap protecting the pipeline from winter storm-erosion will be flush with the sea floor and buried under the beach.

2.3.2.6 Implementation–Land and Permitting

The vertical beach wells and Ranney type wells will require extensive well exploration and testing to determine the optimum location and spacing. Subsurface conditions along the beach are known to vary from rock to fine sand. Drilling of production wells will take a long time depending on the number of drilling rigs and crews that can be mobilized. Setting aside extensive reaches of the beach for this use may be difficult to permit. Permits for construction will be required from the appropriate regulators and government agencies.

The infiltration galleries will also require exploration to determine the subsurface conditions and hence the ultimate feasibility of this alternative. Construction time is indeterminate at this time since it depends on the length of the gallery, which in turn is dependent on the subsurface conditions. Permits for construction on the beach will be required from the appropriate regulators and government agencies.

Sea intake will require an offshore hydrographic survey to map sea floor topography and jet probing of the sediments to determine trenching conditions. Permits for construction of the sea intake line must be obtained from appropriate regulators and government agencies.

2.3.2.7 Summary

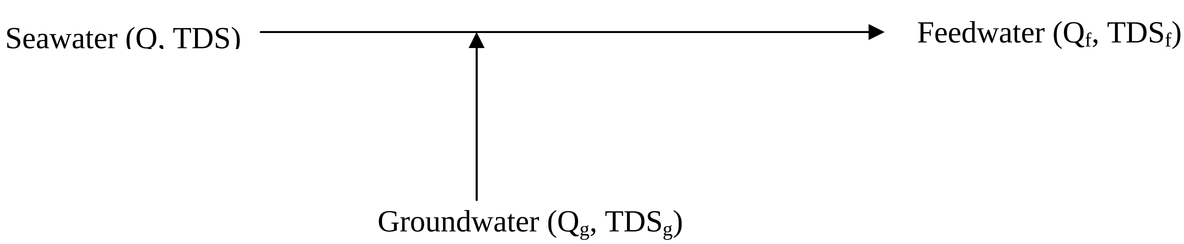
After review of the intake alternatives, the vertical well alternative and the horizontal infiltration gallery alternative have been excluded from further consideration. The significant cost and land requirements make them impractical and economically unfeasible. The open sea intake and the

Ranney type well alternatives should be investigated further to refine design criteria and estimated costs. The Ranney alternative may not be feasible depending on the specific location selected and the hydrogeology of the area. Geotechnical investigations need to be performed to determine characteristics of various geologic strata in coastal locations in the vicinity of the plant site. In addition, the potential for land acquisition or easements must also be determined. While this alternative is projected to be more expensive than the direct intake alternative, the in-situ treatment of the seawater is expected to allow the removal or reduction of the pre-treatment required for the direct seawater intake, which would result in a substantial savings, possibly making the combined cost competitive.

2.3.3 Groundwater Blending

Groundwater extraction at a rate exceeding 10 mgd poses extremely difficult challenges due to seawater infiltration in the Corpus Christi region. This consideration establishes a major constraint, potentially limiting seawater sources to those that could be blended to 35,000 mg/l using available groundwater.

A mass balance was conducted using the seawater total dissolved solids and groundwater total dissolved solids data to determine the amount of blending required to achieve a desalination system feedwater of 35,000 mg/l. The mass balance was then applied to the seawater cumulative distribution data, to determine a new distribution describing the blending flows required to maintain a feedwater of 35,000 mg/l or less.



Given: Q_f = 50-mgd

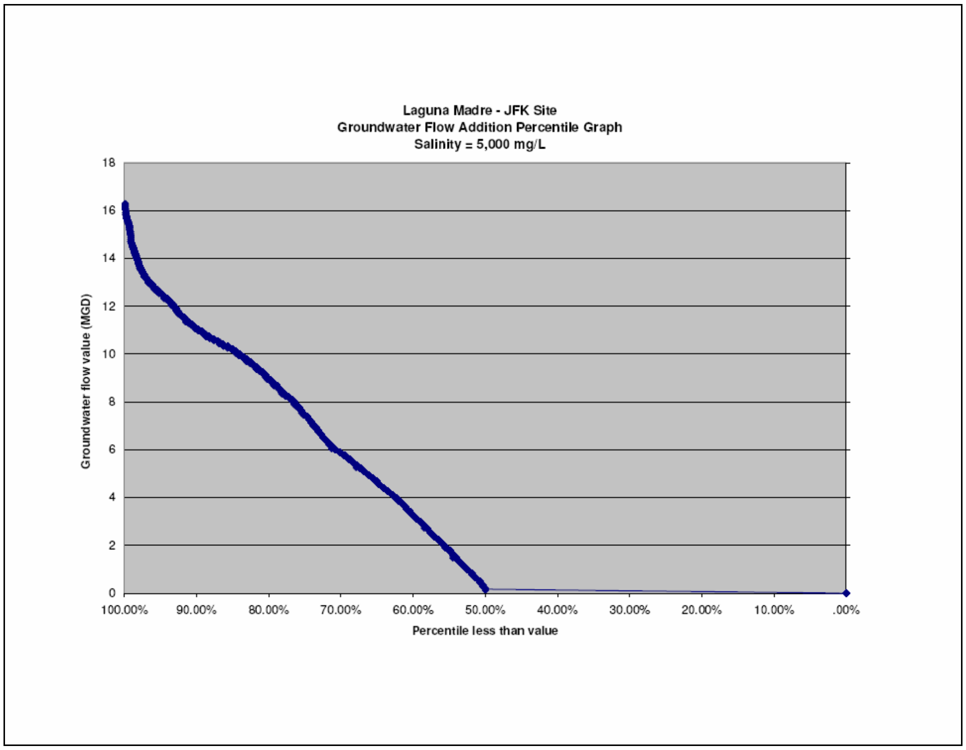
TDS_f = 35,000 mg/l or less
Q_g = 50-mgd – Q; not to exceed 10-mgd
TDS_g = 5,000 mg/l

The results of the mass balance for each potential source water are illustrated in *Figures 4-2.3.3-1* through *4-2.3.3-3* for Laguna Madre, Nueces Bay, and Corpus Christi Bay, respectively.

The results for Laguna Madre are presented in *Figure 4-2.3.3-1.* During 50 percent of the data analyzed, the total dissolved solids of Laguna Madre were less than 35,000 mg/l. During these periods, no blending would be required to maintain a feedwater concentration of less than

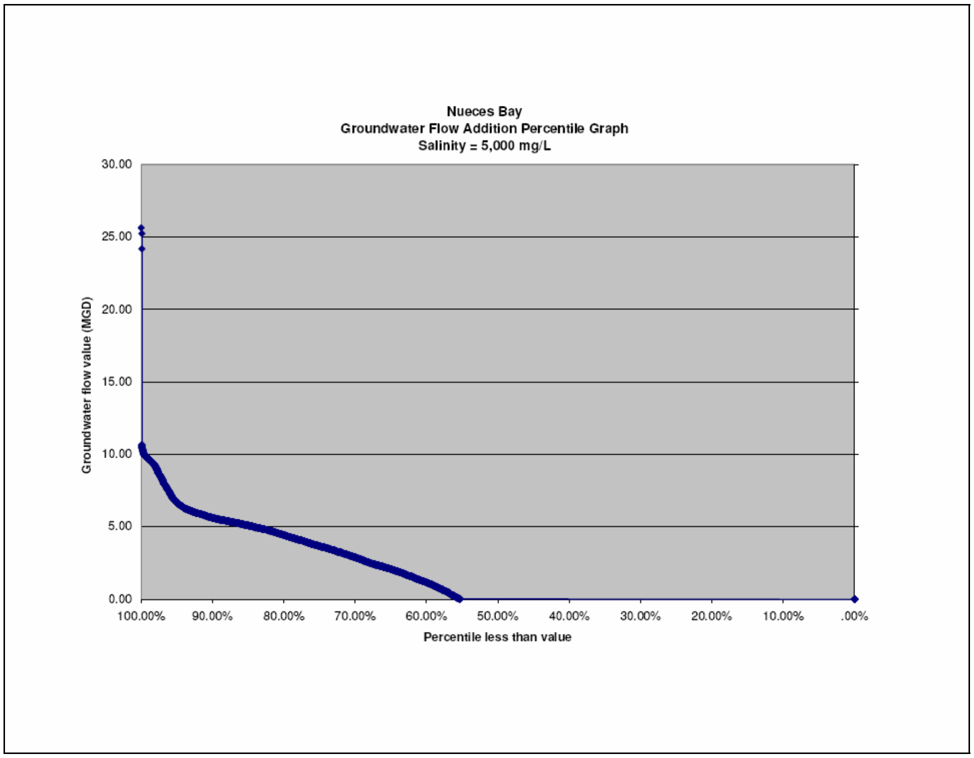
35,000 mg/l. There may be advantages to continue blending through these periods, as lower total dissolved solids in the feedwater equates to lower operating pressures for the reverse osmosis units, with power savings. With approximately 84 percent of the data analyzed, it was determined that groundwater blending flows of less than 10 mgd could maintain the total dissolved solids at less than or equal to 35,000 mg/l. During analysis of 16 percent of the data, the amount of 5,000 mg/l of groundwater required for blending exceeds 10 mgd. As a result, either additional groundwater resources are required, or the desalination system must be designed to operate at reduced recoveries, substantially increasing the required size of the pre-treatment equipment, intake, and outfall facilities.

Figure 4-2.3.3-1   Groundwater Blending Data for Laguna Madre



The results for Nueces Bay are presented in *Figure 4-2.3.3-2*. During 56 percent of the data analyzed, the total dissolved solids of Nueces Bay were less than 35,000 mg/l. During these periods, no blending would be required to maintain the desired feedwater TDS concentration. As discussed previously, there may be advantages to continue blending through these periods, reducing operating costs. During approximately 98 percent of the data analyzed, groundwater blending flows of less

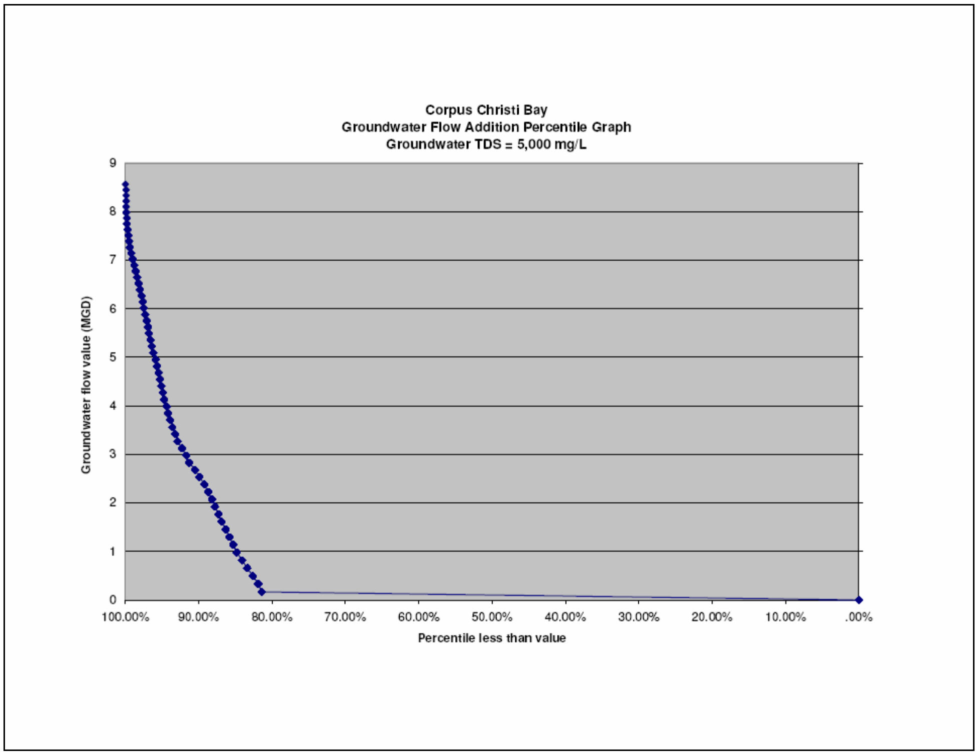
Figure 4-2.3.3-2   Groundwater Blending Data for Nueces Bay



than 10 mgd can maintain the total dissolved solids at less than or equal to 35,000 mg/l. Under the conditions represented in the raw water data analyzed, groundwater blending can adequately reduce the salinity of the feedwater during hypersaline conditions only if water with 5,000 mg/l TDS or less can be produced.

Similar findings exist for Corpus Christi Bay (*Figure 4-2.3.3-3*). During 82 percent of the data analyzed, the total dissolved solids of Nueces Bay were less than 35,000 mg/l. During these periods, no blending would be required to maintain the desired feedwater TDS concentration. As discussed previous, there may be advantages to continue blending through these periods, reducing operating costs. During approximately 100 percent of the data analyzed, groundwater blending flows of less than 10 mgd can maintain the total dissolved solids at less than or equal to 35,000 mg/l.

Figure 4-2.3.3-3 Groundwater Blending Data for Corpus Christi Bay



3 TREATMENT PROCESS

This section will provide background information on the assumptions made, the alternatives evaluated, and the results of the analysis for pre-treatment, desalination, and post-treatment. Also discussed will be finished water quality goals, which will be the basis for the treatment process design.

3.1 Pre-Treatment

3.1.1 Pre-Treatment Introduction

The first commercial seawater reverse osmosis (RO) plants were installed in Saudi Arabia beginning in 1975. Today, there are over 1,000 seawater RO plants constructed worldwide. Pre-treatment of the raw seawater is necessary prior to introduction into the RO membrane to remove potential foulants such as particulates, colloidal inorganic and organic material, biological material, and debris. If these materials pass onto the RO membrane, they will foul the membrane surface resulting in increased pressure drop and power consumption, and reduced permeate production quality. Additionally, in the pre-treatment process, acid and/or scale inhibitor is introduced to eliminate scaling of sparingly soluble salts on the RO membrane surface. Disinfection, either continuous or intermittent shock, is often included in the pre-treatment process as well.

Pre-treatment for seawater RO applications should be segregated into two categories in relation to their feedwater supply system: open sea supply intake or beach well-type intakes. The pre-treatment requirements vary greatly as a function of the selected supply system. Seawater drawn through beach wells requires significantly less pre-treatment than surface supply intakes. Historically, effective pre-treatment has been the most challenging issue confronting users of seawater RO at surface supply intake facilities.

Two pre-treatment categories and bank filtration without pre-treatment are screened and candidate processes selected for further evaluation. The pre-treatment options include (1) conventional clarification and filtration and (2) ultrafiltration using immersed membranes. Similarly, several variations of the bank filtration techniques are also identified.

Pre-Treatment in Beach Well Intake Facilities

Beach well-type intakes can take various forms such as Ranney collector wells, traditional vertical wells on the beach, horizontal wells positioned into the sea, and infiltration galleries. Their commonality is that they all utilize the natural geology in some form to pre-filter the seawater. The limitation of beach wells is almost always the quantity of seawater they can effectively deliver. As a result, only small to medium-size seawater RO plants have been built using these water delivery methods.

Historically, pre-treatment in beach well applications has usually been limited to chemical addition for scale inhibition and cartridge filtration. This limited pre-treatment requirement is a result of the low particulate, biological and colloidal material content of the seawater after it is pre-filtered through the sandy seafloor or beach. Additionally, naturally filtered seawater has shown to exhibit almost steady physical characteristics such as temperature and most water quality parameters. Beach wells have been utilized heavily in the Caribbean desalination market in facilities up to approximately 5 mgd.

Pre-Treatment in Surface Supply Intake Facilities

Surface supply intakes utilize seawater directly from the sea and are usually submerged and extended a distance from the shoreline. Seawater RO plants using open intakes were initially implemented in the Middle East region. One of the original and larger seawater RO plants, the 3.2-mgd facility in Jeddah, Saudi Arabia, became operational in 1978 and was built for the Saline Water Conversion Corporation (SWCC). Today, SWCC is the largest single user of desalination technology.

Pre-treatment has been the Achilles' Heel of the open intake seawater RO plant. Early plants in the Middle East utilized primarily hollow-fiber RO membrane, which was generally considered more prone to fouling than the spiral-wound RO membrane elements used today. Many of the pre-treatment systems in the early plants were insufficiently sized to handle the high particulate content they experienced. The result was poor RO performance. After start-up, these plants often operated at well below design capacities to reduce the loadings on the pre-treatment.

The historical indicator of successful seawater RO pre-treatment is the Silt Density Index (SDI). This simple analytical technique provides a guide to the amount of foulant material remaining in the pre-treated feedwater. RO manufacturers require SDI values generally less than 4 for seawater RO applications, and a value of 3 is preferable. The SDI is not a perfect indicator, but it is still the industry standard used today.

The conventional pre-treatment for open intake seawater RO plants has historically consisted of the following, each of which is described in *Table 4-3.1.1-1:*

- Chlorination
- Coagulation, flocculation, and sedimentation
- Filtration
- Chemical dosage for scale inhibition
- Cartridge filtration
- Dechlorination

In limited cases, additional pre-treatment processes have been introduced such as diatomaceous earth and granular activated carbon (GAC). The GAC is used most often in Arabian Gulf applications to scavenge oil and grease that may be present in the feedwater.

Technological advancements in recent years have altered pre-treatment strategies. These advancements are presently demonstrating their ability to produce pre-treated water of a higher quality in pilot plants around the world. These advancements are listed below and are also discussed in *Table 4-3.1.1-1*.

- Membrane filtration
- Dissolved air flotation

Examples of Full-Scale Installations of Different Pre-Treatments

Two-stage, dual-media filtration
The most common conventional pre-treatment system for open intake systems seen around the world is that typified by the 10.6-mgd seawater RO plant located in Okinawa, Japan. This plant has been operating for over approximately 8 years and uses a two-stage, dual-media filtration including:

- Chlorination (3 mg/l as $Cl_{2)}$ with sodium hypochlorite, continuous
- Direct 2-stage gravity filtration with in-line coagulation using ferric chloride (1.5-3.0 mg/l as $FeCl_3$) consisting of:
  - Dual media filter loading rate of 4.9 gpm/ft^2
  - Polishing sand filter loading rate of 6.9 gpm/ft^2
- pH adjustment with H_2SO_4 to 6.5-7.0
- Dechlorination with sodium bisulfite
- Cartridge filtration (5 micron)

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Table 4-3.1.1-1 Seawater RO Pre-Treatment Components for Surface Seawater Sources

Pre-Treatment Component	Description	Discussion
Chlorination	Chlorination is used for disinfecting the intake and pre-treatment system to mitigate biofouling in the downstream RO. Historically, continuous chlorination was used at levels up to 5 mg/l. Intermittent shock chlorination at higher dosages is more common today. If practical, elimination of chlorination/dechlorination is preferred.	Historically, it was believed that continuous chlorination was necessary to prevent RO biofouling. Chlorination of naturally occurring humic and fulvic acids create high concentrations of assimilable organic carbon (AOCs), which we know today to be a principal player in the RO biofouling process. Intermittent shock chlorination has shown to be an improvement in many plants, while some have totally eliminated disinfection with successful results.
Coagulation/ Flocculation/ Sedimentation	Coagulation and flocculation are used to remove the suspended and colloidal material from the raw seawater. The most common coagulants include ferric salts such as ferric chloride and ferric sulfate dosaged at levels of 5-10 mg/l. Multiple flocculation stages followed by settling have been used successfully. Inline coagulation is more common in treating lower fouling water. Anionic polymer as a filter aid may also be used.	Historically, the most severe water quality has benefited from the most extensive coagulation/flocculation/ sedimentation process. Sufficient mixing is critical, especially when only inline coagulation is used followed by direct filtration.
Filtration	Media filtration is used combining of sand and/or anthracite and garnet. Both single and two-stage systems are common, as are both pressure and gravity filters. Typical loading rates are 2-6 gpm/ft^2.	The media type is highly variable. Many plants only use sand, others a combination of sand and anthracite, while new plants also introduce garnet. There is a high variability in the use of single and two-stage systems and is often a function of the degree of whether inline coagulation is used, i.e. inline coagulation plants more often use two-stage filtration. SDI goals of 3 are generally achievable with sufficient design in the coagulation and filtration processes.
Chemical Addition	Sulfuric acid is used to reduce the pH to prevent calcium carbonate scaling in the RO. Historically, scale inhibitors have also been applied to prevent sparingly soluble sulfate salts from precipitating.	Acid addition has not shown to be problematic, but scale inhibitor addition has been greatly reduced in recent years due to lack of real need and potential except in cases of high RO recovery.
Cartridge Filtration	Cartridge filters are used as the last line of defense against particles reaching the RO membrane surface. Typically 5 micron are used, occasionally 1-3 microns are used especially when a plant initially goes into operation.	When the coagulation/filtration processes have not been sufficiently designed, the cartridge filters incur high loadings requiring frequent replacement. Iron deposits and biofouling are frequent complaints in a poor performing plant.
Dechlorination	RO membranes are susceptible to chlorine oxidation, and therefore, all chlorine must be scavenged from the pre-treated water. Sodium bisulfite (SBS) is the most common dechlorinating agent at dosage sufficient to scavenge all chlorine, typically 3-4 mg/l.	Rapid biofouling occurs immediately following dechlorination in plants with continuous chlorination and high organic content. Additionally, reduction of ferric salts can create catalyzed chlorine oxidation. SBS alone is not problematic and has shown to have biostatic properties.
Membrane Filtration	Membrane filtration pre-treatment uses microfiltration or ultrafiltration to replace the flocculation/sedimentation and filtration processes of conventional pre-treatment.	Pilot studies have shown reduced or eliminated coagulant dosage using membrane filtration and enhanced pre-treated water quality, with SDI generally around 2.
Dissolved Air Flotation (DAF)	DAF is used upstream of conventional or stacked filters to enhance the removal of algae and colloidal material.	Limited pilot data has shown DAF to improve pre-treated water quality especially in removal of algal species.

Single-stage multi-media filtration with diatomaceous earth-coated polypropylene polishing filter
The Las Palmas III plant located in the Canary Islands of Spain has successfully implemented an innovative pre-treatment scheme beginning production in 1989 of 9.5 mgd of product water from an open intake.

- Chlorination with sodium hypochlorite, continuous
- Direct gravity filtration with in-line coagulation using ferric chloride
- Polishing filtration using polypropylene filters coated with diatomaceous earth
- pH adjustment with H_2SO_4
- Dechlorination with sodium bisulfite
- Cartridge filtration (5 micron)

Ultrafiltration
The only full-scale operating open intake seawater RO plant utilizing membrane filtration in a municipal application is located in Bahrain, at the Ad Dur Plant. This facility it rated at 12-mgd treating water of 46,500 mg/l from the Arabian Gulf. This facility successfully piloted hollow fiber UF technology but installed spiral-wound UF technology. The UF pre-treatment became operational in 2000 with mixed results due to the difficulties encountered with the spiral-wound UF technology.

There is an approximate 1-mgd seawater RO system operating in Morocco utilizing membrane filtration pre-treatment in an industrial application, but limited data is available regarding this facility other than it has operated successfully for approximately 3 years.

Examples of Pilot Studies of Advanced Pre-Treatment Processes

Microfiltration (MF) or Ultrafiltration (UF) Membrane Filtration Pilots
Over the last 5 years, about 25 MF/UF pilot studies have been conducted around the world for seawater RO applications. Public data is not available for approximately half of these pilots. Of those published, the sites have been located in:

- Middle East, on the Arabian Gulf, the Red Sea, the Mediterranean Sea, and the Indian Ocean
- United States on the Gulf of Mexico and the Pacific Ocean
- Spain on the Mediterranean Sea
- Gibraltar on the Mediterranean Sea
- Japan on the Pacific Ocean

The results have shown both MF and UF produce pre-treated water with SDI values ranging from 1.5 to 2.5, with only a few rare cases of UF pre-treated waters in excess of 3 SDI. Many of the pilot studies used no coagulant addition. The resulting RO performance has been reduced RO cleanings and lower operating pressures from reduced fouling. Additionally, the membrane filtration systems offer reduced plant footprints over conventional pre-treatment processes

Dissolved Air Flotation (DAF) Pilot
There has been a single pilot study conducted utilizing DAF as pre-treatment in front of two-stage dual media filtration for open intake seawater RO. This study was recently conducted by ONDEO for the Abu Dhabi Water and Electricity Authority (ADWEA) for an upcoming 50-mgd Tawellah plant. Recent discussions with the ADWEA consultant indicated the DAF performed well. The overall pre-treatment process provided SDI values consistently in the 2 to 3.5 range.

Actiflo Microsand Pilot
Recently, Vivendi pilot tested Actiflo at the ADWEA pilot site for the Tawellah plant. Unfortunately, Vivendi did not publish any data regarding its testing. In recent discussions with the Vivendi personnel responsible for the project, they indicated the Actiflo performed well, and they would be conducting follow-on piloting of the technology at the Tawellah site beginning April 2004, in support of their recent win of this project.

Screening of Candidate Pre-Treatment Processes

Historically, outside the US, seawater reverse osmosis (SWRO) has been performed with direct filtration as pre-treatment. Single or two-stage direct filtration can only be used with relatively low raw water turbidities; where water quality has been higher in turbidity or algae, clarification and filtration has been used. In Trinidad, a large SWRO plant is operating with tube settler clarification and single stage filtration as pre-treatment which was necessary due to raw water turbidity excursions. Raw water turbidity has generally been <10 NTU with some excursions to as high as 35 NTU. The tube settler is designed at 1.9 gpm/sf, and the filters are designed at (unknown) gpm/sf. In the United States, the largest SWRO facility in operation in Tampa Bay, Florida, utilizes two-stage direct filtration. Unfortunately, there have been severe problems with the pre-treatment process in Tampa Bay because of water quality issues. Litigation is pending.

Screening of the treatment processes in this feasibility study was performed on the basis of worst-case water quality assuming: turbidity could be greater than 20 NTU; red tides or algae could be present for a significant period of time; there may be variations in temperature of the raw water; there may be moderate TOC; greater than 25 mg/l of coagulant may be required; hurricanes may cause severe water quality excursions; and the density of seawater may affect the performance of the pre-treatment processes. Single or two-stage direct filtration is not suitable for this type of water quality. Therefore, the assumption is that the pre-treatment process must be robust enough to handle expected worst-case variations in water quality and still provide low SDI for maximum efficiency of the RO process. Additional assumptions are that the processes should be space efficient to reduce land requirements and facilitate siting of the plant, and be well proven in drinking water treatment applications.

It is recognized that many high-rate and innovative clarification processes are well proven in drinking water applications and have achieved significant advancements in performance, although they are not well proven in seawater applications. However, the project constraints with respect to area requirements, cost, and performance under worst-case water quality conditions make it imperative to consider innovative, advanced, and proven technology in this analysis.

The candidate processes that were considered for screening of pre-treatment processes capable of treating worst-case water quality were:

- Conventional flocculation, sedimentation, and filtration
- Solids contact clarification (Accelator) and filtration
- Plate or tube settler clarification and filtration
- Pulsator or Superpulsator clarification and filtration
- Dissolved air flotation (DAF) clarification and filtration
- Micro-sand enhanced clarification (Actiflo) and filtration
- Ultrafiltration using immersed membranes (Zeeweed 500D)

Conventional Flocculation, Sedimentation, and Filtration
Conventional flocculation, sedimentation, and filtration are developed as a very worst-case pre-treatment to preliminarily determine the largest conceivable land area requirements for the SWRO facilities. A rapid mix of at least 1 minute detention time is used ahead of flocculation that is normally provided in multiple stages with a minimum detention time of 30 minutes, and the sedimentation process is designed around a surface loading rate of only 0.45 gpm/sf. Conventional flocculation and sedimentation can treat fairly high turbidity and low levels of algae but is susceptible to rapid variations in raw water temperature. Residuals are generally extracted by periodic manual draindown and washdown; mechanically, using chain and flight scrapers that are difficult to maintain and unreliable; or mechanically, by vacuum extraction systems. If sludge scrapers or vacuum extractions are used, the residuals will generally have a solids content of between 0.1 to 0.5 percent solids. Because of the large land area requirements, susceptibility to rapid changes in water temperature, inability to treat high algae concentrations, and high probable capital and operating cost, conventional clarification and filtration was eliminated from further consideration.

Solids Contact Clarification and Filtration
Solids contact clarifiers such as the Accelator marketed by Infilco Degremont, Inc. are extraordinarily well proven in drinking water treatment in both coagulation and softening. Rapid mixing is integral with the process as a central draft tube mixing zone that functions in an up-flow direction. Coagulated solids are flocculated in the inner draft tube and pass into an outer draft tube where they exit in a downward direction along the bottom perimeter of the outer draft tube. The solids then sink readily down into a slurry pool of preformed solids. Solids from the slurry pool are sucked back under a hood and up into the mixing impeller where they are mixed with incoming raw water that has coagulant, hence, the term-solids contact clarification.

Accelators can operate at between 1.0 and 2.0 gpm/sf or two to four times the surface loading ranges of conventional flocculation and sedimentation. Accelators can effectively treat high turbidity, low or moderate algae to some extent, and high coagulant dosages and produce clarifier effluent turbidities of 1.0 to 2.0 NTU, but low turbidities are still achieved through filtration. Accelators are less susceptible to variations in raw water temperature than conventional sedimentation but are still susceptible to rapid variations. Accelators can be equipped with scrapers to collect the sludge and move it to sumps in the floor of the units, or they can be equipped with pie-shaped hoppers around the hood. Each pie-shaped hopper has a mechanical flap that can be manually opened or closed. When closed, the hopper collects sludge because it cannot get back under the hood. Sludge is withdrawn from the hoppers by hydraulic extraction through an air-actuated valve. Residuals concentrations for coagulation are in the range of 0.1 to 0.5 percent solids. Because of some susceptibility to temperature variation, limitations on ability to treat algae, low surface loading rates, and large footprint, Accelators were eliminated from further consideration.

Plate or Tube Settler Clarification and Filtration
Plate or tube settlers are well proven in drinking water treatment and have been used in SWRO as mentioned above (in Trinidad) and can be considered as a base-line approach capable of treating worst-case water quality. A rapid mix with detention time similar to that used for conventional sedimentation is used ahead of multiple stages of flocculation with a total detention time of about 30 minutes. In these types of clarifiers, tubes or plates that are inclined at a 60 degree angle create a "projected" clarification area that enhances clarification over a smaller surface area. The tube settler process can operate at about 2.0 gpm/sf surface loading rate and the plate settler process can operate at higher SLRs of up to 5.0 gpm/sf depending on plate spacing. Tube settler SLRs are equal to that of Accelators and about 4 times that of conventional sedimentation. This results in a much smaller process footprint than for conventional sedimentation. Plate settler SLRs are up to 10 times that of conventional sedimentation and about equal to average dissolved air flotation (DAF) SLRs. Tube and plate settler clarified turbidity may be slightly higher than for conventional sedimentation, but low turbidities are still achieved through filtration. Residuals concentrations are in the range of 0.1 to 0.5 percent solids. Plate and tube settlers are susceptible to rapid changes in water temperature and have limitations in treating high turbidity and algae. The tube openings in tube settlers can become blocked with algae and solids creating short circuiting and deterioration in clarifier performance. Plate and tube clarifiers are being replaced with the more advanced and innovative technologies that follow below. Because tube settlers have been used effectively for SWRO, they are included in the feasibility analysis as a "baseline" alternative of accepted practice.

Pulsator and SuperPulsator Clarification and Filtration:
Pulsator and SuperPulsator clarifiers are solids contact, moderate rate, up-flow, sludge blanket technology that are well proven in water treatment. The coagulated water from rapid mix is introduced uniformly into the bottom of the clarifier through an inlet channel and lateral distribution pipes. A portion of the raw coagulated water is lifted in a vacuum chamber using vacuum blowers, and periodically released rapidly. The energy imparted by releasing this water quickly through the distribution system causes mixing and flocculation within the sludge blanket. The sludge blanket, which is uniformly mixed by the imparted energy, develops to a depth of 9.0 feet defined by the elevation of a sludge concentrator hopper wall. The clarification zone extends about 6.0 feet above the sludge blanket surface. Clarified water is collected through uniformly spaced launders or pipes with submerged orifices. Sludge from the sludge blanket flows naturally into the sludge concentrator hoppers, where it becomes more concentrated. Sludge is extracted hydraulically from the sludge concentrator hoppers through piping and valving that is air actuated.

Pulsator clarifiers operate at a SLR of 1.0 gpm/sf. SuperPulsators have inclined plates (60 degree) spaced about 1 foot apart within the bottom of the clarification zone and extending into the sludge blanket and can operate at SLRs up to 2.5 gpm/sf. SuperPulsators can also be fitted with tubes placed above the inclined plates to further increase surface loading rate to as high as 4.0 gpm/sf. Pulsator and SuperPulsators cover a range of process surface loading rates similar to Accelators, plate and tube settlers and up to the low end of DAF.

Pulsator and SuperPulsator clarifiers can treat high turbidities, low to moderate algae concentrations, and high color and organics. Clarified turbidity may be slightly higher than for conventional sedimentation and similar to that obtained with plate or tube settlers, but low turbidities are still achieved through filtration. Residuals concentrations are in the range of 0.1 to 0.5 percent solids. Like conventional sedimentation, plate or tube settlers, and Accelators, sludge blanket clarifiers are susceptible to rapid variations in water temperature. Pulsator and SuperPulsator clarifiers are being replaced with the more advanced and innovative technologies that follow below. For these reasons, Pulsator and SuperPulsator clarifiers were not considered further, although they should be considered equal or superior to plate or tube settlers in future applications in treatment of seawater.

Dissolved Air Flotation and Filtration:
Dissolved air flotation (DAF) is a high rate process using micro-bubbles to float the coagulated and flocculated particles to the surface of the clarifier. DAF requires a typical two-stage rapid mix and two stages of flocculation sized for about 15 minutes of total detention time ahead of the flotation unit. A portion (approximately 10 percent) of clarified water is drawn off and passed thorough an air saturation system where it is supersaturated with air under high pressure. The supersaturated water under high pressure is released through proprietary valves or nozzles into the water leaving the flocculation stage. The sudden release of pressure causes the formation of micro-bubbles (approximately 60 microns in size). The bubbles quickly attach to preformed floc and carry it to the surface of the DAF basin where it forms a thick floating layer. The clarified water is collected in headers located in the bottom of the DAF basin.

DAF can operate at surface loading rates of from 4.0 to 6.0 gpm/sf or up to 13 times the SLR of conventional sedimentation; up to 3 times that of tube settlers; and about 2 times that of Superpulsators. If ozonation is used between DAF and filtration, the DAF can be operated at up to 8.0 gpm/sf SLR without impairing filtration performance, because the ozone provides microflocculation of turbidity and particles, thus making them more filterable.

DAF can achieve very low clarifier effluent turbidities of <0.5 NTU. DAF can achieve a high level of performance even without using a polymer, which can be an advantage in pre-treatment ahead of RO. DAF is not susceptible to thermal variation and has demonstrated significant advantages in treating very cold (dense) water, thus DAF may be very effective in treating high density seawater. Another important advantage of DAF clarification is that it has proven to be the premier clarifier for treating large concentrations of algae, which are notoriously difficult to settle. This may be a distinct advantage in treatment of seawater where red tides or algae may be a concern. DAF can easily treat the expected worst-case raw seawater quality.

Another potentially important advantage of DAF, not found with all but one other clarifier, is that it can produce a residual concentration of up to 2 percent solids when mechanical extraction is used.

This sludge concentration is about 4 times the maximum solids concentration achievable with plate, tube, Accelator, or sludge blanket clarifiers. Mechanically extracted DAF residuals can be fed directly to dewatering processes such as belt filter presses or centrifuges without further thickening.

DAF is extremely well proven from pilot tests conducted for large plants as indicated by designs for Boston, MA at 450 mgd and the NY City Croton Water Treatment Plant at 290 mgd. In the case of the Croton Water Treatment Plant, the design incorporates the filtration stage under the DAF which reduces process footprint requirements considerably. When the DAF is located above filtration, the maximum surface loading rate of both the DAF and the filter must be limited to less than 5 gpm/sf. DAF is generally replacing all of the previously mentioned processes: conventional sedimentation, plate and tube settlers, Accelators, and sludge blanket clarifiers. Regular DAF is marketed by both Parkson and Leopold. The stacked DAF is supplied by Parkson under the trade name “Flofilter.”

For the reasons above, DAF clarification is included as the most robust and favorable high-rate clarification technology to be considered in this analysis. The “stacked” DAF is being evaluated to provide the most advantageous configuration for reducing plant footprint.

Another recent innovation in DAF technology is the AquaDaf, a proprietary process marketed in the United States by Infilco Degremont. The AquaDaf is identical to regular DAF or stacked DAF in that the same rapid mix conditions, flocculation times, and air saturation and recycle system are used. However, the AquaDaf has two distinct innovations that allow operation at flotation SLRs of from 12.0 to 16.0 gpm/sf. First the geometry of the DAF portion of the process is rotated 90° such that it is wider than it is long. This results in a complete bubble blanket covering the entire DAF basin. Second, there is a false floor in the bottom of the DAF basin, which has holes of various sizes spaced differently across the length of the tank. These holes optimize the hydrodynamics of the flow through the DAF tank. These two innovations result in a deep bubble blanket, active flotation throughout the entire surface of the tank, and the ability of achieving the higher surface loading rates.

The first United States installation of the AquaDaf is in Lake Deforest, New York, where two units each of 10 mgd capacity are installed and operating. In this installation, baffled flocculation was used instead of mechanical flocculation and the residual extraction is hydraulic and not mechanical. It appears that this new type of DAF has all of the advantages of regular DAF, plus the added benefit of a smaller footprint due to the increased SLR. Because the AquaDaf’s innovations are much less proven than typical DAF, AquaDaf was not carried forward in the analysis; however, this process could be considered further in the future as the plant is sited, water quality is confirmed, and residuals disposal options are known.

Micro-Sand Enhanced Clarification (Actiflo)

Micro-sand enhanced settling (MES) uses micro-sand of about 100 microns in size to attach to the floc and greatly enhance settling rate. The MES process is a proprietary process marketed under the trade name “Actiflo” by US Filter. One stage of rapid mix with a detention time of about 1.0 minutes for coagulation; a second stage of rapid mix with a detention of about 1.0 minutes for addition of micro-sand and polymer, and one stage of maturation (flocculation) of about 6 minutes, are incorporated within the process ahead of a tube settling clarification stage. The tube settling stage can operate at up to about 25 gpm/sf or about 5 times greater than a stacked DAF process, representing a significant reduction in overall process footprint of the MES process.

The MES process can achieve turbidities of less than or equal to 0.5 NTU with very low filtered turbidities. The MES process is not susceptible to thermal variation because the micro-sand overcomes thermal gradients and may also be advantageous in treating high density seawater. The process is extremely robust and can treat high turbidity excursions very effectively. The MES process can treat algae, but probably not as effectively as DAF for very high algae levels, which is a concern with respect to the possibility of red tides in seawater applications. The MES process cannot be operated without polymer, and the polymer may cause fouling of a downstream RO process.

In large MES units, a hopper and scraper are included under the tube settler for collection of residuals. The residuals composed of coagulated solids and attached sand particles are pumped up to a hydro-cyclone that separates the coagulated solids (residuals) from the micro-sand. The micro-sand is returned into the second stage mixing and is mostly conserved. The coagulated solids residuals stream is discharged at a fairly low concentration of less than 0.1 percent solids.

The MES process is well proven and is displacing some of the previously mentioned processes except DAF. The primary considerations that eliminated the MES process from further consideration are the low residuals solids concentration, the limitation on treatment of high algae, and the possibility that the polymer may have an adverse affect on the RO process. The MES process could be considered further in the future as the plant is sited, water quality is confirmed, and residuals disposal options are known.

Ultrafiltration Using Immersed Membranes (Zenon Zeeweed 500D)

Membrane microfiltration (MF) and ultrafiltration (UF) (low pressure hollow fiber membrane treatment) technology has developed rapidly over the last 5 years, with several manufacturers offering outside-in and inside-out configurations and pressurized and immersed approaches. In an inside-out configuration, the raw and coagulated water enters the lumen (inside) of the hollow fibers and the purified water flows through the membrane to the outside area. In an outside-in configuration, the raw and coagulated water enters the system on the outside of the hollow fibers and the purified water flows through the membrane surface and into the lumen. Pressurized UF systems use pressure to force the water through the membrane surface. In immersed UF systems, the membrane fibers are immersed in the raw or coagulated water and a vacuum is applied to the lumen of the fibers to draw the water through the membrane and into the lumen.

UF membranes provide physical removal of solids, particles, algae; and physical disinfection by removal of pathogens such as *Giardia*, *Cryptosporidium,* and some viruses. Unless a coagulant is used, UF membranes do not remove color or organics. MF and UF have demonstrated effectiveness for providing low silt density indices (SDI) ahead of high pressure membrane process such as nanofiltration (NF) and reverse osmosis (RO), resulting in greater efficiencies of the NF and RO processes. There is some limited experience for MF and UF in pre-treatment of seawater.

For low turbidity, low solids, low color, low organics, and low coagulant dosage applications, the primary manufacturers are: Infilco Degremont (Aquasource), US Filter (Memcor), Koch, Pall (Microza), Ionics/Norit, Leopold, and Zenon (Zeeweed 1000). Generally, these UF membranes, with the exception of possibly the Pall and Ionics systems, are either used to treat high quality surface water or are used to replace filtration within the clarification and filtration process train and are not applicable to treating this project's assumed worst-case seawater quality.

Several manufacturers have MF or UF systems capable of replacing both clarification and filtration with the single MF or UF process. In fact, MF and UF systems are quickly and effectively competing with clarification and filtration processes. These manufacturers are: Pall (Microza MF), Koch, US Filter Memcor (CMFS), Ionics/Norit, and Zenon (Zeeweed 500D). All membranes are by no means equal. There are significant differences in configuration, operation, robustness, and experience within this group of UF systems with respect to treating high levels of turbidity, algae, color, and organics (enhanced coagulation). Generally, the inside-out pressurized systems are less robust and more easily fouled by higher solids from either natural or coagulated solids. Koch, for example, has significant limitations for turbidity and coagulant dosage. Pall and Ionics/Norit UFs, both of which are pressurized UFs, can treat higher solids than Koch, but still have limitations for turbidity and coagulant dosage, and are not well proven in enhanced coagulation. Generally, immersed MF or UF systems may be less prone to fouling and more able to treat higher solids from enhanced coagulation, than pressurized UF systems. Both the US Filter Memcor CMFS and the Zenon Zeeweed 500D are immersed membrane UF systems. The Zeeweed 500D immersed UF system evolved from immersed membrane treatment of activated sludge in wastewater treatment, an extremely high solids and microbiological environment. The Zeeweed membrane is a "supported" membrane where the functional membrane surface has been applied as a coating to a very strong fiber structure that forms the hollow fiber. The Memcor CMFS UF evolved from the Memcor pressurized UF where the pressure housing was removed and the fiber bundle, still constrained by a mesh, is immersed. The Memcor membrane is an extruded "unsupported" hollow fiber that is not as strong as a supported membrane. The Memcor CMFS has solids limitations due primarily to the constrained nature of the fiber bundle and the system is much less proven than the Zenon UF.

The Zeeweed 500D immersed UF system is an extremely robust treatment process capable of treating extremely high turbidity, high algae concentrations, high color and organics, with high coagulant dosages (enhanced coagulation), and at the same time high dosages of powdered activated carbon. At this time, no other UF membrane system can match the performance levels of the Zenon Zeeweed 500D UF.

The Zeeweed 500D UF operates at fluxes between 25 to 35 gfd and recoveries of from 90 to 95 percent depending on water temperature. The residuals stream from the process is generally less than 0.1 percent solids and will require thickening prior to dewatering. Thermal variation will not have a significant effect on the UF process. Potential red tides or algae should be treatable. Zenon piloted the Zeeweed 500B in Port Hueneme, California, where red tides were experienced. The red tide reduced permeability quickly in this study, but project constraints imposed by the client did not allow coagulation. It is reasonable to assume that if coagulation had been used, the impact of the red tide may have been greatly reduced. Based on other experience with the Zeeweed 500D UF and limitations of all other UF membrane systems, it is reasonable to also assume that the Zeeweed 500D UF may be the only UF capable of treating severe red tides as a stand-alone process.

Because of the high degree of benefit that can be realized and its proven treatment robustness, the Zenon Zeeweed 500D UF was selected for analysis for comparison to the conventional pre-treatment processes using tube settler clarification and filtration and DAF and filtration. Other approaches using other types of UF as a “filtration” replacement may be considered in the future when the plant is sited, water quality is confirmed, and residuals disposal options are known.

Bank Filtration
Bank filtration without pre-treatment was included in this feasibility study to capture the potential least cost process alternative even with assumed worst-case water quality. A bank infiltration system will be conceptualized that will provide “physical” pre-treatment ahead of the RO.

Blending of Seawater with Brackish Groundwater
Seawater in the Corpus Christi, Texas, area has highly variable total dissolved solids (salinity), that ranges between 25,000 mg/l TDS to as high as 60,000 mg/l TDS. Recognizing that it is not economical to desalinate seawater of much higher than about 35,000 mg/l TDS, this level of salinity was set as the maximum design basis for the conceptual feasibility study. When the TDS is less than 35,000 mg/l, the raw seawater will not be diluted with brackish groundwater. When the raw seawater TDS is greater than 35,000 mg/l TDS, brackish groundwater with an assumed worst-case TDS of 5,000 mg/l will be used to dilute the raw seawater back down to the design level of 35,000 mg/l TDS. Since the site and groundwater quality are unknown at this time, the assumption was made that the groundwater could require pre-treatment because of constituents such as iron. Thus, brackish water blending scenarios do not require resizing the RO, or the pre-treatment process. A discussion will be included in the report concerning the potential benefit on operations cost, while treating seawater with TDS of less than 35,000 mg/l part of the year.

3.1.2 Pre-Treatment Train Option 1 – Conventional Pre-Treatment With Tube Settling and Gravity Filtration

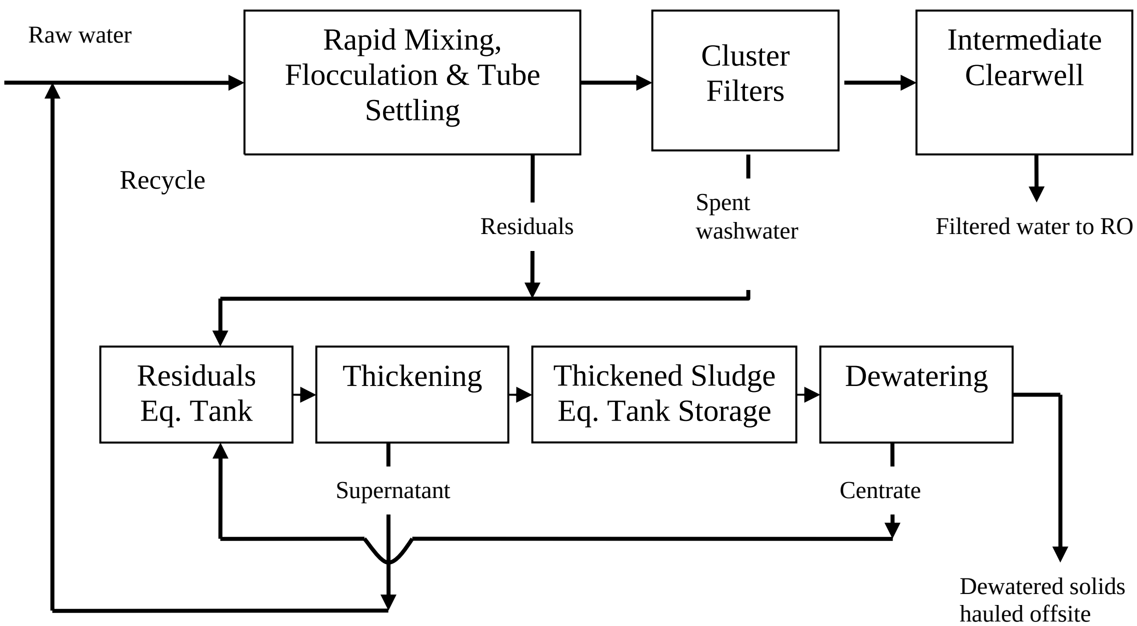
For the purposes of this analysis, clarification via tube settling followed by gravity filtration is considered the “baseline” approach for RO pre-treatment. This section will provide the preliminary design basis for the tube settler/filtration option. Conceptual layout drawings, hydraulic and solids balances, process flow diagram, and manufacturer’s drawings are also presented.

Design Criteria and Description of Pre-Treatment Option 1

Pre-Treatment Option 1 is presented schematically in *Figure 4-3.1.2-1* below.

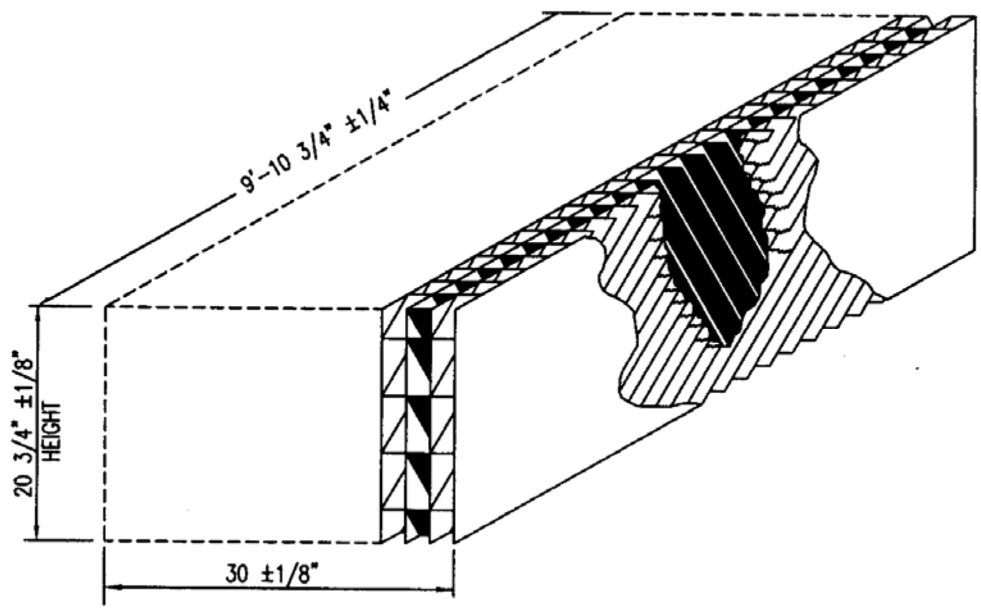
After chemical pre-treatment via rapid mixing and flocculation, settling of the combined raw water and plant recycle water would occur in the tube settlers. The settled water would flow to the cluster filters, and filtered water would then be stored in an intermediate clearwell. This clearwell would also provide supplemental backwash water storage for the cluster filters, if needed. Other features of the Option 1 conceptual design include residuals equalization, clarifier/thickeners for residuals thickening followed by centrifugation for dewatering. The dewatered sludge would be hauled offsite for final disposal. The supernatant from the thickening process would be reclaimed for recycling to the plant head works, in compliance with the filter backwash rule. The centrate from the dewatering process would flow to the residuals equalization tank. A brief description of the Option 1 process components is as follows.

Figure 4-3.1.2-1 Pre-Treatment Option 1



Tube Settlers. The practice of shallow depth sedimentation has been has been employed in water and wastewater treatment for over 40 years. Application of tube settling is based on the principle of using sloped surfaces which allow higher loading rates than other clarifiers due to the effect of overlapping surfaces. Hydraulic loading rates of between 2 and 3 gpm/sf are achievable. Tube settlers increase the effective settling surface within a clarifier based on the geometry (angle) of the tubes themselves. Tube settlers are composed of bundles of tubes assembled into a single module. Modules are then installed in the settling basins. *Figure 4-3.1.2-2* shows a tube settler module as manufactured by US Filter Microfloc. The Microfloc tube settler design and design parameters were used to prepare this analysis, although other vendors are available.

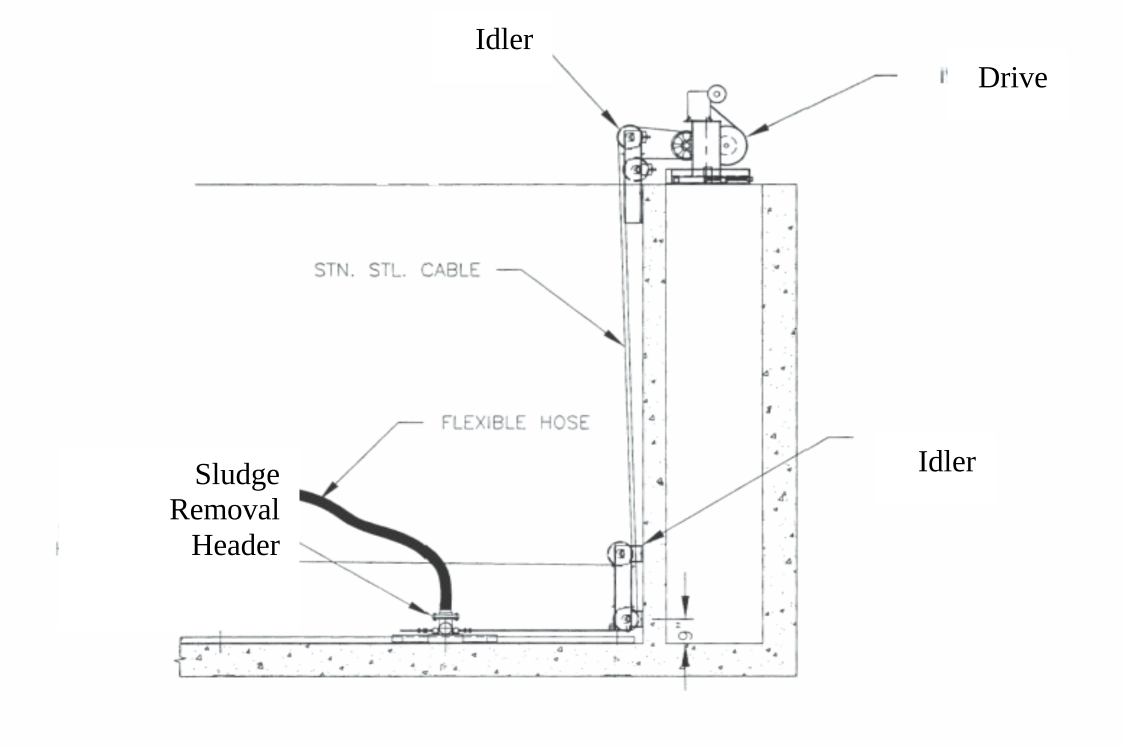
Figure 4-3.1.2-2   Typical Tube Settler Module (US Filter Microfloc)



The optimum angle of the tubes (as measured from the horizontal) ranges from 45 to 60° depending on the specific manufacturer. Plugging of the tubes is less likely with a steeper angle. The Microfloc tube settlers are at 60° from the horizontal. As water flows upwards through tube modules, solids settle on the tube sidewalls. Here, the solids accumulate and the increase in sludge mass causes the sludge to slide off the tubes. A continuous counter-current flow is eventually established. The settled sludge is collected in the bottom of the clarifier and removed.

The removal of sludge from under the tubes is necessary to avoid sludge carryover. Option 1 is based on the use of a Sludge Sucker® traveling continuous sludge extraction system as provided by General Filter. This system expels sludge by using available head (water level) over the extraction point. The suction headers travel the length of the basin floor at a specified rate. The traveling suction header is controlled through a drive mechanisms mounted on top of the basin. *Figure 4-3.1.2-3* shows a cross section of a typical sludge sucker assembly.

Figure 4-3.1.2-3   Typical General Filter Sludge Sucker Installation



Each tube settling basin would be equipped with sludge extraction equipment. The sludge will be stored in a residuals equalization tank, along with filter residuals (filter-to-waste and spent washwater), prior to thickening. Equalization is necessary to allow for steady operation of the clarifier/thickeners.

Other features of the tube settling systems include rapid mixing followed by flocculation for chemical pre-treatment and particle destabilization, as would be provided with other conventional clarification technologies. A two-stage rapid mixing system will be provided, which will have a minimum of 30 seconds of detention time per stage with a velocity gradient between 600 and 1,000 sec^{-1}. Rapid mix inlet piping will be 30 inches in diameter, resulting in a flow velocity of approximately 4 ft/sec at maximum flow. Coagulant and polymer will be injected into the rapid mix basin. Ferric chloride was assumed as the coagulant for the purposes of this report. Following rapid mixing, a two-stage flocculation basin will be provided with 15 minutes of detention time per stage. Finally, the flocculated water will enter into a low velocity quiescent zone prior to entering the tube clarification area. This is to minimize short circuiting and velocity gradients that can upset the clarification process. The preliminary design criteria for the rapid mixing, flocculation, and tube settlers are presented in *Table 4-3.1.2-1*.

Table 4-3.1.2-1 Rapid Mix, Flocculation, and Tube Settling Preliminary Design Criteria*

Total Capacity	mgd	±55
	gpm	38,194
	No. Trains	4
	No. Basins per Train	3
	Total No. Tube Settler Basins	12
Rapid Mix Basins	L (ft)	8
	W (ft)	8
	D (ft)	10
	HRT per stage (secs)	30
	No. stages	2
	No. per train	2
	Mixing velocity gradient (sec^{-1})	600-1000
Flocculation Basins	L (ft)	25
	W (ft)	25
	D (ft)	10
	HRT (mins each stage)	14.7
	No. stages	2
	Total HRT in flocculation (mins)	29.4
	Mixing velocity gradient (sec^{-1})	50-100
Tube Settler Basin	Basin width (ft)	25
	Basin length, tube area (ft)	60
	Basin length total (ft)	66
	Depth of water under tubes (ft)	10
	Height of tube module (ft)	1.75
	Depth of water above tubes (ft)	3
	Angle from horizontal (degrees)	60
	Capacity per basin (gpm)	3183
	Tube SLR(gpm/sf) N	2.12
	N-1	2.31
	Size of tube modules, L x W (ft)	10 x 2.5
	No. Tube modules per basin	60
	Total No. of tube modules	720
Sludge Extraction Equipment	Sludge pipe diameter (in)	4
	Header pipe travel velocity (ft/min)	4 - 12
	Length of travel (ft)	60

* Preliminary design of tube settlers based on US Filter Microfloc and General Filter Sludge Suckers

Figures 4-3.1.2-4 and *4-3.1.2-5* show a plan view and cross-sectional view, respectively, of a single tube settling basin as proposed for Option 1.

Cluster Filters. Following flocculation and tube settling, the settled water would flow to a gravity filter system. Settled water will be conveyed to the filters through a common launder that will be installed at the end of the tube settler basin. Slide gates will be installed between the tube settler basins and the cluster filters for isolation. Four groups of filters are proposed, to coincide with four groups of tube settler basins. Thus, each train will operate independently for maximum reliability.

The filters would be the final process for RO pre-treatment. The filters included with Option 1 for use with the tube settlers are Infilco Degremont Greenleaf Filter Control systems. These are referred to as cluster filters, and they work much the same way that conventional gravity filters work except that filter control is based on siphoning control technology, as opposed to valve control. Valve control can lead to negative pressure and air binding in the filter media, when the headloss exceeds the media submergence. This cannot happen with the Greenleaf system because the filtered water effluent weir is located at an elevation above the filter media. Also, the orientation of the filters around a central inlet well results in reduction of overall footprint, typically two-thirds of what would normally be required for conventional filters. *Figure 4-3.1.2-6* shows a depiction of the Infilco Degremont Greenleaf Filter Control system.

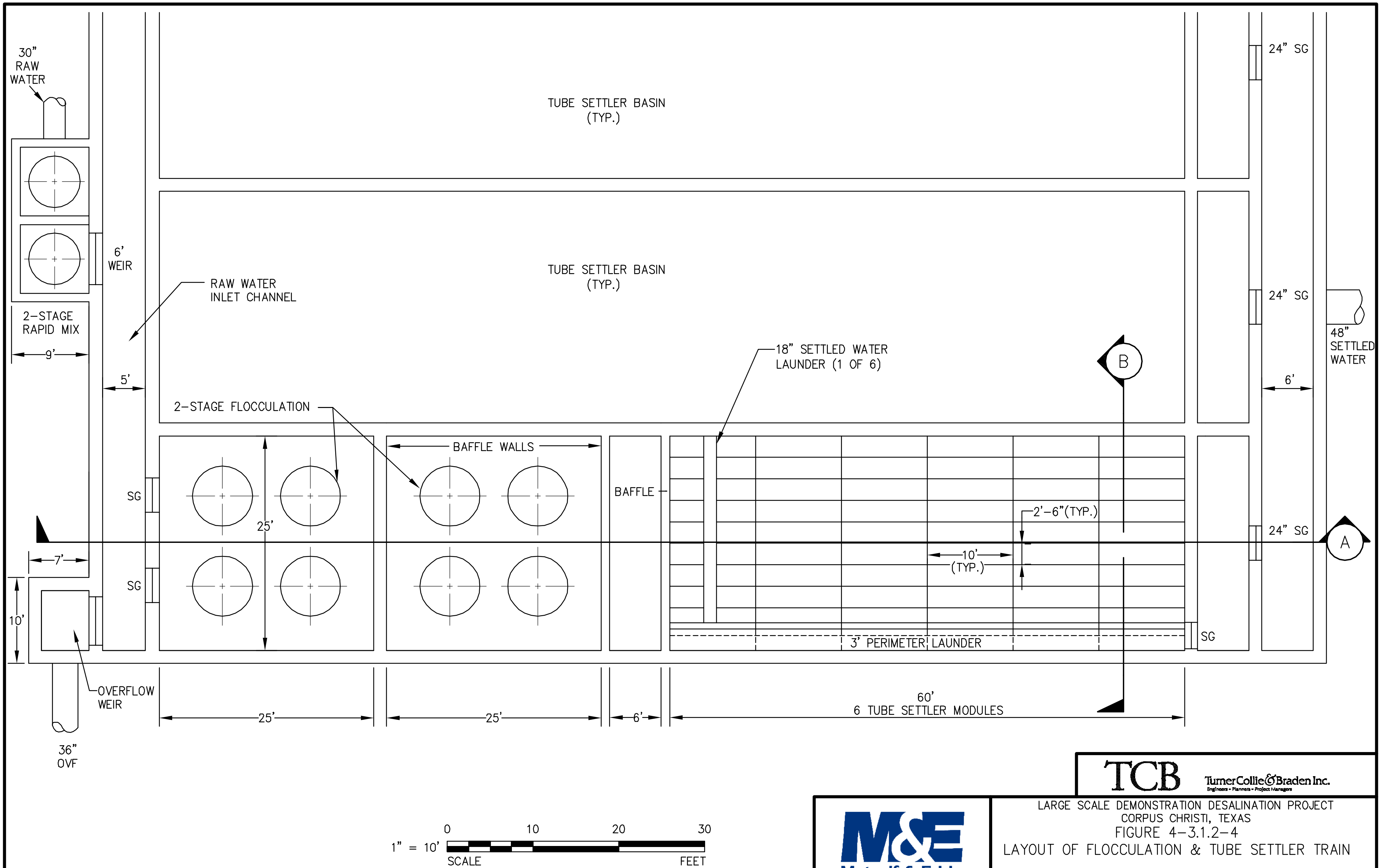


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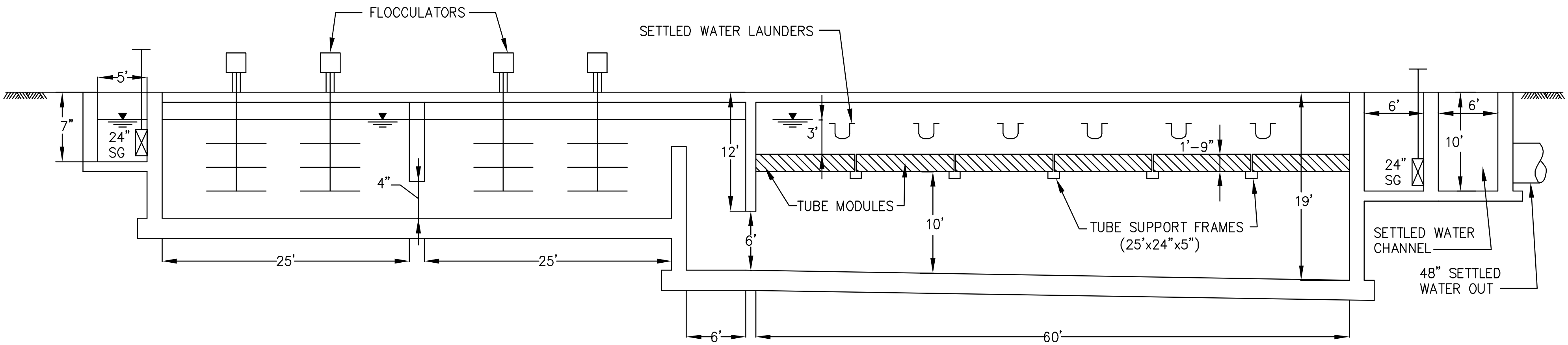
FIGURE 4-3.1.2-4
LAYOUT OF FLOCCULATION & TUBE SETTLER TRAIN

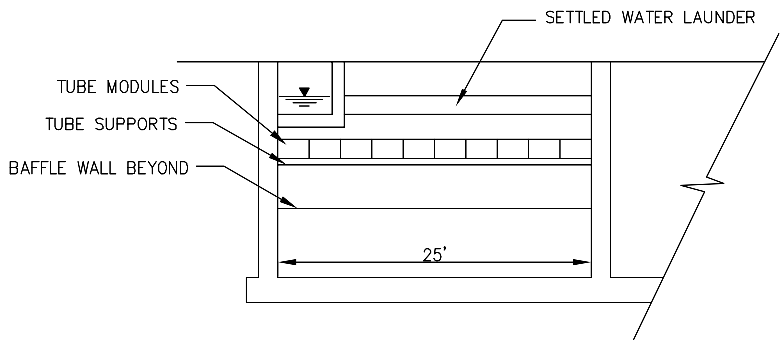
SCALE: 1"=10' | 3/17/04 | W. BALETSA



LONGITUDINAL SECTION A–A

SCALE: 1"=10'

NOTE: SLUDGE EXTRACTION EQUIPMENT NOT SHOWN



TRANSVERSE SECTION B–B

SCALE: 1"=10'

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FIGURE 4–3.1.2–5

CROSS SECTION OF FLOCCULATION AND TUBE SETTLER BASIN

SCALE:	1"=10'	3/17/04	W. BALETSA

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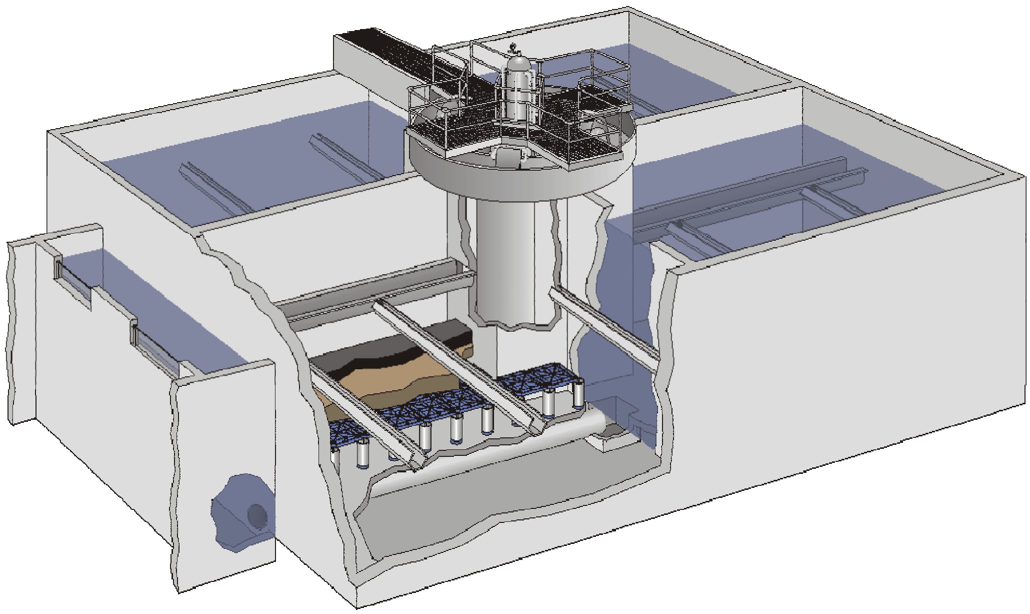
Figure 4-3.1.2-6 Infilco Degremont Greenleaf Filter Control System Cluster Filter



Flow control to the filters is handled by weirs allowing for passive flow distribution. When one filter is off line for backwashing, the inlet siphon valve is vented and flow to that filter ceases while the flow is equally and simultaneously divided among the remaining filters. Filtered water from the effluent weir chamber is used to backwash individual cells while the other three filters continue to operate. When a filter cell requires backwashing, the inlet siphon to that particular cell is vented, which stops the flow to the cell. The water level in the cell drops to match the water level of the filtered water overflow, but because the other filters continue to operate, backwashing is initiated by establishing a backwash siphon using the head off the filtered water overflow weir. Thus, Greenleaf filters do not generally require the use of backwash pumps. However, it is often advisable to install a backwashing pumping system as a standby, in the event that supplemental backwashing is required at times.

The filtered water will be stored in the intermediate clearwell, providing for operating storage for the pre-treatment process as well as supply for the RO process. Spent washwater (SWW) from the cluster filters will be collected in the residuals equalization tank, along with settled sludge from the tube settlers, for thickening. At the end of the backwash cycle, the filters will be operated in a filter-to-waste (FTW) mode. This practice isolates the filter ripening process from filtered water production. Washing, therefore, prevents the high concentration of particles, turbidity, cysts, etc., that often remain at the end of a backwash cycle, from entering the filtered water. The FTW water will also be collected in the residuals equalization tank. For the purposes of the solids balance model, FTW duration of 10 minutes was assumed. As an option, the FTW may be recycled directly to the head of the plant, although this is considered a final design detail. *Table 4-3.1.2-2* lists the preliminary design parameters for the cluster filters. *Figure 4-3.1.2-7* presents a plan view layout of a cluster filter train. One train represents 4 of 16 total filters. Although the Greenleaf filter control system is proprietary, other similar clusters filters are available from other equipment manufacturers.

Table 4-3.1.2-2 Cluster Filter Preliminary Design Criteria*

Filters	
Capacity of cluster filters (mgd)	55
No. trains	4
No. filters cells per train	4
Total No. filters	16
Filter train design flow (gpm)	9,549
Unit cell design flow (gpm)	2,387
Filter HLR with all in service (gpm/sf)	3.82
Filter HLR with 1 filter cell out of service (gpm/sf)	4.07
Filter HLR with 1 entire train out of service (gpm/sf)	5.09
Cell dimensions (ft x ft)	25 x 25
Filter cell area (ft^2, ea)	625
Media Type	Mixed
anthracite	20" (ES = 1.0 mm, UC = 1.7)
sand	7" (ES = 0.45 mm, UC = 1.5)
limonite	3" (ES = 0.26 mm, UC = 1.3)
coarse garnet	4" (ES = 1.0 mm, UC = 1.7)
Underdrain	Monoflor "HD" false bottom with polypropylene nozzles
Supplemental Backwash Pumps Type	Horizontal split case
Number (N+1)	3
BW rate (gpm/sf)	15
Anticipated BW duration	10 -20 mins
Anticipated filter-to-waste duration	10 mins
Flow (gpm)	9,004
Backwash Air Scour Blowers Type	PD
Number (N+1)	2
BW air requirements (SCFM/sf)	3
Flow (SCFM)	1,875
Vacuum Pumps Number (N+1)	2

* Preliminary design criteria are Infilco Degremont Greenleaf Filter Control system.
ES = effective size. UC = uniformity coefficient.

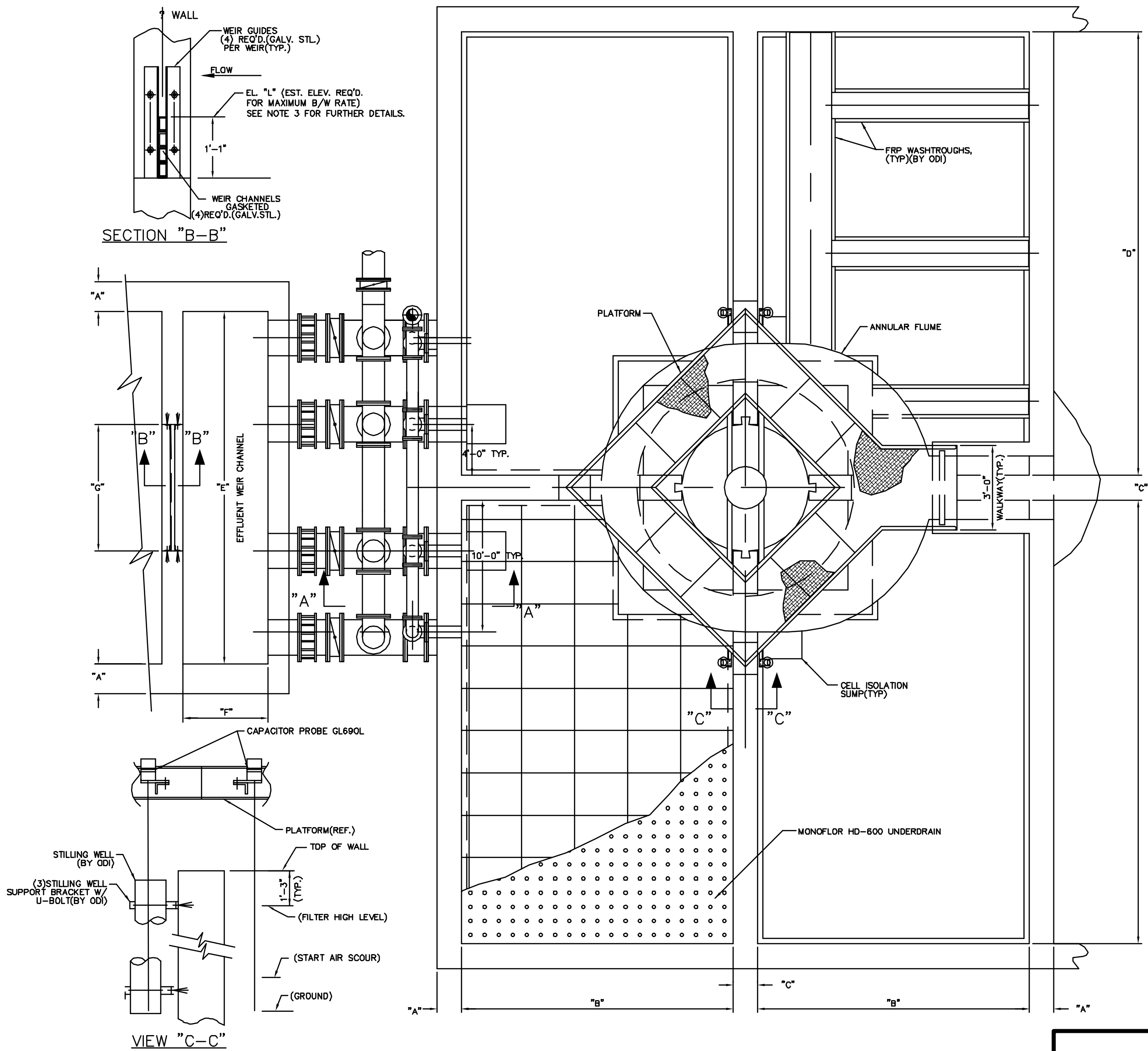


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FIGURE 4-3.1.2-7
GREENLEAF CLUSTER FILTER PLAN VIEW

SCALE:	NONE	3/16/04	C. BENZIGER

Clarifier/Thickeners. The tube settler residuals and the filter residuals (spent washwater and filter to wastewater) will be collected in a residuals equalization tank, which will serve the thickening process. Thickening is necessary to increase the percent solids of the residuals, so that centrifuge dewatering can occur.

The clarifier/thickener included in all pre-treatment options is the Infilco Degremont DensaDeg process. The DensaDeg clarifier is a high-rate solids contact clarifier that combines flocculation, internal and external solids recirculation, and tube settling in one compact process. Because this is a high-rate process, it is particularly effective where site constraints are an issue. For thickening, the process requires coagulant and polymer. According to the equipment supplier, typical polymer doses are 0.5 to 1 mg/l and coagulant doses can range from 30 to 60 mg/l.

The DensaDeg system is a 3-stage process, as depicted in *Figure 4-3.1.2-8*. In the first stage, rapid mixing is used to disperse coagulant and to blend the feed flow with the recirculated sludge. Following rapid mixing, the flow enters the reactor chamber, where the combined influent then flows up through a draft tube and a turbine mixer initiates flocculation. Following the reactor chamber, the thickener/clarifier chamber settles the sludge. A slow moving rake is installed in the zone, and the solids continue to thicken. A portion of the thickened sludge is continuously recycled to the rapid mix stage. Thickened sludge is routinely discharged ("blown down") from the bottom of the thickener. The thickened sludge will be collected in a thickened sludge equalization tank. In the clarification zone, supernatant flows upward through settling tubes. The supernatant water is collected in effluent launders located above the tubes. The supernatant will be recycled to the headworks in compliance with the filter backwash rule.

Table 4-3.1.2-3 summarizes the DensaDeg clarifier/thickener design criteria. Sizing of the DensaDeg clarifiers was based on projections of solids generation. The solids balance model will be discussed in subsequent paragraphs of this section. *Figure 4-3.1.2-9* and *Figure 4-3.1.2-10* show a cross section view and plan view, respectively, of the DensaDeg units selected for this option.

Dewatering. Centrifuge dewatering is proposed as the final residuals handling step. Centrifuges offer an effective, minimal-maintenance solution for solids dewatering. Minimal operator attention is generally required for centrifuges.

Centrifuges consist primarily of a case, bowl, conveyor, motor/backdrive and base. The case serves as a guard and complete enclosure for the rotating assembly, as well as contains and directs the cake solids and effluent as they are discharged from the rotating assembly. The feed slurry (thickened sludge) will be pumped to the centrifuge systems by thickened sludge pumps, located adjacent to the thickened sludge equalization tank. The thickened sludge will be introduced to the centrifuge feed distribution chamber. The feed distribution chamber gradually accelerates the slurry to the speed of the bowl before introducing the slurry. Gravitational forces cause the solids and liquid to separate. The solids migrate against the bowl wall, while the clarified liquid (the centrate) moves to the adjustable overflow weir. The conveyor turns at a slightly different speed and conveys the solids to the inclined beach where it discharges. Optimal liquid/solid separation can be achieved by adjusting the conveyor speed and depth of the liquid in the bowl.

Figure 4-3.1.2-8 General Arrangement of Infilco Degremont DensaDeg Clarifier/Thickener

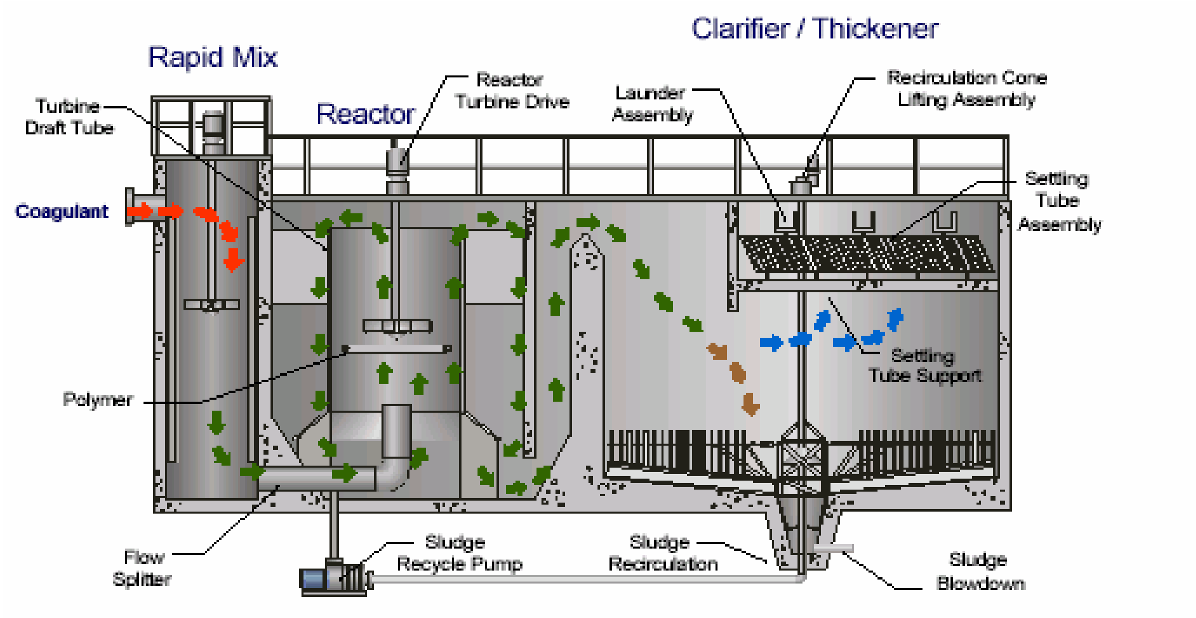

Table 4-3.1.2-3 Option 1 – Residuals Equalization and DensaDeg Clarifier/Thickener Preliminary Design Criteria*

Residuals Equalization Tank Volume (gallons)	440,000	Sized for 3 hours of storage (2 filter washes and FTW plus 180 mins of tube settler sludge flow)
Eq. Tank Volume L x W x SWD (ft)	70 x 70 x 12	
No. of Residuals transfer pumps	3	2 duty + 1 standby
Capacity of Residuals transfer pumps (gpm)	1,300	Dry pit submersible
Total DensaDeg Design Flow* (gpm)	2,500	
Solids Concentration in feed flow (mg/l)	700 - 710	
Lbs/day solids in feed flow (to DensaDeg)	22,000	
Assumed percent solids in DD Underflow (%)	4	
Design Rise Rate (gpm/sf)	7.1	6-8 is typical
Polymer dose (mg/l)	0.5 - 1.0	Typical range
Coagulant (mg/l)	30 to 60	Typical range
No. Units	3	2 duty + 1 standby
Design flow per unit (gpm)	1,284	
Tube Settling Area SF (ea)	177	
Total Length x width (ft)	(41 x 56)	
Thickened Sludge Volume (gals/day)	64,000	(assuming 4% solids)

* Preliminary design basis is Infilco Degremont DensaDeg High Rate Clarifier/Thickener.

NOTES:
1. SEE DRAWING -001 FOR PLAN VIEW.

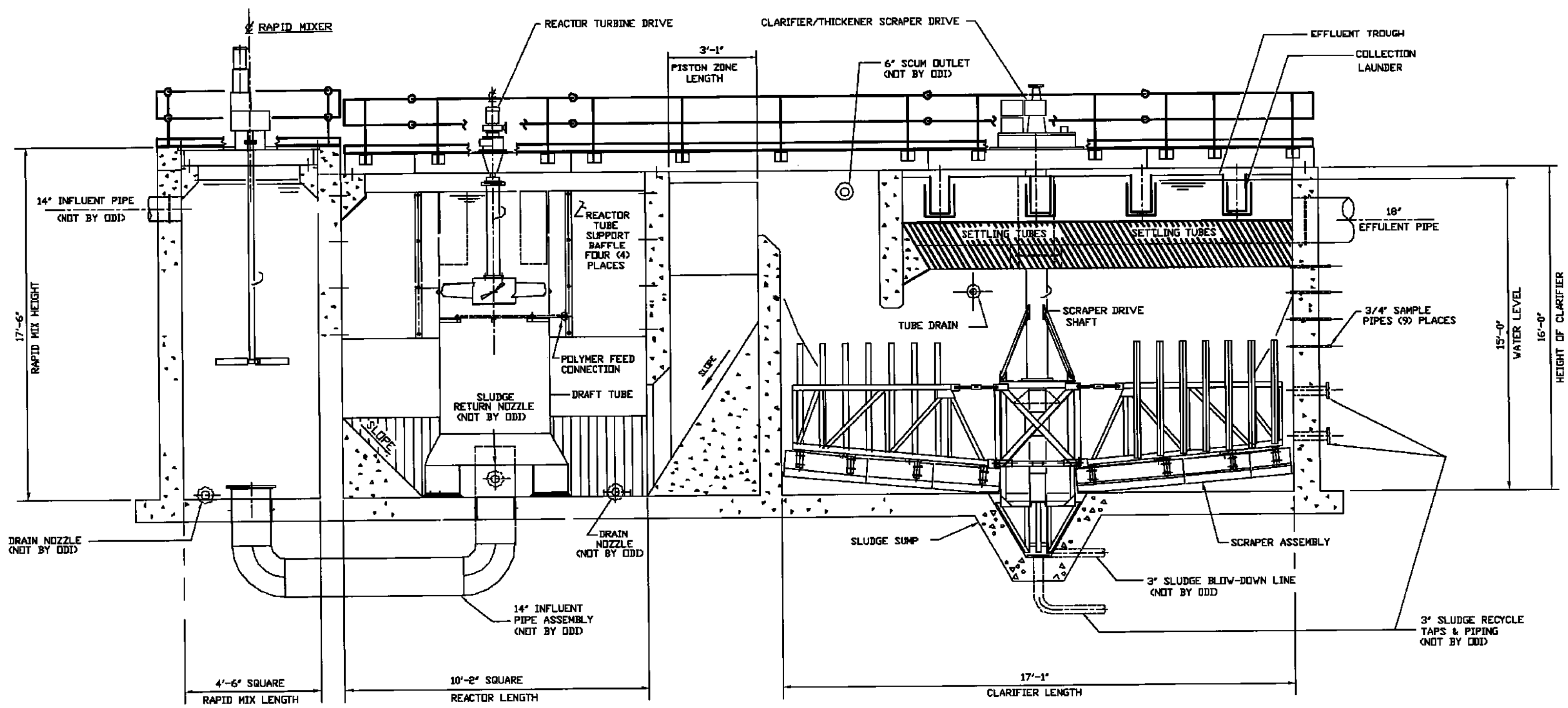

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FIGURE 4-3.1.2-9
CROSS-SECTION OF INFILCO
DEGREMONT DENSADEG CLARIFIER/THICKENER

SCALE:	NONE	3/17/04	C. BENZIGER

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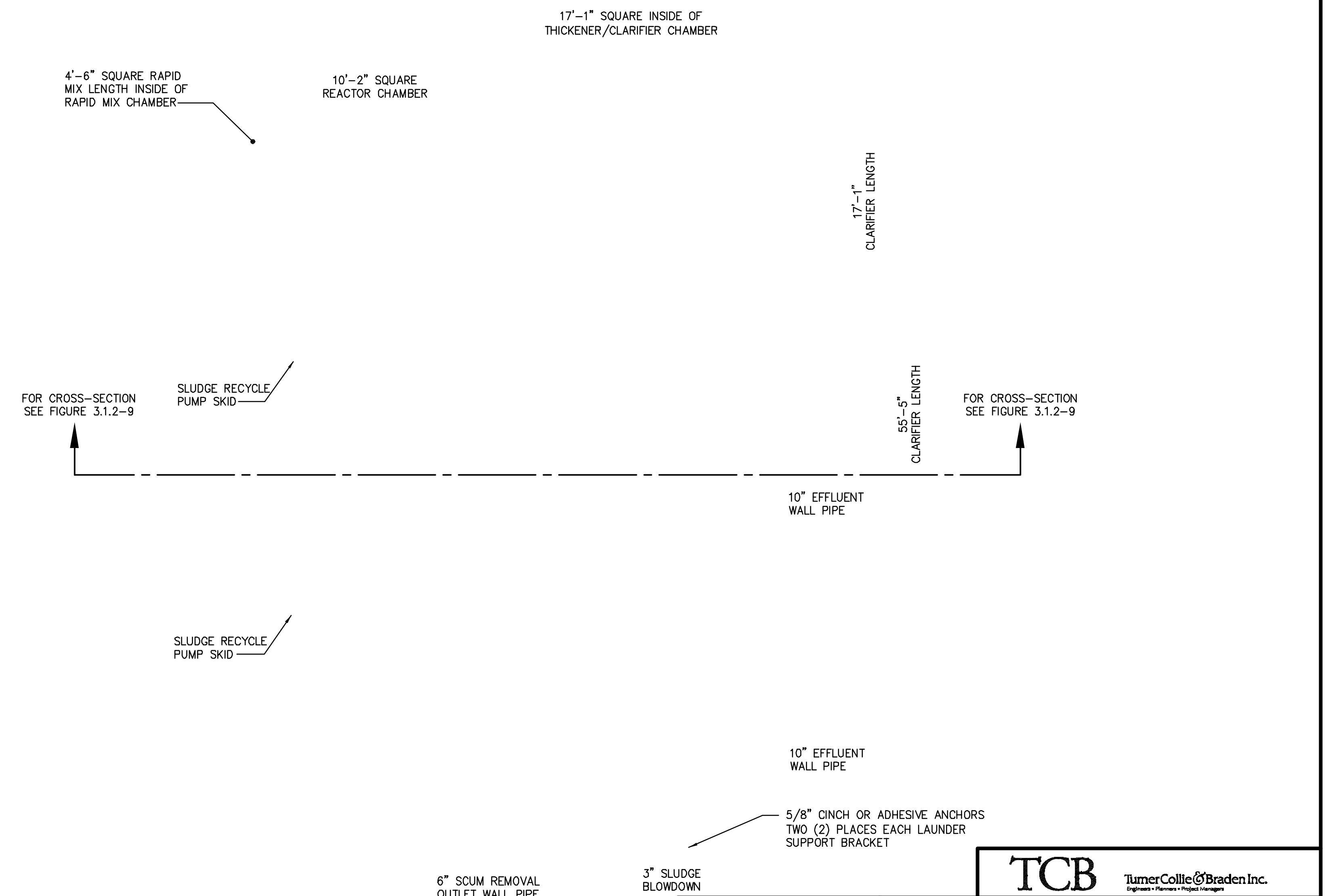

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FIGURE 4-3.1.2-10

PLAN VIEW OF INFILCO DEGREMONT DENSADEG CLARIFIER/THICKENER

SCALE:	NONE	3/17/04	C. BENZIGER

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The centrate will be recovered and pumped to the residuals equalization tank for recycling. The dewatered solids will be contained onsite until the sludge can be hauled offsite for final disposal. It is generally possible to achieve a dewatered solids concentration of between 15 and 25 percent via centrifugation. The degree of cake dryness is a function of raw water turbidity. The solids balance model assumes 17 percent cake dryness. The Option 1 centrifuge dewatering system preliminary design parameters are shown in *Table 4-3.1.2-4*. The preliminary design is based on Andritz Solid Bowl Decanter Centrifuge technology.

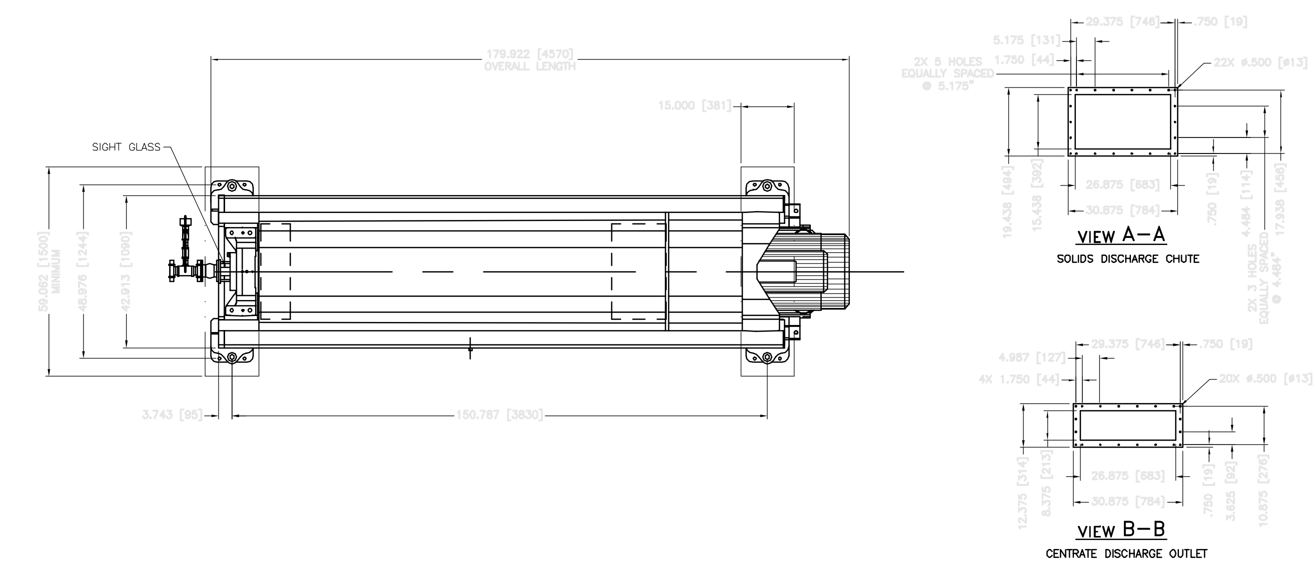
Table 4-3.1.2-4 Thickened Sludge Equalization and Centrifuge Preliminary Design Criteria*

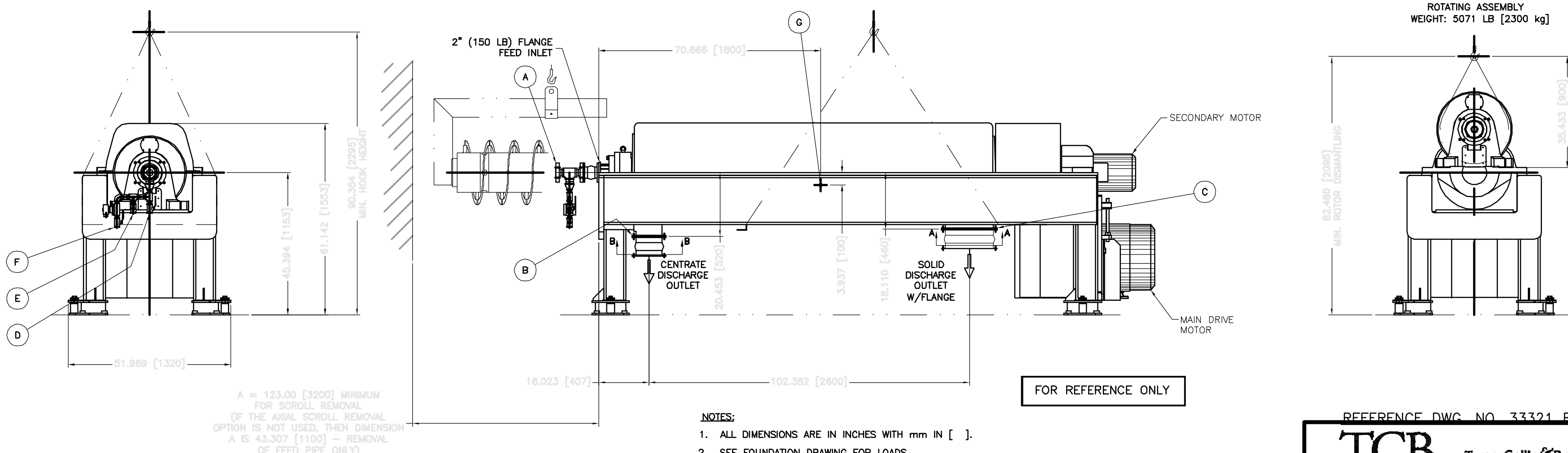
Thickened Sludge Equalization Tank (gallons)	80,000	Sized for 1.3 days of worth of thickened sludge storage
Eq. Tank Volume L x W x SWD (ft)	30 x 30 x 12	
No. of thickened sludge transfer pumps	3	2 duty + 1 standby
Capacity of thickened sludge transfer pumps (gpm)	100	Rotary lobe
Total Centrifuge Design Flow (gpm)	180	
Anticipated Solids Conc. in feed flow (%)	4	
Total lbs/day	21,000	
Lbs/week	147,000	
Gallons per week	440,000	
Production days per week	7	
Hours of dewatering per day	6	
No. of Centrifuges	3	2 duty + 1 standby
No. of operating centrifuges	2	
GPM total	173	
GPM per unit	87	
Lbs/hr per unit	1,750	
Anticipated polymer dose (active lbs/dry ton solids)	4 - 10	Inversely proportional to cake dryness
Anticipated cake dryness (%TS)	15 - 25	Function of raw water turbidity
Diameter (in)	20.5	Model D5LL
Operating Speed (rpm)	3,200	
Force (G)	2,976	
Overall Length (in)	180	
Overall Width (in)	52	
Overall Height (in)	62	

* Preliminary design basis is Andritz Model D5LL Decanter Centrifuge.

Figure 4-3.1.2-11 shows an illustration of the centrifuge model selected for this application. Centrifuges are a non-proprietary technology, and many other vendors are available.

PIPING CONNECTIONS		
PORT	SIZE	DESCRIPTION
A	2"–150 LB ANSI FLANGE	FEED INLET
B	RECTANGULAR 12–3/8 X 30–7/8	CENTRATE DISCHARGE
C	RECTANGULAR 19–1/2 X 30–7/8	SOLID DISCHARGE
D	1" NPT	SLUDGE SAMPLE
E	1" NPT	POLYMER CONNECTION
F	1" NPT	WASHWATER CONNECTION
G	3/4"	BASE FRAME WASHWATER CONN.





FOR REFERENCE ONLY

NOTES:

1. ALL DIMENSIONS ARE IN INCHES WITH mm IN [ ].
2. SEE FOUNDATION DRAWING FOR LOADS.
3. DRY WEIGHT OF MACHINE: 14471 LB [6700 KG]
4. SCROLL WEIGHT: 1543 LB [700 kg]

REFERENCE DWG NO. 33321 REV 6

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FIGURE 4–3.1.2–11
ANDRITZ CENTRIFUGE

SCALE: NONE	3/17/04	W. BALETSA	

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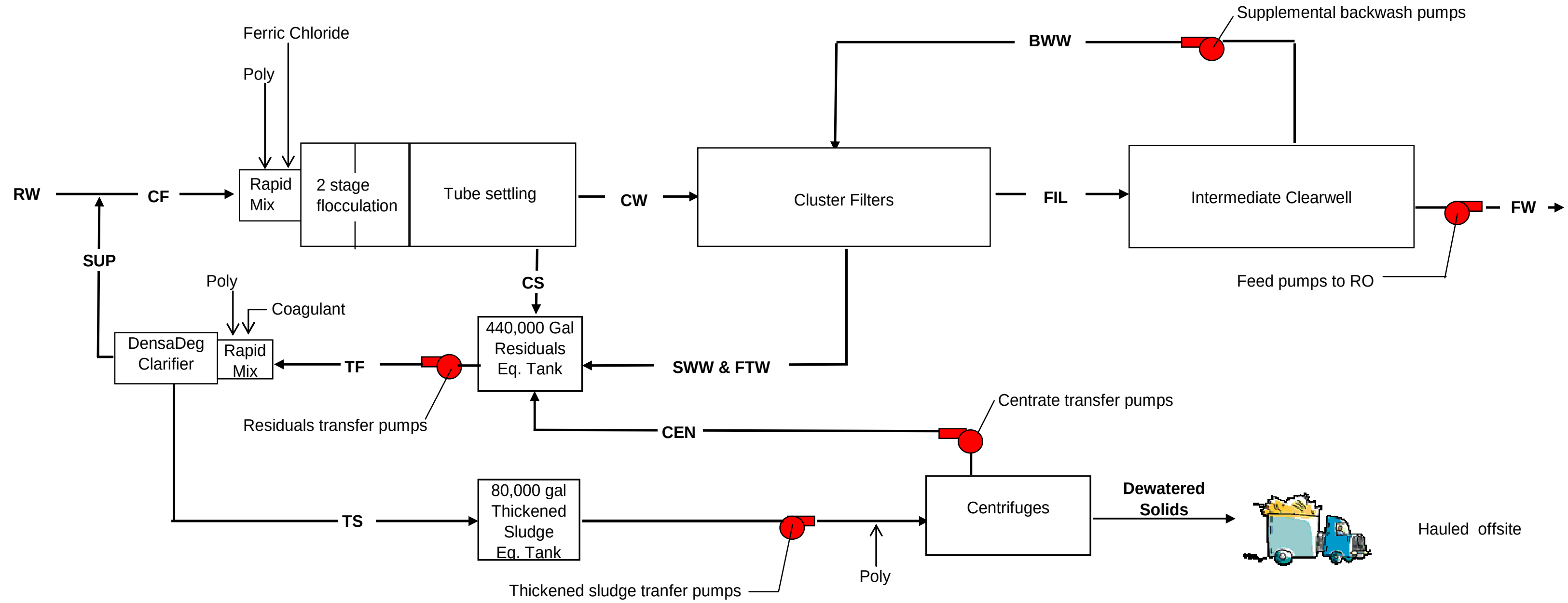
3.1.2.1 Solids Balance and Process Flow Diagram for Pre-Treatment Option 1

The solids summary is shown in *Table 4-3.1.2.1-1*. *Figure 4-3.1.2.1-1* presents the process flow diagram for Option 1, along with the solids and hydraulic balance. The solids balance was based on a finished water production of 50 mgd, a raw water turbidity of 20 NTU, a ferric chloride coagulant dose of 25 mg/l as (ferric chloride), polymer dose of 0.5 mg/l, and source water total organic carbon (TOC) of 6 mg/l.

Table 4-3.1.2.1-1 Summary of Solids Production

From Turbidity		
Production Rate	(mg SS/NTU removed)	1.5
Turbidity In	(NTU)	20.0
Turbidity Removal	(%)	99.7%
Turbidity Out	(NTU)	0.06
Solids Produced	(mg SS/l)	29.91
From TOC Removal		
TOC In	(mg/l)	6.0
TOC Removal	(%)	50%
Solids Produced	(mg SS/l)	3
From Ferric Chloride		
Production Rate	(mg/mg $FeCL_3$ Dose)	0.66
Ferric Dosage	(mg/l)	25.0
Solids Produced	(mg SS/l)	16.6
From Polymer		
Production Rate	(mg/mg Polymer Dose)	0.333
Polymer Dosage	(mg/l)	0.5
Solids Produced	(mg SS/l)	0.167
Total Solids Produced	**(mg SS/l)**	**49.58**
	(kg SS/day)	**9401**
	(lbs/day)	**20,730**

Figure 4-3.1.2.1-1 Solids Balance and Process Flow Diagram for Pre-Treatment Option 1 – Tube Settlers and Cluster Filters



Solids Balance for 20 NTU Raw Water and 25 mg/L Ferric Chloride Dose, 50 mgd production

RW	Raw Water[1]	50.100	MGD	20,729	Lbs SS/day	49.58	mg/L SS		Plant Recycle (% of RW)	5.8%	
CF	Clarifier Feed	53.019	MGD	21,384	Lbs SS/day	48.33	mg/L SS		Raw Water Quality - Turbidity	20	NTU
CW	Clarified Water	52.635	MGD	5,346	Lbs SS/day	21.65	mg/L SS				
FIL	Filtered Water	52.335	MGD	159	Lbs SS/day	0.37	mg/L SS		<u>Tube Settler Performance</u>		
FW	Finished Water	50.038	MGD	153	Lbs SS/day	0.37	mg/L SS		Suspended Solids Removal	75%	
SUP	Supernatant	2.919	MGD	439	Lbs SS/day	18.01	mg/L SS		% Recovery (flow out/flow in)	99.3%	
FTW	Filter to Waste	0.300	MGD	0.91	Lbs SS/day	0.37	mg/L SS		<u>Filter Performance</u>		
BWW	Back Wash Water	2.25	MGD	6.86	Lbs SS/day	0.37	mg/L SS		Suspended Solids Removal	97%	
SWW	Spent Wash Water	2.25	MGD	5,193	Lbs SS/day	277	mg/L SS	0.028%			
CS	Tube Settler Sludge	0.384	MGD	16,038	Lbs SS/day	5,000	mg/L SS	0.50%	<u>Thickener Performance (Densadeg)</u>		
TF	Thickener Feed	2.984	MGD	21,941	Lbs SS/day	881	mg/L SS		Solids Capture	98.00%	
TS	Thickened Sludge	64408	GPD	21,502	Lbs SS/day	40,000	mg/L SS	4.00%			
CEN	Centrate from centrifuges	49394	GPD	215	Lbs SS/day	522	mg/L SS		<u>Centrifuge Solids Capture Performance</u>	99	
SOLIDS	Dewatered solids	15014	GPD	21,287	Lbs SS/day	170000	mg/L SS	17%			

Notes:
1. After chemical addition.

Since all pre-treatment options are based on the same values of raw water turbidity, coagulant dose, and flow, the solids generation for each option is essentially the same. The solids handling approach is also the same for each option, with the use of DensaDeg clarifier/thickeners and centrifuge dewatering. Although not shown in *Table 4-3.1.2.1-1*, the coagulant and polymer used in the DensaDeg also add solids to the process. To quantify the solids production, a solids balance model was produced. The model accounts for recycle flows and loads, and takes into account typical performance criteria, in terms of solids capture and removal. The results of the solids balance (shown in *Figure 4-3.1.2.1-1*) assumes approximately 75 percent solids capture in tube settling, 97 percent solids capture in the filters, and 98 percent and 99 percent solids capture, respectively, in the DensaDeg clarifier/thickener and centrifuge.

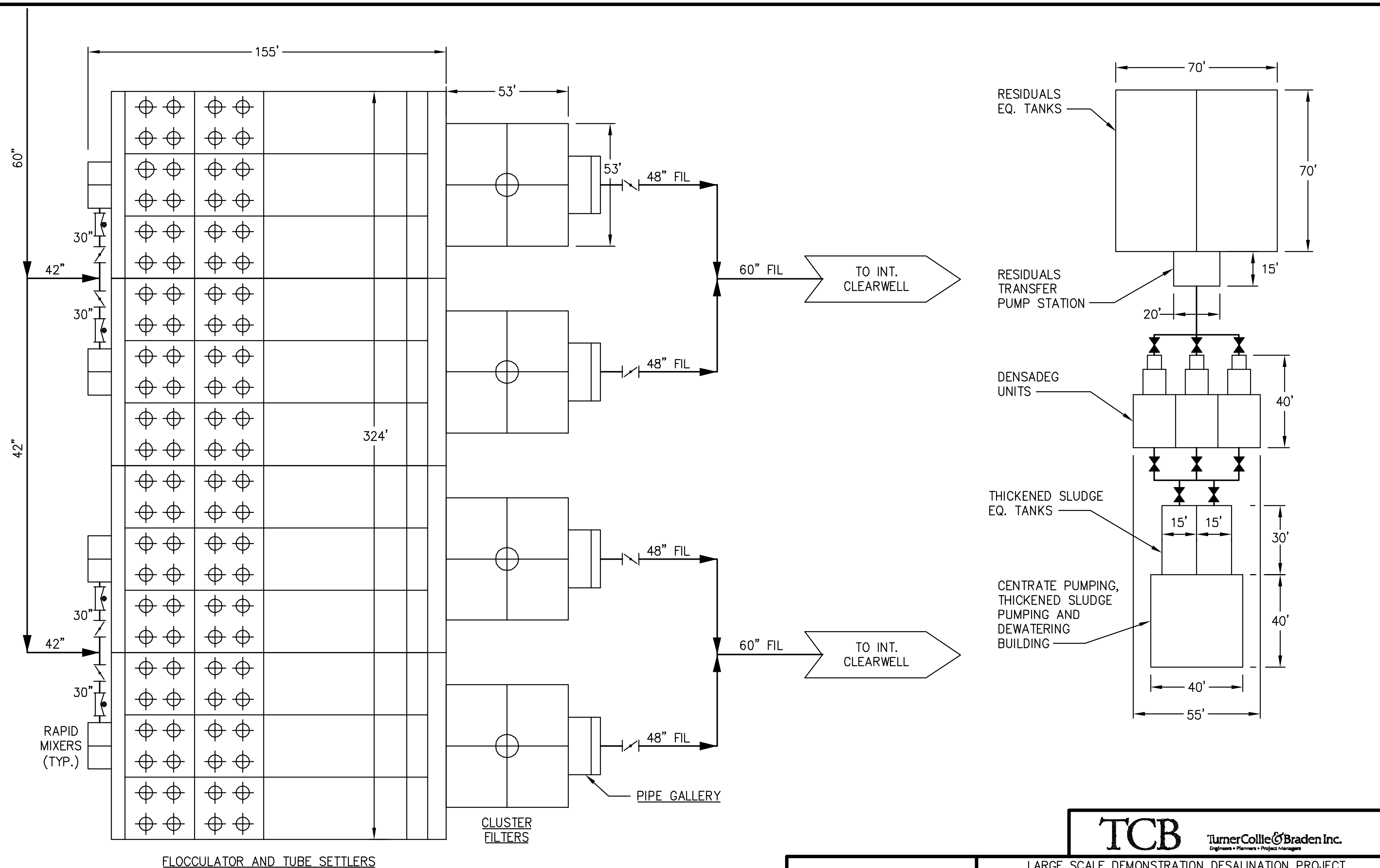
Reclaiming the SWW, FTW, DensaDeg supernatant and centrifuge centrate would minimize raw water pumping because the only losses from the pre-treatment process would occur in the final dewatering step, which results in a loss of approximately 14,500 gallons per day, which is bound in the sludge cake. Recycling the residuals streams also facilitates a "zero liquid discharge" approach to residuals handling.

Figure 4-3.1.2.1-1 also shows the location of intermediate pumping, equalization tanks, and chemical feed points for the entire pre-treatment process. Coagulant and polymer will be required for tube settler chemical pre-treatment, and again for the DensaDeg clarifier/thickener. Polymer will also be required for centrifuge dewatering. Although ranges of anticipated chemical doses were presented in the preceding paragraphs, actual chemical feed requirements will vary and will be as determined through treatability and demonstration studies.

3.1.2.2 Area Requirements for Pre-Treatment Option 1

This estimated space requirement (footprint) for pre-treatment Option 1 was estimated. Because the actual siting at this writing is undetermined, the estimated footprint is two-dimensional and does not take into account additional site constraints resulting from irregular topography. *Table 4-3.1.2.2-1* lists the area requirements of the major unit processes and presents a total footprint requirement for tube settler Option 1. Not included in this assessment are common components to all options, such as the raw water pump station and intake, intermediate clearwell, RO feed pumps, and the RO building and appurtenances.

As shown in *Table 4-3.1.2.2-1*, the total area required for the process components is approximately 73,000 square feet. It should be noted that this value does not represent the entire Option 1 pre-treatment process because the space between structures, roadways, landscaping, etc., is unknown and, therefore not accounted for. A conceptual layout of the Option 1 pre-treatment process is shown in *Figure 4-3.1.2.2-1*.



1" = 40'

0 40 80 120

SCALE FEET

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FIGURE 4–3.1.2.2–1

CONCEPTUAL SITE LAYOUT OF PRE–TREATMENT
OPTION 1: TUBE SETTLERS

SCALE:	1"=40'	3/17/04	W. BALETSA	

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Table 4-3.1.2.2-1 Area Requirements for Major Unit Processes – Option 1

Process Component	Train Dimensions* (L X W)	Ft^2 (per Train)	No. Trains	Total Ft^2
Flocculation, Tube Settlers	155 x 81	12,555	4	50,220
Cluster Filters and Filter Effluent Structure	(53 x 53) + (25 x 14)	3,159	4	12,636
Residuals Equalization Tank and Residuals Transfer Pump Station	(70 x 70) + (15 x 20)	5,200	1	5,200
DensaDeg Clarifier/Thickeners	55 x 40	2,200	1 group	2,200
Thickened Sludge Equalization Tank	30 x 30	900	1	900
Centrate Pumping, Thickened Sludge Pumping and Dewatering Building	40 x 40	1,600	1	1,600
Total Square Feet Required for Process Components				72,756

* 1 train = 3 basins

3.1.3 Pre-Treatment Train Option 2 – Conventional Pre-Treatment With Stacked DAF

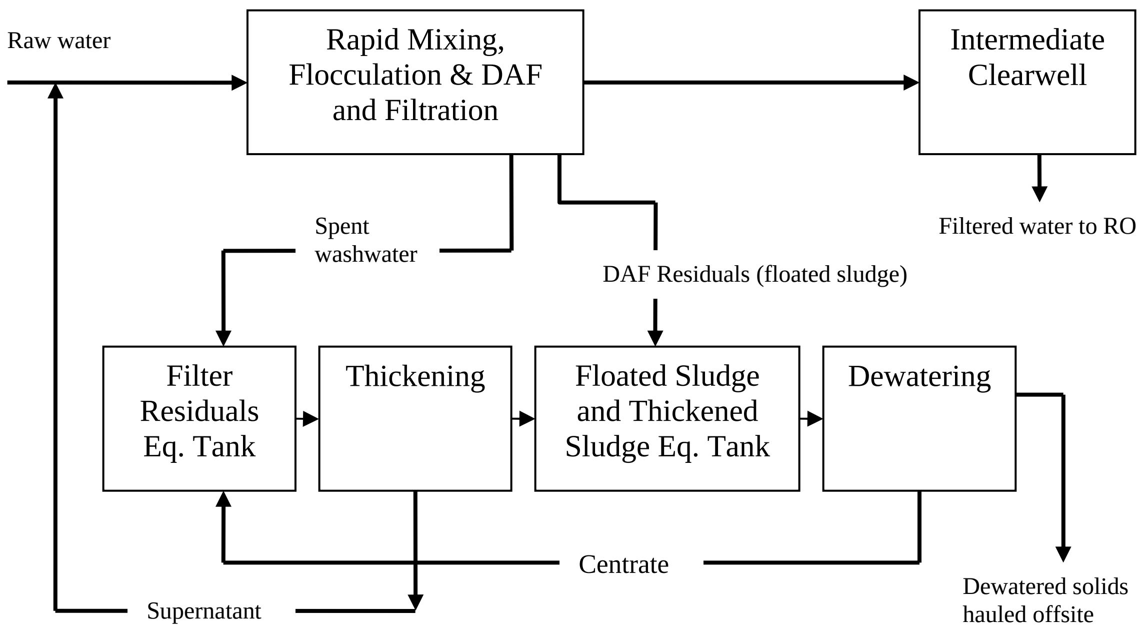
The second option for RO pre-treatment is the use of dissolved air floatation (DAF) coupled with gravity filtration in one compact process. This is commonly referred to as “stacked DAF.” The proposed residuals handling processes for Option 2 are as described for Option 1. This section will provide the design basis for the DAF/filtration option.

Design Criteria and Description of Pre-Treatment Option 2

The basic process for Option 2 is depicted in *Figure 4-3.1.3-1*. This is essentially the same as with Option 1, except that the stacked DAF replaces tube settlers and cluster filters. Also, since the DAF sludge concentration is anticipated to be approximately 2 percent, the sludge can go directly to equalization and can bypass the thickening process.

The DAF process works on the principle that rising air bubbles will attach to floc particles and will carry the particles to the liquid surface, forming a layer of “floated sludge.” A skimmer mechanism travels across the surface of the sludge layer and deposits the floated sludge into a hopper. A portion of the clarified water (8 to 10 percent) is continually pumped from the DAF basin and is saturated with air in a packed tower saturation vessel. This air saturated water is then re-introduced into an inlet of the DAF basin at pressure typically of 80 to 90 psi. Upon introduction into the DAF inlet basin, the sudden drop in pressure causes the air to come out of solution, forming air bubbles, which attach floc particles as they rise to the liquid surface.

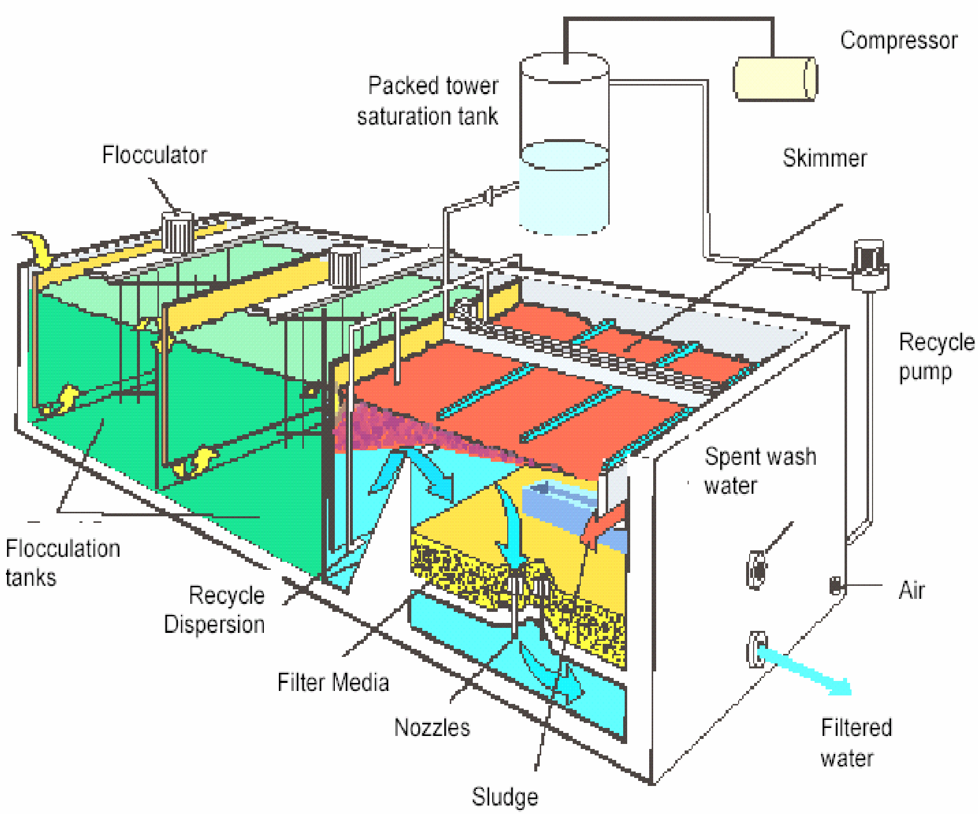
Figure 4-3.1.3-1 Pre-Treatment – Option 2



The DAF process can be either stand-alone or coupled with filtration in a common basin. Option 2 is based on the latter, as noted. The stacked DAF process has the benefit of reduced footprint compared to DAF with separate filters. The Parkson FloFilter stacked DAF process is proposed for Option 2. However, this is a non-proprietary technology. *Figure 4-3.1.3-2* shows a general arrangement of the Parkson FloFilter process.

The DAF process requires rapid mixing and flocculation for chemical pre-treatment, as with other clarification technologies. The DAF process generally does not require a polymer, however. The coagulant dose assumed for the purposes of this report was the same as with the tube settler option, which is 25 mg/l of ferric chloride (as ferric chloride). With the FloFilter operation, the clarified water is simultaneously applied to the filters, as the floc rises to the surface. Mixed media is proposed for FloFilters, as is proposed for the Greenleaf cluster filters. Other filter parameters, such as backwash rates, and loading rates are also comparable to the cluster filters. The design criteria for the FloFilter are summarized in *Table 4-3.1.3-1*.

Figure 4-3.1.3-2   General Arrangement of Parkson DAF FloFilters



A cross section view and plan view of the DAF FloFilter option are presented in *Figure 4-3.1.3-3* and *Figure 4-3.1.3-4,* respectively. As shown, the flocculation, clarification, and filtration process can be accomplished in one single process train. In addition, the filter pipe gallery can be constructed alongside the discharge end of the DAF basin, using common wall construction, further minimizing the need for additional structures. The floated sludge will discharge from each DAF basin into a sludge hopper. A sludge hopper spray system would be used to assist the sludge flow from the hoppers to the sludge discharge piping, as needed periodically. As shown in *Figure 4-3.1.3-3*, the DAF equipment can be installed in a separate area above the filter piping gallery, accessible from grade. The DAF equipment area would include the saturators, the recycle pumps, compressors, and other appurtenant equipment such as chemical feed equipment and spray systems.

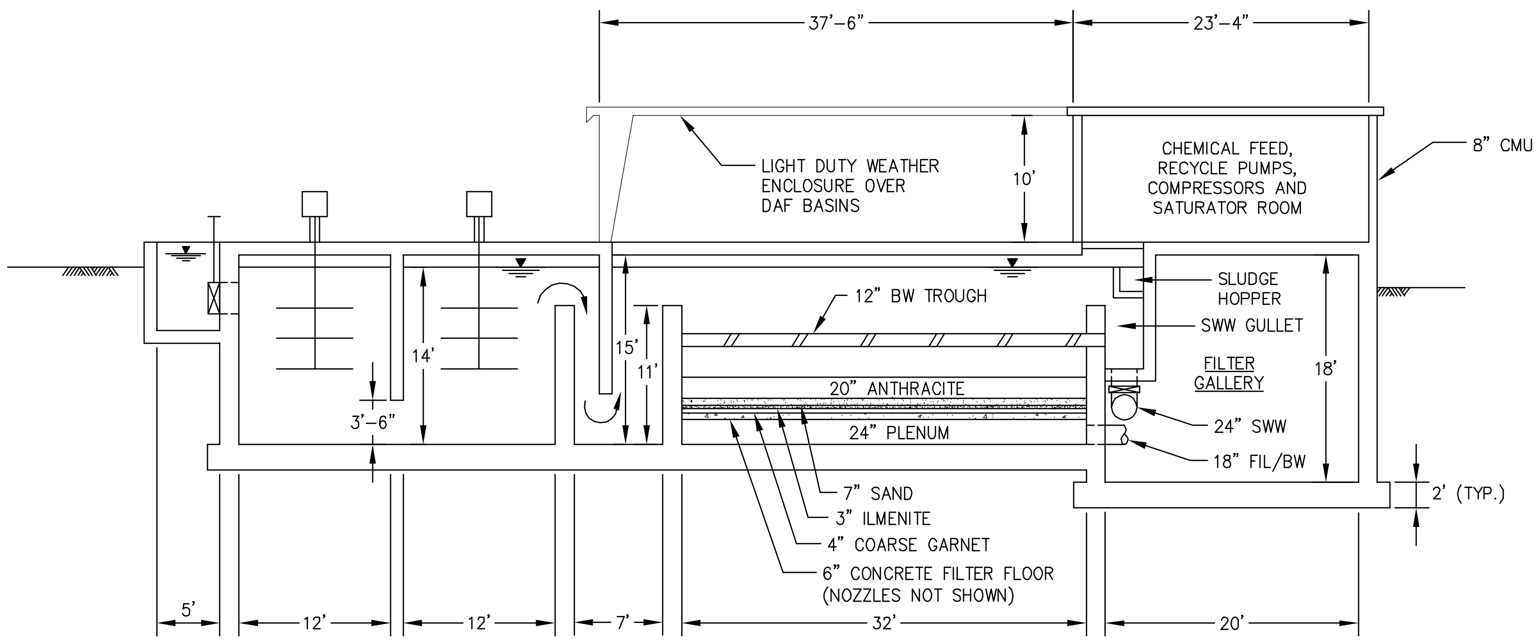


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FIGURE 4–3.1.3–3
DAF FLOFILTER CROSS–SECTION

SCALE:	1"=10'	3/17/04	W. BALETSA

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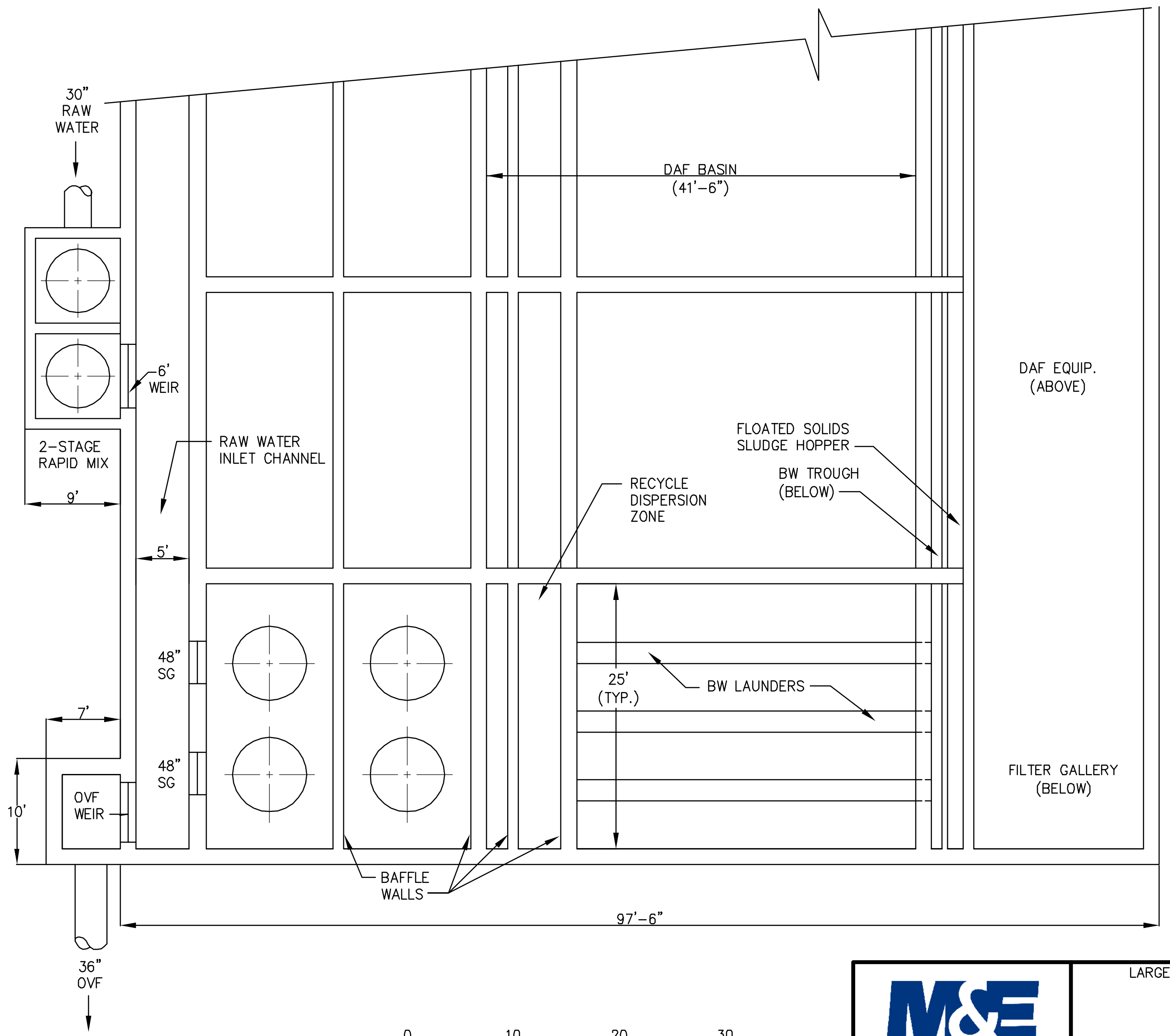

P:\CCCDESAL\321399DESAL\DWGS\FIG43134.dwg ; November 16, 2004 ; 1:44pm

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FIGURE 4-3.1.3-4
DAF FLOFILTER PLAN VIEW

SCALE:	1"=10'	3/17/04	W. BALETSA	

Table 4-3.1.3-1 Rapid Mix, Flocculation, DAF FloFilter Preliminary Design Criteria*

Total Capacity	mgd	±55
	gpm	38,194
	No. Trains	4
	No. Basins per Train	3
	Total No. DAF Basins	12
Rapid Mix Basins	L (ft)	8
	W (ft)	8
	D (ft)	10
	HRT per stage (secs)	30
	No. stages	2
	No. Rapid Mix basins per train	2
	Mixing velocity gradient (sec^{-1})	600 -1000
Flocculation Basins	L (ft)	12
	W (ft)	25
	D (ft)	14
	HRT (mins each stage)	10
	No. stages	2
	Total HRT in flocculation (mins)	20
	Mixing velocity gradient (sec^{-1})	50 - 100
DAF Basin	Model	FloFilter FFL 800
	Basin width (ft)	25
	Basin length (ft)	36.33
	Capacity per basin (gpm)	3,183
	DAF surface loading rates (gpm/sf)	
	With all 12 basins in service	3.5
	With 11 basins in service	3.82
	With 8 basins in service	5.25
	No. packed tower air saturators	4
FloFilters	No. filters per DAF basin	1
	Total No. filters	12
	Unit filter design flow (gpm)	3,183
	Filter HLR - all in service (gpm/sf)	3.98
	Filter HLR - 1 DAF/filter out of service (gpm/sf)	4.34
	Filter HLR - 1 entire DAF/filter group out of service (gpm/sf)	5.97
	Filter dimensions (ft x ft)	32 x 25
	Filter Area (ft^2, ea)	800
	Media Type	Mixed
	(anthracite)	20" (ES = 1.0 mm, UC = 1.7)
	(sand)	7" (ES = 0.45 mm, UC = 1.5)
	(limonite)	3" (ES = 0.26 mm, UC = 1.3)

Table 4-3.1.3-1 (continued)

	(coarse garnet)	4" (ES = 1.0 mm, UC = 1.7)
	Underdrain	Monolithic pour false bottom
	Nozzles	Orthos nozzles at 6" OC
Backwash Pumps	Type	Horizontal split case
	Number (N+1)	2
	BW rate (gpm/sf)	15
	Anticipated BW duration	10 - 20 mins
	Anticipated filter-to-waste duration	10 mins
	Flow (gpm)	12,000 at 40 TDH
Air Scour Blowers	Type	PD
	Number (N+1)	1
	BW air requirements (SCFM/sf)	3
	Flow (SCFM)	2,400

* Preliminary design of DAF process based on Parkson FloFilter FFL 800.
ES = effective size. UC = uniformity coefficient

It should be noted that the DAF process is sensitive to disruption from wind and heavy weather. For this reason, the conceptual layout for DAF shows a light duty weather enclosure over the DAF basins. These weather enclosures would not require HVAC, doors and windows, or major electrical systems.

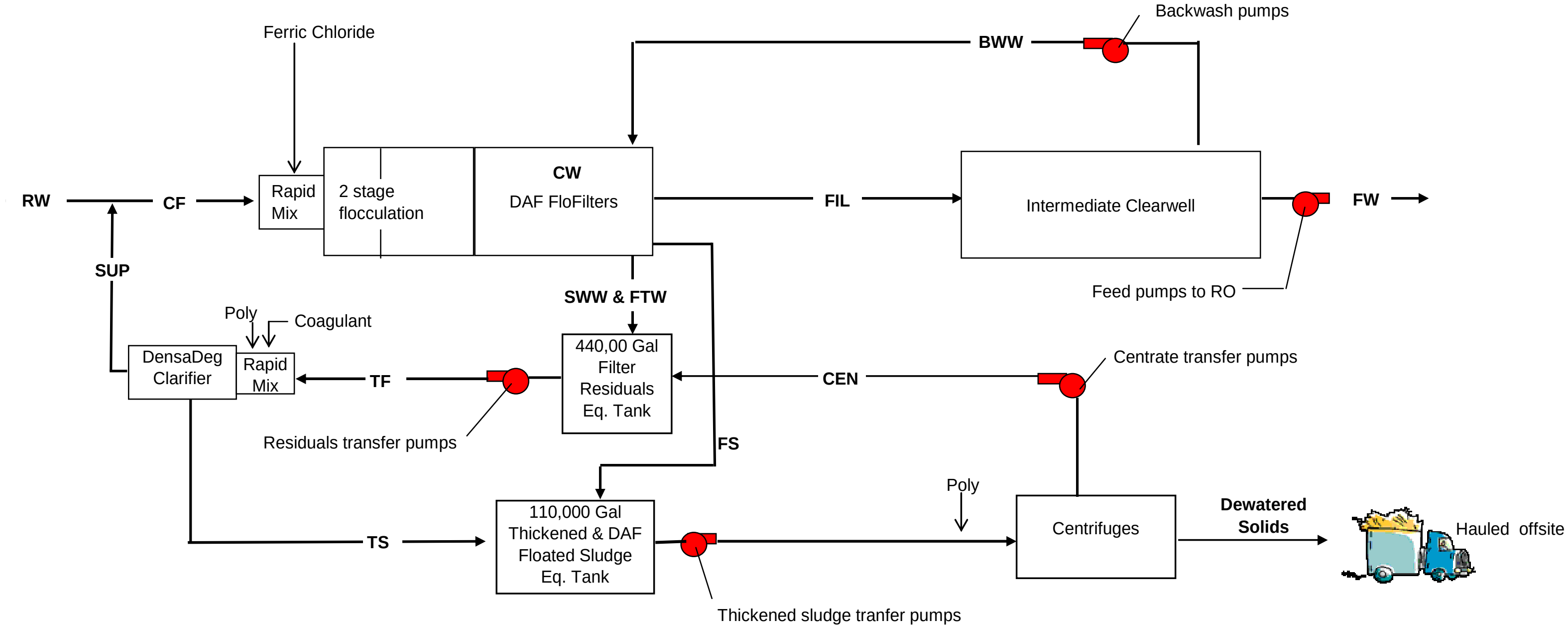
Residuals Handling. Option 2 will utilize DensaDeg technology for thickening as well as centrifuges for dewatering, similar to Option 1. The solids load to Option 2 will be the same as described for Option 1 (refer to *Table 4-3.1.2.1-1*). Thus, a discussion of these residuals handling technologies is presented in *Section 3.1.2* and is not repeated here. In general, the sizing of residuals handling components for Option 2 does not vary significantly compared to Option 1, although some minor differences would exist. For example, because the DAF-floated solids do not require thickening, the solids would go directly to the equalization tank preceding the centrifuges. Thus, the solids load on the DensaDeg thickeners would be reduced, from about 20,000 pounds per day to about 5,500 pounds per day, and therefore, the thickened sludge flow from the DensaDegs would also be reduced (about 16,000 gpd versus 64,000 gpd). However, the hydraulic load to the DensaDegs will be essentially the same, because the majority of process residuals for both options, from a hydraulic standpoint, are spent washwater and filter-to-waste.

Thus, the preliminary design of the DensaDegs for Option 1 and 2 would be the same. The thickened sludge equalization tank will be slightly larger, to accommodate direct input from the DAF sludge as well as the thickened sludge from the DensaDegs. Also for Option 2, the hydraulic load to the centrifuges will be increased requiring additional centrifuge capacity. The residuals handling components for Option 2 are presented in *Table 4-3.1.3-2*. *Figure 4-3.1.3-5* shows the process flow diagram, solids balance, and flow balance model for Option 2.

Table 4-3.1.3-2 Residuals Handling Preliminary Design Criteria Option 2*

Filter Residuals Equalization Eq. Tank Volume (gallons)	440,000	Sized for 3 hours of storage (2 filter washes and FTW)
Eq. Tank Volume L x W x SWD (ft)	70 x 70 x 12	
No. of Residuals transfer pumps	3	2 duty + 1 standby
Capacity of Residuals transfer pumps (gpm)	1,300	Dry pit submersible
DensaDeg		
Total DensaDeg Design Flow* (gpm)	2,500	
Solids Concentration in feed flow (mg/l)	200	
Lbs/day solids in feed flow (to DensaDeg)	5,000	
Assumed percent solids in DD Underflow (%)	4	
Design Rise Rate (gpm/sf)	7.1	6-8 is typical
Polymer dose (mg/l)	0.5 - 1.0	Typical range
Coagulant (mg/l)	30 to 60	Typical range
No. Units	3	2 duty + 1 standby
Design flow per unit (gpm)	1284	
Tube Settling Area SF (ea)	177	
Total Length x width (ft)	(41 x 56)	
Thickened Sludge Volume (gals/day)	16,400	(assuming 4% solids)
Thickened Sludge & DAF Floated Sludge Equalization Tank (gallons)	110,000	Sized for 1 days of worth of sludge storage
Eq. Tank Volume L x W x SWD (ft)	35 x 35 x 12	
No. of thickened sludge transfer pumps	3	2 duty + 1 standby
Capacity of thickened sludge transfer pumps (gpm)	150	Rotary lobe
Centrifuges		
Total Centrifuge Design Flow (gpm)	300	
Anticipated Solids Conc. in feed flow (%)	2.3	
Total lbs/day	21,000	
Lbs/week	147,000	
Gallons per week	770,000	
Production days per week	7	
Hours of dewatering per day	6	
No. of Centrifuges	4	3 duty + 1 standby
No. of operating centrifuges	3	
GPM total	300	
GPM per unit	100	
Lbs/hr per unit	1,167	
Anticipated polymer dose (active lbs/dry ton solids)	4 - 10	Inversely proportional to cake dryness
Anticipated cake dryness (%TS)	18 - 25	Function of raw water turbidity
Centrifuge Size		
Diameter (in)	20.5	Model D5LL
Operating Speed (rpm)	3,200	
Force (G)	2,976	
Overall Length (in)	180	
Overall Width (in)	52	
Overall Height (in)	62	

Figure 4-3.1.3-5 Solids Balance and Process Flow Diagram for Pre-Treatment Option 2 – DAF FloFilters



Solids Balance for 20 NTU Raw Water and 25 mg/L Ferric Chloride Dose, 50 mgd production

RW	Raw Water[1]	50.000	MGD	20,619	Lbs SS/day	49.41	mg/L SS		Plant Recycle (% of RW)	6.9%	
CF	Clarifier Feed	53.437	MGD	20,786	Lbs SS/day	46.61	mg/L SS		Raw Water Quality - Turbidity	20	NTU
CW	Clarified Water	53.344	MGD	5,197	Lbs SS/day	21.04	mg/L SS				
FIL	Filtered Water	52.961	MGD	155	Lbs SS/day	0.35	mg/L SS		<u>DAF Clarifier Performance</u>		
FW	Finished Water	50.033	MGD	146	Lbs SS/day	0.35	mg/L SS		Suspended Solids Removal	75%	
SUP	Supernatant	3.342	MGD	112	Lbs SS/day	4.01	mg/L SS		% Recovery (flow out/flow in)	99.8%	
FTW	Filter to Waste	0.383	MGD	1.12	Lbs SS/day	0.35	mg/L SS		<u>Filter Performance</u>		
BWW	Back Wash Water	2.88	MGD	8.42	Lbs SS/day	0.35	mg/L SS		Suspended Solids Removal	97%	
SWW	Spent Wash Water	2.88	MGD	5,049	Lbs SS/day	210	mg/L SS	0.02%			
FS	DAF Floated Sludge	93397	GPD	15,590	Lbs SS/day	20,000	mg/L SS	2.00%	<u>Thickener Performance (Densadeg)</u>		
TF	Thickener Feed	3.358	MGD	5,589	Lbs SS/day	199	mg/L SS		Solids Capture	98.00%	
TS	Thickened Sludge	16406	GPD	5,477	Lbs SS/day	40,000	mg/L SS	4.00%			
CEN	Centrate from centrifuges	94983	GPD	55	Lbs SS/day	69	mg/L SS		<u>Centrifuge Solids Capture Performance</u>	99	
SOLIDS	Dewatered solids	14820	GPD	21,012	Lbs SS/day	170000	mg/L SS	17%			

Notes:
1. After chemical addition.

3.1.3.1 Area Requirements for Pre-Treatment Option 2

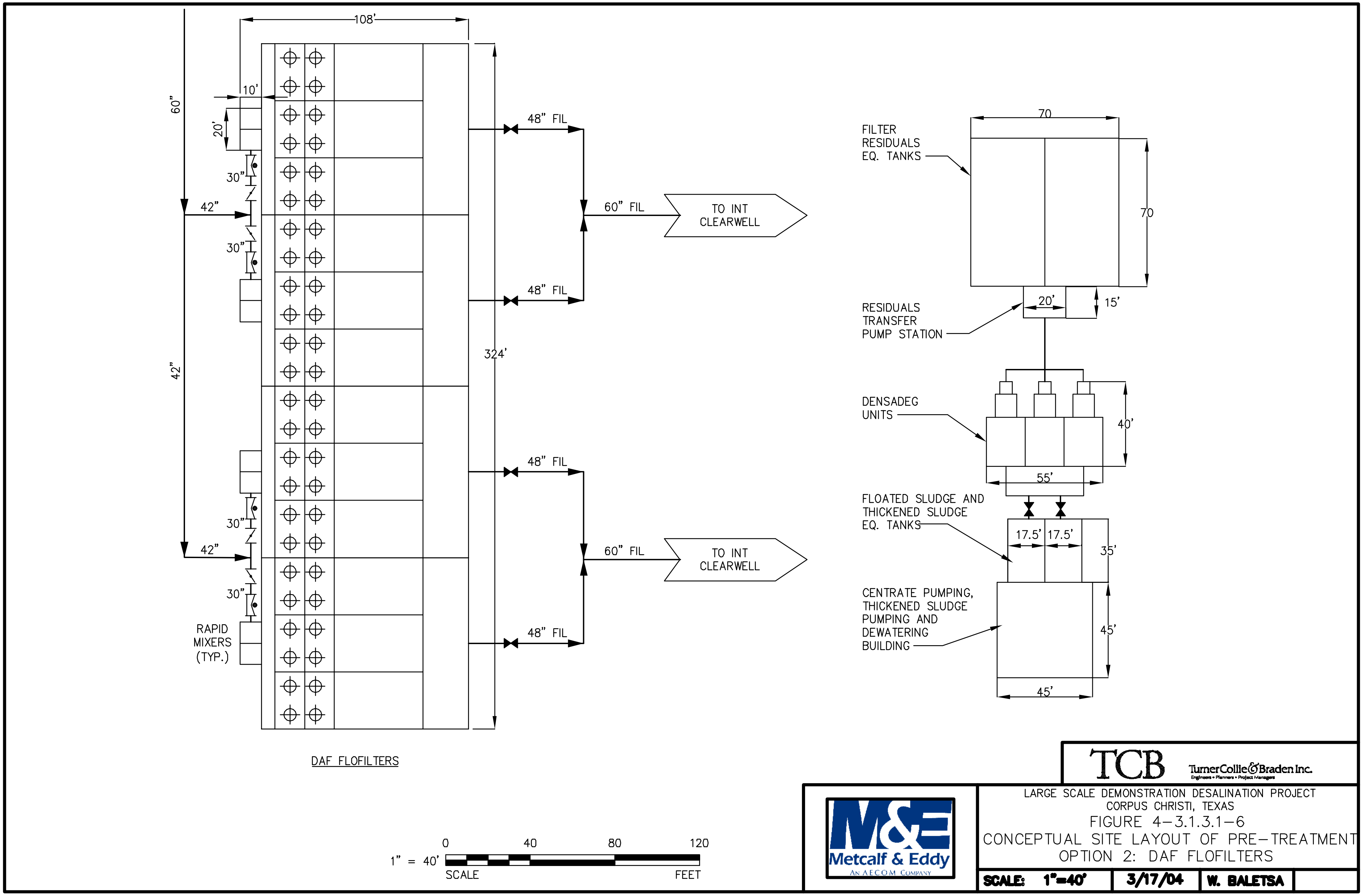
Table 4-3.1.3.1-1 lists the area requirements of the major unit processes and presents a total footprint requirement for DAF FloFilter Option 2. As with Option 1, this assessment does not include common components to all options, such as the raw water pump station and intake, rapid mixing basins, chemical feed areas, intermediate clearwell and filter backwash pumps (which would be located adjacent to the intermediate clearwell), RO feed pumps, and the RO building and appurtenances.

Table 4-3.1.3.1-1 Area Requirements for Major Unit Processes – Option 2

Process Component	Train Dimensions* (L X W)	Ft^2 (per Train)	No. Trains	Total Ft^2
Flocculation & DAF FloFilters	108 x 81	8,748	4	34,992
Residuals Equalization Tank & Residuals Transfer Pump Station	(70 x 70) + (15 x 20)	5,200	1	5,200
DensaDeg Clarifier/Thickeners	55 x 40	2,200	1 group	2,200
DAF Floated Solids & Thickened Sludge Equalization Tank	35 x 35	1,225	1	1,225
Centrate Pumping, Thickened Sludge Pumping and Dewatering Building	45 x 45	2,025	1	2,025
Total Square Feet Required for Process Components				45,642

* 1 train = 3 basins

As shown in *Table 4-3.1.3.1-1*, the total area required for the process components is approximately 46,000 square feet, compared to 73,000 square feet for Option 1, a 37 percent reduction in space. A conceptual layout of the Option 2 pre-treatment process is shown in *Figure 4-3.1.3.1-6*.



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3.1.4 Pre-Treatment Train Option 3 – Pre-Treatment With Immersed Membrane Filtration

The third option for membrane desalination pre-treatment is the use of low-pressure membrane filtration. Low-pressure membrane filtration, which encompasses both microfiltration and ultrafiltration processes, is frequently used as reverse osmosis pre-treatment for brackish surface water supplies and in tertiary reuse applications.

Design Criteria and Description of Pre-Treatment Option 3

Low-pressure membrane filtration typically uses membranes possessing pore sizes of 0.08 µm to 0.2 µm depending upon the manufacturer selected. They have been proven to obtain high removals of particulate contaminants such as suspended solids and pathogens, including bacteria, *Giardia*, *Cryptosporidium*, and some viruses. Third party research has verified removal of *Giardia* and *Cryptosporidium* at levels exceeding 6-logs, although in practical operations, removals of 4 to 4.5-log ranges are achieved for most applications.

Low-pressure membranes manufactured for the potable water market predominantly are designed to achieve efficient removal of particulate contaminants. When coupled with other unit processes, such as coagulation and flocculation, low-pressure membrane systems possess significant removal of color, naturally occurring materials (NOM), and disinfection byproducts precursors (*Table 4-3.1.4-1*).

Table 4-3.1.4-1 Typical Manufacturers of Low-Pressure Membrane Systems

Manufacturer	Zenon	Zenon	US Filter	Pall	Norit
Product	Zeeweed 500	Zeeweed 1000	CMF-S	Microza	X-Flow
Typical Flux (gfd)	20 - 35	20 - 30	25 - 40	35 - 100	35 - 100
Membrane Material	Composite; Proprietary	PVdF	PVdF	PVdF	PES
Membrane Flow	Outside-In	Outside-In	Outside-In	Outside-In	Inside-Out
Filtration Mode	Submerged; partial cross-flow	Submerged; dead-end	Submerged; dead-end	Pressure; dead-end	Pressure; dead-end or cross-flow
Pore Size (µm)	0.08 - 0.01	0.1	0.1	0.1	0.04
Solids Handling Capability	High	Low	Moderate	Moderate	Moderate

In a seawater desalination application, the greatest benefit of utilizing low-pressure membrane filtration as pre-treatment is the ability of these systems to provide very low SDI water. Typical SDIs from conventional systems range from 3 to 5, with some systems exceeding these values. Since reverse osmosis membrane manufacturers tend to include a requirement of feedwater SDI of less than 5 as a condition of warranty, a high level of pre-treatment is frequently warranted. Low-pressure membrane filtration has demonstrated SDIs of less than one when treating seawater from open intakes.

Low SDI water has additional benefits, such as avoiding particulate/colloidal fouling of RO membrane systems. Additionally, the higher removal of algae and other microbial organisms greatly reduces the relative biological fouling rate when compared to conventional pre-treatment.

In a typical submerged membrane system application, feedwater is screened to at least 2 mm to remove large particulate matter. Coagulant, typically polyaluminum chloride or ferric chloride, is added to the screened water at the required dose. Flash mixers ensure rapid and thorough dispersion of the coagulant to enhance coagulation. The coagulated water then flows into a two-stage flocculator, where sufficient mixing energy is added to prevent settling of floc to encourage the aggregation of particles into larger flocs. The flocculated water is then directed to open basins containing the submerged membranes.

The membranes submerged in the treatment tanks operate under a slight vacuum created within the hollow membrane fibers by a permeate pump. Treated water is drawn through the membranes, enters the hollow fibers, and is pumped out to treated water storage. Aerators are located at the bottom of the tank to encourage scour at the membrane surface, mitigating accumulation of solids on the membrane surface. The concentration of solids in the tank is controlled by a reject pump. The rejected solids are pumped to the residuals handling process for recovery and recycling of feedwater.

The membranes typically operate at a flux of 25 to 35 gpd/sq ft at a recovery rate of 90 to 95 percent. The clarified water, or permeate, is pumped from the membrane cassette to the backwash tank. To maintain the membranes' permeability, they are intermittently flushed with a back pulse of water, which removes solids from the surface of the membranes. Low levels of hypochlorite are usually dosed into the back pulse to mitigate organic fouling of the membrane.

The design criteria for the proposed low-pressure membrane filtration system are contained in *Table 4-3.1.4-2*. A typical process flow diagram for the pre-treatment system is contained in *Figure 4-3.1.4-1*.

A plan view of a typical installation is illustrated in *Figure 4-3.1.4-2*. Section views of a typical installation are shown in *Figures 4-3.1.4-3* and *4-3.1.4-4*.

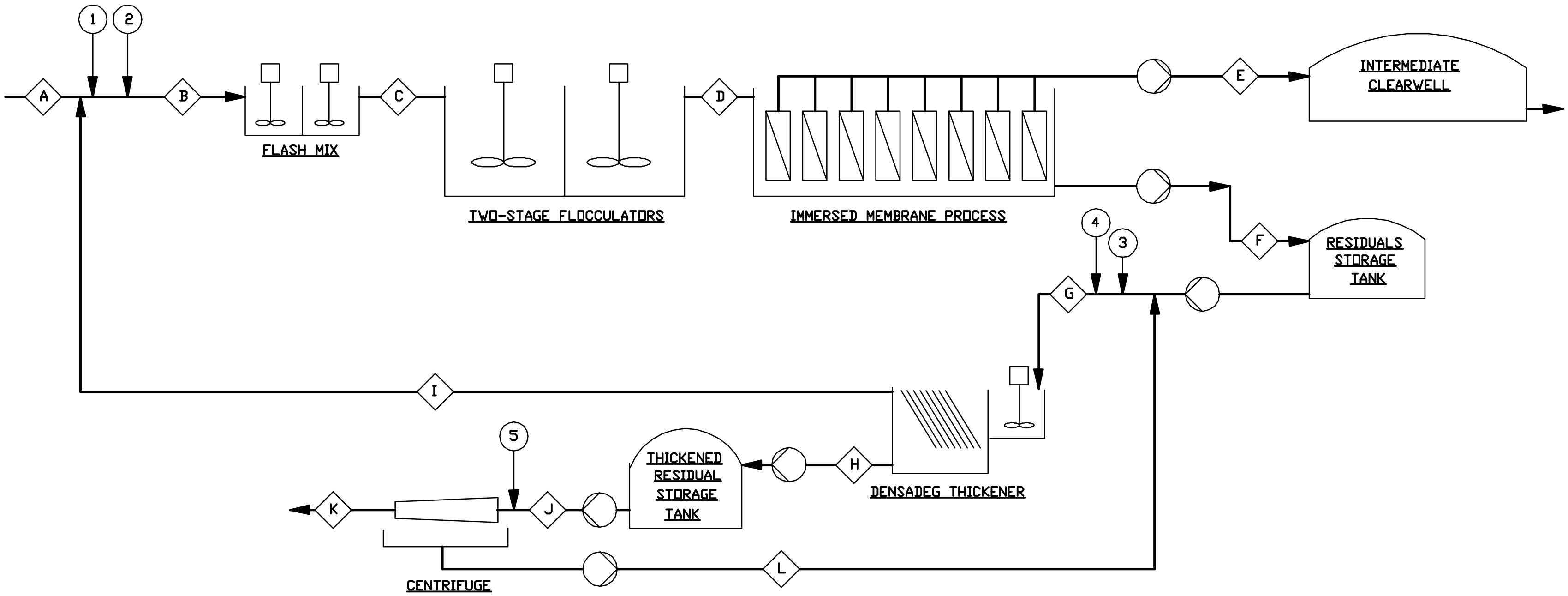
The proposed residuals handling processes for Option 3 are similar to those described for Option 1. *Table 3.1.4-3* displays the proposed design criteria for the dewatering process.

Table 4-3.1.4-2 Design Criteria for Low-Pressure Membrane System

Unit Process	Value	
Plant Capacity - Raw (mgd)	55.0	
Recovery (%)	95%	
Filtered Water (mgd)	52.25	
Pre-Chlorination		
Dosage (mg/l)	3	
12.5% Chlorine Requirement (lbs/day)	11,006	
12.5% Chlorine Requirement (gal/day)	1,091	
Day Tank Volume (gal)	1,309	
Bulk Storage Requirement (day)	30	
Bulk Tank Volume (gal)	39,263	
Influent Flow Metering		
Number (N)	1	
Type	Magnetic Flowmeter	
Range (mgd)	25 - 55	
Coagulation		
Dosage (mg/l)	25	
Ferric Chloride Addition (#/day)	30,170	
Ferric Chloride Addition (gal/day)	2,584	
Day Tank (gal)	3,101	
Bulk Storage Requirement (day)	30	
Storage Tank (gal)	93,022	
Rapid Mixing		
Number (N)	2	
Number of Stages	2	
Type	Vertical Mixer	
Mixing Energy, per stage (G; sec^{-1})	300 - 1000	
Hydraulic Retention Time, stage (sec)	28.2	
Mixing Zone Length (ft)	10	
Mixing Zone Width (ft)	10	
Mixing Zone Height (ft) - water depth	12	
Drive Type	Variable speed	
Motor Hp	100	
Flocculators		
Number of Trains	10	9
Stages/Train	2	2
Detention Time/stage (min)	8.5	7.6
Water Depth	15	15
Volume Train (ft^3)	4,320	4,320

Table 4-3.1.4-2 *(continued)*

Unit Process	Value	
Total Volume (ft^3)	43,200	38,880
Stage 1 & Stage 2		
Type ________________	Variable speed, vertical hydrofoil impellers	Variable speed, vertical hydrofoil impellers
Number	10	9
Compartment Size (ft x ft)	12 x 12	12 x 12
Mixing Energy (G; sec^{-1})	50	50
Motor Hp	1	1
Number of Trains	10	9
Type	Submerged	Submerged
Design Temperature (^oC)	10 - 30	10 - 30
Net Flux (gfd)	25.6	28.5
Instantaneous Flux	30.1	33.5
Membrane Area per Train	2,040,059	2,040,059
Clean-in-Place Frequency (#/yr per train)	12	12
Recovery (%)	95.0%	95.5%
Reject Pumps		
Type ________________	Horizontal Split Casing	Horizontal Split Casing
Number (N)	10	9
Flow (mgd)	0.275	0.3056
Head (ft)	23	23
Drive Type	Variable Speed	Variable Speed
Motor Horsepower	2	2
Permeate Pumps		
Type ________________	Horizontal Split Casing	Horizontal Split Casing
Number (N)	10	9
Flow/pump (mgd)	5.23	5.81
Head (ft)	46	46
Drive Type	Variable Speed	Variable Speed
Motor Horsepower	60	60
Blowers		
Type	Multi-Stage Centrifugal	Multi-Stage Centrifugal -
Number (N + 1)	6	5
Flow/blower (SCFM)	3,000	3,000
Head (psig)	5	5
Motor Horsepower (Hp)	150	150



	STREAMS											
	A	B	C	D	E	F	G	H	I	J	K	L
	RAW	COAGULATED FEED	FLASH MIX	FLOCCULATED	MEMBRANE FILTRATE	WASTE	THICKENER FEED	THICKENED RESIDUALS	THICKENER SUPERNATENT	CENTRIFUGE FEED	CENTRIFUGE CAKE	CENTRIFUGE FILTRATE
FLOW (mgd)	50.01	52.63	52.63	52.63	50.00	2.63	2.67	0.06	2.62	0.057	0.013	0.044
SS (dry lb/d)	10,844	18,474	18,474	18,474	0	18,474	19,363	18,976	387	19,090	18,899	189
TSS (mg/L)	26	42	42	42	0	842	868	40,000	18	40,240	170,000	520

	CHEMICAL FEEDS				
	1	2	3	4	5
	NaHOCL	$FeCL_3$	$FeCL_3$	POLYMER	POLYMER
Dose (mg/L)	5	25	40	5	–
Dose (#/ton ds)	–	–	–	–	6

NOTE:
- ASSUMED 25-mg/L FERRIC CHLORAIDE DOSE
- MEMBRANE SYSTEM RECOVERY OF 95%
- THICKENER SOLIDS RECOVERY 98%
- CENTRIFUGE SOLIDS RECOVERY 99%

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FIGURE 4-3.1.4-1
PROCESS FLOW DIAGRAM: SUBMERGED MEMBRANE SYSTEM

SCALE:	NONE	3/17/04		

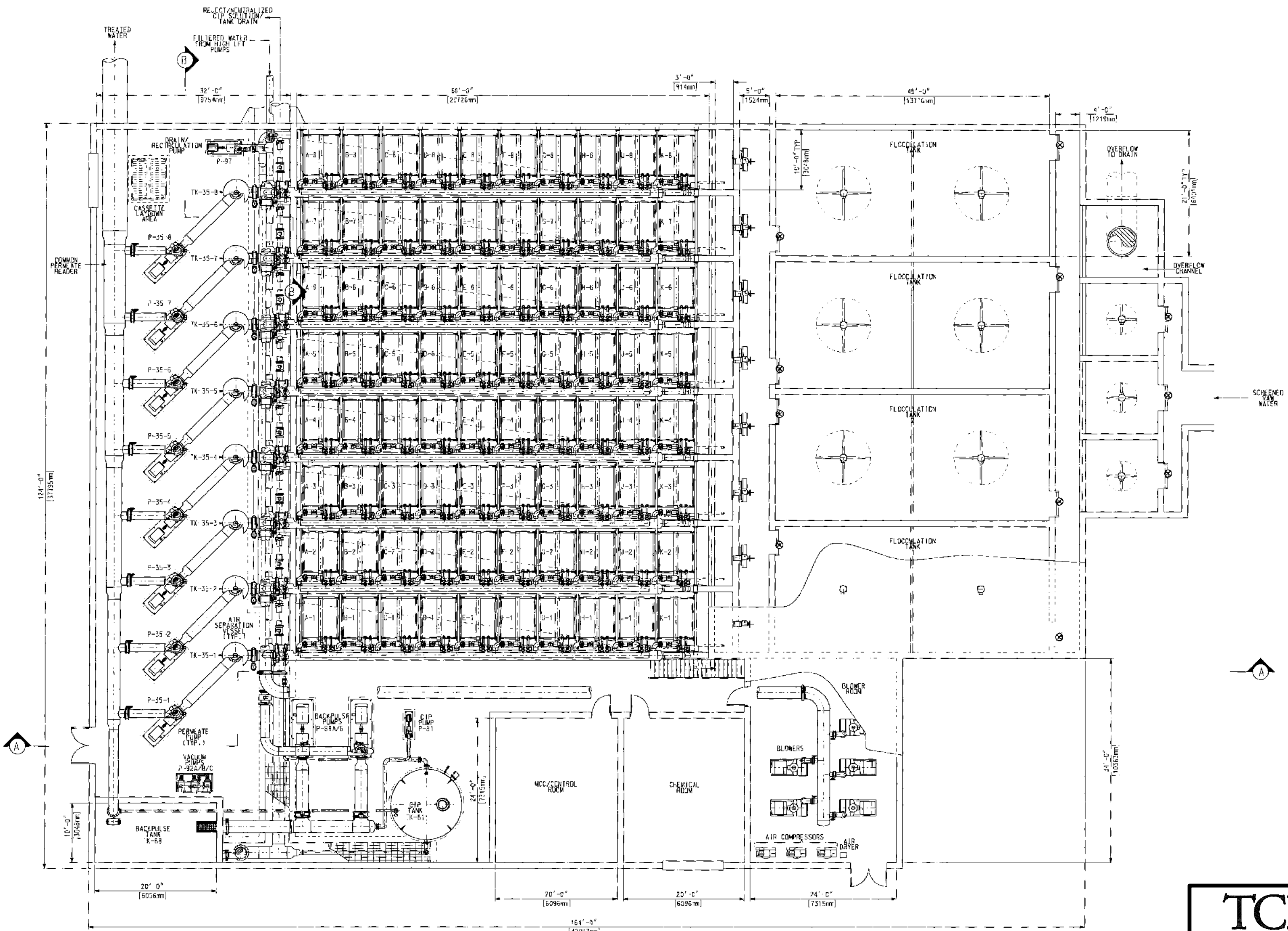

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FIGURE 4–3.1.4–2
PLAN VIEW OF TYPICAL
LOW–PRESSURE MEMBRANE FILTRATION SYSTEM

SCALE:	NONE	3/24/04	C. BENZIGER

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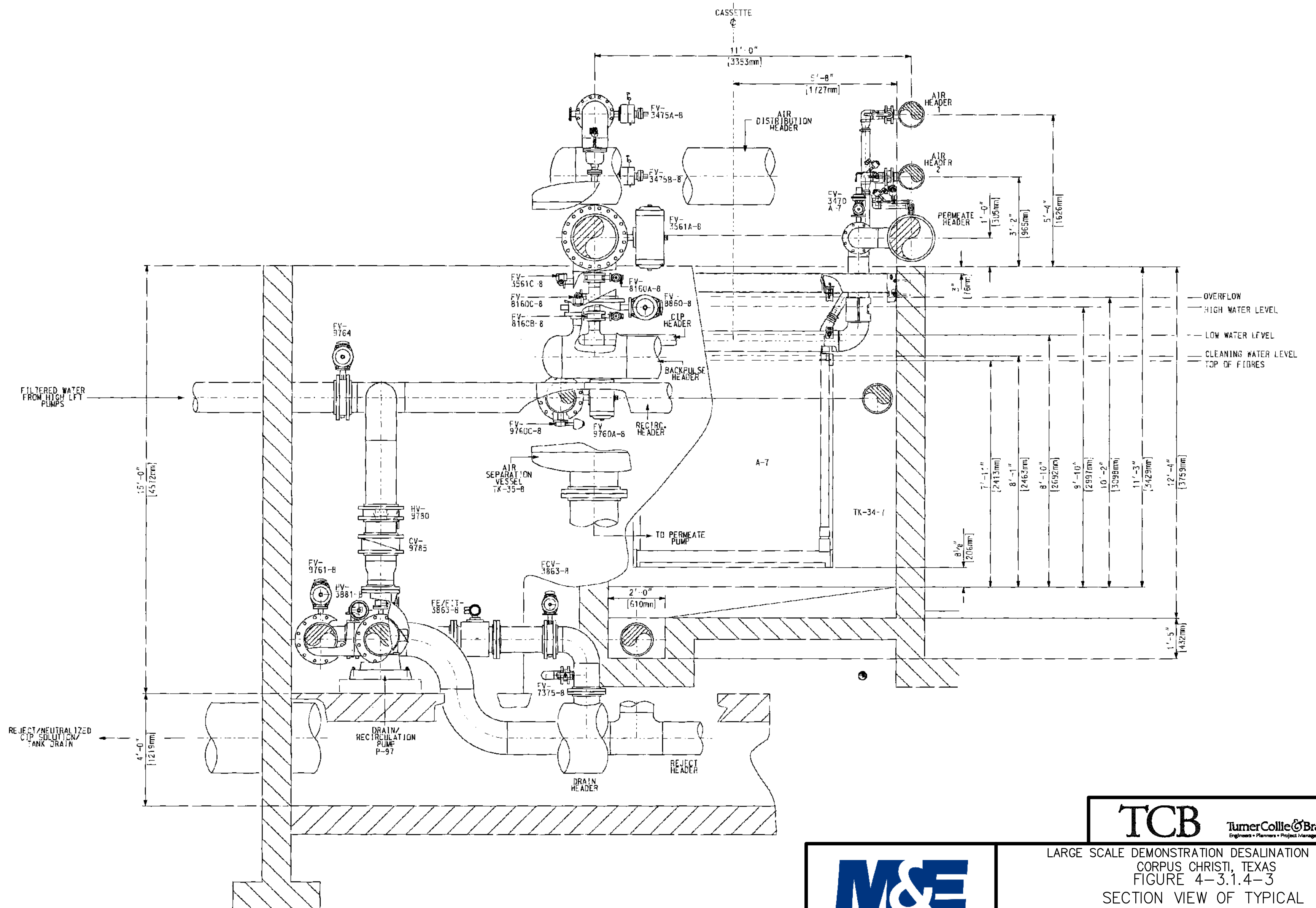

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FIGURE 4-3.1.4-3
SECTION VIEW OF TYPICAL
LOW-PRESSURE MEMBRANE FILTRATION SYSTEM

SCALE:	NONE	3/24/04	C. BENZIGER

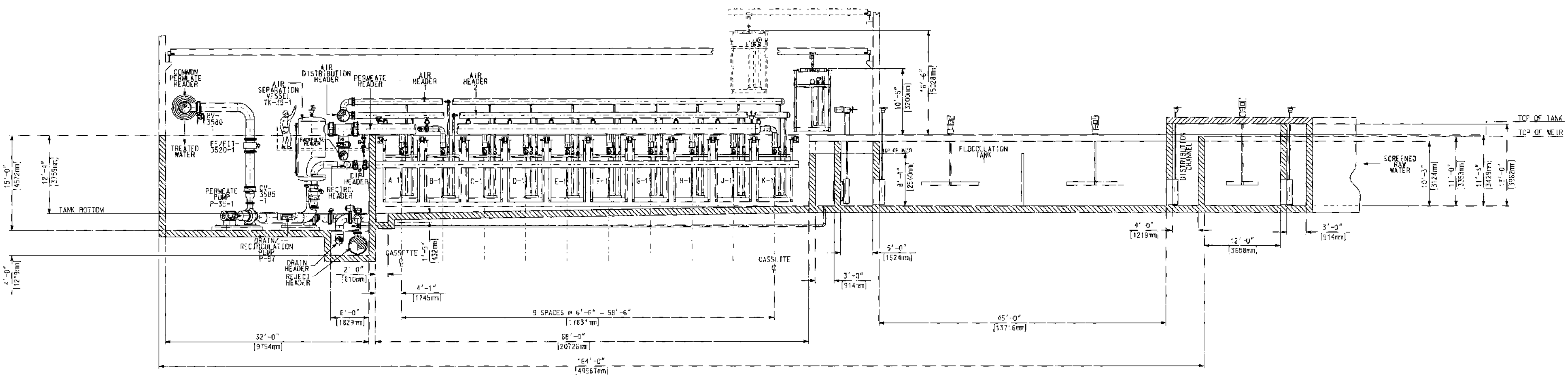

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FIGURE 4–3.1.4–4
PARTIAL SECTION VIEW OF TYPICAL
LOW–PRESSURE MEMBRANE FILTRATION

SCALE:	NONE	3/24/04	C. BENZIGER

Table 4-3.1.4-3 Design Criteria for Pre-Treatment Residuals Dewatering

Filter Residuals Equalization		
Eq. Tank Volume (gallons)	440,000	Sized for 4 hours of storage
Eq. Tank Volume L x W x SWD (ft)	70 x 70 x 12	
No. of Residuals transfer pumps	3	2 duty + 1 standby
Capacity of Residuals transfer pumps (gpm)	1,300	Dry pit submersible
DensaDeg		
Total DensaDeg Design Flow (gpm)	2,500	
Solids Concentration in feed flow (mg/l)	868	
Lbs/day solids in feed flow (to DensaDeg)	19,360	
Assumed percent solids in DD Underflow (%)	4	
Design Rise Rate (gpm/sf)	7.1	6-8 is typical
Polymer dose (mg/l)	0.5 - 1.0	Typical range
Coagulant (mg/l)	30 to 60	Typical range
No. Units	3	2 duty + 1 standby
Design flow per unit (gpm)	1,284	
Tube Settling Area SF (ea)	177	
Total Length x width (ft)	(41 x 56)	
Thickened Sludge Volume (gals/day)	60,000	(assuming 4% solids)
Thickened Sludge Equalization Tank		
Gallons	60,000	Sized for 1 day of sludge storage
Eq. Tank Volume L x W x SWD (ft)	30 x 30 x 12	
No. of thickened sludge transfer pumps	3	2 duty + 1 standby
Capacity of thickened sludge transfer pumps (gpm)	150	Rotary lobe
Centrifuges		
Total Centrifuge Design Flow (gpm)	300	
Anticipated Solids Conc. in feed flow (%)	4	
Total lbs/day	19,100	
Lbs/week	133,700	
Gallons per week	400,000	
Production days per week	7	
Hours of dewatering per day	6	
No. of Centrifuges	3	2 duty + 1 standby
No. of operating centrifuges	2	
GPM total	150	
GPM per unit	75	
Lbs/hr per unit	1,590	
Anticipated polymer dose (active lbs/dry ton solids)	4 - 10	Inversely proportional to cake dryness
Anticipated cake dryness (%TS)	18 - 25	Function of raw water turbidity
Centrifuge Size		
Diameter (in)	20.5	Model D5LL
Operating Speed (rpm)	3,200	
Force (G)	2,976	
Overall Length (in)	180	
Overall Width (in)	52	
Overall Height (in)	62	

Pre-Treatment Building

The approach to covering and sheltering low-pressure membrane systems varies widely from region to region within the United States. In northern climates, it is typical to build all of the process tankage indoors, while in regions of California and Florida, it is typical to provide only roofs or sun shades above the major tankage, with rotating process equipment usually housed in a mechanical/process building. For the purposes of this feasibility study, it is assumed that all process equipment and tankage associated with the low-pressure membrane system is housed indoors.

The Pre-Treatment Building will serve several functions in addition to housing the low-pressure membrane process. For this particular application, a total layout of 200 feet wide by 160 feet long is required to house the pre-treatment train. All chemicals that are added in the pre-treatment will be housed in the Chemical Storage Area and Chemical Rooms, with the exception of sodium hypochlorite, which will be fed throughout the plant from the Pre-Treatment Chemical Building. In addition to housing treatment chemicals such as ferric chloride and coagulant aid, bulk storage for membrane cleaning chemicals is also provided. Based on code requirements, appropriate isolation and containment will be provided for each chemical.

Water will flow from the intermediate clearwell into the intermediate pump station inside the Reverse Osmosis Building. Intermediate pumps will pressurize the water through the cartridge filters and provide adequate suction head to the high pressure reverse osmosis feed pumps. Permeate from the first and second pass skids will blend in a common header and then be conveyed to the UV Disinfection Building for the beach well alternative or directly to the disinfection contactor and finished water storage. After disinfection and storage, the water will be conveyed back to the Reverse Osmosis Building into the Finished Water Pump Station, where it will be pumped offsite to the distribution system.

The Pre-Treatment Building also houses mechanical and electrical rooms, as well as a control room and restrooms.

Area Requirements for Pre-Treatment Option 3

Table 4-3.1.4-4 Area Requirements for Major Unit Processes – Option 3

Facility	Length (ft)	Width (ft)	Diameter (ft)	Footprint (sq ft)
Flash Mix, Flocculation & Membrane Treatment	200	160		32,000
Residuals Equalization Tank & Residuals Transfer Pump Station	70 15	70 20		4,900 300
DensaDeg Clarifier/Thickeners	55	40	1 group	2,200
DAF Floated Solids & Thickened Sludge Equalization Tank	30	30		900
Centrate Pumping, Thickened Sludge Pumping and Dewatering Building	45	45		2,025
Total Square Feet Required for Process Components				42,325

3.1.5 Pre-Treatment Train Option 4 – Bank Filtration

If bank filtration is selected as the seawater intake option, the water will undergo significant treatment during travel through the natural sediment prior to reaching the raw water pump station. It is projected that additional turbidity and organics removal would not be required under these conditions. Therefore, only cartridge filters and pH adjustment are proposed upstream of the reverse osmosis desalination process. Because of the limited disinfection credit of the bank filtration alternative, ultraviolet disinfection is included after desalination to address pathogen disinfection, in addition to a chemical disinfection contactor. Additional information regarding these unit processes is contained in *Section 3.3*.

Design criteria for the selected bank filtration alternative are contained in *Table 4-3.1.5-1*.

Table 4-3.1.5-1 Ranney Type Well Design Criteria Summary

Design Criteria	Units	Value
Type of Beach Well	-	Ranney Type
Number of Caissons	No.	7
No. of Backup Wells	No.	0
Capacity, Each	mgd	8
Capacity, Total	mgd	55
No. of Pumps per Caisson	No.	1+1
Size of Pumps, Each	mgd	8
Pump Station Cap., Firm, Each	mgd	8
Assumed Pump Head	ft	40
Assumed Pump/Motor Eff.	%	70
Operating Pump Station Horsepower	Hp	80
Total Pump Stations Horsepower	Hp	560

3.2 Reverse Osmosis

Today, membrane manufacturers produce a myriad of membranes with various configurations and materials to suit specific water applications. Applications include industrial, municipal/potable, seawater desalination, ultra pure, and commercial. Once the application is identified, the next step is to match the manufacturer's product with the application. *Table 4-3.2-1* shows the high pressure membrane options available and their application.

Nanofiltration (NF), also known as a softening membrane, is typically used for the removal of larger molecular weight dissolved constituents, such as hardness and organics. Pore sizes of NF membranes are typically about 0.001 um, or 1 nanometer. Reverse osmosis (RO) membranes are typically used to remove smaller molecular weight dissolved constituents, such as monovalent ions.

Table 4-3.2-1 Membrane Options

Membrane Type	Application
Nanofiltration	Hardness removal, organics removal
Reverse Osmosis	Total dissolved solids reduction, inorganic ion removal, and removal of synthetic organic chemicals

The different membrane types may be used in various combinations to achieve the final desired water quality.

RO membranes may be further categorized by the water quality being treated. Water with salt concentrations between 250 and 10, 000 mg/l is generally considered brackish water. Water with salt concentrations greater than 10,000 mg/l is generally considered seawater. Feed pressures for brackish water membranes are typically less than feed pressures for seawater membranes. Brackish water RO pressures range between 125 to 300 psi for low-pressure applications and between 350 to 600 psi for standard applications. Seawater RO pressures range between 800 to 1,200 psi.

3.2.1 Water Quality Performance Criteria

Since a site has not yet been selected for the treatment plant, final feedwater quality has not been selected. However, after reviewing seawater quality and groundwater blending options, it was decided to select a feedwater total dissolved solids maximum of 35,000 mg/l for the base alternative. During subsequent project implementation steps, once a site has been selected, it is recommended to perform a significant source water quality evaluation to confirm anticipated water quality parameters. *Table 4-3.2.1-1* lists the RO feedwater assumptions that were used as a preliminary projection for the RO design. This water analysis is a result of an ion balance by the Hydranautics membrane program, *RO Systems Design Software*, Ver. 7.00, which was used in this study to develop the RO system design. Water analyses currently available have not had the test parameters required for a complete ion analysis; therefore, a typical seawater analysis was used. This will need to be modified based on the specific water source identified during future project implementation steps.

3.2.2 Membrane Selection

One of the tools needed to properly select the correct membrane system for the application is a membrane/water projection model. Several membrane manufacturers offer a software program for performance projection, including Hydranautics and FilmTec Corporation. A feedwater analysis is required for the program to project final product water quality. An estimated water analysis may be used for preliminary projections, but water analyses must be performed to predict possible problems such as membrane fouling.

Different membranes and configurations were used on the Hydranautics membrane program to find the best water quality for the least amount of capital and operating costs. A single pass RO system consisting of only seawater membranes could not consistently meet the maximum TDS level of 300 mg/l at all temperature conditions. Brackish water and softening membranes are often used in

Table 4-3.2.1-1 RO Feedwater Analysis and Permeate Goals

Parameter	RO Feedwater	Permeate Goal
Temperature	10 - 30°C	
pH	8.0	
Conductivity	48,000 uS/sec	
Total Dissolved Solids	35,000 mg/L[1]	300 mg/l
Calcium	410 mg/l	
Magnesium	1,300 mg/l	
Sodium	10,800 mg/l	
Potassium	390 mg/l	
Barium	0.05 mg/l	
Strontium	13.6 mg/l	
Iron	<0.3 mg/l	
Bicarbonate	117 mg/l as $CaCO_3$	
Carbonate	27 mg/l as $CaCO_3$	
Sulfate	2,713 mg/l	
H_2S	0 mg/l	
Chloride	19,440 mg/l	
Fluoride	1.3 mg/l	
Nitrate	0.5 mg/l	
Silica	2.1 mg/l	
SDI	<5	

[1] – Maximum based on ability to blend with groundwater when TDS above 35,000 mg/l

conjunction with RO membranes to meet the target water quality. A two-pass RO system with seawater membranes in the first pass and brackish water membranes in the second pass was selected for initial evaluation since the finished water quality goals could not be met with a single pass RO system with SWC3+ membranes. The two-pass system is essentially one pressurized membrane system followed by another pressurized membrane system.

Hydranautics offers several seawater membranes, with the SWC3+ being used for this analysis. See *Table 4-3.2.2-1* for a list of the seawater and brackish water membrane specifications used in the Hydranautics projection program.

3.2.3 RO Sizing and Configuration

Figure 4-3.2.3-1 provides a drawing of a generic reverse osmosis skid. A number of factors were considered to determine the skid size. These included skid piping size, relatively low number of

Table 4-3.2.2-1 Desalination Membrane Specifications

Hydranautics Membrane Model	Nominal Production (gpd)	Rejection (%)	Element Type	Size (inches)
SWC3+	7,000	99.8	Seawater Spiral Wound Polyamide	8.0 x 40.0
ESPA2	9,000	99.6	Brackish Water Spiral Wound Polyamide	8.0 x 40.0

skids, and other existing or proposed desalination plants. Five projected RO skids are required to produce 25 mgd, with each skid producing up to 5 mgd. See *Table 4-3.2.3-1* for RO process design criteria. The RO system was designed to meet performance criteria during all conditions throughout the life of the membranes. Therefore, the design was performed at a 3-year membrane age, a flux decline of 7 percent per year, and a salt passage increase of 10 percent per year.

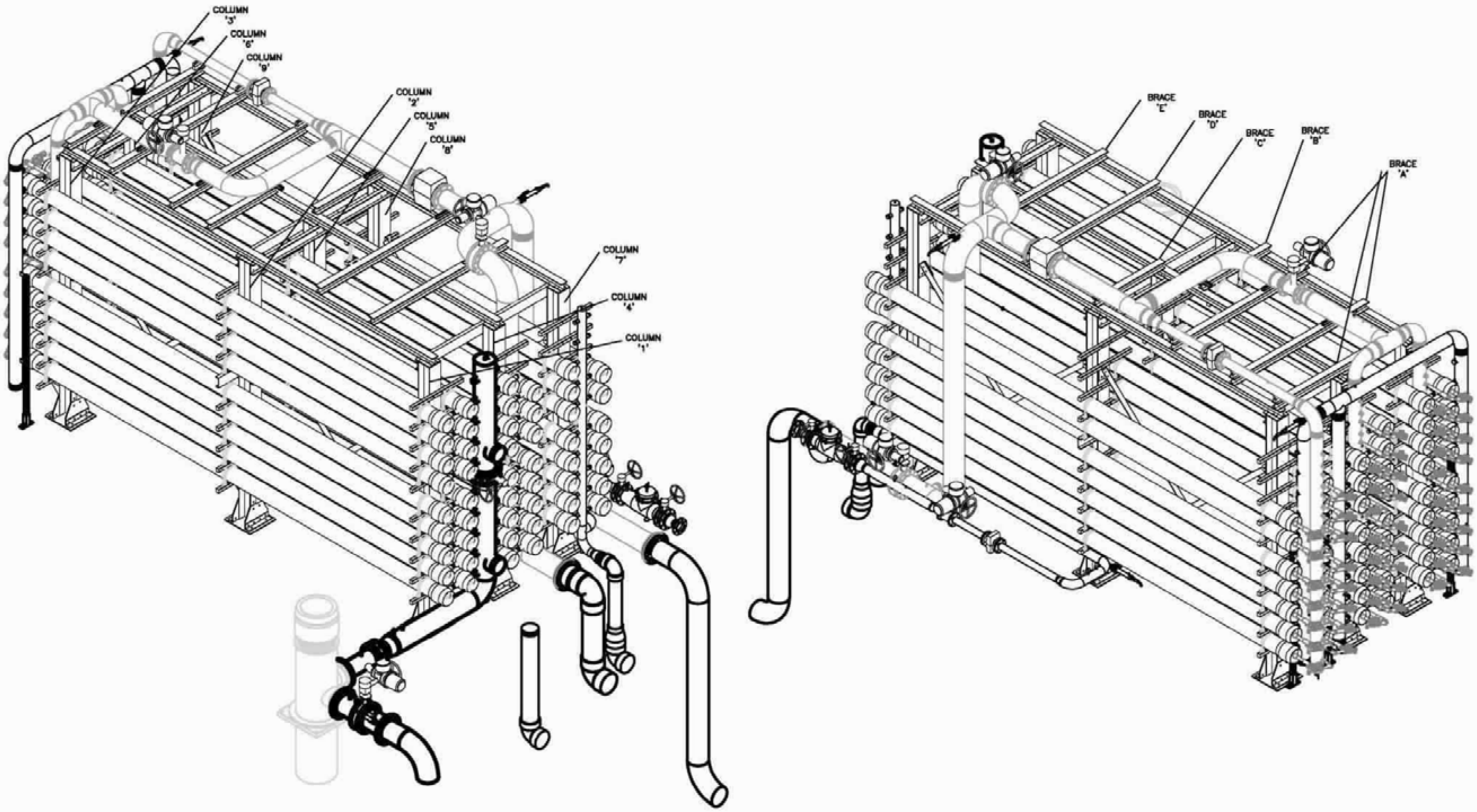

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FIGURE 4-3.2.3-1

GENERIC REVERSE OSMOSIS SKID DRAWING

SCALE: NONE	3/16/04	C. BENZIGER	SK–12

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The proposed RO system consists of two passes. See *Figure 4-3.2.3-2* for the RO configuration. The first pass system consists of one stage using Hydranautics RO membranes, SWC3+, while the second pass, which treats only a small portion of the first pass permeate, consists of two stages using Hydranautics nanofiltration membranes ESPA2. In the second pass, the byproduct or concentrate in the first stage feeds the second stage. The concentrate quality from the second stage is better than the raw feed quality, so it is directed back to the feed, upstream of the RO feed pump. This two-pass configuration uses the least amount of energy while projecting water quality that was consistently below the established maximum water quality limits at temperatures ranging from 10° to 30°C.

The maximum recovery available from the first and second passes of the RO membrane system was estimated at 50 and 90 percent, respectively. The total system recovery is 49.9 percent. The feed flow for one RO skid is 7,000 gpm. The permeate and byproduct flow from the first pass are both 3,500 gpm. The permeate from the first pass is split into two streams. The first stream goes directly as permeate at a flow rate of 3,300 gpm. The second stream is fed into the second pass at a flow rate of 200 gpm. The byproduct flow from the second pass will be returned to the feed stream of the first pass at a flow rate of 20 gpm.

The quality of the finished water is below the limit of 300 mg/l for TDS. At water temperatures of 10°, 20°, and 30°C, projected permeate TDS concentrations are 157, 214, and 285 mg/l, respectively. Byproduct concentration at 10°, 20°, and 30°C are projected at 70,175; 70,120; and 70,400 mg/l, respectively.

The feed pump pressure is nearly the same as the byproduct pressure at seawater feed temperatures of between 10° and 30°C. The maximum RO feed pressure of 1,000 psi occurs at the lowest temperature while the minimum RO feed pressure of 900 psi occurs at the highest temperature. At 20°C, the average flux rate across the first pass RO system is 8 gallons per square foot per day (gfd). The average flux rate across the two stages of the second pass is 26.4 and 5.1 gfd, respectively.

Table 4-3.2.3-1 Reverse Osmosis Design Criteria

Design Criteria	Value
Desalination Capacity – Feed (mgd)	50.1
Overall Recovery (%)	49.9
Permeate (mgd)	25
RO High Pressure Pumps	
Type	Horizontal Split Case
Number (on-line + spare)	5+1
Capacity, each (gpm)	7,000
Total Firm Capacity (gpm)	35,000
Pressure (psi)	1,000
Skid Capacity	
Feedwater Volume, gpm	6,964
Permeate Volume, gpm	3,472
Number of Skids	5
Number of Standby Skids	0
RO Skid Configuration – 1st Pass	Single Stage
Average Flux Rate (gfd)	8
Number of Pressure Vessels	225
Membrane Type	Seawater Composite, SWC3+
Number of Membranes per Vessel	7
Total Number of Membranes in 1st Pass	1,575
RO Skid Configuration – 2nd Pass, Partial Split	Two Stage
Feed Flow Rate (gpm)	200
Average Flux Rate (gfd)	17.4
Number of Pressure Vessels	5
Membrane Type	Brackish Water, ESPA2
Number of Membranes per Vessel	7
Total Number of Membranes in 2nd Pass	35
Entire RO Configuration	
Total Number of High-Pressure Vessels	1,125
Total Number of Seawater Membranes	7,875
Total Number of Medium-Pressure Vessels	25
Total Number of Softening Membranes	175
RO High-Pressure Pump Power Requirement	
Assumed Pump Efficiency, %	85
Assumed Motor Efficiency, %	95
Max. Estimated Skid Power (Hp)	5,075
Total Max. Estimated RO System, without Energy Recovery Devices (Hp)	25,375
Total Estimated RO System Power Draw, without Energy Recovery Devices (MW)	18.9

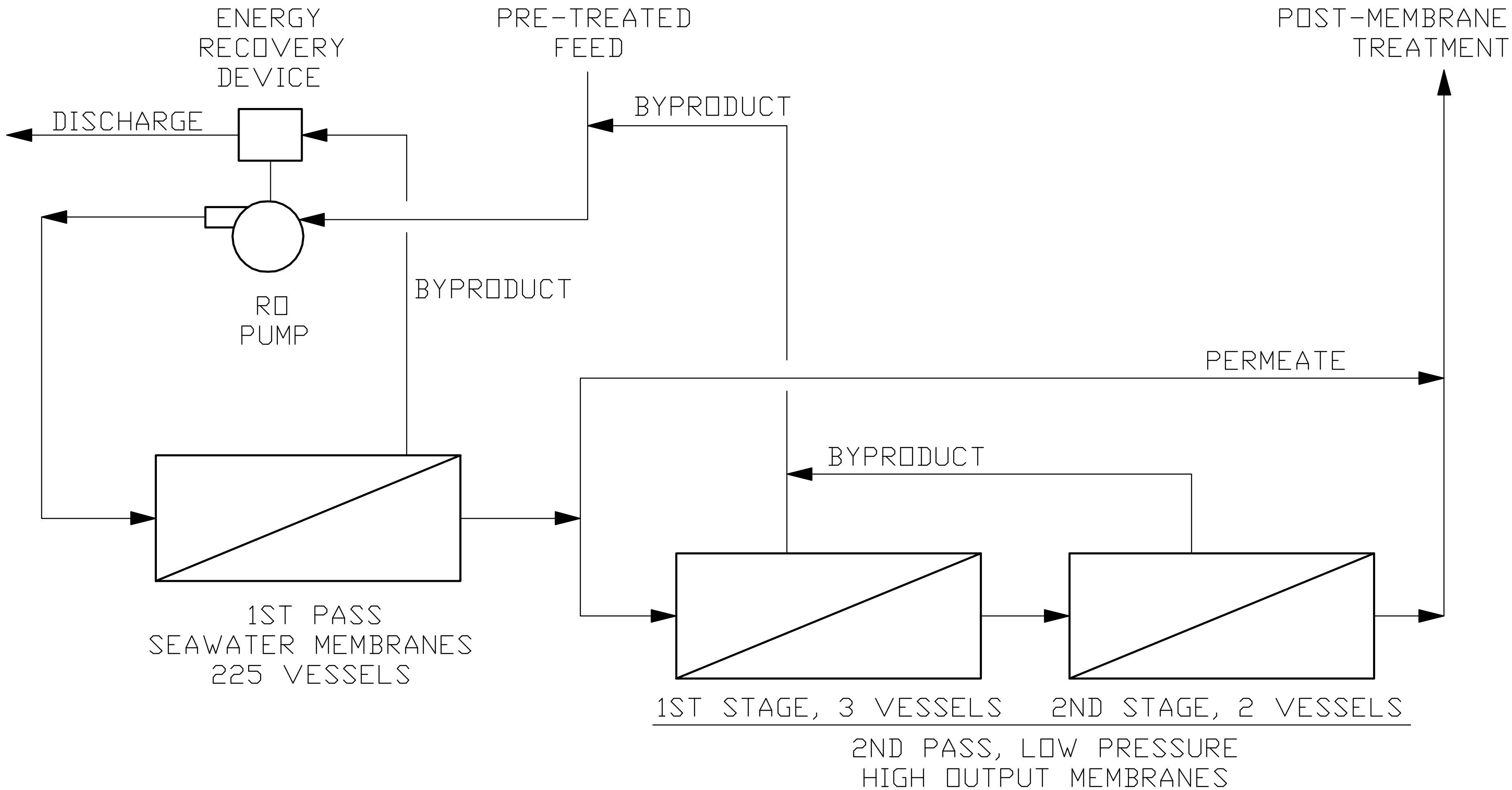

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FIGURE 4-3.2.3-2
REVERSE OSMOSIS SCHEMATIC

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The first pass RO skid consists of 225 high-pressure vessels and 1,575 seawater membranes. The second pass RO consists of 5 medium-pressure vessels and 35 brackish water membranes. The entire 25-mgd first pass system consists of a total of 1,125 high-pressure vessels and 7,875 membrane elements. The entire second pass system consists of a total of 25 medium-pressure vessels and 175 brackish water membrane elements.

3.2.4 Power and Energy Recovery

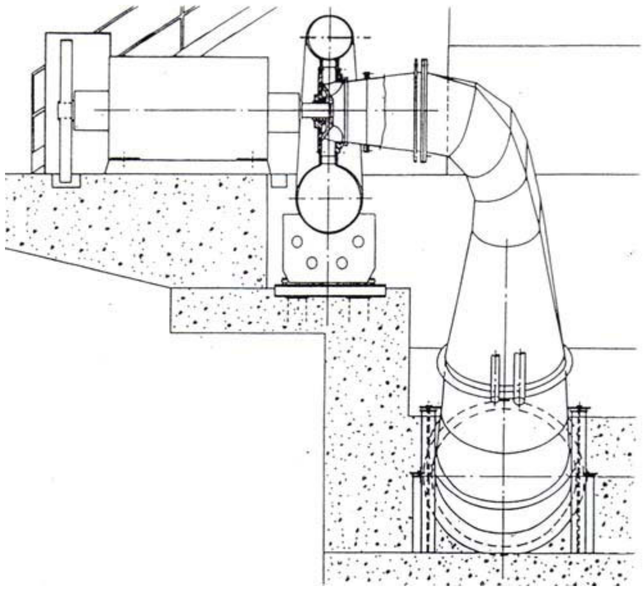
Feed temperature has a significant effect on the treatment efficiency of the RO system. System modeling was performed at temperatures ranging from 10° to 30°C. At the lower temperatures, water quality is typically better, but more energy is required to operate the system. This is the worst-case power required. At higher temperatures, water quality is still excellent, but residual ion values are higher. However, at the higher temperatures, less energy is required to operate the system. An average temperature of 20°C has been assumed for power usage calculations. The estimated power requirement for the RO skid feed pump is 5,075 Hp. See *Table 4-3.2.3-1, RO Process Design Criteria,* for power information. If all skids are in operation without energy recovery devices, the estimated maximum power draw for the RO system is 18.9 MW, with an average power draw of 17.7 MW.

The power requirements can be reduced by taking into account the residual pressure in the waste byproduct stream from the first pass. There are now a variety of commercially available choices that allow energy recovery from the byproduct stream to reduce electrical pumping costs. These include the reverse running pump (Francis turbine), the Pelton wheel turbine, the hydraulic turbocharger, work exchanger, and pressure exchanger. Each of these devices operates on a slightly different concept. Some operate with no moving parts, others with one or many moving parts. Efficiencies also vary between the devices. A brief review of the options is presented below for application on this project and an energy recovery device is recommended.

Francis Turbine

In the Francis turbine, water enters the turbine runner with a radial velocity component and discharges with an axial velocity component like a reverse-running pump. Francis turbines are distinguished by having a band, which surrounds the peripheral end of the blades (also known as buckets), providing a boundary for the water passage and structural rigidity to the runner. Francis turbines are direct coupled to the feed pump and must be designed for specific operating conditions. The result is changes in flow and pressure that must be by-passed around the unit, lowering recovery efficiency. A basic Francis turbine layout is shown in *Figure 4-3.2.4-1.*

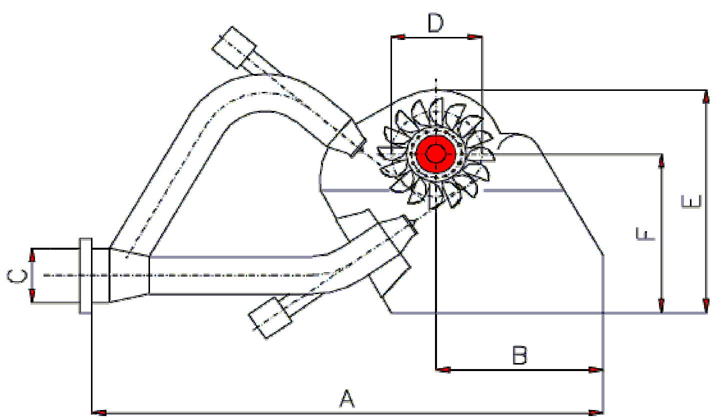
Figure 4-3.2.4-1   Francis Turbine Diagram



Pelton Wheel

The Pelton wheel turbine operates by converting the velocity energy from a byproduct stream into kinetic energy. Nozzles aim the pressurized concentrate stream toward the Pelton wheel. The rotating wheel converts the energy to assist the electric motor in driving the high pressure feed pumps. Up to 90 percent of the byproduct energy can be recovered using this device; however, the initial capital cost is relatively high, since it must be incorporated into the feed pump. *Figure 4-3.2.4-2* shows a schematic of a Pelton wheel.

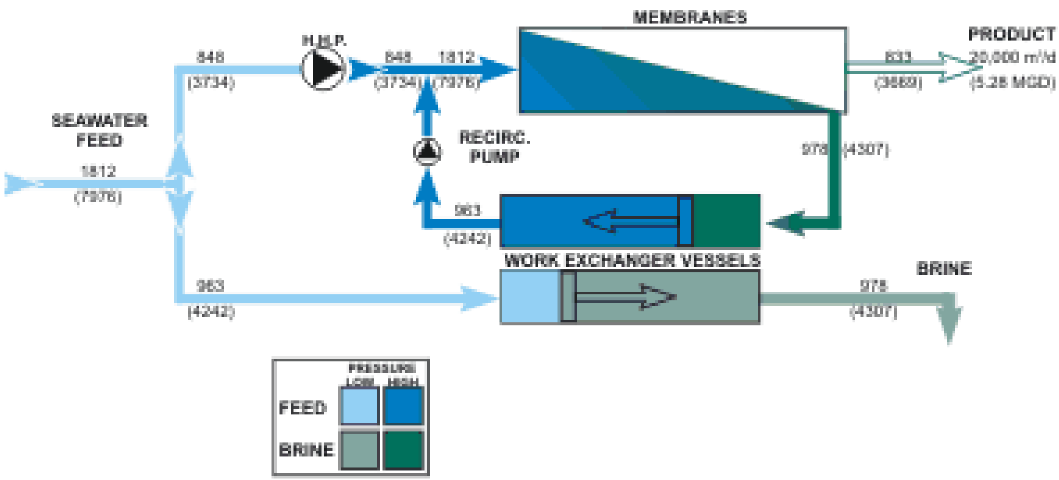
Figure 4-3.2.4-2   Pelton Wheel Schematic



Work Exchanger

A relatively new energy recovery device called the work exchanger has been developed. The high-pressure byproduct is directed to a work exchanger vessel filled with seawater and pressurizes that seawater to byproduct pressure. A small re-circulating pump boosts the seawater exiting the work exchanger vessel to equal the feed pump pressure and joins the flow to the membranes. This allows the feed pumps to pump only an amount equal to the permeate flow. Efficiencies of the work exchanger piston system can be 95 percent or higher, more efficient than centrifugal designs that rely on shaft conversion of power. *Figure 4-3.2.4-3* shows a typical work exchanger flow diagram.

Figure 4-3.2.4-3 Work Exchanger Typical Flow Diagram



Pressure Exchanger

A pressure exchanger transfers byproduct pressure energy directly to a portion of the incoming feedwater. A booster pump then makes up the hydraulic losses through the system to reach the required feed pressure. This seawater stream then joins the feed from the high pressure feed pumps. The pressure exchanger has a single moving part, a shaftless ceramic rotor, which is suspended within a sleeve. *Figure 4-3.2.4-4* shows a picture of a pressure exchanger installed on an RO skid.

Figure 4-3.2.4-4 Pressure Exchanger Installation (MacHarg)

Energy Recovery Design Criteria

Each of the energy recovery devices offers advantages and disadvantages. However, selection of a device and the power recovery associated with it are sensitive to actual operating conditions. Slight variations in pressure, flow, recovery, and other parameters can significantly affect performance of the devices. Because of the generally high recovery rates and simplicity of the device, for the purposes of this study the work exchanger from DWEER has been selected. Once desalination system design has been further refined, a review of the alternatives should be performed again.

In theory, the device should be able to recover 100 percent of the energy of the byproduct stream. However, during operation there is a pressure drop as the feedwater flows from one end of each pressure vessel to the other. Therefore, the pressurized feed from the work exchanger cannot be fed directly into the main feed flow without a small booster pump to make up the difference. In addition, the piston that transfers the energy from the byproduct stream to the feed stream is not 100 percent efficient, so some energy is lost during this operation as well. A small amount of byproduct transfers into the feedwater, also slightly lowering the efficiency.

To calculate the energy savings for the work exchanger, the following equation can be used (Moch et al., date unknown).

Net Energy Consumed = HPP Energy + Booster Pump Energy

HPP Energy = (C) [1 + (% Leakage)(1- Conversion)(1/Conversion)] (Feed Pressure – Pump Inlet Pressure) (1/HPP Efficiency) (1/ Motor Efficiency) (1/Motor/HPP Coupling Efficiency)

Booster Pump Energy = (C) (1 - % Leakage) (Membrane dP + pipe dP + ERD dP) (1/Booster Pump Efficiency) (1/Booster Pump Motor Efficiency) (1/Booster Pump/Motor Coupling Efficiency) (1 – Conversion) (1/Conversion)

Where C = 0.007248 for energy in kWh/1,000 gal product with pressure in psig.

The following equation variables have been assumed

Leakage = 2.5%
Feed Pressure = 900 psi
HPP Efficiency = 85%
HPP Coupling Efficiency = 100%
Pipe dP = 5 psi
Booster Pump Efficiency = 85%
Booster Pump Coupling Efficiency = 100%
Conversion = 50%
Pump Inlet Pressure = 5 psi
HPP Motor Efficiency = 95%
Membrane dP = 13.7 psi
ERD dP = 2%
Booster Pump Motor Efficiency = 95%

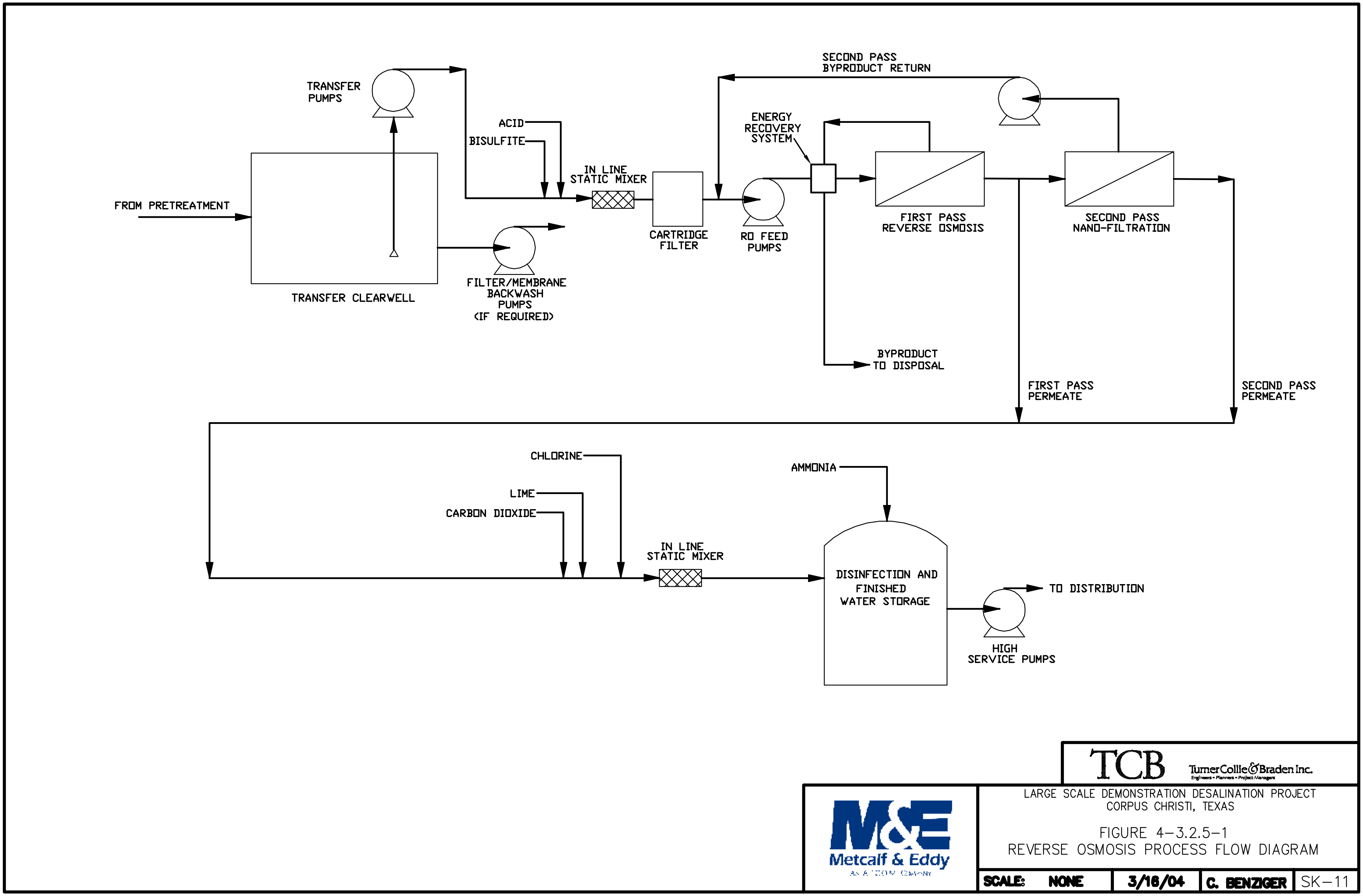
This results in the total energy consumed equaling the high-pressure pump energy (8.1 kWh/kgal produced) plus the booster pump energy (0.2 kWh/kgal produced) or a total of 8.3 kWh/kgal produced. Without energy recovery, the system would require 16.3 kWh/kgal produced, based on the system design criteria contained in *Table 4-3.2.3-1*. This results in an estimated energy savings of approximately 49 percent. Energy recovery device design criteria are contained in *Table 4-3.2.4-1*.

Table 4-3.2.4-1 Energy Recovery Device Design Criteria

Design Criteria	Value
Energy Recovery Device	Work Exchanger
Energy Required Without ERD, kWh/kgal produced	16.3
High-Pressure Pump Energy with ERD, kWh/kgal produced	8.1
Booster Pump Energy with ERD, kWh/kgal produced	0.2
Total Energy Required with ERD, kWh/kgal produced	8.3
Energy Recovery, %	49
Max. Estimated Skid Power w/o ERD (Hp)	5,075
Total Max. Estimated RO System, without Energy Recovery Devices (Hp)	25,375
Total Estimated RO System Power Draw, without Energy Recovery Devices (MW)	18.9
Max. Estimated Skid Power with ERD (Hp)	2590
Total Max. Estimated RO System, with Energy Recovery Devices (Hp)	12,950
Total Estimated RO System Power Draw, with Energy Recovery Devices (MW)	9.64

3.2.5 Membrane Pre-Treatment

The following text describes the proposed treatment upstream of the reverse osmosis (RO) desalination process. The desalination process flow diagram can be seen in *Figure 4-3.2.5-1*.



P:\CCCDESAL\321399DESAL\DWGS\FIG43251.dwg ; November 16, 2004 ; 2:15pm

Intermediate Clearwell and Pump Station

Following any of the possible upstream treatment methods described in *Section 3.1* and prior to the reverse osmosis treatment, the water will be stored in an intermediate clearwell. The clearwell will serve three main functions: (1) serve as a wet well for the low pressure desalination feed pumps, (2) serve as a wet well for pre-treatment backwash processes for granular media filters or ultrafiltration, and (3) provide the ability to dampen the effects of flow variations between the upstream pre-treatment process and the downstream desalination process. Those pre-treatment processes that include granular media filters are significantly impacted by plant flow changes. The RO process also operates most efficiently at constant flow set points. Because minor variations in flows through the plant will be common, an intermediate clearwell will provide storage to make up the difference in upstream and downstream flows, dampening the difference and allowing less frequent changes to unit process flows. Design criteria for the intermediate pump station are contained in *Table 4-3.2.5-1*.

The clearwell will consist of two aboveground prestressed concrete storage tanks providing a total of 120 minutes of detention time at plant capacity. The tanks would normally both be on-line; however, one could be taken out of service for inspection and maintenance while the other tank remains in service. Each tank would hold 1,125,000 gallons and would be 100 feet in diameter and 20 feet high. Depending on upstream hydraulics, dimensions could be modified to reduce footprint by increasing tank height. A sodium hypochlorite optional feed point would be provided at the inlet to the tanks to provide the ability to shock chlorinate the tanks.

An intermediate pump station would be located adjacent to the tanks to convey water from the clearwells to the RO Building. Design criteria for the pump station are shown in *Table 4-3.2.5-1*. Five split-case centrifugal pumps, plus one standby, would be provided with a capacity of 7,000 gpm each, for a total station firm capacity of 35,000 gpm and a discharge pressure of 20 psi to allow sufficient pressure to feed the cartridge filters.

Dechlorination

While continuous chlorination through the pre-treatment process is not proposed, scheduled “shock” chlorine treatments are anticipated. Hypochlorite application points will be finalized during detailed design and may be included at rapid mix, on top of the filters or membranes, and in the intermediate wet well. Residual chlorine in the feedwater must be removed to protect the integrity of RO membranes made of polyamide material. Each membrane manufacturer has determined its membrane’s tolerance level for chlorine. Dechlorination may be accomplished by using sulfur dioxide gas, activated carbon, or sodium bisulfite (or sodium metabisulfite). Sodium bisulfite is recommended for this RO plant due to its cost and availability.

Table 4-3.2.5-1 lists the design criteria for the dechlorination equipment. Metering pumps will be used to inject the solution at the discharge of the intermediate low-lift pumps and ahead of an in-line static mixer.

Table 4-3.2.5-1 Membrane Pre-Treatment Design Criteria

Unit Process	Value
Desalination Capacity – Feed (mgd)	50.1
Overall Recovery (%)	49.9
Permeate (mgd)	25
Intermediate Clearwell	
Type	Above-ground Pre-stressed Concrete
Number	2
HRT (min)	120
Capacity, each (gal)	1,125,000
Total Capacity (gal)	2,250,000
Dimensions, each (dia. ft)	100
Water Depth (ft)	20
Intermediate Low-Lift Pump Station	
Type	Horizontal Split Casing
Number (service+standby)	5+1
Capacity, each (gpm)	7,000
Total Firm Capacity (gpm)	35,000
Pressure (psi)	20
Pump Station Horsepower	500
Pre-Treatment	
Dechlorination System	
Estimated Cl_2 Residual (mg/l)	1.5
Sodium Bisulfite Dosage (mg/l)	2.2
Usage (lbs/day)	920
38% $NaHSO_3$ Sol’n Usage (gal/day)	210
Day Tank Volume (gal)	500
Bulk Tank Volume (gal)	7,500
Sulfuric Acid Feed System	
Dosage (mg/l)	16
Usage (lbs/day)	6,680
96% H_2SO_4 Usage (gal/day)	455
Day Tank Volume (gal)	500
Bulk Tank Volume (gal)	15,000
Cartridge Filters	
Flow Rate (mgd)	50.1
Max Surface Area per Vessel (ft^2)	500
Max Loading Rate (gpm/ft^2)	3
Filter Area Required (ft^2)	11,798
No. of Vessels Required	25
Flow Rate per Vessel (gpm)	1,475

Pre-pH Adjustment

Acid is typically added to the RO feedwater to increase the solubility of some slightly soluble salts, such as calcium carbonate, which cause membrane scaling. The pH of the seawater is approximately 8.0. The feedwater must be adjusted to a pH of 7.7 or lower according to the Hydranautics RO program to be below the Langelier Saturation Index for carbonate in the concentrate stream. Modeling indicated that scale inhibitor is not required, due to the low recovery rate.

Sulfuric acid will be used to reduce the pH of the feedwater. *Table 4-3.2.5-1* lists the design criteria for the acid equipment under the heading, Sulfuric Acid Feed System. Metering pumps would be used to inject the acid into the low-lift pump discharge and ahead of a static mixer. A dose of 16 mg/l is required to achieve the required pH adjustment, and 96 percent sulfuric acid has been assumed. With this feed rate and concentration, a 500-gallon day tank and 15,000-gallon bulk tank would be provided for storage. Three metering pumps, two on-line and one standby, would be provided to achieve the anticipated dose range. Approximately 5 mg/l of alkalinity as $CaCO_3$ will be converted to CO_2, which will pass through to the permeate.

Cartridge Filters

The last pre-treatment units immediately upstream of the RO system are cartridge filters, which act as fine filters to trap silt and other particles that can foul the membranes. These cartridge filters are nominally rated from 1 to 25 microns. Cartridge filters nominally rated for 5 microns are recommended for the RO system. *Table 4-3.2.5-1* lists the design criteria for the cartridge filters. The maximum loading rate will be 3 gallons per minute (gpm) per square foot. Twenty-four cartridge filter housings are required for the operation of a 25-mgd plant.

Cartridge filters should be changed once per month. Spent filters should be disposed in an approved landfill area. No spare cartridge filter housings or redundant cartridge filter trains are required since downtime for maintenance on the vessels is minimal. During change out of the cartridge filters, one vessel would be taken off-line at a time. After the new cartridges have been installed in one vessel, it is returned to service. The process is repeated for the remaining vessels.

3.2.6 Membrane Post-Treatment

The seawater treated by the two-pass RO system is now essentially potable water, but it must be conditioned further for pH and corrosion control and then disinfected. Fluoride is an optional additive that promotes dental health; it will be discussed as a recommended additive. The following chemicals and treatment systems would be added after the membranes:

- Lime and carbon dioxide for pH/alkalinity/hardness control
- Sodium hypochlorite for disinfection
- Hydrofluorosilicic acid for fluoride addition
- Ammonia for formation of chloramines

The pH of the seawater is approximately 8.0. During RO pre-treatment, acid was added to reduce the seawater pH. After RO treatment, the permeate stream was projected to have an acidic pH of approximately 5.7. In addition, almost all of the alkalinity was removed through the RO process. The only portion of the carbonate system that passes through the membrane is CO_2. Because significant pH depression was not required to prevent scaling, only minimal alkalinity was transformed to CO_2. Therefore, to stabilize the potable water for the distribution system, the pH must be raised and alkalinity and hardness added. To match current operating procedures of Corpus Christi WTPs, a separate corrosion inhibitor, such as a phosphate-based corrosion inhibitor, will not be added. It is proposed to use both lime and carbon dioxide to achieve a pH of approximately 8.0, and an alkalinity and hardness of at least 40 mg/l as $CaCO_3$. To model the impact of post-treatment chemicals, the Rothberg, Tamburini & Winsor, Inc. (RTW) water chemistry model was used. This model calculates the impact of chemical addition on water quality parameters.

Two forms of lime are typically available, pebble (quick) lime and hydrated lime. While pebble lime is typically less expensive, it must first be slaked prior to application, which increases the complexity of operations and maintenance. Therefore, hydrated lime has been selected for this application. To meet the alkalinity and hardness goals, approximately 30 mg/l of hydrated lime will be added based on RTW modeling.

The 30 mg/l of hydrated lime (see *Table 4-3.2.6-1*) will produce a finished water pH that is higher than the pH finished water goal of 8. Therefore, liquefied carbon dioxide (CO_2) will be used to reduce the pH to the desired range. Carbon dioxide mixes with water to form carbonic acid, a fairly mild acid which acts to reduce pH. RTW estimates that approximately 31 mg/l will be required to obtain a pH of approximately 8. With the addition of lime and carbon dioxide at the proposed doses, the Langlier Saturation Index is approximately 0.

Carbon dioxide is delivered in the liquid form and stored in an insulated (cryogenic) storage tank. The storage tank is complete with the equipment necessary to maintain the liquid carbon dioxide at approximately 0°F, with non-freezing regulators and temperature gauges. A vaporizer changes the liquid carbon dioxide to a vapor. Carbon dioxide vapor for process use is withdrawn from the tank and passed through regulators, metering equipment and other accessories depending on the type of feed equipment used. *Figure 4-3.2.6-1* shows the process schematic of a liquid carbon dioxide feed system. Carbon dioxide is a non-hazardous, non-corrosive compound. *Table 4-3.2.6-1* shows design criteria for the pH, alkalinity, and hardness chemical feed systems.

Fluoridation

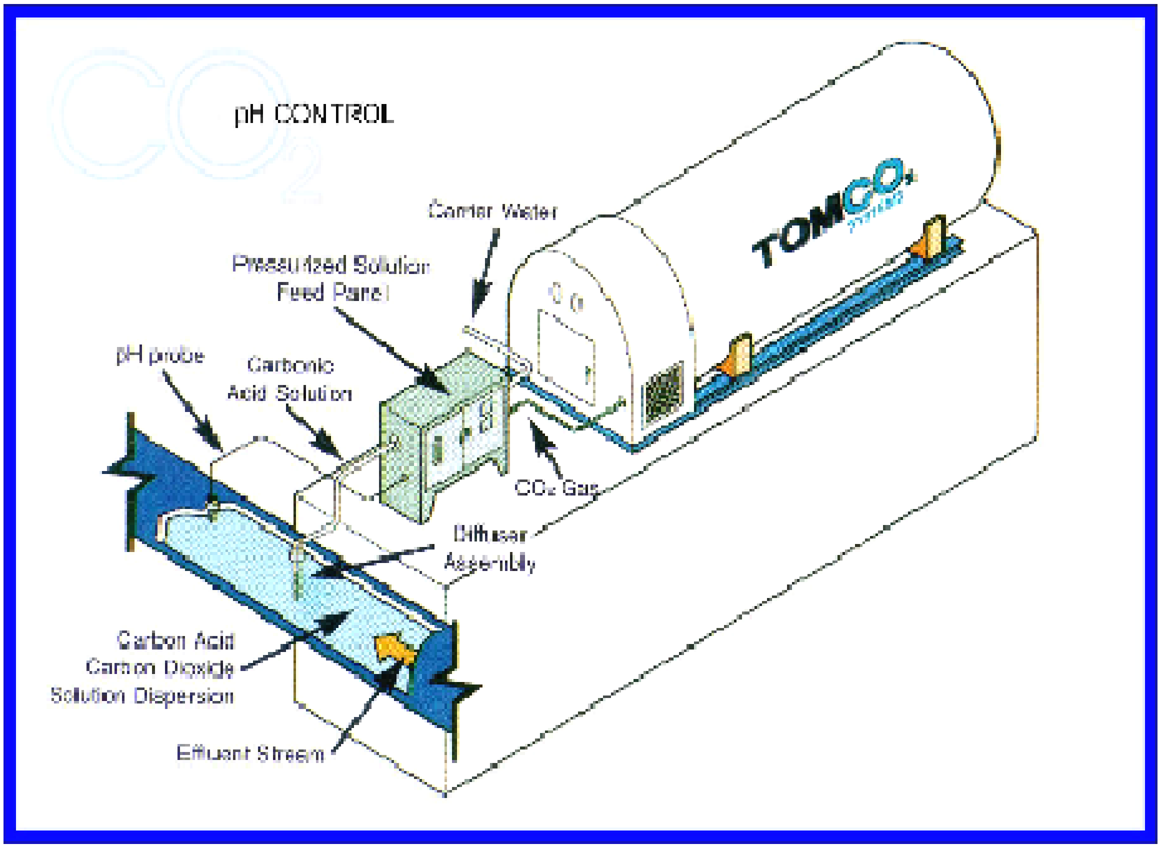
Fluoride is intentionally added to help prevent dental decay. In 1980, The American Dental Association established the optimum fluoride concentration to prevent dental decay at 1 mg/l. This dosage rate should not be raised any higher than 2 mg/l since it may adversely affect teeth cosmetically. Fluoride would be added between the RO process and the finished water pump station.

Table 4-3.2.6-1 Membrane Post-Treatment Design Criteria

Unit Process	Value
Desalination Capacity - Feed (mgd)	50.1
Overall Recovery (%)	49.9
Permeate (mgd)	25
Post Treatment	
Hydrated Lime	
Dose (mg/l)	30
Lime Requirement (lbs/day)	6,250
Min Required Silo Storage (lbs)	7,819
Minimum Lime Delivery Size (lbs)	40,000
Density (lb/cu ft)	35
Min. Silo Storage Capacity (cu ft)	1,200
Carbon Dioxide	
Dose (mg/l)	31
Usage (lbs/day)	6,900
Storage Size (tons)	50
Fluoride	
Dose (mg/l)	1
Hydrofluorosilicic Acid Concentration (%)	23
Usage (gph)	4.6
Day Tank Volume(gal)	150
Bulk Tank Volume (gal)	4,000
Chlorination (sodium hypochlorite)	
Dose (mg/l)	1.5
12.5% Chlorine Requirement (lbs/day)	104
12.5% Chlorine Requirement (gal/day)	361
Day Tank Volume (gal)	500
Bulk Tank Volume (gal)	11,000
Aqueous Ammonia	
Dose ratio to chlorine residual	0.33
Dose (mg/l)	0.33
Percent Concentration	30
Usage (lbs/day)	69
Usage (gal/day)	31
Day Tank Volume (gal)	50
Bulk Tank Volume (gal)	1,000

A liquid feed system using hydrofluorosilicic acid (H_2SiF_6) is proposed to feed an average of 1 mg/l. Hydrofluorosilicic acid is stored as a bulk liquid and is an extremely corrosive chemical (strong acid). See *Table 4-3.2.6-1* for fluoride process design data.

Figure 4-3.2.6-1 Carbon Dioxide Feed System



Chloramination

Current disinfection practice for the City of Corpus Christi is chlorination for primary disinfection and chloramination for secondary disinfection (distribution system residual). It is proposed to use bulk sodium hypochlorite for disinfection. The hypochlorite solution would be added after the RO process and ahead of a static mixer by dedicated metering pumps, as shown in *Figure 4-3.2.6-1*. After achieving suitable chemical disinfection, ammonia will be added at a ratio of 1 part ammonia to 3 parts chlorine to form monochloramines.

This practice limits disinfection byproduct (DBP) formation in the distribution system and matches the Corpus Christi finished water distribution system. See *Table 4-3.2.6-1* for post-treatment membrane process design criteria. A dose of 1.5 mg/l of hypochlorite is assumed to achieve a residual of 1 mg/l, since permeate chlorine demand should be minimal. Therefore, approximately 0.33 mg/l of ammonia will be added at the finished water pump station. Additional information regarding chemical disinfection design criteria is contained in *Section 3.3*, below.

3.3 Disinfection and Finished Water Storage

3.3.1 Disinfection Requirements

The Surface Water Treatment Rule (SWTR) establishes disinfection requirements for potable water supplies using surface waters as their source. In general, the rule requires removal/disinfection of 3-log of *Giardia* and 4-log of viruses, which can be achieved through various methods of treatment. In addition, the Interim Enhanced Surface Water Treatment Rule (IESWTR) requires a minimum of 2-log removal/disinfection of *Cryptosporidium* for large water systems (serving greater than 10,000 people). Both rules establish disinfection credit for unit processes throughout water treatment plants.

Well-operated conventional water treatment (coagulation, flocculation, sedimentation, and filtration) is typically credited with 2.5 log of *Giardia* and 2-log of *Cryptosporidium* removal. Low pressure membrane (UF and MF) processes are also typically granted this level of disinfection on a case-by-case basis. Lower levels of disinfection credit are typically given for other treatment methods, such as direct filtration (coagulation, flocculation, and filtration) and bank filtration. Chemical disinfection is typically used to make up the additional disinfection requirement for *Giardia* and the 4-log virus requirement.

Future regulations include the soon to be promulgated Long-Term (2) Enhanced Surface Water Treatment Rule (LT2 ESWTR), which will include a minimum 2.5-log *Cryptosporidium* disinfection requirement, but will increase the credit to 2.5 logs for well-operated conventional treatment plants. Additional disinfection requirements will be based on a risk-based matrix, determined by an extended source water sampling period for each source water supply. A variety of methods have been identified by US EPA for meeting any additional requirements for disinfection, since chlorine is not effective for disinfecting *Cryptosporidium*. US EPA anticipates over 1,000 plants will install UV disinfection to meet the rule's requirements across the United States.

When the SWTR and subsequent surface water disinfection rules were developed, seawater supplies were neither included nor excluded specifically from the regulations. The issue was first addressed publicly by US EPA in response to a question from the State of Alaska regarding potable water treatment requirements for an offshore oil rig. The response, indexed as EPA Water Supply Guidance (WSG) Document 66 issued in July 1991, indicates that in general, it was not the intention to classify seawater as regulated under the SWTR. The policy states that this is due to several reasons: (1) seawater is not generally affected by surface water runoff, due to depth and volume – the rate of dilution in seawater is much more substantial than freshwater, (2) pathogenic organisms are quickly inactivated due to high salt concentrations, and (3) the RO process used to desalt seawater achieves removal of microbes that greatly surpasses the requirements for surface waters.

The caveat to this finding, however, is that sources such as estuaries, river deltas, and inland salt lakes are not considered to be seawater, since they could be significantly impacted by freshwater runoff. These sources would need to comply with SWTR requirements. In December 1999 these findings were reiterated in WSG H-35.

Since the 1991 directive, little study has been performed regarding *Cryptosporidium* and *Giardia* efficacy in seawater. However, in contrast to US EPA's statements, these microbes have been shown to have some ability to survive for periods of time in seawater conditions. Robertson et al., (1992) showed longevity of oocysts in seawater. Fayer et al., (1998) tested *Cryptosporidium* parvum in laboratory simulated seawater conditions at 10, 20, and 30,000 mg/l at 20°C. Results indicated continued infectivity for 12, 8, and 4 weeks, respectively. Based on the findings of these two studies, it is apparent that more comprehensive research is required to better characterize pathogen survival in seawater, and ultimately develop a regulatory framework for potable water supplies.

Presently however, the seawater desalination facility developed for this project has been designed to meet all current surface water regulations. This is important to note for two reasons: (1) the final location of the seawater supply has not been determined, and therefore, the impact of surface water runoff cannot be quantified, and (2) potential requirements of the upcoming LT2 ESWTR are more stringent than the minimum disinfection levels and have not been considered, since the rule has yet to be promulgated and the occurrence of *Cryptosporidium* in the source water must be quantified to determine if additional disinfection will be required.

Based on this analysis, each treatment process being considered has been designed to meet 3-log *Giardia*, 4-log virus, and 2-log *Cryptosporidium* disinfection. As stated previously, each of the proposed process trains will achieve 2.5-log of *Giardia* and 2-log of *Cryptosporidium* disinfection credits, with the exception of bank filtration, which is assumed to achieve 1-log of each. The remaining disinfection requirements have been achieved through chemical disinfection, through contact with chlorine, as described below, in a chlorine contact and finished water storage tank.

3.3.2 Disinfection Contactor and Finished Water Storage Design

Prior to the finished water pump station, contact time must be provided for disinfection with sodium hypochlorite, discussed above, and on-site storage to allow the treatment plant to operate somewhat independently of the finished water pump station instantaneous flow. Disinfection requirements for seawater supplies are not specifically defined by current US EPA rules. Therefore, it has been assumed that the State would apply fresh surface water supply disinfection requirements to the seawater supply for this project. Disinfection requirements for the various treatment trains are shown in *Tables 4-3.3.2-1* and *4-3.3.2-2*. To meet the Surface Water Treatment Rule (SWTR) disinfection requirements for *Giardia* and viruses, the table also contains the required CT value for each process train considered. Based on a 1 mg/l free chlorine residual, the required detention time has been calculated based on US EPA CT Tables contained in the *Guidance Manual for Compliance with the Surface Water Treatment Rule.* This is based on a well-baffled storage tank, obtaining a T_{10}/T ratio of at least 0.7 and a 25 percent additional capacity for tank level variability with pumping.

Table 4-3.3.2-1 Chemical Disinfection Design Criteria

Design Criteria	Value
Low Temperature (°C)	5
High pH	8
Chlorine Residual (mg/l)	1
Clearwell Volume Operating Band (%)	25
T_{10}/T	0.7
Clearwell Storage Size, Min (% of capacity)	10

Table 4-3.3.2-2 Chemical Disinfection and Finished Water Storage Requirements

Criteria	Alternative 1 Tube Settlers	Alternative 2 DAF	Alternative 3 UF	Alternative 4 Bank Filtration
Additional *Giardia* Disinfection Required (log)	0.5	0.5	0	3
Additional *Giardia* CT Required (mg-min/l)	36	36	0	216[1]
Additional Virus Disinfection Required (log)	4	4	4	4
Additional Virus CT Required (mg-min/l)	8	8	8	8
Required CT (mg-min/l)	36	36	8	8
Theoretical HRT (min)	36	36	8	8
Required CT Volume (gal)	625,000	625,000	140,000	140,000
Minimum Clearwell Size (gal)	2,500,000	2,500,000	2,500,000	2,500,000
Total FW Storage (gal)	2,500,000	2,500,000	2,500,000	2,500,000

1 – Due to significant CT requirement, UV disinfection will be designed for 3-log *Giardia* and *Cryptosporidium* inactivation.

All of the proposed treatment trains will meet the required 2-log of *Cryptosporidium* disinfection/ removal from the Interim Enhanced Surface Water Treatment Rule (IESWTR) except the bank filtration (beach well) option. For this option, it is proposed to provide ultraviolet disinfection downstream of the desalination process to meet these requirements, as well as the additional 1.5-log of *Giardia* disinfection. A dose of 40 mJ/cm^2 is proposed to achieve inactivation of up to 3-log of *Cryptosporidium* and *Giardia* based on the most recent draft versions of the LT2 ESWTR and *US EPA UV Guidance Manual*. This dose may be modified in future project implementation steps based on discussions with the Texas Commission on Environmental Quality (TCEQ) after the final rule has been promulgated. Current draft requirements for design dose to achieve various log reductions in pathogens are contained in *Table 4-3.3.2-3*. Design criteria for the UV disinfection system proposed for this project are contained in *Table 4-3.3.2-4*.

Table 4-3.3.2-3 Draft LT2 ESWTR Log Inactivation Credit for LPHO UV Disinfection Reactors

Log Inactivation Credit	RED Target (mJ/cm^2)[1]		
	Cryptosporidium	***Giardia***	***Virus***
0.5	6.8	6.6	55
1.0	11	9.7	81
1.5	15	13	110
2.0	21	20	139
2.5	28	26	169
3.0	36	34	199
3.5	-	-	227
4.0	-	-	259

1 – RED for low-pressure high output reactors. RED for medium pressure reactors is slightly higher.
Source: US EPA 2003

Table 4-3.3.2-4 UV Disinfection System Design Criteria

Design Criteria	Units	Value
System Capacity	mgd	25
Target Dose	mJ/cm^2	40
Crypto & *Giardia* Log Reduction	log	3
Number of Reactors	online, standby	3+1
Reactor Capacity, Each	mgd	8.5

In addition to the chemical disinfection contact time provided, a criteria of 10 percent of plant flow has been set for finished water storage. The finished water storage has been designed based on the higher of the disinfection detention time or the storage criteria for each case, as shown in *Table 4-3.3.2-4*. Under all conditions, storage size was adequate to meet disinfection requirements. Therefore, for all options, two concrete circular tanks are proposed, each with a storage capacity of 1,125,000 gallons. Because residual pressure from the desalination process will be used to convey water to the tanks, there is no practical limit on tank height. Each tank will be 100 feet in diameter and 22 feet high. Each tank can be taken out of service for inspection and maintenance while the other tank is providing adequate storage and disinfection.

For the bank filtration alternative, a UV facility would be sized to treat up to 25 mgd of permeate immediately downstream of the RO process and prior to chemical disinfection and storage. It is estimated that a 50-foot by 50-foot building would be required to house the equipment and supporting electrical and instrumentation facilities.

3.3.3 Finished Water Pumping

After chemical disinfection and finished water storage, finished water will be pumped to the distribution system by the finished water pump station. The station is located within the RO Building and will consist of five pumps, each with a 6.5-mgd capacity, to provide a firm capacity of 26 mgd. Split-case centrifugal pumps are proposed due to their high efficiencies and access to the pump for inspection and maintenance. Pump sizing must be performed once final siting has been completed and distribution system characteristics are known. *Table 4-3.3.3-1* provides pump station design criteria based on assumed conditions.

Table 4-3.3.3-1 High Service Pump Station Design Criteria

Design Criteria	Value
Type	Horizontal Split Case
Number (N+1)	4+1
Capacity, each (gpm)	4,510
Total Firm Capacity (gpm)	18,000
Pressure (psi)	80
Assumed Pump Efficiency (%)	80
Pump Station Horsepower, Firm	1,050

3.4 Cooling Water Source Option

Design of the desalination system described above is based on a direct seawater intake or beach well with the accompanying anticipated water quality. However, one source option is to take cooling water from the Barney Davis Power Plant. This water would have similar characteristics to the direct seawater intake, with the exception of increased temperature. An additional impact of this water source is the increased salinity of the water, which is taken from Laguna Madre, a hypersaline area of seawater.

Both the increased salinity and the increased temperature would significantly impact the RO design described previously. Increases in feedwater temperature impact the RO process in two ways: (1) it reduces the water viscosity, and thereby the required feed pressure to operate at a given flux, and (2) it increases the rate of diffusion of dissolved constituents (i.e. salts) across the membrane, increasing TDS concentration of the permeate at a given flux. The increased salinity would act to increase the osmotic pressure and increase the rate of diffusion of salts through the membrane. It is, therefore, important to study the impact of this water supply option to determine whether it impacts the plant life cycle cost positively or negatively, due to the competing factors.

Based on historical operating information, records indicate a temperature increase due to the cooling process of 15° to 20°F from the source water, which is Laguna Madre. This would result in an average desalination plant feedwater temperature of approximately 30°C. Water quality records indicate an average TDS concentration of approximately 6,500 mg/l higher than Corpus Christi Bay, which averages 28,500 mg/l. Because of the higher salinity, blending with up to 10 mgd of groundwater at an anticipated TDS of 5,000 mg/l is not enough to meet a maximum 35,000 mg/l of TDS 100 percent of the time. The peak TDS concentration projected is 49,000 mg/l based on historical water quality data for Laguna Madre. At this concentration, blending reduces the TDS to only 43,100 mg/l.

Modeling was performed with the Hydranautics software used for the baseline alternative to determine the impact of the increase in temperature and TDS. Model results indicate that 380 gpm of first pass permeate would need to be treated by the second pass system, in comparison to the 190 gpm of second pass treatment required for the base alternative. Pressure at the higher TDS and temperature concentration increased from 893 psi to 1,063 psi for the first pass feed.

Cost implications of the cooling water intake include a cost savings due to an existing intake, and savings for byproduct disposal if the outfall can be used to blend the byproduct prior to discharge. However, additional costs will be realized due to the increased pressures required and the additional second pass treatment required, compared to the base alternative. While the capital cost increase would not be significant, the increase in required feed pressure due to the increased TDS of the feed is estimated to increase pumping costs approximately 20 percent.

4 DEVELOPMENT OF ALTERNATES

Consideration required for the development of a desalination facility, from the raw water intake through treatment, high-service pumping, and transmission has been described in previous sections of this chapter. Several options for each of these components are detailed. This section combines compatible options for each component to develop complete alternatives for detailed cost evaluation and discussion.

To be a complete and working system, each alternative must have a raw water intake, raw water pumping, a raw water pipeline, pre-treatment facilities, desalination facilities, high-service pumping, and transmission from the treatment plant site to the distribution system. In addition, each of the alternatives must be evaluated for both sites selected for detailed evaluation.

The sites for this evaluation were selected in *Chapter 3 – Site Selection*. Five sites were screened, but only two were selected for detailed consideration: the Barney Davis Power Plant site and the Oxychem site. All of the intake, treatment, and distribution options are conceptually identical for each site. The principal differences between the two sites are the pipelines necessary to provide water to and from the plant site.

4.1 Raw Water Source

The screening processes in the previous sections have identified the open sea in the Gulf of Mexico as being a likely raw water source because of the reliable and consistent water quality with a TDS concentration of 35,000 mg/l or less. The other potential raw water sources such as Laguna Madre, Oso Bay, and Nueces Bay routinely exceeded the 35,000 mg/l criteria or were subject to other significant water quality deficiencies. Corpus Christi Bay had reasonable average water quality but the shallow depth of the bay (14 feet maximum) was not considered to be adequate for a 55 mgd intake design. To be viable, a low profile intake system would have to be constructed in Corpus Christi Bay such as a bank filtration Ranney Well Filtration System as described earlier in this chapter. The Corpus Christi Bay intake is only applicable to the Oxychem Plant site.

Blending raw water with groundwater sources was also considered, but heavy pumping of the groundwater was determined to result in significantly high TDS concentrations. The increasing TDS concentrations that result from over pumping of the aquifer ultimately reduce benefits and increase costs as more and more wells are brought online to meet the raw water quality parameters. These issues resulted in the elimination of all potential raw water sources except the Gulf of Mexico.

In addition to the water quality issues identified, the elimination of the inland saltwater sources described above was also done to put all alternatives on an equal basis from the standpoint of reliability. Subsequent phases of the project for the development of a seawater source in the Corpus Christi area, should include an update screening of potential sources especially in Corpus Christi Bay near the Oxychem site.

The Laguna Madre appears initially to be a very convenient raw water source for a plant at the Barney Davis site. The Barney Davis Power Plant already has an intake, pumping facilities, and permit in place. Using the Barney Davis facilities would dramatically reduce the cost of the raw water supply portions of the proposed facilities. However, the raw water quality in Laguna Madre typically exceeds the desirable raw water quality standards for reverse osmosis treatment.

The Gulf of Mexico as a raw water source is compatible with all intake, treatment, and plant site options and will be carried forward in the development and evaluation of alternates. Corpus Christi Bay is compatible with Ranney Well Filtration Intakes and the Oxychem site. All other inland sea and groundwater source options, other than those noted above, are eliminated from further development.

4.2 Raw Water Intake

An open sea intake and several bank filtration intake options were presented in *Section 2* of *Chapter 4*. The bank filtration options were presented as less reliable due to potential clogging and more expensive than an open sea intake. However, incorporating a bank filtration option would eliminate the need for most, if not all, of the pre-treatment facilities at the plant site. Therefore, it was determined that the bank filtration option should be carried forward to determine the relative costs of bank filtration and an open sea intake with pre-treatment facilities. Further consideration of the bank filtration options will require detailed investigations into the available shoreline land area and a re-evaluation of the cost for procuring land or easements on the shoreline.

The intake options are closely related to the required pre-treatment facilities. The open sea intake options will require full pre-treatment while the bank filtration will only need minimal pre-treatment. Therefore, the bank filtration is both an intake and a pre-treatment component. However, for the sake of clarity, bank filtration is classified as an intake option for this report.

Although bank filtration does remove particulate matter effectively, supplemental disinfection is anticipated to be required. Therefore, for the alternates that include bank filtration, pre-treatment requirements will consist of ultraviolet radiation and related support facilities.

The intake capacity must be sufficient to supply the plant with enough flow to produce 25 mgd of treated water after all byproduct and residual streams are removed. With an anticipated maximum 10 percent loss of water through the pre-treatment facilities and a 50 percent recovery in the RO system, the required intake capacity is approximately 55 mgd. Even though Pre-Treatment Option 4 does not have a residuals stream, no credit is provided in the intake design to accommodate reduced capacity over time associated with clogging of the bank filtration media. Therefore, all intake designs are based on a 55-mgd capacity.

Two intake designs are carried forward in the development of this alternate. The open sea intake in the Gulf of Mexico is compatible with both treatment plant sites and with Pre-Treatment Option 1 (Tube Settlers), Pre-Treatment Option 2 (Dissolved Air Flotation), and Pre-Treatment Option 3 (Ultrafiltration). The Bank Filtration Intake option serves a dual function of both intake and pre-treatment. Although serving both functions, bank filtration is classified as an intake option for this report. As previously described, the bank filtration option is the only intake option compatible with the Corpus Christi Bay raw water source.

4.3 Raw Water Pipeline

The raw water line is the conveyance device between the raw water pump station and the pre-treatment facilities at the treatment plant site. Regardless of the source water supply, the pipe will be of the same diameter and materials. Therefore, the configuration of the raw water pipeline is dependent only upon the starting and ending points. Therefore, separate configurations are developed for each combination of raw water source and treatment plant site.

General routes for the proposed lines were chosen to maximize construction on land and minimize more costly underwater installations. Aerial photographs were used to develop conceptual alignments for the lines serving both sites. Maps were obtained from the Texas Railroad Commission that identified existing pipelines in the area. Alignments for the proposed lines were selected to avoid conflicts with known pipelines. In addition, alignments were chosen to minimize crossings of navigable waterways with large volumes of traffic such as the Intracoastal Waterway and Aransas Pass. Routes should be analyzed with regard to cost and non-economic impacts in subsequent phases of the project to determine a final alignment for the proposed lines.

The raw water intake line and byproduct disposal line are proposed to have parallel alignments and be constructed in a single trench along a majority of the routes. The byproduct disposal line is proposed to be located south of the raw water intake line. This positioning is especially important where the lines terminate in the Gulf of Mexico. The ocean currents generally move in a southwesterly direction along this portion of the Texas Gulf Coast. To minimize cycling of byproduct flow into the raw water intake conduit, the ends of the lines will be separated by 1,400 feet, with the byproduct disposal line located south of the raw water intake line.

The raw water line will have a capacity of 55 mgd and be sized as a 54-inch-diameter HDPE (high density polyethylene) material.

4.4 Pre-Treatment Facilities

Treatment components are grouped into two categories: pre-treatment and reverse osmosis. Pre-treatment facilities are selected to condition the raw water to meet the required feed characteristics of the reverse osmosis system. Generally, the pre-treatment processes are selected to remove suspended solids, total organic carbon (if necessary), and to provide primary disinfection of the water.

Four pre-treatment options are presented. Within the pre-treatment options, individual process components are varied in accordance with the principal pre-treatment component. For example, the utlrafiltration pre-treatment process does not include sedimentation or clarification ahead of the membrane filtration. The feed capacity to all pre-treatment options is 55 mgd.

Each pre-treatment option includes all of the support facilities necessary for that particular pre-treatment option. All support facilities that vary in size, capacity, or configuration are repeated within each pre-treatment option as appropriate. Detailed descriptions of the process components are provided in *Section 3* of this chapter.

4.4.1 Pre-Treatment Option 1 – Conventional Pre-Treatment With Tube Settling

The principal components of Pre-Treatment Option 1 are the use of tube settlers for sedimentation and granular media filters. This option is considered a high-rate process compared to conventional gravity sedimentation, but still is the most land-area intensive approach of all pre-treatment options used in this evaluation.

Coagulant and polymers will be fed to the process flow and will pass through a rapid mix and flocculation area ahead of the tube settlers. Most of the suspended and coagulated solids will be removed in the tube settlers. The clarified water is then sent to the granular media filters for final polishing prior to delivery to the reverse osmosis system.

Residuals removed from both the tube settlers and filters are generally suspended solids and chemicals used in the pre-treatment process. The residuals from both pre-treatment sources are sent to a high rate clarifier/thickener (DensaDeg®) and then to a centrifuge system for dewatering. After dewatering, the solids are trucked offsite for disposal in a landfill. Pre-Treatment Option 1 is anticipated to have little or no impact on the total dissolved solids concentration of the raw water.

A treatment plant site plan showing all the anticipated major facilities resulting from the use of conventional pre-treatment with tube settling and cluster filters is provided in *Figure 4-4.4.1-1*. The reverse osmosis system and support facilities requirements as described in *Section 4.4* and elements common to all treatment options are also included in the site plan.

Of all the pre-treatment options, Pre-Treatment Option 1 is the most land intensive of all options. Common wall construction techniques allow the required facilities to fit within the area allotted on the Oxychem site; however, roadway access to the required maintenance and operating areas would be restricted. During detailed design, if it is determined that additional support facilities are required, the limited site availability would be a significant restriction. Therefore, Pre-Treatment Option 1 is not considered compatible with the Oxychem site.

The Barney Davis site has significantly more land area available than the Oxychem site, and therefore Pre-Treatment Option 1 is considered compatible with the Barney Davis site.

Pre-Treatment Option 1 is compatible with all raw water sources and with the open sea intake option. Pre-Treatment Option 1 is not necessary if bank filtration is used and is, therefore, not considered compatible with the Bank Filtration Intake option.

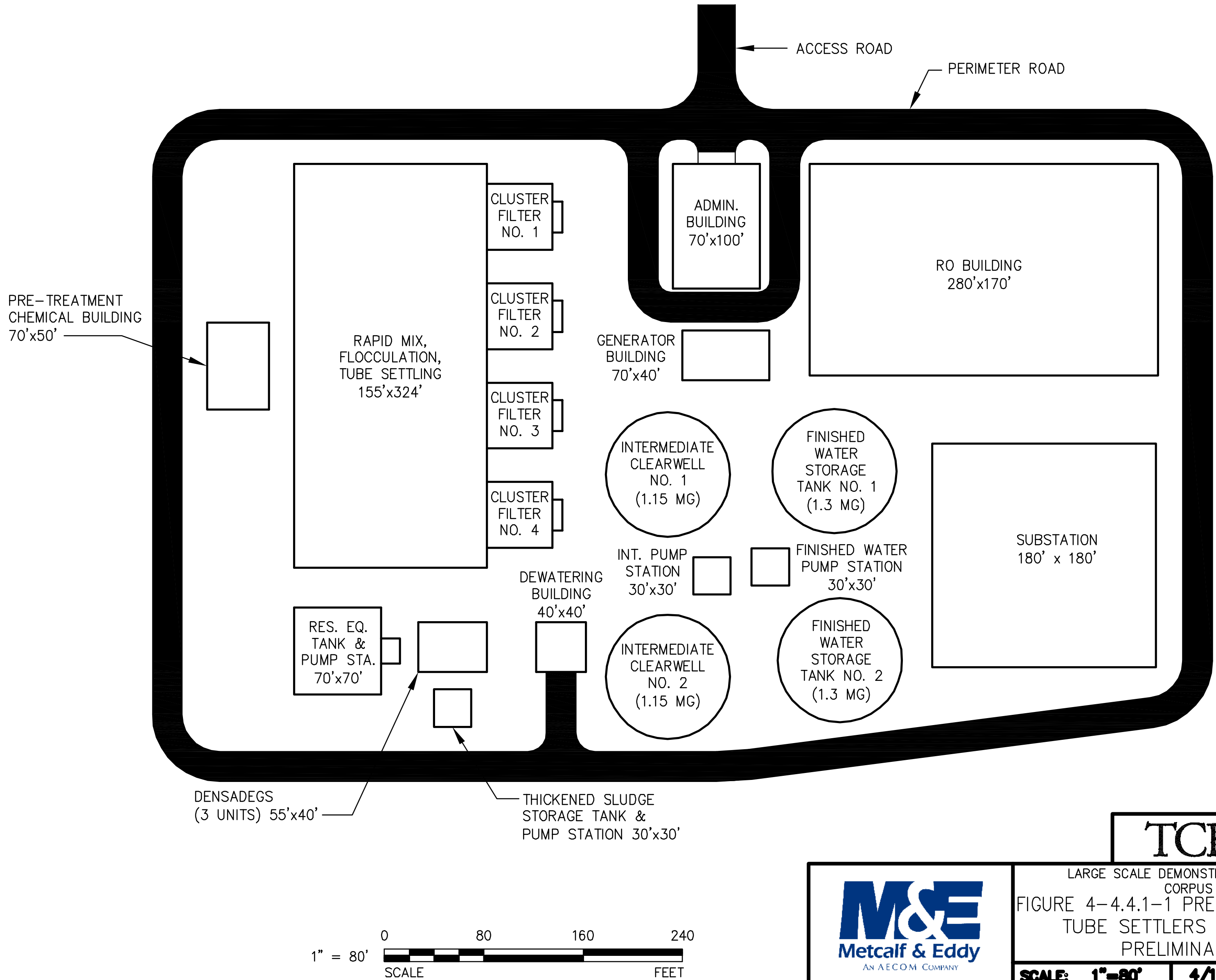


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FIGURE 4-4.4.1-1 PRE-TREATMENT OPTION NO. 1
TUBE SETTLERS & CLUSTER FILTERS
PRELIMINARY SITE PLAN

SCALE:	1"=80'	4/13/04	CPB	

P:\CCCDESAL\321399DESAL\DWGS\FIG44411.dwg ; November 16, 2004 ; 2:09pm

4.4.2 Pre-Treatment Option 2 – Conventional Pre-Treatment With Stacked DAF

The principal components of Pre-Treatment Option 2 are the use of dissolved air flotation (DAF) for sedimentation and granular media filters. This option is considered a higher rate process compared to tube settlers and provides better treatment of potentially problematic algae. The ability to stack the processes vertically allows this pre-treatment option to be contained in a relatively small footprint.

Coagulant and polymers will be fed to the process flow and will pass through a rapid mix and flocculation area ahead of the tube settlers. Most of the suspended and coagulated solids will be removed in the DAF units. The clarified water is then sent to the granular media filters for final polishing prior to delivery to the reverse osmosis system.

Residuals removed from both the DAF units and filters are generally suspended solids and chemicals used in the pre-treatment process. The concentrations of solids from the DAF units are anticipated to be concentrated sufficiently to serve as a feedstock to the dewatering centrifuges without further thickening, though this is a relatively small economic advantage. The residuals from pre-treatment filters are sent to a high-rate clarifier/thickener (DensaDeg®) and then to a centrifuge system for dewatering. After dewatering, the solids will be trucked offsite for disposal in a landfill. Additional support facilities include filtered water (intermediate) storage, an intermediate pump station, and chemical storage and feed system. Pre-Treatment Option 2 is anticipated to have little or no impact on the total dissolved solids concentration of the raw water.

A preliminary treatment plant site plan showing all the anticipated major facilities resulting from the use of conventional pre-treatment with dissolved air flotation and cluster filters is provided in *Figure 4-4.4.2-1*. The reverse osmosis system and support facilities requirements as described in *Section 4.4* are also included in the site plan.

Pre-Treatment Option 2 is very land efficient compared to Pre-Treatment Options 1 and 3 and is compatible with the land area identified with the Barney Davis or Oxychem sites. Pre-Treatment Option 2 is compatible with all identified raw water sources and is compatible with the open sea intake option. Pre-Treatment Option 2 is not necessary if bank filtration is used and is, therefore, not considered compatible with the Bank Filtration Intake option.

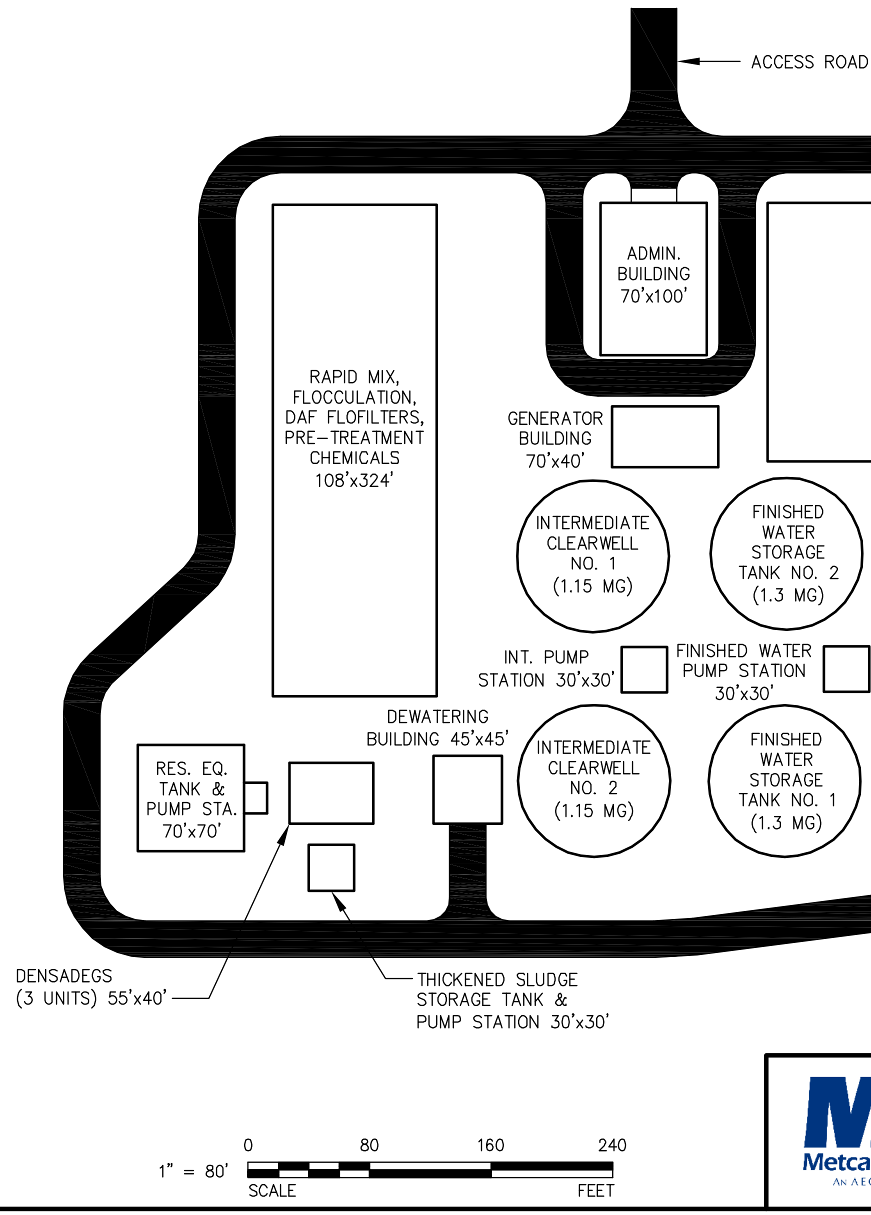

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FIGURE 4–4.4.2–1 PRE–TREATMENT OPTION NO. 2 DAF FLOFILTERS PRELIMINARY SITE PLAN

SCALE:	1"=80'	4/13/04	CPB	

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4.4.3 Pre-Treatment Option 3 – Pre-Treatment With Low-Pressure Membrane Filtration

The principal component of Pre-Treatment Option 3 is the use of low pressure ultrafiltration membranes to remove suspended solids from the raw water. This is a single step pre-treatment process with one filtrate stream and one residuals stream as opposed to the two step pre-treatment configurations in Options 1 and 2.

Coagulant and polymers will be fed to the process flow and will pass through a rapid mix and flocculation area ahead of the low pressure membranes. The filtered water is then sent to the reverse osmosis system.

Residuals removed from both the ultrafiltration process are generally suspended solids and chemicals used in the pre-treatment process. The residuals from the ultrafiltration process are sent to a high-rate clarifier/thickener (DensaDeg®) and then to a centrifuge system for dewatering. After dewatering, the solids will be trucked offsite for disposal in a landfill. Additional support facilities include filtered water (intermediate) storage, an intermediate pump station, and chemical storage and feed system.

A preliminary treatment plant site plan showing all the anticipated major facilities resulting from the use of low pressure ultrafiltration membranes pre-treatment is provided in *Figure 4-4.4.3-1*. The reverse osmosis system and support facilities requirements as described in *Section 4.4* are also included in the site plan.

Pre-Treatment Option 3 is compatible with both the Barney Davis and Oxychem plant site locations, and both source water options, Corpus Christi Bay and the Gulf of Mexico. Pre-Treatment Option 3 is compatible with the open sea intake option, but is not compatible with the bank filtration intake option.

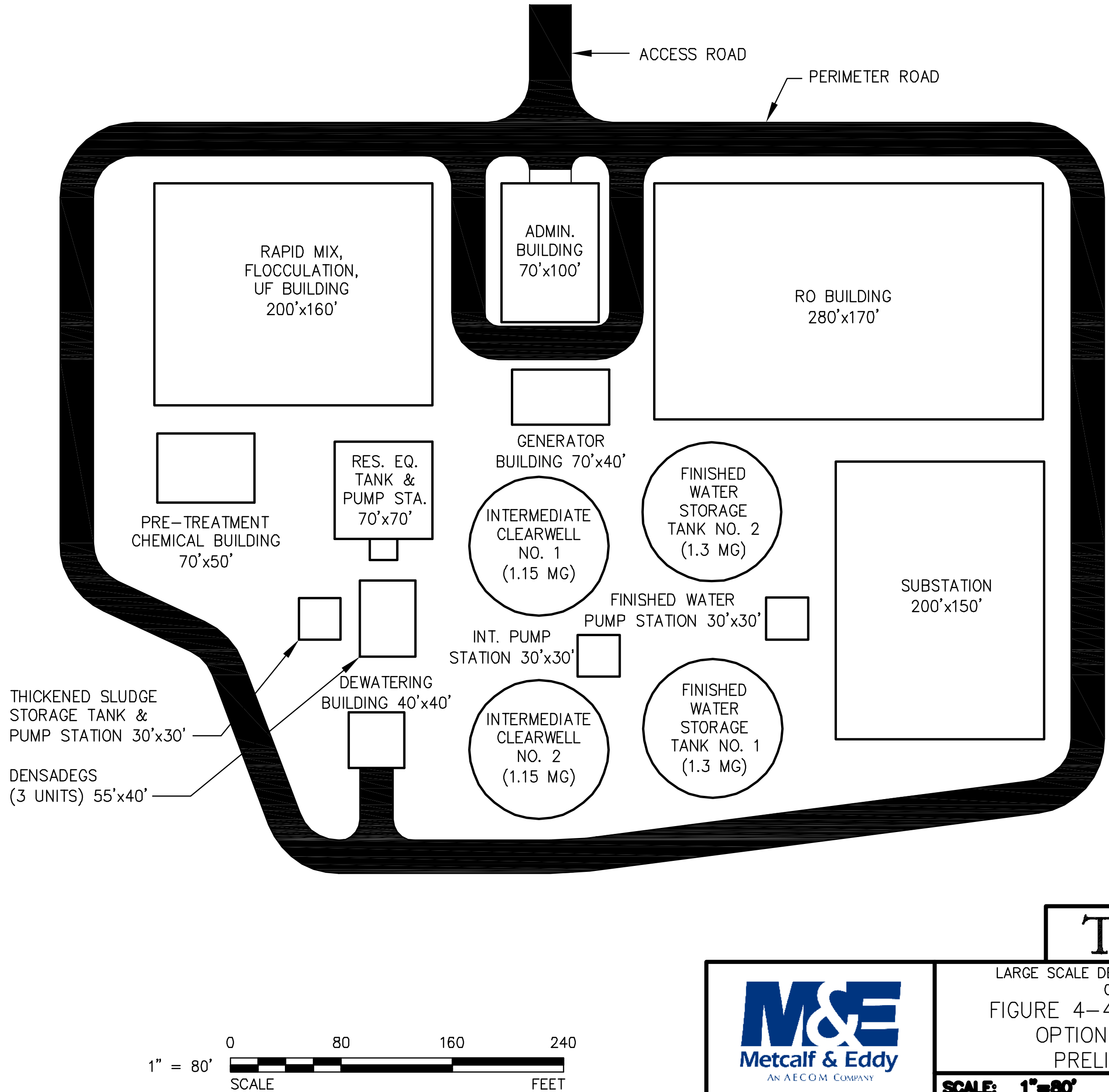

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FIGURE 4-4.4.3-1 PRE-TREATMENT OPTION NO. 3 UF BUILDING PRELIMINARY SITE PLAN

SCALE: 1"=80'	4/13/04	CPB	

4.4.4 Pre-Treatment Option 4 – Ultraviolet Radiation (Bank Filtration)

The primary purpose of the pre-treatment system is to remove particulate matter from the flow stream to minimize the potential for fouling in the reverse osmosis system. Pre-Treatment Option 4 removes the particulate matter by filtering water at the source through a bank filtration system. In this option, seawater is strained through granular media on the shoreline or through the ocean floor. A very substantial surface area is required to accommodate the required flow and long-term accumulation of solids in the bank filter area. There is no particulate removal, thickening, or dewatering equipment required at the plant. This option requires the least amount of land on the plant site because all of the pre-treatment facilities are located on the bank of source water.

Although the bank filtration option is effective at removing particulate substances from the flow stream, it is not considered as effective as the other pre-treatment options at meeting disinfection requirements. To supplement disinfection, an ultraviolet (UV) radiation disinfection system has been included in this Pre-Treatment Option 4. Pre-Treatment Option 4 consists of only the UV disinfection system. For the purpose of this report, the bank filtration system is considered an intake facility.

A preliminary treatment plant site plan showing all the anticipated major facilities resulting from the use of off-site bank filtration is provided in *Figure 4-4.4.4-1*. The reverse osmosis system and support facilities requirements as described in *Section 4.4* are also included in the site plan.

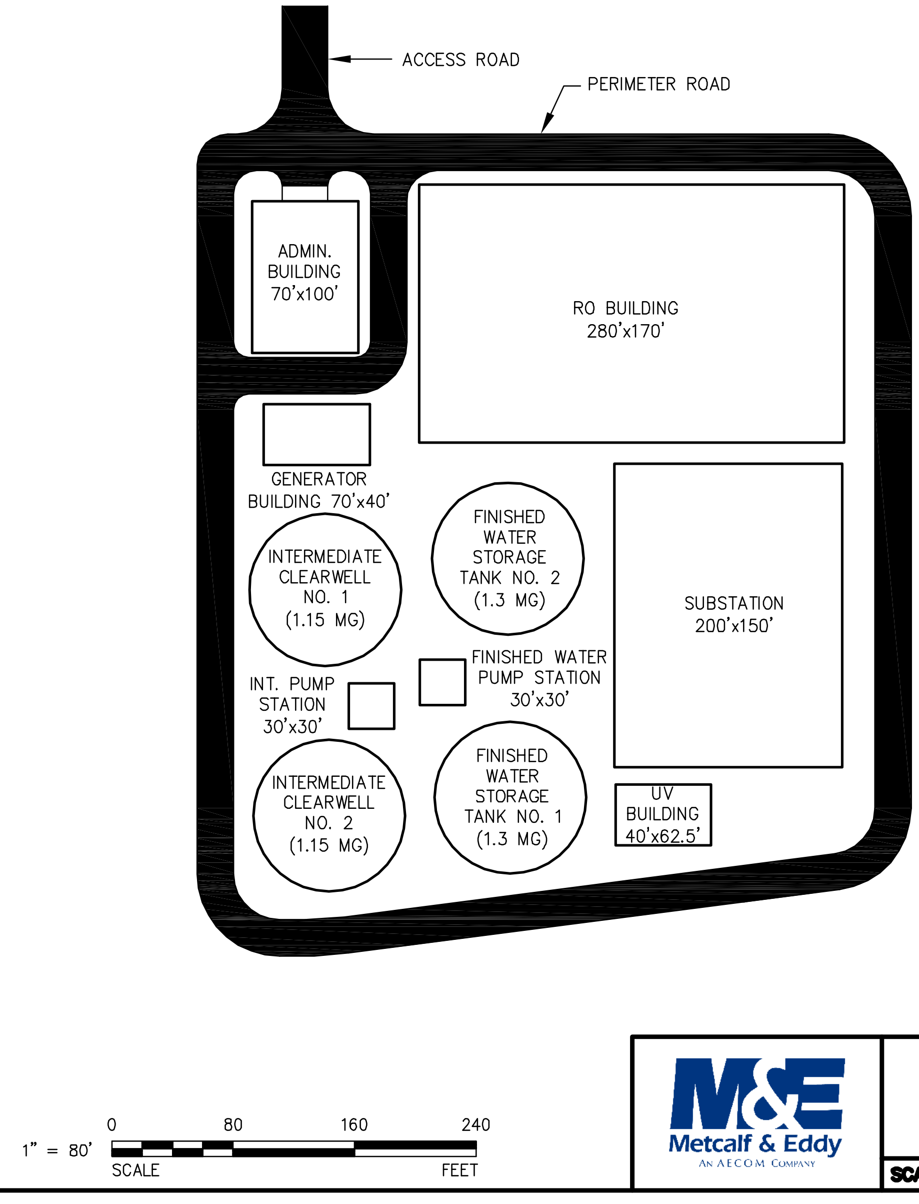

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FIGURE 4-4.4.4-1 PRE-TREATMENT OPTION NO. 4 BANK FILTRATION PRELIMINARY SITE PLAN

SCALE: 1"=80'	4/13/04	CPB	

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4.5 Reverse Osmosis

The Reverse Osmosis (RO) system and many of the RO support facilities will be housed in the Reverse Osmosis Building. A layout of the RO Building, which measures 270 feet by 180 feet, is shown in *Figure 4-4.5-1*. Overall site layouts showing the RO System are included in the site plans for each pre-treatment option in the previous four sections. All chemicals that are added at the intermediate pump station and downstream will be housed in the Chemical Storage Area and Chemical Rooms, with the exception of sodium hypochlorite, which will be fed throughout the plant from the Pre-Treatment Chemical Building. In addition to housing treatment chemicals such as sulfuric acid, lime, sodium bisulfite, fluoride and ammonia; bulk storage for membrane cleaning chemicals is also provided. Based on code requirements, appropriate isolation and containment will be provided for each chemical.

The RO treatment process is the core of the desalination system. The raw water sources, intake systems, and pre-treatment options have all been chosen to support the RO system. Therefore, the RO system is compatible with all defined treatment plant sites, raw water sources, intake facilities, and pre-treatment options in this report. Therefore, the reverse osmosis facility is common to all alternates.

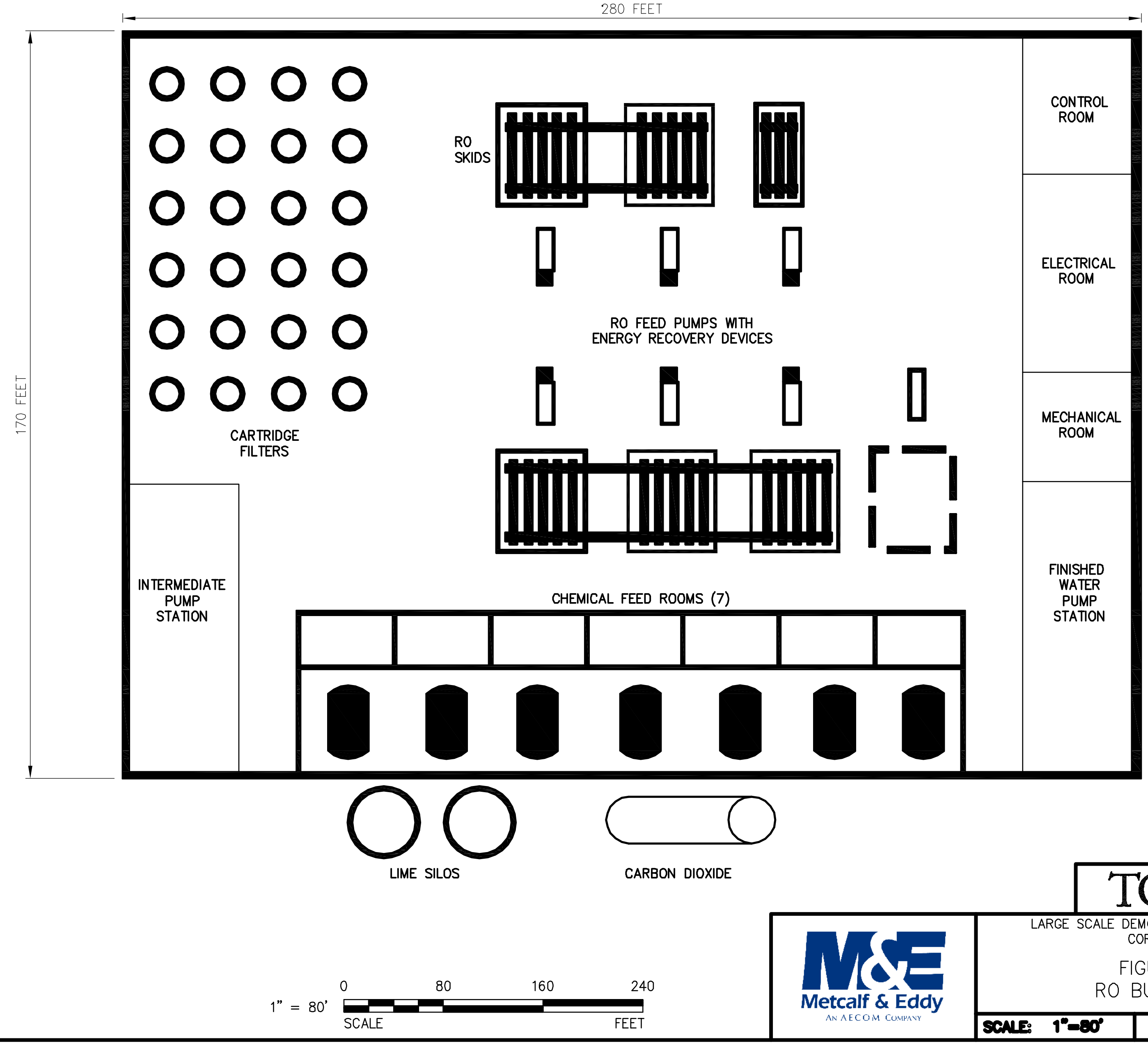

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FIGURE 4-4.5-1
RO BUILDING LAYOUT

SCALE:	1"=80'	4/13/04	CPB	

4.6 Byproduct Disposal

By far the largest waste stream for the treatment plant is the byproduct from the RO process. The byproduct stream is anticipated to be 50 percent of the total feed to the RO system or approximately 25 mgd and will have a total dissolved solids concentration of approximately 70,000 mg/l.

The management of the byproduct stream must address several technical and environmental issues. Several options for the management of the byproduct stream are addressed in *Chapter 5*. Disposal options include dewatering through mechanical or evaporative techniques, delivery to an industrial user as a feedstock, or discharge to sea.

As a result of the analysis in *Chapter 5,* the only reliable and economically viable option for the disposal of the RO byproduct is discharge to the Gulf of Mexico. All other options were considered too expensive or environmentally unsound. Because the byproduct stream is an integral part of the reverse osmosis project, it must be incorporated into all options, and therefore, the byproduct disposal mechanism chosen in *Chapter 5* is open sea disposal into the Gulf of Mexico. Therefore, the costs and configurations of the byproduct management systems are dependent on the relative locations of the treatment plant and the discharge point.

All byproduct management options incorporate a byproduct pump station and HDPE pipeline to the Gulf of Mexico. The pump station will have a capacity of 25 mgd. The HDPE byproduct pipeline is a 42-inch-diameter HDPE pipe constructed in the same trench as the raw water intake line for all open sea intake options. The byproduct line will extend 2 miles into the gulf and at the appropriate location will turn to the south to allow a minimum of 1,400 feet of clearance from the raw water intake structure. General currents in the gulf are from the north and the 1,400-foot separation distance from the intake should be sufficient to eliminate short circuiting to the intake.

4.7 Common Elements

In developing alternatives for a treatment facility, several common or support elements will be required regardless of the selected alternate. The support elements that are required for the development of the treatment plant are described herein as common elements. These common elements are included in all of the alternates.

4.7.1 Administration Building

The administration building has an administrative zone, operational management zone, quality control zone, and a mechanical/workshop zone (Kawamura 2000). Each of the zones will contain several rooms to serve the various zone functions. The administrative zone will have a lobby, an area for a receptionist, records storage, restrooms, a conference/training room, and offices for plant managers. The operational management zone will contain the control room, operators' wet laboratory, lunch room, and locker rooms. The quality control zone should have laboratories divided by specialty: general chemistry, instrumentation lab, bacteriological lab, and water quality supervisor office. Finally, the mechanical/workshop zone will house mechanical equipment–heating, air conditioning, and ventilation–necessary for the entire administration area. Also located in this zone is the machine (maintenance) workshop. A building has been sized at 70 feet by 100 feet to provide 7,000 square feet of space for these uses.

4.7.2 Generator Building

Because of the ability to operate the water treatment plant under adverse conditions, including power outages, it is proposed to supply a level of backup power through a gas or diesel powered generator. In addition to the generator, certain electronic equipment will need to be provided with a continuous power supply. To accomplish this, an uninterruptible power supply (UPS) will be provided to maintain operation of equipment such as programmable logic controllers (PLCs), operator workstations, etc. while the generator is being started. A 40-foot by 70-foot building has been provided to house the generators and UPS system, immediately behind the administration building.

4.7.3 Electrical Substation

An electrical substation is provided as the interface with the power grid. It is anticipated that two power sources are available and will be brought to the treatment plant site on separate power transmission lines. The facility will be a 20-megawatt substation. A 30,000-square-foot area has been reserved for the substation on the site plan.

4.7.4 Raw Water Pump Station

The raw water pump station is located off the plant site, adjacent to the raw water source, and at the terminus of the intake. In all alternates, the capacity of the raw water pump station is 55 mgd, and will consist of vertical shaft pumps in a concrete structure as depicted in *Figure 4-2.3.1.1-3* and *Figure 4-2.3.1.1-4.* Because the capacity of the raw water pump station is the same for all alternates (55-mgd firm capacity), the size of the facility will be the same regardless of other elements within each alternate.

4.7.5 Intermediate Water Storage and Pumping

Ideally, the treatment plant will be base loaded to allow a consistent production rate. Constant flow rates through the plant will allow the plant to operate at peak efficiencies and produces uniform water quality. Unfortunately, demands for treated water vary throughout the day. To accommodate these variances between water production rates and demands, storage tanks are provided within the process train to equalize the flows. When demands exceed upstream production, the equalization/storage tank level drops as the excess water is removed from the tank. In times of low demand, the equalization storage tank level will rise. These equalization storage tanks are also potentially used as contact or mixing chambers to aid in the treatment processes such as disinfection, or enhancing water quality such as post treatment following the RO system.

Ground storage tanks and repumping facilities are anticipated between the pre-treatment process and the RO units. These tanks will equalize flows between the pre-treatment and reverse osmosis processes, serve as a source of backwash supply for the pre-treatment filters, and function as a wet well for the low pressure feed pumps (intermediate pumps) to the RO process. The ground storage tanks are referred to as the intermediate storage facility, and the repump facility is referred to as the intermediate pump station.

The intermediate storage facility will serve as a wet well for the intermediate pumps that pump the water through the pre-RO cartridge filters with sufficient residual head to the suction of the RO feed pumps. The two intermediate storage tanks have a total capacity of 2.25 million gallons and are each 100 feet in diameter.

Depending on final site development details during the project design phase, the intermediate pumps could be housed in a separate structure, within the pre-treatment building (Pre-Treatment Options 1, 2, or 3) or near the cartridge filters in the RO Building. For the purpose of developing the configuration, all alternates assume a separate but identical intermediate pump station. The intermediate pump station will have a firm pumping capacity of 50 mgd, and the footprint is anticipated to cover 2,925 square feet (45-foot x 65-foot).

4.7.6 Finished Water Storage and High Service Pumping

After the reverse osmosis process is completed, the water will be aggressive and must be stabilized prior to leaving the plant. Chemical post-treatment and disinfection is anticipated to occur following the RO process. The finished water storage tank will serve as a conditioning and blending facility to allow all the post-treatment processes to complete and serve as a wet well supply source to the high service pumps. Two finished ground storage tanks are anticipated with a total capacity of 2.5 million gallons. The ground storage tanks are 110 feet in diameter.

High service pumps distribute the finished water to the potable water system at the nearest major transmission pipeline. The average pumping rate will be equal to the plant capacity, but an instantaneous rate could be somewhat higher. To maintain the concept of the plant supplying base-load conditions, the firm pumping capacity is established to be 25 mgd. Depending on the final site configuration, the high service pumps could be located within the RO treatment building or in a separate structure dedicated for high service pumping.

4.8 Transmission Piping to Distribution

Transmission of the finished water from the desalination facility to an adequate take point is entirely dependent on the location of the plant relative to a major distribution system transmission main. At the Barney Davis Plant site, there is a proposed 48-inch-diameter finished water transmission main that will pass very near the Barney Davis Plant. This transmission is already under design and anticipated to be in operation in 2006, which is well in advance of the anticipated implementation schedule for the desalination facility. Tying the desalination finished water transmission main directly into the proposed 48-inch-diameter main will allow the desalination facility to serve the potable water demands in this region and free up line capacity upstream to serve other potential growth areas.

At the Oxychem site, there are no major water distribution lines in the immediate vicinity. The San Patricio Water District currently serves the area immediately around the Oxychem site. Water produced at the desalination facility is anticipated to be more expensive than water produced from the District's existing treatment facility. Therefore, there would be little or no incentive for the San Patricio Water District to purchase water from the desalination facility.

The nearest adequate take point in the Corpus Christi service area is across Corpus Christi Bay from the Oxychem site. To get to this location would require a long circuitous pipeline route around Corpus Christi Bay or constructing the pipeline through Corpus Christi Bay. Both of these options are very expensive. Because of this cost, the evaluation reevaluated some of the other sites that were originally not considered in detail such as Flint Hills Resources East. Although the Flint Hills site is on Nueces Bay, it is also relatively close to Corpus Christi Bay and could use Corpus Christi Bay as the raw water source. However, this option was quickly determined to be probably no better than the Oxychem site because every length of pipe saved in using the 42-inch transmission line would be offset by the increase in the length of the byproduct discharge line. For this reason, the Oxychem Alternates were retained as originally described, and the finished water transmission line cost is based on connecting to the Corpus Christi distribution system in the most economical manner.

4.9 Definition of Alternates

Four base alternates for each treatment plant site are developed for detailed cost evaluations. For a complete and working alternate, each must include the following categories of components.

- Raw water source
- Raw water intake
- Raw water pipeline
- Pre-Treatment
- Reverse osmosis
- Byproduct disposal
- Common elements (including raw water pump station)
- Transmission piping to distribution.

4.9.1 Barney Davis Power Plant Site Alternates

Four alternates were developed for the Barney Davis Power Plant site by selecting combinations of compatible components from each category of facility. The four alternates at the Barney Davis Power Plant site are presented in *Table 4-4.9.1-1*. Detailed analyses of each of these components are included in *Section 4* of this chapter.

4.9.2 Oxychem Site Alternates

Four alternates were developed for the Oxychem site by selecting combinations of compatible components from each category of facility. The four alternates at the Oxychem site are presented in *Table 4-4.9.2-1*.

Table 4-4.9.1-1 Barney Davis Power Plant Desalination Alternates

Parameter	Alternates			
	1	2	3	4
Descriptive Name	**BD-1**	**BD-2**	**BD-3**	**BD-4**
Raw Water Source	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico
Raw Water Intake	Open Sea	Open Sea	Open Sea	Bank Filtration
Raw Water Pipeline	As Required	As Required	As Required	As Required
Pre-Treatment	Tube Settlers	Dissolved Air Flotation	Ultrafiltration Membranes	Ultraviolet Disinfection
Reverse Osmosis	Common to All	Common To All	Common To All	Common To All
Byproduct Disposal	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico
Common Elements	Common to All	Common to All	Common to All	Common to All
Transmission to Distribution	As Required	As Required	As Required	As Required

Table 4-4.9.2-1 Oxychem Site Desalination Alternates

Parameter	Alternates			
	1	2	3	4
Descriptive Name	**OX-1**	**OX-2**	**OX-3**	**OX-4**
Raw Water Source	Corpus Christi Bay	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico
Raw Water Intake	Bank Filtration	Open Sea	Open Sea	Bank Filtration
Raw Water Pipeline	As Required	As Required	As Required	As Required
Pre-Treatment	Ultraviolet Disinfection	Dissolved Air Flotation	Ultrafiltration Membranes	Ultraviolet Disinfection
Reverse Osmosis	Common to All	Common to All	Common to All	Common to All
Byproduct Disposal	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico	Gulf of Mexico
Common Elements	Common to All	Common to All	Common to All	Common to All
Transmission to Distribution	As Required	As Required	As Required	As Required

Detailed analyses of each of these components are included in *Section 4* of this chapter.

5 CONCEPTUAL COST ESTIMATES

To evaluate the project costs for each option, capital and operations and maintenance (O&M) costs were developed. The present worth of the O&M costs are calculated based on a discount rate of 5 percent and a 20-year term, then combined with the capital costs to calculate 20-year present worth life cycle costs of each alternative.

The purpose of this cost estimate is to allow the direct comparison of the desalination options developed for Corpus Christi, but it does not fully develop the financial planning for the feasibility of the total program. The cost model in *Chapter 10* provides additional financial information and costs that include financing costs, and it compares the development of the desalination option with the City of Corpus Christi's water system financial program.

The total life cycle cost estimate is presented in *Appendix C* at the conclusion of this chapter. The cost estimate is divided into four primary categories and several subcategories. The following list describes the categories and subcategories used for the development of each alternate. The costs for the appropriate options from each cost category are selected and combined to formulate the alternatives for each treatment plant site.

- Intake Options
  - Open Sea Intake
  - Bank Filtration

- Off-site Piping Options
  - Raw Water Piping
  - Byproduct Disposal
  - Transmission to Distribution

- Pre-Treatment Options
  - Conventional Pre-Treatment with Tube Settlers
  - Conventional Pre-Treatment with Dissolved Air Flotation
  - Membrane Filtration with submerged Ultrafiltration Membranes
  - Ultraviolet Radiation (compatible only with Bank Filtration Intake)

- Reverse Osmosis and Common Elements

Unit prices that are common to multiple options and alternatives are also summarized at the end of *Appendix C.* Unit costs that are particular to individual alternates or options are identified in the appropriate location in *Appendix C.*

5.1 Construction (Capital) Cost Estimate

Capital costs for each option were developed by sizing individual components within each option and estimating the quantities for the major items comprising the option. Unit prices were developed from quotes from equipment manufacturers or from recent historical data from other projects. When appropriate, additional costs were added for equipment, electrical, and instrumentation. In some instances, allowances were made for minor components and support facilities. After the construction costs were estimated and totaled, a 25 percent contingency was added for items that are currently unidentifiable. The final construction cost estimate also includes contractor's overhead and profit (17 percent), mobilization and demobilization (3 percent), surveying and geotechnical (3 percent), engineering design services (10 percent), and an allowance for environmental restoration and mitigation. The allowance for environmental restoration and mitigation is varied between 1 percent and 10 percent of the capital cost for the particular option, depending on the perceived environmental impacts and anticipated resistance to the proposed alternative.

Each alternate consists of a compatible grouping of options from each cost category. A complete alternate includes an intake, off-site piping for the raw water, byproduct disposal, and transmission to the distribution system, pre-treatment, reverse osmosis, and common elements. The reverse osmosis and elements are facilities located on the treatment plant site, plus a raw water pump station that is common to all alternates. *Table 4-4.9.1-1* (in the previous section) identifies the makeup of the four Barney Davis Power Plant desalination alternates, and *Table 4-4.9.2-1* (in the previous section) identifies the four Oxychem Plant site alternates. A summary of the capital costs for each alternate at each plant site is presented in *Table 4-5.1-1* (Barney Davis site) and *Table 4-5.1-2* (Oxychem alternates). Detailed estimates supporting *Table 4-5.1-1 a*nd *Table 4-5.1-2* are provided in *Appendix C*. All costs are in current year (2004) U.S. dollars.

Table 4-5.1-1 Capital Cost Summary – Barney Davis Site Alternates

	Alternate			
Barney Davis Power Plant	**BD 1**	**BD 2**	**BD 3**	**BD 4**
Intake System	$13.9 M	$13.9 M	$13.9 M	$31.7 M
Raw Water Piping	$34.4 M	$34.4 M	$34.4 M	$34.4 M
Pre-Treatment	$38.6 M	$37.0 M	$75.2 M	$2.4 M
RO & Common Elements	$76.7 M	$76.7 M	$76.7 M	$76.7 M
Transmission to Distribution	$2.5 M	$2.5 M	$2.5 M	$2.5 M
Byproduct Disposal	$32.1 M	$32.1 M	$32.1 M	$32.1 M
Total	$198.2 M	$196.6 M	$234.8 M	$179.8 M

Table 4-5.1-2 Capital Cost Summary – Oxychem Site Alternates

	Alternate			
Oxychem Plant Site	**OX 1**	**OX 2**	**OX 3**	**OX 4**
Intake System	$31.7 M	$13.9 M	$13.9 M	$31.7 M
Raw Water Piping	$10.6 M	$62.6 M	$62.6 M	$62.6 M
Pre-Treatment	$2.4 M	$37.0 M	$75.2 M	$2.4 M
RO & Common Elements	$76.7 M	$76.7 M	$76.7 M	$76.7 M
Transmission to Distribution	$56.9 M	$56.9.0 M	$56.9 M	$56.9 M
Byproduct Disposal	$47.1 M	$47.1 M	$47.1 M	$47.1 M
Total	**$225.4 M**	**$294.2 M**	**$332.4 M**	**$277.4 M**

As shown in the tables of *Appendix C*, the components of the capital cost estimates for each pre-treatment alternative and for the RO system are major equipment, process piping, concrete, buildings, site work, residuals transfer pumping, and chemical feed systems. The major equipment refers to the vendor-supplied process mechanical equipment. For the purposes of this report, budget prices were solicited from equipment vendors.

During development of the alternates, many assumptions had to be made and criteria established to provide a common basis for alternative comparisons. These assumptions and criteria have a very direct impact on the overall magnitude of costs. To fully understand the makeup of the alternates and to compare these alternates with other contemporaneous studies, the assumptions and criteria must be known. For this reason, the major assumptions and criteria used in this analysis are presented in the following list.

Intakes

- Total capacity required is 55 mgd for all options.
- Thirty feet of depth (minimum) is required for open sea intakes to avoid wave action, surf effects, and major shipping traffic.
- Suitable land area is available for construction and operation of bank infiltration options.
- Transmissivity of the soil is adequate to support 1 gpm per foot of length for bank filtration options.

Off-Site Piping

- High density polyethylene piping is used for all raw water and byproduct disposal piping.
- Concrete steel cylinder or ductile iron pipe is used for transmission and distribution system piping.
- Wet dredge installation techniques are used on all open sea pipeline construction except for designated shipping lanes.
- Tunneling is used for crossing designated shipping lanes.
- Open cut pipeline installation techniques are used for all on-land pipe installation.

Plant Site Pre-Treatment, RO, and Common Elements

- All pre-treatment options have a capacity of 55 mgd. Waste stream residuals will not exceed 5 mgd, leaving not less than 50 mgd for the reverse osmosis treatment system.
- The treatment plant cost estimates do not include land acquisition costs.
- Concrete unit costs include purchasing and installing the concrete, installing and removing forms, finishing the concrete, and purchasing and installing reinforcing. The unit cost for slab on grade concrete construction is $400 per cubic yard. All other concrete costs are assumed to be $600 per cubic yard.
- The cost for installing the major equipment, pumps, and chemical feed systems was assumed to be 30 percent of the cost of the particular equipment being installed.
- The cost for the electrical, instrumentation, and control systems for the major equipment and the pumping systems were assumed to be 20 percent of the equipment costs. For the chemical feed systems, the electrical and I&C costs are included in the subtotal.
- With the exception of the Administration Building, all other buildings were assumed to be pre-engineered metal buildings with a construction cost of $64 per square foot, which is based on an allowance of $50 per square foot for the building installation, plus an additional $14 per square foot for lighting and HVAC. It was assumed that the Administration Building would be required to be more aesthetically pleasing, with cavity wall construction and brick veneer. Thus, the assumed unit cost was $100 per square foot with an additional $25 per square foot for lighting and HVAC. The installation cost for the light duty weather enclosure over the DAF basin was assumed to be $35 per square foot.

5.1.1 Barney Davis Alternates

The anticipated capital costs of the Barney Davis Power Plant site alternates range from $174.8 million to $227.4 million. The major cost differences between these options are related to the compatible combinations of Intake and Pre-Treatment options. The three higher cost alternates at this site, Alternates BD 1, BD 2, and BD 3, use an equipment-intensive process to prepare the raw water for the reverse osmosis system, whereas Alternate BD 4 uses bank filtration as the pre-treatment option with only ultraviolet disinfection on the plant site ahead of the RO process.

The mechanical equipment pre-treatment options are better defined and have a significantly greater anticipated long-term reliability than bank filtration. The assumed criteria for the equipment-based options are well established in the treatment industry. The criteria used for sizing the bank filtration option is not based on actual in situ conditions, which must be established prior to a final selection of bank filtration as an intake pre-treatment option. As a result, the level of confidence in the overall magnitude of costs and in the long-term reliability of Alternates BD 1, BD 2, and BD 3 are significantly greater than for Alternate BD 4.

5.1.2 Oxychem Plant Site Alternates

The anticipated capital costs for the Oxychem Plant site alternates range from $158.5 million to $270.3 million. The variability of costs between these alternates is significantly greater than for the Barney Davis Plant site alternates. This variability is entirely a result of the off-site pipelines necessary to support the treatment facility. The lowest cost alternate at the Oxychem site (Alternate OX 1) uses Corpus Christi Bay as the source water, which is located less than one mile from the Oxychem site. The other three alternates use the Gulf of Mexico as the raw water source, which is located 14 miles from the site. The difference in raw water pipe costs alone is $52 million.

Alternate OX 1 also uses bank filtration as the intake option. An open sea intake in Corpus Christi Bay is not recommended because of the shallow depth, susceptibility to water quality variations, and environmental concerns. The development obstacles and the unknown long-term reliability of the bank filtration intake system result in this alternate having the least overall confidence level in the relative evaluation.

5.2 Operation and Maintenance Costs

To allow a total life cycle cost comparison between the alternates, operations and maintenance (O&M) costs have been developed for each component of each alternate examined. The complete development of the O&M costs is presented in detail in *Appendix C – Cost Estimates*.

Five O&M categories were established and the annual O&M costs developed for each category. The five O&M categories used in this analysis are:

- Power
- Chemicals

- Rehabilitation & repair (recurring costs)
- Labor
- Solids handling

Major facilities replacement costs are not included in these O&M costs. The routine replacement for consumables and anticipated replacement of equipment components such as ultraviolet lamps, membrane cartridges, mechanical parts, and filter media are included as line items in the O&M costs under the category of Rehabilitation and Repair. Other routine rehabilitation and repairs, oftentimes referred to as recurring costs, are included in an allowance that is estimated at 4 percent of the equipment cost.

The replacement costs for major facilities are included in the cost model in *Chapter 10*.

Each alternate consists of a compatible grouping of options from each cost category. A complete alternate includes an intake, off-site piping for the raw water, byproduct disposal, and transmission to the distribution system, pre-treatment, reverse osmosis and common elements. The reverse osmosis and elements are facilities located on the treatment plant site plus a raw water pump station that are common to all alternates. *Table 4-4.9.1-1* (in the previous section) identifies the makeup of the four Barney Davis Power Plant desalination alternates, and *Table 4-4.9.2-1* (in the previous section) identifies the four Oxychem Plant site Alternates. A summary of the O&M costs for each alternate at each plant site is presented in *Table 4-5.2-1* (Barney Davis site) and *Table 4-5.2-1* (Oxychem site). Detailed estimates supporting *Table 4-5.2-1* and *Table 4-5.2-2* are provided in *Appendix C*. All costs are in current year (2004) U.S. dollars.

As with the capital cost estimates, several assumptions and baseline criteria were necessary to prepare the O&M cost estimates. A discussion of the major O&M cost criteria and assumptions used in the development of the operations and maintenance costs is presented in the next section.

Table 4-5.2-1 Operations and Maintenance (O&M) Cost Summary – Barney Davis Alternates

	Alternate			
Barney Davis Power Plant	**BD 1**	**BD 2**	**BD 3**	**BD 4**
Intake System	$139 K	$139 K	$139 K	$1,380 K
Raw Water Piping	$313 K	$313 K	$313 K	$313 K
Pre-Treatment	$5,060 K	$5,012 K	$8,790 K	$1,190
RO & Common Elements	$11,740 K	$11,740 K	$11,740 K	$11,740 K
Transmission to Distribution	$25 K	$25 K	$25 K	$25 K
Byproduct Disposal	$290 K	$290 K	$290 K	$290 K
Total	**$17,560 K**	**$17,520 K**	**$21,290 K**	**$14,940 K**

Table 4-5.2-2 Operations and Maintenance (O&M) Cost Summary – Oxychem Alternates

	Alternate50			
Oxychem Plant Site	**OX 1**	**OX 2**	**OX 3**	**OX 4**
Intake System	$1,380 K	$139 K	$139 K	$1,380 K
Raw Water Piping	$106 K	$607 K	$607 K	$607 K
Pre-Treatment	$1,200 K	$5,010 K	$8,790 K	$1,200 K
RO & Common Elements	$11,700 K	$11,700 K	$11,700 K	$11,700 K
Transmission to Distribution	$569 K	$569 K	$569 K	$569 K
Byproduct Disposal	$452 K	$452 K	$452 K	$452 K
Total	**$15,407 K**	**$18,477 K**	**$22,257 K**	**$15,934 K**

5.2.1 Power Costs

A unit power cost of $0.065 was used to estimate annual power consumption costs. This unit power cost was based on current power costs in the Corpus Christi area. The electrical load from the major equipment, pumps, building services (HVAC and lighting), and metering pumps was estimated, and the unit power cost was applied to estimate total energy costs per option. The development of these costs is detailed in *Appendix C* for each option.

5.2.2 Chemicals

Chemical use is based on a raw water flow rate of approximately 50 mgd and a finished water production of 25 mgd. To obtain unit costs for the various chemicals, local area chemical suppliers were contacted for regional prices wherever possible. It was assumed that all pre-treatment options (except Option No. 4 Bank Filtration) will require 25 mg/l of ferric chloride for coagulation. The chemical doses for thickening operations include 30 mg/l of ferric chloride and 1 mg/l of polymer, at the preliminary recommendation of the equipment vendors. For dewatering, a polymer dose of 1 mg/l was assumed. Polymer dosage of 1 mg/l was also assumed for coagulation in Option 1. Polymer for coagulation is not required for Options 2 and 3.

Chemical use includes membrane cleaning chemicals such as citric acid, sodium hypochlorite, sodium hydroxide, and sodium bisulfite. Sulfuric acid will be injected upstream of the RO system for pre-RO pH adjustment. Reverse osmosis post-treatment chemicals include lime and CO_2 for pH adjustment and restabilization, sodium hypochlorite for CT disinfection, ammonia for conversion to chloramines, and fluoride to prevent dental decay.

5.2.3 Recurring Costs

In this estimate of O&M requirement, recurring costs are generally defined as anticipated, regularly scheduled maintenance expenditures that result from replacement of process components and from routine maintenance functions. The recurring costs associated with regularly scheduled maintenance replacement expenditures include items such as the replacement of membranes, filter media, and ultraviolet lamps. Recurring and routine maintenance items generally include the replacement of consumables, equipment repairs, painting, etc.

For the UF membranes included in Option 3, the vendor recommended a 5-year replacement interval for the membranes themselves, at a cost of $703 per module. There will be 6,000 modules. Over a 20-year period, there will be four total replacements, resulting in a total cost of $16,872,000. Reducing this to an annual cost (over a 20-year period), the annualized UF membrane replacement cost is $843,750 per year.

For the RO membranes included in all options, the vendor-recommended replacement interval is 5 years for the first pass modules at a cost of $650 per module. There will be 7,875 first pass modules. Over a 20-year period, there will be four replacements resulting in a cost of $20,475,000. For the second pass modules, the vendor-recommended replacement interval is 10 years at a cost of $500 per module. There will be 175 second pass modules. Over a 20-year period, there will be two replacements resulting in a cost of $175,000 for the second pass membranes. The total replacement cost for the desalination membranes over 20 years will be $20,650,000. Reducing this to an annual cost (over a 20-year period), the annualized RO membrane replacement cost is $1,032,500 per year.

For the conventional Pre-Treatment Options 1 and 2, it was assumed that the filter media would require replacement once every 20 years, at a cost of $150,000 per replacement. This works out to an annualized O&M cost of $7,500 per year.

For Pre-Treatment Option 4, the UV system will incur replacement costs because lamps are normally guaranteed only for a certain number of hours. Beyond this guarantee period, the lamps may not operate at the appropriate intensity, which subsequently will reduce the UV dose. A lamp replacement period of 8,800 hours has been selected, which is in accordance with the *EPA Guidance Manual* and somewhat more frequent than the vendor-recommended replacement interval of 12,000 hours. The 8,800 replacement interval results in each bulb being replaced each year on average. At this rate, over a 20-year period there will be 20 total replacements. Assuming only the two duty reactors would require lamp replacements, with 36 lamps per reactor, a total of 72 lamps will require replacement each time. The lamp cost, in today's dollars, is $185 per lamp. Lamp ballast costs are also recommended to be changed at each lamp replacement for an additional $4 per replacement for a total of $189 per lamp replacement. For replacing all 72 lamps each year with a unit replacement cost of $189, the total annual UV replacement costs are estimated to be $13,500 per year.

In addition to itemized replacement costs, a treatment plant will incur costs for routine maintenance to replace consumables, worn parts, protective coatings, unexpected repairs, and other items. To account for miscellaneous parts replacements and maintenance that will also contribute to the overall O&M costs, it was assumed that the cost of miscellaneous parts replacements and maintenance will be equivalent to 4 percent of the capital equipment costs identified in the capital cost estimate in the previous section. The routine maintenance costs include daily tasks such as flushing, cleaning, installing small replacements parts, etc., but would not include major repairs or major replacements. As previously indicated, major facilities replacement that occurs at the end of a useful life is included in the cost model in *Chapter 10*.

5.2.4 Labor

The projected labor force for each option is included in the worksheets of *Appendix C*. The labor force includes operators, mechanics, supervisors, laboratory technicians, and electricians. Annual salaries consistent with industry standard were applied to each labor category, and adjustments for insurance and benefits (an additional 45 percent) were then applied. The anticipated staffing level is based on the pre-treatment option selected for each alternate. Therefore, all staffing is only identified in the pre-treatment option O&M, which also includes the staffing requirements for the reverse osmosis.

5.2.5 Sludge Disposal

Solids handling costs will contribute to the annual operating expenses. The quantity of sludge generated for reach option is used as the basis for sludge disposal costs. A unit disposal cost of $60 per cubic yard is included in the estimate, which is intended to include hauling costs and tipping fees for disposal in a landfill. Sludge disposal will be required for all alternates that use mechanical equipment for pre-treatment of the raw water. Alternates that use Bank Filtration as the intake do not have mechanical pre-treatment equipment and therefore will not have sludge processing and disposal costs. Additional labor and higher O&M recurring costs are used on the bank filtration options to maintain the capacity and functionality of the bank filtration system.

5.3 Present Worth Analysis

A present worth analysis was prepared to evaluate and compare the economic impacts of all options. The present worth of an expenditure, or “investment,” related with a given option is today’s dollar value (i.e., at the date of implementation of a given option) of all routine annual expenditures ascribable to that option. By this definition, since the O&M costs are routine annual expenditures, the O&M costs of the project period (20 years) can be extrapolated back to a present worth value. Thus, the total option cost is composed of the capital cost plus the present worth of the O&M costs. Detailed calculations are provided in *Appendix C.*

To determine the present worth of an annual expenditure, the annual costs are multiplied by the present worth factor (PF). The present worth factor converts the annual cost to a present day value, which can then be added to the capital costs that results in a single value that can be used to compare otherwise dissimilar alternates. The present worth factor, PF, is a function of the assumed interest rate and period of investment. For this analysis, an interest rate of 5.0 percent was assumed. The period used in the analysis was 20 years. The present worth factor is calculated in the following manner:

$$PF_n = \frac{(1+i)^n - 1}{i(1+i)^n}$$

Where,

n = period (20 years)
i = interest rate (5%)

Then,

$PF_{20} = 12.462$

To determine the present worth of the O&M costs, the present worth factors are used as multipliers against O&M costs. The total present worth is then found by adding the present worth of the O&M cost to the capital cost. *Tables 4-5.3-1* and *4-5.3-2* summarize the results of the present worth analysis of the alternates.

Table 4-5.3-1 Present Worth Comparison of Alternates – Barney Davis Site

	Alternate			
Barney Davis Power Plant	**BD 1**	**BD 2**	**BD 3**	**BD 4**
Estimated Capital Cost	$198.2 M	$196.6 M	$234.8 M	$179.8 M
Estimated Annual O&M Costs	$17.6 M	$17.5 M	$21.3 M	$14.9 M
Present Worth of O&M Costs	$219.6 M	$219.0 M	$266.1 M	$186.8 M
TOTAL PRESENT WORTH COST	$417.8 M	$415.6 M	$500.9 M	$366.6 M

Table 4-5.3-2 Present Worth Comparison of Alternates – Oxychem Site

	Alternate			
Oxychem Plant Site	**OX 1**	**OX 2**	**OX 3**	**OX 4**
Estimated Capital Cost	225.4 M	294.2 M	332.4 M	277.4 M
Estimated Annual O&M Costs	15.4 M	18.5 M	22.3 M	15.9 M
Present Worth of O&M Costs	$191.9 M	$230.5 M	$277.9 M	$198.1 M
TOTAL PRESENT WORTH COST	$417.3 M	$524.7 M	$610.3 M	$475.5 M

5.3.1 Barney Davis Site Alternates

The estimated total life cycle costs of the Barney Davis Power Plant Site Alternates range from $357.6 million to $488.6 million. The major cost differences between these options are related to the compatible combinations of intake and pre-treatment options. The three higher cost alternates at this site, Alternates BD 1, BD 2, and BD 3, use an equipment-intensive process to prepare raw water for the reverse osmosis system, whereas Alternate BD 4 uses bank filtration as the pre-treatment option with only ultraviolet disinfection on the plant site ahead of the RO process. The elimination of the pre-treatment equipment in Alternate BD 4 is a principal factor affecting the cost differential.

The mechanical equipment pre-treatment options are better defined and have a significantly greater anticipated long-term reliability than bank filtration. The assumed criteria for the equipment-based options are well established in the treatment industry. The criteria used for sizing the bank filtration option are not based on actual in situ conditions, which must be established prior to a final selection of bank filtration as an intake-pre-treatment option. As a result, the level of confidence in the overall magnitude of costs and in the long-term reliability for Alternates BD 1, BD 2, and BD 3 is significantly greater than for Alternate BD 4.

All of the alternates at the Barney Davis site discharge the byproduct to the Gulf of Mexico. The present worth cost of discharging to the Gulf is approximately $36 million. Currently, the Barney Davis Power Plant has the ability to discharge 500 mgd of cooling water to Oso Bay, which is immediately adjacent to the Barney Davis cooling ponds. If the byproduct stream could be commingled with the cooling water discharge, it may be possible to save approximately $32 million in present worth cost. This byproduct management option was not included in the main alternates because of the uncertainty of the ability to obtain environmental permits and because of the uncertainty of the long-term status of the Barney Davis Power Plant operations. Both of these conditions should be continuously monitored to preserve the possibility of saving a significant present worth value associated with byproduct management.

5.3.2 Oxychem Plant Site Alternates

The anticipated present worth costs for the Oxychem Plant site alternates range from $417.3 million to $610.3 million. The variability of costs between these alternates is significantly greater than for the Barney Davis Plant site alternates. This variability is entirely the result of the off-site pipelines necessary to support the treatment facility. The lowest cost alternate at the Oxychem site (Alternate OX 1) uses Corpus Christi Bay as the source water, which is located less than 1 mile from the Oxychem site. The other three alternates use the Gulf of Mexico as the raw water source, which is located 14 miles from the site. The difference in raw water pipe costs alone is $52 million.

Alternate OX 1 also uses bank filtration as the intake option. An open sea intake in Corpus Christi Bay is not recommended because of the shallow depth, susceptibility to water quality variations, and environmental concerns. The development obstacles and the unknown long-term reliability of the bank filtration intake system result in this alternate having the least overall confidence level in the relative evaluation.

5.4 Present Worth Analysis Summary

This present worth analysis is presented for the comparison of treatment alternates identified for the Corpus Christi area only. This analysis is not intended by itself to be used to determine rates or to compare with other water costs of the Corpus Christi Water Utility. This present worth cost comparison is a component of the cost model presented in *Chapter 10 – Cost Model*.

At the Barney Davis Plant, two alternates are recommended for further evaluation, Alternate BD 2 and Alternate BD 4. If sufficient land can be found and the transmissivity index of the underlying seabed will support a Ranney Bank Filtration Well, Alternate BD 4 should be pursued as the recommended alternate at the Barney Davis Plant site. In the absence of acceptable data described above, the reliability of Alternate BD 2 compels its selection as the alternate of choice for the Barney Davis site.

Independent of the viability issue of the Ranney Bank Filtration intake, use of the Barney Davis cooling ponds and 500-mgd cooling water pumps should be pursued. If the cooling water pumps and ponds provide an environmentally acceptable means of byproduct management, the Barney Davis site will clearly be the site of choice for the Corpus Christi Large Scale Desalination Facility.

At the Oxychem site, Alternates OX 1 and OX 4 are essentially the same except for the raw water pipeline. With either of these alternates, the availability of shoreline land area and the transmissivity of the soil are extremely important to the viability of these alternates, and detailed field investigations are required. In the absence of this data, Alternate OX 2 is the alternate of choice at the Oxychem site.

6 PRIORITIZATION OF ALTERNATES

The alternatives presented in this analysis have varying degrees of cost, reliability, and complexity of implementation. It is difficult to compare and recommend alternatives with dissimilar criteria without establishing a common denominator for the criteria. To objectively prioritize the alternates, a comparative prioritization technique referred to as a weighted evaluation matrix is used.

For this analysis, the weighted evaluation matrix uses three criteria: Present Worth Cost, Reliability, and Permitting and Implementation. All combinations of these three criteria are compared subjectively to determine their relative ranking in the prioritization process. The relative subjective rankings are then converted to numeric values.

When comparing the criteria, five relative rankings based on their importance to project success are available. The subjective relative rankings and the corresponding numeric values are:

- Much greater importance — Numeric Value = 5
- More important — Numeric Value = 4
- Same relative importance — Numeric Value = 3
- Less important — Numeric Value = 2
- Much less important — Numeric Value = 1

For example, when comparing generic Criteria #1 to generic Criteria #2, the question is asked: What is the relative importance of Criteria #1, relative to Criteria #2? If the answer is that Criteria #1 is "More Important" than Criteria #2, then the comparison is assigned a numeric value of 4. Conversely, when the same Criteria #2 is compared to the same Criteria #1, based on the previous decision, Criteria #2 must be considered "Less Important" than Criteria #1 and is assigned a numeric value of 2. These subjective comparisons are performed for all combinations of criteria. The numeric values of the relative rankings are then summed to determine the overall relative ranking of the criteria.

Placing the criteria in a two-dimensional decision matrix facilitates the manipulation of the criteria ranking system. Because three criteria are selected for this evaluation, the criteria prioritization matrix becomes a three by three two-dimensional matrix. The following *Table 4-6-1* displays the criteria prioritization matrix for this evaluation and includes the assigned relative importance values.

In this evaluation, Cost was ranked lower than Reliability. If there is uncertainty that an alternate will not provide long-term reliable performance, project success will be reduced. It is important that the final recommended solution functions as intended. When making decisions during the design process, Reliability is likely to take precedence over Cost.

Cost was also ranked less important than Complexity of Implementation. A project that is mired down in environmental permitting, land acquisition, and other non-technical issues could easily experience additional costs associated with the delays and concessions that far exceed the relative cost differential of the technical solutions.

Table 4-6-1 Ranking the Criteria

	Cost	**Reliability**	**Implementation**	**Not Used**	**Not Used**	**SUM**
Cost		2	2			4
Reliability	4		4			8
Implementation	4	2				6
Not Used						
Not Used						

In the final criteria comparison, Reliability was ranked as more important than Complexity of Implementation. When implemented, this project will receive high profile attention at a national and international level. This project must work as intended and have a consistent and reliable performance.

The final criteria ranking for the evaluation of alternates is:

1. Reliability — Rank Value = 8
2. Complexity of Implementation — Rank Value = 6
3. Total Life Cycle Costs — Rank Value = 4

During the development of this project and prior to the final selection of the alternate to be implemented, it is anticipated that other criteria may be added to the evaluation matrix and the relative ranking of the criteria will be modified. Additional criteria that could be considered are Vulnerability of the Supply Source, Environmental Impacts, and Permitting. If Environmental Impacts and Permitting are included in the analysis, Complexity of Implementation could be eliminated as being redundant.

In a manner identical to the prioritization of the criteria, all of the alternates are compared against all other alternates for each of the criteria. There are eight alternates and three criteria. An eight by eight matrix of the alternates is required for each of the criteria. Within each criteria matrix, the relative values assigned to each alternate are summed and the result multiplied by the criteria weighting factor defined above. The Alternate Evaluation matrices are presented in *Table 4-6-2, Table 4-6-3,* and *Table 4-6-4.*

Table 4-6-5 summarizes the weighted evaluation matrix with the alternates presented in the order they were evaluated. *Table 4-6-6* summarizes the weighted evaluation matrix with the alternates presented in accordance with rank resulting from this evaluation.

Table 4-6-2 Alternate Evaluation Matrix – COST

CRITERIA	COST											
Criteria Sum	4											
	BD 1 - $417.8	BD 2 - $415.6	BD 3 - $500.9	BD 4 - $366.6	OX 1 - $417.3	OX 2 - $524.7	OX 3 - $610.3	OX 4 - $475.5			SUM	WEIGHTED
BD 1 - $417.4		3	4	2	3	4	4	3			23	92
BD 2 - $415.6	3		4	2	3	4	4	3			23	92
BD 3 - $500.9	2	2		2	2	3	4	3			18	72
BD 4 - $366.6	4	4	4		3	4	5	4			28	112
OX 1 - $417.3	3	3	4	3		4	4	3			24	96
OX 2 - $524.7	2	2	3	2	2		4	3			18	72
OX 3 - $610.3	2	2	2	1	2	2		2			13	52
OX 4 - $475.5	3	3	3	2	3	3	4				21	84

Table 4-6-3 Alternate Evaluation Matrix – RELIABILITY

CRITERIA	RELIABILITY											
Criteria Sum	8											
	BD 1 - $417.8	BD 2 - $415.6	BD 3 - $500.9	BD 4 - $366.6	OX 1 - $417.3	OX 2 - $524.7	OX 3 - $610.3	OX 4 - $475.5			SUM	WEIGHTED
BD 1 - $417.4		3	3	5	5	3	3	4			26	208
BD 2 - $415.6	3		3	5	5	3	3	5			27	216
BD 3 - $500.9	3	3		5	5	3	3	5			27	216
BD 4 - $366.6	1	1	1		3	1	1	3			11	88
OX 1 - $417.3	1	1	1	3		1	1	3			11	88
OX 2 - $524.7	3	3	3	5	5		3	5			27	216
OX 3 - $610.3	3	3	3	5	5	3		5			27	216
OX 4 - $475.5	2	1	1	3	3	1	1				12	96

Table 4-6-4 Alternate Evaluation Matrix – COMPLEXITY OF IMPLEMENTATION

CRITERIA	COMPLEXITY OF IMPLEMENTATION											
Criteria Sum	6											
	BD 1 - $417.8	BD 2 - $415.6	BD 3 - $500.9	BD 4 - $366.6	OX 1 - $417.3	OX 2 - $524.7	OX 3 - $610.0	OX 4 - $475.5			SUM	WEIGHTED
BD 1 - $417.8		3	3	4	5	3	3	4			25	150
BD 2 - $415.6	3		3	4	5	3	3	4			25	150
BD 3 - $500.9	3	3		4	5	3	3	4			25	150
BD 4 - $366.6	2	2	2		4	2	2	3			17	102
OX 1 - $417.3	1	1	1	2		1	1	2			9	54
OX 2 - $524.7	3	3	3	4	5		3	4			25	150
OX 3 - $610.3	3	3	3	4	5	3		4			25	150
OX 4 - $475.5	2	2	2	3	4	2	2				17	102

Table 4-6-5 Alternate Evaluation Matrix Summary of Results

Alternate	Cost	Reliability	Implementation	Not Used	Not Used	SUM	RANK
BD 1	92	208	150			450	2
BD 2	92	216	150			458	1
BD 3	72	216	150			438	3
BD 4	112	88	102			302	6
OX 1	96	88	54			238	8
OX 2	72	216	150			438	3
OX 3	52	216	150			418	5
OX 4	84	96	102			282	7

Table 4-6-6 Alternate Evaluation Matrix Summary of Results – Sorted by Rank

Alternate	Cost	Reliability	Implementation	Not Used	Not Used	SUM	RANK
BD 2	92	216	150			458	1
BD 1	92	208	150			450	2
BD 3	72	216	150			438	3
OX 2	72	216	150			438	3
OX 3	52	216	150			418	5
BD 4	112	88	102			302	6
OX 4	84	96	102			282	7
OX 1	96	88	54			238	8

The goal of the weighted decision matrix technique is to convert subject parameters to objective values. However, in reality, the results remain subjective and are based on the perspective of the evaluators. This decision matrix technique should be periodically reevaluated as the project progresses through the feasibility phase and into the preliminary engineering phase. During development, it is likely that the factors that influence all of the criteria and the relative ranking of the alternates, will become more clarified as more information is obtained. The decision matrix tables presented have additional columns and rows to allow the addition of two additional criteria and two additional alternates, if necessary.

This evaluation has determined that the top two alternates are BD 2 and BD 1 with Alternates BD 3 and OX 2 tied for third. By reviewing this analysis, it is apparent that the Barney Davis site is the best site for the proposed desalination facility. The proximity of the Barney Davis Site to the source water and a major water transmission line result in a significantly reduced costs for offsite piping of the source water, byproduct, and finished water.

Another significant advantage of the Barney Davis site is its location relative to other distribution supply sources. Currently, the City's distribution system supply source is the O. N. Stevens Water Treatment Plant located near the west end of the City's distribution system. Being fed from a single source of supply, the distribution system, though reliable in the past, could be vulnerable to significant system outages if a failure occurs in this area. Also, transmission piping must be oversized to allow the water to be distributed to all locations. The Barney Davis site is near the east end of the distribution system and would provide a major source of supply from the opposite end of the distribution system from the O. N. Stevens Plant. The second source of supply located at the Barney Davis site would allow the east end of the system to be served from the Barney Davis site and allow the water from the O. N. Stevens Plant to be retained in the central and western areas of the service area. This arrangement would allow for increased flexibility in meeting the demands over a wider service area and increase the capacity of the existing distribution system. These distribution system enhancement capabilities are not available from the Oxychem site location.

The Barney Davis site also offers a significant potential for reduced costs from the estimates presented herein. Further investigation is required to determine if the desalination byproduct stream can be blended with the cooling water outfall line discharging to Oso Bay. If this can be made to be an environmentally acceptable byproduct discharge location, the cost of the byproduct discharge line to the Gulf of Mexico can be essentially eliminated. Power is another potential cost savings at the Barney Davis site. The power costs used in this analysis was $0.065 which was based on contacts to power providers in the region. Quotes for power from the Barney Davis Power Plant could not be obtained because of the transition in ownership that was underway during the course of this study. However, preliminary discussions with the new owner of the facility have indicated that the power cost may be less than the $0.065 used in this report. However, the power produced at the Barney Davis Power Plant cannot be sold on a retail basis. The City of Corpus Christi could file the necessary applications to allow them to be a power wholesale distributor and would then be able to purchase the power from the Barney Davis Power Plant at wholesale costs.

6.1 Optimization of Alternate BD 2 (Development of Alternates BD A2 & BD B2)

Based on the prioritization of alternates presented above, the Barney Davis Power Plant site is the clear choice for the proposed desalination facility in Corpus Christi, and Pre-Treatment Option 2 using dissolved air flotation and granular media filters, is the recommended pre-treatment system. The optimization analysis in this section reviews the assumptions and conditions that formulated the treatment philosophies at the Barney Davis Power Plant site and applies value engineering and optimization techniques to further refine the alternate to determine if the cost can be lowered.

The basic alternates developed for the Barney Davis Power Plant site did not use the potentially available resources located at the site. During the alternates' development stage, the Barney Davis Power Plant was in the process of being sold, and the site owners did not want to encumber the site with other commitments. For these reasons, the principal alternates at the Barney Davis Power Plant were developed to be totally self sufficient, other than the use of land on the site.

Near the completion of the feasibility study (July 29, 2004), it was learned that the sale of the Barney Davis Power Plant was completed, the new owners would consider co-locating the desalination facility on the site, and are interested in allowing the desalination facility to use the available resources on the site.

6.1.1 Barney Davis Power Plant Resources

Based on discussions and a letter from the new owners of the Barney Davis Power Plant, the available resources of the Barney Davis Power Plant could be considered for use in the proposed desalination facility. The potentially available resources include land area, discharging the byproduct stream to the cooling ponds, shared use of the intake and outfall, available circulating water, and favorable pricing for power to the desalination facility. All of these potential resources, with the exception of a favorable power pricing structure, are considered in the development of the optimized alternates of this section.

The raw water source used in development of the principal alternates for the Barney Davis site is the Gulf of Mexico. However, the Barney Davis Power Plant owns an intake into Laguna Madre. This intake into Laguna Madre was not used in the principal alternates for the following reasons.

1. The pending sale of the Barney Davis Power Plant suggested that long-term use of the site was unknown during the development of this feasibility study.

2. The total dissolved solids concentration in Laguna Madre is oftentimes significantly above the project goal upper limit of 35,000 mg/l. Blending of the Laguna Madre raw water with groundwater was considered, but sufficient groundwater resources were not available in this area.

The long-term use of the site suggested that a separate intake should be constructed for long-term reliability of the raw water supply. The high TDS in Laguna Madre suggested that if a new intake had to be built, it should be constructed in the gulf to avoid the high treatment costs associated with removing elevated TDS levels. The result of these developments was the proposed construction of a new intake in the Gulf of Mexico, a raw water pump station, and a raw water transmission line at a total cost of over $51 million plus a present worth cost of the O&M of $12 million. The total impact of these developments added nearly $63 million to the present worth of the life cycle costs of the recommended alternative.

The Barney Davis Power Plant currently discharges its warmed cooling water to cooling ponds that ultimately discharge to Oso Bay. Because the long-term operation of the Barney Davis site was in doubt, the principal alternates did not consider that commingling of the byproduct stream would be environmentally viable without the power station cooling water flows. With the resurgence of the long-term viability of the Barney Davis Power Plant and the cooperative attitude of the new owners, the use of the Barney Davis outfall and cooling water is significantly more viable than originally anticipated and is considered in the optimization of the Barney Davis site alternate.

6.1.2 Development of Optimized Alternates

The focus of the alternative optimization is to reduce the total life cycle costs of the proposed desalination facility. Two specific areas of optimization are available: (1) the use of the Barney Davis raw water intake and circulation water and (2) use of the cooling water outfall and mixing of the desalination byproduct stream with the cooling water discharge.

The Barney Davis intake and pumping facility is an existing facility and would not likely need to be modified for the desalination facility. Some minor in-plant piping modifications would be required to divert water to the desalination facility, but coordination of these requirements would only have to be negotiated with the new site owners that have already exhibited a cooperative attitude toward the desalination facility. With this optimization, the raw water intake in the Gulf of Mexico, the raw water pump station, and the construction of the raw water line across Laguna Madre would be eliminated. The use of the Barney Davis raw water intake and pumping facilities would eliminate a potentially complex approval process and significant costs associated with constructing the necessary facilities to take raw water from the Gulf of Mexico.

The discharge of the byproduct stream to the Barney Davis cooling ponds also has significant cost benefits, but environmental concerns will likely be raised over the byproduct stream impacts on Oso Bay. Although the total annual pounds of salt discharge to Oso Bay will remain relatively constant, the dilution water will be reduced by the 25-mgd product stream from the desalination facility. The net effect is a slight increase in the salinity concentration of the blended cooling water stream into Oso Bay. The anticipated increase in salinity concentration is estimated to be approximately 5 percent compared to alternates that discharge the byproduct stream into the Gulf of Mexico.

Based on the co-use of the Barney Davis resources described herein, two optimized sub-alternates are presented for evaluation. The optimization sub-alternates are only applied to the recommended Alternate BD 2 as described earlier in this Chapter.

Alternate BD A2 only uses minimal resources at the Barney Davis Power Plant. Only the land area, intake structure, and a portion of the raw water intake rights from Laguna Madre are incorporated into Alternate BD A2. Therefore in this optimized alternate, the open sea intake into the Gulf of Mexico is eliminated, and a separate raw water pump station is constructed to take advantage of the raw water intake and withdrawal rights from the Laguna Madre source water. Because of the remaining environmental concerns associated with discharge of the byproduct stream to the cooling ponds and ultimately to Oso Bay, the discharge of the byproduct stream into the Gulf of Mexico is retained in this optimized Alternate BD A2. Also, Alternate BD A2 is not dependent on the continuous operation of the Barney Davis Power Plant.

Alternate BD B2 takes full advantage of the potentially available resources of the Barney Davis Power Plant. The raw water to the desalination facility will be supplied from a sidestream from the cooling water system. Also, the byproduct stream will be mixed with the cooling water discharge to the cooling ponds at the existing outfall structure. With this optimized Alternate BD B2, the raw water intake, raw water pipeline, raw water pump station, byproduct pump station, and byproduct outfall line are all eliminated from the proposed facility.

Even with the transfer of ownership of the Barney Davis Power Plant, continuous operation of the power plant at full capacity is not guaranteed. Alternate BD A2 described above is not dependent on operation of the Barney Davis facility; but Alternate BD B2 requires the raw water pumps, intake, outfall, and cooling ponds to remain in continuous operation. For this reason, it is assumed that for the development of the optimized Alternate BD B2, the Barney Davis Power Plant will be functional 60 percent of the time; and during the remaining 40 percent of the time, the desalination facility will be required to fully operate the intake, raw water pumps, and outfall system for 40 percent of the time.

6.1.3 Raw Water Supply

To fully explore the potential savings of using the raw water resources at the Barney Davis site, the additional capital and O&M costs required to treat the higher TDS water in Laguna Madre must be developed. The question becomes is it more economical to treat the high salinity raw water in Laguna Madre or construct additional raw water supply facilities to the Gulf of Mexico.

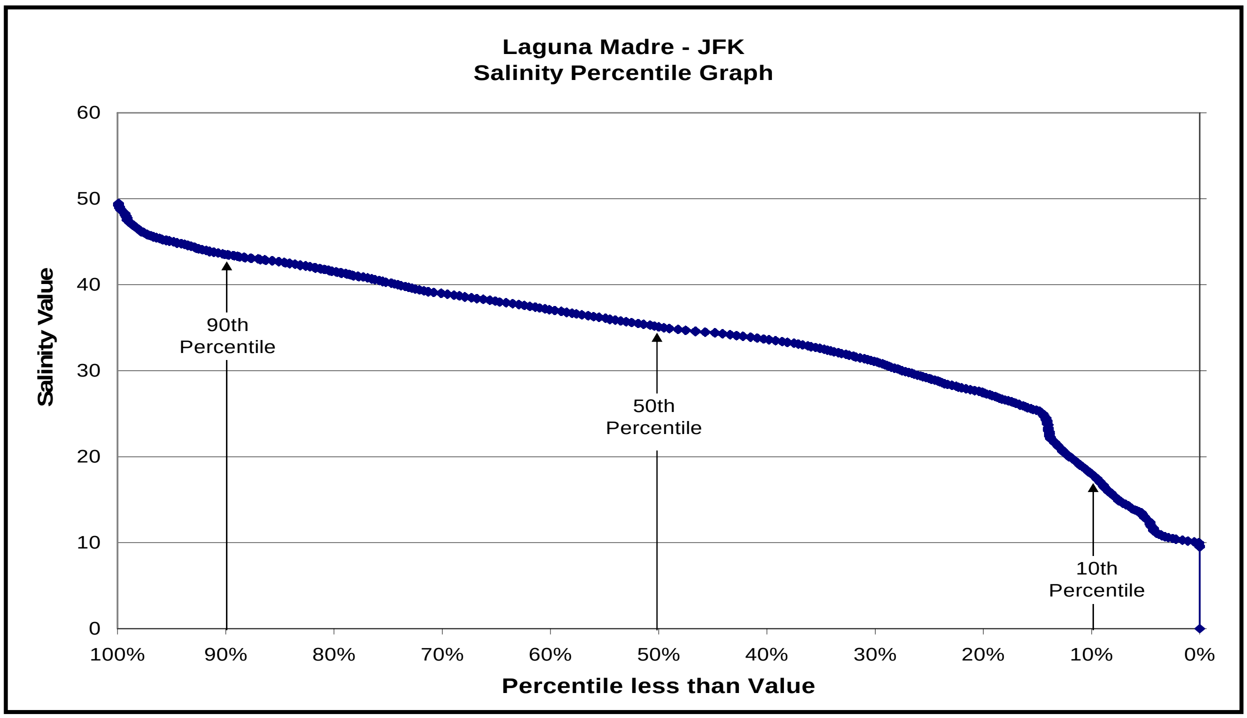
A review of the salinity data presented in *Section 2.2* of this chapter indicates the average salinity for Laguna Madre to be in accordance with the project goals of 35,000 mg/l. However, Laguna Madre frequently experiences hypersalinity with TDS concentrations reaching 50,000 mg/l. Anecdotal data concerning Laguna Madre reveals that the salinity at times can exceed the 50,000 mg/l level, although this did not occur in the 3 years of data presented and analyzed in *Section 2.2*. Representative salinity data for Laguna Madre are presented in *Table 4-6.1.3-1* and *Figure 4-6.1.3-1*.

The purpose and added value of a desalination facility is its drought-proof supply source. Therefore, the desalination facility must be designed to function at full capacity during all anticipated conditions. To meet this project goal, the optimized alternates are based on designing all facilities for a raw water of 50,000 mg/l and to produce a finished product stream of 25 mgd. The average raw water TDS is assumed to be the 50th percentile value of 35,000 mg/l.

Table 4-6.1.3-1 Laguna Madre Salinity Data Summary

Average TDS in Laguna Madre	~ 35,000 mg/l
75th percentile TDS	~ 40,400 mg/l
90th percentile TDS	~ 45,500 mg/l
99th percentile TDS	~ 50,000 mg/l

Figure 4-6.1.3-1 Laguna Madre Salinity Distribution Curve



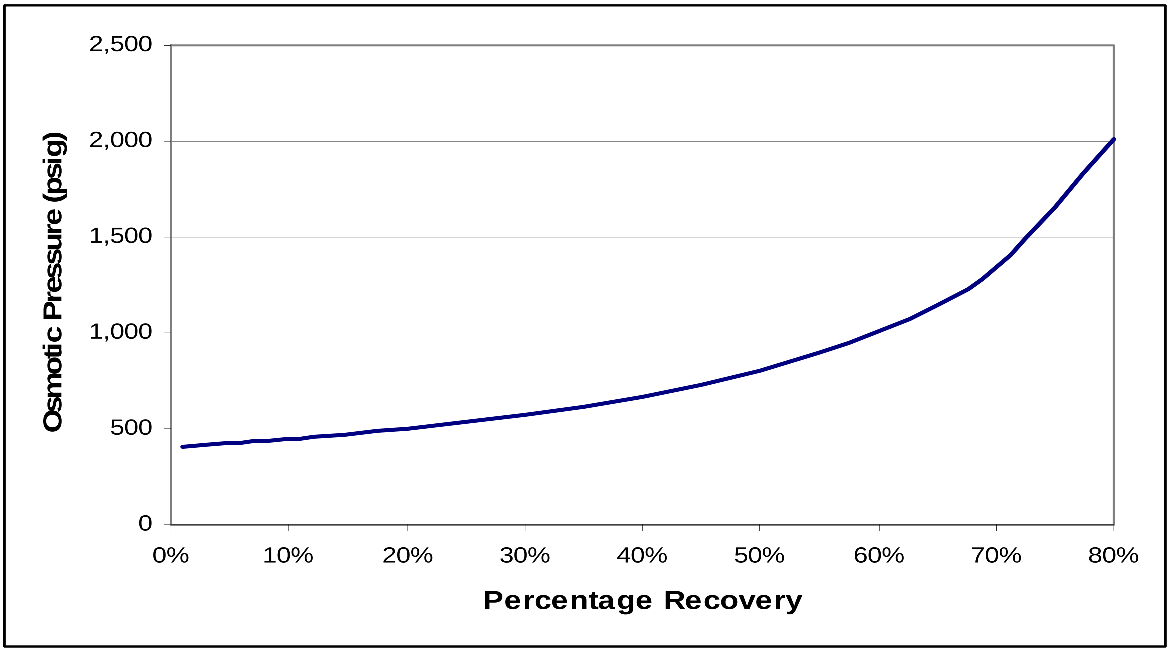
The higher TDS raw water concentration used in the optimization alternates will reduce the recovery of the reverse osmosis system resulting in a higher flow rate through the pre-treatment stream and in the byproduct stream. The capacity of all streams must be determined at the worst-case 50,000 mg/l TDS raw water quality conditions and cost estimates developed for these "oversized facilities." It must further be recognized that by upsizing all of the facilities to accommodate the elevated TDS concentrations, additional capacity will be available during all times when the raw water TDS concentration is less than this defined peak condition.

The impact on "recovery" is the key factor affecting the development of all facilities. Recovery is the ratio defined as the finished water production flow rate divided by the reverse osmosis feed stream flow rate. From all previous alternates, the recovery was estimated to be 50 percent. That recovery is based on a feed stream capacity of 50 mgd and a finished water product stream of 25 mgd and was estimated using a raw water temperature of 10°C and an applied pressure to the membrane of 1,000 psi.

To estimate the recovery at varying salinities, a graph of salinity vs. recovery is developed for the given conditions of 10°C and an applied pressure to the membrane of 1,000 psi. To ensure that all conditions are evaluated equally, the curve used to develop all original alternates is used as the basis for this evaluation.

Figure 4-2-2 is reproduced in the following *Figure 4-6.1.3-2*. The general shape of the curve of Applied Pressure vs. Percent Recovery for a 35,000-mg/l source water is depicted in this figure.

Figure 4-6.1.3-2 Effects of Osmotic Pressure vs. Recovery



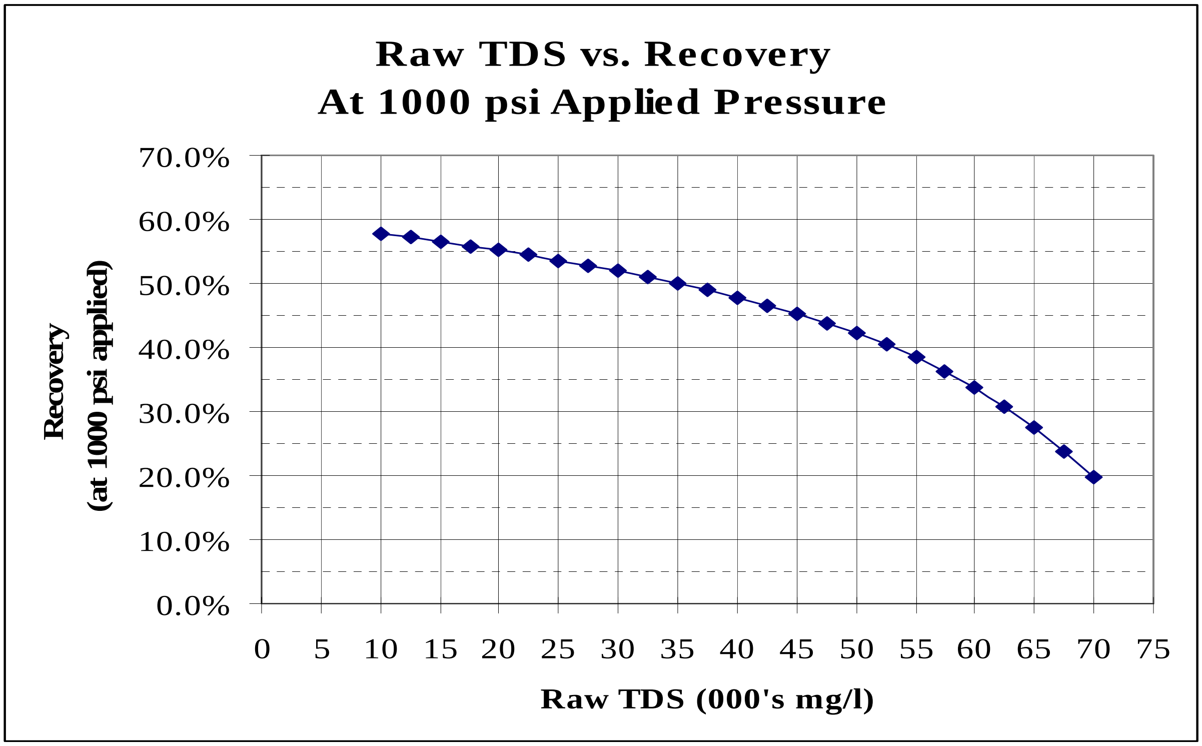
The osmotic pressure for any given water can be generally defined as 0.0115 psig per mg/l TDS. In the above curve, the osmotic pressure crosses the "Y" axis at the osmotic pressure associated with a 35,000-mg/l TDS concentration which equates to about 400 psig. Applying a 400 psig pressure to the system will only offset the osmotic pressure, but not provide the excess pressure that is required to create movement through the membrane. Applying a pressure of 1,000 psig in the above graph will result in a flow through the membrane and a recovery of approximately 60 percent. In this analysis, and in all previous analyses, a safety factor was used such that the recovery is actually determined to be 50 percent under the conditions defined in the above figure.

The graph can easily be redrawn for other raw water TDS concentrations. For instance, the above curve is for 35,000 mg/l, the osmotic pressure is TDS times 0.0115 psig/mg/l = 402 psig, so the Y-intercept is at 402 psig. If the raw water TDS is reduced to 10,000 mg/l, the osmotic pressure reduces to 115 psig; therefore, the above curve moves down vertically so that the Y-intercept is at 115 psig. If applied pressure is maintained at 1,000 mg/l, the percent recovery rises considerably.

Conversely, if the raw water TDS raises to 50,000 mg/l, the osmotic pressure (Y-intercept on the curve) rises to 575 psig, and the recovery is substantially reduced with a constant 1,000 psi applied pressure.

Based on the shape of the curve in the *Figure 4-6.1.3-2*, a nonlinear regression analysis is performed to create an equation that represents the shape of the curve. The curve then can be mathematically "moved" to account for changes in TDS. The equation can also be manipulated to adjust for the design factor of safety. Manipulation of the nonlinear model results in the curve of raw water TDS vs. anticipated recovery for a constant applied pressure of 1,000 psi, as shown in *Figure 4-6.1.3-3*.

Figure 4-6.1.3-3 Raw Water TDS vs. Recovery (10°C at 1,000 psig)

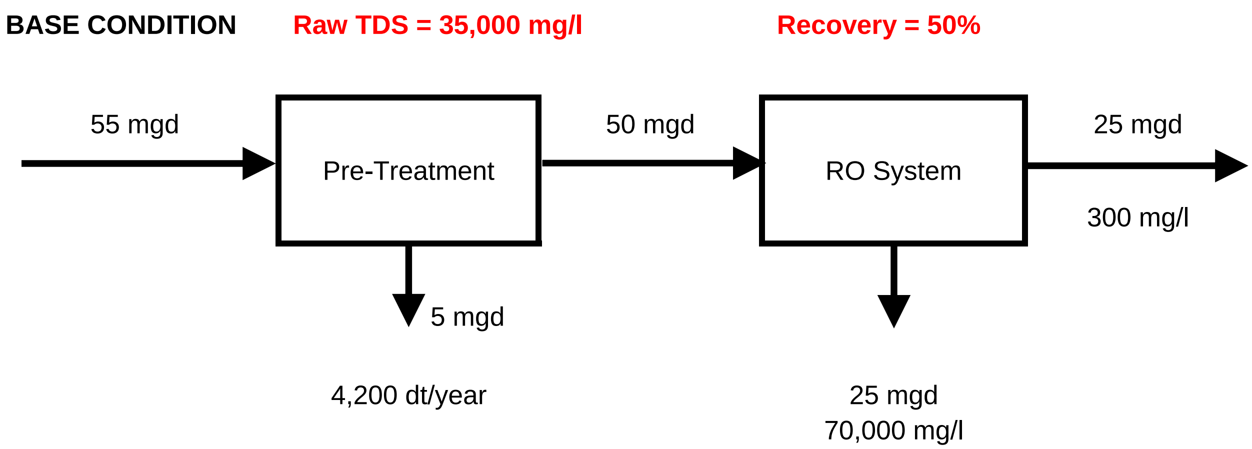


This curve shows that as the feedwater TDS rises, the recovery is reduced. The actual recovery is dependent on many factors such as raw water salinity, temperature, membrane characteristic, fouling, applied pressure, and many other considerations. Although the pressure-recovery relationship is depicted as a discrete line, the true potential relationship includes a broad band on either side of the curves. Therefore, this analysis should be considered to be indicative of the trends that are to be expected as a result of varying the salinity and the raw water source on the treatment system.

6.1.4 Impacts of Varying TDS on Capital Costs

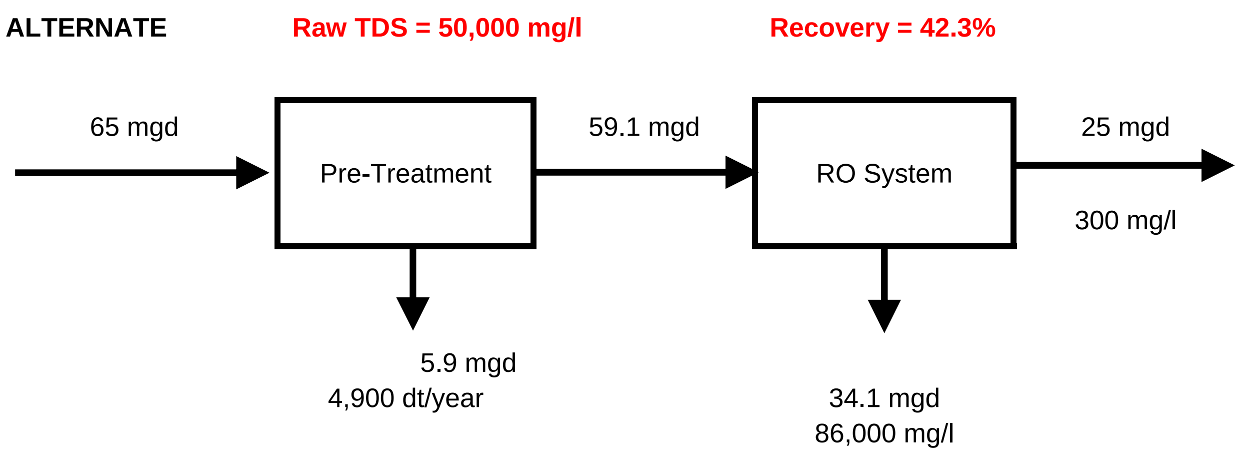
Figure 4-6.1.4-1 provides a tool that facilitates the identification of the impacts of varying raw water TDS concentrations. Once the relationship of RO recovery and raw water TDS is known, the flow streams for the entire treatment process can easily be determined. *Figure 4-6.1.4-1* presents a simplified block flow diagram for the original condition in the report of 35,000 mg/l raw TDS and 50 percent recovery.

Figure 4-6.1.4-1 Base Condition for the Barney Davis Power Plant



If the raw water TDS is changed to 50,000 mg/l, the model recalculates all the flow streams and re-populates the process block flow diagram as presented in *Figure 4-6.1.4-2*.

Figure 4-6.1.4-2 Effects of Increasing Raw Water TDS to 50,000 mg/l on All Major Flow Streams



Once the flow streams are identified, the cost estimate is recalculated to determine the impacts of the raw water TDS on the overall cost of the facility. Capital costs and O&M costs are dealt with separately and then combined to determine the revised overall life cycle cost.

To begin the cost estimate adjustment, six stream categories are defined as follows.

1. RO Input Stream
2. Byproduct Stream
3. Pre-Treatment Influent Stream
4. Pre-Treatment Residuals Stream
5. Common (Unaffected by Raw Water TDS – Administration Building etc.)
6. Raw Water Pumping (This is a special category separate from the others to accommodate the form of the cost estimate.)

Every line item in the cost estimate is assigned to one of the above six stream categories. Each of these stream categories is affected by a different order of magnitude. By separating the costs into these categories, each stream category could be adjusted independently.

An economy of scale formula is then applied to each of the categories of cost. The economy of scale (EOS) formula is:

$$Cost_1 = Cost_0 * \left\{ \frac{Cap_1}{Cap_0} \right\}^{EOS}$$

Where:

$Cost_0$	=	Cost of the Base Condition
$Cost_1$	=	Cost of the Alternate Condition
Cap_0	=	Capacity of the Base Condition
Cap_1	=	Capacity of the Alternate Condition
EOS	=	Economy of Scale Factor

The EOS factor is a number between 0.0 and 1, but typically is not less than 0.5. If the EOS factor is 1, then there are no economies based on the size of the installation and costs vary proportionately with the capacity. For an EOS = 1 condition, if the capacity is doubled, the cost will also double; if the capacity is halved, the cost will also halve.

For an EOS factor of 0.5, there is a significant economy in unit costs associated with building larger facilities. For example, with an EOS factor of 0.5, if the capacity of a facility is doubled, the cost only increases by a factor of 1.41; and if the capacity is halved, the cost will be 71 percent of the original estimate.

For an EOS factor of 0, the costs are totally fixed costs and completely independent of capacity.

Value engineers typically use an EOS of 0.6 for everything associated with treatment plants. Experience indicates that a uniform EOS factor of 0.6 understates the true cost of increasing the capacity of a facility. For this evaluation, separate EOS factors are used for each of the identified flow stream categories as shown in *Table 4-6.1.4-1*. The model allows independent adjustment of EOS factors for each flow stream category.

Table 4-6.1.4-1 Economy of Scale Factors

Cost Category	EOS Factor	Comment
RO Stream	0.9	Very little Economy of Scale. Cost is relatively linear with capacity
Byproduct Stream	0.8	Mid-level economy of scale
Pre-Treatment Influent Stream	0.8	Mid-level economy of scale
Pre-Treatment Residuals Stream	0.8	Mid-level economy of scale
Common (Unaffected)	0.0	Unaffected by capacity - Constant Cost for all Capacity Conditions within anticipated range. Used for non-capacity related costs.
Raw Water Pumping	0.8	Mid-level economy of scale
Piping Systems	0.6	Significant economy of scale

The above methodology forms the basis for all evaluations. The EOS factors presented in *Table 4-6.1.4-1* are for capital costs only. The O&M costs were adjusted based on an EOS factor of 1.0.

Using the above methodology, the following *Table 4-6.1.4-2* summarizes the impact on the capital costs for accommodating an increased raw water TDS. In Alternate BD A2, the costs for developing the raw water intake, pump station, and raw water line are eliminated, and similar facilities available at the Barney Davis Power Plant are used. A summary of both the base Alternate BD 2 and the optimized Alternate BD A2 are presented in *Table 4-6.1.4-2*.

By using the available raw water supply resources of the Barney Davis Power Plant, the capital costs for the proposed facility could be potentially reduced by $28.7 million.

Table 4-6.1.4-2 Capital Costs Impacts of Changing Raw Water TDS to 50,000 mg/l

	Base Alternate BD 2		Revised Alternate BD A2		Revised Alternate BD B2		
Item	**Size/Cap**	**Cost**	**Rev. Size/Cap**	**Rev Cost**	**Rev. Size/Cap**	**Rev Cost**	**EOS Factor**
Intake	55.0 mgd	$13,930,057	0.0 mgd	$0	0.0 mgd	$0	0.8
Raw Water Pumping	55.0 mgd	$2,292,375	65.0 mgd	$2,620,150	0.0 mgd	$0	0.8
Raw Water Pipe	55.0 mgd	$34,440,075	0.0 mgd	$0	0.0 mgd	$0	0.6
Pre-Treatment	55.0 mgd	$32,182,192	65.0 mgd	$36,783,764	65.0 mgd	$36,783,764	0.8
Residuals	5.0 mgd	$9,520,669	5.9 mgd	$10,868,586	5.9 mgd	$10,868,586	0.8
RO System	50.0 mgd	$56,655,925	59.1 mgd	$65,856,866	59.1 mgd	$65,856,866	0.9
Byproduct (plant)	25.0 mgd	$823,259	34.1 mgd	$1,055,329	0.0 mgd	$0	0.8
Byproduct Pipeline	25.0 mgd	$32,136,819	34.1 mgd	$38,716,092	0.0 mgd	$0	0.6
Connection to Dist	25.0 mgd	$2,497,362	25.0 mgd	$2,497,362	25.0 mgd	$2,497,362	0.6
Common Elements	25.0 mgd	$12,278,237	25.0 mgd	$12,278,237	25.0 mgd	$12,278,237	0.0
Totals		$196,756,970		$170,676,386		$128,284,815	

6.1.5 O&M Costs

Operations and maintenance costs can be treated in a similar manner as described for the capital costs. However, it is not reasonable to assume that O&M costs will be incurred at all times based on the worst-case condition used for the design of the facilities. To calculate the operations and maintenance costs, average anticipated conditions should be used over the life of the facility. For the purpose of this evaluation, the average salinity of Laguna Madre is chosen to be 38,500 mg/l, which is 10 percent above the design condition of 35,000 mg/l. An economy of scale factor of 1.0 was used in the development of all O&M costs. *Table 4-6.1.5-1* presents O&M costs developed for the original Alternate BD 2. *Table 4-6.1.5-2* presents the revised O&M costs for an average raw water TDS of 35,000 mg/l for Alternate BD A2. *Table 4-6.1.5-3* presents the revised O&M costs for an average raw water turbidity of 35,000 mg/l for Alternate BD B2.

A review of the previous tables indicates that the average raw water TDS concentration in Laguna Madre is similar to the design condition used in the development of the sea water source. There is very little impact on the overall operations and maintenance costs of the facility for these optimized alternates.

Table 4-6.1.5-1 Alternate BD 2 – Breakdown of O&M Costs by Stream Category

Item	Size/Capacity		Power	Chemical	Recurring	Labor	Solids
Intake	55.0	mgd	$0	$0	$139,301	$0	$0
Raw Water Pumping	55.0	mgd	$388,600	$0	$69,690	$0	$0
Raw Water Pipe	55.0	mgd	$0	$0	$313,358	$0	$0
Pre-Treatment	55.0	mgd	$64,291	$781,003	$926,922	$0	$1,670,381
Residuals	5.0	mgd	$243,972	$0	$271,618	$0	$0
RO System	50.0	mgd	$5,981,810	$0	$2,754,893	$0	$0
Byproduct (plant)	25.0	mgd	$84,542	$0	$25,028	$0	$0
Byproduct Pipeline	25.0	mgd	$0	$0	$290,326	$0	$0
Connection to Dist	25.0	mgd	$0	$0	$24,974	$0	$0
Common Elements	25.0	mgd	$542,244	$1,371,531	$373,270	$1,199,440	$0
Totals	$17,517,527		$7,305,458	$2,152,534	$5,189,379	$1,199,440	$1,670,381

Table 4-6.1.5-2 Alternate BD A2 – Calculation of O&M Costs for TDS = 35,000 mg/l

Item	Size/Capacity		Power	Chemical	Recurring	Labor	Solids
Intake	0.0	mgd	$0	$0	$0	$0	$0
Raw Water Pumping	55.0	mgd	$102,383	$0	$69,690	$0	$0
Raw Water Pipe	0.0	mgd	$0	$0	$0	$0	$0
Pre-Treatment	55.0	mgd	$64,291	$781,003	$926,922	$0	$1,670,381
Residuals	5.0	mgd	$243,972	$0	$271,618	$0	$0
RO System	50.0	mgd	$5,981,810	$0	$2,754,893	$0	$0
Byproduct (plant)	25.0	mgd	$84,542	$0	$25,028	$0	$0
Byproduct Pipeline	25.0	mgd	$0	$0	$290,326	$0	$0
Connection to Dist	25.0	mgd	$0	$0	$24,974	$0	$0
Common Elements	25.0	mgd	$542,244	$1,371,531	$373,270	$1,199,440	$0
Totals	$16,778,316		$7,019,241	$2,152,534	$4,736,720	$1,199,440	$1,670,381

Table 4-6.1.5-3 Alternate BD B2 – Calculation of O&M Costs for TDS = 35,000 mg/l

Item	Size/Capacity		Power	Chemical	Recurring	Labor	Solids
Intake	0.0	mgd	$0	$0	$0	$0	$0
Raw Water Pumping	55.0	mgd	$0	$0	$0	$0	$0
Raw Water Pipe	0.0	mgd	$0	$0	$0	$0	$0
Pre-Treatment	55.0	mgd	$64,291	$781,003	$926,922	$0	$1,670,381
Residuals	5.0	mgd	$243,972	$0	$271,618	$0	$0
RO System	50.0	mgd	$5,981,810	$0	$2,754,893	$0	$0
Byproduct (plant)	25.0	mgd	$953,090	$0	$25,028	$0	$0
Byproduct Pipeline	25.0	mgd	$0	$0	$290,326	$0	$0
Connection to Dist	25.0	mgd	$0	$0	$24,974	$0	$0
Common Elements	25.0	mgd	$542,244	$1,371,531	$373,270	$1,199,440	$0
Totals	$17,474,791		$7,785,406	$2,152,534	$4,667,030	$1,199,440	$1,670,381

6.1.6 Life Cycle Cost Summary

The overall impacts of increasing the raw water salinity on the life cycle costs are calculated as the sum of the capital costs plus the present worth value of the annual O&M costs. *Table 4-6.1.6-1* presents the summary of overall life cycle costs for Alternate BD 2 and optimized Alternates BD A2 and BD B2 as defined in the previous sections.

Table 4-6.1.6-1 Concept Design – Life Cycle Cost Summary

Barney Davis Site	**Alt BD 2 DAF Open Sea Intake – Gulf Outfall**	**Alt BD A2 DAF Existing Intake – Gulf Outfall**	**Alt BD B2 DAF Existing Intake – Oso Outfall**
Total Capital Costs	$196,756,970	$170,676,386	$128,284,815
Total Annual O&M Costs	$17,512,527	$16,778,316	$17,474,791
Present Worth Factor	*12.462*	*12.462*	*12.462*
Present Worth of O&M	$218,302,931	$220,621,278	$217,774,523
TOTAL LIFE CYCLE COSTS	$415,059,901	$388,677,514	$346,059,338

This optimization technique demonstrates that using the Barney Davis Power Plant raw water supply resources could save significant costs on a total life cycle cost basis.

Using only the Barney Davis intake structure and water rights, as depicted in Alternate BD A2, results in a potential life cycle cost savings of $26.4 million. Using all of the available resources at the Barney Davis Power Plant site, as depicted in Alternate BD B2, results in a potential life cycle cost savings of $69.0 million.

Chapter 5

Byproduct Management

CHAPTER 5 – BYPRODUCT MANAGEMENT
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CHAPTER 5 – BYPRODUCT MANAGEMENT

1 INTRODUCTION

In *Chapter 4 – Water Production*, raw water quality criteria are identified, and four treatment process flow diagram options are presented. The four treatment flow diagrams are generally iterated below.

- **Treatment Option 1 –** Pre-treatment with tube settlers and media filters followed by reverse osmosis desalination. Byproduct streams occur from the pre-treatment process and from the reverse osmosis process. The pre-treatment byproduct streams consist of concentrated suspended solids from the tube settler basins and filter backwash. The pre-treatment byproduct stream will be high in suspended solids, and the dissolved solids will be generally unchanged from the raw water conditions. The reverse osmosis byproduct stream will be low in suspended solids with a very high dissolved solids content of approximately 70,000 mg/l.

- **Treatment Option 2 –** Pre-treatment with Dissolved Air Flotation and media filters followed by reverse osmosis desalination. The byproduct streams in Treatment Option 2 are similar to Treatment Option 1, with the exception that the total suspended solids from the DAF units will have a higher concentration and require less processing. The reverse osmosis byproduct stream will be low in suspended solids with a very high dissolved solids content of approximately 70,000 mg/l.

- **Treatment Option 3 –** Pre-treatment with ultrafiltration membranes, followed by reverse osmosis desalination. The ultrafiltration pre-treatment process is a single step process with a single source of byproduct. The byproduct from the ultrafiltration stream contains a similar weight of suspended solids, but is contained in a more dilute stream than Options 1 or 2. The reverse osmosis byproduct stream will be low in suspended solids with a very high dissolved solids content of approximately 70,000 mg/l.

- **Treatment Option 4 –** Pre-treatment with bank filtration followed by reverse osmosis desalination. Bank filtration is a pre-treatment process located at the raw water source, thus eliminating the need for an on-site pre-treatment process. There is no routine byproduct stream from the bank filtration option, although significant maintenance of the bank filtration may be required to keep it functional. The reverse osmosis byproduct stream will be low in suspended solids with a very high dissolved solids content of approximately 70,000 mg/l.

Detailed information is presented in *Chapter 4* on each of these Treatment Options including flow diagrams, process considerations, and cost data. *Chapter 4* also identifies and evaluates the appropriate processing requirements for the pre-treatment byproduct streams. Processing of the pre-treatment byproducts will use proven and economical thickening (dissolved air flotation and DensaDeg®) and dewatering (centrifuge) processes.

The pre-treatment residuals characterization is based on information contained in *Chapter 4.* The pre-treatment residuals will be thickened and dewatered onsite and trucked to a landfill or land application site for disposal. Thickening of clarification residuals and filter residuals will be handled by DensaDeg® clarifier/thickeners, and centrifuges will be used to dewater the thickened residuals.

Table 5-1-1 provides a summary of the residuals production and handling for each of the pre-treatment options that are being evaluated. As shown in *Table 5-1-1*, the total quantity of solids produced from each process is approximately 22,700 pounds per day. This is based on an assumed raw water turbidity of 20 NTUs, a ferric chloride (coagulant) dose of 25 mg/l, and 55 mgd of raw water treatment.

Table 5-1-1 Summary of Anticipated Pre-Treatment Residuals

Pre-Treatment Option	Tube Settling & Cluster Filters	DAF & FloFilter	UF
% solids from clarification process	0.5	2	0.1
% solids from filter backwash & FTW	0.02	0.02	n/a
Total residuals from pre-treatment:			
(mgd)	3.69	3.29	2.75
(lbs/day)	22,700	22,700	22,700
Residuals flow to thickening (mgd)	3.69	3.15*	2.75
Flow of thickened residuals (gal/day)	68,000	15,755	68,000
Volume of thickened residuals (lbs/day)	22,700	5,256*	22,700
% solids of thickened residuals	4	4	4
% solids in feedwater to dewatering	4	2.21	4
Residuals flow to dewatering (gal/day)	68,000	150,755	68,000
Flow of dewatered residuals (gal/day)	16,000	16,000	16,000
Anticipated % solids from centrifuge	17	17	17

* At 2 percent, the DAF floated solids will not require thickening and can go directly to equalization prior to dewatering. Thus, residuals flow to thickening for the DAF option includes only spent washwater and filter-to-waste (FTW) water.

The management of pre-treatment byproducts will use conventional methods described in *Chapter 4*. The purpose of this *Chapter 5 – Byproduct Management* is to address options for the management of the byproduct stream from the reverse osmosis treatment facility. The reverse osmosis system is common to all treatment alternatives and sites selected in this feasibility study, and therefore the byproduct management discussions are also applicable to all alternatives.

The reverse osmosis byproduct stream is the concentrated dissolved solids resulting from the reverse osmosis treatment process. The median seawater salinity of 35,000 mg/l was determined to be appropriate for the raw water design basis. The byproduct stream is anticipated to have a dissolved solids concentration of twice the raw water concentration. Therefore, even if the raw water concentration varies to some degree, the waste byproduct will have a significantly higher dissolved solids concentration than the ambient conditions and could pose a significant disposal challenge.

Therefore, the byproduct concentrate quality, quantity, and disposal evaluations presented in this chapter are based on source water containing approximately 35,000 mg/l total dissolved solids.

Based on the information developed, byproduct disposal options are based on both cost and none-cost factors. The disposal options for byproduct management stream include:

- Evaporative lagoons
- Mechanical evaporators, with or without crystallizers
- Discharge to POTW
- Deep well injection
- Discharge to the open sea (Gulf of Mexico, Laguna Madre, or Oso Bay)

2 BYPRODUCT QUANTITY AND QUALITY

Although there are variations in the byproduct concentration with respect to time for each of the source waters, the byproduct analysis is performed based upon the average design seawater concentration of 35,000 mg/l and a typical reverse osmosis unit recovery of 50 percent.

The impact of the concentrate's salinity is not highly sensitive—in the ±5 percent range. Although the impact of recovery variations will affect the total volume of byproduct produced, it is typical of municipal reverse osmosis installations not to vary recovery unless scaling must be mitigated. Concentrate production of the plant, based on a 24-hour operation day, is estimated to be 25 mgd.

Table 5-2-1 lists the projected water quality data of the membrane system concentrate used to size the byproduct disposal methods.

3 EVAPORATIVE LAGOONS

3.1 Literature Review

Evaporation ponds use the natural evaporation of water to concentrate salts in a pond until they precipitate out. Evaporation ponds are widely utilized by inland desalination plants for the disposal of concentrate. They are particularly well suited for arid regions of the United States such as the southwest, where the evaporation rate consistently exceeds the precipitation rate. Numerous evaporation ponds are in operation in States such as Texas, Arizona, California, New Mexico, Wyoming, and Idaho. Worldwide, evaporation ponds are frequently utilized in the Middle-East and Australia for concentrate disposal.

Table 5-2-1 Estimated Concentrate Water Quality Data

Constituent		Unit	Average
Total Dissolved Solids	TDS	mg/l	70,646
Alkalinity (calculated)	Alk	mg/l as $CaCO_3$	234.6
Total Hardness (calculated)	TH	mg/l as $CaCO_3$	12,784
Temperature	T(^oC)	^oC	20
PH	-	-	8.0
Chloride	Cl^-	mg/l	38,882
Sulfate	SO_4^-	mg/l	5,426
Bromide	Br^{--}	mg/l	132.4
Bicarbonate (calculated)	HCO_3^-	mg/l	286.2
Carbonate (calculated)		mg/l	0
Hydroxide (calculated)	OH^-	mg/l	0
Carbon Dioxide (calculated)	CO_2	mg/l	0
Fluoride	F^-	mg/l	2.6
Iodide	I^-	mg/l	44.8
Nitrate	NO_3^-	mg/l as N	1
Nitrite	NO_2^{--}	mg/l as N	0.02
Phosphate	PO_4^{--}	mg/l	0.02
Sodium	Na^+	mg/l	21,624
Magnesium	Mg^{++}	mg/l	2,604
Calcium	Ca^{++}	mg/l	819.6
Potassium	K^+	mg/l	778.4
Boron	B^{+++}	mg/l	10
Barium	Ba^{++}	mg/l	0.1
Strontium	Sr^{++}	mg/l	27.2
Silica (total)	SiO_2	mg/l	4.2

Advantages associated with evaporation ponds include:

- Ease of design and construction
- Reduced maintenance and operation labor relative to mechanical evaporation equipment
- Minimal mechanical equipment (feed pumps)
- Economically advantageous in regions with high evaporation rates and low land costs

Despite the advantages of evaporation ponds, they possess several disadvantages that can limit their application, such as:

- Very large land requirements in regions with low evaporation rates
- Increased installation costs if impervious liners of clay or synthetic membranes are required
- Potential contamination of underlying aquifers due to liner failure

Although evaporation ponds possess many advantages, several research reports indicate that they may not be well suited for large seawater desalination applications. A comprehensive literature review on the application of evaporation ponds for byproduct disposal (Ahmed 2000) indicated that evaporation ponds were not being used for desalinated seawater at the several brackish water desalination plants included in the study. Evaporation ponds for desalination concentrate disposal are most appropriate for smaller volume flows and for regions having a relatively warm, dry climate with high evaporation rates, level terrain, and low land costs (Mickley 2001). Other studies indicate that evaporation ponds are not suitable for seawater desalination systems due to the large land requirements and capital costs (USDI 2001; Glater and Cohen 2003).

3.2 TCEQ Requirements for Evaporation Ponds

A review of Texas Commission on Environmental Quality (TCEQ) regulations indicates that there are currently no requirements specific to the disposal of desalination facility concentrate. However, TCEQ has established guidelines for the design of evaporation ponds for wastewater treatment. Contained in *Chapter §217.207 Evaporative Ponds*, the regulations outline design criteria for evaporation ponds. Since the issues of concern with wastewater evaporation ponds are similar to those of concentrate evaporation ponds, this analysis has been conducted assuming that TCEQ will require compliance with *Chapter §217.207*. The design criteria outlined in the regulations are summarized in *Table 5-3.2-1*.

3.3 Evaporation Pond Conceptual Design

The size of the evaporation pond is determined by the required evaporation area and based on the estimated concentrate quality and quantity. Representative precipitation and evaporation data was obtained and net evaporation rates were determined. Adjustments were made to the evaporation rates based on known effects of sodium chloride concentrations. The pond dike height and total area including dikes, roads, and other supporting facilities were then estimated.

3.3.1 Typical Precipitation and Evaporation Rates

To provide a screening level analysis of the feasibility of the application of evaporation ponds for concentrate disposal, evaporation and precipitation data obtained from the TWDB were used in lieu of the more rigorous Penman-Monteith Method recommended by TCEQ. The data were tabulated for Quadrangle 1010 of the TWDB map, which corresponds to the location of Corpus Christi.

Summary statistics of precipitation and evaporation data are available in *Table 5-3.3.1-1*.

Table 5-3.2-1 TCEQ Design Criteria for Evaporative Ponds

Parameter	Value
Number	Minimum of Two; Primary (60% of area); Secondary (40% of area)
Depth	Primary: 5 ft maximum Secondary: 8 ft maximum
Liner	Minimum 40 mil UV resistant synthetic liner
Leachate Collection	Leachate collection system and leak detection system required
Sizing	Evaporation rate: Penman-Monteith Method or equal. Precipitation: 25-yr frequency, one-year rainfall amount
Embankment	Maximum slope – 3:1 (Values less than 4:1 must have engineering justification) Recommended slope – 4:1 minimum of 10 ft (top width)
Inlet Structure	Inlet line must terminate in a manhole along the embankment edge. Manhole invert required to be 6" above maximum pond water level Inlet line from the manhole to the center of the pond must be anchored to the bottom of the pond.
Outlet Structure	Outlet structure must have concrete apron to prevent scour. The apron must be corrosion resistant and at least 2' square and 8" thick.

Table 5-3.3.1-1 Monthly Precipitation/Evaporation Statistics for Corpus Christi (Inches/month)

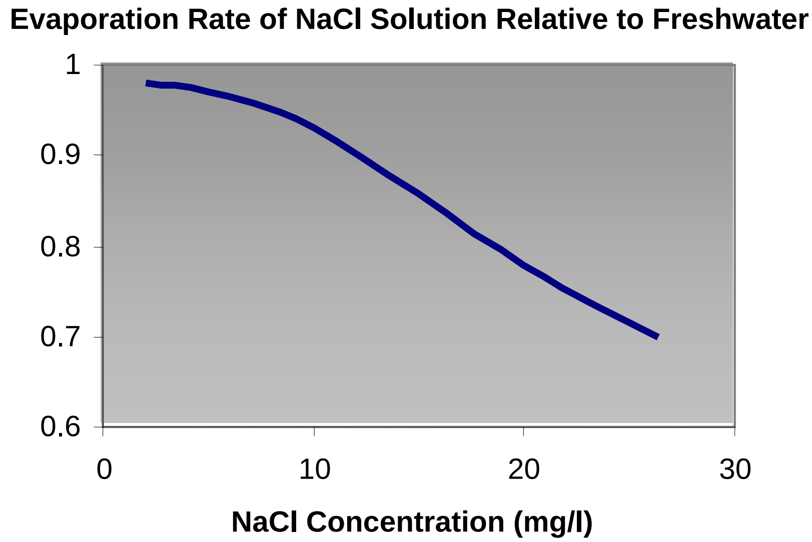
Description	n	Min	Max	Median	Mean	Percentile	
						10%	90%
Evaporation	588	0.56	12.20	5.00	5.03	2.62	7.61
Precipitation	756	0.00	21.31	1.79	2.46	0.32	5.30

3.3.2 Adjusted Seawater Evaporation Rates

A literature review indicates that the evaporation of sodium chloride solutions is a function of the solution concentration. For water saturated with sodium chloride salt (26.4 percent), the solar evaporation rate is generally about 70 percent of the rate for freshwater (USDI 1971). Research performed by the Bureau of Reclamation indicates that evaporation rates of 2, 5, 10, and 20 percent sodium chloride solutions are 97, 98, 93, and 78 percent, respectively, of the rates of freshwater (USDI 1969). *Figure 5-3.3.2-1* displays the effect of concentration of the relative evaporation rate of salt water solution to freshwater.

The mean evaporation rate was corrected by applying a correction factor of 0.70 to account for the lower evaporation rate of seawater. Although it is expected that it would take several years before steady-state conditions of saturated solution will occur in the pond, the pond area must represent end-of-life evaporation rates rather than start-up evaporation rates.

Figure 5-3.3.2-1 Evaporation Rate of Seawater Relative to Freshwater



Source: Adapted from USDI, Bureau of Reclamation (1969)

Based upon analysis of precipitation data (since 1940) and evaporation data (since 1954), the mean monthly net evaporation rate corrected for the salinity effects discussed above is 1.061 inches/month.

3.3.3 Required Evaporation Area

The required evaporation rate was determined using Equation 1.

$$A_{EVAP} = \frac{CLR}{\varphi} SF \qquad \text{Equation (1)}$$

Where,

CLR = concentrate flow (in^3/mth)
Φ = net corrected evaporation rate (in/mth)
SF = Safety Factor

The estimated evaporation area required, using a conservative net evaporation rate of 1 inch/month, and including a 20 percent safety factor (Mickley 2001), is approximately 33,145 acres.

3.3.4 Pond Dike Height

The required dike height is the sum of the storage requirement, precipitate accumulation, and wave freeboard. Based on a review of precipitation data, the 25-year frequency, one-year rainfall amount was determined to occur in 1997. Due to the large amount of available data, a water balance was conducted for the period 1977 to 2002 in accordance with TCEQ *Chapter §309.20,* and incorporates the 25-year frequency, one-year precipitation data as required by *Chapter §309.20*. The maximum water level in the pond is 32.53 inches. Mickley (2001) recommends that an additional 50 percent storage allowance be permitted in the design.

Although not specifically addressed in the TCEQ requirements, Mickley (2001) recommends that allowances be made for deposition of salt precipitates when determining the design pond depth. During operation, salts concentrated in the evaporation pond can precipitate out of solution. Based upon a 25-year design life between clean-out, an allowance of approximately 8 inches for precipitate accumulation has been provided. Allowance for the 50 percent storage allowance and precipitate accumulation increases the design water level to 56.8 inches, less than the maximum evaporation pond water depth of 5 feet required by TCEQ. Given the safety factors and high embankment depths required for storage and wave action, there is little benefit to a shorter design period.

USDI recommends that the freeboard of the embankment consider wave action resulting from wind. The wave action can be determined using Equation 2 (USDI 970).

$$H_w = 0.047\, W\, \sqrt{(F)} \qquad \text{Equation (2)}$$

Where,

H_w = wave height (ft)
W = wind velocity (mph)
F = fetch, or straight-line distance the wind can blow without obstruction (mi)

Mickley (2001) indicates that the height of waves upon striking the embankment approaches the velocity head of the waves and can be approximated as $1.5H_w$. Typical values of H_w reported by Mickley range from 2 to 4 feet. The freeboard resulting from waves is estimated at 3 feet. The required dike height, including required storage, precipitate allowance, and wave formation is estimated to be 8 feet.

3.3.5 Area Requirements

As previously presented, the required evaporative area is approximately 33,145 acres. An allowance for area required for dikes, roads etc., was made using a procedure recommended by Mickley (2001). An area factor of 1.14 was determined based upon an 8-foot dike height and maximum evaporation cell area of 100 acres.

The total required area is estimated to be 37,785 acres, based upon an 8-foot dike height. Because evaporation is dependent on surface area, the decrease in area with increasing depth due to berm/dike slope is not accounted for in these estimates. The berm area has been estimated based upon individual evaporation cells in the 100-acre area. Some small reduction in area will occur using a more rigorous estimation.

3.3.6 Evaporation Pond Capital Costs

Total costs for evaporation ponds include the following considerations:

- Land Acquisition
- Earthwork (land clearing, perimeter dikes, baffle dikes, dike covers)
- Liners
- Miscellaneous (fencing, maintenance roadways, disposal, seepage monitoring etc.)

The Mickley (2001) cost model was used to prepare the cost estimates for the evaporation pond system. Since the model is configured to estimate costs up to 100 acres, it is assumed that the maximum cell size is 100 acres. It is understood that these costs do not consider economies of scale for ponds of the required size.

Costs included in the capital cost model:

- Land
- Land clearing
- Dike
- Liner
- Fencing
- Roadway

Costs not included in the capital cost model:

- Disposal of precipitated salts
- Seepage monitoring
- Cleanup of contaminated soil
- Cost of pipeline to the evaporation pond site

Costs for conveyance of concentrate to the ponds have not been included in this estimate. Based upon the assumptions made, the estimated capital cost of evaporation ponds is estimated to be approximately $2.2 billion. The cost breakdown is contained in *Table 5-3.3.6-1*.

Table 5-3.3.6-1 Cost Summary for Evaporation Ponds

Description	Unit	Value
Total Evaporative Surface	acres	33,145
Maximum Cell Area	acres	100
Number of Cells	#	340
Dike Height	ft	8
Total Liner Thickness	mil	40
Ratio Total Area/Evap. Area	-	1.14
Total Area/Cell		114
Land Acquisition Cost/Acre	$/acre	$5,000
Land Clearing Cost/Acre	$/acre	$1,000
Dike Cost/Acre	$/acre	$3,500
Nominal Liner Cost/Area	$/acre	$28,000
Liner Cost/Acre	$/acre	$18,700
Fence Cost/Acre	$/acre	$1,600
Road Cost/Acre	$/acre	$260
Total Unit Costs	$/acre	$59,000
Total Cost per Cell	$/cell	$5,900,000
Total Cost		$2,006,000,000
Contingency @ 10%		$200,600,000
Grand Total		**$2,206,600,000**

3.3.7 Conclusions

Based on the described calculations, the total required land area for evaporation ponds is estimated to be 37,785 acres, with an estimated capital cost of $2.2 billion. Due to the very large area requirements and capital cost, evaporation ponds are not feasible for concentrate disposal for the proposed application. Because of the anticipated cost and extreme land area requirements, this alternative is dismissed from further consideration.

4 MECHANICAL EVAPORATORS

To evaluate zero liquid discharge options for desalination byproduct disposal, a conceptual design for a Zero Liquid Discharge (ZLD) System was developed and presented. Capital costs for the concentrators are also presented. The work is based on a review of available literature as well as a review of TCEQ applicable design criteria.

4.1 Literature Review

ZLD concepts use evaporation to further concentrate membrane concentrate streams to dry salts, reducing the liquid discharge volume to zero. Disposal of the residual solids cake is required. Available literature indicates that ZLD is the most expensive method of disposal of concentrate due to high capital costs and energy consumption. Therefore, ZLD concepts are typically considered only where a valuable byproduct can be recovered, or where no other disposal options are feasible, such as when permitting or site restrictions prevent other methods of disposal (Mickley 2001; USDI 2003). Based on available information, there are no fewer than 12 ZLD systems treating RO concentrate (Mickley 2001).

4.2 TCEQ Requirements for Zero Liquid Discharge Systems

TCEQ regulations were reviewed to determine if there are primacy agency requirements for the implementation of ZLD technology. The review indicated no regulations specifically governing the operation of these ZLD facilities.

4.3 Membrane/Thermal ZLD System Conceptual Design

When this thermal process is used following an RO system, blending of the byproduct concentrators distillate with RO permeate can result in a capacity reduction in the RO system. A mass balance for the membrane/thermal ZLD system was performed, and a reverse osmosis system concentrate quantity and quality were predicted. Based on this information, the number of evaporators and crystallizers were estimated to determine the approximate size and costs of a conceptual membrane/thermal ZLD system.

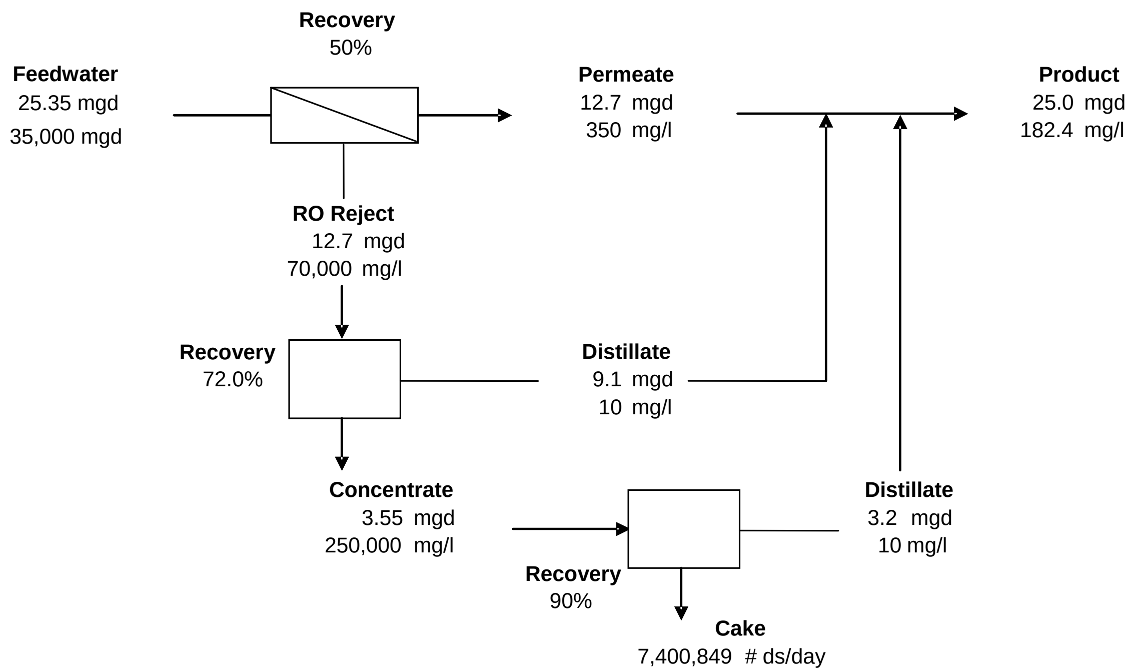
4.3.1 Mass Balance for Membrane/Thermal ZLD System

A mass balance was performed on a combined membrane/thermal process. The following assumptions were made while performing the mass balance:

Reverse osmosis system product recovery = 50 percent
Reverse osmosis system target effluent concentration = 350 mg/l
Maximum concentrator waste stream concentration = 250,000 mg/l
Byproduct concentrator distillate concentration = 0 mg/l

The results of the mass balance are presented in *Figure 5-4.3.1-1*.

Figure 5-4.3.1-1 Zero Liquid Discharge Mass Balance



4.3.2 Concentrate Quantity

Based upon the mass balance illustrated in *Figure 5-4.3.1-1*, concentrate production of the reverse osmosis plant in a combined membrane/thermal process is estimated at 12.7 mgd.

4.3.3 Reverse Osmosis System Concentrate Quality

Table 5-4.3.3-1 below lists the projected water quality data of the membrane system concentrate used to size the evaporators and crystallizers. As the final design of the reverse osmosis system has not yet been completed, the byproduct stream was estimated, for purposes of sizing the residuals handling system, as indicated in Equation 3.

$$Concentrate\ DS_i\,[mg/L] = \frac{Feed\ DS_i\,[mg/L]}{(1-R)} \qquad \text{Equation (3)}$$

Where,

DS_i = Dissolved solids concentration of constituent (i)
R = Reverse osmosis system product recovery

Table 5-4.3.3-1 Estimated Concentrate Water Quality Data

Constituent		Unit	Average
Total Dissolved Solids	TDS	mg/l	70,646
Alkalinity (calculated)	Alk	mg/l as $CaCO_3$	234.6
Total Hardness (calculated)	TH	mg/l as $CaCO_3$	12,784
Temperature	T(°C)	°C	20
PH	-	-	8.0
Chloride	Cl^-	mg/l	38,882
Sulfate	SO_4^-	mg/l	5,426
Bromide	Br^{--}	mg/l	132.4
Bicarbonate (calculated)	HCO_3^-	mg/l	286.2
Carbonate (calculated)		mg/l	0
Hydroxide (calculated)	OH^-	mg/l	0
Carbon Dioxide (calculated)	CO_2	mg/l	0
Fluoride	F^-	mg/l	2.6
Iodide	I^-	mg/l	44.8
Nitrate	NO_3^-	mg/l as N	1
Nitrite	NO_2^{--}	mg/l as N	0.02
Phosphate	PO_4^{--}	mg/l	0.02
Sodium	Na^+	mg/l	21,624
Magnesium	Mg^{++}	mg/l	2,604
Calcium	Ca^{++}	mg/l	819.6
Potassium	K^+	mg/l	778.4
Boron	B^{+++}	mg/l	10
Barium	Ba^{++}	mg/l	0.1
Strontium	Sr^{++}	mg/l	27.2
Silica (total)	SiO_2	mg/l	4.2

4.3.4 Required Byproduct Concentrators and Crystallizers

The required sizes of the byproduct concentrator and crystallizer were estimated based on the maximum size commercially manufactured for each technology. The maximum feed capacity for an individual byproduct concentrator currently in production is ~1-mgd. Using the mass balance illustrated in *Figure 5-4.3.1-1* and a maximum effluent TDS of 250,000 mg/l, a minimum of 13 byproduct concentrators is required.

The maximum feed capacity commercially available for an individual crystallizer is ~50-gpm. Based upon the mass balance illustrated in *Figure 5-4.3.1-1*, a minimum of 50 byproduct crystallizers is required.

There is the potential to use precipitated salts in the crystallizers for a beneficial use (road desalting etc.). This analysis does not specifically evaluate the commercial value of recovered salts when evaluating the economic advantages of using a ZLD process.

4.3.5 Membrane/Thermal ZLD System Capital Costs

A cost model (Mickley 2001) was used to estimate the capital cost of the membrane/thermal ZLD system described above. Since the model is configured to address byproduct concentrator inlet flows of up to 3 mgd, it has been assumed that a scale of economy can be achieved at this size, which is not reflected here due to smaller equipment. It is understood that these costs do not consider economies of scale for flows required for this application.

The model includes capital and installation costs for the byproduct concentrator and crystallizer. Vendors were contacted to confirm maximum process sizes and cost estimates. Costs for conveyance of concentrate to the ZLD system have not been included. Based upon the assumptions made, the estimated capital cost of a ZLD system is estimated to exceed $230 million. The cost breakdown is presented in *Table 5-4.3.5-1*.

Additional details regarding the cost analysis are included in *Appendix C*.

4.3.6 Conclusions

Based upon these calculations, the total number of byproduct concentrators is estimated to be 13, with approximately 50 crystallizers required. The estimated capital cost is on the order of $230 million. Annual operating costs for electricity alone are estimated to exceed $49 million. Due to the very large energy requirements and capital cost, the use of ZLD concepts (byproduct concentrators/evaporators) does not appear feasible for concentrate disposal for the proposed application. No further evaluation of this option is recommended.

5 DISCHARGE TO POTW

Two options were explored for discharge of the byproduct to a publicly owned treatment works (POTW) facility:

1. Discharge of the byproduct into the municipal collection system

2. Blending of the byproduct with POTW effluent to reduce overall TDS of the blended discharge

Table 5-4.3.5-1 Cost Summary for Zero Liquid Discharge System

Description	Unit	Parameter
Byproduct Concentrator Inlet Flow Rate	mgd	12.7
Recovery	%	72.0%
Crystalizer Inlet Flow Rate	mgd	3.56
Crystalizer Inlet Flow Rate	gpm	2469
Maximum Size of Byproduct Concentrator	mgd	1
Maximum Size of Crystalizer	gpm	50
Number of Byproduct Concentrators	#	13
Number of Byproduct Crystalizers	#	50
Estimated Unit Cost, Byproduct Concentrator	$/unit	$6,666,667
Total Cost, Byproduct Concentrator	$	$86,666,667
Power Requirement, Byproduct Concentrator	kW/unit	3,750
Unit Annual Operating Cost, Brine Byproduct Concentrator	$/mgd	$2,135,250
Operating Cost, Byproduct Concentrator	$	$27,758,250
Estimated Unit Cost, Crystalizer	$/unit	$2,900,000
Total Cost, Byproduct Crystalizer	$	$145,000,000
Power Requirement, Byproduct Crystalizer	kW/unit	750
Unit Annual Operating Cost, Crystalizer	$/yr/unit	$427,050
Operating Cost, Crystalizer	$/yr	$21,352,500
Annualized Cost		$60,694,083
Power Cost	$/kWh	0.065
Design Life	yr	20

5.1 Identification of Corpus Christi POTWs

A survey was performed to identify POTWs within the Corpus Christi city limits. The purpose of the survey was to determine the location and sizes of the effluent discharges and which ones that may prove feasible for discharge of desalination byproduct to the collection system or blending of plant effluent to dilute the byproduct. *Table 5-5.1-1* lists the available POTWs identified within the City of Corpus Christi.

Table 5-5.1-1 Identified POTWs Within the City of Corpus Christi

POTW	Address	Capacity (mgd)	Serves
Broadway Treatment Plant	1402 W. Broadway	10	Downtown and North Beach areas
Oso Treatment Plant	501 Nile Drive	16.2	Southside of City
Greenwood Treatment Plant	1541 Saratoga Boulevard	6	Airport and Westside
Allison Treatment Plant	Allison & MacKenzie	5	Calellen and Tuloso areas
Laguna Madre Plant	201 Jester Drive	3	Flour Bluff area
Whitecap Treatment Plant	3909 Whitecap	0.8	North Padre Island area

5.2 Evaluation of POTW Discharge Options

It is estimated that approximately 25 mgd of byproduct will be produced when the plant operates at its design capacity of 25 mgd. TDS of the byproduct is estimated at approximately 71,000 mg/l. The Oso Treatment Plant, rated at a capacity of 16.2 mgd, is the POTW that serves the potential site's desalination plant locations initially identified by TCB. The Oso Treatment Plant is located approximately 5 miles from the Barney Davis Power Plant and approximately 10 to 20 miles from the industrial areas that are being considered by TCB as site options. Because all of the POTWs listed in *Table 5-5.1-1* are less than 20 mgd in capacity, it is apparent that neither the collection system nor the wastewater treatment process at the Oso Treatment Plant or any other of the plants would be capable of receiving the projected flow of byproduct from the desalination plant due to hydraulic and process limitations. Therefore, this option is not technically feasible.

The second option analyzed is the dilution of the concentrated byproduct stream with one of the POTW effluent flows. Under average plant conditions at the largest WWTP, the Oso Treatment Plant (11.5 mgd at 500 mg/l TDS), combining the effluent with 25 mgd of byproduct at 71,000 TDS would result in a combined concentration of approximately 49,000 mg/l of TDS. In addition, it is understood that the effluent from the plant, which discharges into Oso Creek, is already utilized to some extent for dilution of the Laguna Madre water from the Barney Davis Power Plant, which is hypersaline. Therefore, this option has been determined not to be technically feasible.

5.3 Conclusions

Based on the survey and analyses described above, it is apparent that disposal of the byproduct to the collection system of a local POTW, regardless of the cost to construct infrastructure for conveyance, is not technically feasible due to the limited capacity of the plants. In addition, it has also been determined that use of the closest POTW effluent at the Oso Treatment Plant is also not technically feasible due to the limited dilution effect and the existing requirement to provide dilution of elevated TDS cooling water from the Barney Davis Power Plant.

6 DEEP WELL INJECTION

The Corpus Christi area has a number of injection wells disposing of byproducts from the chemical processing industry. These wells normally exceed 5,000 feet in depth and use a discharge pressure in excess of 1,000 psi to force the liquid being disposed into the formation. In addition, the existing injection wells are subject to decreases in capacity as the formation becomes less receptive to the fluid being pumped and cleaning or redeveloping is required. A brief review of records of injection wells in the area, along with the strata they are injecting into, reveals that capacities of most of these wells are less than 1 mgd.

Deep well injection disposal of the byproduct water would require the availability of 45 million cubic yards of sand available for receiving the byproduct water annually. Over the anticipated 30-year life of the facility, the amount of storage space needed is 1.4 billion cubic yards. Assuming a sand porosity of 50 percent, a total storage volume of nearly 3 billion cubic yards is needed to store the byproduct water.

Another area of concern is the need for permitting the injection wells. On a preliminary basis, spacing of the wells is estimated to be 1,000 feet. This estimate is somewhat arbitrary, and may in fact need to be greater. A typical deep well injection layout is presented in *Figure 5-6-1*. With 25 wells located on 1,000-foot centers, the total land area required is over 800 acres.

The requirements for permitting 25 injection wells in a common wellfield will be extensive and time consuming. The cost of each well is estimated to be approximately $2 million. If the wells must be pressurized to 1,000 psi, the cost of the electrical energy alone will be in excess of $5 million per year. Capital costs for developing the wellfield are presented in *Table 5-6-1*. Annual power costs are presented in *Table 5-6-2*.

The use of injection wells for disposal of the byproduct waters introduces a significant level of uncertainty in handling the byproduct. For smaller quantities using injection wells, the amounts can be trucked to another injection well and injected there as a relief measure when the injection wells are experiencing operational difficulties. However, the volume of byproduct water produced makes it unlikely that trucking would be a viable alternative.

Figure 5-6-1 Deep Well Injection Typical Layout

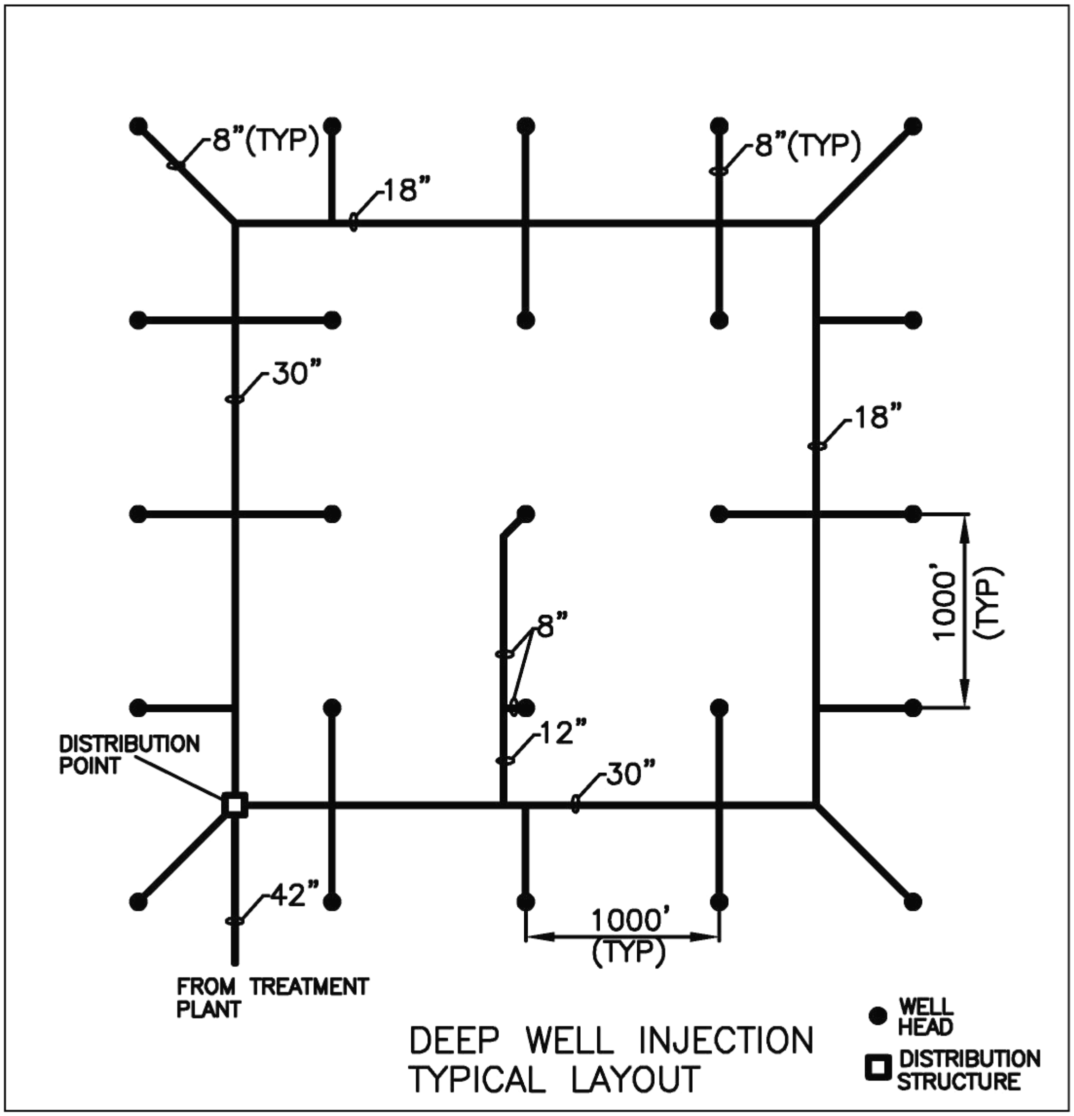


Table 5-6-1 Cost Estimate for Deep Well Injection

Capital Costs Item	Quantity	Unit Price	Total
Injection Wells	25	$1,500,000	$37,500,000
4" Dia. From Plant to Wellfield	10,500 (assumed distance)	$275	$2,900,000
30" Dia. Wellfield Distribution	6,000 lf	$215	$1,300,000
18" Dia. Wellfield Distribution	6,000 lf	$150	$900,000
12" Dia. Wellfield Distribution	500	$110	$55,000
8" Dia. Wellfield Distribution	12,900	$80	$1,100,000
Distribution Structure	1 ea	$75000	$75,000
Valve, Controls, Appurtenances	1 ls	$320,000	$320,000
Subtotal Construction			$41,600,000
Engineering, Administration etc.	25%		$10,400,000
Contingency	25%		$10,400,000
Total Capital Costs			$62,400,000

Table 5-6-2 Power Costs

Flow	kW-Hrs/ Year	Annual Power Costs	Present Worth Power	Present Worth Life Cycle
25 mgd	87,800,000	$5,700,000	$87,600,000	$96,700,000

Power costs are based on 75 percent w-w efficiency and $0.065/kW-hrs.
Present worth is based on 5 percent interest and 30-year term

6.1 Conclusions

Deep well injection of the byproduct is not considered to be a viable alternative for byproduct disposal in view of the cost, the need for multiple permits, and the potential operational issues in trying to keep 25 individual wells open and available for disposal at any one time. No further analysis was performed on this option.

7 OPEN SEA DISCHARGE

Discharge of the byproduct stream to the open sea is a practical and a straightforward method of disposal. However, the inland seas (Laguna Madre, Oso Bay, Corpus Christi Bay and Nueces Bay) are already experiencing hypersaline conditions (compared to the Gulf waters) and the environmental issues would be very difficult to resolve in these waters. Depending on the final disposition of the Barney Davis Power Plant and the outcome of additional environmental studies, it may be possible to incorporate a discharge into Oso Bay. If the Oso Bay discharge option is determined not to be viable, the only remaining sea discharge is into the Gulf of Mexico.

7.1 Oso Bay Discharge

Depending on the ultimate long-term use of the Barney Davis Power Plant, commingling the byproduct stream with the power plant cooling water stream may be viable. Circulation of water through Oso Bay would improve the environmental conditions. By itself, the byproduct discharge would not be of sufficient quantity to supplement the circulation in this body of water. However, if the Barney Davis Power Plant is in operation, cooling water discharges from that power plant will be either 560,000 acre-ft per year or 280,000 acre-ft per year, depending on the number of operating generating units. The 25 mgd of byproduct water would only contribute 5 or 10 percent of the total flow. The increase in total dissolved solids concentrations would be similar ratios. The byproduct water would also slightly reduce the temperature of the cooling water discharge.

If the Barney Davis Power Plant does not continue to operate, it may be possible to negotiate the use of the intake pumps and continue to circulate water into Oso Bay and combine the byproduct stream with that water.

The capital and O&M costs for discharging the byproduct stream into Oso Bay would be very small. The only significant costs would be the operation of the 560,000 acre-ft cooling water system if the Barney Davis Power Plant is not running. If the power plant is in operation, that cooling water stream would be available. The outfall structure and cooling ponds are also already in place, and no additional costs would be incurred to improve these facilities. The potential for discharging the byproduct stream to Oso Bay should continue to be considered. However, due to the uncertain nature of the operations of the Barney Davis Power Plant and the potential environmental problems that could arise, this option should not be considered a primary option at this point.

7.2 Discharge to Gulf of Mexico

Discharge to the Gulf of Mexico is the most straightforward possibility for the management of the byproduct stream. Although significant and important environmental concerns will have to be addressed, it is intuitively apparent that discharging to the Gulf of Mexico offers the greatest opportunity for environmental support.

The byproduct stream will have a TDS concentration of twice the ambient conditions, but proper design of diffusion outfalls should minimize environmental impacts. The final location of the outfall will require further investigation. For the purposes of this feasibility study, the outfall is located 2 miles from the shoreline in waters that are approximately 40 feet deep. The line will be constructed mostly in the same trench used to construct the raw water intake line. Near the outfall location, the byproduct line will deviate to the south from the intake line so that a separation distance of 1,400 feet is maintained between the intake and outfall. Currents in this area of the Gulf tend to travel to the southeast and locating the discharge to the southeast will minimize the possibility of short-circuiting between the outfall and intakes.

Discharging the reverse osmosis byproduct stream to the Gulf of Mexico is considered the most likely option that will allow the project to move forward. For this reason, the open sea discharge is recommended for the detailed feasibility cost analyses and considerations. The open sea discharge cost implications are included in the development of costs in *Section 4*, and this cost information is summarized in *Table 5-7.2-1*

Table 5-7.2-1 Open Sea Discharge Cost Summary

Description	Capital Costs	O&M Costs	Present Worth O&M	Present Worth Life Cycle
Discharge to Gulf of Mexico	$30,900,000	$279,000	$4,300,000	$35,200,000

7.3 Recycling of the Byproduct Water

One of the possible byproduct management alternatives that was previously discussed was the use of the byproduct water as a raw material for a chemical process at the Oxychem site. Limited discussions with the Oxychem staff indicated that Oxychem currently purchases brine prepared to levels of approximately 300,000 mg/l for use in their process. Oxychem staff expressed interest in using the byproduct water from the desalination facility. However, the cost of byproduct concentrators and evaporators was already reviewed and determined to be too costly. In addition, the operation of the desalination facility would be restricted to only those times when Oxychem was able to take all of the byproduct water, assuming that it could be concentrated to the level that Oxychem wanted. For this reason, it was determined that use of the byproduct water by Oxychem could not be the sole management alternative available for the byproduct water in order to maintain reliability for the plant. As a result, no costs for concentrating the byproduct water to meet Oxychem's needs are presented, other than those already looked at under the ZLD option.

The potential for byproduct recycling offers significant environmental advantages in that the economic value of the salt contained in the byproduct is recovered. For this reason, it is recommended that further discussions be held in the next phase of the project to refine the potential for this reuse, even if another management option is the primary option. This recommendation is subject to whether or not Oxychem is determined as a viable site for further investigation.

8 EVALUATION OF ALTERNATIVES AND RECOMMENDATIONS

Evaporation ponds provide a technically feasible option for concentrate disposal for the proposed application. However, due to the very large area requirements (estimated 37,785 acres) and capital cost (estimated $2.2 billion), evaporation ponds are not an economically feasible disposal option.

ZLD concepts provide a technically feasible option for concentrate disposal for the proposed application. However, due to the very large energy requirements (estimated $57 million annually) and capital cost (estimated $265 million), byproduct concentrators and evaporators are not an economically feasible disposal option.

POTW discharge is not a technically feasible option for concentrate disposal for the proposed application due to the limited capacity of the local wastewater treatment plants. None of the local plants is large enough to accept the estimated 25 mgd of concentrate with TDS concentrations of approximately 71,000 mg/l, and the plant effluents are not large enough to provide an adequate dilution stream.

Deep well injection is not a feasible option for byproduct disposal because of the large volume of aquifer sand needed to dispose of the material, the limited capacity for individual wells to inject the material, and the complex system needed to pressure the byproduct and force it into the formations. The complexity of the permitting process for multiple wells, each of which would be one of the largest wells permitted for injection in the area, is also a factor indicating against further study of this option.

Byproduct recycling at the Oxychem site is not a candidate for the primary management option for the byproduct water. Unexpected shutdowns of the Oxychem processing facility would leave the byproduct water with no viable means of disposal and the desalination plant would have to close. However, if the Oxychem site does warrant further study, further discussions on the byproduct recycling are warranted solely based on the desirability of recycling this material instead of putting it back into the marine environment.

No further evaluation of any of these four disposal options is recommended.

At this time, open sea discharge is the only viable option for the disposal of the byproduct stream. The option for discharging to Oso Bay should be retained for future consideration, but the environmental concerns keep this option from being a likely solution. Open sea discharge to the Gulf of Mexico is the recommended byproduct management technique and is the alternate that is used in all evaluations.

Chapter 6

Water Transfers and Partnerships

CHAPTER 6 – WATER TRANSFERS AND PARTNERSHIPS
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CHAPTER 6 – WATER TRANSFERS AND PARTNERSHIPS

1 INTRODUCTION AND PURPOSE OF STUDY

The City of Corpus Christi has a history of developing water resources for a large and diverse regional system as noted previously. The City has had the ability to go out and acquire water rights and build infrastructure as needed to suit its needs in order to assure an adequate supply of water for the City and for its customers in its service area. The Mary Rhodes Pipeline was constructed on a fast track to be in place when additional supplies were needed. For that project, the Nueces River Authority provided the necessary bond funds and the Port of Corpus Christi provided the construction oversight.

A list of potential partnerships was developed early in the process and presented to City staff for discussion. Several meetings were held in which the potential for partnerships was discussed; however, no formal consensus was reached. It was agreed that partnerships would fall into one of several different categories, which will be dealt with separately.

1.1 Public Private Partnerships

The issue of public private partnerships has been at the forefront of the thought process since the City of Corpus Christi made the decision to move forward with a Statement of Interest in response to the request for such statements published by the TWDB. The City staff and the consultant team have been contacted by several different groups and listened to various presentations concerning the development of desalination facilities in the Corpus Christi area. In fact, there were multiple submittals of Statements of Interest based on the Barney Davis Plant site in addition to the submittal from the City of Corpus Christi. Two separate groups made presentations concerning the development of a project that would meet Corpus Christi's needs for a desalination demonstration project, but each sought an understanding that the City of Corpus Christi would commit to their team prior to going forward and expending funds on the necessary studies. This path would have yielded additional funds for the necessary studies, including the pilot plant studies that are now needed to move the project forward from this point. This is currently the strategy being followed by the Dow/Poseidon/Brazos River Authority consortium. This consortium has allowed the resources of the Brazos River Authority to be directed solely to the development of customers for the water without expending any TWDB funding on the development of the desalination facility itself.

The City and its utility staff have been consistent in their rejection of selecting a development contractor on any basis other than a published request for competitive bids. The staff and the consultant team concur that some form of alternative project delivery is likely to be a key component of the successful completion of a Large Scale Desalination Facility in the Corpus Christi area. They are similarly convinced that such a process must include competition to ensure that the City receives maximum benefit for the dollars expended. As a result of the above deliberations, no partnerships with private entities were sought.

1.2 Public Entity Partnerships

The issue of partnerships with public entities was similarly considered by the City of Corpus Christi and the consultant team. The City had previously partnered with the Nueces River Authority to provide the funding mechanism and with the Port of Corpus Christi to handle construction management of the Mary Rhodes pipeline. This fast track project was brought online in a short period of time and provided a major relief to the City of Corpus Christi during the most recent dry period. The partnership was very successful and would be considered by the City for the desalination facility. However, there was no financial input by either of the two partners, so the bottom line of the project is that the City of Corpus Christi paid for the entire project and continues to do so. This type of partnership would not impact the cost of the desalination facility or the amount of subsidy that would be required to make the desalination facility feasible. Similar partnerships with other entities were considered but no further contacts were made, again because it would not impact the financial analysis for the project.

1.3 Research Partners

Texas A&M University at Corpus Christi and the Marine Science Institute of the University of Texas both submitted letters of support for the establishment of a seawater desalination facility in the Corpus Christi area. That support included a recognition that a number of areas of study would open up where the universities would be valuable partners in determining the impacts of a desalination plant on the environment. The universities were contacted for water quality and particularly salinities data they had available on the bays in the Corpus Christi area. Dr. George Ward was engaged as a member of the consultant team because of his experience with the University of Texas system in the Corpus Christi area.

One issue that prevented the development of further ties to the research community was the uncertainty surrounding the Barney Davis Plant and the status of the plant's ownership. A previous commitment from American Electric Power (AEP) was conservative because of the knowledge by AEP that the Barney Davis Plant was scheduled for sale. AEP desired to have no undue encumbrance on the plant that would affect its value on the open market. For that reason, it was not possible to determine what access might be possible on the plant site for research partners. The recent sale of the Barney Davis Plant to Topaz Power Partners and the draft letter of July 29, 2004, from Topaz Power Partners to the consultant team (see *Appendix D-1*) lend additional clarity to that situation, and further contacts with the potential research partners will be made. It was also necessary to better define the likely plant site location and some financial information in order to present that material to the research partners.

Discussions were held with Texas A&M University at Corpus Christi (TAMUCC), Center for Water Supply Studies, on August 25, 2004. Dr. Alan Berkebile and Rick Hay attended, along with Scott Duff of the Division of Nearshore Research. TAMUCC is interested in partnering with this project as a research arm and has several ongoing data collection efforts that might be of interest in a pilot phase of the project. Mr. Duff is one of the researchers involved with the Texas Coastal Ocean Observation Network. He indicated that there would be interest on their part in locating data collection stations for collecting water quality and other data, but only if there was a long-term need for the data and a reason for locating the collection station in a particular place. As noted previously, however, no funding is currently available that would shift a data collection station from one location to another. Data could be collected relatively efficiently by coordinating with the Network, but the cost would be borne by the entity desiring to collect the data.

Project team members made a brief presentation on the project results and provided the TAMU-CC researchers with a copy of the potential research topics as generated by the project team. This listing of potential topics is included as *Appendix D-2*.

Several contacts were made with researchers at the University of Texas Marine Science Institute at Port Aransas, and attempts were made to meet and discuss the project. The researchers were directed to a copy of the draft report on the City of Corpus Christi website and provided a copy of the draft report presentation given at the Public Meeting. They were also provided a list of potential research topics developed by the Project Team. A request was made to review the materials and provide input on the potential ability of the UTMSC to participate in the long-term research efforts of such a facility. No response has been received to date.

1.4 Customers as Partners

The City of Corpus Christi currently serves a large and diverse area with water for municipal and manufacturing needs in the Coastal Bend area (see *Figure 6-1.4-1*). It has partnerships with a number of cities, water districts, and water supply corporations in the area to provide either raw or treated water supplies. In addition, the City recognizes that subsidies will be needed to make a desalination facility cost-effective to their extended service area. For that reason, the City is willing to entertain the idea of a partnership with a public entity that is in need of additional water supply and is willing to help underwrite the cost of the desalination facility as a part of securing additional supplies. As noted below, in the discussion of water transfers, some factors have prevented the finalization of any contracts in that regard.

There have been a number of direct interactions between City of Corpus Christi and San Antonio Water System (SAWS) staff related to the development of scope items and shared participation in the costs of a U.S. Corps of Engineers Feasibility Study of the Nueces Basin. Staff from both entities have participated in this process, which includes some aspects of desalination facility resource management issues. These negotiations have resulted in a Federal Cost Sharing Agreement among the Department of the Army, the Nueces River Authority, the City of Corpus Christi, the San Antonio Water System, the San Antonio River Authority, and the Guadalupe Blanco River Authority. This agreement was executed on September 24, 2004. A copy of the agreement is included in *Appendix D-3*. In addition, there is an ongoing dialogue between the two entities related to the current recharge dams in the San Antonio area, as well as proposed recharge dams that SAWS is looking at as a management strategy for enhancing recharge to the Edwards Aquifer. Discussions have been held at the staff level concerning the potential reduction in the surface water flows that belong to the City of Corpus Christi through the recharge dam projects. Corpus Christi staff has noted that there will be mitigation required if surface water flows that comprise the City's water rights are reduced. One of the mitigation options that has been put on the table is the possibility that SAWS would pay a portion of the desalination plant facility costs in exchange for the reduced surface water flows caused by the recharge dams. As additional information is learned from the feasibility study of the Nueces Basin and the studies on the Aquifer Recharge projects, then additional attention will be paid to the issue of potential water sales from Corpus Christi to SAWS and how the potential mitigation will factor into those sales agreements.

1.5 Groundwater Issues

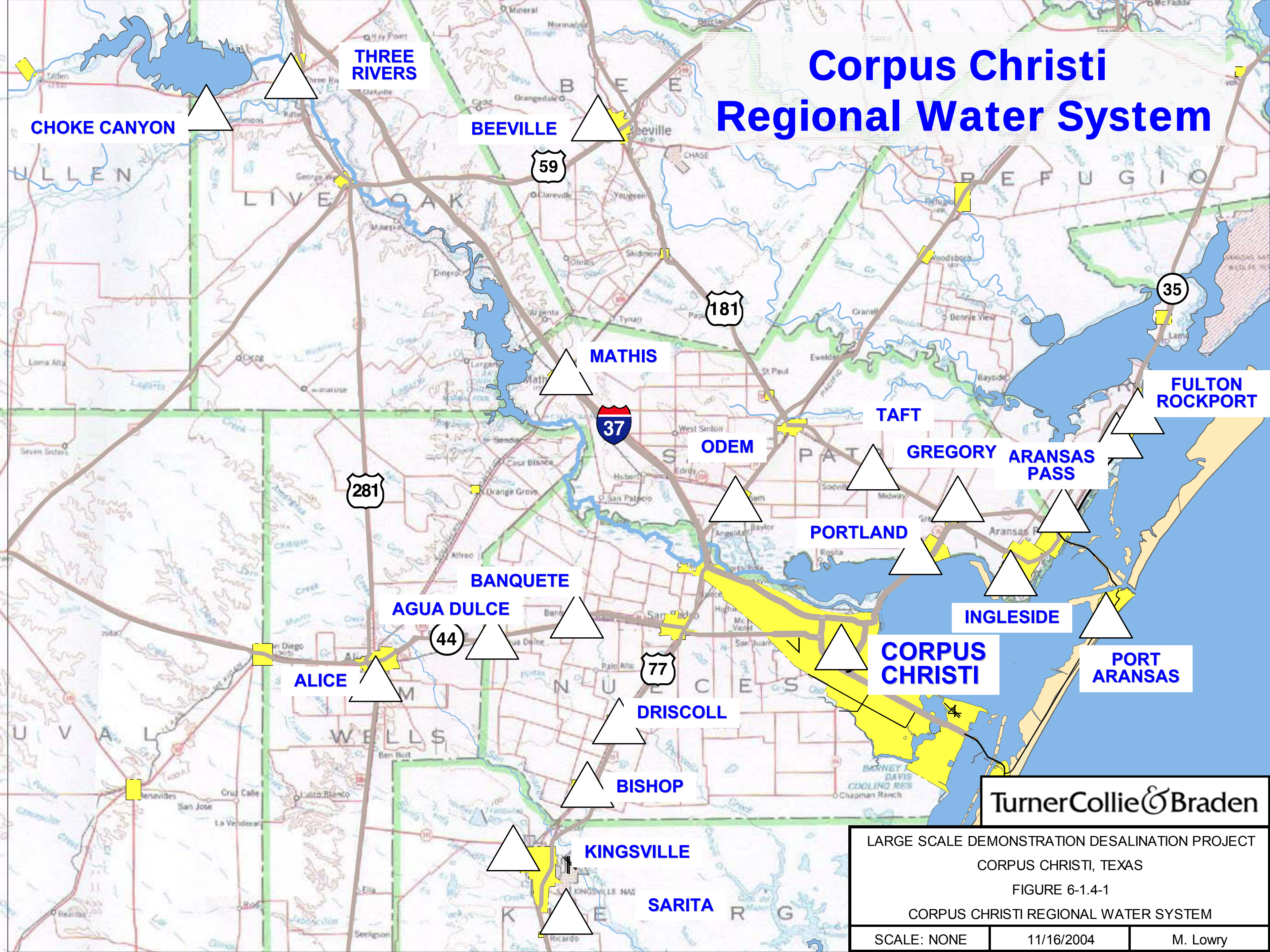
There are a number of potential clients for Corpus Christi water, either from Choke Canyon Reservoir or the Colorado River as outlined in the 2001 regional plans. While these clients have professed interest in surface water in the past, many are now receiving multiple offers to look at groundwater supplies as the export market for groundwater becomes more active. Groundwater has the advantage of not requiring extensive treatment if it is of good quality initially and if the wells that produce it are constructed to state standards. However, the actual availability of groundwater and the impacts of heavy pumping in areas where such pumping has not occurred in the past are yet to be determined. For that reason, many potential clients are desirous of leaving their options open and are not ready to commit to Corpus Christi's Large Scale Desalination Facility until those questions are resolved.

1.6 Status of Regional Planning Efforts

In addition to the issue noted above, the regional plans are somewhat delayed by the lack of availability of the Groundwater Availability Models (GAMS) for some areas, notably the Central Gulf Coast GAM. Informal discussions have been held with consultant teams for other regions. Interest has been expressed in certain options involving Corpus Christi water, but it is too early in the process for commitments to be made until all the options are evaluated. In several cases, previous strategies for Corpus Christi water have been replaced by imported groundwater sources until studies either prove up or eliminate those groundwater strategies.

1.7 Site Partners

One recent development involving the Barney Davis Plant location is the sale of the power plant to Topaz Power Partners (TPP). This sale from American Electric Power (AEP) to TPP was consummated during the summer of 2004. As a result of a request from the City of Corpus Christi, TPP reviewed the needs and issues regarding a desalination facility and provided a letter of proposal for discussion. At the time this report is being finalized, the letter is still in draft format, but it eliminates several issues of considerable concern dealing with the raw water permit for the Barney Davis Plant cooling water as well as the discharge of the desalination plant byproduct water into the cooling ponds at the plant. This letter once again allows the City to explore receiving some benefit from the existing cooling water intake and heated cooling water discharge.



LARGE SCALE DEMONSTRATION DESALINATION PROJECT
CORPUS CHRISTI, TEXAS
FIGURE 6-1.4-1
CORPUS CHRISTI REGIONAL WATER SYSTEM

SCALE: NONE	11/16/2004	M. Lowry

The letter referenced above indicates that Topaz Power Partners has purchased the Barney Davis Plant and intends to continue to run the plant as a power generation facility. As a result of that purchase, representatives for Topaz have indicated that they are willing to provide a site for the desalination facility on the Barney Davis Plant property. They have also indicated that they are willing to work with the City and the desalination plant project developers to amend the withdrawal permit to include municipal use in addition to the once through cooling currently permitted. In addition, they have agreed in principal to the discharge of the desalination plant byproduct water into the main cooling ponds for the power plant, and the amendment of the discharge permit for those ponds to include the byproduct. The issues of the intake and discharge permits may be a moot point if intake and discharge takes place in the Gulf as the primary desalination plant configuration option assumes at present. However, location of the desalination facility at the Barney Davis site benefits from a controlled access facility, proximity to power lines and gas lines for plant use, and other features common to industrial facilities, even without the intake and discharge issues. It should be noted that all of the above items are subject to the development of a suitable agreement between the City of Corpus Christi and Topaz Power Partners.

The uncertainty of the Barney Davis Power Plant ownership has hindered development of potential partnerships for research facilities co-located at the plant site as was noted previously. It is not possible to discuss access to a site that is not owned by the City until such time as an agreement is presented that allows such access. Much the same situation has held true with the Oxychem site, although that site has been largely ruled out as a viable alternative. Initial discussions were held with Don Roach, San Patricio Municipal Water District (SPMWD), with the intent of discussing the potential formation of a high purity water distribution network with SPMWD as a partner, but Mr. Roach indicated that had been investigated as a part of their own Statement of Interest, and there was not sufficient demand or interest in a higher priced water for that area. One of the issues of concern is the fact that high purity water is extremely aggressive and must be treated with post-treatment chemicals to prevent that water from dissolving any metal fixtures it comes in contact with. At the same time, the true high purity need at industrial facilities is relatively small in terms of the magnitude of process water uses. For high purity water to be distributed to the plant, it would either have to utilize an entirely separate distribution system, which would require extensive and costly repiping, or it would have to be treated with a polishing reverse osmosis treatment for it to be usable as boiler feedwater. As a result, it was determined that there was not sufficient demand for high purity water to establish a separate distribution system. It was also determined through conversations with plants in the area and through the local knowledge of consultant team members that the manufacturing interests were unwilling to pay a premium for the desalinated water for their process water needs.

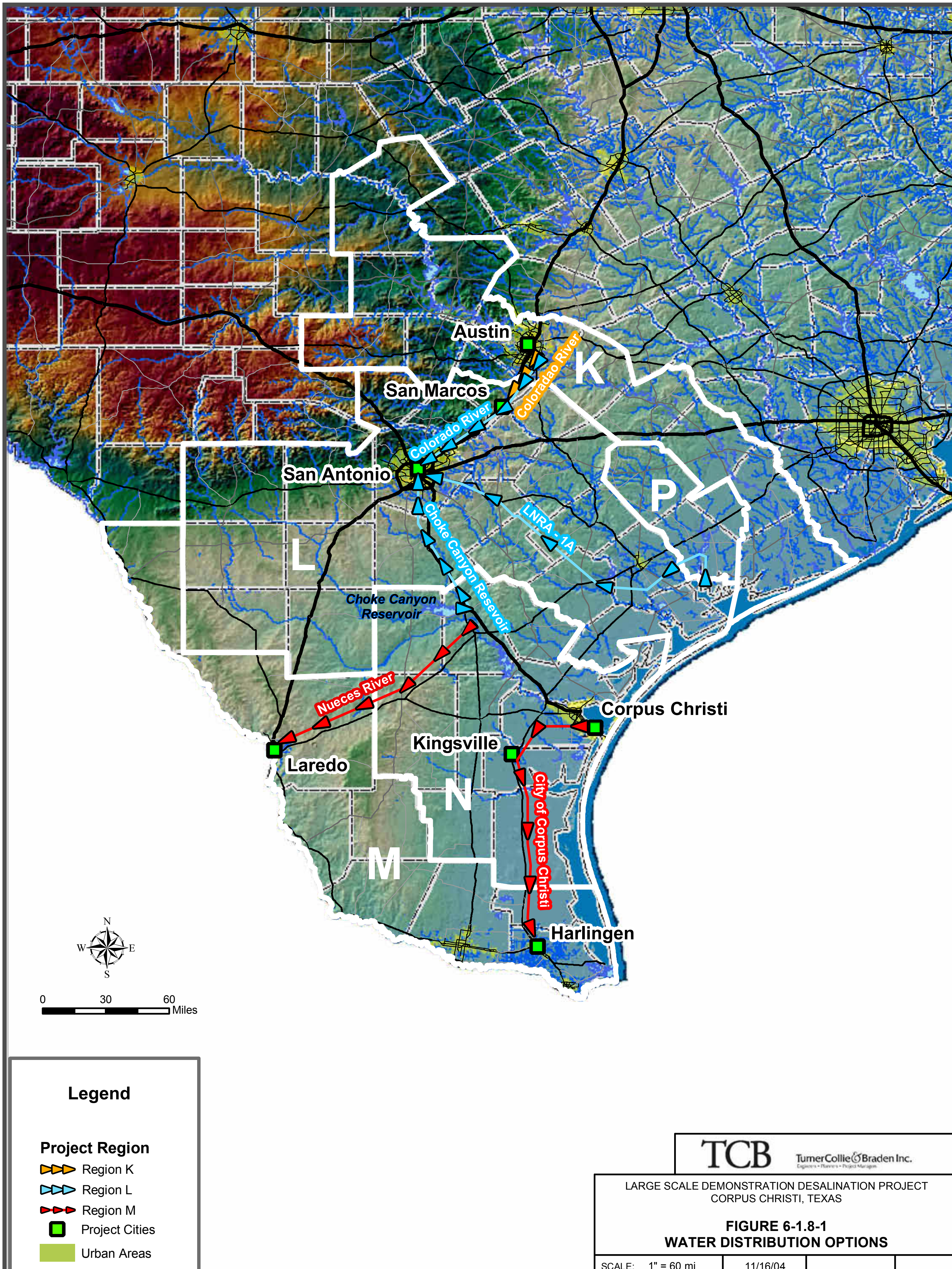
1.8 Water Transfers

Development of a seawater desalination facility by the City of Corpus Christi will produce an estimated 25 mgd of quality drinking water. Currently, the City of Corpus Christi has adequate drinking water supplies; therefore, an opportunity may exist for the City of Corpus Christi to deliver raw or treated water to areas outside of the City’s current service area. The Corpus Christi Desalination Feasibility Study involves identifying potential water customers based on information available from the approved regional water plans (1st Planning Cycle) for nearby regions, as well as Region N, where Corpus Christi is located. The list of potential customers was narrowed by eliminating those users with projected water needs less than 10,000 acre-feet (ac-ft), to maximize the possibility of locating a financially beneficial scenario. Using unit cost, annual cost, and annual need data from these regional plans, a revenue stream for the City of Corpus Christi was developed for each potential option. A brief discussion of each option, along with a summary of the collected cost and revenue data, is provided below. *Figure 6-1.8-1* illustrates the proposed routings for these options.

2 SOUTH CENTRAL TEXAS REGION – WATER FROM THE CCR/LCC SYSTEM

The South Central Texas (Region L) Regional Water Plan identified three potential water management strategies involving exchanges of water with the City of Corpus Christi. The first strategy (referred to as SCTN-14a) consists of “enhancing” the firm yield of the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System by purchase and delivery of 80,000 ac-ft/yr of water from the Guadalupe River, in exchange for a diversion of 79,000 ac-ft/yr from the CCR/LCC System to a water treatment plant in Region L. Like the first, the second option (referred to as SCTN-14b) includes “enhancement” of the firm yield of the CCR/LCC System by delivery of 80,000 ac-ft/yr of Guadalupe River water, as well as the delivery of unappropriated streamflow and treated effluent from the San Antonio River at Falls City to the CCR/LCC System via Choke Canyon Reservoir; in exchange for 148,200 ac-ft/yr from the CCR/LCC System to a water treatment plant in Region L. Finally, the third option (referred to as SCTN-13) involves exchanging yield from the construction of the Palmetto Bend Stage II Dam and Reservoir on the Lavaca River for coastal area surface water rights and/or options owned by Corpus Christi for Colorado River streamflow with a possible diversion near Columbus.

Each of the three options for Region L involved an exchange of water with Corpus Christi. Therefore, the cost estimates for these options in the Regional Water Plan included costs associated with delivering water to the CCR/LCC System (i.e. purchase of water, transmission, pumping, etc). With the potential availability of excess water supply in the City of Corpus Christi, it is possible that water could be delivered to Region L via the routing described in each of the three options without the need for an exchange of water; thereby increasing the value to the potential buyer. For strategies SCTN-14a and SCTN-14b, the raw water cost was assumed to be equal to the cost of raw Guadalupe River water. The cost of raw Guadalupe River water in the Region L Water Plan was assumed to be $61/ac-ft, which was the cost of firm water purchased from the GBRA at the time of publishing of the Water Plan. However, the current price of water purchased from the GBRA is $80, so this value is used in the cost calculations for this report. This raw water cost was also used for calculations for strategy SCTN-13, since it is assumed the water for the various quantities would be supplied from the same location in the CCR/LCC System. *Table 6-2-1* summarizes the potential revenue data should Corpus Christi provide water to Region L, using a raw water cost of $80/ac-ft.



TCB TurnerCollie&Braden Inc.

LARGE SCALE DEMONSTRATION DESALINATION PROJECT
CORPUS CHRISTI, TEXAS

FIGURE 6-1.8-1
WATER DISTRIBUTION OPTIONS

SCALE: 1" = 60 mi	11/16/04		

Table 6-2-1 Potential Revenue Data for Corpus Christi With Region L as Water User

Water User Group	Quantity of Corpus Water Purchased (ac-ft/yr)	Unit Cost of Raw Water ($/ac-ft)	Annual Revenue ($/yr)
South Central Texas Region (Region L) - SCTN-13	28,200	$80	$2,256,000
South Central Texas Region (Region L) - SCTN-14a	80,000	$80	$6,400,000
South Central Texas Region (Region L) - SCTN-14b	148,200	$80	$11,856,000

The South Central Texas Regional Water Plan selected numerous water management strategies for eliminating future water supply shortages; however, none of the strategies involving supply from Corpus Christi were originally selected. The range of estimated annual costs of treated and distributed water for the selected strategies is $55 to $1,595 per ac-ft. *Table 6-2-2* below summarizes the potential estimated annual costs for strategies SCTN-14a, SCTN-14b, and SCTN-13. The same routing is assumed for all three cases (see *Figure 6-1.8-1*), and the annual cost differences are attributed to the differences in the amount of water transmitted to Region L. The values for SCTN-14a and SCTN-14b were taken directly from the Region L Water Plan (substituting a raw water cost of $80/ac-ft for the $61/ac-ft value originally used). No costs were determined for sending the water from the CCR/LCC System to Region L for strategy SCTN-13, so these values were extrapolated linearly from the other two strategies using the lower quantity of water.

Table 6-2-2 Potential Treated/Distributed Annual Costs for Region L

Potential Water Management Strategy	Total Annual Costs ($/yr)	Quantity of Water (ac-ft/yr)	Annual Cost of Water ($/ac-ft)
SCTN-13	$28,004,500	28,200	$993
SCTN-14a	$58,701,000	80,000	$734
SCTN-14b	$99,116,200	148,200	$669

Using cost estimates from the Region L water plan, the total annual cost includes the costs for moving the water from Choke Canyon Reservoir to the South Central Texas Region, as well as treating and distributing the water. The annual cost also includes the purchase of raw water at $80/ac-ft. As can be seen from the table, the potential annual value to Region L, when compared with the selected water management strategies for the region, ranges from $0 to $602 for SCTN-13, $0 to $861 per ac-ft for SCTN-14a, and $0 to $926 per ac-ft for SCTN-14b.

3 SOUTH CENTRAL TEXAS REGION – COLORADO RIVER WATER PURCHASE

The Region L Water Plan explored the possibility of purchasing Colorado River water from the Lower Colorado River Authority (LCRA). Several diversion locations were examined, and cost estimates developed for each location. For the purposes of this report, a diversion near Bastrop, conveying water from the Colorado River via an 89.4-mile, 54-inch transmission pipeline was assumed (option referred to as C-13C). Costs were taken from the Region L plan for this transmission routing, reducing the water purchased from 50,000 to 35,000 ac-ft/yr. The raw water purchase cost used in the estimates was $105/ac-ft, the current price published by the LCRA. A 25 percent out-of-basin surcharge could be required, but is not factored into this analysis. The purchase of water from the LCRA was not chosen as a water management strategy for the region. However, due to the potential surplus supply in Corpus Christi and the potential availability of Colorado River water rights owned by Corpus Christi, the sale of these water rights to the South Central Texas Region becomes a viable option. *Table 6-3-1* lists the potential revenue available should Corpus Christi provide water to Region L through the sale of current Colorado River rights at a raw water rate equal to that of the LCRA.

Table 6-3-1 Potential Revenue Data for Corpus Christi With Region L as Water User

Water User Group	Quantity of Corpus Water Purchased (ac-ft/yr)	Unit Cost of Raw Water ($/ac-ft)	Annual Revenue ($/yr)
South Central Texas Region (Region L)	35,000	$105	$3,675,000

As discussed in *Section 2*, the range of estimated annual costs of treated and distributed water for the selected water management strategies for the South Central Texas Region is $55 to $1,595 per ac-ft. *Table 6-3-2* summarizes the potential estimated annual costs for the Colorado River Water Purchase option. Using cost estimates from the Region L water plan, the total annual cost includes the costs for moving the water from a diversion point near Bastrop to the South Central Texas Region, as well as treating and distributing the water, and delivering it for municipal use or for Edwards Aquifer Recharge. The annual cost also includes the purchase of raw water at $105/ac-ft. The potential annual value of this strategy to Region L, when compared with the selected water management strategies for the region, ranges from $0 to $541 per ac-ft.

Table 6-3-2 Potential Treated/Distributed Annual Costs for Region L

Potential Water Management Strategy	Total Annual Costs ($/yr)	Quantity of Water (ac-ft/yr)	Annual Cost of Water ($/ac-ft)
Colorado River Water Purchase	$36,888,000	35,000	$1,054

4 SURFACE WATER SUPPLIES TO LAREDO

The Rio Grande Regional Water Plan (Region M) considered an option to provide Laredo with approximately 22,400 ac-ft/yr (20 mgd) of surface water from the Nueces River, just downstream of Choke Canyon. The strategy consists of 110 miles of 36-inch pipe, one intake structure/pump station, and four booster stations. The proposed alignment follows the right-of-way of Highway 59. The regional plan used a water right purchase cost of $195/ac-ft to determine annualized costs for the strategy. *Table 6-4-1* summarizes the potential revenue data should Corpus Christi provide water to Laredo, using a raw water cost of $195/ac-ft.

The Choke Canyon to Laredo strategy was not selected by the Region M Planning Group for inclusion in the Phase I Water Plan. However, several other strategies were chosen to supply Laredo with its water needs. These included advanced water conservation measures, non-potable reuse, development of local groundwater supply, and acquisition of additional Rio Grande supplies. In addition, Laredo is currently exploring the possibility of imported groundwater as a means of meeting its needs.

Table 6-4-1 Potential Revenue Data for Corpus Christi With Laredo as Water User

Water User Group	Quantity of Corpus Water Purchased (ac-ft/yr)	Unit Cost of Raw Water ($/ac-ft)	Annual Revenue ($/yr)
Laredo	22,404	$195	$4,368,780

The annual costs for the Choke Canyon to Laredo strategy, along with the annual costs associated with the selected strategies for Laredo are listed in *Table 6-4-2*.

Table 6-4-2 Treated/Distributed Annual Costs for Laredo Strategies

Water Management Strategy	Total Annual Costs ($/yr)	Quantity of Water (ac-ft/yr)	Annual Cost of Water ($/ac-ft)
Laredo (DMI-12)	$23,141,351	22,404	$1,033
Advanced Water Conservation Measures	$2,145,536	9,248	$232
Non-potable Reuse	$1,664,640	4,624	$360
Development of Local Groundwater Supply	$6,351,000	10,950	$580
Acquisition of Additional Rio Grande Supply	$10,357,840	24,088	$430

As can be seen from *Table 6-4-2*, the annual unit cost for the Choke Canyon to Laredo strategy (DMI-12) is much higher than the selected strategies for Laredo. In order to provide adequate value to the City of Laredo, the raw water cost of $195/ac-ft would need to be reduced and the supply of water shown to be more reliable than that of one or more of the selected management strategies. In this case, the reliability is the key component, as the reduction of the raw water cost alone will not produce a cost for Choke Canyon water that is competitive with other options for Laredo.

5 SARITA PIPELINE TO THE LOWER VALLEY

The Rio Grande Regional Water Plan (Region M) considered an option to provide the Lower Rio Grande Valley with approximately 19,042 ac-ft/yr of surface water from Corpus Christi. This would require the construction of an extension to an existing 42-inch pipeline currently extending from Corpus Christi to Kingsville. The strategy consists of 98 miles of 42-inch pipe, one booster station in Corpus Christi, one booster in Kingsville, and two more along the pipeline route to Harlingen. The proposed alignment follows the right-of-way of Highway 77. A water right purchase cost of $195/ac-ft is used for this report as it is unclear the value used in the Region M Water Plan. *Table 6-5-1* summarizes the potential revenue data should Corpus Christi provide water to Harlingen, using a raw water cost of $195/ac-ft.

Table 6-5-1 Potential Revenue Data for Corpus Christi With Harlingen as Water User

Water User Group	Quantity of Corpus Water Purchased (ac-ft/yr)	Unit Cost of Raw Water ($/ac-ft)	Annual Revenue ($/yr)
Harlingen	19,042	$195	$3,713,190

The Corpus Christi to Harlingen strategy was not selected by the Region M Planning Group for inclusion in the Phase I Water Plan. However, several other strategies were chosen to supply Harlingen with its water needs. These included advanced water conservation measures, non-potable re-use, conversion from agricultural use to municipal use, and acquisition of additional Rio Grande supplies. The annual costs for the Corpus Christi to Harlingen strategy, along with the annual costs associated with the selected strategies for Harlingen, are listed in *Table 6-5-2*.

Table 6-5-2 Treated/Distributed Annual Costs for Harlingen Strategies

Water Management Strategy	Total Annual Costs ($/yr)	Quantity of Water (ac-ft/yr)	Annual Cost of Water ($/ac-ft)
Harlingen (DMI-14)	$23,141,351	22,404	$1,033
Advanced Water Conservation Measures	$227,360	980	$232
Non-potable Reuse	$1,764,720	4,902	$360
Conversion from Ag. To Muni. Use	$159,250	490	$325
Acquisition of Additional Rio Grande Supply	$210,700	490	$430

Table 6-5-2 illustrates that the annual unit cost for the Corpus Christi to Harlingen strategy (DMI-14) is much higher than the selected strategies for Harlingen. Even a raw water cost of $0 would not make this option competitive with the other options. In addition, the proposed Brownsville Desalination Facility would be able to produce desalinated water much closer to the point of use in Harlingen if the Brownsville Facility proves to be viable.

6 COLORADO RIVER WATER RIGHTS TO HAYS COUNTY (REGION K)

Although not previously considered as a potential water management strategy in the Lower Colorado Regional Water Plan (Region K), the sale of Colorado River water rights totaling 35,000 ac-ft/yr to Hays County is a potential strategy, which could address water needs in Region K and provide a revenue stream for the City of Corpus Christi. The raw water purchase cost used in the estimates was $105/ac-ft, the current price published by the LCRA. A 25 percent out-of-basin surcharge could be required, but is not factored into this analysis. *Table 6-6-1* lists the potential revenue available should Corpus Christi provide water to Region K through sale of current Colorado River rights at a raw water rate equal to that of the LCRA.

Table 6-6-1 Potential Revenue Data for Corpus Christi With Region K as Water User

Water User Group	Quantity of Corpus Water Purchased (ac-ft/yr)	Unit Cost of Raw Water ($/ac-ft)	Annual Revenue ($/yr)
Lower Colorado Region (Region K)	35,000	$105	$3,675,000

Since this strategy was not studied during the initial regional water planning process, no detailed cost data is available for this potential strategy. Therefore, for the purposes of this report, the diversion mentioned in *Section 1.2* (Region L strategy C-13C) is assumed, with transmission of the purchased Colorado River water originating near Bastrop and distributing water to the Hays County area. The transmission pipeline will be assumed to be the same size as in C-13C (54-inch-diameter) and

40 miles in length. Costs for this analysis were scaled down from the values provided in the Region L report for strategy C-13C where appropriate; otherwise, the Region L costs were used directly in the analysis. *Table 6-6-2* summarizes the potential estimated annual costs for the Colorado River water purchase option for Region K utilizing these assumptions.

Table 6-6-2 Potential Treated/Distributed Annual Costs for Region L

Potential Water Management Strategy	Total Annual Costs ($/yr)	Quantity of Water (ac-ft/yr)	Annual Cost of Water ($/ac-ft)
Colorado River Water Purchase	$34,213,950	35,000	$978

Selected water management strategies for the Lower Colorado Region have annual costs in the range of $105 to $1,562 per ac-ft. Using the cost assumptions previously mentioned and data from the Region L water plan, the total annual cost for this potential strategy includes the costs for moving the water from a diversion point near Bastrop to the Lower Colorado Region, as well as treating and distributing the water. The annual cost also includes the purchase of raw water at $105/ac-ft. The potential annual value of this strategy to Region L, when compared with the selected water management strategies for the region, ranges from $0 to $584 per ac-ft. It should be noted that the current plan for the City of San Marcos is to pursue options in the San Marcos River and import groundwater to meet their planning needs for the next plan period. San Marcos accounts for a major portion of the demand in central Hays County. In addition, the Canyon Regional Water Authority and several water supply corporations have joined with San Marcos to look at other alternatives as well.

Given the circumstances noted above, the most likely scenario for water sales from Corpus Christi surplus water will occur either from the Garwood water or from Choke Canyon water to the Greater San Antonio area. Moving the Garwood water will depend upon the results of studies of the LCRA/SAWS Water Supply Plan, and it will take place in larger pipelines that are sized to convey much larger flows than those anticipated with the Garwood water alone. For that reason, there was no attempt to update costs for transmitting that water to the San Antonio area. The one transfer project that is the most likely to be able to stand upon its own merits, even at flows only equal to the desalination plant capacity is the Choke Canyon to San Antonio transfer. Costs were prepared for that transfer and are presented in *Appendix D-4*. As this table indicates, the cost of water in this transfer is $1,217 per acre-foot, including the cost per acre-foot of $180 provided to the City of Corpus Christi as revenue. It should be noted that the updated cost of $1,217 per acre-foot is within the range of costs for management strategies selected for inclusion in the plan. In addition, there is a possibility of reducing those costs further if the City of Corpus Christi is willing to sell a larger amount of water than the desalination plant produces. For the purposes of this report, however, this is the more restrictive option.

7 ENVIRONMENTAL FLOW BENEFITS

The above analysis concentrates primarily on the identification of Water User Groups (WUGs) recognized in the 2001 Regional Water Plans. However, a potential buyer of water was not listed as a WUG in either the 2001 Regional Plans or in the current revision to the plans. The potential buyer is the environmental groups. Environmental flow needs continue to be a significant topic of discussion in the Regional Planning Areas and particularly in the dry areas that make up most of the watershed of the Nueces Basin. There are numerous areas where water rights are being contracted to augment environmental flows, and there are federal programs to purchase or contract for those rights. The water flowing in the Nueces Basin from Choke Canyon Reservoir, if contracted for by an environmental group or groups, could be released on a schedule that provides increased freshwater inflows to the bays as well as meeting instream needs in the Nueces River between Choke Canyon Reservoir and the bays. Purchase of this water for instream flow and bay and estuary needs has the added advantage that no additional infrastructure is needed to make this a reality.

Successful demonstration of a seawater desalination facility has a number of possible environmental benefits. Production of potable water from previously untapped sources can potentially reduce the pressure to develop water supplies inland. Reservoir sites that have been proposed over the last 20 years have faced significant opposition for flooding of bottomland hardwoods and loss of habitat for a number of different species. In addition, local landowners have issues with the taking of their property when a new reservoir is proposed. While a new reservoir may attract wildlife, it will potentially be wildlife of a type different from that which is supported by the existing configuration of trees and river bottom. In addition, environmental needs have only been imposed on new reservoir construction, and additional flows are likely to be needed for some existing streams. Water that is developed from desalination of seawater and sold inland can be required to return a specified percentage to the basin in which the water is used, thereby increasing the streamflow after that flow is discharged. This increased streamflow will be beneficial for instream flows in the basin of use and will potentially benefit any bays and estuaries that flow supplies.

In the same vein as noted above, the City of Corpus Christi has water rights in diverse basins that could be used by other entities, if desalinated water proves to be an economical alternative. As noted above, some of this water could be purchased on a contract basis for needed environmental flows. Some could also be contracted to entities in need of additional supply, and the return flows from those uses could provide a benefit to the environment as they increase instream flows, if they are not reused as the source. The user of the water would be the determining factor in what basin the return flows occurred.

There are two important issues to address in any discussion of the environmental benefits of seawater desalination. One is the management of the byproduct water. For the proposed facilities being studied here, the byproduct water will be a minimum of 25 million gallons per day and will have an estimated concentration of 70,000 TDS under normal dry weather conditions. This material will require management to ensure that it does not degrade the water quality at the discharge points. This is particularly important if the discharge point is into a coastal bay. The bays in Corpus Christi tend to be hypersaline, and additional dissolved solids loading will have to be managed to avoid environmental damage.

The second issue relates to the cost of desalination. The interest in desalination is primarily a result of the anticipation that costs of other alternatives have continued to rise, especially costs of building new reservoirs. This study has shown that desalination is currently not the lowest cost alternative for new water supply, but costs have fallen over the past 10 years. If costs continue to fall, then the City of Corpus Christi would be well advised to seek additional supplies of desalinated water to expand its overall supply system. If those costs do not continue to fall, then the City will not make the necessary investment to continue development of desalination facilities and will rely on more conventional sources instead.

One significant change from the existing regional plans that was mentioned briefly in the partnerships section is the presence of groups that are actively trying to sell groundwater. These groups have the advantage in that water from properly constructed wells may not require treatment beyond minimal disinfection processes, thereby avoiding up to $1 per 1,000 gallons or $326 per acre-foot in treatment costs. Several of the City's potential customers for surface water are currently entertaining offers to purchase groundwater. This includes both Laredo and Bexar Metropolitan Water District, among others. In fact, San Patricio Municipal Water District is currently negotiating with a group to study the availability of groundwater for distribution by the SPMWD in lieu of water purchased from the City of Corpus Christi as a means of lowering the cost of water to its customers. The potential of achieving lower costs through the use of groundwater has greatly diminished the interest in surface water, particularly in smaller quantities such as the 25 mgd that would be made available by the construction of the desalination facilities.

A second factor that has prevented the development of specific commitments at this time is the current status of the regional plans. The Groundwater Availability Models in some areas have not been finalized, and a true accounting of surpluses and shortages has not been developed, even though it was originally anticipated that this work would be completed by now. For this reason, management strategies have lagged behind where they would have been anticipated to be by this time.

A third factor is the results of this study. Potential buyers of water are reluctant to make commitments until they understand the ramifications of the overall picture. An entity might be willing to pay a premium price for water from another source to be able to share in the data developed in a desalination facility. This is particularly true for those entities with larger needs that may look to Corpus Christi to prove the technology to the extent that more City water may be surplus and allow larger strategies for moving surplus City supplies. Until this study is completed and some analysis is made of the cost implications as well as the likelihood of subsidies, there is not enough information for a potential purchaser to make an informed decision.

For all the reasons noted above, the consultant team also looked at raw water rates statewide and chose to set a fixed amount of likely revenue for the project. Given the increasing scarcity of water supplies statewide, a revenue estimate of $5,000,000 annually has been developed. This represents a value of approximately $180 per ac-ft for the 28,000 ac-ft annually that the desalination facility would produce.

8 LIKELY IMPACTS ON OTHER WATER RESOURCES AND MANAGEMENT STRATEGIES

The development of new water from a desalination facility on the coast has a number of potential impacts on other water resources. Desalinated seawater is the ultimate drought-proof supply, provided that the environmental issues associated with management of the byproduct water can be overcome. Use of desalinated seawater as the base flow for the City of Corpus Christi allows the City to maximize its use of interruptible supplies upstream and to conserve stored water for a longer period of time. This allows the system to use water from more high flow periods where the withdrawal is less of an environmental concern for instream and bay and estuary flows. Such a facility would potentially reduce the stress on inland rivers and streams by developing more water from the coastal areas.

Corpus Christi and its regional customers have an adequate supply of water for the next 50 years, although not all of the necessary infrastructure is in place to deliver that water.

The financial analysis of the desalination facility versus no desalination facility assumes that the City would contract some of their surplus water, with the obvious choices being either from the Garwood rights on the Colorado River or the Choke Canyon rights in the Nueces Basin. Water could be diverted from the Colorado River at Bay City and sent to the Greater San Antonio area as a part of the larger LCRA/SAWS agreement identified in the Region L and Region K regional plans. Pipelines that are already proposed for this project could be enlarged to carry the additional 35,000 acre-feet of water from the City's Garwood rights. The impact on other water resources of this diversion would be an increase in the instream flows of the Colorado River as this water would be in the river all of the way to Bay City, and from Bay City to Matagorda Bay there would be a decrease in the flow equivalent to the amount of water diverted. If diverted, this water would be treated and used in the San Antonio area and at least a portion of it would probably end up as wastewater effluent discharged into the San Antonio River Basin and would contribute to instream flows in that basin after discharge.

A second option for contract sales of surplus water would be diversion from the Choke Canyon Reservoir followed by a pipeline to the Greater San Antonio area. In this instance, there would be a reduction in instream flows in the Nueces Basin below Choke Canyon Dam as a result of the movement of this water out of the basin. There would also be some reduction in losses of water in the streambed of the Nueces Basin between Choke Canyon and Lake Corpus Christi as a result of the earlier diversion.

There are some direct impacts on management strategies for the Corpus Christi area and Region N that would be felt if a desalination facility were built. The Garwood Pipeline that would move water from the Bay City area to the Lake Texana Pump Station would not have to be built by Corpus Christi as a management strategy to deliver the Garwood water. As an alternative, this pipeline might be constructed by San Antonio and water diverted from the Bloomington Pump Station to be mixed with water from the Lower Guadalupe Diversion for delivery to the San Antonio area. This would constitute an impact on both the Region N and Region L plans. The financial analysis of the desalination facility assumed that the costs of this pipeline, currently scheduled tentatively for the 2020 time period, would be avoided by Corpus Christi.

A second alternative would be to include the water from the Garwood rights in the pipeline and pump stations further upstream that might be developed as a part of the LCRA/SAWS Water Sharing Plan. Under this plan, water may be diverted from the Colorado River as far upstream as the Bastrop area. Again, the costs would be avoided in the Region N plan and would be covered in the Region L plan along with the estimated raw water contract costs.

Finally, the management of the desalination plant byproduct would have no impact on other management strategies as currently envisioned in any regional plan. Discharge of the byproduct to the coastal bays in the Corpus Christi area will have environmental consequences that must be minimized, but no other management strategy uses Corpus Christi Bay, Oso Bay, or the Laguna Madre as a raw water source, so discharge to any one of these locations would not degrade the quality of the water in those bays for production of drinking water. Similarly, discharge of the byproduct offshore would not impact any other management strategy.

9 COMPARISON TO OTHER REGION L MANAGEMENT STRATEGIES

A review of the alternative management strategies that were included in the 2001 regional plans was conducted, and strategies that produced approximately the same or slightly higher amounts of water were compared to the cost of desalination. *Table 5.1-1* of the 2001 Region N plan includes 9 strategies that produce amounts of water greater than 10,000 acre-feet per year. The costs of these strategies range from a low of $268 per acre-foot for an Aquifer Storage and Recovery Strategy along the South Texas Water Authority Pipeline to $930 per acre-foot for Stage II of Lake Texana, to $1,168 per acre-foot for desalination of seawater. All of these costs are in Second Quarter 1999 dollars.

10 CCC DESALINATION PLANT BENEFITS TO UPSTREAM WATER USERS

The City of Corpus Christi and its regional customers currently rely on supplies that are a considerable distance from Corpus Christi. Some of those supplies are strategically located in areas such that upstream customers could benefit by diverting water supplies that would have otherwise been used by Corpus Christi. Development of reliable supplies of freshwater from seawater brings a new source of supply that does not involve flooding prime bottomland hardwood habitat and taking land away from farm families who have lived on it for generations. Many of the potential inland reservoir sites that are left for development of surface water supplies will have limited yield and significant environmental concerns, so the development of new water that does not add to the development pressures of inland sites is a significant benefit. Although costly at present, desalinated water costs are comparable to or less than many new inland reservoir costs when the costs for surface water treatment are included.

If Gulf water desalination is viable, the existing pipeline operated by the City of Corpus Christi could even be operated in a reverse flow situation, and water delivered from new desalination plants all along the coastline back toward Lake Texana. Finally, the more interest and attention that desalination receives in full scale operations, the more innovation and improvements are likely. Lessons learned in full scale seawater desalination plants can be used in brackish groundwater desalination as well, which will further benefit upland water users.

Chapter 7

Power

CHAPTER 7 – POWER
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CHAPTER 7 – POWER

1 INTRODUCTION

It is estimated that the Corpus Christi desalination plant operations would require approximately 470,000 kW-hr per day of power, the amount of energy produced by a 20 MW power plant. The desalination plant would not have a peak demand throughout the day, but rather would require a constant source of power to operate 24 hours a day, 7 days a week.

Potential energy sources to power the Corpus Christi desalination plant were investigated. Sources explored include conventional power obtained from the grid, wind power, solar power, and nuclear energy.

2 CONVENTIONAL POWER

Electricity is deregulated in Texas such that individual customers have the ability to shop around and bargain for the best deal on power. The Public Utility Commission of Texas' website gives a listing of companies that provide power within the State (Public Utilities Commission of Texas 2004). This website was used to determine which companies supply electricity to businesses and which of those supply power within Corpus Christi. A total of six companies were contacted to provide general price ranges for the power consumption required for the Corpus Christi desalination plant. Contact information for the utility companies is included in *Appendix E*.

Although power is deregulated, there is a single company that provides transmission and distribution of power within Corpus Christi, American Electric Power (AEP).

2.1 Costs

Table 7-2.1-1 provides a summary of the quoted rates from the six providers that were contacted for this study.

Table 7-2.1-1 Comparison of Rates From Conventional Power Suppliers in Corpus Christi, Texas

Power Provider	CPL Retail Energy	Entergy Solutions Ltd.	First Choice Power, Inc.	Green Mountain Energy Company	Reliant Energy Solutions, LLC	TXU Energy Company
$/kW-hr Estimate	$0.030	$0.050	$0.045	$0.110	$0.045	$0.046

As a function of the competition between power providers and the ability of the consumer to bargain for the best price, the standard offer rate is generally higher than the rate that may actually be negotiated for a power contract. For example, Entergy Solutions Ltd. quoted a standard rate of 10 to12 cents per kW-hr; however, an estimate of what could be negotiated for the desalination plant power needs ranged from 4.74 to 5.25 cents. Green Mountain Energy Company's higher cost is based on a standard two-year energy contract rate (i.e., without an estimation of potential lower negotiated rates).

The negotiated costs are generally based on a base-load power agreement in which a base monthly, annual, or seasonal power requirement is specified and a range around that power load, called the swing, is assumed as a reasonable fluctuation in power demand. Often contracts are negotiated with a 10 to 20 percent monthly swing. If the swing is exceeded, either by drawing more or less power, a penalty is assessed on the customer. It is possible to negotiate a larger swing, however, that is often more costly due to the greater uncertainty in power demand.

In addition to the costs listed here, an additional charge per kW-hr is called a transmission and distribution service provider (TDSP) charge. This is a fee charged by the owner of the grid infrastructure, American Electric Power, for delivering the electricity and is based on the amount of power used. It is estimated that the TDSP charge will be approximately an additional 1 cent per kW-hr.

Taxes will also apply to the total cost of conventional power including a 6.25 percent State sales tax, up to 2 percent maximum local tax, and a gross receipts tax of 1.2 percent. It is possible that this project would be exempt from both the State and local taxes, but would not be exempt from the gross receipts tax, which is levied by the State comptroller on all energy companies that do business within Texas.

Based on this information, an estimated total annual and per kW-hr cost for the Corpus Christi desalination plant was calculated. A base cost of 4.5 cents per kW-hr was used, which is approximately the average of the costs in *Table 7-2.1-1*. The estimated cost for Green Mountain Energy Company's power was eliminated because it was based on a standard package rate. With TDSP charges the cost is 5.5 cents per kW-hr, and factoring in all potential taxes, the total cost would be 6 cents per kW-hr, for a total annual cost of $10.3 million. If this project were tax-exempt for State and local taxes, the total cost would be approximately 5.6 cents per kW-hr and $9.6 million per year.

3 WIND ENERGY

Wind energy harvests the power of the wind using turbines with rotors that spin as the wind passes through their blades, as seen in *Figure 7-3-1*. Wind is an excellent power source in areas of consistent and fairly high winds; however, in areas where the wind is variable, it is necessary to either store excess energy with batteries onsite for use when wind speeds are lower, or sell excess energy to the grid and arrange to purchase energy when not enough power can be generated from wind alone.

Figure 7-3-1 Turbines Generating Power on the Fenner, NY Wind Farm

Source: Madison County, NY, 2002

3.1 Available Technology

Several potential vendors of wind turbines including GE Wind, Vestas, and NEG Micon were contacted. GE Wind offers three lines of turbines with power ratings ranging from 1.5 MW to 3.6 MW. Vestas offers eight turbine models with a range of power ratings from 660 kW to 3.0 MW. NEG Micon offers turbines with rated capacities ranging from 750 kW to 4.2 MW. Contact information for the three turbine vendors is included in *Appendix E.*

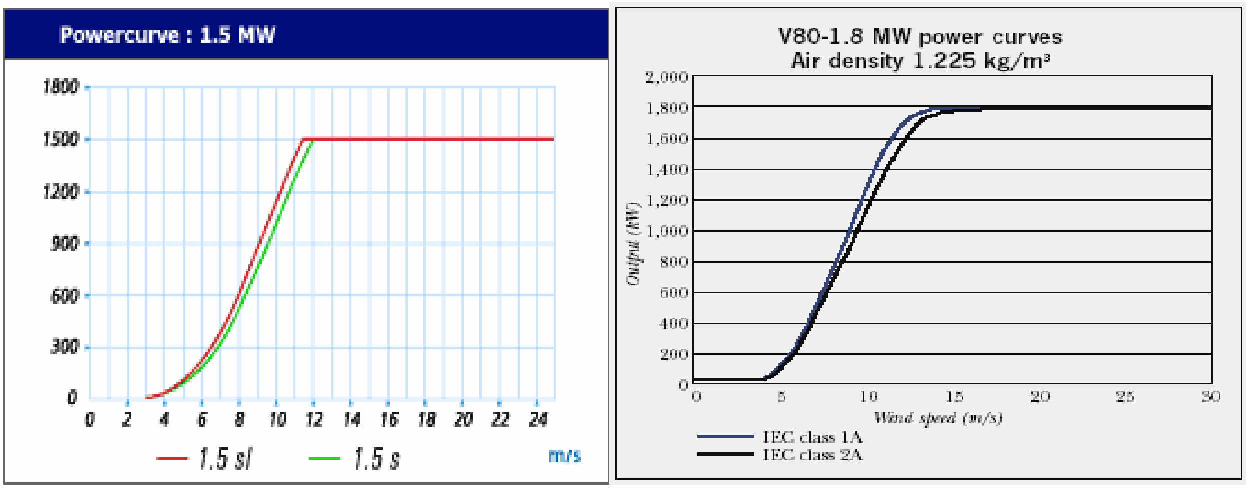
The GE Wind 1.5 MW wind turbine, the Vestas 1.8 MW turbine, and the NEG Micon 1.65 MW turbine were suggested by the vendors as the recommended technologies for this project because they are efficient turbines at lower speed winds. Depending on the model chosen, the three-bladed rotor would have a diameter ranging from 70.5 m to 80 m, and the hub height would range from 61.4 m to 100 m. The cut-in wind speed, the speed at which a turbine begins to operate, is 3 to 4 m/s and the cut-out wind speed, the speed at which a turbine shuts off, is 25 m/s. The rated wind speed, the minimum speed at which the turbine generates the rated amount of power, is approximately 12 m/s for the GE Wind turbine, 16 m/s for the Vestas turbine, and 15 m/s for the NEG Micon turbine.

The Corpus Christi project would require a minimum of approximately 12 turbines to meet the 20 MW power requirement of the desalination plant. This number assumes that the turbines can produce the rated power at all times.

3.2 Technical Feasibility

The maximum power that can be generated by a single turbine is equivalent to its power rating; however, the actual power output is generally lower due to variations in wind speed as shown in *Figure 7-3.2-1*.

Figure 7-3.2-1 GE Wind 1.5 MW (Left) and Vestas 1.8 MW (Right) Turbine Power Production in kW



Source: GE Wind 2004; Vestas 2004

Based on National Weather Service climatological data obtained from NOAA's website, the average wind speed in Corpus Christi, measured by an anemometer at a height of 10 m, is 4.99 m/s. The above powercurves are based on the wind speed at the hub height, which on average would range from 70 to 80 m for the turbines discussed previously. Average Corpus Christi wind speeds at this height can be estimated using the following equation (Manwell et al. 2002):

$$\frac{U(z)}{U(z_r)} = \ln\left(\frac{z}{z_o}\right) / \ln\left(\frac{z_r}{z_o}\right)$$

Where U is the wind speed at the indicated height,

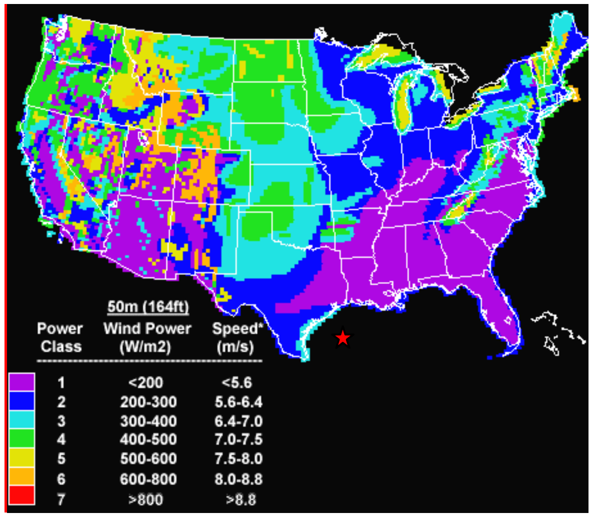
z is 70 to 80 m depending on the turbine,

z_r is the reference height of 10 m, and

z_o is the surface roughness length.

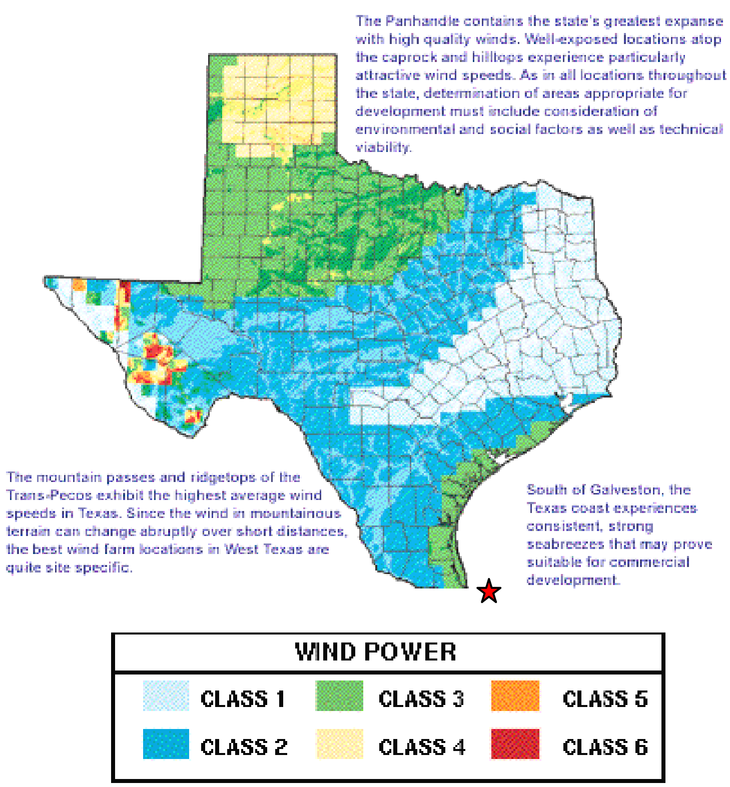
For purposes of this calculation, it was assumed that the terrain would be similar to that of a fallow field with a z_o of 30 mm. The wind speed at the 70 to 80 m hub height range would be approximately 6.7 m/s, based on the average wind speed data obtained for Corpus Christi.

Figure 7-3.2-2 Wind Energy Resources of the United States



Source: U.S. Department of Energy Wind and Hydropower Technologies Program 2004

Figure 7-3.2-3 Wind Resources of Texas



Source: Texas State Energy Conservation Office 2004a

These wind speeds are verified by information from the U.S. Department of Energy (DOE) and the Texas State Energy Conservation Office, shown in *Figures 7-3.2-2* and *7-3.2-3*, which illustrate the wind resources of Texas and the United States, with wind speeds shown at a height of 50 m. The Corpus Christi area, marked by a red star, generally has at maximum Class 3 winds. Class 4 (minimum 5.8 m/s at a height of 10 m) and greater wind areas are considered by the DOE to be viable locations for wind farms using currently available technology; however, Class 3 areas may be possible locations for wind power generation using future technology (U.S. Department of Energy Wind and Hydropower Technologies Program 2004).

According to the power curves, at this wind speed GE Wind turbine power generation would be approximately 300 kW, or 20 percent of the potential for the turbine. The Vestas turbine would generate 400 kW (22 percent) and the NEG Micon turbine would produce approximately 325 kW (20 percent). Therefore, to produce all power requirements for this project would require between 50 and 67 turbines, rather than the approximately 12 turbines that would be needed if operating at the turbines' rated power. As a result, roughly 100 MW of power capacity would have to be constructed in order to provide sufficient power for the Corpus Christi desalination facility.

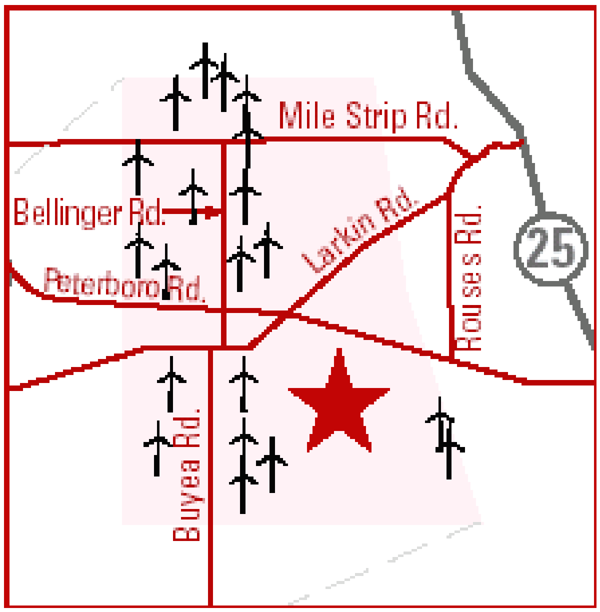
A new type of wind turbine, being developed by Centripetal Dynamics, is expected to be more efficient at lower wind speeds, and therefore may be a power option for the Corpus Christi area in the future. Centripetal Dynamics is expecting to complete the development of the new turbine model by 2006-2007. Planned features include a two-blade rotor with an innovative blade shape and the use of a composite material which would make the rotor lighter.

3.3 Land Requirements

Approximately 2,500 to 3,400 acres would be required for the 50 to 67 turbines estimated for this project, based on a rule of thumb of approximately 50 acres of land required per turbine. GE Wind indicated that that a minimum of approximately 50 acres of land is required for each turbine and indicated that turbine spacing rules of thumb are 3 to 5 rotor diameters (225 to 375 m) apart for turbines in the same row, and approximately 10 to 15 rotor diameters (750 to 1125 m) apart between rows. Vestas offered somewhat different spacing requirements for wind turbines, with 4 to 5 rotor diameters apart in the same row but only 5 to 7 rotor diameters between rows, approximately half that indicated by GE Wind. NEG Micon confirmed a minimum spacing of 5 rotor diameters between the turbines and indicated that the final service area required to be maintained around the tower bottom is approximately 20 x 20 m. The exact land requirements for a wind farm depend greatly on a number of factors including the type of turbine selected, prevailing wind direction, the topography of the land, and final design of the wind farm, and cannot be determined until potential sites are examined for usability. It is also possible to still utilize portions of the land for certain activities (e.g., farming) once the wind turbines have been installed.

An example of land use for a wind farm is a 30 MW installation of twenty 1.5 MW turbines in Fenner, New York. The total wind farm project area is 1,536 acres of land, averaging about 77 acres per turbine; however, the turbines are clustered closer on some parts of the area and further on others, as seen in *Figure 7-3.3-1*. The turbines were placed on land acquired from 14 separate landowners, and therefore pre-existing land uses, as well as topography, affected spacing of the turbines. Since only one percent of the total land area is dedicated to the turbines, the remaining land continues to be used for farming and ranching activities (Madison County, NY 2002).

Figure 7-3.3-1 Layout of Fenner, New York Wind Project



Source: Madison County, NY 2002

3.4 Costs

Capital and operation and maintenance (O&M) costs were estimated for an approximately 100 MW facility to provide the power needed for the Corpus Christi desalination plant. These costs do not include the cost of land, permitting requirements, feeders, and other components required for the transmission of electricity from the wind farm site to the desalination plant location. It is likely that permitting for a wind farm may be time consuming and costly. Also not incorporated are the costs associated with wind speed variability including batteries or costs to connect to the grid, which would likely be required based on the wind characteristics in Corpus Christi. Utilizing power from the grid for occasional demand may incur a high facility charge because there would not be a consistent baseload.

As shown in *Table 7-3.4-1*, an estimate for the capital cost for the turbines is $1 million per megawatt installed, which includes the cost of the equipment plus installation of the turbines. The total capital cost for all turbines is approximately $100 million, assuming 67 1.5 MW turbines would be necessary to meet the Corpus Christi desalination plant power requirements. The annualized capital cost is approximately $8 million per year for a 20-year project lifetime with a 5 percent interest rate. The annual O&M is approximately $15,000 per turbine, for a total O&M cost of roughly $1 million per year. The total annual cost for O&M and capital costs is approximately $9 million per year, with a cost per kW-hr of 5.3 cents.

GE Wind, Vestas, and NEG Micon confirmed that the approximate capital cost for the turbines is $1 million per megawatt installed. The O&M estimates from the three vendors ranged from $15,000 to $20,000 per turbine per year, consistent with the cost assumption made below.

Table 7-3.4-1 Cost Estimate for Wind Power

Project Assumptions		
Project lifetime	20	Years
Annual interest rate	5%	
Daily power usage	470,000	kW-hr/day
Annual power usage	171,667,500	kW-hr
Lifetime power usage	3,433,350,000	kW-hr
Technology Requirements		
Average wind speed at 10 m	4.99	m/s
Estimated hub height	80.00	M
Average wind speed at hub height	6.78	m/s
Maximum power output per turbine	1.5	MW
Average feasible power output per turbine	300	kW
Required total power output	20	MW
Required number of turbines	67	
Capital Costs		
Unit capital cost	$1,000,000	per MW installed (based on max output)
Total capital cost	$100,500,000	
Annualized capital cost	$8,100,000	
Operations and Maintenance Costs		
Unit O&M cost	$15,000	per turbine per year
Annual O&M cost	$1,005,000	
Cost Summary		
Total project annual cost	$9,105,000	
Unit cost	$0.053	per kW-hr

There can be up to 5 to 10 percent efficiency loss during distribution of power. This may result in the need for a slightly higher number of turbines to provide sufficient power for the Corpus Christi desalination plant.

The cost of electricity is a significant portion of the operations and maintenance costs for a desalination facility. In addition, the cost of electricity does fluctuate in response to market pressures and fuels costs. The United States Energy Information Agency website was reviewed to determine the long term forecast for natural gas prices as a surrogate for electricity costs for the desalination industry. This forecast runs through 2025, and shows a mild fluctuation in gas prices, with a very slight upward trend. Forecast fuel prices for electricity generators were shown as $5.01 per 1000 cubic feet in 2025, as compared to $5.73 in 2003 and $4.59 in 2004. Forecast prices fall as low as $4.12 per 1000 cubic feet and are as high as $5.10 during the forecast period.

In addition to the information reviewed above, the TCB team was provided with a confidential document by Topaz Power Partners as a part of their assistance to the City of Corpus Christi on this project. Officials for Topaz required that TCB staff sign a confidentiality agreement concerning release of this material. However, they did agree to discussion of the results in the report. The document was a report on wholesale power prices from now until 2025 that Topaz had paid an independent consulting firm to perform for them as a part of their investigation into the purchase of the Barney Davis Plant. This projection provided a reasonably flat outlook for wholesale power prices which was similar to the natural gas price prediction. In addition, the power cost used by the TCB team assumed a separate retail power provider being responsible for retail power provision to the City of Corpus Christi. The City of Corpus Christi is still exploring the option of setting up their own retail power firm, or of encouraging the South Texas Aggregation Project (STAP) to apply for status as a power retailer. In either event, the cost of the retailing of power could be less than estimated by the TCB team. For all of the above noted reasons, the power cost used was flat throughout the life of the desalination facility.

4 SOLAR ENERGY

Solar power is produced when photovoltaic cells are exposed to radiation from the sun. Solar energy is a good source of power for projects where power demand is mainly during daytime hours, when the sun is shining. If power is required at night or on days when the sun is blocked by clouds and precipitation, it is possible to either use energy stored with on-site batteries during peak sunlight, or sell excess energy to the grid and arrange to purchase energy when power cannot be generated by the photovoltaic cells.

4.1 Available Technology

Two vendors of photovoltaic cells were contacted including Shell Solar and BP Solar. Contact information for the two vendors can be found in *Appendix E*. The two companies offer a range of solar panels including monocrystalline, multicrystalline, and CIS thin film technology lines.

Shell Solar's monocrystalline product line was suggested by the manufacturer for this application. Modules range from 50 to 160 watts each, with dimensions ranging from 48 x 13 inches to 63.9 x 32.1 inches and depths of 1.3 to 2.2 inches. Modules are arranged in arrays and angled and spaced to maximize the amount of sun received by each solar cell. The life expectancy of the modules is approximately 30 years, although the inverters only last 10 to 15 years and would require replacement at least once during the 20-year assumed lifetime of this project.

Figure 7-4.1-1 Angled Solar Array on a Rooftop in Hawaii

Source: Shell Solar Industries 2003

Two types of systems are available for adjusting the angle of the array to maximize energy production. The ground-mount, single-access tracking system was suggested by Shell because it is a low maintenance system capable of adjusting the modules to respond to seasonal changes in the sun's position. A dual-access tracking system is also available, which tracks the position of the sun throughout the day and therefore increases the efficiency of the array. However, capital costs are somewhat higher, and O&M costs for the dual-access system are often prohibitive.

4.2 Technical Feasibility

Hypothetically, if the solar panels were to be exposed to peak sunlight 24 hours a day, the Corpus Christi project would require a 20 MW photovoltaic installation to power the desalination plant around the clock. However, the maximum power that will be generated by a solar cell is actually a fraction of the maximum power rating because solar modules are rated based on peak sunlight. The amount and intensity of sunlight changes throughout the year, as the position of the earth changes with respect to the sun. For Corpus Christi, approximately 4 hours of peak sunlight each day are anticipated on average, known as the insolation value, as shown in *Figure 7-4.2-1*. Therefore, on average, a 1 MW solar array in Corpus Christi will only generate a maximum of 4 to 5 MW-hr per day of power rather than 24 MW-hr per day. This is because the peak sunlight only shines for a few hours each day, and during the remaining daytime hours, the intensity of the sun is only strong enough to create a fraction of the maximum power rating of the array.

Based on a power output of 4 MW-hr per day per 1 MW installation of photovoltaic cells, the Corpus Christi project would require a minimum solar array of 120 MW to provide the 20 MW of power needed to run the desalination plant.

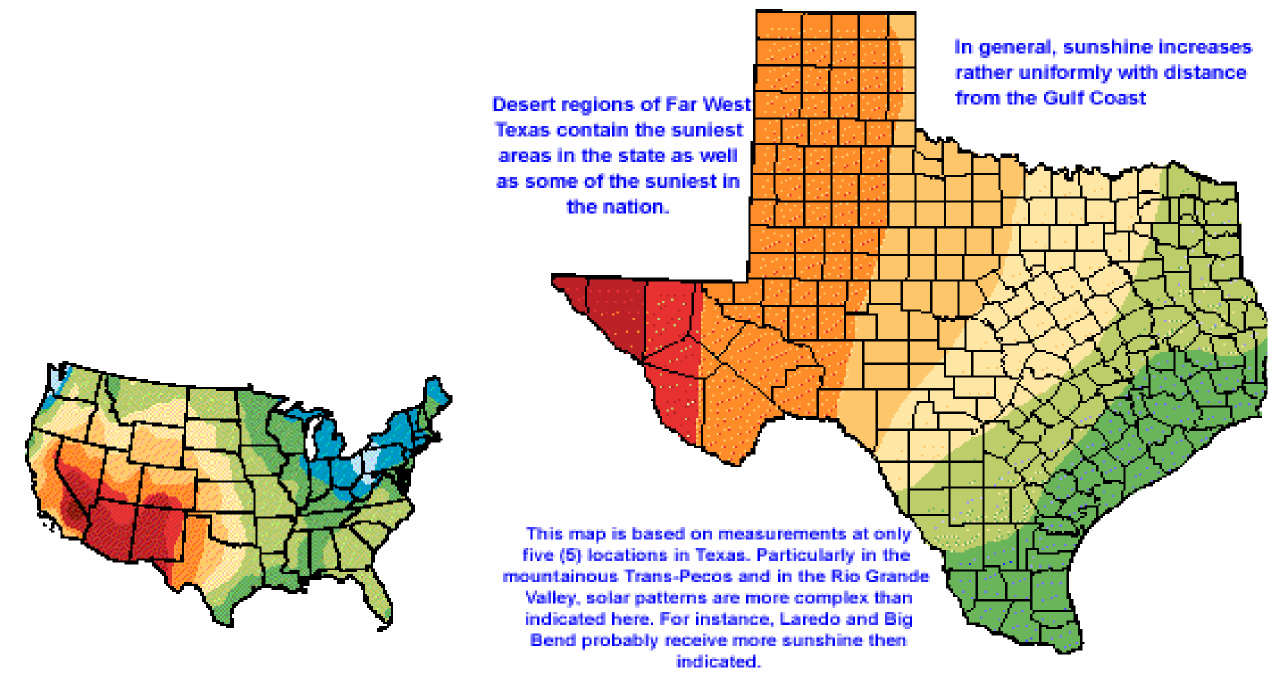
An additional complication with solar power is that while sufficient power to run the desalination plant for 24 hours would likely be produced each day with a 120 MW solar array, the power would be produced only during a portion of the daylight hours and would require storage until it would be needed during periods of darkness, either through a connection to the electrical grid or through on-site batteries.

4.3 Land Requirements

Shell Solar has indicated that approximately 5.75 acres of land would be required for a 1 MW photovoltaic power plant. In general, the more level the land at the location of a solar power array, the lower the cost because of lower mounting and setup costs. Based on the estimated need of a 120 MW photovoltaic installation, the required land would be approximately 690 acres.

A unique siting option available for solar power is the placement of photovoltaic modules on preexisting structures in industrialized areas. Flat rooftops can be used to house several modules, taking advantage of space that would otherwise go unused. The size of a rooftop or other flat, open space would limit the number of solar arrays that can be set up together at a single location, potentially requiring additional cost and materials to link several locations to the lines that would deliver power to the desalination plant. An example of a rooftop installation can be found in Austin, Texas, as shown in *Figure 7-4.3-1*.

Figure 7-4.2-1 Direct Normal Insolation in Texas and Across the United States



AVERAGE DIRECT NORMAL INSOLATION MAP LEGEND			
COLOR KEY	per day (kWh/m^2-day)	per YEAR	
		(MJ/m2)	(quads/100 mi^2)
	<3.0	<3,940	<1.0
	3.0 - 3.5	3,940 - 4,600	1.0 - 1.1
	3.5 - 4.0	4,600 - 5,260	1.1 - 1.3
	4.0 - 4.5	5,260 - 5,910	1.3 - 1.5
	4.5 - 5.0	5,910 - 6,570	1.5 - 1.6
	5.0 - 5.5	6,570 - 7,230	1.6 - 1.8
	5.5 - 6.0	7,230 - 7,880	1.8 - 1.9
	6.0 - 6.5	7,880 - 8,540	1.9 - 2.1
	6.5 - 7.0	8,540 - 9,200	2.1 - 2.3
	>7.0	>9,200	>2.3

Source: Texas State Energy Conservation Office 2004b

4.4 Costs

Capital and O&M costs were estimated for an approximately 120 MW photovoltaic array to provide the power needed for the Corpus Christi desalination plant. These costs do not include the cost of land or other open space, permitting, feeders, and other components required for the transmission of electricity from the solar installation to the desalination plant location. Also not incorporated are the costs associated with storing power to be used during times of low or no sunlight. In addition, the photovoltaic modules have a life expectancy of 30 years; however, the inverters have a life expectancy of only 10 to 15 years and will incur an additional cost for replacement at that time, which cannot be estimated at present.

Figure 7-4.3-1 Solar Power Array on a Parking Lot Rooftop in Austin, Texas

Source: Denapoli 2004

As shown in *Table 7-4.4-1*, an estimate for the capital cost of a photovoltaic array is approximately $6.00 per watt or $6 million per MW installation. With a minimum of a 120 MW total installation required, the total capital cost would be $720 million with an annualized capital cost of nearly $58 million. The annual O&M cost for the project is estimated at $3,000 per facility, and assuming a single facility, this cost would cover quarterly visits to the power plant for inspection of the array and the inverters. The overall annual cost for this project would be approximately $58 million, with a cost of 33.7 cents per kW-hr.

Table 7-4.4-1 Cost Estimate for Solar Power

Project Assumptions		
Project lifetime	20	Years
Annual interest rate	5%	
Daily power usage	470,000	kW-hr/day
Annual power usage	171,667,500	kW-hr
Lifetime power usage	3,433,350,000	kW-hr
Technology Requirements		
Unit array maximum power output	1	MW
Average power available during daylight	4.00	MW-hr
Percentage of power rating generated	17%	
Power generated per unit	166.67	kW-hr/day
Required total power output	20	MW
Required number of 1 MW arrays	120	
Capital Costs		
Unit capital cost	$6,000,000	per MW installed (based on max output)
Total capital cost	$720,000,000	
Annualized capital cost	$57,800,000	
Operations and Maintenance Costs		
Unit O&M cost	$3,000	per facility
Annual O&M cost	$3,000	(assuming a single facility)
Cost Summary		
Total project annual cost	$57,803,000	
Unit cost	$0.337	per kW-hr

5 CONCLUSION

Table 7-5-1 shows a comparison of costs for conventional power, wind power, and solar power. Based on the factors used for calculation, wind power has the lowest cost per kW-hr, followed by conventional power. The cost of solar power is more than five times the cost of other alternatives before land costs are factored in and therefore does not appear to be an economically feasible power alternative for this project.

Table 7-5-1 Alternative Energy Cost Comparison

Power Source	Annual Cost (M)	Cost per kW-hr
Conventional Power*	$10.3	$0.060
Wind Power**	$9.0	$0.053
Solar Power**	$57.8	$0.337

* Assumes State and local taxes must be paid
**Does not include cost of land or potential taxes associated with setup or operation

The price of wind power will increase with the addition of the cost for land. Assuming a land cost of approximately $5,000 per acre, a wind farm for Corpus Christi would have an additional capital cost of $15 million for approximately 3,000 acres of land. Factoring this into the existing costs yields an annualized cost of $10.3 million and a kW-hr cost of 6 cents, roughly equal to that of conventional power.

As discussed in *Section 3.0*, wind is not a consistent source of power and may sometimes provide more or less power than is required. Rather than build a wind farm to provide on average 100 percent of the power required by the desalination plant, a wind farm could be sized to provide a portion of the power needs, with the remaining electricity from conventional power. This would allow cost savings during times of high wind because a lower amount of conventional power would be required. If the wind farm were intended to provide an average of 100 percent of the required power, the additional power generated during high winds would likely be wasted, or possibly be sold to the grid.

Based on the analysis, it appears that wind energy could be a potentially feasible option for a cost-effective alternative to conventional power for the Corpus Christi conceptual desalination facility. A number of factors are likely to affect the economic factors and feasibility of this option:

- Conventional power would be considered less costly if the desalination plant was granted tax exempt status, for a savings of roughly $700,000 per year.

- The land on which the wind farm is located could be leased for several uses including farming and ranching. The revenue brought in by the lease of the wind farm could help offset land purchase costs and provide an economic benefit. Alternatively, it could be possible to lease land for the wind turbines from local landowners instead of purchasing land.

- Transmission and substation costs are site specific. American Electric Power has estimated that transmission lines cost approximately $700,000 to $1 million per mile and a substation with a 25 Mva transformer with two breakers would cost approximately $2.7 million. This infrastructure would be required for both conventional and wind power; however, depending on the location chosen for the desalination plant, some of the infrastructure may or may not currently exist. It is expected that it will take more miles of transmission line to connect the desalination plant location to the wind farm site than it will to connect to the power grid, and therefore it is likely that the transmission costs will be higher for wind power; however, the costs cannot be estimated until locations for both the wind farm and desalination plant have been determined.

Based on the analysis, it appears that the costs of wind power and conventional power may be comparable depending on several factors described above. Therefore, it is recommended that there be further evaluation of wind as a potential source of power to provide a portion of the power needs of the plant once a location has been selected. This approach could provide a technically and financially feasible approach along the with environmental benefits gained from the use of a renewable energy source as the primary power for the desalination plant, without a large increase anticipated in the cost of power over conventional energy and with a guarantee of a steady power supply from the grid during times of low wind.

Chapter 8

Permitting Requirements

CHAPTER 8 – PERMITTING REQUIREMENTS
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CHAPTER 8 – PERMITTING REQUIREMENTS

1 INTRODUCTION

The analysis of the feasibility of a large scale desalination plant along the Texas coast includes an evaluation of environmental constraints, including permit requirements that may influence facility design, cost, or construction schedules. There are few major brackish and no seawater desalination plants constructed in Texas, and the regulatory requirements for permitting such facilities are not well defined. Key environmental issues associated with large scale desalination plants is management of the byproduct water and the dilution of the byproduct discharge.

The two sites evaluated for environmental issues and constraints are the Barney Davis Power Plant site in Corpus Christi and the Oxychem site in Ingleside, Texas. For both sites, the prospect of discharging byproduct water into the Corpus Christi Bay, Oso Bay, or the Laguna Madre is less likely due to the environmental issues surrounding an increase in salinity of these estuarine areas. Other environmental considerations include potential impacts to the natural environment such as water quality, biological resources and associated habitat, wetlands, hydrodynamic characteristics including freshwater inflows and circulation patterns, and protected areas such as wildlife refuges, nature preserves, piping plover habitat, bird rookeries, or public parks.

1.1 General Environmental Setting

The desalination plant sites are located in or near the Corpus Christi Bay and intake and discharge of byproduct water will occur in the nearshore Gulf of Mexico (Texas Territorial Sea). The raw water intake and byproduct discharge pipeline proposed for the Barney Davis Power Plant site crosses the upper Laguna Madre south of Corpus Christi Bay. The raw water intake and byproduct discharge pipelines proposed for the Oxychem site is proximal to the northeastern shoreline of Corpus Christi Bay, cross Redfish Bay, the Aransas Channel, Intracoastal Waterway, Mustang Island, Mustang Beach, and Port Aransas to the Gulf of Mexico.

The Barney Davis Power Plant site is located landward of the Laguna Madre and intake and byproduct discharge pipelines cross the Laguna Madre. Discharge to the cooling ponds of the power plant would result in discharge to Corpus Christi Bay system within the Nueces Estuary. In the vicinity, the upper Laguna Madre system is a long, narrow, and shallow lagoon, bordered on the east by Padre Island and on the west by the City of Corpus Christi. The surrounding areas have little development and industrialization. The upper Laguna Madre, with no constant openings into the Gulf of Mexico and limited freshwater inflow, is characterized as a hyper saline estuary where evaporation exceeds rainfall. Hypersaline environments tend to have fewer species but a large number of individuals per species. Freshwater inflow is intermittent and is primarily associated with rainfall and municipal or industrial discharges. Channelization has altered bathymetry, tides and hydrology, and subsequently salinity, in the Laguna Madre. Tidal characteristics, water circulation, and salinity are all important environmental parameters that govern the distribution of biota and habitats.

The Laguna Madre, described by TPWD as a highly productive and ecologically sensitive lagoon ecosystem, is protected from the high energy of the Gulf of Mexico by a barrier island and peninsula system. Padre Island extends the entire length of the Laguna Madre. The northern half of Padre Island near Corpus Christi is slightly higher in elevation and more vegetated, providing protection from storms to lagoons with few washover passes. Three major habitats in the upper Laguna Madre: seagrass beds, bare bay bottom, and wind-tidal flats. The upper Laguna Madre ecosystem is dominated by seagrass and bare bottom habitats in the aquatic system; wind-tidal flats and shallow sandy margins comprise the shoreline. Several other habitats present are unique to the Laguna Madre ecosystem and these include jettied tidal inlets at Aransas Pass. Submergent seagrass meadows and emergent wind-tidal flats make up the most extensive habitat types of Laguna Madre. Wind-tidal flats are common on the Padre Island side of Laguna Madre. Seagrass beds are dominant in the shallows and are among the most common coastal ecosystem. The fundamental function of seagrasses is to provide complex structure in both water column and sediment. Physically, seagrasses baffle waves, reduce erosion, increase bottom areas, and promote water clarity by removing suspended sediments. Biologically, seagrasses provide nursery areas, refuge, and rich foraging grounds for a variety of estuarine fish and invertebrates, including a number of commercially and recreationally important species. In addition, seagrasses are essential food sources for some waterfowl and sea turtles and are among the most productive submerged habitats. Wind-tidal flats are formed by wind and storm tides and are nearly featureless sand and/or mud habitats found in estuaries adjacent to hypersaline lagoons. Wind-tidal flats replace salt marshes when freshwater inflow and annual precipitation decreases. The primary productivity of algal mats and persistent benthic invertebrate communities in areas with frequent flooding provide significant feeding areas for aquatic birds on the Texas coast. They are essential foraging habitats for wintering and migrating shorebirds and wading birds and are important habitat for several State and federally listed threatened and endangered species or other species of concern such as Piping and Snowy Plovers, Reddish Egrets, White-Tailed Hawks, and Peregrine Falcons.

The Laguna Madre is in a state of long-term change primarily due to anthropogenic influences. Since the 1940s, several hundred islands were created from the deposition of dredged material disposal generated during construction of the Intracoastal Waterway. Plant succession has occurred over time, and most of the island with sufficient elevation supports a diversity of grass, forb, and shrub vegetation assemblages. Many islands are used by colonial waterbirds as rookeries, or breeding grounds, from early January through September of each year. The larger dredged material disposal islands are located adjacent to the Intracoastal Waterway, and active disposal areas continue to be used. Most colonial waterbirds are dependent upon estuarine habitats for both foraging and reproduction, typically feeding on fish and crustaceans in shallow and open water areas. Natural and artificial islands for nesting are critical to survival, and the presence of colonial waterbirds provides and indicator of ecosystem health. Although dredging of the Intracoastal Waterway has brought about hydrologic change, resultant dredged material disposal islands provide valuable habitat. Key rookery islands, such as the Pita Island/Humble Channel Spoil rookery adjacent to the proposed intake and discharge pipelines of the Barney Davis Power Plant site, have been modified for oil production, thereby limiting available nesting habitat. South Bird Island, managed by the National Audubon Society located in the Padre Island National Seashore, encompasses approximately 12.4 acres (5 hectares) of yucca, prickly pear, subshrubs, grasses, and loose sand/shell hash habitat. This island has experienced prolonged and extensive colonial waterbird nesting usage.

The proposed Oxychem desalination plant site is located in Ingleside, Texas adjacent to and south of Aransas Pass, Texas. The ecology of the Aransas Pass jetties located on the north end of Mustang Island, immediately north of Padre Island and the Laguna Madre at Port Aransas, Texas, have been studied since the 1940s. The Texas jetties at Port Aransas are more than 100 years old and over 100 species of algae have been reported with a distinctive seasonal succession. Although the jettied inlets provide a migratory route between the Gulf of Mexico and the bays and lagoons for many species of shellfish and finfish, certain fishes are characteristic of the jetty habitat. Jetty-associated fish include herbivorous blennies, sergeant-major damselfish, Atlantic spadefish, and carnivores such as spotted jewfish, Atlantic needlefish, halfbeak, and toadfish. The most common bird groups that use the jetties for resting, and using adjacent waters for feeding, are Gulls and Terns. In addition, some sea turtles and Atlantic bottlenose dolphin use the jettied tidal inlets for passage and feeding areas. Due to their proximity to navigation lanes, jetties are vulnerable to the introduction of exotic or non-indigenous species from foreign shipping traffic. In 1990, an invasive, edible brown mussel was discovered on the Port Aransas jetties. Within four years, this mussel spread a distance of 807 miles (1,300 kilometers). Due to the macrofouling characteristics of the species, there was a potential for major disruption to the established jetty community and its ecology. However, by 1996, the mussel beds began to decline and can now be found only in preferred high-energy habitats near the seaward end of the jetties for reasons not well understood. In addition to providing for water and migratory exchange between lagoons and the Gulf, jettied inlets also provide a hard-substrate habitat for a variety of estuarine, Gulf, temperate, and tropical species that normally would not be present, or abundant, in an area dominated by soft substrates.

The Corpus Christi Bay system is also in the National Estuary Program. The primary source of freshwater inflows to Corpus Christi Bay is Nueces River and the Oso Creek. Reservoir construction, increased population, and industrial growth in the area have greatly reduced freshwater inflows. Reduced inflows have contributed to the increase in salinity of the delta and shoreline erosion. Extensive recreational and commercial fishing cause overharvest and excess bycatch of non-targeted species. Intension industrial, commercial and shoreline development have affected Corpus Christi Bay. Dredging of the Intracoastal Waterway and dredged material deposition also have impaired the water quality.

The Texas Territorial Sea is that portion of the Gulf of Mexico extending seaward from the Texas Gulf shoreline a distance of nine nautical miles. Extensive oil, gas, and petrochemical production, marine commerce, and transportation are major industries that use the Texas Territorial Sea. It is widely used for commercial shrimp trawling, menhaden trawling, longlining, recreational fishing, oil and gas production, and recreational scuba diving. Threats to the nearshore gulf area and its associated marine organisms include potential oil and chemical spills; over-harvest of shrimp, finfish and other marine species; bycatch of fish, invertebrates and sea turtles; damage from hypoxia, or reduced oxygen zone and harmful algal blooms.

1.2 Texas Regulatory Framework (Water Planning)

A broad understanding of the regulatory framework that may encompass water supply through desalination of seawater is of value to appreciate the overlapping, interrelated and jurisdictional issues that may influence water-supply decisions. Historically, water-planning efforts were instigated as a result of one of the worst droughts in Texas history that started in 1948. This drought lasted for nearly 10 years and, by 1956, the combined river discharge to the estuaries of the State was 86 percent below average (Longley 1994). There were declines in the harvest of oysters, white shrimp, and blue crabs (Copeland 1966); invasion of the bays by stenohaline marine organisms (Hoese 1960); and a negative effect on fish such as black drum (Longley 1994). As a result of the 1948 drought, the Texas Water Planning Act was passed in 1957 and contained a legislative directive to give consideration to the effects of upstream development on coastal waters. The initial plan, formally adopted in 1969, included the establishment of a cooperative Bays and Estuaries Program by the Texas Water Development Board (TWDB).

The Texas Water Plan of 1968 tentatively allocated specific annual amounts of water to supplement freshwater inflows to Texas bays and estuaries. At the time, these amounts were recognized as preliminary estimates of freshwater needs based on historical inflows to each estuary. Established public policy provided by Texas Water Code (TWC) §1.003, as amended, provides for the conservation and development of the natural resources of the State, including "the maintenance of a proper ecological environment of the bays and estuaries of Texas and the health of related living marine resources."

Both Senate Concurrent Resolution 101 (63rd Texas Legislature) and Senate Resolution 267 (64th Texas Legislature) declared, "A sufficient inflow of freshwater is necessary to protect and maintain the ecological health of Texas estuaries and related living marine resources." In 1975, the 64th Texas Legislature mandated a comprehensive study of the influence of freshwater inflows to Texas estuaries, including Corpus Christi Bay and the Laguna Madre (Senate Bill [SB] 137). Reports published as part of this effort were to address the relationship of freshwater inflow to the health of living estuarine resources (*e.g.*, fish, shrimp, wetlands, *etc.*) and to present methods of providing and maintaining a suitable ecological environment. These early studies identified the need for further information to support water management; bills passed in 1985 and 1987 directed the TWDB and Texas Parks and Wildlife Department (TPWD) to conduct studies to determine the bay conditions necessary to support a sound ecological environment. The results of these efforts, along with a description of an analytical methodology for developing estuarine freshwater inflow requirements, were published in a report jointly produced by the two departments (Longley 1994). In 1985, the 69th Texas Legislature introduced provisions to the Texas Water Code requiring the maintenance of *beneficial inflows* to Texas estuaries, which were defined as inflows necessary for maintaining an ecologically sound environment (Texas Water Code §11.147). Key language added to the Texas Water Code by the State legislature in 1985 provided specific directives that continue to shape the Texas approach to the problem:

> "For permits issued within an area that is 200 river miles from the coast, to commence from the mouth of the river thence inland, the commission shall include in the permit, to the extent practicable when considering all public interest, those conditions considered necessary to maintain beneficial inflows to any affected bay or estuary system (Texas Water Code §11.147(b) [2002])."

The phrase *beneficial inflows* was defined further:

> "A salinity, nutrient, and sediment loading regime adequate to maintain an ecologically sound environment in the receiving bay and estuary system that is necessary for the maintenance of productivity of economically important and ecologically characteristic sport or commercial fish and shellfish species and estuarine life upon which such fish and shellfish are dependent (Texas Water Code §11.147(a) [2002])."

The legislation specifically recognized inflow effects (salinity, nutrient, and sediment loading), which in turn affect estuarine resources including sport or commercial finfish and shellfish species and their food sources such as phytoplankton (microscopic free-floating plants), zooplankton (microscopic animals), fishes, and benthic organisms in sediments such as polychaete worms and amphipods. The TPWD has primary responsibility for protecting fish and wildlife resources. The ability of TPWD to participate in water management decisions is mandated by amendments to Texas laws.

1.2.1 Senate Bill 1—State Water Planning

In 1997, the Texas Legislature adopted SB 1, a comprehensive water planning and management bill, which began a programmatic statewide water planning process. The TWDB is the lead agency for SB1 administration, while other State agencies provide technical assistance to the water planning regions, including TPWD, TCEQ, and the Texas Department of Agriculture. The objective of SB 1 is to develop a State Water Plan that will "provide for the orderly development, management, and conservation of water resources and preparation for, and response to drought conditions, in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the State."

The 1997 State Water Plan identified an environmental planning methodology to consider instream flow needs during the evaluation of permits for new reservoirs or diversion of water from new or amended water rights. The methodology is based on the concept of establishing target flows, while allowing diversion for human use. Since 1985, all new surface water use permits and all amendments to existing use permits may contain provisions to reserve water for public purposes. Water rights holders are required to limit their diversion of water from rivers and streams when stream flows are below a certain level. Under SB 1, the TCEQ was required to develop water availability models (WAMs) for all river basins by the end of 2001. The TCEQ may use these models to estimate water availability during a drought, the amount of wastewater effluent available for reuse, and the amount of water available for diversion.

Regional water planning efforts incorporate environmental impact issues and water plans are designed to protect natural resources. The San Antonio-Nueces and Nueces-Rio Grande River Basins, including Corpus Christi Bay and Laguna Madre, are located in the Coastal Bend Regional Water Planning Group (Region N). Seawater desalination at the Barney Davis Power Plant is included in the *Coastal Bend Regional Water Plan* as a viable, long-term, water supply option.

1.2.2 *Freshwater Inflows (Bay and Estuary Flows)*

In 1975, the 64th Texas Legislature mandated a study of the influence of freshwater inflows to Texas estuaries. In 1985, the 69th Texas Legislature introduced provisions to the Texas Water Code requiring the maintenance of *beneficial inflows* to Texas estuaries, which were defined to be those necessary for maintaining an ecologically sound environment (Texas Water Code §11.147). According to the latest Texas Water Plan, there is an increasing need to incorporate results from these beneficial inflow studies into the operating rules of water impoundment and diversion projects to minimize harmful environmental effects to estuaries, rivers, habitat and wildlife while allowing the maximum beneficial use of State waters. Because of potential conflicts with inland water users with future water demands, there is an increasing need to incorporate results from the freshwater inflow studies into the operating rules of diversion projects to cause the least harm to the environment while allowing the maximum beneficial use of State waters.

In other legislation, the phrase *state water* is defined as:

> "The water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the stormwater, floodwater, and rainwater of every river, natural stream, and watercourse in the State. State water also includes water which is imported from any source outside the boundaries of the State for use in the State and which is transported through the bed and banks of any navigable stream within the State or by utilizing any facilities owned or operated by the State. Additionally, State water injected into the ground for an aquifer storage and recovery project remains State water (Texas Water Code §11.021(a) [2002])."

As instream flow study and freshwater inflow study collaborators, the TWDB, TCEQ, and TPWD have engaged in a cooperative effort to address environmental impact issues in regional and State water planning. While responsibilities vary among agencies, each agency recognizes the importance of producing water plans that protect the natural resources of the State, as required by the Texas Water Code §16.051 and §16.053. Additionally, 31 Texas Administrative Code (TAC), Chapter 357, *Regional Water Planning Guidelines*, was amended in 2001 to include additional requirements regarding environmental issues, in particular requiring a "quantitative reporting of environmental factors including effects on environmental water needs, wildlife habitat, cultural resources, and effect of upstream development on bays, estuaries, and arms of the Gulf of Mexico" in evaluating water management strategies.

1.3 State Agency Roles and Project Alternatives

The TCEQ is responsible for waste management and permitting waste disposal such as discharge of byproduct water from desalination plants. The TPWD is charged with primary responsibility for protecting fish and wildlife resources and with providing information and recommendations regarding permits, licenses, and construction projects that may impact fish and wildlife. The TWDB is assigned as the lead agency for facilitating the Governor's initiative for desalination plants in

Texas and is responsible for regional water planning. *Regional Water Planning Guidelines*, codified as 31 TAC Chapter 357, was amended in 2001 to include additional requirements regarding environmental issues. In particular, 31 TAC Chapter 357 requires "a quantitative reporting of environmental factors including effects on environmental water needs, wildlife habitat, cultural resources, and effect of upstream development on bays, estuaries, and arms of the Gulf of Mexico" in evaluating water management strategies.

The Texas Department of Health (TDH) monitors contamination and human health risk of oyster beds and fish. The purpose of the Seafood Safety Division of the TDH is to protect consumers of molluscan shellfish and crab meat from disease or other health hazards transmissible by these products produced or imported into Texas.

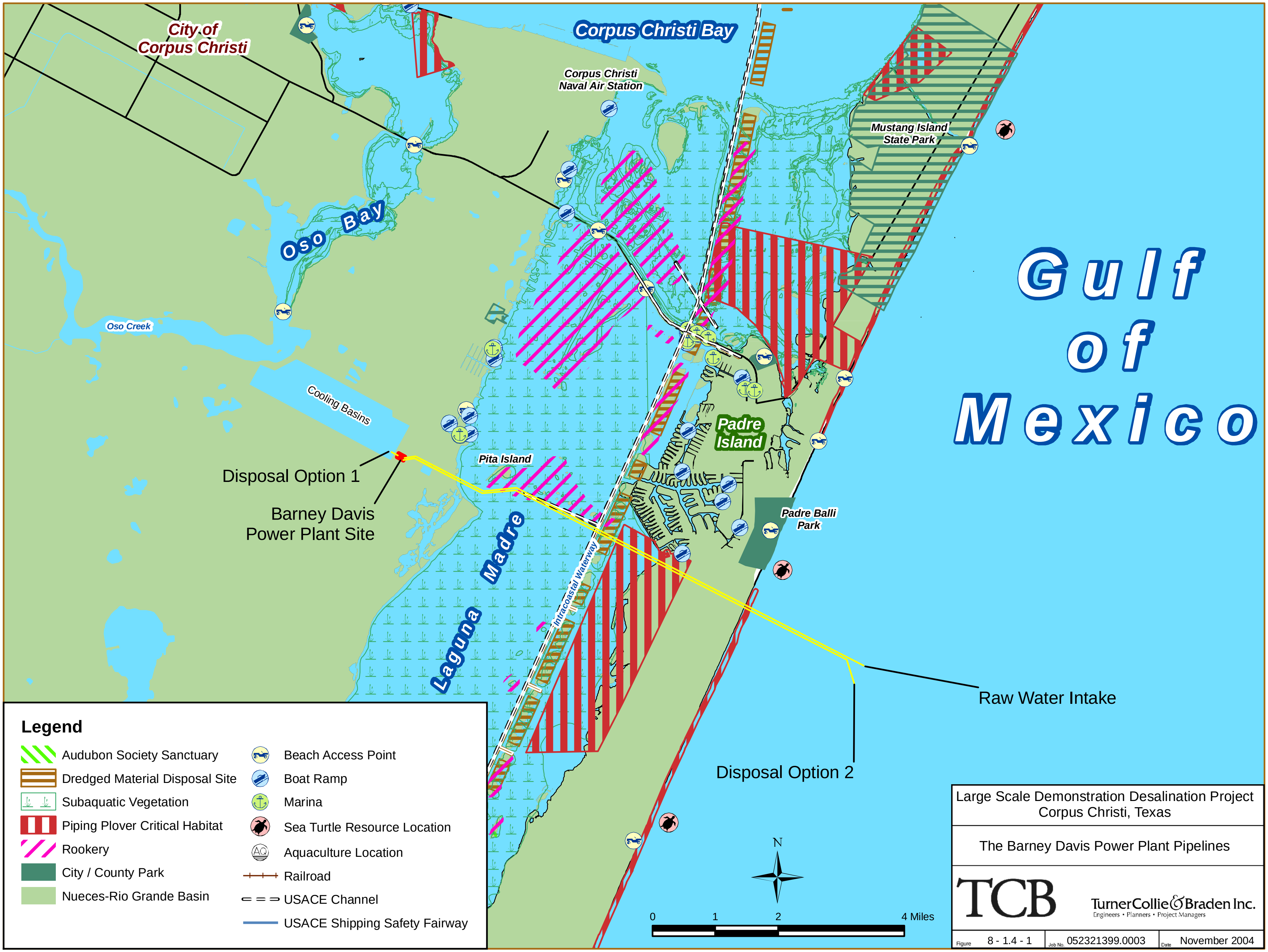
From the perspective of environmental impacts to the bays, the two desalination plant sites are generally equivalent with respect to environmental issues since all of the intake, treatment, and distribution options are conceptually identical for each site in that intake water will be drawn from the Gulf of Mexico and byproduct water will be discharged into the Gulf of Mexico. Twin pipelines will be needed to reach intake and discharge structures at least 2 nautical miles (4 kilometers) offshore in order to reach homogeneous water for the intake and to ensure sufficient water depths for dilution. Diffusion and dilution modeling (see below) can be used to refine the necessary separation. It would be desirable to trench (wet dredge) the pipeline in the Gulf of Mexico reach, both to protect from adverse currents and to avoid snagging by trawlers. Both intake and the discharge pipelines would require a platform to lift the structure off the seabed. These structures will have to be buoyed and marked to avoid being fouled, which will also require coordination with the U.S. Coast Guard.

Blending of raw water with groundwater sources was considered as an alternative, but heavy pumping of groundwater could potentially result in aquifer mining, land subsidence, and high total dissolved solids (TDS) concentrations. These issues outweighed any benefit from use of groundwater as a source for water mixing.

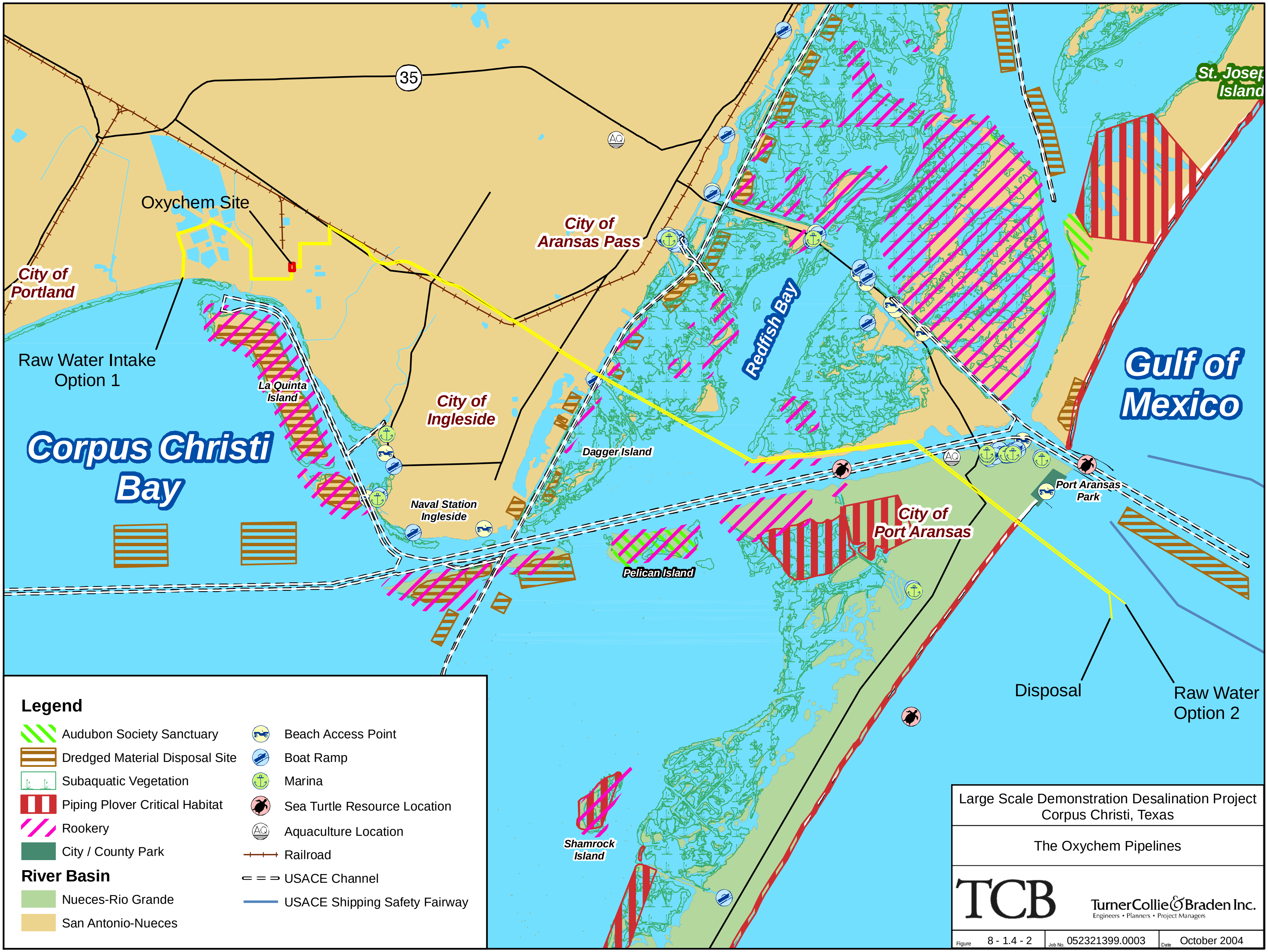
1.4 Pipeline Route Studies (Gulf of Mexico Disposal)

From the environmental perspective, routing of the intake and discharge pipelines from the proposed plant sites to the Gulf of Mexico would not be equivalent. The route for the raw water and byproduct disposal pipelines would be essentially parallel, diverging when reaching the Gulf of Mexico. For the Barney Davis Power Plant site, the route for the byproduct disposal pipeline would extend from the desalination plant to the intake channel, across the Laguna Madre to the Intracoastal Canal. From the Intracoastal Canal, the pipeline would extend across Padre Island to the shoreline and into the Gulf of Mexico. The raw water intake would essentially reverse this route with the intake pump structure located on Padre Island. The method of pipeline installation would vary from open cut to wet dredge with directional drilling used for the byproduct disposal pipeline and tunneling used for the raw water piping when crossing the Intracoastal Canal. The Barney Davis Power Plant pipelines would extend at least 32,000 linear feet (9,754 meters [m]) across the Laguna Madre and Padre Island (*Figure 8-1.4-1*). Of this total, the intake and discharge pipelines would extend at least 10,500 feet (3,200 m) into the Gulf of Mexico, separated by a distance to be established by modeling.

For the Oxychem site, the route for the byproduct disposal pipeline would extend from the desalination plant through Ingleside across the Intracoastal Waterway and from there to Harbor Island, crossing Redfish Bay. From Redfish Bay, the pipeline would parallel the north side of Aransas Pass to Harbor Island, crossing Aransas Pass and Mustang Island to the Gulf of Mexico shoreline and beyond to extend 10,500 feet into the Gulf (Texas Territorial Sea). The raw water intake would essentially reverse this route with the intake pump structure located on Mustang Island. The method of pipeline installation would vary from open cut to wet dredge with directional drilling used for the byproduct disposal pipeline and tunneling used for the raw water piping when crossing the Intracoastal Canal. The Oxychem site pipelines would extend at least 78,000 linear feet across the Redfish Bay, Aransas Pass, and Mustang Island. Of this total, the intake and discharge pipelines would extend at least 10,500 feet (3,200 m) into the Gulf of Mexico, separated by a distance to be established by modeling (*Figure 8-1.4-2*).



City of Corpus Christi
Corpus Christi Bay
Corpus Christi Naval Air Station
Mustang Island State Park
Oso Bay
Oso Creek
Cooling Basins
Gulf of Mexico
Padre Island
Pita Island
Disposal Option 1
Barney Davis Power Plant Site
Padre Balli Park
Laguna Madre
Intracoastal Waterway
Raw Water Intake
Disposal Option 2
Legend
Audubon Society Sanctuary
Dredged Material Disposal Site
Subaquatic Vegetation
Piping Plover Critical Habitat
Rookery
City / County Park
Nueces-Rio Grande Basin
Beach Access Point
Boat Ramp
Marina
Sea Turtle Resource Location
Aquaculture Location
Railroad
USACE Channel
USACE Shipping Safety Fairway
N
0
1
2
4 Miles
Large Scale Demonstration Desalination Project
Corpus Christi, Texas
The Barney Davis Power Plant Pipelines
TCB
TurnerCollie&Braden Inc.
Engineers • Planners • Project Managers
Figure 8 - 1.4 - 1
Job No. 052321399.0003
Date November 2004



35
St. Joseph Island
Oxychem Site
City of Aransas Pass
City of Portland
Raw Water Intake Option 1
La Quinta Island
City of Ingleside
Redfish Bay
Gulf of Mexico
Corpus Christi Bay
Dagger Island
Naval Station Ingleside
City of Port Aransas
Port Aransas Park
Pelican Island
Disposal
Raw Water Option 2
Shamrock Island
Legend
Audubon Society Sanctuary
Dredged Material Disposal Site
Subaquatic Vegetation
Piping Plover Critical Habitat
Rookery
City / County Park
River Basin
Nueces-Rio Grande
San Antonio-Nueces
Beach Access Point
Boat Ramp
Marina
Sea Turtle Resource Location
Aquaculture Location
Railroad
USACE Channel
USACE Shipping Safety Fairway
Large Scale Demonstration Desalination Project
Corpus Christi, Texas
The Oxychem Pipelines
TCB
TurnerCollie&Braden Inc.
Engineers • Planners • Project Managers
Figure 8 - 1.4 - 2
Job No. 052321399.0003
Date October 2004

Pipeline routing studies would be needed to identify routes that would minimize impacts to the sensitive natural environment of Laguna Madre, Padre Island, Redfish Bay, Mustang Island, and Aransas Pass. Seagrass beds, Piping Plover habitat, and other sensitive natural habitats such as bird rookeries and oyster beds in the Gulf of Mexico would need to be mapped and avoided to the extent possible to minimize impacts. Coupled with the pipeline routing studies, investigation of installation methods to minimize potential environmental impacts, including those to seagrass beds, would be required. *Table 8-1.4-1* enumerates preliminary features of environmental impacts to be evaluated in future studies. Additional features may be identified during the proposed studies.

1.5 Byproduct Discharge and Intake Alternatives

According to the latest Texas Water Plan, there is an increasing need to incorporate results from beneficial inflow studies into the operating rules of water supply projects to minimize harmful environmental effects to estuaries, rivers, habitat, and wildlife while allowing the maximum beneficial use of State waters, including estuaries. The definition of *estuary* includes marine coastal habitats extending from the head of tide downstream to nearshore terminus structures, such as barrier islands, reefs, sand bars, mudflats, and headlands in proximity to the connection with the open sea.

Four alternatives at the Barney Davis Power Plant site and the Oxychem site have been evaluated, and all alternatives would affect sensitive environmental habitats found within estuaries. The alternatives evaluated include various options related to pre-treatment, intake, off-site piping, and the desalination process as discussed in *Chapter 5*. For example, the lowest cost alternative for the Oxychem site assumes the source of intake or raw water is Corpus Christi Bay. All of the alternatives analyzed for the Barney Davis Power Plant site discharge byproduct water to the Gulf of Mexico; however, cooling water at the power plant during operation is withdrawn from the Laguna Madre and the facility is permitted to discharge 500 million gallons per day to the plant cooling ponds. The plant cooling ponds discharge to Oso Creek and then to Oso Bay. If the byproduct water from the Barney Davis Power Plant site could be commingled with the cooling water discharge, there may be a significant project cost savings with discharge of byproduct water ultimately to Oso Bay.

Potential discharge of byproduct water to Oso Bay or intake from Corpus Christi Bay would trigger consideration by the TWDB, TPWD, and TCEQ of freshwater inflow needs of the Corpus Christi Bay system and the maintenance of salinity regimes conducive to habitat and wildlife productivity. Due to environmental complexities, the most feasible environmental strategy for raw water intake and byproduct water discharge would be through pipelines extending to the Gulf of Mexico. In general, discharges that significantly alter the natural salinity regime of coastal waters would likely not be permitted. The residence time of waste discharged into bays and estuaries is an important consideration with respect to contact with marine life. Flushing rates play an important role in byproduct production and chemical transport, residence time and dilution of discharge concentrations. The placement of byproduct discharges in areas with high flushing rates, short residence times, and substantial dilution is integral to the protection of surface water quality.

Table 8-1.4-1 Potential Environmental Impacts Related to Pipeline Installation

Feature	Positive Conditions	Negative Conditions	Barney Davis Site	Oxychem Site
Seagrass beds (subaquatic vegetation)	No seagrass beds present within proposed route	Extensive area of seagrass beds within proposed route	Approximately 2.3 miles of seagrass beds mapped through entire span of Laguna Madre	Approximately 1.4 miles of seagrass beds mapped through route
Piping Plover critical habitat	No critical habitat identified within proposed route	Extensive area of critical habitat identified within or immediately adjacent to proposed route	Approximately 1.5 miles of critical habitat for Piping Plover	Immediately adjacent to or within 0.1 miles of critical habitat
Presence of sea turtles and/or other threatened and endangered species	Not present within proposed route	Prolific within or immediately adjacent to proposed route	Sea turtles noted in general vicinity, subject for future study	Sea turtles noted in general vicinity, subject for future study
Discharge location of wastewater stream	Gulf of Mexico with diffuser	Within a coastal bay/estuary, thus compounding hypersaline conditions	Option 1 – Within Oso Bay Option 2 - Gulf of Mexico	Gulf of Mexico
Parks, refuges, wildlife management areas, and sanctuaries	Not present or immediately adjacent to proposed route	Within or immediately adjacent to proposed route	Within 0.6 miles of Padre Beli Park and 5.1 miles of Mustang Island State Park	Audubon Sanctuary on Pelican Island (1.5 miles from route) and St. Joseph Island (3.8 miles from route); Port Aransas Park is 0.4 miles from route
Rookeries	Not present or immediately adjacent to proposed route	Within or immediately adjacent to proposed route	Adjacent to 2-mile stretch of scattered islands designated as rookeries	Adjacent to 1.1 mile stretch of area designated as a rookery
Oyster reefs	Not present or immediately adjacent to proposed route	Within or immediately adjacent to proposed route	Currently unknown, subject for future study	Currently unknown, subject for future study

Table 8-1.4-1 *(continued)*

Feature	Positive Conditions	Negative Conditions	Barney Davis Site	Oxychem Site
Wetland-upland configuration	Upland communities present along entirety of landward route	Exclusively wetlands present along landward route	Wetland areas in vicinity; subject for future study and jurisdictional determination	Wetland areas in vicinity; subject for future study and jurisdictional determination
Construction practices	Seasonally adjusted to accommodate wildlife and implementation of best management practices (BMPs) to protect water quality and minimize disturbance to sensitive areas	Not seasonally adjusted and no BMPs implemented	Would be adjusted to comply with Piping Plover critical habitat requirements; subject for future study	Would be adjusted to comply with Piping Plover critical habitat requirements; subject for future study
Total length of route	As short as possible, thus minimizing acres impacted and converted in land use	"Wandering" route adding unnecessary acres of impacted terrain	Approximately 8.3-mile proposed route with little "wandering" of the alignment	Approximately 19-mile proposed route with some "wandering" of the alignment on the intake Option 1 and toward the Gulf of Mexico

2 SUMMARY OF ENVIRONMENTAL REQUIREMENTS

Permitting of the proposed desalination facility, including an ocean outfall and construction of pipelines crossing Laguna Madre and Padre Island, would require extensive coordination with applicable regulatory and resource agencies and other stakeholders. The installation and operation of a seawater desalination water treatment plant would need to address, at minimum, the following issues:

- Disposal of byproduct from the desalination plant
- Permitting and constructing the intake and discharge pipelines through seagrass beds and barrier islands and other sensitive, private or publicly held land
- Impacts to sensitive estuary, bay, and ocean habitats, and bird and aquatic species
- Permitting of the intake or discharge pipelines across streams, bird rookeries, wind-tidal flats, lagoons, wetlands, highways, agricultural land, and private rural and urban property
- Disposal of chemicals used for pre-treatment and for defouling plant equipment; disposal of solid waste such as spent pre-treatment filters and removed solid particles
- Disposal of waste associated with back-flushing of anti-fouling compounds
- Impacts to and reduction measures associated with the impingement and entrainment of aquatic organisms such as phytoplankton, zooplankton, fish, crustaceans, shellfish, and seagrass
- Cultural resources surveys, protection, and mitigation prior to construction
- Power requirements for the desalination process
- Funding sources and the procurement process

2.1 National Environmental Policy Act (NEPA) Compliance

Since public funds will be used to construct the proposed desalination plant, the agency with primary funding responsibility must ensure that compliance with NEPA and other environmental statutes and overall coordination of the environmental review and public involvement is achieved before a Record of Decision is signed based on the findings of an Environmental Impact Statement (EIS). Before the facility can begin construction, the project sponsor must demonstrate to the satisfaction of the TCEQ and local permitting authorities that the facility and its operation will not significantly impact the environment or that appropriate mitigation is identified and implemented. Council on Environmental Quality (CEQ) guidelines for preparing EISs require that cumulative impacts be addressed by the impact assessment in addition to direct and indirect effects. Cumulative impacts are those incremental impacts that result from the action when added to other past, present, and reasonably foreseeable future actions. Key components of the EIS needed for project funding approvals will be the assessment of cumulative environmental impacts associated with the proposed project and an evaluation of alternatives.

2.2 Environmental Permits

There are few major brackish and no seawater desalination plants constructed in Texas, and the regulatory requirements for permitting such facilities are not well defined. Regulatory and resource agency involvement and coordination will, therefore, be more extensive and time consuming. The identification of permitting and environmental implementation issues summarized below was based on review of the Tampa Bay Desalination project and interviews with staff, requirements for oil and gas pipeline installation along the coast, the TWDB Region N Water Plan, consultation with experts, and review of the Southmost Regional Water Authority's desalination discharge permit.

This assessment of potential environmental permits assumes that all water rights permits have been obtained. Potentially applicable environmental permitting and agency coordination requirements are summarized in *Table 8-2.2-1* below.

According to Tampa Bay Water, the permitting process for the desalination plant was lengthy and extensive (18 months in duration). Permit applications were accompanied by scientific research and public comment. Ultimately more than 20 environmental and construction permits were required from local, State, and Federal agencies. To ensure protection of Tampa Bay, a pilot plant at a scale of 1/1000th the size of the Tampa Bay Seawater Desalination Plant was constructed to test plant operations and identify any adverse environmental impacts on Tampa Bay. Separate, independent studies were conducted by the following organizations using the pilot plant:

- Mote Marine Laboratory
- Danish Hydraulic Institute
- University of South Florida (USF)
- Savannah Laboratory/STL Precision
- Marinco Laboratory of Sarasota
- Hillsborough County

Each study was developed to examine the possibility of a specific, potentially negative environmental impact on Tampa Bay and was performed as approved by the Florida Department of Environmental Protection and conducted in accordance with approved methodologies identified through the stakeholder consultation process. Researchers studied the nearfield (close to the desalination plant) and farfield (areas away from the plant such as at Hillsborough Bay). Mote Marine Laboratory and the Danish Hydraulic Institute performed salinity studies. Marinco Laboratory tested toxicity levels of saline-sensitive animals such as mysid shrimp and Gulf silverside fish using concentrated seawater. Savannah Laboratory/STL Precision of Miramar, Florida, conducted tests to determine if chemicals were present in Tampa Bay that could harm water quality or marine life at the concentrated levels produced from the desalination process. The University of South Florida studied the bay's circulation to determine if desalination-related changes in salinity could change the currents in Tampa Bay. Hillsborough County performed an independent study of the potential environmental impacts of the proposed desalination plant.

Table 8-2.2-1 Permitting and Agency Coordination Requirements

Responsible Entity		Permit/Coordination
Federal	U.S. Environmental Protection Agency	Section 402 NPDES Industrial Wastewater Permit NPDES Stormwater Discharge during Construction Ocean Discharge Criteria Regulations (40 CFR Part 125) Oversight authority for Section 404 Dredge and Fill Permit
	U.S. Army Corps of Engineers	Clean Water Act (CWA) Section 404 Dredge and Fill Permit CWA Section 401 Water Quality Certification (with TCEQ) CWA Section 10 River and Harbors Permit Coordination concerning pipeline crossing the Intracoastal Waterway Wetland mitigation plan review and approval as part of conditions of the Section 404 permit
	U.S. Coast Guard	Navigation and Obstructions Permit Safety issues associated with ocean outfall
	U.S. Fish and Wildlife Service	Endangered Species Act Section 7 Consultation (Section 10 Permit) Fish and Wildlife Coordination Act including Essential Fish Habitat coordination
	National Marine Fisheries Service	Review impacts to threatened and endangered species
	Minerals Management Service	Ocean pipeline permits Coordination concerning pipeline routing in deep water
	Federal Emergency Management Agency	Public water supply protection planning; Floodplain
	Federal Energy Regulatory Commission	Coordination concerning pipeline routing through areas with FERC-permitted facilities
State	Texas Commission on Environmental Quality	Section 401 Water Quality Certification TPDES Industrial Wastewater Permit Public Drinking Water Facility Construction Permit TPDES Stormwater Permit Texas Air Quality Permit Safe Drinking Water Assessment under SDWA Coordination on Section 404 permit Stream Alteration Permit
	Texas Department of Transportation	Easements and permits for installation of pipeline within roadway right-of-ways
	Texas General Land Office	Sand and gravel removal permit Licensed State land survey platting Beach access permit Dune protection permit Coastal easements or lease agreements for pipeline construction (dredging) on State lands Texas Coastal Management Program coordination
	Texas Department of Health	Drinking water supply permit On-site sewage disposal system construction permit Fish and shellfish consumption advisory coordination
	Texas Historical Commission	Texas antiquities permit National Historic Preservation Act (NHPA) compliance for protection of historic resources

Table 8-2.2-1 *(continued)*

Responsible Entity		Permit/Coordination
	Texas Parks & Wildlife Department	Threatened and endangered species coordination Sand, shell and marl mining permit Aquatic plant collection permit
	Texas Water Development Board	Consistency with Regional Water Planning determination
Regional	Coastal Coordination Council	Consistency determination with CZMA
	Lower Nueces River Authority	Coordination
	Region N Water Planning Authority	Consistency with regional water plans; endorsement
Local	Environmental Resource or Environmental Management Departments	Nueces County environmental permits and coordination
	City/County Building Departments	Beachfront or coastal construction permit
	City/County Engineering Departments	Review of plans and approvals Floodplain administrator approvals
	City/County Planning or Zoning Departments	Review of plans and approvals
	Port of Corpus Christi	Permit and coordination concerning pipeline
Other Entities	Railroads	Easements or ROW permits for pipeline routes
	Texas Inland Water Navigation District	Permits and coordination
	Oil and gas pipeline companies	Coordination concerning pipeline routing
	Nueces Estuary Advisory Council	Coordination concerning freshwater inflows
	Various environmental groups such as the Audubon Society and Sierra Club	Coordination and stakeholder involvement

The main technical effort necessary to support the NPDES permit is the effect on quality of the receiving water, which will require model calculations and related studies similar to those described for the Tampa Bay Seawater Desalination Plant. Further, discharges into territorial seas, contiguous zones, and the ocean must undergo an additional level of review to ensure that they do not cause unreasonable degradation of the marine environment. The review is based on the EPA's ocean discharge criteria regulations codified as Subpart M of 40 CFR Part 125. Before issuing an NPDES permit for discharges to the Gulf of Mexico, the EPA must consider various factors including the following when granting NPDES permits:

- Quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged
- Potential transport of such pollutants by the biological, physical, or chemical processes
- Composition and vulnerability of the biological communities that may be exposed to such pollutants
- Importance of the receiving water area to the surrounding biological community (including the presence of spawning sites, nursery areas, seagrass beds, and migratory pathways)

- Existence of special aquatic sites such as marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, protected habitat

- Potential impacts on human health through direct and indirect pathways, existing or potential recreational or commercial fishing, and numeric water quality criteria for specific pollutants

The proposed desalination project sites are located in coastal areas subject to flooding or in areas that are exposed to direct wave action. Planning for the proposed desalination facilities will need to incorporate flood management strategies into the design, operation, and construction. The Federal Emergency Management Agency (FEMA) performs studies to estimate the frequency and likelihood of flooding in an area. FEMA publishes maps and reports to document these studies; these maps are called the Flood Insurance Rate Maps (FIRM). Generally, the County Engineer is designated the Floodplain Administrator for those communities that participate in the National Flood Insurance Program (NFIP).

3 STAKEHOLDER INVOLVEMENT

SB 1, a comprehensive water planning and management bill, began the programmatic statewide water planning process. The TWDB is the lead agency with responsibility for implementation of this process. The TPWD and TCEQ provide support and assistance to the TWDB, and representatives of these agencies serve as non-voting members of the regional water planning groups statewide. The objective of SB 1 is to develop a State Water Plan that

> "…provides for the orderly development, management, and conservation of water resources and preparation for, and response to drought conditions, in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the State."

At this time, it is not clear how the stipulation that all new surface water use permits and all amendments to existing use permits consider containing provisions to reserve water for public purposes would affect the proposed desalination project. However, regional water planning efforts are tasked with incorporating environmental impact issues and protection of Texas natural resources with water planning. In addition, regional water planning guidelines include "quantitative reporting of environmental factors, including the effects on environmental water needs, wildlife habitat, cultural resources, and the effect of upstream development on bays and estuaries" during water management strategy development.

In addition to the regional water planning efforts, opportunities for stakeholder agency and community involvement occur under the Safe Drinking Water Act (SDWA) Source Water Assessment Program as well as in conjunction with the facility discharge permit (ocean disposal) and the development of the NEPA document. It is recommended that a collective outreach and consensus-building effort among appropriate stakeholders occur in order to effectively manage and streamline the agency consultation process related to the development of:

- Environmental Impact Statement
- NPDES permit for discharge to the Gulf of Mexico or Oso Bay
- Section 404 dredge and fill permit
- Regional water planning efforts
- SDWA Source Water Assessment Program
- Associated environmental permits

Agency stakeholders would include Federal, State, and local agencies with jurisdiction or planning responsibility for the Corpus Christi area and key private organizations dedicated to environmental resource issues. Stakeholder agencies and organizations could ultimately be responsible for review and comment on draft reports, assistance with identification of appropriate modeling, studies, analyses, and assessment methodologies for the environmental impact assessment process. Planned outreach and establishment of a stakeholder consultation group are recommended to facilitate the permitting process and gain (maintain) project support.

The Section 404 permitting process would be initiated with a General Evaluation Meeting (GEM). A GEM is a private meeting between the lead permitting agencies, cooperating and commenting agencies, and the permit sponsor. This agency consultation meeting would initiate the permitting process and serve as a vehicle for proactive, upfront agency involvement that would facilitiate agency decision-making and project concurrence.

4 DESIGN STUDY RECOMMENDATIONS

In addition to studies that would be identified during the stakeholder consultation process associated with permit requirements, freshwater inflow analyses, and development of the EIS, the following studies or investigations are recommended: (1) modeling of currents, salinities, and transport mechanisms during design of the byproduct discharge structure and (2) investigations of installation methods to minimize negative environmental impacts, including those to seagrass beds, during pipeline design.

All discharge of the byproduct stream to the Gulf of Mexico would be designed to avoid and minimize environmental impacts. Modeling will be needed to accomplish this goal and to provide sufficient information and convincing arguments to regulatory and resource agencies and other stakeholders. The byproduct discharge may need a diffuser to enhance turbulent dilution of the discharge plume. The plume configuration and the utility of a diffuser for such a low-flow discharge can be addressed by an appropriate model. The need for a diffuser to enhance turbulent dilation is a two-stage modeling problem:

1. Determine the initial dilution in the vicinity of the diffuser orifice.

2. Determine the overall distribution of the effluent as mixed and transported by ambient currents.

The first is sometimes referred to as the nearfield problem, the second as the farfield problem. To support offshore NPDES permitting, the EPA recommends a new model system for the initial dilution problem, called *Visual Plumes*. The UM3 model in *Visual Plumes* is the closest approach to an analysis of a multi-port diffuser into a water column with ambient stratification.

For the far field problem, EPA suggests a spreadsheet model called, appropriately, "FARFIELD." At the present level of conceptual design, these models would be adequate for determining the distribution of effluent from a discharge. For preliminary analyses, currents and stratification assumptions can be used. As the project moves through the permitting process, physical oceanographic data would need to be compiled to refine the problem analysis and to provide a demonstration of the model results to EPA.

The infrastructure for transporting the water, intake or discharge, between the desalination plant and the Gulf shoreline is very different for the two sites. The Barney Davis Power Plant site is close to Laguna Madre. Construction and installation of a small pipeline to the Gulf of Mexico should be fairly straightforward. In this region of the upper Laguna Madre there is substantial oil and gas activity and precedence for trenching pipelines across the bay. The Oxychem site poses a greater routing challenge, because the pipeline distance to the Gulf of Mexico shoreline is much greater, and there are many regions that should be avoided for either environmental or economic reasons. As described above, pipeline routing studies would be needed to identify routes that would minimize impacts to the sensitive natural environment of Laguna Madre, Padre Island, Redfish Bay, Mustang Island, and Aransas Pass. Seagrass beds and other sensitive natural habitats, such as oyster beds within the Gulf of Mexico, will need to be mapped and avoided to the extent possible to minimize impacts and resultant mitigation requirements.

5 COSTS OF ENVIRONMENTAL COMPLIANCE

The estimated cost for environmental compliance is based on a percentage of the capital construction costs of each of the proposed alternatives that are documented in the *Coastal Bend Regional Water Plan* dated January 2001. Environmental compliance costs, including permits, stakeholder consultation, modeling and studies, NEPA documentation, and mitigation, are assumed to be equivalent to 4.6 percent of the projected capital costs for each alternative until more detailed analyses can be performed based on stakeholder involvement and environmental compliance requirements. Of this total, NEPA documentation and related studies are assumed to be equivalent to 1 percent of the projected capital costs for each alternative. Of the remaining 3.6 percent available for environmental compliance, permits and mitigation represent 1.8 percent of the projected capital costs, studies and modeling efforts represent 1.44 percent of the projected capital costs, and stakeholder involvement represents 0.36 percent of the remaining projected capital cost. These percentage estimates are based on regional water planning studies and represent the best available information for the conceptual design alternatives proposed. For environmental compliance costs, see *Chapter 4*.

Chapter 9

Project Financing and Implementation

CHAPTER 9 – PROJECT FINANCING AND IMPLEMENTATION
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CHAPTER 9 – PROJECT FINANCING AND IMPLEMENTATION

1 INTRODUCTION

Traditionally in the United States, water and wastewater treatment projects have been constructed on the basis of a prescribed, single method for treatment. An engineer codifies the requirements for accomplishing the selected treatment method through a specific design. Then, the engineer produces drawings and specifications to comprehensively define the tanks, piping, and equipment—collectively the “process,” as well as the support and ancillary facilities. The deliverable is a set of detailed plans and specifications, together with a set of general and specific conditions or contract terms that make up a bid package. This bid package is then used to solicit bids from general contractors on the basis of a “lump-sum, low bid” award. While the design engineer provides an “engineer’s estimate” of the cost of the project, the contractors are generally viewed as providing a commodity service and are selected on the bid price.

Features of this traditional Design-Bid-Build (DBB) approach may result in some areas of concern:

1. Design engineers’ services are generally procured without regard to the cost of the facility.

2. Selection of the low-bid construction contractor heightens the risk of performance failure.

3. Risks associated with the failure of a facility to operate and perform in accordance with the owner’s needs rest primarily with the owner.

Recently, more innovative and alternative approaches, some involving public-private partnerships of various forms, have stirred significant interest in the water industry. These alternative approaches include:

- Design-Build (DB)
- Design-Build-Operate (DBO)
- Design-Build-Own-Operate (DBOO)
- Design-Build-Own-Operate-Transfer (DBOOT)

The most common form of alternative project delivery in the United States is Design-Build-Operate (DBO). The DBO form changes the roles of the traditional participants. For example, a water utility procures the services of key project participants differently using a DBO approach. Under the traditional Design-Bid-Build approach, services of the engineer and the contractor are procured by the owner under separate procurements. Under the DBO approach, a single Request for Qualifications (RFQ) is issued, followed by a Request for Proposals (RFP) to the prequalified bidders where a single proposer forms a DBO team to provide engineering, construction, and operating services for the project.

The DBO approach allows for wide latitude of innovation on the part of the proposers in meeting the needs of the owner while allowing for a common denominator comparison of the proposals. In responding to the RFP, proposers must focus on the overall performance of the project based on performance-based specifications and guidelines, as well as the detailed project requirements.

Planning, designing, engineering, construction, and long-term operation of the facility can be combined into one package—a single contract with a legally and financially responsible entity.

In the traditional DBB approach, each project component is viewed separately, resulting in multiple participants and different contractual arrangements. When there is a problem on the project, there is a triangle of responsibilities with finger pointing between the engineer-contractor, owner-contractor and owner-engineer. The DBO approach *may* offer benefits of a single point of responsibility, innovative technology and/or process, shortened overall project schedule, reduced owner financial and technology risk, and operational and construction cost savings.

Typically, two specific groups have initiated and promoted the DBO and other alternative procurement—design engineers and the international water services companies. Several design engineering firms have strategically positioned themselves in the market to foster, develop, and capture a share of the growing Design-Build (DB) market. The international water services companies have brought the Design-Build-Operate (DBO) and Build-Own-Operate-Transfer (BOOT) project delivery approaches to the North American and United States markets. Over the last two decades, privatization in the water/wastewater industry has driven the industry to refocus on competition, performance, and the benefits of financial engineering to project delivery.

1.1 Market Drivers

There are four principles or "market drivers" that shape the direction of the water market. The four major market drivers are:

- Aging facilities in need of major capital investment
- Implementation of more strict federal and state regulations
- Water industry globalization
- Water industry privatization

One or more of these drivers is the impetus for many in the water industry to examine new and more innovative approaches to project delivery. There is some pressure for water utilities to offer more value to the stakeholders.

1.2 Aging Facilities in Need of Major Capital Investments

Many water treatment systems, especially those in the more urban areas, are aging and require significant capital renewals and replacements. Water and wastewater utilities are significantly more capital intensive than any other utility. Building new or expanded facilities or replacing outdated or inadequate facilities will require investments by utilities and rate increases to repay the debt. Because the majority of the assets are in excess of 20 years old, the cost of construction for renewal and replacement of these assets and the new technologies have increased manyfold since the original construction.

In the past, many utilities received significant contributed assets, such as federal and state funding under the Clean Water Act-Construction Grants Program, and these utilities will be replacing those assets with their own funds. Consequently, water rates of today are based upon the recovery of only a part of the current replacement costs of the utilities' assets. This means that in the future, rates will have to be increased significantly just to keep pace with the current service and new capital requirements. The alternative procurement techniques have been developed at least in part in response to the desire to keep total project costs to a minimum.

1.3 Implementation of More Strict Regulation

There are a number of new regulatory requirements being mandated by Congress that have a direct effect on water and wastewater utilities. The Safe Drinking Water Act (SDWA), the Clean Water Act (CWA), and the Clean Air Act (CAA) are the source of major new regulatory initiatives. It is expected, that as the science and understanding of pollutants and their effects increase, new regulations will continue to emerge from the Congress and the United States Environmental Protection Agency (USEPA).

Under the Safe Drinking Water Act, the Disinfectant and Disinfection By-Product Rule (D/DBP) and the Enhanced Surface Water Treatment Rule (ESWTR) have set new and lower standards for Total trihalomethanes (TTHMs), haleoacetic acids (HAA5), and lower turbidity limits. Additional filtration and monitoring requirements are likely, and the necessity for active and real-time monitoring for meeting Cryptosporidium is also being considered. This is due to the fatal outbreaks of Cryptosporidiosis, such as in the City of Milwaukee water system in 1993, which focused national media attention on the need for improved treatment regulations.

The 1996 Amendments to the SDWA required USEPA to mandate that water utilities provide their customers with "Consumer Confidence" reports on an annual basis. These reports, which must include monitoring results, violations of standards, water source information, health implications of violations, and identification of susceptible populations will arm the general public and the utility customer with information which will drive utilities to make capital investments and/or operational changes.

The above examples of regulatory drivers suggest that the pace of capital investment and the need for utilities to seek alternative project delivery will increase in the coming years.

1.4 Water Industry Globalization

The investor-owned segment of the water industry is also undergoing significant change. Mergers and acquisitions, as well as divestitures, have been occurring with increasing frequency in the water industry. The French companies—Veolia (formerly Vivendi) and ONDEO—as well as the German company RWE have, over the last decade, have been strategic acquirers of water utility assets and water equipment manufacturers. More recently, large United States-based companies such as General Electric and ITT Industries have been acquiring water equipment manufacturing assets. GE has acquired Glegg and Osmonics, and ITT has acquired Sanitaire and WET. Ionics recently announced the acquisition of Ecolochem.

Recently, Veolia announced the sale of the equipment segment of US Filter, a company it had acquired 5 years earlier in a multibillion dollar transaction. ONDEO has also announced the sale of its equipment manufacturing segment. Actions of the two French water industry giants have indicated that they are more interested in the acquisition and holding of water utility assets rather than water equipment manufacturing assets. It appears that the process of strategic acquisition and divestiture will continue as the industry globalizes.

1.5 Water Industry Privatization

Privatization, especially in the delivery of recent large scale desalination plants, has been a significant factor in the reduction of the cost of delivering high quality potable water. The advantages to the owner of a privatized desalination plant are that the developer, not the owner, bears the technology and financial risk associated with the project. The developer brings private capital to the project and the financial engineering to underwrite the project. The owner signs a "take-or-pay" contract which obligates him to buy the water that is produced, but only when the developer produces that water at the predetermined quantity/quality requirements.

Beyond the desalination segment of the water and wastewater industry, there have been significant developments in the establishment of "public-private partnerships." These partnerships cover a wide range of activities from a utility contracting with a private entity for medium-term operations and maintenance (O&M) services at a specific plant to the long-term contracting of overall utility operations with provisions for capital improvements. This market is extremely competitive with some notable examples of recent failures. Most notably, in Atlanta, Georgia, United Water, a United States subsidiary of ONDEO, agreed with the City to a termination of their long-term, multibillion dollar contract. It turns out that United had underbid the contract and could not perform. On the other hand, US Filter recently won a 20-year contract with the City of Indianapolis, Indiana, and both parties appear to be pleased with this arrangement.

These large private firms provide some unique and new features that have not historically been available in the United States water industry. These features include:

- Multinational corporate level research and development
- Access to private capital
- Off-balance sheet financing
- Performance and financial guarantees
- Ability to "wrap" a project with technology, construction, operations, financing, etc.

These features may translate into such benefits as:

- Cost reduction
- Innovative technologies

- Guarantees
- Management expertise
- Private-Public capital partnerships

2 ALTERNATIVE PROJECT DELIVERY OPTIONS

Project delivery options to be reviewed and considered as relevant to the Corpus Christi Desalination Plant Project include the following:

- Traditional Design-Bid-Build (DBB)

  compared to:

- Design-Build (DB)
- Design-Build-Operate (DBO)
- Design-Build-Own-Operate (DBOO)
- Design-Build-Own-Own-Operate-Transfer) DBOOT

2.1 Traditional Design-Bid-Build (DBB)

The traditional approach begins when the owner, such as a state, city, regional utility, municipality or district, defines the need for a new project and makes a commitment to secure the funding, necessary regulatory approvals, and permits to advance the project. A project management group, such as a municipal engineering staff or outside consultant, solicits the services of an engineer/architect to develop the design. In Texas the engineer is selected based upon qualifications and experience under the Professional Services Procurement Act.

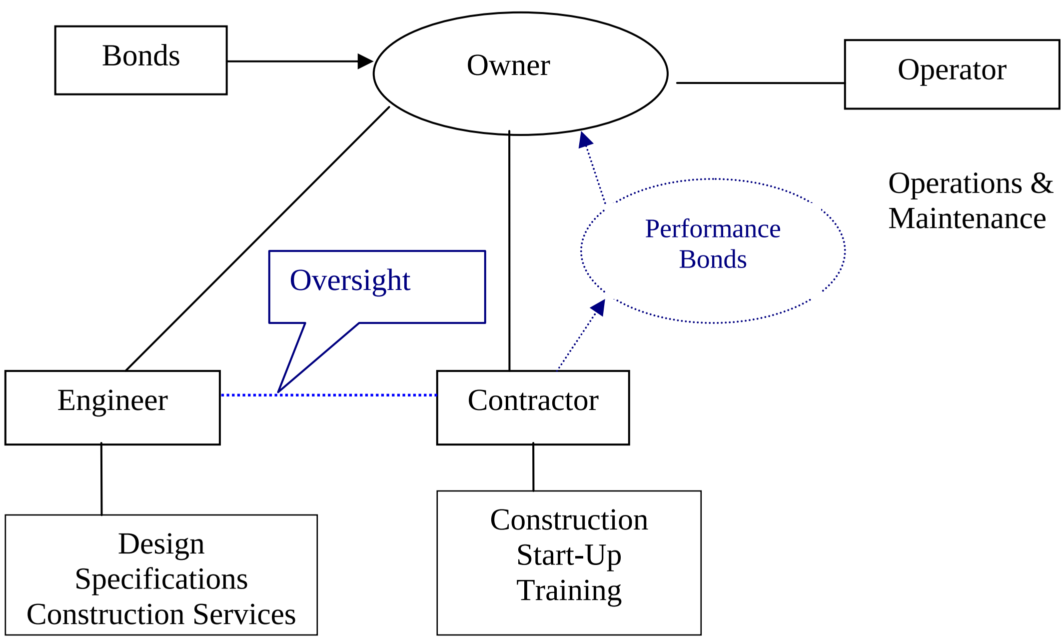
The engineer prepares and provides the owner a complete design, including the supporting technical bid specifications. An attorney for the owner may prepare the contract documents, or the engineer may use a standard form contract documents. The design, technical specifications, and contract documents, including general and specific conditions, are issued with a request for bids for the construction of the project. Bids are received and reviewed by the engineer, and the owner awards the construction contract to the "lowest, responsive bidder." Permits for the construction are secured from relevant agencies based upon the complete design. The engineer generally provides services during construction to the owner, which could include review of shop drawings, field services, review of testing, certification of payment etc. See *Figure 9-2.1-1*.

The contractor provides bonds to the owner in support of the completion and/or performance of the project. In addition, the owner may hold "retainage" during the course of the project to maintain leverage over the contractor during the construction and until the project reaches "substantial completion."

Ownership and funding for the project are public under the DBB structure. The owner secures funding for the project from revenue, general obligation, or other forms of public debt. Upon completion of the project, the asset becomes a public asset, and the responsibility for operations and maintenance of the asset rests with the owner.

The basis for fulfilling the construction contractor's obligations is that the construction has been completed in accordance with the design engineer's specifications. Typically, any guarantees or warrantees provided by the contractor are limited to whether the facilities constructed and equipment installed meet industry standards. Generally, neither the design engineer nor the contractor is explicitly obligated to demonstrate the completed facility will operate and perform to its intended purpose. The contracts are based primarily on delivery of an asset meeting the design specifications. As a result, the owner maintains most of the project risk.

Figure 9-2.1-1 Traditional Design-Bid-Build Structure



In addition, the process is linear and in distinct phases: planning, design, permitting, construction, start-up, and operations. Deficiencies at any stage of the process may not be understood until the project is complete, and corrections are very expensive. Changed or unforeseen conditions lead to change orders between the owner and the contractor.

The benefits of the DBB process stem from the fact that this is the traditional method, and the structure and relative role and relationship of the parties is well understood. As this is the historical benchmark for public water and wastewater projects, the regulatory, legal, financial, insurance, and political requirements are well understood by all stakeholders. The model provides for a maximum of public input as generally there is public debate at each stage of the development and implementation of the project. There is a high degree of transparency and public acceptance in a "lump-sum award to the lowest, responsive bidder."

The role of the engineer in providing services during construction serves as a check-and-balance in the process by keeping the designer-of-record involved as a witness and by providing assurances to the owner and the public, that the project was constructed in conformance with the plans and specifications.

The drawbacks of the DBB approach, when compared to the alternative delivery methods, are related to project schedule, allocation of risk, design and technology innovation, project performance, and constructability and operability. While the linear, sequential approach provides maximum potential for public involvement, it necessarily leads to a longer project delivery schedule from conceptualization to operations.

One explicit goal of the DBB process is to achieve the lowest construction bid price. Public perception is that transferring risk to an engineer or a contractor will increase cost; therefore, the majority of the project risk is retained by the owner. When the process works well, the owner, engineer, and contractor communicate well and are committed to resolving issues, disputes, and problems early and fairly. However, when, for whatever reason, the process does not work as intended, the potential for finger-pointing, delays, change orders, claims, arbitration and/or litigation increases dramatically. As demonstrated in *Figure 9-2.1-1*, the owner is responsible for accurately and completely defining the project, communicating those requirements to all the parties, and then directing, coordinating, and executing project delivery to meet all parties' needs. In this role, with multiple contracts with parties with disparate needs, the task is inherently challenging and prone to disputes.

As the design engineer is contracted on a fee-for-service basis, there is limited incentive for the engineer to risk undertaking innovative technologies. There is no incentive or reward for the engineer to move away from the plans and specifications that have been proven successful even though new methods or technologies are available.

The development of a life cycle cost analysis for a project involves the balancing of the capital costs against the operating costs over the life of the project. In the water sector, projects are generally more sensitive to operating costs over capital costs. This means a dollar saved on operating cost has more value than a dollar saved in capital costs. Seeking the lowest construction cost may disregard features, which will have a significant impact on reducing operating costs over the service life of the project.

2.2 Design-Build (DB)

In the Design-Build (DB) approach to project delivery, a DB contractor is retained by the owner. There are two prevalent approaches to the selection by the owner of the DB contactor. In the first approach, the owner uses qualifications and experience as the selection criteria. In the second approach, the owner uses a combination of qualifications, experience, and price to select the DB contractor.

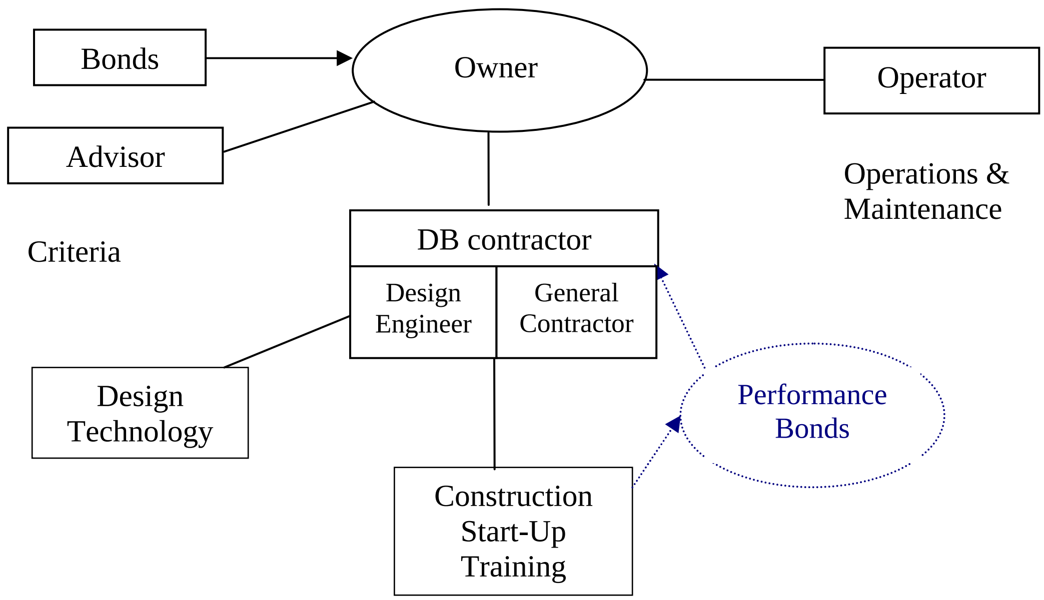
In the first approach, a DB contractor generally includes a construction firm and an engineering firm with one or the other as the prime contractor and the other as a subcontractor. Alternatively, the business relationship may be a joint venture of the engineer and the contractor. In this case, the engineer develops the project design criteria for the owner, and the criteria are used to contractually define the project that the owner desires. (There is a variation of alternative project delivery known as construction management at risk which is similar to this model, but is not being evaluated in this feasibility study.) Once contractually defined, the owner's project criteria form the basis of payment for the project, either under a lump sum arrangement or a maximum guaranteed price for construction of the facility.

The second approach involves the owner developing its own project criteria, containing either performance specifications or a partial design, perhaps up to a 30 percent complete stage with limited specifications. Typically, the owner will use a procurement advisor or an owner's representative to advise and assist in the preparation of the documents (RFQs, RFPs etc.) as well as to develop the owner's project criteria. The DB contractor is then selected based on an established set of qualification criteria and a fixed price. The owner typically evaluates the technical merits as well as the financial proposal submitted by the DB contractors. *Figure 9-2.2-1* sets the structure of a typical DB approach.

During the design development phase of the project, there can be varying levels of interaction between the design engineer and the construction contractor. In some cases, the design engineer may complete the design with limited input from the contractor. This tends to occur in DB projects without lump sum, fixed price, or guaranteed maximum price provisions. In other instances, the design engineer and the contractor work in an integrated and iterative manner to develop a project that maximizes constructability, expedites schedule, and minimizes cost. This tends to occur in projects with a fixed price and an allocation of schedule risk to the DB contractor. Owners are likely to gain the maximum from the DB approach with the interactive model and should consider this as a factor in the selection criteria for the DB contractor.

Under the DB approach, the owner necessarily surrenders some control over the details of the design and the schedule. The owner needs to consider the logical points in the public review and approvals under the DB approach. A principal advantage of the DB approach over the conventional DBB approach is that the development of the design can lead to innovation, new technologies, and cost savings, as both the owner and the design engineer have incentives to seek cost-effective solutions for the project.

Figure 9-2.2-1 Design-Build Approach Structure



The single point of responsibility and accountability reduces the potential for disputes between the design engineer and the construction contractor. Even without significant changes to the project's installed material and equipment, the concurrent implementation of the design and permitting activities with the pre-construction work, site preparation, temporary utilities, access road construction, etc., can shorten the overall project schedule. A shortened project schedule can lead to a lower project cost.

In a DB approach, the contracted price to design and build the project is established at an earlier point in the project than with the traditional DBB approach. In the DBB approach, the design is completed and the project permitted before the construction bid is generally available.

As the DB approach is a relatively new method of project delivery, the legal framework for its use and implementation is not as well codified or understood when compared to the more traditional and long-standing DBB approach. Consequently, on a state-by-state basis, the legal basis for the use of the DB approach is frequently unclear, limited, or even precluded. In some areas, the selection of design engineers and/or construction contractors is perceived as controversial. There may be issues with respect to insurance and bonding as all aspects of the risk allocation aspects of the DB delivery method have not been tested in the full spectrum of the legal system so precedent and case law may be lacking. In Texas, procurement laws governing public entities do not allow the selection of the contractor and engineering services under the same system for water and wastewater system improvements. Engineers must be selected based on qualifications with the fees negotiated only after selection. Construction contractors must be selected based on the lowest responsive bid. The procurement laws preclude the simultaneous selection of engineers and construction contractors.

Permitting a DB project requires some planning and forethought as the design stage is not necessarily completed prior to the commencement of construction, as in the DBB approach. Some states or other jurisdictions may require a completed and stamped design prior to the review and issuance of appropriate permits. To avoid delays and potential delay claims, the permitting process and division of responsibility between the owner and the DB contractor for the permitting process should be clearly addressed at the outset of the project.

In spite of the areas of concern for the DB approach, there is no question that there is a distinctive trend, especially in certain regions of the United States, toward DB as a method of delivery. As owners, engineers, contractors, attorneys, and the insurance/bonding companies gain more experience with the DB approach, it will gain wider acceptance as a reasonable and more advantageous alternative to the DBB approach.

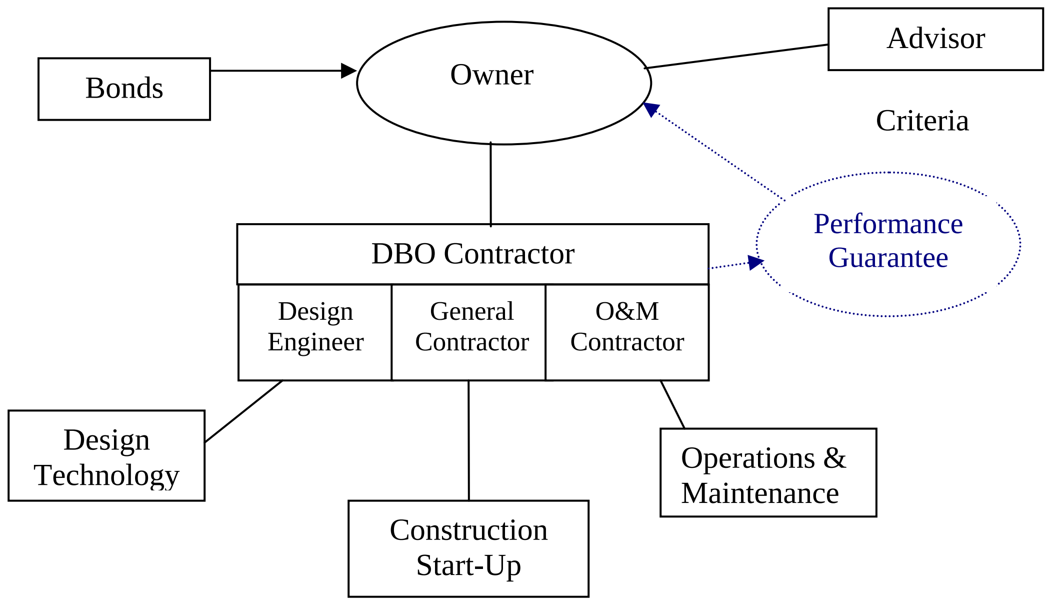
2.3 Design-Build-Operate (DBO) Approach

The Design-Build-Operate (DBO) approach is fundamentally similar to the DB approach with the important distinction that the responsibility for the operations phase of the project is added. The operations phase can be relatively short, two to three years, or it can be long term, 15 or 20 years—essentially the life of the project. While the fundamentals are the same, the addition of the operations phase adds another dimension of complexity to the project definition, the preparation of the RFP packages, and the consideration and evaluation of the O&M Contractor as a third player who is now a part of the team. Often this added complexity will require that the owner add additional capabilities and resources to the owner's project team. The owner's project team will establish the project criteria, which may be performance-based, or may have some prescriptive design requirements in addition to the performance requirements.

Like the DB structure, the DBO structure requires a single-point of responsibility between the owner and the DBO contractor. The DBO contractor entity will have the contractual responsibility for the development, design, construction, start-up, and operations of the project. The DBO contractor's responsibility is to deliver an asset with a given design/construction and operational performance. Generally, one of the participants in the DBO team is the project guarantor. Its role is to provide a financial guarantee that the project will meet the design, construction, and operations performance criteria. The performance guarantee is a financial contract between the project guarantor and the owner. The project structure for the DBO method of project delivery is shown in *Figure 9-2.3-1*.

DBO contractors are generally selected based upon a combination of the design engineer's, construction contractor's, operator's and project guarantor's qualifications; their technical proposal; and proposed capital and operating price. Each proposal will include the DBO contractor's design approach, construction approach, operations approach, the fixed capital price, and the operating

Figure 9-2.3-1 Design-Build-Operate Approach Structure



price. The owner will typically impanel an evaluation committee to evaluate the economic, financial, technical, and legal aspects of the DBO proposals.

The owner may use an owner's agent or owner's representative to provide arm's length oversight and assure the owner that the construction follows the performance criteria developed and issued by the owner. The design engineer is the engineer of record for the project, and the DBO contractor must meet stringent performance testing requirements to demonstrate that the plant meets all of the performance requirements and will operate to the standards set in the service agreement.

Typically, the RFP characterizes the owner's desired risk position. The objective is to allocate project risk to the party best able to manage that risk. Commercial and performance risks tend to be shifted to the DBO contractor through future capital risk. Risks for future regulatory change, uncontrollable circumstances, and change in law tend to remain with the owner.

The DBO method suffers from some of the same legal impediments in certain jurisdictions as the DB method, since the enabling statutes and case law have generally been developed around the traditional DBB method. While the DBO method blends the operator into the DB method, it also adds the financial guarantee component. Generally, the financial guarantee is provided by one of the project partners, or in some cases, by a parent company of one of the partners.

It is very important to the success of the DBO method that the owner develop well-defined project criteria. These should be included in the RFP and should set forth the desired level of quality, cost, and schedule for the project. The criteria define all the requirements that the DBO contractor has to fulfill in terms of design, permitting, construction, and operation of the facilities. The DBO contractor will have substantial control over the details and even methods to achieve the owner's criteria.

The DBO contract should protect the owner from delays in any stage of the project.

The advantages of the DBO delivery method include all the advantages of the DB method set forth in the previous section including:

- Single point of contractual accountability for design, construction, and operations
- Cooperative teaming effort of the design engineer and the construction contractor, which can reduce capital costs and shorten the schedule
- Collaborative design and construction effort, competitively procured, which can foster innovation and new technologies
- Concurrent design, permitting, and construction activities which can shorten the project schedule
- Certainty of the project cost that is determined at an earlier stage in the project

The addition of the operator to a project delivery team has the potential to create a new dynamic in the design process. For example, if the project selection criterion for the DBO contractor includes 20-year life cycle project costs, then the facility's annual operating expense can be a more significant factor in DBO contractor selection than the consideration of only the installed project capital cost. With a significant competitive incentive to minimize project operating expenses, contract operators have the opportunity to discuss the engineer's designs with the engineer and the contractor to optimize the facility's operability. This may involve incorporating technologies that have a higher installed capital cost, but will result in significantly lower operating costs. Therefore, the overall life cycle project costs are reduced as compared to traditional approaches.

Some DBO contracts include shifting the long-term capital operating risk to the DBO contractors. The long-term capital operating risk is associated with the future cost to maintain a facility. Other terms used by utilities to describe these expenses include extraordinary maintenance, nonroutine maintenance, and major capital maintenance.

When the operator is obligated to provide cost guarantees for this long-term operating capital risk, he/she has an incentive to assure optimal equipment quality to minimize maintenance expense for the term of the contract and renewals. This may have significant cost benefit for the public.

An additional benefit is that the rates for the utility can be reduced to a formula for the term of the contract because of the fixed cost-basis for operations. Many communities have found it beneficial for economic growth and development to be able to predict their utility rates long term with the added certainty of a guaranteed contract.

Owners must recognize that the success of the DBO method is predicated upon the owner giving up control over the details that are usually subject to owner control in the conventional DBB method. By allowing the DBO contractor to make the decisions on the details of the project, the owner gains benefits in fixing the construction and the long-term operations costs. Appropriate due diligence in selecting competent and proven performers on the DBO contractor team is crucial to the overall success of the project.

The owner may have very limited experience with long-term DBO contracting and thus have difficulty adequately defining the contractual relationship with the DBO vendor-team. A contract that includes, at a minimum, the provisions for project development, design, permitting, start-up, acceptance testing, operations, regulatory compliance, monitoring and reporting, and future plant modifications is undoubtedly complex. A multi-phase project contract can be difficult to prepare, understand, and administer. This is the reason that the owner agent, procurement advisor, owner representatives, and specialized outside legal counsel are typically used on DBO projects.

The requirements for significant financial strength of the project guarantor and the high cost of developing a DBO proposal are frequently cited as deterrents to smaller, less sophisticated contractors participating in the DBO process. These two features tend to necessitate that at least one of the project participants is a major corporation with significant financial assets. This is often interpreted as meaning that DBO project delivery approach limits competition to major companies in the water and wastewater field. However, the procurement process can be structured to require a portion of the work to be performed by local, minority, or disadvantaged contractors.

A significant DBO contract issue is the owner's administrative oversight during the operations period and the applicable standards of care for maintenance during the operating period of the contract. In a long-term, fixed price contract for the O&M of a facility, the owner must be able to hold the DBO contractor to enforceable standards for equipment maintenance. Otherwise, DBO contractors have an incentive to increase their profits by shortchanging equipment maintenance. DBO contracts should have clearly defined and measurable standards for acceptable equipment maintenance, periodic inspections, and an owner's remedy for inadequate maintenance by the DBO contractor's operations.

2.4 Build-Own-Operate-Transfer (BOOT)

While Build-Own-Operate-Transfer (BOOT) projects have generally had little general application in the water and wastewater industry in the United States, it was the project delivery model used in the Tampa Bay Desalination Plant Project. BOOT projects can be characterized as an "absolute" performance-based contract in that they are structured around a "take-or-pay" contract, buying a commodity at a fixed price.

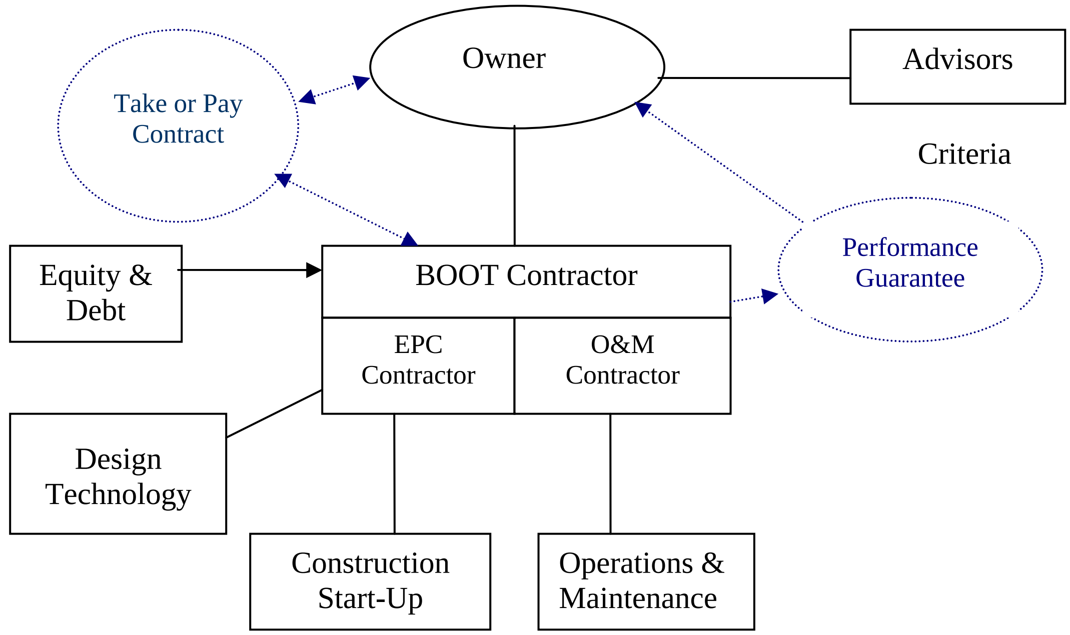
The characteristics of a BOOT project include the vendor providing the design, permitting, financing, construction, commissioning, and long-term operation of the constructed utility asset. Consequently, the vendor uses commercial private financing and owns the asset. The security for the BOOT contractor to secure financing is a purchase contract for the asset from the owner. BOOT contractors are generally prequalified, but the final contractor selection is based fundamentally on providing a commodity at a given price or tariff. An example of a tariff for a water contract would be a contract based on providing a minimum quantity of quality water for a fixed dollar value for a specified period of time. This type of project delivery is common throughout many developing nations of the world where cost of service is critical and design and operational expertise of the owners in these areas can be very limited.

Solicitations for BOOT contractors are similar to a DBO contractor. The RFPs for BOOTS are typically performance-based. The vendor teams are typically prequalified based on qualifications and experience, including the team's ability to secure financing for facility design and construction. The vendors prepare and submit extensive proposals that generally include a concept design, operating plan, and a guaranteed tariff in a form specified by the owner to either deliver water or treat wastewater. A "take-or-pay" form of contract between the owner and the private vendor generally secures financing. The private vendor owns the facility until such time as debt is repaid to the investors. Then, the asset is transferred to the owner at the end of the contract term, for either its market value, or some preset, minimal value prescribed in the contract.

The owner's role and responsibility in a BOOT project may be simpler than in a DBO, because the private investors have an interest in assuring that the project begins commercial operations and generates revenue to repay the debt. Owners will typically use an independent engineer to see that the BOOT vendor develops, designs, and constructs the project consistent with the requirements of the service agreement. The designer in the BOOT contractor's consortium is the designer of record for the project. Upon completion of construction, an acceptance test is performed to demonstrate that the facility can operate within the service agreement performance criteria. Once the facility has met the acceptance test conditions, the facility commences commercial operations and is operated by the BOOT vendor's operator.

The terms of service and the tariff paid for the operation of the facility are competitively established and guaranteed in the BOOT service agreement. The BOOT vendor is allocated nearly all project risks, except the commercial risk related to the owner's ability to pay the tariff, change in law, or Force Majeure. The project structure for a BOOT contract is shown in *Figure 9-2.4-1*.

Figure 9-2.4-1 Build-Own-Operate-Transfer Approach Structure



A BOOT project is structurally similar to a DBO project. The major differences is that the BOOT vendor will finance the project based on the strength of a "Take-or-Pay"-type water purchase or wastewater treatment agreement. The key contract issues for a BOOT project are then similar to those for a DBO project. The project criteria that define the owner's objectives and desired outcomes for the project must accurately reflect the owner's needs. The complexity of the termination conditions in a BOOT project also requires careful consideration. A subordinate agreement with an EPC contractor is usually developed and is consistent with the service agreement. A key area for disputes can be the inadequate characterization of the quality or quantity of raw water in the case of a water treatment plant, or effluent wastewater in the case of a wastewater treatment plant.

The key benefits of a BOOT project delivery are that the commercial and technology risks of a project can be fully allocated to the BOOT vendor. From the perspective of the owner, the BOOT project is "off-balance sheet financing." Thus, the project is neither an encumbrance upon, nor directly dependent upon the credit limits of the owner. This factor can be significant when the owner needs to preserve public credit or has debt limitations.

One area where BOOT projects have been recently used in the United States is with seawater desalination plants—specifically the Tampa Bay Desalination Plant project. The design and project implementation risks associated with a developing technology is daunting to most public owners. In the BOOT approach, with the owner primarily responsible only to buy water exceeding stated quality standards for a fixed unit cost, the owner can be significantly insulated from the project's technology risk.

In the case of Tampa Bay, the wholesale water utility was forced by state regulators to find alternatives to groundwater pumping as its primary source. After a review of technologies, seawater desalination was selected, and an RFP for a BOOT contractor was commenced. After three rounds of RFPs, Poseidon Resources (developer), with Stone & Webster (EPC), was selected for the 30-year, 25-mgd project. Subsequently, Stone & Webster filed for bankruptcy, and they were replaced as EPC with Ogden Water, a subsidiary of Ogden Energy, later to change its name to Covanta. After the project was under construction and for reasons having to do with project financing, Tampa Bay Water elected to buy-out Poseidon and execute the "T" or transfer provisions of the contract. Unfortunately, Covanta was not able to satisfy the requirements of the performance testing due to problems with its proprietary pre-treatment system, and Tampa Bay Water has recently settled a lawsuit to default Covanta and take control over the plant and its start-up and completion. Tampa Bay is seeking the services of an interim operator to correct the operational problems and operate the plant.

The negative lesson learned from the Tampa Bay desalination experience is that once committed to the BOOT process, the owner should not change methods in midstream or let the BOOT contractor off the hook, as the owner then takes back much of the technology and financial risk that was initially allocated to the BOOT contractor and its EPC and O&M contractors.

The positive lesson learned from the Tampa Bay desalination experience is that the BOOT process did foster a significant number of innovations in the siting and design of a seawater desalination plant. While a number of the innovations proposed for the Tampa Bay facility may be in question until the design/operational problems are resolved, there is no question that the BOOT process did generate innovations.

The areas of concern applicable to DBO generally apply to BOOT. These include the following:

- Reduced owner control over project details
- Use of a complex multi-phase contract
- Cost of proposal preparation may limit competition
- O&M oversight standards which are required to protect and maximize asset life

In addition, there may be some incrementally higher cost to provide the service due to the higher cost of private capital. Proponents of this form of project development suggest that these incrementally higher costs are offset by risk transfer, project cost reductions, and technology performance guarantees.

3 COMPARISON, ANALYSIS, AND RANKING OF DELIVERY METHODS

All desalination plant projects are unique as the location and site of the plant necessarily requires consideration of different factors that affect the design and operations of the plant. These basic factors include: feedwater salinity and water temperature, seasonal variations in salinity, temperature, and other feedwater chemistry and biology, and available cost-effective methods of concentrate-disposal.

Likewise, no single project delivery method is likely to fit every potential site for a desalination plant or for the Corpus Christi desalination plant. Factors such as project delivery methods allowed under the statutes of the State of Texas, policies and procedures, local practices for the City of Corpus Christi, and sources of capital and operational revenues will be major factors that the City will have to resolve in the selection of a project delivery method for the desalination plant.

Table 9-3-1 lists a comparison of the alternate delivery methods for the Corpus Christi demonstration desalination plant project. For the purposes of the comparison and analysis of the four methods (DBB, DB, DBO, and BOOT), it is assumed that all other site and physical external factors are neutral.

Table 9-3-1 Corpus Christi Desalination Plant Project Analysis and Comparison of Alternative Delivery Methods

Item	Method / Criteria	Design-Bid-Build (DBB)	Design-Build (DB)	Design-Build-Operate (DBO)	Build-Own-Operate-Transfer (BOOT)
1.	Procurement Process & Cost	Owner controls process at each stage; however, procurement costs are spread over the entire process from planning through construction supervision.	Owner must develop criteria and manage the procurement process, but schedule and costs are less than traditional DBB.	Owner must develop criteria and manage the procurement process, but schedule and costs are less than traditional DBB.	Owner must develop criteria and manage the procurement process, but schedule and costs are less than traditional DBB.
2.	Competition	Competition at each stage in the process. Contractor selected on lump-sum, low-bid and not based on qualifications.	Large number of qualified vendors in the market. Selection is based on qualifications and price.	Large number of qualified vendors in the market. Selection is based on qualifications and price.	Limited competition in the USA for privatized desalination plants. Problems with Tampa Bay.
3.	Owner PM Costs & Burden	Costs and burden predictable based on past experience.	Owner must prepare criteria and provide some review during construction.	Owner must prepare criteria and provide some review during construction.	Owner must prepare criteria and provide some review during construction.
4.	Risk Allocation in Construction & Operations	Owner assumes performance and operations risk.	Owner bears the operations risk; DB contractor bears the construction risk.	DBO contractor bears both the construction and operations risk.	BOOT contractor assumes performance and financial risks.
5.	Project Schedule	Schedule is elongated to meet the pubic input, permitting, and bidding phase requirements	Schedule improved over DBB. Concurrent activities speed up the process. Permitting is a concern for the owner.	Schedule improved over DBB. Concurrent activities speed up the process. Permitting is a concern for the owner.	BOOT projects can move more quickly than DBB projects, as the BOOT contract has financial incentives.
6.	Capital & Life Cycle Cost	Good design engineer will develop life cycle cost analysis for owner. Up to owner to determine.	DB contractor is not required to consider operations cost unless so specified by the owner.	DBO contractor bids construction and operations, and owner can easily establish life cycle basis for award.	Life cycle cost is inherent in the development of the BOOT bid.
7.	Cost and Schedule Growth	Costs more predictable than schedule.	Has minimal risk for cost and/or schedule growth. DB contractor at risk.	Owner has minimal risk for cost and/or schedule growth DBO contractor at risk.	Cost and schedule growth favor the owner as the BOOT contractor holds the financial and completion risks.
8.	Rate Stability	Once capital costs are known, the effects on the rate can be determined based upon the cost of debt, but this information comes late in the process.	Costs for the project are known much earlier in the project cycle and can be evaluated for impact on rates earlier than the DBB.	Costs for the project are known much earlier in the project cycle and can be evaluated for impact on rates earlier than the DBB. Owner should realize savings in the O&M.	Owner only pays for water on a take-or-pay basis over the life of the project and does not need to raise the capital costs for the project. Promotes rate stability.
9.	Performance Guarantees	No performance guarantees provided. Owner has risk for design and operations performance.	DB contractor must meet the performance criteria for the design. Operations are up to owner after acceptance.	DBO contractor must meet performance criteria for the design and operations of the plant.	BOOT contractor takes most of the risk. Owner only pays for the water after acceptance test.
10.	Long-Term Asset Management	Requires owner to operate and so asset management over the life of the project is up to the owner.	Owner is responsible for long-term maintenance of the asset.	DBO contractor is responsible for the long-term maintenance of the asset for the life of the project.	BOOT contractor has incentive to protect the asset over the life of the project.
11.	Project Financing Flexibility	Traditional project financing is available.	Traditional financing is available.	Traditional financing is available. Innovation possible in the O&M.	Most flexible, as private sector provides the equity and debt.
	Relative Ranking	**Third**	**Second**	**First**	**Fourth**

4 NON-PUBLIC ENTITIES

Although alternative project delivery methods are becoming increasing popular, these methods are not currently allowed in Texas for use by public entities. There have been instances where alternative procurement methods have been used, such as the Northeast Water Purification Plant in Houston, Texas, but legislation barring these procurement methods was passed after these projects were underway or completed. For any procurement methods that simultaneously procure professional engineering services and construction services by public entities, state legislation must first be passed. It may be possible to have project-specific legislation to allow the Large Scale Demonstration Desalination Project to incorporate alternative procurement methodologies.

Due to statutory constraints in Texas and for the Corpus Christi desalination plant project, it may be more appropriate to use “nonpublic” entities as the procurement vehicle if alternative project delivery methods are pursued. Examples of nonpublic entities that could be used would include:

- Nonprofit water supply corporation
- Municipal development district
- Local government corporation
- Public facility corporation
- Nonprofit industrial development corporation

5 PROJECT TIMELINE

In Texas, unless comprehensive or at least project-specific legislation is passed to allow the use of alternate procurement methods, the conventional design-bid-build process will be used if the City of Corpus Christi is the entity to develop the project.

After completion of this feasibility study, and including time for the planning and funding of future phases and the procurement of the engineer, pilot studies could begin in the summer of 2005. One complete year of piloting is recommended to identify seasonal treatability issues that will likely occur as a result of temperature fluctuations and variability of other ambient conditions.

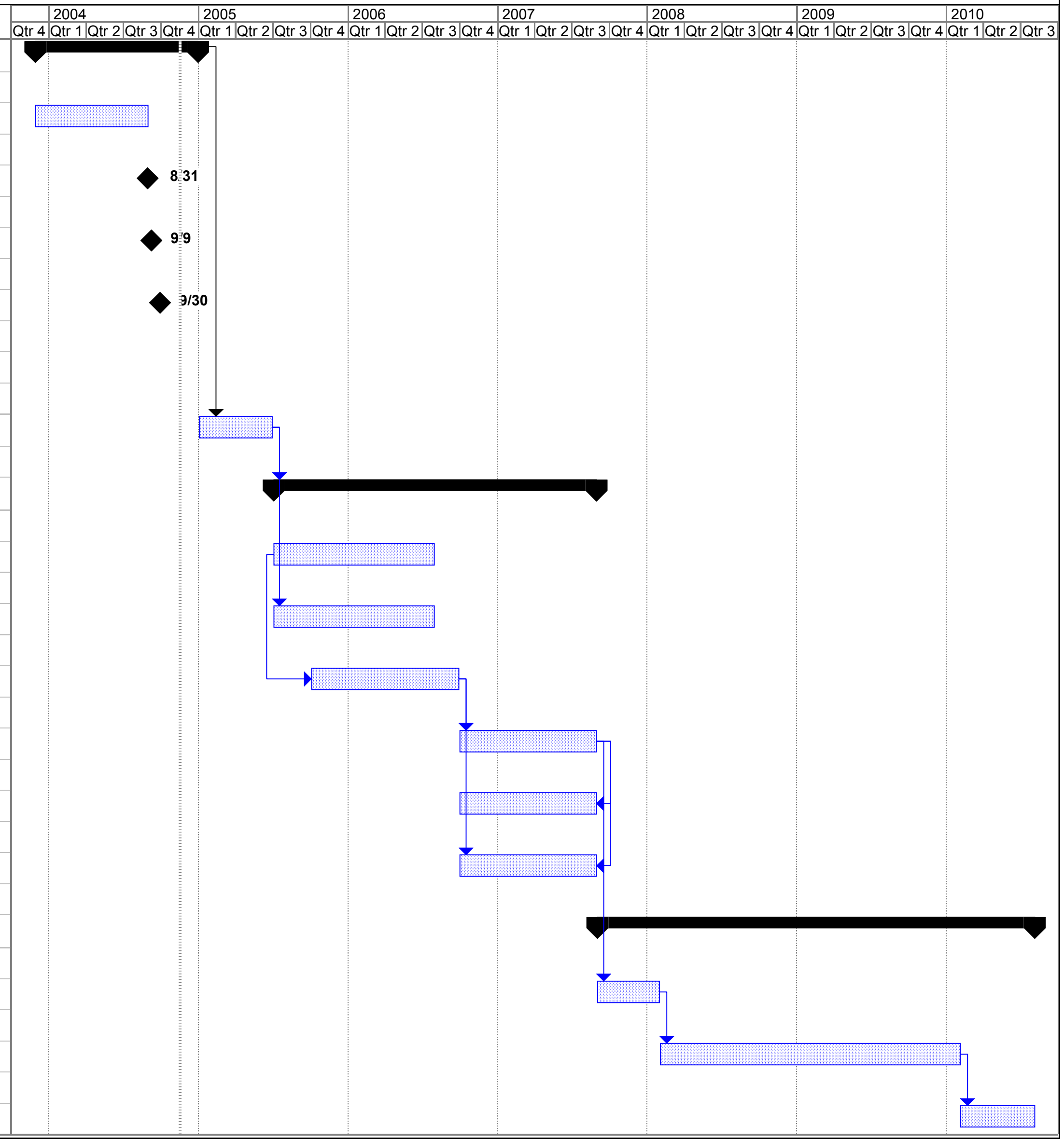
Environmental studies and preliminary engineering should be initiated to allow near simultaneous completion shortly following the completion of the pilot plant treatability studies. Detailed designs, permitting, and land acquisition and easements can be performed simultaneously and structured to be completed simultaneously.

Once the engineering, permitting, and land acquisition is completed, the project can begin the contractor selection process. The bidding phase is estimated to take 5 months. A 2-year construction period is anticipated followed by a 6-month demonstration startup period prior to full-scale operation.

The schedule identified in this analysis is presented in *Figure 9-5-1*. This schedule is a linear and sequential schedule and has sufficient time to accommodate unforeseen contingencies such as pilot

City of Corpus Christi
Large Scale Demonstration Desalination Project
PROJECT SCHEDULE

ID	Task Name	Start	Finish
1	**Feasibility Study**	**12/1/03**	**12/31/04**
2			
3	Preparation of Draft Report	12/1/03	8/31/04
4			
5	Draft Report to TWDB	8/31/04	8/31/04
6			
7	Public Meeting	9/9/04	9/9/04
8			
9	Final Report To TWDB	9/30/04	9/30/04
10			
11	TWDB Analyses and Recommendations	10/1/04	12/31/04
12			
13	Project Planning and Procurement	1/4/05	6/30/05
14			
15	**Engineering, Design, and Environmental**	**7/5/05**	**8/31/07**
16			
17	Pilot Plant	7/5/05	7/31/06
18			
19	Environmental Studies	7/5/05	7/31/06
20			
21	Preliminary Engineering	10/5/05	9/29/06
22			
23	Design	10/2/06	8/31/07
24			
25	Permitting	10/2/06	8/31/07
26			
27	Land Acquisition and Easements	10/2/06	8/31/07
28			
29	**Construction & Implementation**	**9/3/07**	**8/5/10**
30			
31	Advertising and Bidding Phase	9/3/07	2/1/08
32			
33	Construction	2/4/08	2/4/10
34			
35	Startup	2/5/10	8/5/10



Date: 11/15/04

Task	Progress	Summary	External Tasks	Deadline
Split	Milestone	Project Summary	External Milestone	

Figure 9-5-1
Project Timeline

plant failures, resolution of environmental issues, and obtaining difficult permits. The identified startup time in 2010 has also been selected in recognition of the technological improvements and the trend toward lowering of the cost associated with reverse osmosis desalination processes. Also, increasing demand with time will also tend to make the desalination process more economically feasible in the future.

Several project timeline modifications can be developed if the project needs to be online sooner than 2010. The pilot plant study time can be shortened and less time can be allotted for the preliminary engineering, design, and permitting functions. Maintaining the conventional design-bid-build process and using schedule acceleration techniques, the project could conceivably be ready for full-scale operation in early to mid 2009. If legislation is passed to permit the simultaneous procurement of the engineer and construction contractor, such as the design-build or design-build-operate procurement methods, significant additional savings in time may also be available.

Chapter 10

Cost Model

CHAPTER 10 – COST MODEL
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CHAPTER 10 – COST MODEL

1 PURPOSE AND APPROACH

A cost model was developed to assess the projected long-term costs associated with the proposed desalination facilities and to compare these costs to expected long-term costs associated with other water supply and treatment alternatives for the City of Corpus Christi. The primary purpose of the cost model was to evaluate the level of State subsidies required to make the construction and operation of desalination facilities cost neutral to the rate payers of the City. In addition, a sensitivity analysis was also conducted on several components of cost to determine the degree of fluctuation in required subsidies as a function of variance in specific components of cost.

The approach used for the cost model was to develop and compare two separate cost models assuming different long-term water supply delivery alternatives for the City. The first cost model developed assumed that the City would use its current water supplies (i.e., Choke Canyon, Lake Corpus Christi, Lavaca-Navidad River Authority [LNRA] contract, and Garwood water) to meet the projected treated and raw water demands for the City and that a desalination plant would not be constructed. This is called the No-Desalination Alternative. The second cost model developed assumed that the City would construct a 25-mgd desalination plant to supplement its existing supplies. This is called the Desalination Alternative. The desalination option selected for analysis in the cost model was the Barney Davis site using dissolved air flotation pre-treatment and an open sea intake structure (Barney Davis Option 2). A comparison of total net present value for these two cost models was then used to determine the level of State subsidies required to make the desalination cost neutral to the City. Cost neutral was defined for this analysis as an equal total net present value between the two models developed.

In addition, two other desalination design alternatives were also analyzed to assess potential reductions to estimated State subsidies as a result of assumed design modifications. The first design modification alternative assumed the use of existing intake facilities at the Barney Davis Plant. The second alternative assumed the use of both existing intake and discharge facilities at the Barney Davis Plant. The cost model was modified to incorporate these modifications, and the resulting required State subsidies were determined.

2 ASSUMPTIONS

Several key assumptions had to be made in the development of the cost model for this project. In general, the assumptions involved inflation, interest and discount rates, useful life of facilities, and replacement costs. However, other key assumptions had to be made regarding long-term water supply strategies for the City. A summary of the key assumptions made in developing the cost model are included below:

1. The period of analysis for the cost model is from present to 2030.

2. The rate of inflation used in the analysis is set at a constant 2.5 percent per year for the period of analysis.

3. The interest rate applied to capital costs for purposes of developing debt service is 5.5 percent, based on the TWDB General Obligation Bond rate.

4. Debt service on capital costs is calculated assuming an equal payment of principal and interest over the period of financing.

5. Plants and pumps are financed over 20 years.

6. Pipes and structures are financed over 30 years.

7. The replacement of plants and pumping facilities occurs on a 20-year cycle with replacement costs equal to the inflated cost of capital expenditures using the rate of inflation specified for this study.

8. The replacement of pipelines and structures occurs on a 50-year cycle with replacement costs equal to the inflated cost of capital expenditures using the rate of inflation specified for this study.

9. Replacement costs are assumed to begin the year following the life cycle of the facility and are financed at an interest rate of 5.5 percent at equal payments of principal and interest.

10. The treatment capacity of the O. N. Stevens Water Treatment Plant is 167 mgd. No expansions in treatment capacity are expected over the period of analysis for this study.

11. Water demand projections are based on information obtained from the *TWDB 2006 Region N Regional Water Plan.*

12. Estimates of capital costs for the pipeline and pumping facilities required to transport Garwood water to the City were obtained from the *TWDB 2001 Region N Regional Water Plan.*

13. Actual operating expenses, debt service, and planned debt service estimates for raw and treated water facilities were obtained from the City and inflated over the period of analysis using an inflation rate of 2.5 percent.

14. The costs for distribution of water are not included in the cost model. It is assumed that distribution costs are the same for all scenarios.

15. It was assumed that the City will construct the pipeline and pumping facilities to transport Garwood water to the City in 2020, if a desalination facility is not constructed.

16. The facilities to transport Garwood water to the City will not be constructed, if a desalination plant is constructed.

17. The City will sell excess raw water supplies, if a desalination plant is constructed. This sale of raw water is assumed to equal the capacity of the desalination plant (i.e., 28,000 acre-feet). The

sale of excess raw water is assumed to generate a revenue stream of $5 million per year or approximately $180 per acre-foot.

18. Total net present value is calculated at a discount rate of 1.25 percent per year.

19. Power costs for the operation of the desalination plant are $0.065 per kW-hr and are assumed to be held constant for the period of analysis.

3 WATER DEMAND PROJECTIONS

The projected unit cost of water delivered and treated to the end user is a function of monetary components such as projected capital costs, operating expenses, and existing debt service obligations, but is also highly dependent on future projections of water customer demands for the supply entity. It appears that the City currently has significant excess raw water supplies as well as excess treatment capacity in the O. N. Stevens Plant, which results in relatively fixed capital expenditures and debt service obligations over time. Therefore, the accurate projection of future water demands is critical to developing accurate projections of long-term unit costs of water.

Water demand projections for year 2000 for entities receiving water from the City of Corpus Christi provided in the *2001 Region N Regional Water Plan* are significantly higher than what is currently reported by the City. This is primarily due to overly aggressive increases in water usage projected for San Patricio Municipal Water District as well as significant increases in manufacturing demands in Nueces County being allocated to the City for supply. The reported sales of water to San Patricio as well as to manufacturing customers are less than what was projected in the 2001 Regional Plan. For these reasons, the water demand projections included in the *2001 Region N Regional Water Plan* were not used for this analysis.

For this study, water demand projection information developed for the 2006 Regional Water Plan was used to project future demands of existing City of Corpus Christi water customers. Information was obtained from the City summarizing actual fiscal year 2003-2004 water sales for each water customer of the City. This current demand was then projected using the information developed for the *2006 Region N Regional Water Plan.* Water demand growth factors calculated from the *2006 Regional Water Plan* for the planning decades 2010, 2020, and 2030 were applied to the City's current demand to develop projected water demands for the planning period. *Table 10-3-1* below provides a summary of the projected water demands for each water customer used for the cost model. Water demands for years between planning decades were developed using straight-line interpolation between decades.

Table 10-3-1 City of Corpus Christi Projected Water Demands

User	Water Demand (acre-feet)			
	2004	2010	2020	2030
City of Corpus Christi	64,600	71,318	78,644	84,140
San Patricio	21,875	25,594	28,438	31,281
South Texas Water Authority	1,335	1,575	1,736	1,829
Port Aransas	1,297	2,114	2,957	3,696
Alice	1,387	1,470	1,553	1,595
Beeville	2,677	2,784	2,838	2,891
Mathis	660	640	620	607
Koch	4,394	5,141	5,536	5,888
Celanese	4,088	4,783	5,151	5,478
Total	102,313	115,419	127,473	137,405

4 COST MODEL RESULTS

Tables 10-4-1 through *10-4-3* provide a summary of the cost model results. Additional details of these costs, as well as the completed cost model, are provided in *Appendix F* of this report. *Table 10-4-1* provides the summary of projected costs as well as the projected unit cost of water, assuming the City of Corpus Christi does not include a desalination facility in its future water supply plans. The results summarized in *Table 10-4-1* indicate that the City's current cost structure results in a raw water cost of approximately $0.85 per 1,000 gallons and a treated water component of approximately $0.39 per 1,000 gallons. This results in a current total combined cost of water of approximately $1.24 per 1,000 gallons. The projected combined cost of water varies over the planning period and, in general, increases over time. The combined cost of water for the City, assuming no-desalination plant facilities, is projected at approximately $1.43, $2.21, and $1.90 per 1,000 gallons in the years 2010, 2020, and 2030, respectively.

It is important to note that the costs of water projected with the cost model for this study do not include the cost to distribute the water to the end users. The costs for distribution were assumed to be equal for all scenarios and, therefore, could be disregarded for purposes of this analysis. Therefore, the actual cost of water from the City could potentially be higher depending on the costs associated with distribution.

Table 10-4-1 Summary of Projected Costs for No-Desalination Scenario

Cost Component	Year			
	2004	**2010**	**2020**	**2030**
O. N. Stevens Plant Expenses	$5,344,873	$8,148,764	$10,431,107	$13,352,699
Raw Water Expenses	$10,099,638	$11,838,687	$14,542,577	$18,044,590
Existing Debt Service	$21,863,684	$22,355,846	$15,082,622	$827,934
Planned Debt Service	-	$4,660,972	$9,241,227	$9,241,227
Future Capital Projects	-	-	$23,490,048	$22,534,544
Future Operation & Maintenance	-	-	$4,503,398	$5,764,730
Raw Cost of Water (per 1,000 gallons)	**$0.85**	**$0.85**	**$1.09**	**$0.79**
Treated Cost of Water (per 1,000 gallons)	**$0.39**	**$0.58**	**$1.12**	**$1.11**
Combined Cost of Water (per 1,000 gallons)	**$1.24**	**$1.43**	**$2.21**	**$1.90**
Total Present Value	**$37,308,195**	**$289,437,875**	**$744,676,179**	**$1,325,513,755**

Table 10-4-2 Summary of Projected Costs for Desalination Scenario (Without Subsidies)

Cost Component	Year			
	2004	**2010**	**2020**	**2030**
O. N. Stevens Plant Expenses	$5,344,873	$5,637,872	$7,538,233	$9,915,108
Raw Water Expenses	$10,099,638	$11,838,687	$14,542,577	$18,044,590
Existing Debt Service	$21,863,684	$22,355,846	$15,082,622	$827,934
Planned Debt Service	-	$4,660,972	$9,241,227	$9,241,227
Future Capital Projects	-	-	$11,370,788	$11,370,788
Desalination Plant Debt	-	$16,320,811	$16,320,811	$8,589,750
Desalination Plant Repair & Rehab	-	$5,871,307	$7,515,770	$9,620,820
Desal Plant Operation & Maintenance	-	$12,983,127	$14,574,661	$16,611,958
Desal Plant Replacement	-	-	-	$12,668,244
Raw Cost of Water (per 1,000 gallons)	**$0.85**	**$1.13**	**$0.94**	**$0.58**
Treated Cost of Water (per 1,000 gallons)	**$0.39**	**$0.74**	**$1.39**	**$1.32**
Desal Cost of Water (per 1,000 gallons)	-	**$3.86**	**$4.21**	**$5.21**
Combined Cost of Water (per 1,000 gallons)	**$1.24**	**$2.35**	**$2.74**	**$2.57**
Total Present Value	**$37,308,195**	**$342,352,753**	**$1,080,153,003**	**$1,835,210,498**

Figure 10-4-1 graphically demonstrates the projected unit costs for raw, treated, and combined water over the analysis period. Based on a review of *Figure 10-4-1*, the unit cost of raw water supplies, in general, decreases over time as demand for water increases. However, there are increases in the 2020 time frame for raw water costs as additional capital projects are assumed implemented, such as the Garwood pipeline project. The unit cost for treated water generally increases over time as operational costs increase. In addition, there are additional increases in the 2020 time frame based on an assumption of plant replacement costs for the O. N. Stevens Plant. The combined water unit costs are basically constant until the 2020 period at which time increases are projected due to the assumed implementation of the additional capital projects discussed.

Table 10-4-2 provides the summary of projected costs as well as the projected unit cost of water assuming the City of Corpus Christi includes a desalination facility in its future water supply plans. The results summarized in *Table 10-4-2* indicate that the projected combined cost of water increases significantly over the planning period as a result of the addition of desalination to the City's water supply plans. The combined cost of water for the City, assuming a desalination plant is constructed, is projected at approximately $2.35, $2.74, and $2.57 per 1,000 gallons in the years 2010, 2020, and 2030, respectively. The projections included in *Table 10-4-2* do not include any reduction in future unit costs of water due to State subsidies and/or water sales from excess supplies.

Figure 10-4-1 Projected Cost of Water No-Desalination Plant

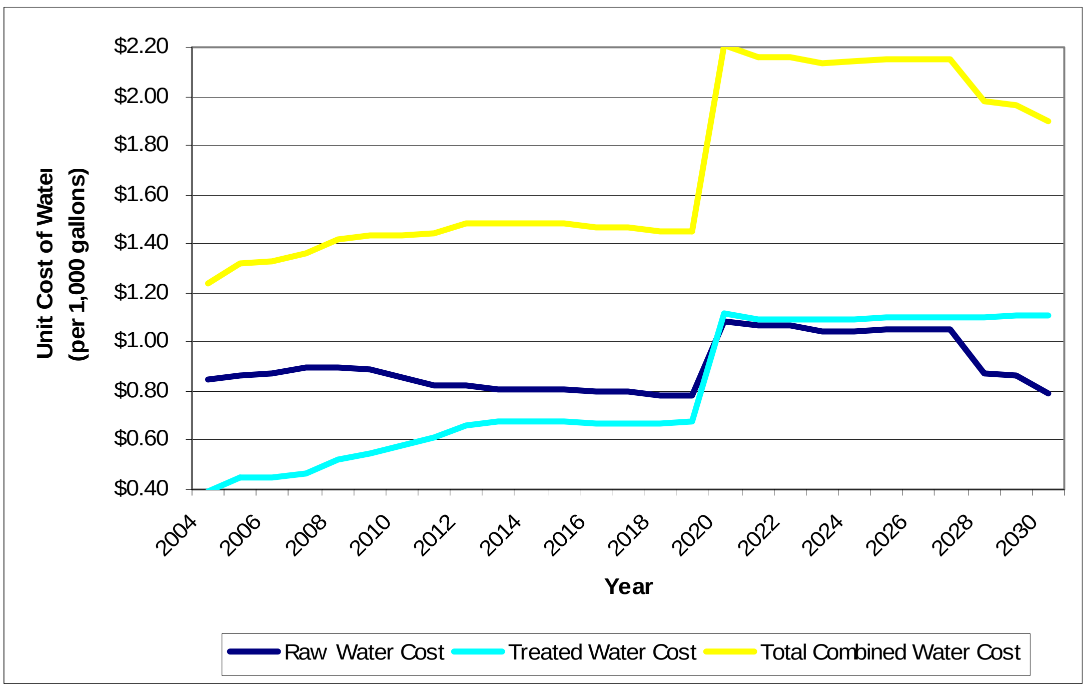
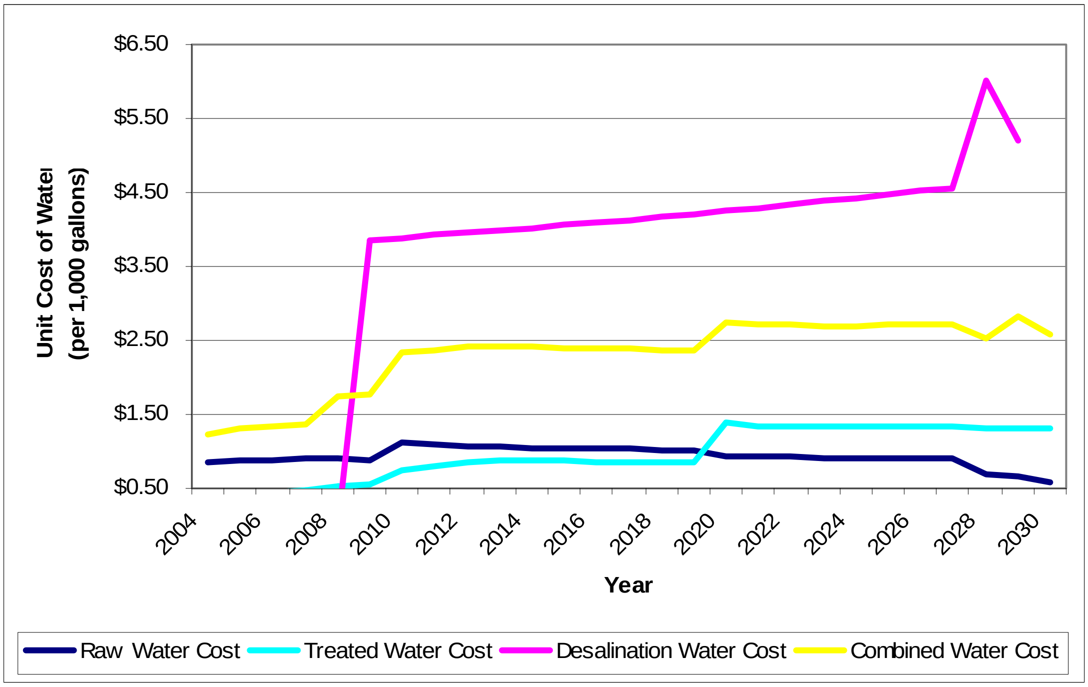


Figure 10-4-2 graphically demonstrates the projected unit costs for raw, treated, desalination, and combined water over the analysis period. Based on a review of *Figure 10-4-2*, the unit cost of raw water supplies decreases over time as demand for water increases. The increases in the 2020 time frame for the unit costs of raw water projected in the no-desalination scenario are not projected in this scenario due to the assumption that the Garwood pipeline project would not be implemented during the analysis period for this scenario. Similarly to the no-desalination scenario, the unit cost for treated water generally increases over time as operational costs increase. In addition, the unit cost of treated water for this scenario is slightly higher overall in comparison to the no-desalination scenario. This is due to the reduction in overall treated water volumes sold to customers from the O. N. Stevens Plant. The unit cost for desalination water is projected at approximately $3.86 initially, increasing steadily over time, with a sharp increase in projected costs occurring around 2029 due to assumed replacement costs associated with the desalination facilities. The

combined water unit costs are basically constant until the 2020 period, when increases are projected due to the assumed implementation of the additional capital projects discussed.

Figure 10-4-2 Projected Cost of Water Desalination Plant Without Subsidy



A review of *Table 10-4-2* indicates that the projected total present value of costs at the end of the analysis period (2030) for the desalination scenario (without inclusion of subsidies) is approximately $509 million greater than the scenario assuming no-desalination facilities. The approach taken in this study was to determine the level of subsidy required to make the total end of period (2030) present values for both the desalination scenario and the no-desalination scenario equal. By achieving this, it was assumed that a cost neutral condition would be achieved for the rate payers of Corpus Christi. *Table 10-4-3*, discussed below, provides the results of the analysis of subsidies required.

Table 10-4-3 Summary of Projected Costs for Desalination Scenario (With Subsidies)

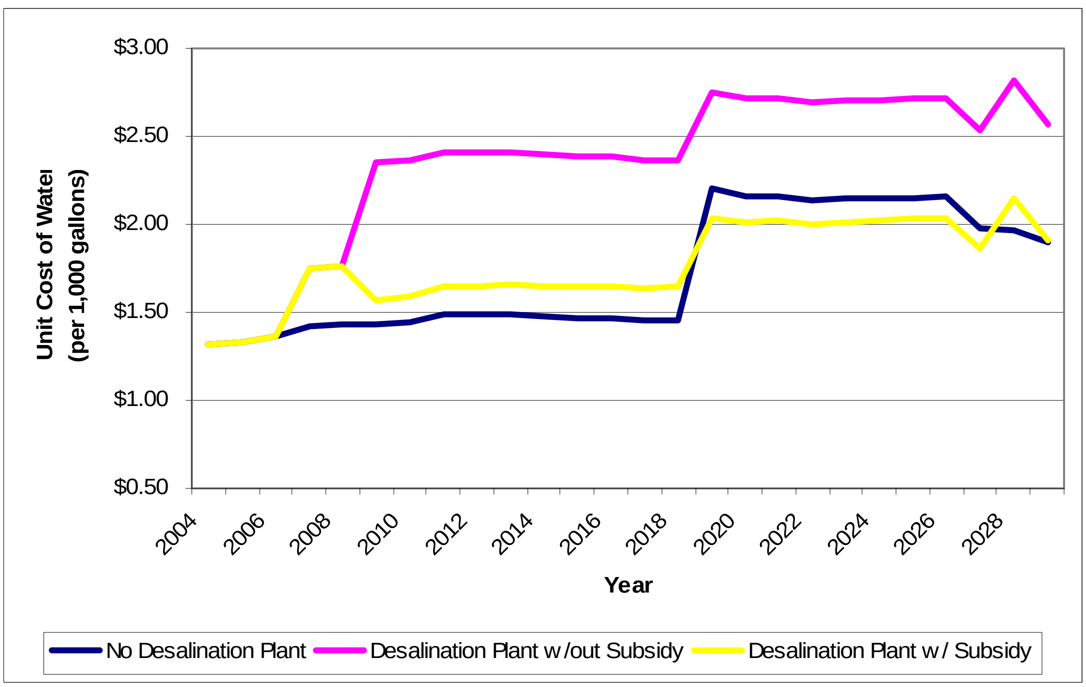
Cost Component	Year			
	2004	**2010**	**2020**	**2030**
O. N. Stevens Expenses	$5,344,873	$5,637,872	$7,538,233	$9,915,108
Raw Water Expenses	$10,099,638	$11,838,687	$14,542,577	$18,044,590
Existing Debt Service	$21,863,684	$22,355,846	$15,082,622	$827,934
Planned Debt Service	-	$4,660,972	$9,241,227	$9,241,227
Future Capital Projects	-	-	$11,370,788	$11,370,788
Desalination Plant Debt	-	$16,320,811	$16,320,811	$8,589,750
Desalination Plant Repair & Rehab	-	$5,871,307	$7,515,770	$9,620,820
Desal Plant Operation & Maintenance	-	$12,983,127	$14,574,661	$16,611,958
Desal Plant Replacement	-	-	-	$12,668,244
Total Subsidies	-	$29,466,335	$29,528,677	$29,583,737
Raw Cost of Water (per 1,000 gallons)	**$0.85**	**$1.13**	**$0.94**	**$0.58**
Treated Cost of Water (per 1,000 gallons)	**$0.39**	**$0.74**	**$1.39**	**$1.32**
Desal Cost of Water (per 1,000 gallons)	**-**	**$0.63**	**$0.97**	**$1.96**
Combined Cost of Water (per 1,000 gallons)	**$1.24**	**$1.57**	**$2.03**	**$1.91**
Total Present Value	**$37,308,195**	**$315,002,841**	**$796,906,319**	**$1,325,513,755**

Table 10-4-3 provides the summary of projected costs as well as the projected unit cost of water assuming the City of Corpus Christi receives State subsidies and/or revenues from the sale of excess water supplies. The total amount of subsidies provided in *Table 10-4-3* includes $5 million from the assumed sale of excess water supplies of 28,000 acre-feet and approximately $25 million per year of State subsidies. Subsidies of this level achieve a condition in which end of period (2030) net present value of costs are equal for both the desalination scenario and the no-desalination scenario.

The results summarized in *Table 10-4-3* indicate that the projected cost of desalination water decreases significantly over the planning period as a result of the assumed subsidies. The combined cost of water for the City, assuming total subsidies of approximately $30 million per year, is projected at approximately $1.57, $2.03, and $1.91 per 1,000 gallons in the years 2010, 2020, and 2030, respectively. These projected unit costs of water are in line with those projected for the no-desalination plant scenario provided in *Table 10-4-1*.

Figure 10-4-3 graphically demonstrates the comparison of projected unit costs for combined water between the no-desalination scenario and the desalination scenario with and without assumed subsidies over the analysis period. Based on a review of *Figure 10-4-3*, the unit cost of the desalination scenario without subsidies included is significantly higher than the no-desalination scenario. The cost model developed for this study was used to determine the level of subsidies required to make the desalination scenario cost neutral to the City of Corpus Christi rate payers. This was accomplished by determining the annual subsidy required to make the end of period (2030) net present value of costs for the desalination and no-desalination scenarios equal. *Figure 10-4-3* demonstrates the projected unit cost for water, assuming a total annual subsidy of approximately $30 million for the desalination scenario. As demonstrated in *Figure 10-4-3*, the projected unit costs for water for both the desalination with subsidy and no-desalination scenarios are similar to one another for most of the project period and appear to be approximately the same at the end of the project period.

Figure 10-4-3 Projected Cost of Water Desalination Plant With Subsidy



The costs included in *Tables 10-4-1, 10-4-2, 10-4-3* and discussed throughout *Chapter 10* of this report are a result of the detailed analysis performed and included in the cost model in *Appendix F*. These costs are reported for each decade over the planning period and reflect the projected cost of water considering inflation over the planning period. The costs reported in *Chapter 10* and the costs reported in the *Executive Summary* for this report do not match and were derived using different methodologies. The costs included in *Chapter 10* reflect the best estimate of costs for each planning decade using the assumptions listed in Section 2. The costs of $3.51 per 1000 gallons reported in the *Executive Summary* for this report do not consider the impacts of inflation and are reported as the aggregate costs over the planning period as opposed to decadal reporting as performed in *Chapter 10*. The unit cost for desalination water is projected at approximately $3.86 per 1,000 gallons initially, increasing steadily over time, with a sharp increase in projected costs occurring around 2029 due to assumed replacement costs associated with the desalination facilities. This is the cost without any subsidy. The use of a different methodology in developing the costs reported in the *Executive Summary* was done in order to report costs in a similar fashion as reported by the other desalination projects (i.e., Freeport and Brownsville) and to make comparisons by the TWDB easier.

5 DESIGN ALTERNATIVES ANALYSIS

The cost model was also used to assess resulting subsidies associated with alternative design assumptions. Two alternative desalination plant design modifications were analyzed using the same cost model and approach described previously. Present value of costs for each alternative was compared to the no-desalination scenario to determine the amount of subsidies required to make desalination cost neutral to the City.

The first alternative analyzed assumed that existing seawater intake facilities at the Barney Davis Power Plant would be utilized for the desalination facility. The desalination scenario discussed previously in this report assumed that new seawater intake facilities would be constructed for the desalination plant. The reduction of capital costs associated with this first design modification alternative (approximately $26 million) resulted in an average overall reduction in required subsidies of approximately $5 million annually over the analysis period. This includes the same assumption of additional revenues from the sale of excess water in the amount of $5 million.

The second alternative assumed that both existing seawater intake and discharge facilities at the Barney Davis Power Plant would be utilized for the desalination facility. The reduction of capital costs associated with this second design modification alternative (approximately $69 million) resulted in an overall average reduction in required subsidies of approximately $7 million for a total of $23 million annually over the analysis period.

6 SENSITIVITY ANALYSIS

A sensitivity analysis was performed for several of the variables included in the cost model including interest rate, power costs, discount rate, and estimated desalination plant capital costs. The variables that appear to be most sensitive in terms of how they affect the estimates of subsidies required to make desalination cost neutral are desalination capital costs, interest rates applied to capital expenditures, and desalination power costs, with capital costs being the most sensitive variable.

Reductions in desalination capital costs, interest rates, and estimated desalination power costs result in reductions in the amount of subsidies required to make desalination cost neutral. Likewise, increases in these variables result in increases to the estimated subsidy amounts. While other variables such as inflation rates and discount rates tend to impact the results of estimated subsidies, the impacts are in general of a lesser degree than the changes made to capital costs, interest rates, and power costs.

Table 10-5-1 is provided to summarize the results of the sensitivity analysis performed for the cost model. Variables in the cost model were decreased and increased by the percentages shown in *Table 10-5-1* resulting in the estimates of total required subsidy amounts provided.

Based on this analysis, exploring reductions in capital costs for the desalination facilities, lowering interest rates, and obtaining reductions in the long-term power costs for the project will provide the greatest impact to minimizing the degree of subsidy required to make desalination cost neutral to the City.

Table 10-5-1 Results of Sensitivity Analysis

Variable	% Change to Variable		% Change to Subsidy	
Desalination Capital Costs	-30	+30	-30	+30
Interest Rate	-40	+40	-12	+20
Desalination Power Costs	-30	+30	-12	+10
Discount Rate	-20	+20	-2	+2
Inflation Rate	-20	+20	0	0

7 COMPARISON TO SUBSIDIES IN OTHER PARTS OF THE UNITED STATES

There is currently a significant interest in desalination of seawater nationally, with specific subsidies being provided in at least two states. The Metropolitan Water District of Southern California has approved a subsidy of $250 per acre-foot to any of its sponsoring member agencies that successfully implement a seawater desalination project to augment the District's scarce supplies of water. In addition, the South Florida Water Management District has provided $85 million of the capital cost for the Tampa Bay Desalination Facility owned by Tampa Bay Water. Eighty-five million dollars reduced to an annual payment over 20 years and with a 6 percent interest rate would be approximately $7.4 million annually for a throughput of 28,005 acre-feet annually. This results in a potential subsidy of $265 per acre-foot.

In addition to the actions of the individual states, there is also Federal legislation, HR 3834, that is moving through Congress. This bill, entitled the Desalination Energy Assistance Act of 2004, is intended to provide a national subsidy for desalination projects. This bill initially provides for a subsidy of $0.62 per 1000 gallons, or a subsidy of approximately $200 per acre-foot for a period of ten years. Subsequent discussions have considered the possibility of removing the 10-year limitation but that has not occurred at this date.

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Appendices

Appendix A

City of Corpus Christi Water Rate Ordinance

ARTICLE III. WATER RATES AND CHARGES

Sec. 55-50. Schedule.

(a) *Base rates for water service.* The rates for water service are as follows:

(1) Monthly minimum charges.

a. *Metered treated water customers.*

1. Inside city limits:

TABLE INSET:

Meter Size (Inches)	August 1, 2003 to July 31, 2004
Residential	
5/8– 3/4	$ 6.124
Commercial	
5/8– 3/4	8.838
Residential and Commercial	
1	14.104
1 1/2	23.695
2	36.866
3	132.277
4	150.913
6	226.747
8 and larger	340.581
Large Volume	
Any size	11,482.099

2. Outside city limits:

TABLE INSET:

Meter Size (Inches)	August 1, 2003 to July 31, 2004

Residential	
5/8– 3/4	$ 13.001
Commercial	
5/8– 3/4	18.447
Residential and Commercial	
1	28.941
1–1 1/2	48.138
2	74.465
3	265.289
4	302.580
6	454.266
8 and larger	681.928
Large Volume	
Any size	19,159.030

b. *Untreated water customers.*

TABLE INSET:

	August 1, 2003 to July 31, 2004
Minimum monthly service charge, water districts/ municipalities with raw water supply contracts executed after January 1, 1997	$274.117
Minimum monthly service charge for public agency for resale untreated water without a raw water supply contract executed after January 1, 1997 1	166.950
Minimum monthly service charge, industrial	274.117
Minimum monthly service charge, domestic	9.132
Minimum annual service charge, domestic	91.370

1 Minimum monthly charge for public agency for resale untreated water customer without a raw water supply contract executed after January 1, 1997: If the charge based on the volume of water taken in a monthly billing period is less than one hundred sixty-six dollars and ninety-five cents ($166.95), the customer shall be billed one hundred sixty-six dollars and ninety-five cents ($166.95), unless a valid water supply contract between the customer and city that was executed prior to January 1, 1997, provides for a minimum annual payment. If a valid water supply contract between the customer and

city executed prior to August 1, 2000, provides for a minimum annual payment, the customer shall pay the minimum annual payment under the contract.

(2) Monthly volume charges per 1,000 gallons.

a. *Residential rate.*

1. Inside city limits:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 2,000 Gallons	Minimum*
Next 13,000 Gallons	$2.118
Next 15,000 Gallons	2.988
Next 20,000 Gallons	3.657
Over 50,000 Gallons	4.437

*Use the minimum charges in subsection (a)(1).

2. Outside city limits:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 2,000 Gallons	Minimum*
Next 13,000 Gallons	$4.437
Next 15,000 Gallons	4.437
Next 20,000 Gallons	4.437
Over 50,000 Gallons	4.437

*Use the minimum charges in subsection (a)(1).

b. *Commercial rate.*

1. Inside city limits:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 2,000 Gallons	Minimum*
Next 13,000 Gallons	$2.118

Next 85,000 Gallons	1.884
Next 900,000 Gallons	1.432
Over 1,000,000 Gallons	1.122

*Use the minimum charges in subsection (a)(1).

2. Outside city limits:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 2,000 Gallons	Minimum*
Next 13,000 Gallons	$4.618
Next 85,000 Gallons	4.146
Next 900,000 Gallons	3.221
Over 1,000,000 Gallons	1.758

*Use the minimum charges in subsection (a)(1).

c. *Reserved.*

d. *Public agency for resale treated water rates.* Treated water rates purchased by a public agency for resale are hereby set as follows:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 2,000 Gallons	Minimum*
Next 13,000 Gallons	$2.045
Next 85,000 Gallons	1.830
Next 900,000 Gallons	1.376
Next 9,000,000 Gallons	1.086
Over 10,000,000 Gallons	0.707

*Use the minimum charges in subsection (a)(1).

e. *Large volume customers.* A commercial customer who agrees to pay for a minimum of ten million (10,000,000) gallons of treated water per month is considered a large volume customer. Once a customer has elected to become a large volume customer, the customer will be billed as a large volume customer until the customer notifies the city and requests reclassification as a commercial customer in writing. However, a commercial customer may not elect to become a large volume customer more than once in any twelve-month period.

1. Inside city limits:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 10,000,000 Gallons	Minimum*
Each Additional 1,000 Gallons	$ 0.744

*Use the minimum charges in subsection (a)(1).

2. Outside city limits:

TABLE INSET:

	August 1, 2003 to July 31, 2004
First 10,000,000 Gallons	Minimum*
Each Additional 1,000 Gallons	1.087

*Use the minimum charges in subsection (a)(1).

f. Public agency for resale untreated water rates. The rates for the purchase of untreated water purchased by a public agency, which does not have a raw water supply contract with the city executed after January 1, 1997, is the average of the monthly raw water cost adjustments, established under subsection (b) of this section, for the period used to determine the composite cost of untreated water under the city's current contract with the public agency.

(b) *Raw water cost adjustment (RWCA).* In addition to the charges for the base rates for water service, established in subsection (a), a separate charge for the costs of raw water, the RWCA, will be added to each consumer's bill, except public agency for resale untreated water customers without a raw water supply contract executed after January 1, 1997. (A public agency for resale untreated water customer without a raw water supply contract executed after January 1, 1997, will pay the lower of the composite cost, as defined in its contract with the city or the rate for public agency for resale untreated water customers without a raw water supply contract executed after January 1, 1997, specified in subsection (a)(2)f. The RWCA will be based on projected system-wide raw water sales. The RWCA will be calculated on an annual basis according to the following procedures:

(1) Use projected system-wide water sales based on historical consumption and projected growth.

(2) Include the annual budgeted cost of debt service. Bond payments, amortization of deferred losses on refundings, and other debt service costs shall be applied to the RWCA in the same proportion as the raw water activities proportion of the original bond proceeds.

(3) Include budgeted expenditures for purchases of water.

(4) Include purchases of water rights, amortized over the duration of the water right agreement.

(5) Budgeted expenditures for capital items shall be included as follows:

a. The expense of acquiring a capital item that costs not more than one hundred thousand dollars ($100,000.00) shall be charged in the year in which it is acquired.

b. The expense of acquiring a capital item that costs more than one hundred thousand dollars ($100,000.00) shall be amortized over the number of years used to calculate depreciation expenses, with the half-year convention used in the year of acquisition.

(6) All operating and maintenance expenditures shall be charged based on annual budgeted amounts. These expenditures include operation and maintenance of dams, reservoirs, pipelines, wells, pumping stations, and related interfund charges.

(7) All expenses for consultants, engineering, legal services, and administration charged based on annual budgeted amounts in the proportion to which they apply to raw water issues.

(8) Expenses related to the acquisition and transportation of emergency water supplies shall be included in the RWCA for the following fiscal year, unless foreseen and budgeted in advance, in which case they are included in the year budgeted.

(9) Miscellaneous revenues related to raw water activity, such as oil and gas lease revenues and interest earned on debt service surety bonds, is applied as an offset based on annual budgeted amounts.

(10) At fiscal year end, determine the amount of over or under collections that have resulted from differences between budgeted and actual expenses and offsetting revenues and the difference between projected and actual volume of water sold. Apply this amount as an adjustment to the following fiscal year's RWCA.

(11) Apply the credit for levelized Choke Canyon debt payments to city rate payers' projected water consumption, and deduct from their RWCA. (The escalating payment schedule on the Choke Canyon debt was levelized through the creation of a reserve fund. In the initial years, payments greater than the debt service were made, with the excess going into the reserve fund. This excess was paid through a rate surcharge on ICL and OCL metered treated water customers. Now that bond payments exceed the levelized payment amount, the reserve fund is drawn on to make up the difference. Since only ICL and OCL metered treated water customers participated in building the reserve fund, the drawing on the reserve fund is only credited to the RWCA assessed against ICL and OCL metered treated water customers.

(c) *Definitions.*

Costs of raw water is the total of all costs of acquiring, producing, storing, conserving, and transporting untreated water from its source to the city's treatment facility and all other points of diversion. These costs include, but are not limited to, the costs of:

Construction, including debt service, operation, and maintenance of dams and reservoirs.

Construction, including debt service, operation, and maintenance of raw water supply transmission pipelines.

Construction, including debt service, operation, and maintenance of wells.

Construction, including debt service, operation, and maintenance of facilities capable of converting wastewater effluent, salt water, and brackish ground water into water suitable for municipal, industrial, or agricultural uses.

Acquisition of new water supplies and water rights.

Payments to the P.L. 104-318 Alternative Water Supply Acquisition and Facilities Construction Special Fund.

Construction, operation, and maintenance of facilities to reduce water losses from water resources due to evaporation or the release of water from a reservoir due to the operation of law.

Acquisition and transportation of emergency water supplies, including the costs of transporting water by vessel or pipelines from other regions.

Water supply development and protection, including consultants' studies and reports, investigations, legal fees, court costs, and any other costs related to the development or protection of the water supply.

Administrative costs, including overhead and the portion of the city's general administrative costs applicable to the activities enumerated in this definition.

(Ord. No. 9472, 8-27-69; Ord. No. 11613, 8-8-73; Ord. No. 12208, §§ 1, 2, 8-7-74; Ord. No. 14140, §§ 1--3, 1-25-78; Ord. No. 16446, §§ 1, 2, 8-12-81; Ord. No. 1693 § 1, 10-14-81; Ord. No. 17166, §§ 1--3, 7-28-82; Ord. No. 17762, 1, 2, 8-3-83; Ord. No. 18351, §§ 1, 2, 7-24-84; Ord. No. 18587, § 1, 2, 12-4-84; Ord. No. 20411, §§

1, 2, 7-26-88; Ord. No. 21001, § 1, 10-9-90; Ord. No. 21438, §§ 1--4, 7-21-92; Ord. No. 21814, § 1(a)--(c), 12-14-93; Ord. No. 22741, § 1, 11-12-96 Ord. No. 22832, § 1, 1-28-97; Ord. No. 22879, § 1, 3-25-97; Ord. No. 23706, § 1, 7-20-99; Ord. No. 23910, § 1, 1-11-00; Ord. No. 24132, § 1, 7-25-00; Ord. No. 24531, § 1a, 7-24-01; Ord. No. 24969, § 1, 7-23-02; Ord. No. 25386, § 1, 7-22-03)

Sec. 55-50.1. Water service to city without charge.

No rate or charge shall be assessed for water service provided to city buildings, institutions, and activities operated by the city. The city shall maintain records showing the free service provided and the value thereof. However, rates and charges shall be assessed for city utilities provided to city buildings, institutions, and activities operated by the city for which operating and maintenance expenditures are recorded in the aviation, golf, and marina funds.

(Ord. No. 20164, § 1, 1-12-88; Ord. No. 21835, § 1, 12-21-93; Ord. No. 24969, § 3, 7-23-02; Ord. No. 25396, § 3, 7-22-03)

Sec. 55-51. Reserved.

Editor's note: Ord. No. 25593, § 11, adopted Dec. 16, 2003, deleted § 55-51, which pertained to delinquent notices, disconnection of service and reconnection procedures and derived from 1966 Supp., § 38-34; Ord. No. 13760, § 1, adopted June 1, 1977; and Ord. No. 24531, § 2, adopted July 24, 2001.

Secs. 55-52, 55-53. Reserved.

Sec. 55-54. Contracts for sale of irrigation water.

The director of public utilities is authorized to execute contracts for the sale of irrigation water for periods not to exceed five(5) years, according to the form of contract attached to Ordinance No. 10806, on file in the city secretary's office, any modifications of standard contract to be approved by the city manager.

(Ord. No. 10806, § 1, 4-19-72)

Sec. 55-55. Service charge for same day water service.

The customer must pay a thirty dollar ($30.00) service charge for turning on water service on the same day the customer requests gas service from the city.

(Ord. No. 24531, § 3, 7-24-01)

Secs. 55-56--55-59. Reserved.

ARTICLE XII. WATER CONSERVATION*

***Editor's note:** Ord. No. 24396, § 1, adopted March 20, 2001, amended Art. XII, in its entirety, to read as herein set out. Prior to inclusion of said ordinance, Art. XII pertained to similar subject matter. See the Code Comparative Table.

Sec. 55-150. Scope, purpose and authorization.

(a) *Scope.* There is hereby established a City of Corpus Christi Water Conservation Plan.

(b) *Declaration of policy.*

(1) It is hereby declared that the general welfare requires that the water resources available to the city be put to the maximum beneficial use to the extent to which they are capable, and that the waste or unreasonable use, or unreasonable method of use of water be prevented, and the conservation of such water is to be extended with a view to the reasonable and beneficial use thereof in the interests of the people of the area served by the city's water resources and for the public welfare.

(2) In making decisions under this article concerning the allocation of water between conflicting interests, highest priority will be given to allocation necessary to support human life and health; i.e., the minimum amount of water necessary for drinking, prevention of disease, and the like. Second highest priority will be given to allocations which will result in the least loss of employment to persons whose income is essential to their families.

(c) *Authorization.* The city manager, or his designee, upon the recommendation of the assistant city manager, public works and utilities, is hereby authorized and directed to implement the applicable provisions of this article upon their determination that such implementation is necessary to protect the public welfare and safety.

(Ord. No. 24396, § 1, 3-20-01)

Sec. 55-151. Water conservation and drought contingency plan.

(a) The Water Conservation and Drought Contingency Plan for Corpus Christi, dated August 24, 1999, a true copy of which is on file in the office of the city secretary, is adopted, and shall be followed in matters concerning water conservation, drought management, and water supply enhancement programs.

(b) The city manager shall pursue a water well leasing program to obtain groundwater to supplement surface supplies, as economically feasible.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24726, § 1, 1-8-02)

Sec. 55-152. Automatic water conservation measures.

(a) When combined storage in the Choke Canyon/Lake Corpus Christi Reservoir System ("Reservoir System Storage") falls below fifty (50) per cent of reservoir system storage capacity:

(1) The city manager shall issue a public notice informing water users of the Corpus Christi water supply region of voluntary conservation measures that are requested immediately and required drought management measures that must be taken if the amount of water in the reservoirs falls to under forty (40) per cent of reservoir system storage capacity and when the amount of water in the reservoirs falls to under thirty (30) per cent of reservoir system storage

capacity.

(2) No person may:

a. Allow water to run off yards or plants into gutters or streets.

b. Permit or maintain defective plumbing in a home, business establishment or any location where water is used on the premises. Defective plumbing includes out-of-repair water closets, underground leaks, defective or leaking faucets and taps.

c. Allow water to flow constantly through a tap, hydrant, valve, or otherwise by any user of water connected to the city system.

(b) To the extent of the city's legal authority, the city manager shall require the city's wholesale customers to issue public notice advising their water customers of voluntary conservation measures that are requested immediately and required drought management measures that must be taken if the amount of water in the reservoirs falls to under forty (40) per cent of the reservoir system storage capacity and when the amount of water in the reservoirs falls to under thirty (30) per cent of the reservoir system storage capacity.

(c) When combined storage in the Choke Canyon/Lake Corpus Christi Reservoir System ("Reservoir System Storage") falls below forty (40) per cent of reservoir system storage capacity, the city manager shall publish a public notice in a daily newspaper of general circulation in Nueces County when the city manager determines that the amount of water in storage has fallen below forty (40) per cent of reservoir system storage capacity. From the date of publication of the notice until the date the notice is rescinded by the city manager, no person may use water for irrigation of vegetation between the hours or 10:00 a.m. and 6:00 p.m.

(d) It shall be a defense to prosecution of a violation under subsection(c) of this section that the use of water was for one of the following purposes and the city manager had specifically authorized the use of water for the purpose on the date of the violation:

(1) The water was used, at the minimum rate necessary, for the establishment and maintenance of commercial nursery stock and applied using:

a. A hand held hose equipped with a positive shutoff nozzle.

b. A sprinkler system.

c. A drip irrigation system equipped with an automatic shutoff device.

d. A soaker hose, which does not spray water into the air, equipped with an automatic shutoff device.

e. A root feeder equipped with an automatic shutoff device.

f. A hand held bucket or watering can.

(2) Wastewater treatment plant effluent, graywater, well water (which is not mixed with any water from the city's water supply), or other water not obtained from the city water system was used, if a permit was obtained from the city manager and a sign was posted stating that the water used for irrigation is wastewater effluent, graywater, water from a permitted private well, or water that was not obtained from the city's water supply.

(3) The water was used for short periods of time for testing related to the installation, maintenance, and repair of sprinkler systems.

(4) The water was used for irrigation of vegetation on a large parcel of land or unique botanical institution, such as the Corpus Christi Botanical Gardens and Blucher Nature Center, in conformance with a special watering plan, specifically approved for that parcel by an official designated by the city manager. The official approving any special watering plan shall ensure that the plan achieves similar water conservation goals to the mandatory conservation measures applicable to other customers under this subsection.

(e) When combined storage in the Choke Canyon/Lake Corpus Christi Reservoir System ("Reservoir System Storage") falls below thirty (30) per cent of reservoir system storage capacity, the city manager shall publish notice in a daily newspaper of general circulation in Nueces County when the city manager determines that the amount of water in reservoirs has fallen below thirty (30) per cent reservoir system storage capacity and publish a lawn watering plan that allows customers to water lawns no more often than every five days, while maintaining the prohibition on using water for irrigation between 10:00 a.m. to 6:00 p.m.

(f) From the date of publication of the notice and plan, until the date the notice and plan are rescinded by the city manager, no person may use water for irrigation of a lawn, except on a day lawn water is authorized under the lawn watering plan.

(g) It shall be a defense to prosecution of a violation under subsection (f) of this section that the use of water was for one of the following purposes and the city manager had specifically authorized the use of water for the purpose on the date of the violation:

(1) The water was used, other than during the hours between 10:00 a.m. and 6:00 p.m., for irrigation, at the minimum rate necessary, for the establishment of newly planted lawns within thirty (30) days of planting.

(2) Wastewater treatment plant effluent, graywater, well water (which is not mixed with any water from the city's water supply), or other water not obtained from the city water system was used, if a permit is obtained from the city manager and a sign is posted stating that the water used for irrigation is wastewater effluent, graywater, water from a permitted private well, or water that was not obtained from the city's water supply.

(3) The water was used, other than during the hours between 10:00 a.m. and 6:00 p.m., for irrigation, at the minimum rate necessary, for maintenance of golf course greens and tee boxes.

(4) The water was used for irrigation on a large parcel of land or unique botanical institution, such as the Corpus Christi Botanical Gardens and Blucher Nature Center, in conformance with a special watering plan, specifically approved for that parcel by an official designated by the city manager. The official approving any special watering plan shall ensure that the plan achieves similar water conservation goals to the mandatory conservation measures applicable to other customers under this subsection.

(h) This section shall only be effective at any time the city is entitled, under to Order of the Texas Natural Resource Conservation Commission under Certificate of Adjudication No. 21-3214, to (1) reduce targeted inflows of water to Nueces Bay to 1200 acre feet when reservoir system storage falls below forty (40) per cent of capacity, and (2) suspend targeted inflows below thirty (30) per cent of capacity.

(i) Copies of the notices published by the city manager under this section shall be filed with the city secretary. The city secretary shall send a copy of the notice to each member of the city council and a certified copy of the notice to the judges of the municipal court.

0) Courts shall take judicial notice of the notices published by the city manager under this section, and the notices may be read into evidence without pleading or proof.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24576, § 1, 9-11-01)

Sec. 55-153. Water conservation measures.

(a) The city manager shall develop guidelines, based upon the recommendations of the water superintendent and assistant city manager for public works and utilities, which shall set forth the criteria for determining when particular water conservation measures should be implemented and terminated based on water available in the city's reservoir system, other available water resources, the needs of customers, human life and health concerns, the effect water conservation measures on the jobs of residents of the area, and the effect on the long term viability of local businesses and industries.

(1) The guidelines shall be updated when, in the opinion of the city manager, the conditions of the water system have changed so as to necessitate such update.

(2) The guidelines shall be published and filed in the office of the city secretary.

(b) The city manager, in the exercise of the city manager's discretion may implement any or all of the water conservation measures the city manager deems necessary at any particular time.

(1) The city manager shall notify the members of the city council before implementing any measures under this section.

(2) The city manager shall publish notice in a daily newspaper of general circulation in Nueces County when each water conservation measure takes effect.

(3) Copies of the notices published by the city manager under this section shall be filed with the city secretary. The city secretary shall send a copy of the notice to each member of the city council and a certified copy of the notice to the judges of the municipal court.

(c) The use or withdrawal of water from the water supply system of the city for the following purposes or uses is hereby regulated during any period of water shortage commencing with the promulgation and implementation of water conservation guidelines by the city manager and continuing until such water conservation measures are no longer deemed necessary by the city manager in accordance with the guidelines.

(d) The following water conservation measures may be included in the implementation guidelines developed by the city manager and implemented by the city manager.

(1) Request customers of the water system of the City of Corpus Christi through the news media announcements and utility bill inserts to voluntarily conserve and limit their use of water and notify them that they must comply with the implemented restrictions on the use of water for irrigation of vegetation.

(2) Place municipal operations on mandatory conservation.

(3) Prohibit the use of water for irrigation of lawns or lawns and other vegetation between the hours of 10:00 a.m. and 6:00 p.m.

(4) Restrict the use of water for irrigation of lawns or lawns and other vegetation, other than between the hours of 10:00 a.m. and 6:00 p.m., to specific dates or frequencies based on street numbers, as may be designated by the city manager.

a. However, any person may raise as a defense to prosecution for violation of this section the fact that the use of water for the following purposes had been specifically authorized by the city manager, if the City manager had actually authorized the use of water for that purpose on the date of the violation:

1. The water was used, other than during the hours between 10:00 a.m. and 6:00 p.m., for irrigation, at the minimum rate necessary, for the establishment and maintenance of flower gardens, vegetable gardens, fruit gardens, trees, and shrubs, or plants in containers, and applied using:

i. A hand held hose equipped with a positive shutoff nozzle.

ii. A drip irrigation system equipped with an automatic shutoff device.

iii. A soaker hose, which does not spray water into the air, equipped with an automatic shutoff device.

iv. A root feeder equipped with an automatic shutoff device.

v. A hand held bucket or watering can.

2. The water was used at any hour for irrigation, at the minimum rate necessary, for the establishment and maintenance of commercial nursery stock and applied using:

i. A hand held hose equipped with a positive shutoff nozzle.

ii. A sprinkler system.

iii. A drip irrigation system equipped with an automatic shutoff device.

iv. A soaker hose, which does not spray water into the air, equipped with an automatic shutoff device.

v. A root feeder equipped with an automatic shutoff device.

vi. A hand held bucket or watering can.

3. The water was used, other than during the hours between 10:00 am. and 6:00 p.m., for irrigation, at the minimum rate necessary, for the establishment of

newly planted lawns and plant materials within thirty (30) days of planting. Water used for this purpose may be applied by any means.

4. Wastewater treatment plant effluent, graywater, well water (which is not mixed with any water from the city's water supply), or other water not obtained from the city water system was used, may be used at any hour, if a permit is obtained from the city manager and a sign is posted stating that the water used for irrigation is wastewater effluent, graywater, water from a permitted private well, or water that was not obtained from the city's water supply.

5. The water was used, other than during the hours between 10:00 a.m. and 6:00 p.m., for irrigation, at the minimum rate necessary, for maintenance, of golf course greens and tee boxes.

6. The water was used at any hour for short periods of time for testing related to the installation, maintenance, and repair of sprinkler systems.

7. The water was used for irrigation of vegetation on a large parcel of land or unique botanical institutions, such as the Corpus Christi Botanical Gardens and Blucher Nature Center, in conformance with a special watering plan, specifically approved for that parcel by an official designated by the city manager. The official approving any special watering plan shall ensure that the plan achieves similar water conservation goals to the mandatory conservation measures applicable to other customers under this section.

b. In the event the premises have no number, application shall be made to the city building official for the assignment of a number to such premises and such premises shall thereafter bear the number so assigned. Such day or days may be changed by further directive of the city manager. In the event any premises do not have a number at the time of the occurrence of any violation under this article, the premises shall be in the category of premises with street numbers ending in zero. No person or customer shall cause or permit water to run or waste in any gutter or otherwise.

(5) Restrict the use of water for watering foundations during specific hours, specific dates, or specific frequencies based on street numbers, as may be designated by the city manager.

(6) Prohibit the washing of automobiles, trucks, trailers, boats, airplanes and any other type of mobile equipment, except that individuals and filling stations may wash cars or boats if they use a bucket, pail, or other receptacles not larger than of five-gallon capacity; however, an individual or filling station, before or after such washing, shall be permitted to rinse the car or boat off with a hose using only a reasonable amount of water in so doing. Commercial or automatic car wash establishment shall use minimum practical water settings.

(7) Prohibit the washing of building exteriors and interiors, trailers, trailer houses and railroad cars with potable water, except by a professional power washing contractor or that in the interest of public health the director of public health may permit limited use of the water as the case may be, including allowing the use of water for the removal of graffiti.

(8) Restrict the use of water for recreational uses, such as playing in sprinklers, except during times when the use of water for irrigating lawns is permitted, operating water toys such as "slip & slides", or operating sprayers on pool slides.

(9) Restrict the use of fire hydrants for any purpose other than firefighting; except that the city manager may permit the use of metered fire hydrant water by the city or by commercial operators using jet rodding equipment to clear and clean sanitary and storm sewers.

(10) Prohibit the use of potable water in ornamental fountains or in artificial waterfalls is prohibited where the water is not reused or recirculated in any manner.

(11) Prohibit the use of potable water to wash down any sidewalks, walkways, driveways, parking lots, tennis courts, or other hard-surfaced area, or building or structure, except by a professional power washing contractor.

(12) Prohibit the use of potable water for dust control.

(13) Prohibit the use of potable water by a golf course to irrigate any portion of its grounds, except those areas designated as tees and greens may be watered between the hours of 6:00

a.m. and 10:00 a.m. on Mondays, Wednesdays, Fridays, and Sundays.

(14) Prohibit the use of water to serve a customer in a restaurant, unless requested by the customer.

(15) Prohibit new service connections to the city's water system where some other source independent of the city's water system is existing and in use at the time this element of Condition III is implemented.

(16) Reserved.

(17) Impose mandatory limit of normal water use by customers without use penalty, in amounts as determined by the city manager in accordance with guidelines established by the city council.

a. In connection with the enforcement of this subdivision, the city manager shall request the city council establish a maximum limit beyond which water service will be terminated.

b. Concurrently with the implementation of this conservation measure, the city manager shall request the appointment of an allocation and review committee by city council, for the purpose of reviewing water conservation policies and establishing exemptions.

(18) Prohibit the use of potable water (water obtained from the city's water utility) for scenic and recreational ponds and lakes.

(19) Prohibit the use of potable water to put new agricultural land into production.

(20) Deny applications for new, additional, further expanded, or increased-in-size water service connections, meters, service lines, pipeline extensions, mains, or other water service facilities of any kind, except as approved by the allocation and review committee.

(21) Establish allocations of water use to industrial and commercial customers in amounts, after consultation with the allocation and review committee.

(22) Establish the maximum monthly use for a residential customer with revised rate schedules and penalties approved by the city council, based on recommendations by the allocation and review committee.

(e) The city council and city manager shall take any additional actions deemed necessary to meet the conditions resulting from the emergency.

(f) Any use of water in violation of this section or any measure implemented by the city manager under this section is deemed a waste of water.

(g) No person may use water in violation of this section or any measure implemented by the city manager under this section.

(h) Proof that a particular premises has a water meter connection registered in the name of the defendant named in the complaint, shall constitute in evidence a prima facie presumption that the person in whose name the water connection was registered was the person who permitted or caused the act of waste charged to occur on the premises.

(i) Courts shall take judicial notice of the notices published by the city manager under this section, and the notices may be read into evidence without pleading or proof.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24576, § 2, 9-11-01)

Sec. 55-154. Allocation and review committee, establishment, composition, powers, and duties.

(a) The allocation and review committee shall be composed of six (6) members, the assistant city manager for public works and utilities, the director of public health, a representative of industry, a representative of business and commerce, a homemaker-citizen, and a citizen of the city.

(1) The industry, business, homemaker, and citizen members shall be appointed by the mayor and council and shall serve at the pleasure of the city council.

(2) In addition, six (6) alternate members shall be appointed. Each alternate shall serve in place of his/her respective regular committee member whenever that regular committee member is unavailable to participate.

(3) The city manager shall appoint alternates for the assistant city manger for public works and utilities and the director of public health.

(4) The mayor and council shall appoint alternates for the industry, business, homemaker, and citizen members of the committee. Alternates appointed shall have qualifications similar to those of their respective regular member.

(5) An alternate serving in place of a regular committee member shall exercise the same powers and have the same duties as a regular member.

(b) The committee shall consider requests of water users for special consideration to be given as to their respective particular circumstances and the committee shall hear and decide such requests and is hereby authorized to, in special cases, grant such variance from the terms of this plan as will not be contrary to the public interest, where, owing to special conditions, a literal enforcement of the provisions of this plan will result in unnecessary hardship, and so that the spirit of this plan shall be observed and substantial justice done.

(1) Should a permit for special exception be granted by such committee, it shall be in effect from the time of granting; provided, that the permit is prominently posted on the premises within two (2) feet of the street number located on the premises.

(2) Should protest be received after the granting of any such special permit, the committee shall consider the revocation of such permit and shall reconsider the granting of such permit at a public hearing, notice of which shall have been given at least one (1) day prior to the holding of such hearing.

(3) After the conclusion of such hearing, the committee shall take such action by way of revocation of such permit, or refusal to revoke the same, or modification of such permit as the committee may deem proper under the circumstances.

(Ord. No. 24396, § 1, 3-20-01)

Sec. 55-155. Violations, penalties, and enforcement.

(a) Any person that intentionally, knowingly, recklessly, or with criminal negligence violates any provision of this article shall be deemed guilty of a misdemeanor and, upon conviction, shall, upon conviction, be guilty of a misdemeanor, punishable by a fine of not more than five hundred dollars ($500.00) per violation per day.

(b) The commission of a violation of each provision, and each separate violation thereof, shall be deemed a separate offense, in and upon conviction thereof, shall be fined as hereinabove provided.

(c) If any person or a second person in the same household or premises, is found guilty of a second violation of this plan, the water superintendent shall be authorized to discontinue water service to the premises where such violation occurs.

(d) Any police officer, or other city employee designated by the city manager, may issue a citation to a person he reasonably believes to be in violation of this article.

(e) The citation shall be prepared in duplicate and shall contain the name and address of the alleged violator, if known, the offense charged, and shall direct him to appear in the Corpus Christi Municipal Court no sooner than ten (10) days and no later than twenty-one (21) days of service of the citation.

(1) The alleged violator shall be requested to sign the citation, and shall be served a copy of the citation.

(2) Service of the citation shall be complete upon the attempt to give it to the alleged violator, to an agent or employee of a violator, or to a person over fourteen (14) years of age who is a member of the violator's immediate family or is a resident at the violator's residence.

(f) The alleged violator shall appear in municipal court to make his plea no sooner than ten (10) days and no later than twenty-one (21) days of service of the citation, and failure to so appear shall be a violation of this article.

(g) A police officer may arrest for any offense under this article where permitted by state arrest law.

(h) Cases filed under this section shall be expedited and given preferential setting in municipal court before all other cases.

(i) A person in apparent control of the property where the violation occurs or originates shall be presumed to be the violator, and proof of facts showing apparent control by such person of the premises and proof that the violation occurred on the premises shall constitute prima facie evidence that said person committed the violation, but said person shall have the right to show that he did not commit the violation.

(j) Any person whose name is on file with the utilities billing office as the customer on the water account for the property where the violation occurs or originates shall be presumed to be the violator, and proof that the violation occurred on said premises shall constitute prima facie evidence that the customer committed the violation, but said customer shall have the right to show that he did not commit the violation.

(k) Parents shall be presumed to be responsible for violations of their minor children, and proof that a child committed a violation on property within the parent' s control shall constitute prima facie evidence that said parent committed the violation, but said parent may be excused if he proves that he had previously directed the child not to use the water as it was used in the violation and that the parent could not have reasonably known of the violation.

(l) If any person fails to respond to a citation or summons issued for a violation of this article within the time allowed, upon receipt of notice from the director or a judge of the municipal courts, the water superintendent is authorized to discontinue water service to the premises where such violation occurs.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24576, § 3, 9-11-01)

Sec. 55-156. Reserved.

Editor's note: Ord. No. 24576, § 4, adopted Sept. 11, 2001, renumbered §§ 55-155.1, 55-156, 55-157 as §§ 55-157, 55-158, 55-159. To maintain sequence of sections, 55-156 has been reserved by the editor. See the Code Comparative Table.

Sec. 55-157. Surcharges and termination of service.

(a) *General.*

(1) This section is provided to implement and enforce the mandatory limits on water usage called for in Condition III and IV of this drought contingency plan.

(2) The surcharges established herein are solely intended to regulate and deter the use of water during a period of serious drought in order to achieve necessary water conservation.

(3) The city council expressly finds that the drought poses a serious and immediate threat to the public and economic health and general welfare of this community, and that the surcharges and other measures adopted herein are essential to protect said public health and welfare.

(4) This section, and the surcharges and measures adopted herein are purely an exercise of the city's regulatory and police power, and the surcharges and connection fees herein are in no way to be considered rates for production of revenue.

(5) All monies collected from surcharges shall be placed in a special fund to be used for research and development of alternative or expanded water sources for the City of Corpus Christi and its water customers.

(b) *Residential water customers, who are not billed through a master water meter.*

(1) Residential water customers, who are billed through a master water meter, shall pay the following surcharges:

a. Five dollars ($5.00) for the first one thousand (1,000) gallons over allocation.

b. Eight dollars ($8.00) for the second one thousand (1,000) gallons over allocation.

c. Sixteen dollars ($16.00) for the third one thousand (1,000) gallons over allocation.

d. Forty dollars ($40.00) for each additional one thousand (1,000) gallons over allocation.

e. The surcharges shall be cumulative.

(2) When the combined reservoir capacity is less than twenty (20) per cent of total capacity, the allocation to residential customers shall be as follows:

TABLE INSET:

Persons Per Household	Gallons Per Month
1 or 2	6,000
3 or 4	7,000
5 or 6	8,000
7 or 8	9,000
9 or 10	10,000
11 or more	12,000

(3) In this subsection:

" *Household* " means the residential premises served by the customer's meter.

" *Persons per household* " includes only those persons currently physically residing at the premises and expected to reside there for the entire billing period.

(4) Size of households.

a. It shall be assumed that a particular customer's household is comprised of two (2) persons unless the customer notifies the city of a greater number, on a form prescribed by the city manager.

1. The city manager shall give his best effort to see that such forms are mailed to every residential customer.

2. If, however, a customer does not receive such a form, it shall be the customer's responsibility to go to the city's utility billing office and sign the form if the customer desires to claim more than two (2) persons.

3. New customers may claim more persons at the time of applying for their water service on the form prescribed by the city manager.

4. When the number of persons in a household increases so as to place the customer in a different category, the customer may notify the city of the change on such form, and the change will be implemented in the next practicable billing period.

5. If the number of persons in a household is reduced, the customer shall notify the city in writing within two (2) days.

6. In prescribing the method for claiming more than two (2) persons, the city manager shall adopt methods to insure the accuracy of the claim.

7. Any person who knowingly, recklessly, or with criminal negligence falsely reports the number of persons in a household or fails to timely notify the city of a reduction in the number of persons in a household shall be fined not less than two hundred dollars ($200.00).

(c) *Residential customers who are billed from a master water meter.*

(1) When the combined reservoir capacity is less than twenty (20) per cent of total capacity, a residential customer billed from a master water meter, which jointly measures water to multiple permanent residential dwelling units (for example, apartments, mobile homes), shall be allocated six thousand (6,000) gallons for each dwelling unit.

(2) Number of dwelling units assigned to a master water meter.

a. It shall be assumed that such a customer's meter serves two (2) dwelling units unless the customer notifies the city of a greater number, on a form prescribed by the city manager.

b. The city manager shall give his best effort to see that such forms are mailed to every such customer.

c. If, however, such customer does not receive such a form, it shall be the customer's responsibility to go to the city's utility billing office and sign the form if the customer desires to claim more than two (2) dwellings.

d. A dwelling unit may be claimed under this provision whether it is occupied or not. New customers may claim more dwelling units at the time of applying for their water service on the form prescribed by the city manager.

e. If the number of dwelling units served by a master meter is reduced, the customer shall notify the city in writing within two (2) days.

f. In prescribing the method for claiming more than two (2) dwelling units, the city manager shall adopt methods to insure the accuracy of the claim.

g. Any person who knowingly, recklessly, or with criminal negligence falsely reports the number of dwelling units on a meter or fails to notify the city of a reduction in the number of dwelling units on a meter shall be fined not less than two hundred dollars ($200.00).

(3) In this subsection, "person" includes individuals, partnerships, associations, corporations, and all other legal entities.

(4) Residential customers billed from a master meter under this provision shall pay the following monthly surcharges:

1. Five dollars ($5.00) for each one thousand (1,000) gallons over allocation up through one thousand (1,000) gallons for each dwelling unit.

2. Eight dollars ($8.00), thereafter, for each additional one thousand (1,000) gallons over allocation up through a second one thousand (1,000) gallons for each dwelling unit.

3. Sixteen dollar ($16.00), thereafter, for each additional one thousand (1,000) gallons over allocation up through a third one thousand (1,000) gallons for each dwelling unit.

4. Forty dollars ($40.00), thereafter, for each additional one thousand (1,000) gallons over allocation.

Examples of applications of the surcharge formula are as follows:

Apartment complex contains one hundred (100) units. Allocation is six hundred thousand (600,000) gallons (hypothetically):

Usage is six hundred ten thousand (610,000) gallons. Surcharge is fifty dollars ($50.00), computed as follows: ten (10) thousands of gallons at five dollars ($5.00) each.

Usage is seven hundred ten thousand (710,000) gallons. Surcharge is five hundred eighty dollars ($580.00), computed as follows: one hundred (100) thousands of gallons at five dollars ($5.00) each plus ten (10) thousands of gallons at eight dollars ($8.00) each.

Usage is nine hundred ten thousand (910,000) gallons. Surcharge is three thousand three hundred dollars ($3,300.00), computed as follows: one hundred (100) thousands of gallons at five dollars ($5.00) each, plus one hundred (100) thousands of gallons at eight dollars ($8.00) each, plus one hundred (100) thousands of gallons at sixteen dollars ($16.00) each, plus ten (10) thousands of gallons at forty dollars ($40.00) each.

(d) *Nonresidential commercial customer, other than an industrial customer, who uses water for processing.*

(1) A monthly water usage allocation shall be established by the city manager or his designee for each nonresidential commercial customer, other than an industrial customer, who uses water for processing.

(2) Method of establishing allocation.

a. When the combined reservoir capacity is less than twenty (20) per cent of total capacity, the nonresidential commercial customer's allocation shall be approximately seventy-five (75) per cent of the customer' s usage for the corresponding month's billing period during previous twelve (12) months.

b. If the customer's billing history is shorter than twelve (12) months, the monthly average for the period for which there is a record shall be used for any monthly period for which no history exists.

c. Provided, however, a customer, seventy-five (75) per cent of whose monthly usage is less than six thousand (6,000) gallons, shall be allocated six thousand (6,000) gallons.

d. The city manager shall give his best effort to see that notice of each nonresidential commercial customer's allocation is mailed to such customer.

e. If, however, the customer does not receive such notice, it shall be the customer's responsibility to contact the city' utilities billing office to determine the allocation, and the allocation shall be fully effective notwithstanding lack of receipt of written notice.

f. Upon request of the customer or at the initiative of the city manager, the allocation may be reduced or increased,

(1) If the designated period does not accurately reflect the customer's normal water usage,

(2) If one (1) nonresidential customer agrees to transfer part of its allocation to another nonresidential customer, or

(3) If other objective evidence demonstrates that the designated allocation is inaccurate under present conditions.

g. A customer may appeal an allocation established hereunder to the water allocation and review committee on grounds of unnecessary hardship.

(e) *Industrial customers, who use water for processing.*

(1) A monthly water usage allocation shall be established by the city manager or his designee for each an industrial customer, which uses water for processing (e.g., an industrial customer).

(2) Method of establishing allocation.

a. When the combined reservoir capacity is less than twenty (20) per cent of total capacity, the industrial customer allocation shall be ninety (90) per cent of the customer' s water usage baseline.

b. Three (3) months after the initial imposition of the allocation for industrial customers, the industrial customer's allocation shall be further reduced to eighty-five (85) per cent of the customer's water usage baseline.

c. The customer's water usage baseline will be computed on the average water usage for the thirty-six (36) month period ending prior to the date of implementation of Condition II.

d. If the customer's billing history is shorter than thirty-six (36) months, the monthly average for the period for which there is a record shall be used for any monthly period for which no history exists.

e. The city manager shall give his best effort to see that notice of each industrial customer's allocation is mailed to such customer.

f. If, however, the customer does not receive such notice, it shall be the customer's responsibility to contact the city utilities billing office to determine the allocation, and the allocation shall be fully effective notwithstanding lack of receipt of written notice.

g. Upon request of the customer or at the initiative of the city manager, the allocation may be reduced or increased, if:

1. The designated period does not accurately reflect the customer's normal water usage because customer had shutdown a major processing unit for overhaul during the period.

2. The customer has added or is in the process of adding significant additional processing capacity. Only additional capacity that was under contract and publicly announced prior to the implementation of Condition II should be considered.

3. The customer has shutdown or significantly reduced the production of a major processing unit.

4. The customer has previously implemented significant permanent water conservation measures.

5. The customer agrees to transfer part of its allocation to another industrial customer.

6. Other objective evidence demonstrates that the designated allocation is inaccurate under present conditions.

h. A customer may appeal an allocation established under this provision to the water allocation and review committee on grounds of unnecessary hardship.

(f) *Nonresidential commercial and industrial customers shall pay the following surcharges:*

(1) Customers whose allocation is six thousand (6,000) gallons through twenty thousand (20,000) gallons per month:

a. Five dollars ($5.00) per one thousand (1,000) gallons for the first one thousand (1,000) gallons over allocation.

b. Eight dollars ($8.00) per one thousand (1,000) gallons for the second one thousand (1,000) gallons over allocation.

c. Sixteen dollars ($16.00) per one thousand (1,000) gallons for the third one thousand (1,000) gallons over allocation.

d. Forty dollars ($40.00) for each additional one thousand (1,000) gallons over allocation.

e. The surcharges shall be cumulative.

2. Customers whose allocation is twenty-one thousand (21,000) gallons per month or more:

a. One (1) times the block rate for each one thousand (1,000) gallons in excess of the allocation up through five (5) per cent above allocation.

b. Three (3) times the block rate for each one thousand (1,000) gallons from five (5) per cent through ten (10) per cent above allocation.

c. Five (5) times the block rate for each one thousand (1,000) gallons from ten (10) per cent through fifteen (15) per cent above allocation.

d. Ten (10) times the block rate for each one thousand (1,000) gallons more than fifteen (15) per cent above allocation.

e. The surcharges shall be cumulative.

f. As used herein, "block rate" means the charge to the customer per one thousand (1,000) gallons at the regular water rate schedule at the level of the customer's allocation.

(g) *Nonresidential customer is billed from a master meter.*

(1) When a nonresidential customer is billed from a master meter which jointly measures water to multiple residential dwelling units (for example: apartments, mobile homes), the customer may pass along any surcharges assessed under this plan to the tenants or occupants, provided that:

a. The customer notifies each tenant in writing:

1. That the surcharge will be passed along.
2. How the surcharge will be apportioned.
3. That the landlord must be notified immediately of any plumbing leaks.
4. Of methods to conserve water (which shall be obtained from the city).

b. The customer diligently maintains the plumbing system to prevent leaks.

c. The customer installs water saving devices and measures (ideas for which are available from the city) to the extent reasonable and practical under the circumstances.

d. The surcharge shall be passed along, where permissible, to dwelling units in proportion to the rent or price charged for each dwelling unit.

(h) *Water service to the customer may be terminated under the following conditions:*

(1) Monthly residential water usage exceeds allocation by four thousand (4,000) gallons or more two (2) or more times (which need not be consecutive months).

(2) Monthly water usage on a master meter which jointly measures water usage to multiple residential dwelling units exceeds allocation by four thousand (4,000) gallons times the number of dwelling units or more two (2) or more times (which need not be consecutive months).

(3) Monthly nonresidential water usage for a customer whose allocation is six thousand (6,000) gallons through twenty thousand (20,000) gallons exceeds its allocation by seven thousand (7,000) gallons or more two (2) or more times (which need not be consecutive months).

(4) Monthly nonresidential water usage for a customer whose allocation is twenty-one thousand (21,000) gallons or more exceeds its allocation by fifteen (15) per cent or more two (2) or more times (which need not be consecutive months).

(5) For residential customers and nonresidential customers whose allocation does not exceed twenty thousand (20,000) gallons, after the first disconnection water service shall be restored upon request for a fee of fifty dollars ($50.00).

(6) For such customers, after the second disconnection, water service shall be restored within twenty-four (24) hours of the request for a fee of five hundred dollars ($500.00).

(7) If water service is disconnected a third time for such customer, water service shall not be restored until the city re-enters a level of water conservation less than Condition III.

(8) For master meter customers, the service restoration fees shall be the same as above times the number of dwelling units.

(9) For nonresidential customers whose allocation is twenty-one thousand (21,000) gallons per month or more.

a. After the first disconnection water service shall be restored upon request for a fee in the amount of "X" in the following formula:

$$X = \frac{\$50.00 \times \text{Customer's Allocation in gallons}}{20{,}000 \text{ gallons}}$$

b. After the second disconnection for said customers, water service shall be restored within twenty-four (24) hours of the request for a fee of ten (10) times "X".

c. If water service is disconnected a third time for such customer, water service shall not be restored until the city re-enters a level of water conservation less than Condition III.

d. The city manager is directed to institute written guidelines for disconnection of water service under this provision which will satisfy minimum due process requirements, if any.

(i) It shall be a defense to imposition of a surcharge hereunder, or to termination of service, that water used over allocation resulted from loss of water through no fault of the customer (for example, a major water line break).

(1) The customer shall have the burden to prove such defense by objective evidence (for example, a written certification of the circumstances by a plumber).

(2) A sworn statement may be required of the customer.

(3) This defense shall not apply if the customer failed to take reasonable steps for upkeep of the plumbing system, failed to reasonably inspect the system and discover the leak, failed to take immediate steps to correct the leak after discovered, or was in any other way negligent in causing or permitting the loss of water.

(j) When this section refers to allocation or water usage periods as "month," "monthly," "billing period," and the like, such references shall mean the period in the city's ordinary billing cycle which commences with the reading of a meter one (1) month and commences with the next reading of that meter which is usually the next month.

(1) The goal for the length of such period is thirty (30) days, but a variance of two (2) days, more or less, will necessarily exist as to particular meters.

(2) If a meter reader is prevented from timely reading a meter by a dog or any other obstacle which is attributable to the customer, the original allocation shall apply to the longer period without modification.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24576, § 4, 9-11-01)

Note: Formerly § 55-155.1.

Sec. 55-158. Effluent distribution; permit and regulations.

(a) Upon implementation of the City of Corpus Christi Water Conservation Plan as provided in this section, the city may make available effluent water discharged from its sewage treatment plants for the purpose of watering lawns, grass, and other plants, dust control and similar uses.

(1) Such effluent water shall be made available only under the terms and conditions herein provided and only to such persons as are duly permitted as distributors as provided in this section.

(2) The city shall be under no obligation to provide such effluent and reserves the right to discontinue such service at any time and to limit the volume and to establish or alter loading procedures and/or locations as necessary for the efficient administration of the wastewater division.

(b) No effluent distribution permit shall be issued except upon application filed with the wastewater division of the city. Every such application shall contain the following information:

(1) Name of applicant.

(2) Name of authorized representative (e.g. president of corporation; partner; etc.) if applicant is other than an individual.

(3) Business address and phone number.

(4) Residence address and phone number of authorized individual representative.

(5) Description of each vehicle and container unit to be used in the transportation or distribution of effluent water, including the make, year, model, type, weight and gross vehicle weight, container capacity in gallons, vehicle registration number, and the state safety inspection certificate number and expiration date.

(6) Names and driver's license number of every proposed driver of such vehicles.

(7) Statement of previous use of container units and any proposed use after or concurrently with such units use for effluent distribution.

(8) Statement of the proposed uses of any effluent water, including whether the use is proposed for residential, commercial, or industrial purpose.

(c) Upon the filing of the required application, and payment of the permit fee specified herein for each container unit, the wastewater superintendent, or the superintendent's designee, shall upon his determination that the applicant and vehicles and container units are in compliance with all applicable provisions of this article, issue a permit for each such container unit.

(1) The permit shall identify the particular unit for which it is issued and shall be displayed in a prominent place upon the unit.

(2) Each unit shall be separately permitted.

(d) The permit fee shall be fifty dollars ($50.00) per month for each unit plus five dollars ($5.00) per month for each unit per one thousand (1,000) gallons of capacity (or portion thereof) over the first one thousand (1,000) gallons of capacity.

(e) Permits shall be issued on a quarterly basis from the effective date of this plan; fee proration shall be on a monthly basis.

(f) Notwithstanding subsection (g) of this section, a resident of the City of Corpus Christi may obtain effluent at no charge from a wastewater treatment plant, designated by the wastewater superintendent, for the irrigation of vegetation, dust control, or watering a foundation at the individual's personal residence.

(1) Any effluent received under this subsection may not be sold or transferred to another individual or used for commercial purposes.

a. Before receiving effluent the resident must obtain a permit from the wastewater superintendent, or the superintendent's designee.

b. Prior to receiving a permit, the resident must complete a course of instruction on the handling of wastewater effluent that has been developed by the city's health department.

c. Any container used to receive and transport effluent must have a lid or cap, be watertight, and be properly secured to the vehicle.

d. All containers are subject to inspection and approval of the city health department or wastewater department.

e. Any effluent received under this subsection must be immediately transported to the personal residence of the individual receiving the effluent and used for the irrigation of vegetation, dust control, or watering a foundation.

f. The effluent may not be stored for future use.

g. A resident using effluent for the irrigation of vegetation or dust control must post a sign on the property legible from the street stating that effluent is being used on the property.

h. Every resident obtaining effluent under this subsection must either:

1. Provide proof of and maintain in force a property liability insurance policy (homeowner/renter) in the amount of three hundred thousand dollars ($300,000.00) per occurrence. or

2. Sign a form provided by the superintendent that releases the City of Corpus Christi from any liability resulting from the resident's improper use or transportation of the effluent and agree to hold the city harmless, including reimbursing the city for the costs of defending itself.

(g) Every effluent distribution permit shall be subject to the following terms and conditions and no person shall receive or distribute effluent water except in compliance herewith:

(1) Container units or tanks shall have a minimum capacity of five hundred (500) gallons; shall be capable of being closed water tight and shall be so closed during transport of effluent water; and shall be maintained in a leak-proof condition; provided, however, that special permits may be issued for container units with a capacity of less than five hundred (500) gallons upon the determination by the wastewater division superintendent that all other container unit specifications herein required have been met and that the particular container unit does not create an increased risk to the public health and safety.

(2) No vehicle may be used in connection herewith which has not been reported on the application and approved for such use.

(3) Every driver or handler must be certified by the wastewater division prior to receiving any effluent water from the city.

a. The wastewater division may certify a driver or handler who has completed a course of instruction on the handling of wastewater effluent that has been developed by the city's health department.

(4) Effluent water shall be used as soon as possible to prevent regrowth of bacteria.

a. Permittees shall check effluent water in their units not less than every four (4) hours for chlorine residual, except for effluent stored in fixed-site containers which shall be checked not less than every eight (8) hours.

(5) Chlorine residuals shall be maintained at one (1) milligram per liter (parts per million) [1 mg/l (ppm)], consistent throughout the effluent container.

(6) The minimum quality of the effluent must not exceed conditions on the use of effluent set out in any permits or authorizations issued to the city by a federal or state regulatory agency or the applicable regulations of a federal or state regulatory agency.

(7) Effluent containers, including those used for storage, shall be subject to inspection and approval of the city health department or wastewater division, whose inspectors are hereby authorized to prohibit the use of any container or effluent water which is determined to be outside the parameters established in this section or is otherwise determined to present a danger to public health.

(8) Every permittee shall provide proof of and shall maintain in force a policy of comprehensive general liability insurance in the amount specified by the city's risk manager under section 17-15; or shall maintain a policy of general business liability insurance in the same or greater amount with a contractual liability endorsement; and shall maintain a policy of automobile liability insurance in the minimum amounts set by state law. The city shall be named as an additional insured on the general liability insurance policies.

(9) By acceptance of a permit under this section and/or receipt of effluent water from the city system, the permittee and/or recipient of such effluent agree to fully indemnify, save and hold harmless, the City of Corpus Christi, Texas, its agents and employees, from and against all claims and actions, and all expenses incidental to the investigation and defense thereof, based upon or arising out of damages or injuries to person or property in any way related to or in connection with the use or distribution of effluent water under this section.

(10) Permittees shall provide a written notice to every person to whom effluent is furnished which shall state in not less than ten (10) point type, substantially as follows:

"CAUTION

"You are hereby advised that effluent water is the discharged water from a sewage treatment plant. The Director of Public Health has determined that improper use or handling could be harmful and recommends the following precautions:

"1. Do not use effluent water for drinking, bathing, or personal hygiene purposes.

"2. Do not use effluent water for washing autos, clothes, or other personal contact items.

"3. Do not use effluent water in swimming pools or for similar recreational uses.

"4. Do not allow children to play on grass wet with effluent water, wait until it dries.

"5. Do not use effluent which has been stored for more than four (4) hours unless the chlorine residual level has been tested and is not less than one (1) part per million [1 mg/1(p.m.)].

"6. Application of effluent shall be by coarse stream and shall not be by fine spray."

(h) Violation of any of the cautions set forth in subsection (g)(10) of this section, by any person, is a violation of this section.

(i) Violation of any of the provisions of this section, in addition to the general penalties provided in this particle, shall result in denial or revocation of any such violator's effluent distribution permit.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24576, § 4, 9-11-01)

Note: Formerly § 55-156.

Sec. 55-159. Operations plan for reservoir system.

To maximize the amount of water reliably available to the city and its water customers, the city manager shall operate the Lake Corpus Christi/Choke Canyon Reservoir System as follows:

(1) A minimum of two thousand (2,000) acre-feet per month will be released from Choke Canyon Reservoir to meet conditions of the release agreement between the City of Corpus Christi and the Texas Parks and Wildlife Department.

(2) In order to provide maximum dependable yield from the two (2) reservoirs, the water level in Lake Corpus Christi will be allowed to drop to elevation seventy-four (74) feet before water is released from Choke Canyon Reservoir in excess of the two thousand (2,000) acre-feet per month requirement.

(Ord. No. 24396, § 1, 3-20-01; Ord. No. 24576, § 4, 9-11-01)

Note: Formerly § 55-157.

Sec. 55-159.1. Procedures for allocating water to raw water and wholesale treated water customers on a pro rata basis during a water shortage.

(a) *Method of allocating water.* In the event that the levels in the Lake Corpus Christi/Choke Canyon Reservoir system are below fifteen (15) per cent of the combined reservoir capacity, the city manager may initiate allocation of water supplies to raw water and wholesale treated water customers on a pro rata basis under Texas Water Code Section 11.039 and the following water allocation policies and procedures:

(1) A raw water or wholesale treated water customer's monthly allocation shall be a percentage of the customer's water usage baseline. The percentage will be set by resolution of the city council based on the city manager's assessment of the severity of the water shortage condition and the need to curtail water diversions and deliveries, and may be adjusted periodically by resolution of the city council as conditions warrant. Once pro rata allocation is in effect, water diversions by or deliveries to each raw water or wholesale treated water customer shall be limited to the allocation established for each month.

(2) A monthly water usage allocation shall be established by the city manager, or the city manager's designee, for each raw water or wholesale treated water customer. The raw water or wholesale treated water customer's water usage baseline will be computed on the average water usage by month for the previous five-year period, as shown in the example given below. If the raw water or wholesale treated water customer's billing history is less than five (5) years, the monthly average for the period for which there is a record shall be used for any monthly period for which no billing history exists.

TABLE INSET:

									MONTHLY

	1996	1997	1998	1999	2000	SUM	AVE	ALLOCATION	ALLOCATION
Jan	133	137	146	148	156	720	144	0.75	108
Feb	115	122	133	133	147	650	130	0.75	98
March	130	150	146	149	159	1370	146.8	0.75	110.1
April	130	167	168	157	187	809	161.8	0.75	121.35
May	160	152	179	183	171	845	169	0.75	126.75
June	226	184	172	205	249	1654	207.2	0.75	155.4
July	235	274	232	314	246	1301	260.2	0.75	195.15
Aug	222	203	206	337	309	1277	255.4	0.75	191.55
Sept	199	160	196	229	198	2578	196.4	0.75	147.3
Oct	165	172	197	165	185	884	176.8	0.75	132.6
Nov	139	142	149	155	162	747	149.4	0.75	112.05
Dec	142	143	150	156	165	1631	151.2	0.75	113.4
Total	1996	2006	2074	2331	2334		2018.2		

(3) The city manager shall provide notice, by certified mail, to each raw water or wholesale treated water customer informing them of their monthly water usage allocations and shall notify the news media and the Executive Director of the Texas Natural Resource Conservation Commission upon initiation of pro rata water allocation.

(4) Upon request of the raw water or wholesale treated water customer or at the initiative of the city manager, the allocation may be reduced or increased if:

a. The designated period does not accurately reflect the raw water or wholesale treated water customer's normal water usage;

b. The customer agrees to transfer part of its allocation to another raw water or wholesale treated water customer; or

c. Other objective evidence demonstrates that the designated allocation is inaccurate under present conditions. A customer may appeal an allocation established under this section to the City Council of the City of Corpus Christi.

(b) *Enforcement.* During any period when pro rata allocation of available water supplies is in effect, raw water or wholesale treated water customers shall pay the following surcharges on excess water diversions and/or deliveries:

(1) One and one-quarter (1.25) times the normal water charge per acre-foot for water diversions or deliveries in excess of the monthly allocation up through ten (10) per cent above the monthly allocation.

(2) Two (2) times the normal water charge per acre-foot for water diversions and/or deliveries more than ten (10) per cent above the monthly allocation.

(3) The above surcharges shall be cumulative.

(c) *Variances.*

(1) The city manager, or the city manager's, may, in writing, grant a temporary variance to the pro rata water allocation policies provided by this section if it is determined that failure to grant such variance would cause an emergency condition adversely affecting the public health, welfare, or safety, and if one (1) or more of the following conditions are met:

a. Compliance with the plan cannot be technically accomplished during the duration of the water supply shortage or other condition for which the plan is in effect.

b. Alternative methods can be implemented which will achieve the same level of reduction in water use.

(2) Raw water or wholesale treated water customers requesting an exemption from the provisions of this section shall file a petition for variance with the city manager within five (5) days after pro rata allocation has been invoked.

(3) All petitions for variances shall be reviewed by the city council, and shall include the following:

a. Name and address of the petitioner(s).

b. Detailed statement with supporting data and information as to how the pro rata allocation of water under the policies and procedures established in this section adversely affects the petitioner or what damage or harm will occur to the petitioner or others if petitioner complies with this section.

c. Description of the relief requested.

d. Period of time for which the variance is sought.

e. Alternative measures the petitioner is taking or proposes to take to meet the intent of this section and the compliance date.

f. Other pertinent information.

(4) Variances granted by the city council shall be subject to the following conditions, unless waived or modified by the city council.

a. Variances granted shall include a timetable for compliance.

b. Variances granted shall expire when the pro-rata allocation of water to raw water or wholesale treated water customers is no longer in effect, unless the petitioner has failed to meet specified requirements.

c. No variance shall be retroactive or otherwise justify any violation of this section occurring prior to the issuance of the variance.

(d) *Contractual remedies not affected.* Nothing in this section supersedes any remedies available to the city under any contract with a raw water or wholesale treated water customer due to the customers failure to adopt or impose water conservation measures required by the contract.

(Ord. No. 24605, § 1, 10-9-01)

Appendix B

Support Documentation for Facility Siting and Site Selection and Analysis

Appendix B-1

Support Documentation for Facility Sizing

Memorandum

DATE: February 17, 2004

TO: Mark Lowry

FROM: Larry VandeVenter

SUBJECT: Corpus Christi Desalination Facility Feasibility Study

CC: Stan Williams

PROJECT: 036202033.0001.00001

Attached please find the supporting data for the Task 1 Memorandum submitted on January 30, 2004. The following tables summarize the preliminary design criteria (to be re-visited in Task 3), sizing and power requirements of the pre-treatment system, pre-treatment residuals handling system and desalination system.

Unit process data were selected from typical values outlined in either:

Kawamura, S., 2000. Integrated Design and Operation of Water Treatment Facilities, 2nd Edition, John Wiley & Sons, Inc., ISBN-0-471-35093-1

AWWA / ASCE, 1990. Water Treatment Plant Design, 3rd Edtion, McGraw-Hill, ISBN-0-07-001643-7

The design criteria for the pre-treatment process developed under Task 1 are summarized in Table 1 below. Design criteria for the pre-treatment residuals section are summarized in Table 2.

The reverse osmosis design criteria were generated from the vendors proprietary performance projection software. The vendor used for this preliminary phase was Hydranautics. Design criteria for the reverse osmosis system are contained in Table 3.

Power requirements for each unit process were calculated based upon the design criteria. A detailed summary of the predicted power requirements is contained in Table 4.

Based upon the unit process design criteria, footprints for each unit process were estimated. The summary of all estimated footprints are contained in Table 5.

The purpose of Task 1 was to outline a plant size envelope and power consumption to permit site evaluation to occur. All information generated under Task 1 including data, sizing, power consumption and footprint are being revisited as part of Task 3 and are therefore subject to change.

Table 1 Pretreatment Preliminary Design Criteria

UNIT PROCESS	VALUE
Plant Capacity - Raw (mgd)	52.5
Recovery (%)	47.6
Permeate (mgd)	25
Pre-Chlorination	
Dosage (mg/L)	3
12.5% Chlorine Requirement (lbs/day)	10,656
12.5% Chlorine Requirement (gal/day)	1,068
Day Tank Volume (gal)	1,300
Bulk Tank Volume (gal)	20,000
Influent Flow Metering	
Number (N)	2
Type	Magnetic Flowmeter
Range (mgd)	25 – 55
Coagulation	
Dosage (mg/L)	25
Total Coagulation Requirement (gal/day)	2,327
Day Tank (gal)	2,800
Storage Tank (gal)	42,000
Rapid Mixing	
Number (N)	2
Number of Stages	2
Type	Vertical Mixer
Mixing Energy, per stage (G; sec^{-1})	1000
Hydraulic Retention Time, stage (sec)	30
Mixing Zone Length (ft)	10
Mixing Zone Width (ft)	10
Mixing Zone Height (ft) - water depth	12
Flocculators	
Number of Trains	6
Stages/Train	4
Detention Time (min)	46.2
Water Depth	15
Basin Volume (ft^3)	37,500
Total Volume (ft^3)	225,000
Stage 1 & Stage 2	
Type	Variable speed, vertical hydrofoil impellers
Number	8
Compartment Size (ft x ft)	25 x 25
Mixing Energy (G; sec^{-1})	50
Stage 2 & Stage 3	
Type	Variable speed, vertical hydrofoil impellers
Number	8
Compartment Size	25 x 25
Mixing Energy (G; sec^{-1})	30
Polymer (Optional)	
Dosage (mg/L)	1
Total Coagulation Requirement (#/day)	46,000
Storage Tank (#)	690,000

Table 1 Pretreatment Preliminary Design Criteria (*continued*)

UNIT PROCESS	VALUE
Sedimentation Basin	
Number	6
Type	rectangular
Size	510 x 25
Area, Basin (sq.ft.)	12750
Water Basin Depth (ft)	15
Basin Volume, each (ft^3)	191,250
Length:Width Ratio	20:1
Length: Depth Ratio	34:1
Total Volume (ft^3)	1,147,500
Detention Time (min)	235.4
Hydraulic Loading (gpm/sq.ft.)	0.50
Gravity Filters	
Design Flow per Filter (gpm)	10,000
Loading Rate (gpm/ft^2)	4
Backwash Frequency (#/day)	1/day
Backwash air requirements ($scfm/ft^2$)	3
Backwash Requirements (gpm/ft^2)	15
Backwash Duration (min)	10
Filter to Waste Duration (min)	5
Area per Filter (ft^2)	2,500
Number of Cell per Filter	4
Total Number of Filters/Cells	4/16
Area per Cell (ft^2)	625
Cell Dimensions (ft x ft)	25 x 25
Media Type	Anthracite/Sand/Garnet
Backwash Pumps	
Type	Horizontal Split Casing
Number (N + 1)	2
Flow	9375
Backwash Air Scour Blowers	
Type	-
Number (N + 1 + 1)	3
Flow (SCFM)	1875
Intermediate Clearwell	
Type	Below Grade
Number	2
HRT (min)	120
Capacity, each (gal)	4,200,000
Total Capacity (gal)	8,400,000
Dimensions, each (ft x ft)	200 x 200
Water Depth (ft)	14
Reverse Osmosis System Low-Lift Pump	
Type	Horizontal Split Casing
Number (N+1)	4
Capacity, each (gpm)	12,200
Total Capacity (gpm)	36,600

Table 2 Pretreatment Residuals Handling System Design Criteria

UNIT PROCESS	VALUE
Filter Wash Water Equalization Tank	
Type	Below Grade
Number (N)	1
Capacity, each (gal)	365,000
Total Capacity (gal)	365,000
Diameter (ft)	72
Water Depth (ft)	12
Washwater Decant Pumps	
Type	Vertical Turbine, variable speed
Number (N + 1 + 1)	4
Capacity, each (gal)	1,200
Total Capacty (gal)	2,400
Thickening Polymer Dosing	
Dosage (mg/L)	5
Total Coagulation Requirement (#/day)	70.0
Storage Tank (#)	1,050
Densadeg Solids Contact Thickener	
Inlet Flow (mgd)	2.4
Type	High Rate Solids Contact
Number (N + 1)	2
Capacity, each (gpm)	1,667
Recycle Pump	
Type	Progessive Cavity, variable speed
Number (N + 1)	3
Capacity, each (gpm)	45
Total Capacty (gpm)	45
Waste Transfer Pump	
Type	Progessive Cavity, variable speed
Number (N + 1)	2
Capacity, each (gpm)	30
Total Capacty (gpm)	30
Sludge Conditioning/Storage Tank	
Type	Above Grade
Number (N + 1)	2
Capacity, each (gal)	440,385
Total Capacity (gal)	880,770
Diameter (ft)	50
Water Depth (ft)	30
Dewatering Polymer Dosing	
Dosage (mg/L)	5
Total Coagulation Requirement (#/day)	8
Storage Tank (#)	120

Table 2 Pretreatment Residuals Handling System Design Criteria (continued.)

UNIT PROCESS	VALUE
Centrifuge Feed Pumps	
Type	Progessive Cavity, variable speed
Number (N + 1)	2
Capacity, each (gpd)	672,000
Total Capacty (gpd)	672,000
Centrifuge	
Type	Solid Bowl
Number (N + 1)	2
Solids Capacity, each (#/day)	14,000
Capacty (gpd)	672,000

Table 3 Preliminary Reverse Osmosis Unit Design Criteria

UNIT PROCESS	VALUE Feed is 50 mgd @50% recovery Permeate is 25 mgd
Skid Capacity	
Feed Water Volume, m^3/d	
Feed Water Volume, gpm	3,910
Permeate Volume, m^3/d	
Permeate Volume, gpm	1,955
Number of Skids	9
Number of Standby Skids	0
RO Skid Configuration – 1st Pass	Single Stage
Number of Pressure Vessels	160
Membrane Type	Seawater Composite, SWC3
Number of Membranes per Vessel	7
Total Number of Membranes in 1st Pass	1,120
RO Skid Configuration – 2nd Pass, 1st Split	Single Stage
Number of Pressure Vessels	42
Membrane Type	Brackish Water, ESPA2
Number of Membranes per Vessel	6
Total Number of Membranes in 2nd Pass	252
RO Skid Configuration – 2nd Pass, 2nd Split	Single Stage
Number of Pressure Vessels	21
Membrane Type	Brackish Water, ESPA2
Number of Membranes per Vessel	6
Total Number of Membranes in 2nd Pass	126
RO Skid Configuration	
Total Number of Pressure Vessels on Skid	223
Total Number of Membranes on Skid	1,498
Entire RO Configuration	
Total Number of High-Pressure Vessels	1440
Total Number of Seawater Membranes	10,080
Total Number of Medium-Pressure Vessels	567
Total Number of Softening Membranes	3,402
Power Requirement	
Without Energy Recovery Device	
Estimated Skid Power (hp)	2,600
Total Estimated RO System (hp)	23,400
Total Estimated RO System Power Draw (MW)	18
Energy Recovery Estimate	40%
With Energy Recovery Device	
Estimated Skid Power (hp)	1,560
Total Estimated RO System (hp)	14,040
Total Estimated RO System Power Draw (MW)	11

Table 4 Estimated Footprint by Unit Process

FACILITY	DIMENSIONS (FEET) Length	Width	Dia.	SITE FOOTPRINT (sq ft)	Notes
Seawater Intake				0	Assume Off-Site Location
Seawater Screening				0	Assume Off-Site Location
Seawater Low-Lift Pump Station				0	Assume Off-Site Location
Metering and Rapid Mix	40	40		1,600	
Flocculation	250	120		30,000	
Sedimentation	530	250		132,500	
Filtration	240	70		16,800	
Pre-treatment Chemical Building	70	50		3,500	
Intermediate Pump Station/wet well	200	200		40,000	Assume pump-station in clear-well footprint
RO Building	280	170		47,600	Based on 50% Increase from Gaza
Degasifier	40	60		2,400	
Disinfection Contactor/Clearwell	200	180		36,000	Based on 15% of Max Day14'depth
High Service Pump Station					Included in Clearwell Footprint
FWW EQ Tank			72	4,069	assume 12' deep, 3 backwashes
Sludge Thickening and Dewatering	150	100		15,000	
Administrative Building	70	100		7,000	
Includes:					
On-Site Laboratory					
Maintenance Shop					
Locker Room/Restroom/Showers					
Small Meeting Room					
Control Room					
Offices					
Total Facility Footprint Req'd			336,469	sq ft	
Roads/Unused Space/Etc.. Factor	50	percent	168,235	sq ft	
Total Required Site Size			504,704	sq ft	
			11.6	acres	

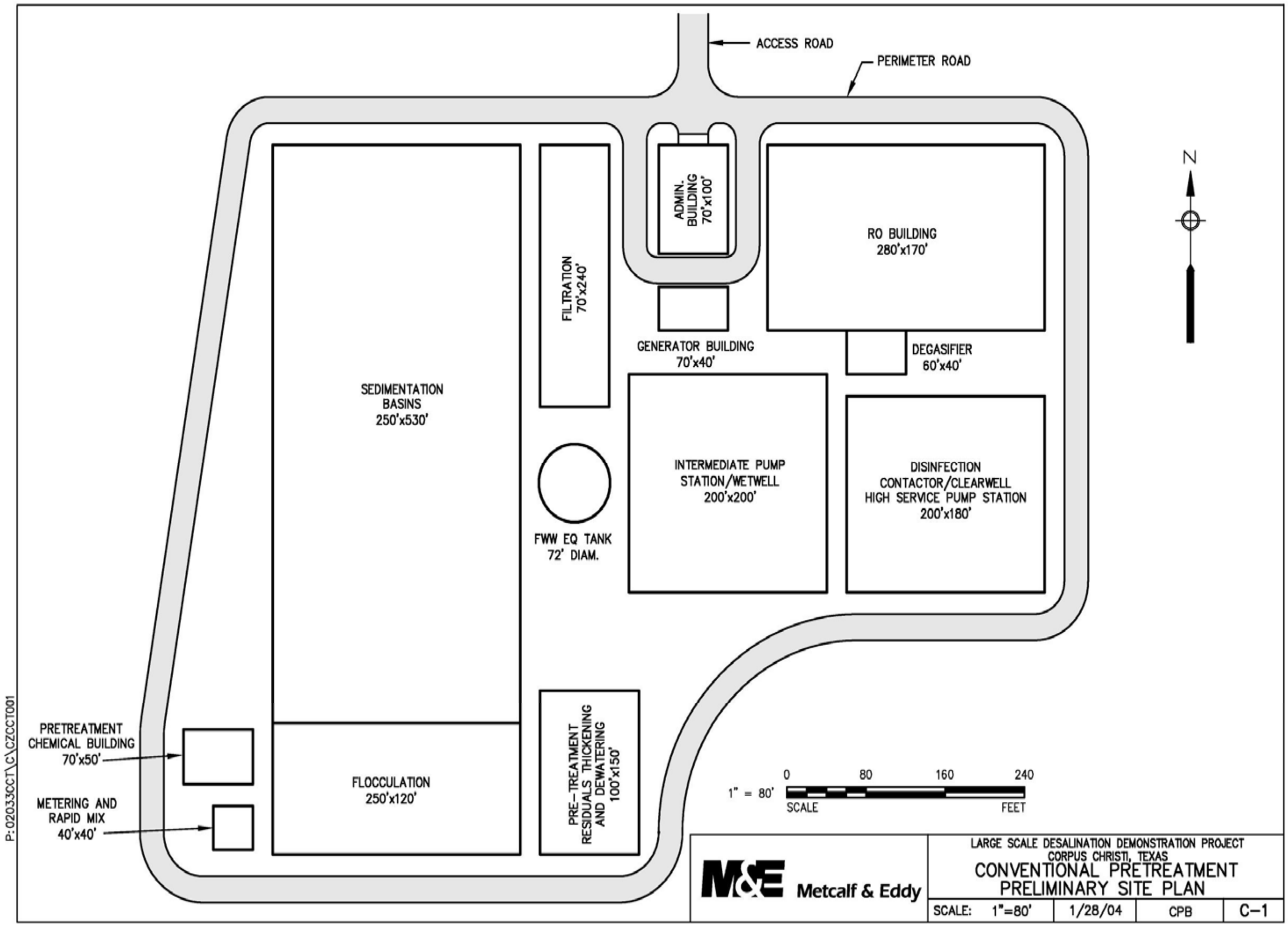
Table 5 Power Estimate

Description	Flow (mgd)	TDH (psig)	Pump Eff.	Brake HP	Motor Eff.	Motor HP	kW	Hour/ Day	Days/ yr	kWhr/Year	Cost/yr ($)
Raw Water Pumps	55	0	0.85	0	93	0	0	24.0	365	0	$0
Sed Basin Sludge Pumps	0.6	20	0.85	6	93	6	5	24.0	365	40,201	$2,613
Filter Backwash Pumps	13.5	15	0.85	97	93	104	77	4.0	365	113,064	$7,349
RO Low-Lift Pumps	50	45	0.85	1072	93	1153	860	24.0	365	7,537,620	$489,945
Densadeg Feed Pumps	2.4	20	0.85	23	93	25	18	24.0	365	160,803	$10,452
Densadeg Recycle Pumps	0.2	15	0.85	1	93	2	1	24.0	365	10,050	$653
Densadeg Waste Pumps	0.17	15	0.85	1	93	1	1	24.0	365	8,543	$555
Dewatering Feed Pumps	0.68	20	0.85	6	93	7	5	24.0	365	45,561	$2,961
RO High Pressure Pumps, First Pass	50	735	0.85	17514	93	18833	14054	24.0	365	123,114,464	$8,002,440
RO High Pressure Pumps, Second Pass	27.5	225	0.85	2949	93	3171	2366	24.0	365	20,728,456	$1,347,350
High-Service FW Pumps	25	80	0.85	953	93	1025	765	24.0	365	6,700,107	$435,507

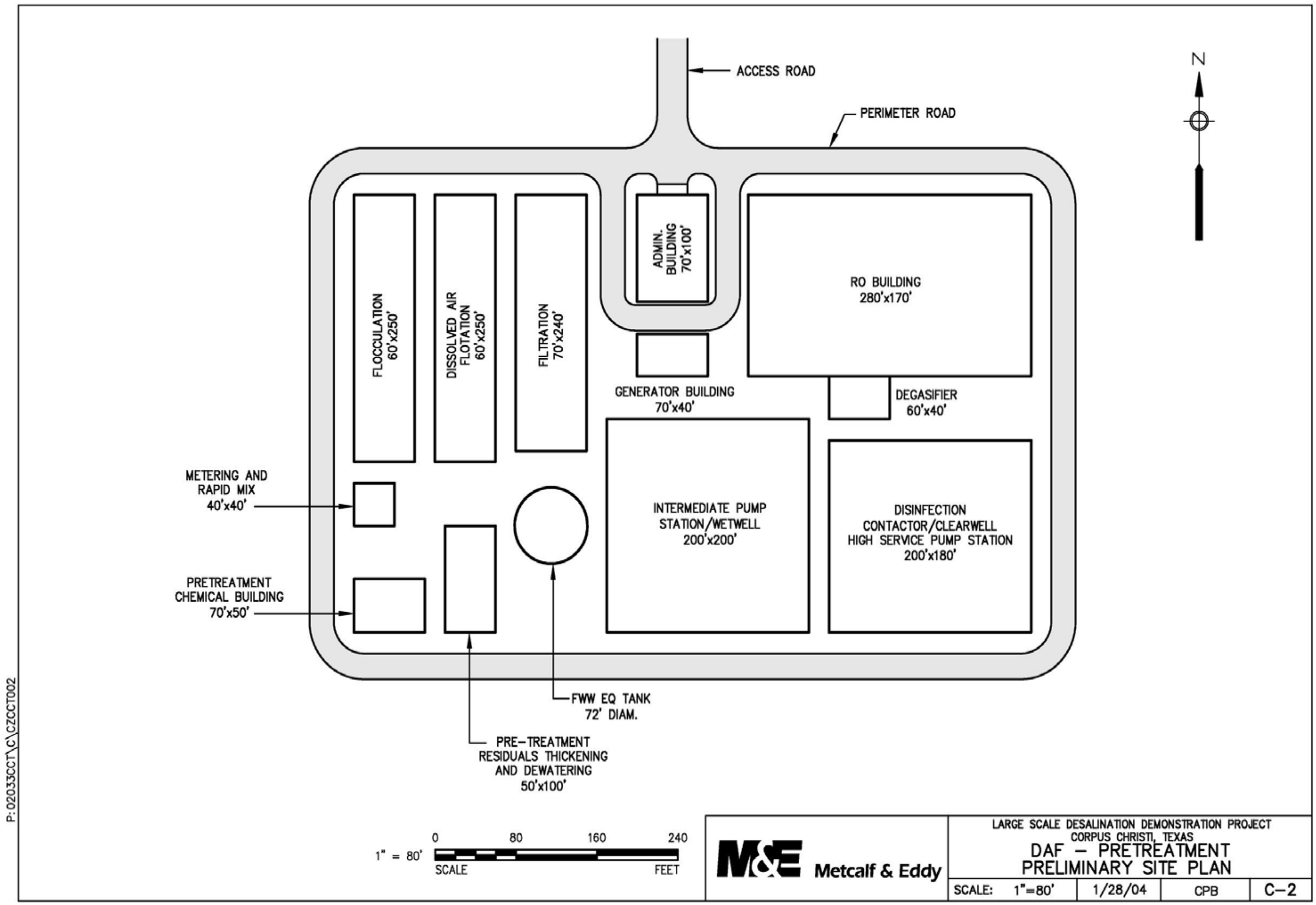
Description	System HP	kW	Hour/ Day	Days/ yr	kWhr/Year	Cost/yr ($)
Metering Pumps						
Sodium Hypochlorite Feed System	50	37	24.0	365	326,866	$21,246
Ferric Chloride Feed System	10	7	24.0	365	65,373	$4,249
DAF Polymer Feed System	10	7	24.0	365	65,373	$4,249
Filter Aid Feed System	10	7	24.0	365	65,373	$4,249
Acid Feed System	5	4	24.0	365	32,687	$2,125
Antiscalant Feed System	5	4	24.0	365	32,687	$2,125
Caustic Feed System	5	4	24.0	365	32,687	$2,125
Fluoride Feed System	5	4	24.0	365	32,687	$2,125
Corrosion Inhibitor System	5	4	24.0	365	32,687	$2,125
Lime Feed System	25	19	24.0	365	163,433	$10,623
Ammonia Feed System	5	4	24.0	365	32,687	$2,125

Table 5 Power Estimate *(continued)*

Description	SCFM	SCFM/ HP	No.	Brake HP	Motor Eff.	Motor HP	kW	Hour/ Day	Days/ yr	kWhr/Year	Cost/yr ($)
Mixers											
Rapid Mix - 1st Stage			2	70	75%	93	139	24.0	365	1,220,299	$79,319
Rapid Mix - 2nd Stage			2	70	75%	93	139	24.0	365	1,220,299	$79,319
Flocculator Drives – 1st Stage			8	2	75%	3	16	24.0	365	139,463	$9,065
Flocculator Drives – 2nd Stage			8	2	75%	3	16	24.0	365	139,463	$9,065
Flocculator Drives – 3rd Stage			8	1	75%	1	8	24.0	365	69,731	$4,533
Flocculator Drives – 4th Stage			8	1	75%	1	8	24.0	365	69,731	$4,533
Equalization Tank			1	5	75%	7	5	24.0	365	43,582	$2,833
Densadeg - 1st stage			2	20	75%	27	40	24.0	365	348,657	$22,663
Densadeg - 2nd stage			2	20	75%	27	40	24.0	365	348,657	$22,663
Description	**SCFM**	**SCFM/ HP**	**No.**	**Brake HP**	**Motor Eff.**	**Motor HP**	**kW**	**Hour/ Day**	**Day/ yr**	**kWhr/Year**	**Cost/yr ($)**
Filter Blowers	1875	10	1	188	93%	202	150	4.0	365	219,668	$14,278
Degas Blowers	1500	10	1	150	93%	161	120	4.0	365	175,734	$11,423
Description			**No.**	**Brake HP**	**Motor Eff.**	**Motor HP**	**kW**	**Hour/ Day**	**Day/ yr**	**kWhr/Year**	**Cost/yr ($)**
Sed Basin Flight Drives			6	15	93%	16	12	24.0	365	632,643	$41,122
Centrifuge			1	200	93%	215	160	16.0	365	937,249	$60,921
Centrifuge Conveyor			1	20	93%	22	16	16.0	365	93,725	$6,092
Screens			1	5	93%	5	4	24.0	365	35,147	$2,285
Allowance for Lighting			1				200	24.0	365	1,752,000	$113,880
Allowance for HVAC			1				150	24.0	365	1,314,000	$85,410
Allowance for Misc			1				150	24.0	365	1,314,000	$85,410
Total							19629				$11,012,004



ACCESS ROAD
PERIMETER ROAD
ADMIN. BUILDING 70'x100'
RO BUILDING 280'x170'
FILTRATION 70'x240'
GENERATOR BUILDING 70'x40'
DEGASIFIER 60'x40'
SEDIMENTATION BASINS 250'x530'
INTERMEDIATE PUMP STATION/WETWELL 200'x200'
DISINFECTION CONTACTOR/CLEARWELL HIGH SERVICE PUMP STATION 200'x180'
FWW EQ TANK 72' DIAM.
PRETREATMENT CHEMICAL BUILDING 70'x50'
METERING AND RAPID MIX 40'x40'
FLOCCULATION 250'x120'
PRE-TREATMENT RESIDUALS THICKENING AND DEWATERING 100'x150'
N
0
80
160
240
1" = 80'
SCALE
FEET
P:02033CCT\C\CZCCT001
Metcalf & Eddy
LARGE SCALE DESALINATION DEMONSTRATION PROJECT
CORPUS CHRISTI, TEXAS
CONVENTIONAL PRETREATMENT
PRELIMINARY SITE PLAN
SCALE: 1"=80'
1/28/04
CPB
C-1


ACCESS ROAD
PERIMETER ROAD
N
FLOCCULATION 60'x250'
DISSOLVED AIR FLOTATION 60'x250'
FILTRATION 70'x240'
ADMIN. BUILDING 70'x100'
RO BUILDING 280'x170'
GENERATOR BUILDING 70'x40'
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FWW EQ TANK 72' DIAM.
PRE-TREATMENT RESIDUALS THICKENING AND DEWATERING 50'x100'
P:02033CCT\C\CZCCT002
1" = 80'
0 80 160 240
SCALE
FEET
M&E Metcalf & Eddy
LARGE SCALE DESALINATION DEMONSTRATION PROJECT
CORPUS CHRISTI, TEXAS
DAF – PRETREATMENT
PRELIMINARY SITE PLAN
SCALE: 1"=80'
1/28/04
CPB
C-2

Appendix B-2

Support Documentation for Site Selection and Analysis

715 OAK PARK
AVECORPUS
CHRISTI, TEXAS
78408

P) 361-693-6200

F) 361-884-3522

BHP ENGINEERING & CONSTRUCTION, INC.

July 26, 2004

TO: Mark Lowry, PE, Project Manager, Turner, Collie, and Braden

FROM: Gerald FitzSimmons, PE, BHP Engineering

SUBJECT: Large-Scale Demonstration Seawater Desalination Plant, Potential Industrial Co-siting Investigation.

The scope of this investigation was to was to identify potential sites for a desalination facility among the industrial facilities around Nueces and Corpus Christi Bays.

1.A. Industrial Entities with Water Rights Permits for Saltwater in Nueces and San Patricio counties:

Elementis Chromium	84,200 ac-ft/yr	Nueces County
Flint Hill Resources East (Koch)	9,331 ac-ft/yr	Nueces County
Qualitech Steel	161,300 ac-ft/yr	Nueces County
DuPont	4,000 ac-ft/yr	San Patricio County

Also holding Water Rights Permits in Nueces and San Patricio counties are two AEP power plants, the Barney Davis power plant and the Nueces Bay power station. Since these have already been investigated previously and the status of their continued ownership by AEP has only recently been resolved, we did not pursue any investigation of these facilities. These six facilities are the only holders of Saltwater Water Rights Permits in Nueces and San Patricio counties.

1.B. Other industrial facilities of interest:

One of the other interesting possibilities is the Oxychem plant at Ingleside. It was originally built as a Caustic/Chlorine facility by DuPont and is contiguous to the DuPont plant. It was acquired several years ago by Oxychem and uses high concentration saltwater as its primary feedstock. There was some uncertainty as to whether DuPont or Oxychem had the saltwater intake permit when our investigation began. It was eventually resolved that the DuPont plant had the water rights permit, but the possibility of utilizing the reject brine from the RO unit as a plant feedstock presented some unique opportunities for this project. Therefore it was decided to further investigate the Oxychem site as a potential prospective site.

1.C. Preliminary contact assessment:

Qualitech: It was difficult to determine the present status of ownership of this facility as it is currently involved in bankruptcy proceedings. The site has a currently unused large saltwater intake which would be possibly adequate for the desalination design. However, with the current status of the ownership of this plant and those involved in the bankruptcy proceeding, it is not recommended for further followup.

Flint Hills Resources East: The contact was made with Dave Allen, Facilities Manager and Mike Wilkes, Manufacturing Manager. It was determined that the existing saltwater intake was not currently in use and was scheduled for removal. The interest level was very strong for this site and they are willing to develop further discussions. They do have sufficient land available and are willing to consider an arrangement for co-siting at this facility. They also currently are at the end of the City water main and are very interested in developing and alternate feed of water to the refinery in event of disruption of the service with the current main. Even thought this site was considered for further followup, subsequent work on this project had concerns about the salinity stability and quality of the potential intake water from the ship channel. With the decision to provide the demo plant with a salt water intake from the Gulf, and the distance of this site from the Gulf, it was not investigated further at this time.

Elementis Chromium: The contact was made with Jaime Garcia, Plant Manager of Elementis Chromium. It was determined that the saltwater intake was currently being used by Calpine for cooling water for the Cogeneration facility which is located adjacent to the Elementis facility. The interest level for this facilities management was not extremely high and further followup is not recommended. Even though followup was not recommended, and independent private entity had approached the City requesting opportunity to present a proposal. A meeting was held with A2 Water, a local water treatment equipment supplier, but after discussions they have decided not to pursue the project further at this time.

DuPont: The contact was made with Corky Neischwietz, Unit Manager and Bob Blaschke, Environmental Coordinator. It was determined that the saltwater intake is owned by DuPont and is currently not is use. The process that it had been used for has been shut down and removed from service. There was interest in cooperating with any desalination effort, but there was no compelling need for the water at the DuPont site. They do have sufficient land available for siting the facility and would be willing to be considered for locating the facility and negotiating for the necessary land. Because of the lack of compelling need for the facility at this site it is not recommended for followup.

Oxychem: The contact was made with Tom Feeney, Plant Manager, Dennis Biggs, Project Engineering Superintendent, Brian Rapp, Cogen Technical Superintendent, and Ray Gritte, Manager of Diaphragm Cell Technology. There was a very strong interest in co-siting a desalination plant with their facilities. They use a feed stream of saltwater for their process and stated that some of their plants use a concentrated seawater feed. The pros and cons and specific requirements will be addressed later in the report, but the possibility of them using the RO reject stream as a feedstock seemed very viable. They have sufficient land for the proposed site and also have a cogen facility which has excess generating capacity at this time. There are many good synergies for considering this site and is it recommended for followup.

Industrial Site Evaluation Matrix:

INDUSTRIAL SITE EVALUATION MATRIX

No.	Site	Salt Water Intake Water Rights Permit	Available Land	Level of Interest	Location of Intake	Location of Discharge
1	Qualitech	161,300 ac-ft/yr	Probable	Site in Bankruptcy – Do not recommend pursuing	CC Ship Channel	CC Ship Channel
2	Flint Hills East	9,331 ac-ft/yr	Yes	High level of interest – need alternative water supply source for this site	CC Ship Channel	CC Ship Channel
3	Elementis	84,200 ac-ft/yr	Unknown	Initial response was positive, but unable to resume contact after repeated calls. Must assume low interest level	CC Ship Channel	CC Ship Channel
4	DuPont/Oxychem	4,000 ac-ft/yr	Yes	DuPont/Oxychem is a semi-integrated site. A portion of the plant was purchased by Oxychem from DuPont. Both companies expressed a high level of interest in the project. The Oxychem plant provides the greatest level of interest because of the potential synergies with their Caustic/ Chlorine plant potential of utilizing the reject brine for a feed stream.	LaQuinta Channel. This site is the closest to the Gulf if a Gulf water intake is deemed necessary and desireable.	No Discharge if used as feed to Caustic/Chlorine plant.

1.D. Based on the observations and information in 1.C. above it is recommended that the Oxychem site be given further evaluation and consideration as potential desalination site options. Results of the additional site visits and information for site analysis will be provided in section 1.E. below.

1.E. Developed site analysis

Oxychem:

Oxychem has a salt water feed that is now being piped from near Markham, Texas to their plant at Ingleside. The nominal feed rate of the plant is 3000 tons/day of 30.0 % NaCl. Some minor deviation from these numbers could be tolerated by the plant operation. The desired feed temperature is 160 degrees F. If the seawater is concentrated to a 30.0 % level, the recovery rate of the desal process would be at near 90%. Coincidentally a 25 MGD seawater desal plant would provide nearly exactly the nominal feed rate of the current feed required for the existing Caustic/Chlorine plant. With a 90% water recovery, the intake quantity of the 25 MGD plant could be reduced by about 40%. The concentration of the brine after treatment by an RO system would most likely be done by multi-effect distillation to achieve the 30 % concentration. Oxychem is the controlling partner in an existing 450 MW Cogen plant adjacent to the Caustic/Chlorine facility and has sufficient excess heat capacity to provide the required heat for concentration by evaporation. The Cogen plant also has an excess capacity of about 240 MW which would be more than sufficient to operate the RO and the distillation processes. There is an existing wastewater treatment plant on site to provide disposal of non-brine wastes. The existing feed stream also requires pretreatment similar to what would be required for the RO unit and potential incorporation of those facilities might be included in the design. There is also a tail gas stream from the Chlorine unit which could potentially be used for disinfection of the product water. The site security for the Oxychem plant could also be used to control access to the new desal facility. There are also a number of utility type services which could be shared with the Oxychem plant. A new LNG terminal facility is being planned for the site and some of the reject heat from condensing the water could potentially be used for heat up of the LNG as it is being vaporized for use. The water requirements of the adjacent facilities and an existing 24 inch treated water pipeline the Corpus Christi water system provides a means of transporting water to the end users.

There is only a very small salt water intake at the docks which is currently not being used by DuPont, but it would not be of any value for the size of the RO facility. In nearly all cases, a new inlet structure will most likely be required with a new water rights permit being needed as well. With the consideration of a Gulf intake being likely, this may be one of the closest sites to the Gulf at an industrial facility which could accommodate a desal plant. However, with the resolution of the AEP sale of the Barney Davis power plant, even though this is the closest industrial site to the Gulf, the Barney Davis site provides a substantially shorter route to a Gulf water intake. The existing brine pipeline would most likely have to be maintained for a backup brine supply and even if it was not, there would be some stranded cost for Oxychem for this facility. Probably the major deterrent to this site option is the need to provide a continuous water supply to the dependent users during plant outages. Short term plant downtime could be accommodated with brine storage capabilities, but long term outages would potentially cause an interruption of the water supply to the users that could not be compensated for with other water sources.

1.F. Degree of interest

All of the contacts which were made expressed some level of interest in the project. Oxychem has expressed the strongest level of interest and conversations with Ray Gritte, their technical manager, indicated that they would be willing to expend some time and effort to developing potential adaptations of their process for using concentrated Gulf saltwater should the project indicate further feasibility studies for this option. They also indicated a willingness to cooperate with and facilitate any common infrastructure use to provide the most economical plant configuration.

Gerald FitzSimmons, P. E.

Director of Environmental and Regulatory Services

Appendix C

Cost Estimates

LIFE CYCLE COSTS

Concept Design - LIFE CYCLE COST SUMMARY

Barney Davis site

	Alt BD 1	Alt BD 2	Alt BD 3	Alt BD 4
Pretreatment Option	Tube Settlers	DAF	Ultrafiltration	Bank Filtration
Intake Option	Open Sea Intake	Open Sea Intake	Open Sea Intake	Bank Filtration

Estimated Capital Cost				
Intake	$13,900,000	$13,900,000	$13,900,000	$31,700,000
Raw Water Line	$34,400,000	$34,400,000	$34,400,000	$34,400,000
Pre-Treatment	$38,600,000	$37,000,000	$75,200,000	$2,390,000
Reverse Osmosis & Common Elements	$76,700,000	$76,700,000	$76,700,000	$76,700,000
Transmission to Distribution	$2,500,000	$2,500,000	$2,500,000	$2,500,000
Byproduct Disposal (Open Sea)	$32,100,000	$32,100,000	$32,100,000	$32,100,000
TOTAL ESTIMATED CAPITAL COST	$198,200,000	$196,600,000	$234,800,000	$179,790,000

Breakdown of Capital Cost by Cost Type				
Equipment	$74,700,000	$75,700,000	$110,800,000	$85,700,000
Pipe	$82,900,000	$83,400,000	$82,900,000	$68,200,000
Structures	$32,600,000	$29,700,000	$33,200,000	$17,900,000
Other	$8,000,000	$8,000,000	$8,000,000	$8,200,000
TOTAL CAPITAL COSTS BY TYPE	$198,200,000	$196,800,000	$234,900,000	$180,000,000

Estimated O&M Costs				
Intake System	$139,000	$139,000	$139,000	$1,380,000
Raw Water Piping	$313,000	$313,000	$313,000	$313,000
Pretreatment	$5,058,000	$5,012,000	$8,789,000	$1,189,000
RO & Common Items	$11,738,000	$11,738,000	$11,738,000	$11,738,000
Transmission to Distribution	$25,000	$25,000	$25,000	$25,000
Byproduct Disposal	$290,000	$290,000	$290,000	$290,000
TOTAL ANNUAL O&M COST	$17,560,000	$17,520,000	$21,290,000	$14,940,000

Concept Design - LIFE CYCLE COST SUMMARY

Oxychem Site

	Alt OX 1	Alt OX 2	Alt OX 3	Alt OX 4
Pretreatment Option	Bank Infiltration	DAF	Ultrafiltration	Bank Filtration
Intake Option	Bank Infiltration	Open Sea Intake	Open Sea Intake	Bank Filtration
Estimated Capital Cost				
Intake System	$31,700,000	$13,900,000	$13,900,000	$31,700,000
Raw Water Piping	$10,590,000	$62,600,000	$62,600,000	$62,600,000
Pretreatment	$2,390,000	$37,000,000	$75,200,000	$2,390,000
RO & Common Items	$76,700,000	$76,700,000	$76,700,000	$76,700,000
Transmission to Distribution	$56,900,000	$56,900,000	$56,900,000	$56,900,000
Byproduct Disposal	$47,100,000	$47,100,000	$47,100,000	$47,100,000
TOTAL ESTIMATED CAPITAL COST	$225,380,000	$294,200,000	$332,400,000	$277,390,000

Breakdown of Capital Cost by Cost Type				
Equipment	$85,700,000	$75,700,000	$110,800,000	$85,700,000
Pipe	$117,900,000	$183,300,000	$182,800,000	$168,000,000
Structures	$17,900,000	$29,700,000	$33,200,000	$17,900,000
Other	$3,930,000	$5,720,000	$5,720,000	$5,870,000
TOTAL CAPITAL COSTS BY TYPE	$225,430,000	$294,420,000	$332,520,000	$277,470,000

Estimated O&M Costs				
Intake System	$1,380,000	$139,000	$139,000	$1,379,761
Raw Water Piping	$106,000	$607,000	$607,000	$606,821
Pretreatment	$1,200,000	$5,010,000	$8,790,000	$1,189,171
RO & Common Items	$11,700,000	$11,700,000	$11,700,000	$11,737,676
Transmission to Distribution	$569,000	$569,000	$569,000	$568,544
Byproduct Disposal	$452,000	$452,000	$452,000	$451,934
TOTAL ANNUAL O&M COST	$15,407,000	$18,477,000	$22,257,000	$15,933,907

INTAKES

Concept Design Capital Costs - Open Sea Intake
Off Plant Site Common Elements

Open Sea Intake

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
Gulf of Mexico to Pump Station on Mustang Island or Padre Island	UW-72	72" HDPE Wet Dredge	10,500	LF	$650	$6,825,000
Subtotal Pipe Segments						$6,825,000
	Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
	IS	Intake Structure	1	EA	$250,000	$250,000
	CPA-2	Concrete Pipe Anchors	10,500	EA	$48	$499,800
				EA		
				LS		
				EA		
				LF		
	Subtotal Appurtenances					$749,800
		SUBTOTAL Concept Design Capital Costs - Open Sea Intake				$7,574,800
		Construction Contingency (%)			25%	$1,893,700
		Construction Cost Total				$9,468,500
		Contractors OH&P (%)			17%	$1,609,645
		Mobilization/Demobilization			3%	$284,055
		Estimated Comnstruction Costs				$11,362,200
		Survey, Geotech, Easements (%)			8%	$908,976
		Environmental Mitigation		ENV-3	4.6%	$522,661
		Engineering fees (%)			10%	$1,136,220
		Total Open Sea Intake				$13,930,057

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$13,470,307	1% of Pipe	$134,703
Structures	$459,750	1% of Structures	$4,598
Other		Itemized	
TOTAL Annual Repair and Rehabilitation Costs			$139,301

Concept Design Capital Costs - Bank Filtration
Off Plant Site Common Elements

Bank Filtration Intake

Item	DESCRIPTION	QUAN.	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL COST	20.0% ELEC / I&C	SUBTOTAL
1	**Major Equipment & Maintenance Items**							
1.1	Ranney Collectors (24" diameter)	42,000	LF	$275	$11,550,000	n/a	n/a	$11,550,000
1.2	Pumps (8 mgd ea.) (including standby units)	9	EA.	$80,000	$720,000	$216,000	$144,000	$1,080,000
SUBTOTAL Major Equipment & Maintenance Items								$12,630,000
2	**Pipe, Caissons, and Appurtenances**							
2.1	Beach Well Caissons	7	EA.	$450,000	$3,150,000			$3,150,000
2.2	Well Collection Line (42" diameter)	7,000	LF	200	$1,400,000	n/a	n/a	$1,400,000
2.3	Land Acquisition / Easements	16	AC	$5,000	$80,349	n/a	n/a	$80,349
SUBTOTAL Pipe, Caissons, and Appurtenances								$4,630,349
TOTAL Bank Filtration Intake								$17,260,349
				Construction Contingency (%)			25%	$4,315,087
				Construction Cost Total				$21,575,436
				Contractors OH&P (%)			17%	$3,667,824
				Mobilization/Demobilization			3%	$647,263
				Estimated Comnstruction Costs				$25,890,523
				Survey, Geotech, Easements (%)			8%	$2,071,242
				Environmental Mitigation		ENV-5	5%	$1,190,964
				Engineering fees (%)			10%	$2,589,052
				Total Bank Filtration Intake				**$31,741,782**

Annual Repair and Rehabilitation Costs

Equipment	$31,594,020	4% of Equipment	$1,263,761
Pipe		1% of Pipe	
Structures		1% of Structures	
Other [(1)]			$116,000
TOTAL Annual Repair and Rehabilitation Costs			$1,379,761

1. Additional labor to maintain bank filtration intake.

Labor Class	Annual Salary	Fringe	Total
Operator - Sr.	$40,000	45%	$58,000
Operator I	$40,000	45%	$58,000
			$116,000

OFFSITE PIPING

Concept Design O&M Costs - Offsite Piping Systems
Offsite Piping

BARNEY DAVIS PLANT SITE

Raw Water Piping - 55 MGD

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
Pump Station across Padre Island	OC-54	54" HDPE Open Cut	8,400	LF	$320	$2,688,000
Padre Island to Intracoastal Canal	UW-54	54" HDPE Wet Dredge	5,000	LF	$470	$2,350,000
Across Intracoastal Canal	SP-54	54" HDPE Tunnel	2,000	LF	$1,300	$2,600,000
Across Laguna Madre to Intake Channel	UW-54	54" HDPE Wet Dredge	12,100	LF	$470	$5,687,000
Along Intake Channel	UW-54	54" HDPE Wet Dredge	4,000	LF	$470	$1,880,000
Intake Channel to Desalination Plant	OC-54	54" HDPE Open Cut	1,300	LF	$320	$416,000
Subtotal Pipe Segments						$15,621,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
TS	Tunnel Shaft	2	EA	$500,000	$1,000,000
V-54	54" Valve	2	EA	$50,000	$100,000
CPA-1	Concrete Pipe Anchors	21,100	LF	$15	$318,610
SC	Silt Curtain for Seagrass	42,200	LF	$40	$1,688,000
Subtotal Appurtenances					$3,106,610

SUBTOTAL Raw Water Piping - 55 MGD			$18,727,610
Construction Contingency (%)		25%	$4,681,903
Construction Cost Total			$23,409,513
Contractors OH&P (%)		17%	$3,979,617
Mobilization/Demobilization		3%	$702,285
Estimated Comnstruction Costs			$28,091,415
Survey, Geotech, Easements (%)		8%	$2,247,313
Environmental Mitigation	ENV-3	5%	$1,292,205
Engineering fees (%)		10%	$2,809,142
Total Raw Water Piping - 55 MGD			$34,440,075

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$31,335,843	1% of Pipe	$313,358
Structures		1% of Structures	
Other			
TOTAL Annual Repair and Rehabilitation Costs			$313,358

Concept Design O&M Costs - Offsite Piping Systems

Offsite Piping

BARNEY DAVIS PLANT SITE

Byproduct Disposal

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
Desalination Plant to Intake Channel	OC-42	42" HDPE Open Cut	1,300	LF	$200	$260,000
Intake Channel to Laguna Madre	UW-42	42" HDPE Wet Dredge	4,000	LF	$350	$1,400,000
Across Laguna Madre to Intracoastal Canal	UW-42	42" HDPE Wet Dredge	12,100	LF	$350	$4,235,000
Across Intracoastal Canal	SP-42	42" Directional Drill	2,000	LF	$600	$1,200,000
Intracoastal Canal to Padre Island	UW-42	42" HDPE Wet Dredge	5,000	LF	$350	$1,750,000
Across Padre Island to Shoreline	OC-42	42" HDPE Open Cut	8,400	LF	$200	$1,680,000
Padre Island Shoreline to Gulf of Mexico	UW-42	42" HDPE Wet Dredge	10,500	LF	$350	$3,675,000
Subtotal Pipe Segments						$14,200,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
TS	Tunnel Shaft	2	EA	$500,000	$1,000,000
V-42	42" Valve	2	EA	$30,000	$60,000
OS	Outfall Structure	1	EA	$50,000	$50,000
CPA-1	Concrete Pipe Anchors	31,600	LS	$15	$477,160
SC	Silt Curtain for Seagrass	42,200	EA	$40	$1,688,000
			LF		
Subtotal Appurtenances					$3,275,160

SUBTOTAL Byproduct Disposal			$17,475,160
Construction Contingency (%)		25%	$4,368,790
Construction Cost Total			$21,843,950
Contractors OH&P (%)		17%	$3,713,472
Mobilization/Demobilization		3%	$655,319
Estimated Comnstruction Costs			$26,212,740
Survey, Geotech, Easements (%)		8%	$2,097,019
Environmental Mitigation	ENV-5	5%	$1,205,786
Engineering fees (%)		10%	$2,621,274
Total Byproduct Disposal			$32,136,819

Annual Repair and Rehabilitation Costs

$5,924,079

Equipment		4% of Equipment	
Pipe	$28,940,637	1% of Pipe	$289,406
Structures	$91,950	1% of Structures	$920
Other			
TOTAL Annual Repair and Rehabilitation Costs			$290,326

Concept Design O&M Costs - Offsite Piping Systems
Offsite Piping

BARNEY DAVIS PLANT SITE

Transmission to Distribution

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
42" Water Line - Urban			9,700	LF	$140	$1,358,000
Subtotal Pipe Segments						$1,358,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
			EA		
			EA		
			EA		
			LS		
			EA		
			LF		
Subtotal Appurtenances					

SUBTOTAL Transmission to Distribution			$1,358,000
Construction Contingency (%)		25%	$339,500
Construction Cost Total			$1,697,500
Contractors OH&P (%)		17%	$288,575
Mobilization/Demobilization		3%	$50,925
Estimated Comnstruction Costs			$2,037,000
Survey, Geotech, Easements (%)		8%	$162,960
Environmental Mitigation	ENV-3	4.6%	$93,702
Engineering fees (%)		10%	$203,700
Total Transmission to Distribution			$2,497,362

$460,362

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$2,497,362	1% of Pipe	$24,974
Structures		1% of Structures	
Other			
TOTAL Annual Repair and Rehabilitation Costs			$24,974

Concept Design O&M Costs - Offsite Piping Systems
Offsite Piping

OXYCHEM PLANT SITE

Raw Water Piping - 55 MGD - Gulf 54 " Pipe

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
Pump Station on Mustang Island to Aransas Pas	OC-54	54" HDPE Open Cut	8,500	LF	$320	$2,720,000
Cross Aransas Pass to Harbor Islan	SP-54	54" HDPE Tunnel	3,500	LF	$1,300	$4,550,000
Aransas Pass to Redfish Bay across Harbor Islan	OC-54	54" HDPE Open Cut	13,700	LF	$320	$4,384,000
Harbor Island-Intracoastal Waterway-Redfish Ba	UW-54	54" HDPE Wet Dredge	13,200	LF	$470	$6,204,000
Cross Intracoastal Waterway to Inglesid	SP-54	54" HDPE Tunnel	2,000	LF	$1,300	$2,600,000
Ingleside to Desalination Plan	OC-54	54" HDPE Open Cut	32,000	LF	$320	$10,240,000
Subtotal Pipe Segments						$30,698,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
TS	Tunnel Shaft	4	EA	$500,000	$2,000,000
V-54	54" Valve	2	EA	$50,000	$100,000
CPA-1	Concrete Pipe Anchors	13,200	EA	$15	$199,320
SC	Silt Curtain for Seagrass	26400	LS	$40	$1,056,000
			EA		
			LF		
Subtotal Appurtenances					$3,355,320

SUBTOTAL Raw Water Piping - 55 MGD - Gulf			$34,053,320
Construction Contingency (%)		25%	$8,513,330
Construction Cost Total			$42,566,650
Contractors OH&P (%)		17%	$7,236,331
Mobilization/Demobilization		3%	$1,277,000
Estimated Comnstruction Costs			$51,079,980
Survey, Geotech, Easements (%)		8%	$4,086,398
Environmental Mitigation	ENV-3	5%	$2,349,679
Engineering fees (%)		10%	$5,107,998
Total Raw Water Piping - 55 MGD - Gulf			$62,624,055

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$60,682,071	1% of Pipe	$606,821
Structures		1% of Structures	
Other			
TOTAL Annual Repair and Rehabilitation Costs			$606,821

Concept Design O&M Costs - Offsite Piping Systems
Offsite Piping

OXYCHEM PLANT SITE

Raw Water Piping - 55 MGD - Corpus Christi Bay 54 " Pipe

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
CC Bay to Oxychem Plant Site	OC-54	54" HDPE Open Cut	18,000	LF	$320	$5,760,000
Subtotal Pipe Segments						$5,760,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
Subtotal Appurtenances					

SUBTOTAL Raw Water Piping - 55 MGD - Corpus Christi Bay			$5,760,000
Construction Contingency (%)		25%	$1,440,000
Construction Cost Total			$7,200,000
Contractors OH&P (%)		17%	$1,224,000
Mobilization/Demobilization		3%	$216,000
Estimated Construction Costs			$8,640,000
Survey, Geotech, Easements (%)		8%	$691,200
Environmental Mitigation	ENV-10	5%	$397,440
Engineering fees (%)		10%	$864,000
Total Raw Water Piping - 55 MGD - Corpus Christi Bay			$10,592,640

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$10,592,640	1% of Pipe	$105,926
Structures		1% of Structures	
Other			
TOTAL Annual Repair and Rehabilitation Costs			$105,926

Concept Design O&M Costs - Offsite Piping Systems
Offsite Piping

OXYCHEM PLANT SITE

Byproduct Disposal 25 mgd - Gulf 42 " Pipe

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
Desalination Plant through Ingleside to Intracoastal Waterway	OC-42	42" HDPE Open Cut	32,000	LF	$200	$6,400,000
Across Intracoastal Waterwa	SP-42	42" Directional Dril	2,000	LF	$600	$1,200,000
Intracoastal Waterway to Harbor Island Across Redfish Bay	UW-42	42" HDPE Wet Dredge	13,200	LF	$350	$4,620,000
Redfish Bay to Aransas Pass Across Harbor Island	OC-42	42" HDPE Open Cut	13,700	LF	$200	$2,740,000
Across Aransas Pas	SP-42	42" Directional Dril	3,500	LF	$600	$2,100,000
Aransas Pass to Shoreline - Mustang Islan	OC-42	42" HDPE Open Cut	8,500	LF	$200	$1,700,000
Mustang Island Shoreline to Gul	UW-42	42" HDPE Wet Dredge	10,500	LF	$350	$3,675,000
Subtotal Pipe Segments						$22,435,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
TS	Tunnel Shaft	4	EA	$500,000	$2,000,000
V-42	42" Valve	3	EA	$30,000	$90,000
OS	Outfall Structure	1	EA	$50,000	$50,000
CPA-1	Concrete Pipe Anchors		LF	$15	
SC	Silt Curtain for Seagras	26,400	EA	$40	$1,056,000
Subtotal Appurtenances					$3,196,000

SUBTOTAL Byproduct Disposal 25 mgd - Gulf			$25,631,000
Construction Contingency (%)		25%	$6,407,750
Construction Cost Total			$32,038,750
Contractors OH&P (%)		17%	$5,446,588
Mobilization/Demobilization		3%	$961,163
Estimated Comnstruction Costs			$38,446,500
Survey, Geotech, Easements (%)		8%	$3,075,720
Environmental Mitigation	ENV-5	5%	$1,768,539
Engineering fees (%)		10%	$3,844,650
Total Byproduct Disposal 25 mgd - Gulf			$47,135,409

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$45,101,475	1% of Pipe	$451,015
Structures	$91,950	1% of Structures	$920
Other			
TOTAL Annual Repair and Rehabilitation Costs			$451,934

Concept Design O&M Costs - Offsite Piping Systems
Offsite Piping

OXYCHEM PLANT SITE

Transmission to Distribution

Pipe Segments	Designator	Item	Quantity	Unit	Unit Cost	Total ($)
	UW-42	42" HDPE Wet Dredge	79,200	LF	$350	$27,720,000
Subtotal Pipe Segments						$27,720,000

Appurtenances	Item	Quantity	Unit	Unit Cost	Total ($)
CPA-1	Concrete Pipe Anchors	79,200	EA	$15	$1,195,920
TS	Tunnel Shaft	4	EA	$500,000	$2,000,000
			EA		
			LS		
			EA		
			LF		
Subtotal Appurtenances					$3,195,920

SUBTOTAL Transmission to Distribution			$30,915,920
Construction Contingency (%)		25%	$7,728,980
Construction Cost Total			$38,644,900
Contractors OH&P (%)		17%	$6,569,633
Mobilization/Demobilization		3%	$1,159,347
Estimated Comnstruction Costs			$46,373,880
Survey, Geotech, Easements (%)		8%	$3,709,910
Environmental Mitigation	ENV-3	5%	$2,133,198
Engineering fees (%)		10%	$4,637,388
Total Transmission to Distribution			$56,854,377

Annual Repair and Rehabilitation Costs

Equipment		4% of Equipment	
Pipe	$56,854,377	1% of Pipe	$568,544
Structures		1% of Structures	
Other			
TOTAL Annual Repair and Rehabilitation Costs			$568,544

TREATMENT PLANT
PRETREATMENT OPTION 1
TUBE SETTLERS

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 1

Tube Settler Pretreatment

						30%	20%	
ITEM	**DESCRIPTION**	**QUAN.**	**UNITS**	**UNIT PRICE**	**SUB-TOTAL**	**INSTALL COST**	**ELEC/I&C**	**SUBTOTAL**
1.	**Major Equipment**							
1.1	5 hp mixers for Rapid Mix Basins	8	EA	$37,500	$300,000	$90,000	$60,000	$450,000
1.2	1 hp mixers for Flocculation Basins	96	EA	$7,000	$672,000	$201,600	$134,400	$1,008,000
1.3	Tube Settling Equipment (Tube settlers, water launders, etc.)	1	LS	$310,000	$310,000	$93,000	$62,000	$465,000
1.4	Sludge Sucker (Sludge removal equipment)	1	LS	$305,000	$305,000	$91,500	$61,000	$457,500
1.5	Greenleaf Filter & Control System (4 units, 4 filters/ unit)	4	EA	$822,500	$3,290,000	$987,000	$658,000	$4,935,000
1.6	DensaDeg Clarifier / Thickener (Rapid Mix & DensDeg unit)	3	EA	$433,333	$1,299,999	$390,000	$260,000	$1,949,999
1.7	Centrifuge Equipment	3	EA	$350,000	$1,050,000	$315,000	$210,000	$1,575,000
1.8	Residuals Transfer Pumps 1300 gpm 25 TDH submersible	3	EA	$40,000	$120,000	$36,000	$24,000	$180,000
1.9	TSLPs 100 gpm at 12 TDH rotary lobe (w/vfd)	3	Ea	$35,000	$105,000	$31,500	n/a	$136,500
1.10	Centrate transfer pumps 150 gpm 15 TDH, 1 HP	2	Ea	$7,500	$15,000	$4,500	$3,000	$22,500
	SUBTOTAL Major Equipment							$11,179,499
2.	**Process Piping (includes valves, appurt, etc)***							
2.1	60" DICL (raw, filtered)	900	LF	$400	$360,000	n/a	n/a	$360,000
2.2	48" DICL (filtered)	200	LF	$264	$52,800	n/a	n/a	$52,800
2.3	42 " DICL (raw)	200	LF	$200	$40,000	n/a	n/a	$40,000
2.4	30" DICL (raw)	80	LF	$120	$9,600	n/a	n/a	$9,600
2.5	18" DICL (FTW & SWW)	400	LF	$55	$22,000	n/a	n/a	$22,000
2.6	10" DICL (residuals piping)	50	LF	$35	$1,750	n/a	n/a	$1,750
2.7	4" DICl (TSLP, centrate pumping)	500	LF	$22	$11,000	n/a	n/a	$11,000
2.8	18" PVC push on jt supernatant return pipe	350	LF	$55	$19,250	n/a	n/a	$19,250
2.9	30" x 30" x 42" tees	2	EA	$12,400	$24,800	n/a	n/a	$24,800
2.10	30" butterfly valves with motor operators	4	EA	$30,000	$120,000	n/a	n/a	$120,000
2.11	24" flow meters	4	EA	$20,000	$80,000	n/a	n/a	$80,000
2.12	24" x 30" reducers	8	EA	$3,000	$24,000	n/a	n/a	$24,000
2.13	24" slide gates FRP	24	EA	$5,000	$120,000	n/a	n/a	$120,000
2.14	48" isolation butterfly valves	4	EA	$18,000	$72,000	n/a	n/a	$72,000
2.15	48"x48"x60" tees	2	EA	$24,500	$49,000	n/a	n/a	$49,000
2.16	Allowance for misc fittings & smaller valves (5%)	1	LS	$50,310	$50,310	n/a	n/a	$50,310
	SUBTOTAL Process Piping (includes valves, appurt, etc)*							$1,056,510
3.	**Chemical Feed Systems**							
3.1	Ferric Chloride bulk storage tank 20' D, 20' H*	4	Ea	$50,000	$200,000	$60,000	n/a	$260,000
3.2	FeCL3 day tanks, 400 gallons each	12	Ea	$1,500	$18,000	$5,400	n/a	$23,400
3.3	FeCl3 metering pumps (400 gpd each)	14	Ea	$7,000	$98,000	$29,400	n/a	$127,400
3.4	Polymer bulk storage tank 7 ft diam, 7 feet high*	2	Ea	$3,000	$6,000	$1,800	n/a	$7,800
3.5	Polymer feed pumps (10 gpd each)	12	Ea	$5,000	$60,000	$18,000	n/a	$78,000
3.6	NaOCL bulk storage tanks	4	Ea	$30,000	$120,000	$36,000	n/a	$156,000
3.7	NaOCL day tanks, 400 gallons each	6	Ea	$1,500	$9,000	$2,700	n/a	$11,700
3.8	NaOCL metering pumps (400 gpd each)	6	Ea	$7,000	$42,000	$12,600	n/a	$54,600
3.9	Allowance for chem feed piping, appurtenances (5% of chem feed equip costs)	1	LS	$27,650	$27,650	$8,295	n/a	$35,945
	SUBTOTAL Chemical Feed Systems							$754,845

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 1

Tube Settler Pretreatment

ITEM	DESCRIPTION	QUAN.	UNITS	UNIT PRICE	SUB-TOTAL	30% INSTALL COST	20% ELEC/I&C	SUBTOTAL
4.	**Concrete**							
4.1	Rapid Mix Basins (2 stages/ group, 4 groups)	171	CY	$600	$102,600	n/a	n/a	$102,600
4.2	Influent Distribution Channel	211	CY	$600	$126,600	n/a	n/a	$126,600
4.3	Influent Distribution Channel - Overflow Areas	43	CY	$600	$25,800	n/a	n/a	$25,800
4.4	Tube Settler Basins including flocculation (12 trains)	5,903	CY	$600	$3,541,800	n/a	n/a	$3,541,800
4.5	Clarified Water Distribution Channel & Launder	692	CY	$600	$415,200	n/a	n/a	$415,200
4.6	Greenleaf Filter Control System (4 filters/ cluster, 4 clusters)	1,790	CY	$600	$1,074,000	n/a	n/a	$1,074,000
4.7	Residuals Equalization Tank & PS	783	CY	$600	$469,800	n/a	n/a	$469,800
4.8	DensaDeg Clarifier/Thickener (Rapid Mix & DensDeg unit)	400	CY	$600	$240,000	n/a	n/a	$240,000
4.9	Thickened Sludge Equalization Tank	205	CY	$600	$123,000	n/a	n/a	$123,000
4.10	Chem Feed Bldg Slab on Grade	208	CY	$400	$83,333	n/a	n/a	$83,333
4.11	Dewatering Building Slab on Grade	90	CY	$400	$36,000	n/a	n/a	$36,000
4.12	Thickened Sludge Equal Pump Station Slab on Grade	89	CY	$400	$35,556	n/a	n/a	$35,556
	SUBTOTAL Concrete							$6,273,689
5.	**Buildings**							
5.1	Chem Feed Bldg (pre-engineered)	3,750	SF	$64	$240,000	n/a	n/a	$240,000
5.2	Dewatering Building (pre-engineered)	1,600	SF	$64	$102,400	n/a	n/a	$102,400
5.3	Thickened Sludge Equal Pump Station	300	SF	$64	$19,200	n/a	n/a	$19,200
	SUBTOTAL Buildings							$361,600
6.	**Site work**							
6.1	Excavation for floc & tube settler basins	33,000	CY	$15	$495,000	n/a	n/a	$495,000
6.2	Excavation for cluster filters	7,000	CY	$15	$105,000	n/a	n/a	$105,000
6.3	Excavation for DensaDeg units	1,630	CY	$15	$24,450	n/a	n/a	$24,450
6.4	Excavation for Thickened Sludge Eq. Tank	500	CY	$15	$7,500	n/a	n/a	$7,500
6.5	Excavation for Residuals Eq Tank	3,000	CY	$15	$45,000	n/a	n/a	$45,000
6.6	Excavation for Chem Feed Building	8,333	CY	$15	$125,000	n/a	n/a	$125,000
6.7	Excavation for Dewatering Building	3,556	CY	$15	$53,333	n/a	n/a	$53,333
6.8	Excavation for Thickened Sludge Pump Station	667	CY	$15	$10,000	n/a	n/a	$10,000
6.9	Excavation for piping	2,000	CY	$12	$24,000	n/a	n/a	$24,000
6.10	Sheeting for tube settlers basins	17,000	SF	$12	$204,000	n/a	n/a	$204,000
6.11	Sheeting for Eq. Tanks & Cluster Filters & DD's	21,000	SF	$12	$252,000	n/a	n/a	$252,000
	SUBTOTAL Site work							$1,345,283
SUBTOTAL ESTIMATED CONSTRUCTION DIRECT COST - Tube Settler Pretreatment					$17,084,731	$2,414,295	$1,472,400	$20,971,426

* Piping and fittings costs include bedding and an aditional 20% for corrosion protection

** Inlcudes storage volume for DensaDeg operation & centrifuge operation

Construction Contingency (%)		25%	$5,242,856
Construction Cost Total			$26,214,282
Contractors OH&P (%)		17%	$4,456,428
Mobilization/Demobilization		3%	$786,428
Estimated Comnstruction Costs			$31,457,139
Survey, Geotech, Easements (%)		8%	$2,516,571
Environmental Mitigation	ENV-1	5%	$1,447,028
Engineering fees (%)		10%	$3,145,714
Total Tube Settler Pretreatment			$38,566,452

Concept Design O&M Costs - SUMMARY
Pre-Treatment Option 1
Tube Settler Pretreatment

Description	Power	Chemicals	Replacement Items	Labor	Solids Handling	TOTAL
Annual Costs	$142,350	$1,001,649	$1,044,082	$1,199,440	$1,670,381	$5,057,903
Present Worth Factor						12.462
Presnt Worth of Annual O&M						$63,032,646

Concept Design O&M Costs - POWER O&M

Pre-Treatment Option 1

Tube Settler Pretreatment

Description	Units in Operation	Flow (mgd)	Head (ft)	BHP	kW	Hours / Day	Kw-hrs/yr	Total Cost per year
Major Equipment								
Thickened Sludge Transfer Pumps	2	0.15	30	2.0	1.47	6	3,222	$209
Residuals Transfer Pumps	2	1.80	35	27.6	20.60	24	180,423	$11,727
Centrate Transfer Pumps	1	n/a	n/a	5	3.73	6	8,165	$531
Densadeg Units	2	n/a	n/a	30	22.371	24	195,970	$12,738
Centrifuges	3	n/a	n/a	100	223.71	6	489,925	$31,845
Rapid Mix Basins	8	n/a	n/a	5	29.828	24	261,293	$16,984
Flocculation Mixers	96	n/a	n/a	1	71.5872	24	627,104	$40,762
Sludge Suckers	12	n/a	n/a	0.5	4.4742	24	39,194	$2,548
SUBTOTAL Major Equipment								$117,344
Electricity for Buildings								
Chem Feed Bldg (pre-engineered)	1	n/a	n/a	n/a	29.8	24	261,375	$16,989
Dewatering Building (pre-engineered)	1	n/a	n/a	n/a	7.3	24	63,520	$4,129
Thickened Sludge Equal Pump Station	1	n/a	n/a	n/a	1.4	24	11,910	$774
SUBTOTAL Electricity for Buildings								$21,892
Chemical Metering Pumps								
Rapid Mix Ferric Chloride metering pumps	8	n/a	n/a	0.33	1.99	24	17,420	$1,132
Rapid Mix Polymer Pumps	8	n/a	n/a	0.33	1.99	24	17,420	$1,132
Densadeg Polymer Pump	2	n/a	n/a	0.33	0.50	24	4,355	$283
Densadeg Ferric Chloride metering pumps	2	n/a	n/a	0.33	0.50	24	4,355	$283
Centrifuge Mix Polymer Pumps	2	n/a	n/a	0.33	0.50	24	4,355	$283
SUBTOTAL Chemical Metering Pumps								$3,114
TOTAL Concept Design O&M Costs - POWER O&M Pre-Treatment Option 1								$142,350

Concept Design O&M Costs - LABOR O&M
Pre-Treatment Option 1
Tube Settler Pretreatment with RO Desalination

	Title	# of Staff	Hours Per Day	Days Per Week	Hours Per Week	Annual Salary	Hourly Rate	Total
Operations								
	Manager - Operations	1	8	5	40	$75,000	$36.06	$108,750
	Administrative Assistant	1	8	5	40	$30,000	$14.42	$43,500
	Operator - Sr.	4	8	7	224	$45,000	$21.63	$365,400
	Operator I	1	8	5	40	$40,000	$19.23	$58,000
	Operator II	1	8	4	32	$35,000	$16.83	$40,600
	Assistant to Operator	1	8	5	40	$30,000	$14.42	$43,500
	Assistant to Operator II	1	8	2	16	$28,000	$13.46	$16,240
	Lab Chemist	1	8	5	40	$45,000	$21.63	$65,250
	Lab Chemist II	1	8	2	16	$40,000	$19.23	$23,200
SUBTOTAL Annual Labor Costs - Operations								$764,440
Maintenance								
	Manager - Maintenance	1	8	5	40	$60,000	$28.85	$87,000
	Mechanics	2	8	5	80	$40,000	$19.23	$116,000
	Mechanic Assistant	1	8	5	40	$35,000	$16.83	$50,750
	Electrician	1	8	5	40	$45,000	$21.63	$65,250
	Elect./Instr. Assistant	1	8	5	40	$35,000	$16.83	$50,750
	Instrumentation	1	8	5	40	$45,000	$21.63	$65,250
SUBTOTAL Annual Labor Costs - Maintenance								$435,000
Total Annual Labor Costs - Tube Settler Pretreatment with RO Desalination								$1,199,440

* M-F from 9 to 5 have 8 staff

**Saturday and Sunday 9 to 5 have 4 staff

***Off hours only one operator present at all times.

**** Assume operated by City of Corpus Christi and not by a contract operator

Concept Design O&M Costs - CHEMICAL O&M COSTS
Pre-Treatment Option 1
Tube Settler Pretreatment

Chemical	Dose (mg/L)	Flow (gpm)	lbs/day	Cost per lb or gal	Cost per Year
Ferric Chloride (Coagulation)	25	38,194	11468	$0.17	$711,559
Polymer (Clarification)	1	38,194	459	$1.38	$231,047
Polymer (Thickening)	1	2,069	25	$1.38	$12,516
Polymer (Dewatering)	1	45	1	$1.38	$272
Ferric Chloride (Thickening)	30	2,069	745	$0.17	$46,254
TOTAL Concept Design O&M Costs - CHEMICAL O&M COSTS - Tube Settler Pretreatment					$1,001,649

Concept Design O&M Costs - REHAB & REPAIR O&M COSTS
Pre-Treatment Option 1
Tube Settler Pretreatment

Annual Repair and Rehabilitation Costs

Equipment	$21,947,258	4% of Equipment	$877,890.31
Pipe	$1,987,058	1% of Pipe	$19,871
Structures	$14,632,136	1% of Structures	$146,321
Other	$0		
TOTAL Annual Repair and Rehabilitation Costs			$1,044,082

1. Taken from costs in the capital cost estimate and include major equipment, chemical

2. Assumes 1 replacement per 20 year period at a cost of $150,000 per replacement

Concept Design O&M Costs - SOLIDS PROCESSING O&M COSTS
Pre-Treatment Option 1
Tube Settler Pretreatment

SOLIDS PRODUCTION

Solids Source	Conc/Dose (mg/l)	Flow (mgd)	Dry Solids (lbs/day)	Dry Solids (Tons/year)
Solids from TSS	25	55	11,468	2,093
Solids from treatment chemicals	40	55	18,348	3,349
Solids Precipitated	5	55	2,294	419
TOTAL SOLIDS	**70**		**32,109**	**5,860**

SLUDGE CHARACTERISTICS

Density of Water	62.4	lbs/cf
Density of Solids	110	lbs/cf
Cake Solids concentration	24.0%	
Specific Gravity of Sludge	1.2	
Compaction Ratio	88%	
Density of Sludge to Transport	65.0	lbs/cf

ANNUAL SLUDGE DISPOSAL COST

Solids Produced	5,860	dt/yr
Weight of Sludge produced	24,416	tons/yr
Volume of Sludge Produced	27,840	CY/yr
Cost to Dispose of sludge cake	$60.00	per CY
Annual Solids disposal Cost	**$1,670,381**	**$/yr**

Concept Design O&M Costs - Lighting & HVAC Energy Consumption
Pre-Treatment Option 1
Tube Settler Pretreatment

					Electric Energy (kW*hr/ft_2/yr)						
					Lighting	Ventilation	Heating	Cooling	Cool-Admin	Total	Total
OPTION 1 HVAC POWER		Length (ft)	Width (ft)	Bldg Area (SF)	Per ft_2/yr	Per ft_2/yr	Per ft_2/yr	Per ft_2/yr	Per ft_2/yr	kW*hr/yr	kW*hr/day
Option 1 Buildings					17.5	2.2	15	5	35		
1	Chem Feed Bldg (pre-engineered)	75	50	3,750	65,625	8,250	56,250		131,250	261,375	716
2	Dewatering Building (pre-engineered)	40	40	1,600	28,000	3,520	24,000	8,000		63,520	174
3	Thickened Sludge Equal Pump Station	15	20	300	5,250	660	4,500	1,500		11,910	33
TOTAL Annual Lighting & HVAC Energy Consumption - Tube Settler Pretreatment										**336,805**	**923**

TREATMENT PLANT
PRETREATMENT OPTION 2
DISSOLVED AIR FLOTATION

Concept Design Capital Costs - Pretreatment Capital Costs
Pre-Treatment Option 2
Dissolved Air Flotation Pretreatment

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL. COST	20% ELEC. & I&C COST	SUBTOTAL
1.	**Major Equipment**							
1.1	DAF equipment, rapid mixers, flocculators, filters	1	LS	$5,650,000	$5,650,000	$565,000	$1,130,000	$7,345,000
1.2	DensaDeg Clarifier / Thickener (Rapid Mix & DensDeg unit)	3	EA	$433,333	$1,299,999	$390,000	$260,000	$1,949,999
1.3	Centrifuge Equipment	4	EA	$350,000	$1,400,000	$420,000	$280,000	$2,100,000
SUBTOTAL Major Equipment								$11,394,999
2.	**Process Piping (includes valves, appurt, etc)***							
2.1	60" DICL (raw, filtered)	1,100	LF	$400	$440,000	n/a	n/a	$440,000
2.2	48" DICL (filtered)	400	LF	$264	$105,600	n/a	n/a	$105,600
2.3	36" DICL (filtered)	100	LF	$220	$22,000	n/a	n/a	$22,000
2.4	24" DICL (filtered)	100	LF	$100	$10,000	n/a	n/a	$10,000
2.5	18" DICL (filtered)	80	LF	$55	$4,400	n/a	n/a	$4,400
2.6	10" DICL (resduals piping)	50	LF	$35	$1,750	n/a	n/a	$1,750
2.7	4" DICl (TSLP, centrate pumping)	100	LF	$22	$2,200	n/a	n/a	$2,200
2.8	6" centrate piping	260	LF	$35	$9,100	n/a	n/a	$9,100
2.9	18" x 24" reducers	12	Ea	$2,000	$24,000	n/a	n/a	$24,000
2.10	42 " DICL (raw)	200	LF	$200	$40,000	n/a	n/a	$40,000
2.11	30" DICL (raw)	80	LF	$110	$8,800	n/a	n/a	$8,800
2.12	18" DICL (FTW & SWW)	400	LF	$55	$22,000	n/a	n/a	$22,000
2.13	18" PVC push on jt supernatant return pipe	350	LF	$55	$19,250	n/a	n/a	$19,250
2.14	30" x 30" x 42" tees	2	EA	$12,400	$24,800	n/a	n/a	$24,800
2.15	30" butterfly valves with motor operators	4	EA	$30,000	$120,000	n/a	n/a	$120,000
2.16	24" flow meters	4	EA	$20,000	$80,000	n/a	n/a	$80,000
2.17	24" x 30" reducers	8	EA	$3,000	$24,000	n/a	n/a	$24,000
2.18	48" isolation butterfly valves	4	EA	$18,000	$72,000	n/a	n/a	$72,000
2.19	48"x48"x60" tees	2	EA	$24,500	$49,000	n/a	n/a	$49,000
2.20	6" SS Recycle piping	1,200	LF	$110	$132,000	n/a	n/a	$132,000
2.21	8" CS Sch 40 air piping	400	LF	$90	$36,000	n/a	n/a	$36,000
2.22	Allowance for misc. fittings & smaller valves (5%)	1	LS	$62,345	$62,345	n/a	n/a	$62,345
SUBTOTAL Process Piping (includes valves, appurt, etc)*								$1,309,245

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 2

Dissolved Air Flotation Pretreatment

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL. COST	20% ELEC. & I&C COST	SUBTOTAL
3.	**Concrete**							
3.1	Rapid Mix Basins (2 stages/ group, 4 groups)	171	CY	$600	$102,600	n/a	n/a	$102,600
3.2	Influent Distribution Channel	211	CY	$600	$126,600	n/a	n/a	$126,600
3.3	Influent Distribution Channel - Overflow Areas	43	CY	$600	$25,800	n/a	n/a	$25,800
3.4	Flocculation Basins (12 trains)	1,387	CY	$600	$832,200	n/a	n/a	$832,200
3.5	Dissolved Air Floatation Clarifiers (12 trains)	1,634	CY	$600	$980,400	n/a	n/a	$980,400
3.6	Dissolved Air Floatation Filter Gallery (4 groups)	1,621	CY	$600	$972,600	n/a	n/a	$972,600
3.7	Filter Residuals Equalization Tank	783	CY	$600	$469,800	n/a	n/a	$469,800
3.8	DensaDeg Clarifier/Thickener (Rapid Mix & DensDeg unit)	400	CY	$600	$240,000	n/a	n/a	$240,000
3.9	Thickened Sludge Equalization Tank	258	CY	$600	$154,800	n/a	n/a	$154,800
3.10	Buildings for Chem Feed Systems, Recycle pumps, Compressors & Saturators (130 x 60) CMU	433	CY	$400	$173,333	n/a	n/a	$173,333
3.11	DAF Weather enclosure (110 X 100)	611	CY	$400	$244,444	n/a	n/a	$244,444
3.12	Dewatering Building (pre-engineered) (45 X 45)	113	CY	$400	$45,000	n/a	n/a	$45,000
3.13	Thickend Sludge Equal Pump Station (20 X 15)	17	CY	$400	$6,667	n/a	n/a	$6,667
SUBTOTAL Concrete								$4,374,244
4.	**Buildings**							
4.1	Buildings for Chem Feed Systems, Recycle pumps, Compressors & Saturators (130 x 60) CMU	7,800	SF	$64	$499,200	n/a	n/a	$499,200
4.2	DAF Weather enclosure (110 X 100)	11,000	SF	$35	$385,000	n/a	n/a	$385,000
4.3	Dewatering Building (pre-engineered) (45 X 45)	2,025	SF	$35	$70,875	n/a	n/a	$70,875
4.4	Thickend Sludge Equal Pump Station (20 X 15)	300	SF	$64	$19,200	n/a	n/a	$19,200
SUBTOTAL Buildings								$974,275
5.	**Site work**							
5.1	Excavation for DAF basins	23,500	CY	$15	$352,500	n/a	n/a	$352,500
5.3	Excavation for DensaDeg units	1,630	CY	$15	$24,450	n/a	n/a	$24,450
5.4	Excavation for Thickened Sludge Eq. Tank	650	CY	$15	$9,750	n/a	n/a	$9,750
5.5	Excavation for Residuals Eq Tank	3,000	CY	$15	$45,000	n/a	n/a	$45,000
5.6	Excavation for piping	2,000	CY	$12	$24,000	n/a	n/a	$24,000
5.7	Sheeting for DAF basins	15,000	SF	$12	$180,000	n/a	n/a	$180,000
5.8	Sheeting for Eq. Tanks & DD's	5,300	SF	$12	$63,600	n/a	n/a	$63,600
5.10	Excavation for Chemical Feed Building	17,333	CY	$15	$260,000	n/a	n/a	$260,000
5.11	Excavation foe Dewatering Building	4,500	CY	$15	$67,500	n/a	n/a	$67,500
5.12	Excavation for Thickened Sludge PS	667	CY	$15	$10,000	n/a	n/a	$10,000
SUBTOTAL Site work								$1,036,800

Concept Design Capital Costs - Pretreatment Capital Costs
Pre-Treatment Option 2
Dissolved Air Flotation Pretreatment

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL. COST	20% ELEC. & I&C COST	SUBTOTAL
6.	**Residuals Transfer Pumping**							
6.1	Residuals Transfer Pumps 1300 gpm 25 TDH 15 HP	3	EA	$40,000	$120,000	$36,000	$24,000	$180,000
6.2	TSLPs 100 gpm at 12 TDH hose pumps (w/vfd) 1 HP	3	Ea	$35,000	$105,000	$31,500	n/a	$136,500
6.3	Centrate transfer pumps 300 gpm 15 TDH, centrifugal 2 HP	2	Ea	$10,000	$20,000	$6,000	$4,000	$30,000
SUBTOTAL Residuals Transfer Pumping								$346,500
7.	**Chemical Feed Systems**				$0			
7.1	Ferric Chloride bulk storage tank 20' D, 20' H**	4	Ea	$50,000	$200,000	$60,000	n/a	$260,000
7.2	FeCL3 day tanks, 400 gallons each	12	Ea	$1,500	$18,000	$5,400	n/a	$23,400
7.3	FeCl3 metering pumps (400 gpd each)	14	Ea	$7,000	$98,000	$29,400	n/a	$127,400
7.4	Polymer bulk storage tank 5 ft diam, 6 feet high**	1	Ea	$2,000	$2,000	$600	n/a	$2,600
7.5	Polymer feed pumps (10 gpd each)	3	Ea	$5,000	$15,000	$4,500	n/a	$19,500
7.6	NaOCL bulk storage tanks	4	Ea	$30,000	$120,000	$36,000	n/a	$156,000
7.7	NaOCL day tanks, 400 gallons each	6	Ea	$1,500	$9,000	$2,700	n/a	$11,700
7.8	NaOCL metering pumps (400 gpd each)	6	Ea	$7,000	$42,000	$12,600	n/a	$54,600
7.9	Allowance for chem feed piping, appurtenances (5% of chem feed equip costs)	1	LS	25200	$25,200	$7,560	n/a	$32,760
SUBTOTAL Chemical Feed Systems								$687,960
SUBTOTAL ESTIMATED CONSTRUCTION DIRECT COST - Dissolved Air Flotation Pretreatment						$912,420	$195,000	$20,124,023
				Construction Contingency (%)			25%	$5,031,006
				Construction Cost Total				$25,155,029
				Contractors OH&P (%)			17%	$4,276,355
				Mobilization/Demobilization			3%	$754,651
				Estimated Comnstruction Costs				$30,186,034
				Survey, Geotech, Easements (%)			8%	$2,414,883
				Environmental Mitigation		ENV-1	5%	$1,388,558
				Engineering fees (%)			10%	$3,018,603
				Total Dissolved Air Flotation Pretreatment				$37,008,078

* Piping and fittings costs include bedding and an aditional 20% for corrosion protection

** Inlcudes storage volume for DensaDeg operation & centrifuge operation

Concept Design O&M Costs - SUMMARY

Pre-Treatment Option 1

Tube Settler Pretreatment

Description	Power	Chemicals	Replacement Items	Labor	Solids Handling	TOTAL
Annual Costs	$307,696	$778,226	$1,055,814	$1,199,440	$1,670,381	$5,011,557
Present Worth Factor						12.462
Presnt Worth of Annual O&M						$62,455,082

Concept Design O&M Costs - POWER O&M
Pre-Treatment Option 2

Dissolved Air Flotation

Description	Units in Operation	Flow (mgd)	Head (ft)	BHP	kW	Hours/ Day	Kw-hrs/ yr	Total Cost / year
Major Equipment								
Thickened Sludge Transfer Pumps	2	0.22	20	2.5	1.90	6	4,157	$270
Residuals Transfer Pumps	2	1.87	35	29.0	21.6	24	189,141	$12,294
Centrate Transfer Pumps	1	n/a	n/a	5	3.73	6	8,165	$531
Densadeg Units	2	n/a	n/a	30	22.4	24	195,970	$12,738
Centrifuges	3	n/a	n/a	100	224	6	489,925	$31,845
DAF Units	12	n/a	n/a	35	313	24	2,743,579	$178,333
SUBTOTAL Major Equipment								$236,011
Electricity for Buildings								
Buildings for Chem Feed Systems, Recycle pumps, Compressors & Saturators (130 x 60) CMU	1	n/a	n/a	n/a	62.1	24	543660	$35,338
DAF Weather enclosure (110 X 100)	1	n/a	n/a	n/a	49.9	24	436700	$28,386
Dewatering Building (pre-engineered) (45 X 45)	1	n/a	n/a	n/a	9.2	24	80393	$5,226
Thickend Sludge Equal Pump Station (20 X 15)	1	n/a	n/a	n/a	1.4	24	11910	$774
SUBTOTAL Electricity for Buildings								$69,723
Chemical Metering Pumps(1)								
Densadeg Ferric Chloride metering pumps	2	n/a	n/a	0.33	0.492	24	4311	$280
Centrifuge Mix Polymer Pumps	2	n/a	n/a	0.33	0.492	24	4311	$280
Densadeg Polymer Pump	2	n/a	n/a	0.33	0.492	24	4311	$280
Rapid Mix Ferric Chloride metering pumps	8	n/a	n/a	0.33	1.969	24	17245	$1,121
SUBTOTAL Chemical Metering Pumps(1)								$1,962
TOTAL Concept Design O&M Costs - POWER O&M Pre-Treatment Option 2								$307,696

Notes: 1. Assume 8 chemical metering pumps for ferric and 8 for polymer for mixing tanks and 2 for Densadeg Dose

Concept Design O&M Costs - LABOR O&M

Pre-Treatment Option 2

Dissolved Air Flotation Pretreatment With Reverse Osmosis

	Title	# of Staff	Hours Per Day	Days Per Week	Hours Per Week/Pers	Annual Salary	Hourly Rate	Total
Operations								
	Manager - Operations	1	8	5	40	$75,000	$36.06	108,750
	Administrative Assistant	1	8	5	40	$30,000	$14.42	43,500
	Operator - Sr.	4	8	7	224	$45,000	$21.63	365,400
	Operator I	1	8	5	40	$40,000	$19.23	58,000
	Operator II	1	8	4	32	$35,000	$16.83	40,600
	Assistant to Operator	1	8	5	40	$30,000	$14.42	43,500
	Assistant to Operator II	1	8	2	16	$28,000	$13.46	16,240
	Lab Chemist	1	8	5	40	$45,000	$21.63	65,250
	Lab Chemist II	1	8	2	16	$40,000	$19.23	23,200
SUBTOTAL Annual Labor Costs - Operations								764,440
Maintenance								
	Manager - Maintenance	1	8	5	40	$60,000	$28.85	87,000
	Mechanics	2	8	5	80	$40,000	$19.23	116,000
	Mechanic Assistant	1	8	5	40	$35,000	$16.83	50,750
	Electrician	1	8	5	40	$45,000	$21.63	65,250
	Elect./Instr. Assistant	1	8	5	40	$35,000	$16.83	50,750
	Instrumentation	1	8	5	40	$45,000	$21.63	65,250
SUBTOTAL Annual Labor Costs - Maintenance								435,000
TOTAL ANNUAL LABOR COSTS								**1,199,440**

*** M-F from 9-5 have 8 staff**

****Sat - Sun 9 to 5 have 4 staff**

*****Off Hours only one operator present at all times**

******Assumed operate by City of Corpus Christi.**

Operations estimated to require 2.0 man-hours per day (40 min per 8 hour shift).

Labor for routine maintenance estimated at 2 man-weeks per yearor 1.5 man-hours per week.

Labor required for standard equipment maintenance per manufacturers instructions

Concept Design O&M Costs - CHEMICAL O&M COSTS

Pre-Treatment Option 2

Dissolved Air Flotation

Chemical	Dose$_{(7)}$ (mg/L)	Flow (gpm)	lbs/day	Cost per lb or gal	Cost per Year
Ferric Chloride (Coagulation)	25	38,194	11467	$0.17	$711,558
Polymer (Thickening)	1	2,333	28	$1.38	$14,113
Polymer (Dewatering)	1	66	1	$1.38	$399
Ferric Chloride (Thickening)	30	2,333	841	$0.17	$52,156
TOTAL Concept Design O&M Costs - CHEMICAL O&M COSTS - Dissolved Air Flotation					$778,226

Concept Design O&M Costs - REHAB & REPAIR O&M COSTS
Pre-Treatment Option 2
Dissolved Air Flotation

Annual Repair and Rehabilitation Costs

Equipment	$22,857,774	4% of Equipment	$914,311
Pipe	$2,451,838	1% of Pipe	$24,518
Structures	$11,698,466	1% of Structures	$116,985
Other	$0		
TOTAL Annual Repair and Rehabilitation Costs			$1,055,814

1. Taken from costs in the capital cost estimate and include major

2. Assumes 1 replacement per 20 year period at a cost of $150,000 per replacementincluding freight and removal of old media. Annualized cost is $7500 per yr.

Concept Design O&M Costs - SOLIDS PROCESSING O&M COSTS

Pre-Treatment Option 2
Dissolved Air Flotation

SOLIDS PRODUCTION

Solids Source	Conc/Dose (mg/l)	Flow (mgd)	Dry Solids (lbs/day)	Dry Solids (Tons/year)
Solids from TSS	25	55	11,468	2,093
Solids from treatment chemicals	40	55	18,348	3,349
Solids Precipitated	5	55	2,294	419
TOTAL SOLIDS	**70**		**32,109**	**5,860**

SLUDGE CHARACTERISTICS

Density of Water	62.4	lbs/cf
Density of Solids	110	lbs/cf
Cake Solids concentration	24.0%	
Specific Gravity of Sludge	1.2	
Compaction Ratio	88%	
Density of Sludge to Transport	65.0	lbs/cf

ANNUAL SLUDGE DISPOSAL COST

Solids Produced	5,860	dt/yr
Weight of Sludge produced	24,416	tons/yr
Volume of Sludge Produced	27,840	CY/yr
Cost to Dispose of sludge cake	$60.00	per CY
Annual Solids Disposal Cost	**$1,670,381**	**$/yr**

Concept Design O&M Costs - HVAC O&M COSTS

Pre-Treatment Option 2

Dissolved Air Flotation Pretreatment

	OPTION 2 - HVAC POWER	Length	Width	Building Area (SF)	Electric Energy ($kW*hr/ft_3/yr$) Lighting Per ft_2/yr	Ventilation Per ft_2/yr	Heating Per ft_2/yr	Cooling Per ft_2/yr	Cool-Admin Per ft_2/yr	Total kW*hr/yr	Total kW*hr/day
					17.5	2.2	15	5	35		
Option 2 Building											
1	Buildings for Chem Feed Systems, Recycle pumps, Compressors & Saturators (130 x 60) CMU	130	60	7,800	136,500	17,160	117,000		273,000	543,660	1,489
2	DAF Weather enclosure (110 X 100)	110	100	11,000	192,500	24,200	165,000	55,000		436,700	1,196
3	Dewatering Building (pre-engineered) (45 X 45)	45	45	2,025	35,438	4,455	30,375	10,125		80,393	220
4	Thickend Sludge Equal Pump Station (20 X 15)	20	15	300	5,250	660	4,500	1,500		11,910	33
TOTAL Annual Lighting & HVAC Energy Consumption - Dissolved Air Flotation Pretreatment										**1,072,663**	**2,939**

TREATMENT PLANT
PRETREATMENT OPTION 3
ULTRAFILTRATION

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 3 - Ultrafiltration Pretreatment

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUBTOTAL	30% INSTALL COST	20% ELEC. & I&C COST	SUBTOTAL
1	**Major Equipment**							
1.1	UF Zeeweed 500D (Installation Reduced to 10%)	1	LS	$20,000,000	$20,000,000	$2,000,000	$4,000,000	$26,000,000
1.2	DensaDeg Clarifier / Thickener (Rapid Mix & DensDeg unit)	3	EA	$433,333	$1,299,999	$390,000	$260,000	$1,949,999
1.3	Centrifuge Equipment	3	EA	350000	$1,050,000	$315,000	$210,000	$1,575,000
1.4	5 hp mixers for Rapid Mix Basins	10	EA	37500	$375,000	$112,500	$75,000	$562,500
1.5	1 hp mixers for Flocculation Basins	40	EA	$7,000	$280,000	$84,000	$56,000	$420,000
SUBTOTAL - Major Equipment								$30,507,499
2	**Process Piping (valves, appurtenances etc.**							
2.1	60" DICL (raw, permeate)	700	LF	$400	$280,000	n/a	n/a	$280,000
2.2	48" DICL (permeate)	240	LF	$264	$63,360	n/a	n/a	$63,360
2.7	42 " DICL (raw)	200	LF	$200	$40,000	n/a	n/a	$40,000
2.8	30" DICL (raw, permeate)	180	LF	$110	$19,800	n/a	n/a	$19,800
2.9	24" DICL (reject, drain, CIP nuetralized)	400	LF	$100	$40,000	n/a	n/a	$40,000
2.6	10" DICL (eq. residuals piping)	100	LF	$35	$3,500	n/a	n/a	$3,500
2.7	4" DICl (TSLP, centrate pumping)	500	LF	$22	$11,000	n/a	n/a	$11,000
2.11	18" PVC push on jt supernatant return pipe	260	LF	$55	$14,300	n/a	n/a	$14,300
2.12	48" elbows	2	EA	$5,000	$10,000	n/a	n/a	$10,000
2.13	24" butterfly valves with motor operators	10	EA	$22,000	$220,000	n/a	n/a	$220,000
2.14	18" flow meters	10	EA	$16,000	$160,000	n/a	n/a	$160,000
2.18	24" slide gates	40	EA	$5,000	$200,000	n/a	n/a	$200,000
2.20	Allowance for misc. fittings & smaller valves	1	LS	$30,000	$30,000	n/a	n/a	$30,000
SUBTOTAL - Process Piping (valves, appurtenances etc.								$1,091,960
3	**Concrete**							
3.1	Rapid Mix & Floc Basins	1,150	CY	$600	$690,000	n/a	n/a	$690,000
3.2	Influent Distribution Channel	211	CY	$600	$126,600	n/a	n/a	$126,600
3.3	Influent Distribution Channel - Overflow Areas	43	CY	$600	$25,800	n/a	n/a	$25,800
3.4	Nuetralization Tank	170	CY	$600	$102,000	n/a	n/a	$102,000
3.5	Zeeweed Process Tanks	1,700	CY	$600	$1,020,000	n/a	n/a	$1,020,000
3.6	Reject Equalization Tank	1,634	CY	$600	$980,400	n/a	n/a	$980,400
3.7	DensaDeg Clarifier/Thick (Rapid Mix & DensDeg unit)	1,621	CY	$600	$972,600	n/a	n/a	$972,600
3.8	Thickened Sludge Equalization Tank	783	CY	$600	$469,800	n/a	n/a	$469,800
3.9	Zeeweed Process Buildings Slab on Grade	1,778	CY	$400	$711,111	n/a	n/a	$711,111
3.10	Chem Feed Building Slab on Grade	208	CY	$400	$83,333	n/a	n/a	$83,333
3.11	Dewatering Building Slab on Grade	400	CY	$400	$160,000	n/a	n/a	$160,000
3.12	Equalization Tank Pump Station Slab	17	CY	$400	$6,667	n/a	n/a	$6,667
SUBTOTAL - Concrete								$5,348,311

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 3 - Ultrafiltration Pretreatment

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUBTOTAL	30% INSTALL COST	20% ELEC. & I&C COST	SUBTOTAL
4	**Building**							
4.1	Bldgs for Zeeweed Process & Chem Feeds (200 x 160)	32,000	SF	$64	$2,048,000	n/a	n/a	$2,048,000
4.2	Chem Feed Bldg (pre-engineered) (75 x 50)	3,750	SF	$64	$240,000	n/a	n/a	$240,000
4.3	Dewatering Building (pre-engineered) (40 x 40)	1,600	SF	$64	$102,400	n/a	n/a	$102,400
4.4	Equalization Tank Pump Station (15 X 20)	300	SF	$64	$19,200	n/a	n/a	$19,200
SUBTOTAL - Building								$2,409,600
5	**Site work**							
5.1	Excavation for RM & flocculation (40 x 120 x 12)	2,133	CY	15	$31,995	n/a	n/a	$31,995
5.2	Excavation for Zenon process (13 x 120 x 75)	4,333	CY	$15	$64,995	n/a	n/a	$64,995
5.3	Excavation for Nuetralization Tanks	450	CY	$16	$7,200	n/a	n/a	$7,200
5.4	Excavation for DensaDeg units	1,630	CY	$15	$24,450	n/a	n/a	$24,450
5.5	Excavation for Thickened Sludge Eq. Tank	650	CY	$15	$9,750	n/a	n/a	$9,750
5.6	Excavation for Reject Eq Tank	3,000	CY	$15	$45,000	n/a	n/a	$45,000
5.7	Excavation for piping	2,000	CY	$12	$24,000	n/a	n/a	$24,000
5.8	Sheeting for Zenon Basins	5,500	SF	$12	$66,000	n/a	n/a	$66,000
5.9	Sheeting for Eq. Tanks & DD's	5,300	SF	12	$63,600	n/a	n/a	$63,600
5.11	Excavation for Chemical Feed Building	8,333	CY	$15	$125,000	n/a	n/a	$125,000
5.12	Excavation for Dewatering Building	3,556	CY	$15	$53,333	n/a	n/a	$53,333
5.13	Excavation Equalization Pump Station	667	CY	$15	$10,000	n/a	n/a	$10,000
SUBTOTAL - Site work								$525,323
6	**Residuals Transfer Pumping**							
6.1	Residuals Transfer Pumps 1300 gpm 25 TDH 15 HP	3	EA	$40,000	$120,000	$36,000	$24,000	$180,000
6.2	TSLPs 100 gpm at 12 TDH hose pumps (w/vfd) 1 HP	3	Ea	$35,000	$105,000	$31,500	n/a	$136,500
6.3	Centrate transfer pumps 300 gpm 15 TDH, centrifugal 1 HP	2	Ea	7500	$15,000	$4,500	$3,000	$22,500
SUBTOTAL - Residuals Transfer Pumping								$339,000

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 3 - Ultrafiltration Pretreatment

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUBTOTAL	30% INSTALL COST	20% ELEC. & I&C COST	SUBTOTAL
7	Chemical Feed Systems (1)							
7.1	Ferric Chloride bulk storage tank 20' D, 20' H**	4	Ea	$50,000	$200,000	$60,000	n/a	$260,000
7.2	FeCL3 day tanks, 400 gallons each	12	Ea	$1,500	$18,000	$5,400	n/a	$23,400
7.3	FeCl3 metering pumps (400 gpd each)	14	Ea	$7,000	$98,000	$29,400	n/a	$127,400
7.4	Polymer bulk storage tank 5 ft diam, 6 feet high**	1	Ea	$2,000	$2,000	$600	n/a	$2,600
7.5	Polymer feed pumps (10 gpd each)	3	Ea	$5,000	$15,000	$4,500	n/a	$19,500
7.6	NaOCL bulk storage tanks	4	Ea	$30,000	$120,000	$36,000	n/a	$156,000
7.7	NaOCL day tanks, 400 gallons each	6	Ea	$1,500	$9,000	$2,700	n/a	$11,700
7.8	NaOCL metering pumps (400 gpd each)	6	Ea	7000	$42,000	$12,600	n/a	$54,600
7.9	Allowance for chem feed piping, appurtenances (5% of chem feed equip costs)	1	LS	25200	$25,200	$7,560	n/a	$32,760
	(1) Zenon cleaning chemical feed systems included with Zenon scope of supply.							
SUBTOTAL - Chemical Feed Systems (1)								$687,960
#REF!					$33,149,393	$3,132,260	$4,628,000	$40,909,653

* Piping and fittings costs include bedding and an aditional 20% for corrosion protection

** Inlcudes storage volume for DensaDeg operation & centrifuge operation

Construction Contingency (%)		25%	$10,227,413
Construction Cost Total			$51,137,066
Contractors OH&P (%)		17%	$8,693,301
Mobilization/Demobilization		3%	$1,534,112
Estimated Comnstruction Costs			$61,364,479
Survey, Geotech, Easements (%)		8%	$4,909,158
Environmental Mitigation	ENV-1	5%	$2,822,766
Engineering fees (%)		10%	$6,136,448
#REF!			$75,232,852

Concept Design O&M Costs - SUMMARY

Pre-Treatment Option 3

Ultrafiltration Pretreatment

Description	Power	Chemicals	Rehab & Repairs	Labor	Solids Handling	TOTAL
Annual Costs	$731,388	$1,087,327	$3,335,835	$1,963,880	$1,670,381	$8,788,811
Present Worth Factor						12.462
Presnt Worth of Annual O&M						$109,528,011

Concept Design O&M Costs - POWER O&M

Pre-Treatment Option 3

Ultrafiltration Pretreatment

Description	Units in Operation	Flow (mgd)	Head (ft)	BHP	kW	Hours/ Day	Kw-hrs/ yr	Total Cost / year
Major Equipment								
Thickened Sludge Transfer Pumps	2	0.22	20	2.5	1.9	6	4,157	$270
Residuals Transfer Pumps	2	1.87	35	29.0	21.6	24	189,141	$12,294
Centrate Transfer Pumps	1	n/a	n/a	5	3.7	6	8,165	$531
Densadeg Units	2	n/a	n/a	30	22.4	24	195,970	$12,738
Centrifuges	3	n/a	n/a	100	224	6	489,925	$31,845
Rapid Mix Basins	8	n/a	n/a	5	29.8	24	261,293	$16,984
Flocculation Mixers	96	n/a	n/a	1	71.6	24	627,104	$40,762
Permeate Pumps	10	5.2	46	602.7	461	24	4,042,654	$262,772
Backwash Pumps	2	3.0	50	75.2	56	7.8	160,171	$10,411
CIP Transfer Pumps	1	n/a	n/a	28.8	21.5	0.02	157	$10
Vacuum Pumps	3	n/a	n/a	36.7	27.4	24	240,024	$15,602
Membrane Air Scour Blowers	6	n/a	n/a	451.9	337	24	2,952,120	$191,888
SUBTOTAL Major Equipment								$596,107
Electricity for Buildings								
Bldgs for Zeeweed Process & Chem Feeds (200 x 160	1	n/a	n/a	n/a	145.0	24	1,270,400	$82,576
Chem Feed Bldg (pre-engineered) (75 x 50)	1	n/a	n/a	n/a	52.3	24	458,250	$29,786
Dewatering Building (pre-engineered) (40 x 40)	1	n/a	n/a	n/a	7.3	24	63,520	$4,129
Equalization Tank Pump Station (15 X 20)	1	n/a	n/a	n/a	1.4	24	11,910	$774
SUBTOTAL Electricity for Buildings								$117,265
Chemical Metering Pumps(1)								
Rapid Mix Ferric Chloride metering pumps	8	n/a	n/a	0.33	2.0	24	17,245	$1,121
Rapid Mix Polymer Pumps	8	n/a	n/a	0.33	2.0	24	17,245	$1,121
Densadeg Polymer Pump	2	n/a	n/a	0.33	0.5	24	4,311	$280
Sodium Hypochlorite for Disinfection	4	n/a	n/a	0.33	1.0	24	8,623	$560
Densadeg Ferric Chloride metering pumps	2	n/a	n/a	0.33	0.5	24	4,311	$280
Centrifuge Mix Polymer Pumps	2	n/a	n/a	0.33	0.5	24	4,311	$280
SUBTOTAL SUBTOTAL Major Equipment								$120,908

Concept Design O&M Costs - POWER O&M
Pre-Treatment Option 3
Ultrafiltration Pretreatment

Description	Units in Operation	Flow (mgd)	Head (ft)	BHP	kW	Hours/ Day	Kw-hrs/ yr	Total Cost / year
Option 3 Only Equipment for Pre-Treatment Option: Low Pressure Membranes								
Backpulses Sodium Hypo Feed Pumps	2	n/a	n/a	1.0	0.7457	7.8	2,131	$139
CIP MC-1 Feed Pumps	2	n/a	n/a	2.4	1.8	24	15,768	$1,025
CIP Sodium Hydroxide Feed Pumps	2	n/a	n/a	0.3	0.2	24	1,752	$114
CIP Sodium Hypochlorite Feed Pumps	4	n/a	n/a	1.5	1.1	24	9,636	$626
CIP Sodium Bisulfite Feed Pumps	2	n/a	n/a	0.1	0.1	24	876	$57
CIP Tank Heater #1	2	n/a	n/a	196.7	146.7	3.3	174,558	$11,346
Air Compressors	2	n/a	n/a	14.3	10.7	2.8	10,935	$711
Air Driers	1	n/a	n/a	0.3	0.2	2.8	204	$13
Controls and Instrumentation	1	n/a	n/a	0.4	0.3	24	2,628	$171
Miscellaneous	1	n/a	n/a	0.4	0.3	24	2,628	$171
SUBTOTAL Option 3 Only Equipment for Pre-Treatment Option: Low Pressure Membranes								$14,373
TOTAL Concept Design O&M Costs - POWER O&M Pre-Treatment Option 3								$731,388

1. Assume 8 chemical metering pumps for ferric and 8 for polymer for mixing tanks and 2 for Densadeg Dose

Concept Design O&M Costs - LABOR O&M
Pre-Treatment Option 3
Ultrafiltration Pretreatment With Reverse Osmosis

	Title	# of Staff	Hours Per Day	Days Per Week	Hours Per Week/Pers	Annual Salary	Hourly Rate	Total
Operations								
	Manager - Operations	1	8	5	40	$75,000	$36.06	108,750
	Administrative Assistant	1	8	5	40	$30,000	$14.42	43,500
	Operator - Sr.	4	8	7	224	$45,000	$21.63	365,400
	Operator I	1	8	5	40	$40,000	$19.23	58,000
	Operator II	1	8	4	32	$35,000	$16.83	40,600
	Assistant to Operator	1	8	5	40	$30,000	$14.42	43,500
	Assistant to Operator II	1	8	2	16	$28,000	$13.46	16,240
	Lab Chemist	1	8	5	40	$45,000	$21.63	65,250
	Lab Chemist II	1	8	2	16	$40,000	$19.23	23,200
SUBTOTAL LABOR O&M Operations								764,440
Maintenance								
	Manager - Maintenance	1	8	5	40	$60,000	$28.85	87,000
	Mechanics	2	8	5	80	$40,000	$19.23	116,000
	Mechanic Assistant	1	8	5	40	$35,000	$16.83	50,750
	Electrician	1	8	5	40	$45,000	$21.63	65,250
	Elect./Instr. Assistant	1	8	5	40	$35,000	$16.83	50,750
	Instrumentation	1	8	5	40	$45,000	$21.63	65,250
SUBTOTAL LABOR O&M Maintenance								435,000
TOTAL ANNUAL LABOR COSTS								**1,963,880**

*** M-F from 9-5 have 8 staff**

****Sat - Sun 9 to 5 have 4 staff**

*****Off Housrs only one operator present at all times**

******Assumed operate by City of Corpus Christi.**

Operations estimated to require 2.0 man-hours per day (40 min per 8 hour shift).

Labor for routine maintenance estimated at 2 man-weeks per yearor 1.5 man-hours per week.

Labor required for standard equipment maintenance per manufacturers instructions

Concept Design O&M Costs - CHEMICAL O&M COSTS
Pre-Treatment Option 3
Ultrafiltration Pretreatment

Chemical	Dose(7) (mg/L)	Flow (gpm)	lbs/day	Gallons Per Day	Cost per Pound or gallon	Cost per Year
Ferric Chloride (Coagulation)	25	38,194	11467		$0.17	$711,550
Polymer (Dewatering)	1	40	0.5		$1.38	$242
Polymer (Thickening)	1	1,854	22		$1.38	$11,215
Ferric Chloride (Thickening)	30	1854	668		$0.17	$41,448
Sodium Hypochlorite	3	17,361	521	628	$0.74	$169,623
Zenon Cleaning Chemical Requirements						
Sodium hypochlorite				350	$0.74	$94,589
Sodium bisulphite			300		$0.26	$28,489
Sodium hydroxide			193		$0.05	$3,513
Citric acid			72		$0.60	$15,702
Hydrochloric acid			67		$0.45	$10,955
TOTAL ANNUAL CHEMICAL COSTS						$1,087,327

Notes

1. Sodium Hypochlorite for Zenon prechlorination is assumed to be a shock treatment: 5 hours at 3 mg/l once per week to 50 mgd.
2. Sodium Bisulfite will provide dechlorination for shock treatment so assume 3 mg/L dosed to 50 mgd for 5 hours per week. Assumes chlorine residual of 2 mg/l

Concept Design O&M Costs - REHAB & REPAIR O&M COSTS
Pre-Treatment Option 3
Ultrafiltration Pretreatment

Annual Repair and Rehabilitation Costs

Equipment	$57,991,869	4% of Equipmer	$2,319,675
Pipe	$2,008,114	1% of Pipe	$20,081
Structures	$15,232,868	1% of Structures	$152,329
Other (1)			$843,750
TOTAL Annual Repair and Rehabilitation Costs			$3,335,835

1. Zenon Membrane replacement. Assumes $703 per module x 6000 modules = $4,218,000 per replacement. Assuming 4 replacments per 20 yr period (5 yr membrane life), annual cost is $843,750.

Concept Design O&M Costs - SOLIDS PROCESSING O&M COSTS
Pre-Treatment Option 3
Ultrafiltration Pretreatment

SOLIDS PRODUCTION

Solids Source	Conc/Dose (mg/l)	Flow (mgd)	Dry Solids (lbs/day)	Dry Solids (Tons/year)
Solids from TSS	25	55	11,468	2,093
Solids from treatment chemicals	40	55	18,348	3,349
Solids Precipitated	5	55	2,294	419
TOTAL SOLIDS	**70**		**32,109**	**5,860**

SLUDGE CHARACTERISTICS

Density of Water	62.4	lbs/cf
Density of Solids	110	lbs/cf
Cake Solids concentration	24.0%	
Specific Gravity of Sludge	1.2	
Compaction Ratio	88%	
Density of Sludge to Transport	65.0	lbs/cf

ANNUAL SLUDGE DISPOSAL COST

Solids Produced	5,860	dt/yr
Weight of Sludge produced	24,416	tons/yr
Volume of Sludge Produced	27,840	CY/yr
Cost to Dispose of sludge cake	$60.00	per CY
Annual Solids disposal Cost	**$1,670,381**	**$/yr**

Concept Design O&M Costs - HVAC O&M COSTS
Pre-Treatment Option 3
Ultrafiltration Pretreatment

OPTION 3 - HVAC POWER

					Electric Energy (kW*hr/ft3/yr)						
					Lighting	Ventilation	Heating	Cooling	Cool-Admin	Total	Total
					Per ft2/yr	Per ft2/yr	Per ft2/yr	Per ft2/yr	Per ft2/yr	kW*hr/yr	kW*hr/day
Option 3 Buildings		**Length**	**Width**	**Building Area (SF)**	17.5	2.2	15	5	35		
1	Bldgs for Zeeweed Process & Chem Feeds (200 x 160)	200	160	32,000	560,000	70,400	480,000	160,000		**1,270,400**	3,481
2	Chem Feed Bldg (pre-engineered) (75 x 50)	75	50	3,750	65,625	8,250	56,250		328,125	**458,250**	1,255
3	Dewatering Building (pre-engineered) (40 x 40)	40	40	1,600	28,000	3,520	24,000	8,000		**63,520**	174
4	Equalization Tank Pump Station (15 X 20)	15	20	300	5,250	660	4,500	1,500		**11,910**	33
TOTAL Annual Lighting & HVAC Energy Consumption - Ultrafiltration Pretreatment										**1,804,080**	**4,943**

TREATMENT PLANT
PRETREATMENT OPTION 4
BANK FILTRATION

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 4

Bank Filtration Pretreatment

ITEM	DESCRIPTION	QUAN.	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL COST	20.0% ELEC/I&C	SUBTOTAL
1	**Major Equipment**							
1.1	UV System (40 mJ/cm^2, 12.5 mgd per reactor)	3	Ea	$153,300	$459,900	$137,970	$91,980	$689,850
SUBTOTAL Major Equipment								$689,850
2.	**UV Process Piping**							
2.1	48" DICL (RO permeate)	200	LF	$264	$52,800	$0	$0	$52,800
2.2	36" DICL (post-UV)	40	LF	$175	$7,000	$0	$0	$7,000
2.3	36" x 48" reducers	6	Ea	$3,000	$18,000	$0	$0	$18,000
2.4	48" tees	2	Ea	$20,000	$40,000	$0	$0	$40,000
2.5	48" elbows	1	Ea	$5,000	$5,000	$0	$0	$5,000
2.6	48" isolation valve	3	Ea	$18,000	$54,000	$0	$0	$54,000
2.7	36" flow meters	3	Ea	$30,000	$90,000	$0	$0	$90,000
2.8	36" motor operated butterfly valves	3	Ea	$30,000	$90,000	$0	$0	$90,000
2.9	Allowance for misc fittings & smaller valves (5%)	1	LS	$5,322	$17,840	$0	$0	$17,840
SUBTOTAL UV Process Piping								$374,640
3	**Concrete**							
3.1	UV Building Slab on Grade (50 x 50)	140	CY	$400	$56,000	$0	$0	$56,000
3.2	UV flow distribution chambers	33	CY	$401	$13,233	$0	$0	$13,233
SUBTOTAL Concrete								$69,233
4	**Buildings**							
4.1	Pre-engineered UV Bldg (50 X 50)	2500	SF	$64	$160,000	$0	$0	$160,000
SUBTOTAL Buildings								$160,000

Concept Design Capital Costs - Pretreatment Capital Costs

Pre-Treatment Option 4

Bank Filtration Pretreatment

ITEM	DESCRIPTION	QUAN.	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL COST	20.0% ELEC/I&C	SUBTOTAL
5	**Site work**							
5.1	Excavation for UV Bldg slab on grade	200	CY	$15	$3,000	$0	$0	$3,000
5.2	Excavation for UV chambers	100	CY	$15	$1,500	$0	$0	$1,500
SUBTOTAL Site work								$4,500
SUBTOTAL ESTIMATED CONSTRUCTION DIRECT COST - Bank Filtration Pretreatment					$1,068,273	$137,970	$91,980	$1,298,223

Construction Contingency (%)		25%	$324,556
Construction Cost Total			$1,622,779
Contractors OH&P (%)		17%	$275,872
Mobilization/Demobilization		3%	$48,683
Estimated Comnstruction Costs			$1,947,335
Survey, Geotech, Easements (%)		8%	$155,787
Environmental Mitigation	ENV-1	5%	$89,577
Engineering fees (%)		10%	$194,733
Total Bank Filtration Pretreatment			$2,387,432

Equipment Costs for Maintenance & Parts O&M

$689,850

Concept Design O&M Costs - SUMMARY
Pre-Treatment Option 4
Bank Filtration Pretreatment

Description	Power	Chemicals	Rehab & Repairs	Labor	Solids Handling	TOTAL
Annual Costs	$28,891	$200	$75,479	$1,084,600	$0	$1,189,171
Present Worth Factor						12.462
Presnt Worth of Annual O&M						$14,819,696

Concept Design O&M - Power Costs
Pre-Treatment Option 4
Bank Filtration Pretreatment

Description	Units in Operation	Flow (mgd)	Head (ft)	BHP	kW	kw/hrs/day	Kw-hrs/ yr	Total Cost / year
Major Equipment								
UV reactors	2	n/a	n/a	n/a	14.0	337	122,990	$7,994
SUBTOTAL Major Equipment								$7,994
Buildings								
Pre-engineered UV Bldg (50 X 50)	1	n/a	n/a	n/a	n/a	272	99,250	$6,451
SUBTOTAL Buildings								$6,451
TOTAL Concept Design O&M - Power Costs - Bank Filtration Pretreatment								$28,891

Concept Design O&M Costs - LABOR

Pre-Treatment Option 4

Bank Filtration Pretreatment

	Title	# of Staff	Hours Per Day	Days Per Week	Hours Per Week/Pers	Annual Salary	Hourly Rate	Total
Operations								
	Manager - Operations	1	8	5	40	$75,000	$36.06	$108,750
	Administrative Assistant	1	8	5	40	$30,000	$14.42	$43,500
	Operator - Sr.	4	8	7	224	$45,000	$21.63	$365,400
	Operator I	1	8	5	40	$40,000	$19.23	$58,000
	Operator II	0	8	4	0	$35,000	$16.83	$0
	Assistant to Operator	1	8	5	40	$30,000	$14.42	$43,500
	Assistant to Operator II	0	8	2	0	$28,000	$13.46	$0
	Lab Chemist	1	8	5	40	$45,000	$21.63	$65,250
	Lab Chemist II	1	8	2	16	$40,000	$19.23	$23,200
SUBTOTAL Labor - Operations								$707,600
Maintenance								
	Manager - Maintenance	1	8	5	40	$60,000	$28.85	$87,000
	Mechanics	1	8	5	40	$40,000	$19.23	$58,000
	Mechanic Assistant	1	8	5	40	$35,000	$16.83	$50,750
	Electrician	1	8	5	40	$45,000	$21.63	$65,250
	Elect./Instr. Assistant	1	8	5	40	$35,000	$16.83	$50,750
	Instrumentation	1	8	5	40	$45,000	$21.63	$65,250
SUBTOTAL Labor - Maintenance								$377,000
TOTAL ANNUAL LABOR COSTS								**$1,084,600**

*** M-F from 9-5 have 8 staff**

****Sat - Sun 9 to 5 have 4 staff**

*****Off Housrs only one operator present at all times**

******Assumed operate by City of Corpus Christi.**

Operations estimated to require 2.0 man-hours per day (40 min per 8 hour shift).

Labor for routine maintenance estimated at 2 man-weeks per yearor 1.5 man-hours per week.

Labor required for standard equipment maintenance per manufacturers instructions

Concept Design O&M Costs - Chemical
Pre-Treatment Option 4
Bank Filtration Pretreatment

Chemical	Dose (mg/L)	Flow (gpm)	lbs/day	Gallons/ day	Unit Cost	Cost per Year
UV cleaning chemicals						$200
					O&M Cost Total, $/yr.	$200

Concept Design O&M Costs - REHAB & REPAIR O&M

Pre-Treatment Option 4

Bank Filtration Pretreatment

Annual Repair and Rehabilitation Costs

Equipment	$1,268,634	4% of Equipment	$50,745
Pipe	$688,963	1% of Pipe	$6,890
Structures	$429,835	1% of Structures	$4,298
Other (1)			$13,546
TOTAL Annual Repair and Rehabilitation Costs			$75,479

(1) Lamp Replacement Cost Calculation

No. Of Lamps	72
Hours per year	8,760
Lamp hours per year	630,720
Lamp Life Estimate	8,800
Lamp Replacements per Year	72
Lamp Cost	$185
Ballast Replacement (2% of Lamp Cost)	$4
Annual Lamp Replacement Cost	$13,546

Concept Design O&M Costs - Lighting & HVAC O&M

Pre-Treatment Option 4

Bank Filtration Pretreatment

					Electric Energy (kW*hr/ft^3/yr)					
					Lighting	Ventilation	Heating	Cooling	Total	Total
					Per ft2/yr	Per ft2/yr	Per ft2/yr	Per ft2/yr	kW*hr/yr	kW*hr/day
Option 4 Buildings		Length	Width	Building Area (SF)	**17.5**	**2.2**	**15.0**	**5.0**	**39.7**	
1	Pre-engineered UV Bldg (50 X 50)	50	50	2,500	43,750	5,500	37,500	12,500	99,250	**272**
	Total for Option 4			**2,500**	**43,750**	**5,500**	**37,500**	**12,500**	**99,250**	**272**

TREATMENT PLANT
COMMON ELEMENTS
Storage tanks, Reverse Osmosis systems,
Admin Building, Pump Stations,
Appurtenances, Etc

Concept Design Preliminary Capital Cost Estimate

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL. COST	20% ELEC. & I&C COST	SUBTOTAL
1. Major Equipment								
1.1	RO System[(1)] (Installation reduced to 10%)	1	LS	$15,500,000	$15,500,000	$1,550,000	$3,100,000	$20,150,000
1.2	Intermediate Pumps (150 Hp split case)	6	EA	$119,000	$714,000	$214,200	$142,800	$1,071,000
1.3	Finished water split case pumps (450 HP)	4	EA	$74,000	$296,000	$88,800	$59,200	$444,000
1.4	Raw Water Pumps	4	EA	$133,000	$532,000	$159,600	$106,400	$798,000
1.5	Byproduct Pumps	4	EA	$57,000	$228,000	$68,400	$45,600	$342,000
SUBTOTAL Major Equipment				$15,883,000	$17,270,000	$2,081,000	$3,454,000	$22,805,000
2. Process Piping (includes valves, appurtenances &								
2.1	Allowance for process piping at 10%	1	LS	n/a	$1,727,000	$208,100	$345,400	$2,280,500
2.2	24" butterfly control valves with motor operators	12	EA	$22,000	$264,000	n/a	n/a	$264,000
SUBTOTAL Process Piping				$22,000	$1,991,000	$208,100	$345,400	$2,544,500
3. Concrete & Storage Tanks								
3.1	RO Building Slab on grade (47600 SF x 1.5)	2,644	CY	$400	$1,057,778	n/a	n/a	$1,057,778
3.2	FW Storage Tanks (2 @ 1.3 MG)	2.6	MG	$500,000	$1,300,000	n/a	n/a	$1,300,000
3.3	Intermediate Clearwell (2 $ 1.1 MG)	2.2	Ea	$500,000	$1,100,000	n/a	n/a	$1,100,000
3.4	Intermediate Pump Station (40 ft x 60 ft)	325	CY	$400	$130,000	n/a	n/a	$130,000
3.5	Finished Water Pump Station (slab on grade)	672	CY	$400	$268,889	n/a	n/a	$268,889
3.6	Generator Bldg (slab on grade)	171	CY	$400	$68,444	n/a	n/a	$68,444
3.7	Admin Bldg (slab on grade)	428	CY	$400	$171,111	n/a	n/a	$171,111
3.8	Raw Water Pump Station	456	CY	$600	$273,333	n/a	n/a	$273,333
3.9	Byproduct PS (slab on Grade)	67	CY	$400	$26,667	n/a	n/a	$26,667
SUBTOTAL Concrete & Storage Tank				$1,003,000	$4,396,222			$4,396,222
4. Buildings								
4.1	RO Building (280 x 170)	47,600	SF	$64	$3,046,400	n/a	n/a	$3,046,400
4.2	Admin Bldg PS (100 x 70)	7,000	SF	$125	$875,000	n/a	n/a	$875,000
4.3	Generator Bldge PS (70 x 40)	2800	SF	$64	$179,200	n/a	n/a	$179,200
4.4	Intermediate PS (65 x 45)	2925	SF	$64	$187,200	n/a	n/a	$187,200
4.5	High Service PS (110 x 55)	6050	SF	$64	$387,200	n/a	n/a	$387,200
4.6	Raw Water PS (45 x 40)	1800	SF	$64	$115,200	n/a	n/a	$115,200
4.7	Byproduct PS (40 x 30)	1200	SF	$64	$76,800	n/a	n/a	$76,800
SUBTOTAL Buildings				$509	$4,867,000			$4,867,000

Concept Design Preliminary Capital Cost Estimate

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL. COST	20% ELEC. & I&C COST	SUBTOTAL
5. Site work								
5.1	Excavation for RO Bldg slab on grade	5818	CY	$15	$87,267	n/a	n/a	$87,267
5.2	Exc for Intermediate Clearwell Tanks	700	CY	$15	$10,500	n/a	n/a	$10,500
5.3	Exc for Finished Water Storage Tanks	800	CY	$15	$12,000	n/a	n/a	$12,000
5.4	Excavation for Generator Bldg slab on grade	285	CY	$15	$4,278	n/a	n/a	$4,278
5.5	Excavation for Admin Bldg slab on grade	713	CY	$15	$10,694	n/a	n/a	$10,694
5.6	Excavation for Intermediate PS slab on grade	358	CY	$15	$5,363	n/a	n/a	$5,363
5.7	Excavation for High Service PS slab on grade	739	CY	$15	$11,092	n/a	n/a	$11,092
5.8	Excavation for yard piping	700	CY	$12	$8,400	n/a	n/a	$8,400
5.9	Excavation For Raw Water PS	4000	CY	$15	$60,000	n/a	n/a	$60,000
5.10	Excavation for Byproduct PS Slab on Grade	147	CY	$15	$2,200	n/a	n/a	$2,200
5.11	Site Utilities, Drainage, Power Dist., Paving, etc.	20	AC	$50,000	$1,000,000	n/a	n/a	$1,000,000
SUBTOTAL Sitework								$1,211,793
6. Chemical Feed Systems								
6.1	Lime storage and feed system	1	LS	$400,000	$400,000	$120,000	$80,000	$600,000
6.2	Ammonia storage and feed system	1	LS	$200,000	$200,000	$60,000	$40,000	$300,000
6.3	HSF acid feed system	1	LS	$200,000	$200,000	$60,000	$40,000	$300,000
6.4	CO2 feed system	1	LS	$250,000	$250,000	$75,000	$50,000	$375,000
6.5	H2SO4 bulk storage tanks	1	LS	$75,000	$75,000	$22,500	$15,000	$112,500
6.6	RO cleaning chemical bulk storage	1	LS	$75,000	$75,000	$22,500	$15,000	$112,500
6.7	Sodium bisulfite bulk tanks	1	LS	$75,000	$75,000	$22,500	$15,000	$112,500
6.8	Allowance for chem feed piping, appurtenances (5% of chem feed equip costs)	1	LS	$63,750	$63,750	$19,125	$12,750	$95,625
SUBTOTAL Chem Feed Systems								$2,008,125

Concept Design Preliminary Capital Cost Estimate
For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

ITEM	DESCRIPTION	Quan	Unit	UNIT PRICE	SUB-TOTAL	30% INSTALL. COST	20% ELEC. & I&C COST	SUBTOTAL
7. Miscellaneous Equipment								
7.1	2 ton hoist	3	LS	$2,500	$7,500	$2,250	$1,500	$11,250
7.2	Monorail crane track (300 LF)	900	LF	$28	$25,200	$7,560	$5,040	$37,800
7.3	Emergency Generator	1	LS	$650,000	$650,000	n/a	n/a	$650,000
7.4	20 MW Substation	1	LS	$3,200,000	$3,200,000	n/a	n/a	$3,200,000
SUBTOTAL Miscellaneous Equipment								$3,899,050
SUB TOTAL ESTIMATED CONSTRUCTION DIRECT COST					$63,481,688	$4,989,635	$7,873,090	$41,731,690

Construction Contingency (%)	25%	$10,432,923
Construction Cost Total		$52,164,613
Contractors OH&P (%)	17%	$8,867,984
Mobilization/Demobilization	3%	$1,564,938
Estimated Construction Costs		$62,597,535
Survey, Geotech, Easements (%)	8%	$5,007,803
Environmental Mitigation ENV-1	5%	$2,879,487
Engineering fees (%)	10%	$6,259,754
Total		$76,744,578

1.839

* Piping and fittings costs include bedding and an additional 20% for corrossion protection

** Includes storage volume for DensaDeg operation & centrifuge operation

1) Includes cartridge filters, membranes, vessels, valving, skid piping, racks, local inst, controls, HP feed pumps, chem feed equip (limited), cleaning skid

Concept Design O&M Costs - SUMMARY

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

Description	Power	Chemicals	Rehab & Repairs	Labor	TOTAL
Annual Costs	$6,997,762	$1,374,307	$3,365,606	*	$11,737,676
Present Worth Factor					12.462
Presnt Worth of Annual O&M					$146,277,389

* Costs for all labor are included in the pretreatment options

Concept Design O&M Costs - POWER O&M

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

Desc.	Units in Oprtn	Flow (MGD)	Head (ft)	BHP	kW	Hours / Day	Kw-hrs/yr	Total Cost per year
Major Equipment								
Intermediate Pump Station	5	10	45	493	367.79	24	3,222,000	$209,430
Finished Water Pumps	3	8.3	208	1139	849.56	24	7,442,000	$483,730
Raw Water Pump Station	3	18.33	75	904	674.28	24	5,907,000	$383,955
Byproduct Pump Station	3	8.33	35	192	143.03	24	1,253,000	$81,445
Reverse Osmosis	5	10	2309	25,307	18,872	24	165,300,000	$10,744,500
RO Energy Recovery System (47% Recovery)							-78,500,000	$-5,102,500
SUBTOTAL Major Equipment								$6,800,560
Electricity Buildings - Lighting and HVAC								
RO Building (280 x 170)	1	n/a	n/a	n/a	215.72	24	1,889,720	$122,832
Admin Bldg PS (100 x 70)	1	n/a	n/a	n/a	55.70	24	487,900	$31,714
Generator Bldge PS (70 x 40)	1	n/a	n/a	n/a	12.69	24	111,160	$7,225
Intermediate PS (65 x 45)	1	n/a	n/a	n/a	13.26	24	116,123	$7,548
High Service PS (110 x 55)	1	n/a	n/a	n/a	27.42	24	240,185	$15,612
Raw Water PS (45 x 40)	1	n/a	n/a	n/a	8.16	24	71,460	$4,645
Byproduct PS (40 x 30)	1	n/a	n/a	n/a	5.44	24	47,640	$3,097
SUBTOTAL Electricity Buildings - Lighting and HVAC								$192,672
Chemical Metering Pumps								
Shock Hypo	4	n/a	n/a	0.33	0.99	0.71	8	$0
Shock Bisulfite	4	n/a	n/a	0.33	0.99	0.71	8	$0
SUBTOTAL Chemical Metering Pumps								$1
RO Pre & Post Treatment								
Metering Pump Sodium Hypochlorite	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metering Pump Sodium Bisulfite	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metring PumpSulfuric Acid	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metering Pump Hydrated Lime	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metering Pump Carbon Dioxide	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metering Pump Flouride	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metering Pump Sodium Hypochlorite	4	n/a	n/a	0.33	0.99	24	8,710	$566
Metering Pump Ammonia	4	n/a	n/a	0.33	0.99	24	8,710	$566
SUBTOTAL RO Pre & Post Treatment								$4,529
TOTAL Concept Design O&M Costs - POWER O&M - For Plant Site Common Elements								$6,997,762

Concept Design O&M Costs - CHEMICAL O&M COSTS

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

Chemical	Dose (mg/L)	Flow (gpm)	lbs/day	Gallons/ day	Cost per Pound or gallon	Cost per Year
RO Pre & Post Treatment						
Shock Treatment Sodium Hypochlorite	3	38,194	41	10.3	$0.74	$2,777
Shock Treatment Sodium Bisulfite	3	38,194	41	6.25	$0.26	$593
Sulfuric Acid	16	38,194	7339	455.0	$0.24	$39,858
Hydrated Lime	30	17,361	6255		$0.37	$844,732
Carbon Dioxide	33	17,361	6880		$0.15	$376,705
Flouride	1	17,361	208	110.4	$0.17	$6,850
Sodium Hypochlorite	1.5	17,361	313	376.8	$0.74	$101,774
Ammonia	0.33	17,361	69	31.0	$0.09	$1,018
TOTAL Concept Design O&M Costs - CHEMICAL O&M COSTS ($/yr.)						$1,374,307

Notes

1. Sodium Hypochlorite for prechlorination is assumed to be a shock treatment: 5 hours at 3 mg/l once per week to 50 mgd.
2. Sodium Bisulfite will provide dechlorination for shock treatment . Assume 3 mg/L dose,50 mgd for 5 hrs per wk and chlorine residual of 2 mg/l.

Concept Design O&M Costs - REPLACEMENT O&M COSTS

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

Annual Repair and Rehabilitation Costs

Equipment	$52,801,690	4% of Equipment	$2,112,068
Pipe	$4,694,783	1% of Pipe	$46,948
Structures	$17,409,105	1% of Structures	$174,091
Other [(1)]			$1,032,500
TOTAL Annual Repair and Rehabilitation Costs			$3,365,606

1. RO membrane annual replacement cost =

$650 per first pass membrane x 7875 membranes = $5,118,750 per replacement.

$500 for second pass membranes x 175 membranes = $87500 per replacement

4 replacements over 20 years for first pass membranes and 2 replacements over 20 yrs for second pass membranes = $20,650,000 total over a 20 yr period or $1,032,500 per year, annualized

Concept Design O&M Costs - Lighting & HVAC O&M COSTS

For Plant Site Common Elements

Storage tanks, Reverse Osmosis systems, Admin Building, Pump Stations, Appurtenances, Etc

COMMON ELEMENTS HVAC & POWER

					Electric Energy (kW*hr/ft^2/yr)					Total	Total
					Lighting	Ventilation	Heating	Cooling	Cool-Admin	kW*hr/yr	kW*hr/day
Common Elements - Buildings		**Length (ft)**	**Width (ft)**	**Area (SF)**	17.5	2.2	15	5	35		
4	RO Building (280 x 170)	280	170	47,600	833,000	104,720	714,000	238,000		1,889,720	5177
5	Admin Bldg PS (100 x 70)	100	70	7,000	122,500	15,400	105,000		245,000	487,900	1337
6	Generator Bldge PS (70 x 40)	70	40	2,800	49,000	6,160	42,000	14,000		111,160	305
7	Intermediate PS (65 x 45)	65	45	2,925	51,188	6,435	43,875	14,625		116,123	318
8	High Service PS (110 x 55)	110	55	6,050	105,875	13,310	90,750	30,250		240,185	658
9	Raw Water PS (45 x 40)	45	40	1,800	31,500	3,960	27,000	9,000		71,460	196
10	Byproduct PS (40 x 30)	40	30	1,200	21,000	2,640	18,000	6,000		47,640	131
Total for Concept Design O&M Costs - Lighting & HVAC O&M COSTS ($/yr)										**2,964,188**	**8,121**

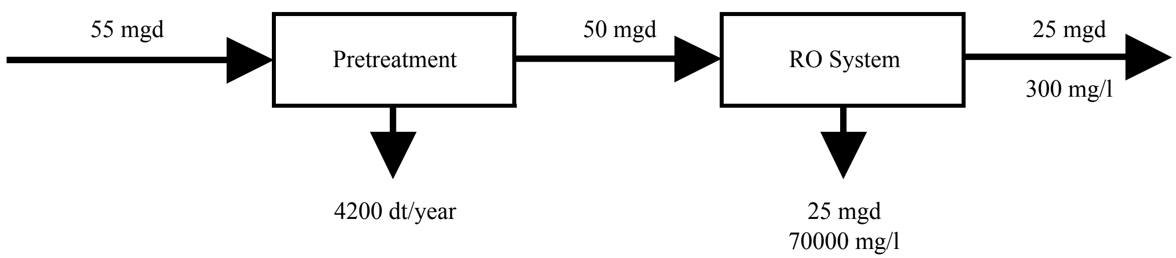
OPTIMIZATION OF
SELECTED ALTERNATE

BASE CONDITION - Alternate BD 2
Flow Stream & Capital Cost Summar

Alt BD 2 — Base Condition - Open Sea Intake - Raw Water is 35000 mg/l

Design Raw Water TDS — 35,000 mg/l

	FLOW	SOLIDS - TDS	SOLIDS TSS
Goal Output	25 mgd	300 mg/l	0 mg/l
Recovery	50.00%		
RO Input	50 mgd	35,000 mg/l	0 mg/l
RO Byproduct	25	70,000 mg/l	0 mg/l
Pretreatment Residuals	9.1%		
Pretreatment Input	55.0 mgd	35,000 mg/l	25 mg/l
Preatment Residuals	5.0 mgd	35,000 mg/l	275 mg/l
Coagulant Dose			25 mg/l
Pretreatment Solids		35,000 mg/l	4200 dt/year



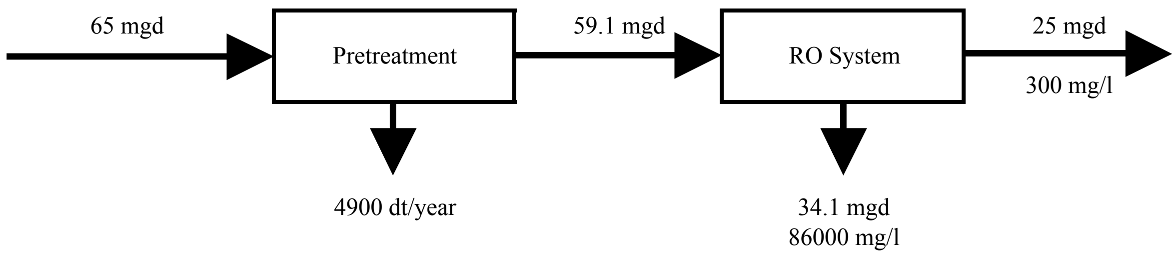
	BASE ALTERNATE BD 2		
ITEM	SIZE/CAPACITY		COST
Intake	55.0	MGD	$13,930,057
Raw Water Pumping	55.0	MGD	$2,292,375
Raw Water Pipe	55.0	MGD	$34,440,075
Pretreatment	55.0	MGD	$32,182,192
Residuals	5.0	MGD	$9,520,669
RO System	50.0	MGD	$56,655,925
Byproduct (plant)	25.0	MGD	$823,259
Byproduct Pipeline	25.0	MGD	$32,136,819
Connection to Dist	25.0	MGD	$2,497,362
Common Elements	25.0	MGD	$12,278,237
			$196,756,970

OPTIMIZED ALTERNATES

Alt BD A2 & BD B2 — What if the Design Condition is 50000 mg/l

Design Raw Water TDS — **50,000** mg/l

	FLOW	SOLIDS - TDS	SOLIDS - TDS
Goal Output	25 mgd	300 mg/l	0 mg/l
Recovery	42.3%		
RO Input	59.1 mgd	50,000 mg/l	0 mg/l
RO Byproduct	34.1	86,000 mg/l	0 mg/l
Pretreatment Residuals	9.1%		
Pretreatment Input	65.0 mgd	50,000 mg/l	25 mg/l
Preatment Residuals	5.9 mgd	50,000 mg/l	275 mg/l
Coagulant Dose			25 mg/l
Pretreatment Solids		50,000 mg/l	4900 dt/year
BD Plant Operating Time	60%		



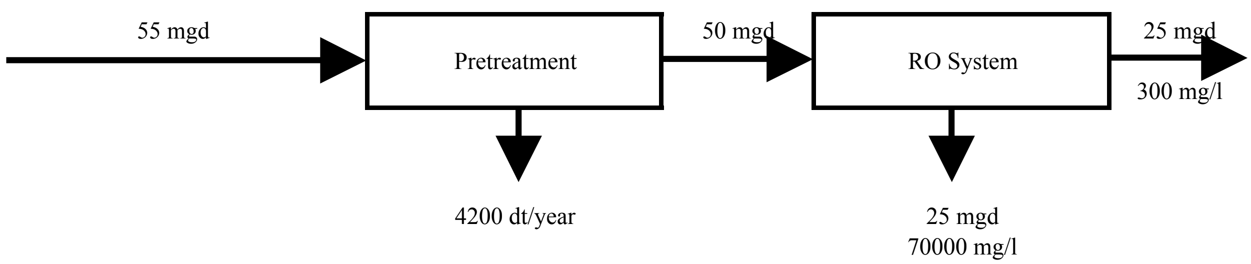
	BASE ALTERNATE BD 2			REVISED ALTERNATE BD A2			REVISED ALTERNATE BD B2			
ITEM	SIZE/CAPACITY		COST	REVISED SIZECAF		REV COST	REVISED SIZECAF		REV COST	EOS Factor
Intake	55.0	MGD	$13,930,057	0.0	MGD	$0	0.0	MGD	$0	0.8
Raw Water Pumping	55.0	MGD	$2,292,375	65.0	MGD	$2,620,150	0.0	MGD	$0	0.8
Raw Water Pipe	55.0	MGD	$34,440,075	0.0	MGD	$0	0.0	MGD	$0	0.6
Pretreatment	55.0	MGD	$32,182,192	65.0	MGD	$36,783,764	65.0	MGD	$36,783,764	0.8
Residuals	5.0	MGD	$9,520,669	5.9	MGD	$10,868,586	5.9	MGD	$10,868,586	0.8
RO System	50.0	MGD	$56,655,925	59.1	MGD	$65,856,866	59.1	MGD	$65,856,866	0.9
Byproduct (plant)	25.0	MGD	$823,259	34.1	MGD	$1,055,329	0.0	MGD	$0	0.8
Byproduct Pipeline	25.0	MGD	$32,136,819	34.1	MGD	$38,716,092	0.0	MGD	$0	0.6
Connection to Dist	25.0	MGD	$2,497,362	25.0	MGD	$2,497,362	25.0	MGD	$2,497,362	0.6
Common Elements	25.0	MGD	$12,278,237	25.0	MGD	$12,278,237	25.0	MGD	$12,278,237	0.0
			$196,756,970			$170,676,386			$128,284,815	

CAPITAL COST SUMMARY - Base Alternate BD 2 & Optimized Alternate BD A2 and BD B2

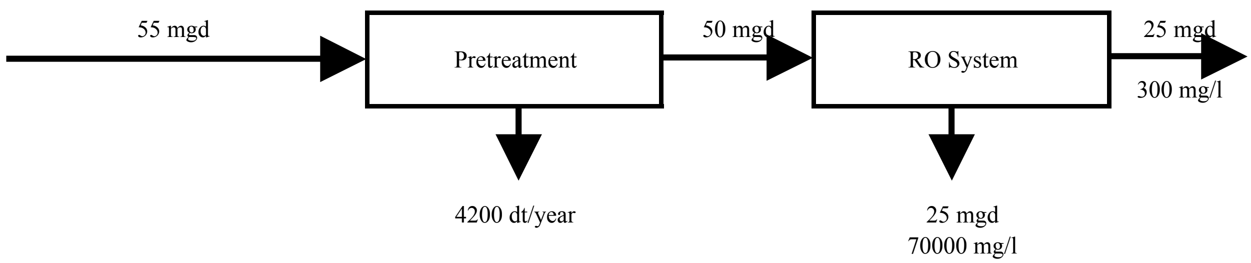
Breakdown of Capital Cost by Cost Type	**Base Alternate BD 2**	**Alternate BD A2**	**Alternate BD B2**
Equipment	$75,700,000	$65,700,000	$49,300,000
Pipe	$83,400,000	$72,300,000	$54,400,000
Structures	$29,700,000	$25,800,000	$19,400,000
Other	$8,000,000	$6,900,000	$5,200,000
TOTAL CAPITAL COSTS BY TYPE	$196,800,000	$170,700,000	$128,300,000

O&M Cost Summary By Stream Category
STREAM DETERMINATION

Alt BD 2	**Base Condition - Open Sea Intake - Raw Water is 35000 mg/l**		
Design Raw Water TDS		35,000 mg/l	
Average Raw Water TDS		35,000 mg/l	
	FLOW	SOLIDS - TDS	SOLIDS TSS
Goal Output	25.0 mgd	300 mg/l	0 mg/l
Recovery	50.00%		
RO Input	50.0 mgd	35,000 mg/l	0 mg/l
RO Byproduct	25.0	70,000 mg/l	0 mg/l
Pretreatment Residuals	9.1%		
Pretreatment Input	55.0 mgd	35,000 mg/l	25 mg/l
Preatment Residuals	5.0 mgd	35,000 mg/l	275 mg/l
Coagulant Dose			25 mg/l
Pretreatment Solids		35,000 mg/l	4200 dt/year



Alt BD A2 & BD B2	**What if the Design Condition is 35000 mg/l**		
Design Raw Water TDS		50,000 mg/l	
Average Raw Water TDS		35,000 mg/l	
	FLOW	SOLIDS - TDS	SOLIDS -
Goal Output	25 mgd	300 mg/l	0
Recovery	50.0%		
RO Input	50 mgd	35,000 mg/l	0
RO Byproduct	25	70,000 mg/l	0
Pretreatment Residuals	9.1%		
Pretreatment Input	55.0 mgd	35,000 mg/l	25
Preatment Residuals	5.0 mgd	35,000 mg/l	275
Coagulant Dose			25
Pretreatment Solids		35,000 mg/l	4200
BD Plant Operating Time	60%		



O&M Cost Summary By Stream Category
Breakdown of O&M Costs by Stream Category

ALTERNATE BD 2
Calculation of O&M Costs for TDS = 35000 mg/l

ITEM	AVG FLOW		POWER	CHEMICAL	RECURRING	LABOR	SOLIDS
Intake	55.0	MGD	$0	$0	$139,301	$0	$0
Raw Water Pumping	55.0	MGD	$383,935	$0	$69,690	$0	$0
Raw Water Pipe	55.0	MGD	$0	$0	$313,358	$0	$0
Pretreatment	55.0	MGD	$64,291	$781,003	$926,922	$0	$1,670,381
Residuals	5.0	MGD	$243,972	$0	$271,618	$0	$0
RO System	50.0	MGD	$5,981,810	$0	$2,754,893	$0	$0
Byproduct (plant)	25.0	MGD	$84,542	$0	$25,028	$0	$0
Byproduct Pipeline	25.0	MGD	$0	$0	$290,326	$0	$0
Connection to Dist	25.0	MGD	$0	$0	$24,974	$0	$0
Common Elements	25.0	MGD	$542,244	$1,371,531	$373,270	$1,199,440	$0
TOTALS	$17,512,527		$7,300,793	$2,152,534	$5,189,379	$1,199,440	$1,670,381

ALTERNATE BD A2
Calculation of O&M Costs for TDS = 35000 mg/l

ITEM	AVG FLOW		POWER	CHEMICAL	RECURRING	LABOR	SOLIDS
Intake	0.0	MGD	$0	$0	$0	$0	$0
Raw Water Pumping	55.0	MGD	$102,383	$0	$69,690	$0	$0
Raw Water Pipe	0.0	MGD	$0	$0	$0	$0	$0
Pretreatment	55.0	MGD	$64,291	$781,003	$926,922	$0	$1,670,381
Residuals	5.0	MGD	$243,972	$0	$271,618	$0	$0
RO System	50.0	MGD	$5,981,810	$0	$2,754,893	$0	$0
Byproduct (plant)	25.0	MGD	$84,542	$0	$25,028	$0	$0
Byproduct Pipeline	25.0	MGD	$0	$0	$290,326	$0	$0
Connection to Dist	25.0	MGD	$0	$0	$24,974	$0	$0
Common Elements	25.0	MGD	$542,244	$1,371,531	$373,270	$1,199,440	$0
TOTALS	$16,778,316		$7,019,241	$2,152,534	$4,736,720	$1,199,440	$1,670,381

ALTERNATE BD B2
Calculation of O&M Costs for TDS = 35000 mg/l

ITEM	AVG FLOW		POWER	CHEMICAL	RECURRING	LABOR	SOLIDS
Intake	0.0	MGD	$0	$0	$0	$0	$0
Raw Water Pumping	55.0	MGD	$0	$0	$0	$0	$0
Raw Water Pipe	0.0	MGD	$0	$0	$0	$0	$0
Pretreatment	55.0	MGD	$64,291	$781,003	$926,922	$0	$1,670,381
Residuals	5.0	MGD	$243,972	$0	$271,618	$0	$0
RO System	50.0	MGD	$5,981,810	$0	$2,754,893	$0	$0
Byproduct (plant)	25.0	MGD	$953,090	$0	$25,028	$0	$0
Byproduct Pipeline	25.0	MGD	$0	$0	$290,326	$0	$0
Connection to Dist	25.0	MGD	$0	$0	$24,974	$0	$0
Common Elements	25.0	MGD	$542,244	$1,371,531	$373,270	$1,199,440	$0
TOTALS	$17,474,791		$7,785,406	$2,152,534	$4,667,030	$1,199,440	$1,670,381

O&M Cost Summary By Stream Category

Power Calculation for RO System

	Alt BD 2	Alt BD A2	Alt BD B2	
Total Flow	50.0	50.0	50.0	MGD
Product Flow	25.0	25.0	25.0	MGD
Byproduct Flow	25.0	25.0	25.0	MGD
RO Supply Head	1000	1000	1000	PSI
RO Total Power Required	25307	25307	25307	BHP
RO Product Flow Power	12654	12654	12654	BHP
RO Byproduct Flow Power	12654	12654	12654	BHP
RO Byproduct Energy Recovery	95%	95%	95%	
RO Recovered Energy	12,021	12,021	12,021	BHP
RO Net Energy Consumed	13,286	13,286	13,286	BHP
RO kW-hrs/year	86,790,771	86,790,771	86,790,771	kW-hrs/yr
RO Annual Power	$5,641,400	$5,641,400	$5,641,400	$/Yr
Other Power in Category	$340,410	$340,410	$340,410	$/Yr
Annual RO Power	5,981,810	5,981,810	5,981,810	$/Yr

Power Calculation for Raw Pumping

RWPS Flow Water	55	55	0.0	MGD
RWPS Head	75	50	0	Ft
RWPS Operating time	100%	40%	0%	
Efficiency	80%	80%	80%	
RWPS Power (BHP)	904	241	0	BHP
RWPS kW-hrs/yr	5,906,691	1,575,118	0	kW-hrs/yr
RWPS Annual Power	$383,935	$102,383	$0	$/yr

Power Calculation for Byproduct Blend Stream Includes Raw Water Pumping

Byp Blend Stream Q (MGD)	25.0	34.1	512.0	MGD
Byp Blend Stream TDH (Ft)	35	35	50	Ft
Byp Blend Stream Eff (%)	80%	80%	80%	
Byp Blend Stream Operating Time	100%	100%	40%	
Byp Blend Stream Power (BHP)	192	262	2245	BHP
Byp Blend Stream kW-hrs/yr	1,252,935	1,709,004	14,662,922	kW-hrs/year
Other Power In Category	$3,097	$4,224	$0	$/yr
RWPS Annual Power	$84,537	$115,309	$953,090	$/Yr

SUMMARY OF O&M COSTS

Base Alternate BD 2	TOTAL	POWER	CHEMICAL	RECURRING	LABOR	SOLIDS
RO + Common	$12,223,187	$6,524,054	$1,371,531	$3,128,163	$1,199,440	$0
Pretreatment	$3,442,597	$64,291	$781,003	$926,922	$0	$1,670,381
All other	$1,846,743	$712,449	$0	$1,134,295	$0	$0
TOTAL	$17,512,527	$7,300,793	$2,152,534	$5,189,379	$1,199,440	$1,670,381

Alternate BD A2	TOTAL	POWER	CHEMICAL	RECURRING	LABOR	SOLIDS
RO + Common	$12,223,187	$6,524,054	$1,371,531	$3,128,163	$1,199,440	$0
Pretreatment	$3,442,597	$64,291	$781,003	$926,922	$0	$1,670,381
All Other	$1,112,532	$430,897	$0	$681,636	$0	$0
TOTAL	$16,778,316	$7,019,241	$2,152,534	$4,736,720	$1,199,440	$1,670,381

Alternate BD B2	TOTAL	POWER	CHEMICAL	RECURRING	LABOR	SOLIDS
RO + Common	$12,223,187	$6,524,054	$1,371,531	$3,128,163	$1,199,440	$0
Pretreatment	$3,442,597	$64,291	$781,003	$926,922	$0	$1,670,381
All Other	$1,809,007	$1,197,062	$0	$611,945	$0	$0
TOTAL	$17,474,791	$7,785,406	$2,152,534	$4,667,030	$1,199,440	$1,670,381

Concept Design - LIFE CYCLE COST SUMMARY

Barney Davis site	Alt BD 2	Alt BD A2	Alt BD B2
Pretreatment Option	DAF	DAF	DAF
Intake Option	Open Sea Intake Byprod to Gulf	Existing Intake Byprod to Gulf	Exist Intake Byprod to Oso
Estimated Capital Cost			
Intake	$13,930,057	$0	$0
Raw Water Pumping	$2,292,375	$2,620,150	$0
Raw Water Pipe	$34,440,075	$0	$0
Pretreatment	$32,182,192	$36,783,764	$36,783,764
Residuals	$9,520,669	$10,868,586	$10,868,586
RO System	$56,655,925	$65,856,866	$65,856,866
Byproduct (plant)	$823,259	$1,055,329	$0
Byproduct Pipeline	$32,136,819	$38,716,092	$0
Connection to Dist	$2,497,362	$2,497,362	$2,497,362
Common Elements	$12,278,237	$12,278,237	$12,278,237
TOTAL CAPITAL COSTS	$196,756,970	$170,676,386	$128,284,815
Intake	$139,301	$0	$0
Raw Water Pumping	$453,625	$172,073	$0
Raw Water Pipe	$313,358	$0	$0
Pretreatment	$3,442,597	$3,442,597	$3,442,597
Residuals	$515,590	$515,590	$515,590
RO System	$8,736,703	$8,736,703	$8,736,703
Byproduct (plant)	$109,569	$109,569	$978,118
Byproduct Pipeline	$290,326	$290,326	$290,326
Connection to Dist	$24,974	$24,974	$24,974
Common Elements	$3,486,484	$3,486,484	$3,486,484
TOTAL ANNUAL O & M COSTS	$17,512,527	$16,778,316	$17,474,791
Present Worth Factor	12.462	12.462	12.462
Present Worth of O&M	$218,244,795	$209,094,900	$217,774,523
TOTAL LIFE CYCLE COSTS	$415,001,765	$379,771,286	$346,059,338

UNIT PRICES

Concept Design Preliminary Capital Cost Estimate
Background Cost Information

Power Costs	$0.065	per KW-hr
Building Utilities		
Lighting	17.5	kW-Hr/ft^2/yr
Ventilation	2.2	kW-Hr/ft^2/yr
Heating	15.0	kW-Hr/ft^2/yr
Cooling	5.0	kW-Hr/ft^2/yr
Cool-Admin	35.0	kW-Hr/ft2/yr
Soft Costs		
Construction Contingency (%)	25.0%	
Contractors OH&P (%)	17.0%	
Mobilization/Demobilization	3.0%	
Survey, Geotech, Easements (%)	8.0%	
Engineering fees (%)	10.0%	
Present Worth Calculations		
Equipment		
Life	20	years
Interest Rate	5.0%	
Present Worth Factor	12.462	
Pipe and Structures		
Life	30	years
Interest Rate	5.0%	
Present Worth Factor	15.372	
Rehabilitation and Repair Costs		
Equipment	4%	of equipment cost
Pipe	1%	of pipe costs
Structures	1%	of structures cost
Other	Itemized	

Environmental Compliance, including NEPA, Agency Coordination, Mitigation, and Permitting

ENV-1	4.6% of capital construction cost
ENV-3	4.6% of capital construction cost
ENV-5	4.6% of capital construction cost
ENV-10	4.6% of capital construction cost

Concept Design Preliminary Capital Cost Estimate
Background Cost Information

Labor Rates

Pay Rates - Operations	Annual Salary	Hourly Rate	Benefits Ratio
Manager - Operations	75,000.00	36.06	45%
Administrative Assistant	30,000.00	14.42	45%
Operator - Sr.	45,000.00	21.63	45%
Operator I	40,000.00	19.23	45%
Operator II	35,000.00	16.83	45%
Assistant to Operator	30,000.00	14.42	45%
Assistant to Operator II	28,000.00	13.46	45%
Lab Chemist	45,000.00	21.63	45%
Lab Chemist II	40,000.00	19.23	45%

Pay Rate - Maintenance	Annual Salary	Hourly Rate	Benefits Ratio
Manager - Maintenance	60,000.00	28.85	45%
Mechanics	40,000.00	19.23	45%
Mechanic Assistant	35,000.00	16.83	45%
Electrician	45,000.00	21.63	45%
Elect./Instr. Assistant	35,000.00	16.83	45%
Instrumentation	45,000.00	21.63	45%

Chemical Costs

Chemical	Cost per lb (or gal)	
Ferric Chloride (Coagulation)	$0.17	/lb
Polymer (Clarification)	$1.38	/lb
Polymer (Thickening)	$1.38	/lb
Polymer (Dewatering)	$1.38	/lb
Ferric Chloride (Thickening)	$0.17	/lb
Shock Treatment Sodium Hypochlorite	$0.74	/gal
Shock Treatment Sodium Bisulfite	$0.26	/lb
Sulfuric Acid	$0.24	/lb
Hydrated Lime	$0.37	/lb
Carbon Dioxide	$0.15	/lb
Flouride	$0.17	/lb
Sodium hydroxide	$0.05	/lb
Citric acid	$0.60	/lb
Hydrochloric acid	$0.45	/lb
Sodium Hypochlorite	$0.74	/gal
Sodium bisulphite	$0.26	/lb
Ammonia	$0.09	/lb

Solids Disposal Costs		
Dewatered Sludge to Landfill	$60.00	/CY

Concept Design Preliminary Capital Cost Estimate
Background Cost Information

RAW WATER - Pipeline Construction Costs

Underwater Pipe Costs - Installed				
Designator	Item	Pipe Cost	Installation	Installed Cost
UW-30	30 " HDPE Wet Dredge			
UW-36	36 " HDPE Wet Dredge			
UW-42	42 " HDPE Wet Dredge	$350		$350
UW-48	48 " HDPE Wet Dredge			
UW-54	54 " HDPE Wet Dredge	$470		$470
UW-60	60 " HDPE Wet Dredge			
UW-66	66 " HDPE Wet Dredge			
UW-72	72 " HDPE Wet Dredge	$650		$650
UW-78	78 " HDPE Wet Dredge			
UW-84	84 " HDPE Wet Dredge			

Open Cut Pipe Costs - Installed				
Designator	Item	Pipe Cost	Installation	Installed Cost
OC-30	30 " HDPE Open Cut			
OC-36	36 " HDPE Open Cut			
OC-42	42 " HDPE Open Cut	$200		$200
OC-48	48 " HDPE Open Cut			
OC-54	54 " HDPE Open Cut	$320		$320
OC-60	60 " HDPE Open Cut			
OC-66	66 " HDPE Open Cut			
OC-72	72 " HDPE Open Cut			
OC-78	78 " HDPE Open Cut			
OC-84	84 " HDPE Open Cut			

Specialty Pipe Costs - Installed				
Designator	Item	Pipe Cost	Installation	Installed Cost
SP-30	30 " Directional Drill			
SP-36	36 " Directional Drill			
SP-42	42 " Directional Drill	$600		$600
SP-48	48 " HDPE Tunnel			
SP-54	54 " HDPE Tunnel	$1,300		$1,300
SP-60	60 " HDPE Tunnel			
SP-66	66 " HDPE Tunnel			
SP-72	72 " HDPE Tunnel			
SP-78	78 " HDPE Tunnel			
SP-84	84 " HDPE Tunnel			

Concept Design Preliminary Capital Cost Estimate
Background Cost Information

RAW WATER - Pipeline Construction Costs

Valves				
Designator	Item	Mat'ls	Installation	Installed Cost
V-30	30 " Valve			
V-36	36 " Valve			
V-42	42 " Valve	$30,000		$30,000
V-48	48 " Valve			
V-54	54 " Valve	$50,000		$50,000
V-60	60 " Valve			
V-66	66 " Valve			
V-72	72 " Valve			
V-78	78 " Valve			
V-84	84 " Valve			

Appurtenances				
Designator	Item	Mat'ls	Installation	Installed Cost
TS	Tunnel Shaft	$500,000		$500,000
OS	Outfall Structure	$50,000		$50,000
IS	Intake Structure	$250,000		$250,000
CPA-1	Concrete Pipe Anchors	$15.10		$15
CPA-2	Concrete Pipe Anchors	$47.60		$48
RC	Road Crossing			
SC	Silt Curtain for Seagrass	$40		$40
StrC	Stream Crossing			

Appendix D

Support Documentation for Water Transfers and Partnerships

Appendix D-1

Topaz Power Partners Letter
Dated July 29, 2004

Sempra Energy Resources

William Nelson
Project Development Manager
Project Development

HQ01H
101 Ash Street
San Diego, CA 92101-3017

Tel: 619-696-4911
Cell: 619-857-8487
Wnelson@sempra-res.com

July 29, 2004

Mark V. Lowry, P.E.
P.O. Box 130089
Houston, Texas 77219-0089
5757 Woodway
Houston, Texas 77057-1599

Subject: Corpus Christi Desalination Plant at Barney Davis
Topaz Power Partners

Dear Mark:

It was a pleasure to talk with you again. As you know, we recently completed the acquisition of several AEP plants in Texas including Barney Davis. Now that we have completed this purchase, we wanted to express our interest in further discussions with you regarding our hosting the Corpus Christi Desalination Plant at Barney Davis.

As we discussed, Topaz Power Partners could potentially provide a number of attractive infrastructure features to support the Desalination Plant including:

- 10 acres of free land
- Discharge to the cooling ponds
- Sharing intake and outfall
- Circulating water available
- We can work towards a more competitive power supply option by working through or with STAP or the local Coop/Muni
- We believe all of these features are feasible but further investigation will be required
- We have assumed all permitting issues can be addressed and although we have not investigated the permitting related impacts/benefits associated with the proposal, we are willing to work with the City and other interested parties to explore mutually beneficial solutions including the possibility of repowering the Barney Davis site.

As you requested, we have attached the wholesale electricity price forecasts for the next 24 years.

This indicative proposal outline is non-binding and does not represent a commitment by Topaz Power Partners; it is intended strictly as a summary of certain terms that Topaz Power Partners is considering. Topaz Power Partners neither intends to enter, nor has by any other means entered, into any agreement to negotiate a definitive agreement pursuant to this indicative proposal outline, and Topaz Power Partners may, at any time prior to execution of such definitive agreement, propose different terms from those summarized herein or unilaterally terminate all negotiations with respect to the subject matter of this letter without any liability whatsoever to Topaz Power Partners.

We hope this information has been helpful and that your bid is successful.
Please feel free to contact me if you need any additional information at
619 696-4911.

Sincerely,

W. L. Nelson

W. L. Nelson

Project Development Manager

Appendix D-2

Potential Research Topics

List of Potential Research Topics

1. Investigation of Membrane Fouling in Seawater Desalination Processes by Fractionation of NOM

2. Investigation into the Efficacy of Dissolved Air Flotation for Seawater Desalination Pretreatment

3. Investigation into Reduction of Fouling Potential Using Foam Fractionation

4. Investigation into the Efficacy of Biological Filtration for Mitigation of Organic Fouling in Seawater Desalination

5. Salinity Impacts of Seawater Desalination Concentrate Discharge into Corpus Christi Bay and into Oso Bay

6. Investigation into Potential Cost Reduction using Large Diameter Membranes

Appendix D-3

Federal Cost Sharing Agreement

AGREEMENT
BETWEEN THE DEPARTMENT OF THE ARMY
AND
THE NUECES RIVER AUTHORITY,
CITY OF CORPUS CHRISTI,
SAN ANTONIO WATER SYSTEM,
SAN ANTONIO RIVER AUTHORITY,
AND THE GUADALUPE-BLANCO RIVER AUTHORITY
FOR THE NUECES RIVER AND TRIBUTARIES, TEXAS FEASIBILITY STUDY

THIS AGREEMENT is entered into this **24th** day of **September**, 2004, by and between the Department of the Army (hereinafter the "Government"), represented by the District Engineer executing this Agreement, and the Nueces River Authority (hereinafter the NRA) represented by the Executive Director signing this Agreement, the City of Corpus Christi (hereinafter the City) represented by the City Manager signing this Agreement, the San Antonio Water System (hereinafter the SAWS) represented by the President/Chief Executive Officer signing this Agreement, the San Antonio River Authority (hereinafter the SARA) represented by the General Manager signing this Agreement, and the Guadalupe-Blanco River Authority (hereinafter the GBRA) represented by the General Manager signing this Agreement, hereinafter collectively referred to as "Sponsors" ,

WITNESSETH, that

WHEREAS, the Congress (Senate Committee on Environment and Public Works) has requested the Secretary of the Army to review the Nueces River, Texas published as House Document 235, Sixty-third Congress, 1st Session and other pertinent reports, to determine the feasibility of measures for improvements to address water resources need of Texas within the Nueces River basin in the interest of comprehensive watershed and stream corridor management, including flood damage reduction, ecosystem restoration and protection, water conservation and supply, water quality, aquifer recharge, and other allied purposes. The review should coordinate and integrate with ongoing study efforts within the basin pursuant to Senate Resolution adopted 23 June 2004; and

WHEREAS, the U.S. Army Corps of Engineers has conducted a reconnaissance study of opportunities for flood damage reduction, ecosystem restoration and water supply along the Nueces River and tributaries published as the Nueces River Basin Reconnaissance Study, December 2002, and has determined that further study in the nature of a "Feasibility Phase Study" (hereinafter the "Study") is required to fulfill the intent of the study authority and to assess the extent of the Federal interest in participating in a solution to the identified problem; and

WHEREAS, Section 105 of the Water Resources Development Act of 1986 (Public Law 99-662, as amended) specifies the cost sharing requirements applicable to the Study;

WHEREAS, the Sponsors have the authority and capability to furnish the cooperation hereinafter set forth and are willing to participate in study cost sharing and financing in accordance with the terms of this Agreement; and

WHEREAS, the Sponsor and the Government understand that entering into this Agreement in no way obligates either the Sponsors or the Government to agree to or to implement a project and that whether the Government supports a project authorization and budgets it for implementation depends upon, among other things, the outcome of the Study and whether the proposed solution is consistent with the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies and with the budget priorities of the Administration;

NOW THEREFORE, the parties agree as follows:

ARTICLE I - DEFINITIONS

For the purposes of this Agreement:

A. The term "Study Costs" shall mean all disbursements by the Government pursuant to this Agreement, from Federal appropriations or from funds made available to the Government by the Sponsors, and all negotiated costs of work performed by the Sponsors pursuant to this Agreement. Study Costs shall include, but not be limited to: labor charges; direct costs; overhead expenses; supervision and administration costs; the costs of participation in Study Management and Coordination in accordance with Article IV of this Agreement; the costs of contracts with third parties, including termination or suspension charges; and any termination or suspension costs (ordinarily defined as those costs necessary to terminate ongoing contracts or obligations and to properly safeguard the work already accomplished) associated with this Agreement.

B. The term "estimated Study Costs" shall mean the estimated cost of performing the Study as of the effective date of this Agreement, as specified in Article III.A. of this Agreement.

C. The term "excess Study Costs" shall mean Study Costs that exceed the estimated Study Costs and that do not result from agreement of the parties, a change in Federal law that increases the cost of the Study, or a change in the scope of the Study requested by the Sponsors.

D. The term "study period" shall mean the time period for conducting the Study, commencing with the release to the U.S. Army Corps of Engineers, Fort Worth, District of initial Federal feasibility funds following the execution of this Agreement and ending when the Assistant Secretary of the Army (Civil Works) submits the feasibility report to the Office of Management and Budget (OMB) for review for consistency with the policies and programs of the President.

E. The term "PMP" shall mean the Project Management Plan, which is attached to this Agreement and which shall not be considered binding on any party and is subject to change by the Government, in consultation with the Sponsors.

F. The term "negotiated costs" shall mean the costs of in-kind services to be provided by the Sponsors in accordance with the PMP.

G. The term "fiscal year" shall mean one fiscal year of the Government. The Government fiscal year begins on October 1 and ends on September 30.

ARTICLE II - OBLIGATIONS OF PARTIES

A. The Government, using funds and in-kind services provided by the Sponsors and funds appropriated by the Congress of the United States, shall expeditiously prosecute and complete the Study, in accordance with the provisions of this Agreement and Federal laws, regulations, and policies.

B. In accordance with this Article and Article III.A., III.B. and III.C. of this Agreement, the Sponsors shall contribute cash and in-kind services equal to fifty (50) percent of Study Costs other than excess Study Costs. The amount each Sponsor is required to contribute is as follows:

City-18.280% in cash and in-kind services;

SAWS- 27.525% in cash and in-kind services;

SARA- 2.150% in cash and in-kind services;

GBRA- 1.075% in cash and in-kind services; and

NRA- in kind services valued at $97,000, as defined in the PMP, which is anticipated to be 0.970% of total Study Costs.

In no event shall NRA be expected to contribute cash or in-kind services above those listed above. However, in the event that the value of those in-kind services combined with the contributions of the other Sponsors shall equal less than 50% of the Study Costs, the other Sponsors shall be liable for such additional amounts as necessary to ensure that the Sponsors' total shall be 50 percent of the study costs. In no event shall the Sponsors' total contribution be less than 50 percent of the study costs. After NRA reaches its $97,000 limit, the remaining 4 sponsors (City, SAWS, SARA, GBRA), shall contribute the remainder of the Sponsors' 50% cost-sharing contribution as follows: City-18.64%, SAWS-28.07%, SARA-2.19%, GBRA-1.10% of the Study Cost. The Government will monitor the contributions and give notice well before NRA reaches its limit.

The Sponsors may, consistent with applicable law and regulations, contribute up to 50 percent of Study Costs through the provision of in-kind services. The in-kind services to be provided by the Sponsors, the estimated negotiated costs for those services, and the estimated schedule under which those services are to be provided are specified in the PMP. Negotiated costs shall be subject to an audit by the Government to determine reasonableness, allocability, and allowability.

C. The City, SAWS, SARA, GBRA, and NRA shall pay a fifty (50) percent share of excess Study Costs (City- 17.00% in cash and in-kind services; SAWS- 25.60% in cash and in-kind services; SARA- 2.00% in cash and in-kind services; GBRA- 1.00% in cash and in-kind services; and NRA- 4.40% in in-kind services only) in accordance with Article III.D. of this Agreement. After NRA reaches its $97,000 limit, the remaining 4 sponsors (City, SAWS, SARA, GBRA), shall contribute the remainder of the Sponsors' 50% cost-sharing contribution for excess Study Costs as follows: City- 18.64%, SAWS-28.07%, SARA-2.19%, GBRA-1.10% of the total study cost. The Government will monitor the contributions and give notice well before NRA reaches its limit.

D. The Sponsors understand that the schedule of work may require the Sponsors to provide cash or in-kind services at a rate that may result in the Sponsors temporarily diverging from the obligations concerning cash and in-kind services specified in paragraph B. of this Article. Such temporary divergences shall be identified in the quarterly reports provided for in Article III.A. of this Agreement and shall not alter the obligations concerning costs and services specified in paragraph B. of this Article or the obligations concerning payment specified in Article III of this Agreement.

E. If, upon the award of any contract or the performance of any in-house work for the Study by the Government or the Sponsors, cumulative financial obligations of the Government and the Sponsors would result in excess Study Costs, the Government and the Sponsors agree to defer award of that and all subsequent contracts, and performance of that and all subsequent in-house work, for the Study until the Government and the Sponsors agree to proceed. Should the Government and the Sponsors require time to arrive at a decision, the Agreement will be suspended in accordance with Article X., for a period of not to exceed six (6) months. In the event the Government and the Sponsors have not reached an agreement to proceed by the end of their 6 month period, the Agreement may be subject to termination in accordance with Article X.

F. No Federal funds may be used to meet the Sponsors' share of Study Costs unless the Federal granting agency verifies in writing that the expenditure of such funds is expressly authorized by statute.

G. The award and management of any contract with a third party in furtherance of this Agreement which obligates Federal appropriations shall be exclusively within the control of the Government. However, the Government will consult with the Sponsors prior to the award of any contract. The award and management of any contract by any of the Sponsors with a third party in furtherance of this Agreement which obligates funds of the Sponsors and does not obligate Federal appropriations shall be exclusively within the control of the Sponsors, but shall be subject to applicable Federal laws and regulations.

H. The Sponsors shall be responsible for the total cost of developing a response plan for addressing any hazardous substances regulated under the Comprehensive Environmental Response, Compensation and Liability Act of 1980, Pub. L. No. 96-510, 94 Stat. 2767, (codified at 42 U.S.C. Sections 9601-9675), as amended, existing in, on, or under any lands, easements or rights-of-way that the Government determines to be required for the construction, operation, and maintenance of the project. Such costs shall not be included in total study costs.

ARTICLE III - METHOD OF PAYMENT

A. The Government shall maintain current records of contributions provided by the parties, current projections of Study Costs, current projections of each party's share of Study Costs, and current projections of the amount of Study Costs that will result in excess Study Costs. At least quarterly, the Government shall provide the Sponsors a report setting forth this information. As of the effective date of this Agreement, estimated Study Costs are $10,000,000 and the Sponsors' 50% share of estimated Study Costs is $5,000,000. In order to meet the Sponsors' cash payment requirements for their 50% share of estimated Study Costs, the Sponsors, other than NRA, must provide a cash contribution currently estimated to be $4,850,000 , and approximately $53,000 in in-kind services. NRA shall provide an amount not to exceed $97,000 in in-kind services. The dollar amounts set forth in this Article are based upon the Government's best estimates, which reflect the scope of the study described in the PMP, projected costs, price-level changes, and anticipated inflation. Such cost estimates are subject to adjustment by the Government and are not to be construed as the total financial responsibilities of the Government and the Sponsors.

B. The Sponsors shall provide their cash contributions required under Article II.B. of this Agreement in accordance with the following provisions:

1. For purposes of budget planning, the Government shall notify the Sponsors by August 1st of each year of the estimated funds that will be required from each of the Sponsors to meet the Sponsors' share of Study Costs for the upcoming fiscal year.

2. No later than 60 calendar days prior to the scheduled date for the Government's issuance of the solicitation for the first contract for the Study or for the Government's anticipated first significant in-house expenditure for the Study, the Government shall notify the Sponsors in writing of the funds the Government determines to be required from each of the Sponsors to meet their required share of Study Costs for the first fiscal year of the Study. No later than 30 calendar days thereafter, the Sponsors shall provide the Government the full amount of the required funds by Electronic Funds Transfer in accordance with procedures established by the Government or by delivering a check payable to "FAO, USAED, FORT WORTH DISTRICT" to the U.S. Army Corps of Engineers Finance Center ATTN: CEFC-FD-C EROC M2, 5722 Integrity Drive, Millington, TN 38054-5005.

3. For the second and subsequent fiscal years of the Study, the Government shall, no later than 60 calendar days prior to the beginning of the fiscal year, notify the Sponsors in writing of the funds the Government determines to be required from each of the Sponsors to meet their required share of Study Costs for that fiscal year, taking into account any temporary divergences identified under Article II.D of this Agreement. No later than 30 calendar days prior to the beginning of the fiscal year, the Sponsors shall make the full amount of the required funds available to the Government through the funding mechanism specified in paragraph B.2. of this Article.

4. The Government shall draw from the funds provided by the Sponsors such sums as the Government deems necessary to cover the Sponsors' share of contractual and in-house fiscal obligations attributable to the Study as they are incurred.

5. In the event the Government determines that the Sponsors must provide additional funds to meet their share of Study Costs, the Government shall so notify the Sponsors in writing. No later than 60 calendar days after receipt of such notice, the Sponsors shall make the full amount of the additional required funds available through the funding mechanism specified in paragraph B.2. of this Article.

C. Within ninety (90) days after the conclusion of the Study Period or termination of this Agreement, the Government shall conduct a final accounting of Study Costs, including disbursements by the Government of Federal funds, cash contributions by the Sponsors, the amount of any excess Study Costs, and credits for the negotiated costs of the Sponsors, and shall furnish the Sponsors with the results of this accounting. Within thirty (30) days thereafter, the Government, subject to the availability of funds, shall reimburse the Sponsors for the excess, if any, of cash contributions and credits given over their required share of Study Costs, other than excess Study Costs, or the Sponsors shall provide the Government any cash contributions required for the

Sponsors to meet their required share of Study Costs other than excess Study Costs.

D. Each of the Sponsors shall provide its cash contribution for excess Study Costs as required under Article II.C. of this Agreement by delivering a check payable to "FAO, USAED, FORT WORTH DISTRICT" to the U.S. Army Corps of Engineers Finance Center ATTN: CEFC-AD-C EROC M2, 5722 Integrity Drive, Millington, TN 38054-5005, as follows:

1. After the project that is the subject of this Study has been authorized for construction, no later than the date on which a Project Cooperation Agreement is entered into for the project; or

2. In the event the project that is the subject of this Study is not authorized for construction by a date that is no later than 5 years after the date of the final report of the Chief of Engineers concerning the project, or by a date that is no later than 2 years after the date of the termination of the study, the Sponsors shall pay their share of excess costs on that date (5 years after the date of the Chief of Engineers or 2 year after the date of the termination of the study).

ARTICLE IV - STUDY MANAGEMENT AND COORDINATION

A. To provide for consistent and effective communication, the Sponsors and the Government shall each appoint named senior representatives to an Executive Committee. Thereafter, the Executive Committee shall meet regularly until the end of the Study Period.

B. Until the end of the Study Period, the Executive Committee shall generally oversee the Study consistently with the PMP, including the application of and compliance with the Davis-Bacon Act, Contract Work Hours and Safety Standards Act and the Copeland Anti-Kickback Act for non-Federal work-in-kind.

C. The Executive Committee may make recommendations that it deems warranted to the District Engineer on matters that it oversees, including suggestions to avoid potential sources of dispute. The Government in good faith shall consider such recommendations. The Government has the discretion to accept, reject, or modify the Executive Committee's recommendations.

D. The Executive Committee shall appoint representatives to serve on a Study Management Team. The Study Management Team shall keep the Executive Committee informed of the progress of the Study and of significant pending issues and actions, and shall prepare periodic reports on the progress of all work items identified in the PMP.

E. The costs of participation in the Executive Committee (including the cost to serve on the Study Management Team) shall be included in total project costs and cost shared in accordance with the provisions of this Agreement.

ARTICLE V - DISPUTES

As a condition precedent to a party bringing any suit for breach of this Agreement, that party must first notify the other parties in writing of the nature of the purported breach and seek in good faith to resolve the dispute through negotiation. If the parties cannot resolve the dispute through negotiation, they may agree to a unanimously acceptable method of non-binding alternative dispute resolution with a qualified third party acceptable to all parties. The Government and the Sponsors collectively, shall each pay an equal share of any costs for the services provided by such a third party as such costs are incurred. Such costs shall not be included in Study Costs. The existence of a dispute shall not excuse the parties from performance pursuant to this Agreement.

ARTICLE VI - MAINTENANCE OF RECORDS

A. Within 60 days of the effective date of this Agreement, the Government and the Sponsors shall develop procedures for keeping books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to this Agreement to the extent and in such detail as will properly reflect total Study Costs. These procedures shall incorporate, and apply as appropriate, the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to state and local governments at 32 C.F.R. Section 33.20. The Government and the Sponsors shall maintain such books, records, documents, and other evidence in accordance with these procedures for a minimum of three years after completion of the Study and resolution of all relevant claims arising therefrom. To the extent permitted under applicable Federal laws and regulations, the Government and the Sponsors shall each allow the other to inspect such books, documents, records, and other evidence.

B. In accordance with 31 U.S.C. Section 7503, the Government may conduct audits in addition to any audit that the Sponsors are required to conduct under the Single Audit Act of 1984, 31 U.S.C. Sections 7501-7507. Any such Government audits shall be conducted in accordance with Government Auditing Standards and the cost principles in OMB Circular No. A-87 and other applicable cost principles and regulations. The costs of Government audits shall be included in total Study Costs and shared in accordance with the provisions of this Agreement.

ARTICLE VII - RELATIONSHIP OF PARTIES

The Government and the Sponsors act in independent capacities in the performance of their respective rights and obligations under this Agreement, and neither is to be considered the officer, agent, or employee of the other parties.

ARTICLE VIII - OFFICIALS NOT TO BENEFIT

No member of or delegate to the Congress, nor any resident commissioner, shall be admitted to any share or part of this Agreement, or to any benefit that may arise therefrom.

ARTICLE IX - FEDERAL AND STATE LAWS

In the exercise of the Sponsors' rights and obligations under this Agreement, the Sponsors agree to comply with all applicable Federal and State laws and regulations, including Section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.11 issued pursuant thereto and published in 32 C.F.R. Part 195, as well as Army Regulations 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army". The Non-Federal Sponsors are also required to comply with all applicable federal labor standards requirements including, but not limited to the Davis-Bacon Act (40 USC 276a et seq), the Contract Work Hours and Safety Standards Act (40 USC 327 et seq) and the Copeland Anti-Kickback Act (40 USC 276c).

ARTICLE X - TERMINATION OR SUSPENSION

A. This Agreement shall terminate at the conclusion of the Study Period, and neither the Government nor the Sponsors shall have any further obligations hereunder, except as provided in Article III.C.; provided, that prior to such time and upon thirty (30) days written notice, any party may terminate or suspend this Agreement. In addition, the Government shall terminate this Agreement immediately upon any failure of the parties to agree to extend the study under Article II.E. of this agreement, or upon the failure of the Sponsors to fulfill their obligation under Article III. of this Agreement. In the event that any party elects to terminate this Agreement, and the remaining parties do not agree upon a continuance of this Agreement in accordance with Article X.C., all parties shall conclude their activities relating to the Study and proceed to a final accounting in accordance with Article III.C. and III.D. of this Agreement. Upon termination of this Agreement, all data and information generated as part of the Study shall be made available to all parties.

B. Any termination of this Agreement shall not relieve the parties of liability for any obligations previously incurred, including the costs of closing out or transferring any existing contracts. Those obligations considered "previously incurred" may include but are not necessarily limited to (i) the Terminating Party's percentage interest of the Study Costs and excess Study Costs incurred through the date of the Termination; (ii) any damages which may be payable by the Terminating Party for a breach of this Agreement in accordance with Article V above; and (iii) the costs for closing out or transferring any existing contracts. In no event shall the terminating party be liable for expenditures made after the date of termination, other that those associated with closing out or transferring any existing contracts.

C. In the event that any of the Sponsors elect to terminate its own responsibilities under this Agreement, and there are remaining Sponsors who elect to continue to participate in the Study, the Government shall negotiate in good faith with the remaining Sponsors to effect a timely and productive conclusion to that portion of the Study pertaining to the remaining Sponsors' area of statutory authority. The Government shall prepare a revised PMP and revised estimated Study costs, including the remaining Sponsors' share, to complete that portion of the Study of interest to the remaining Sponsors. If the remaining Sponsors elect to complete the Study, this Agreement shall be amended to reflect the negotiated revisions to the PMP and Study costs. Cost amendments to this Agreement made pursuant to this sub-article shall reflect credits for the previous cash and in-kind contributions of all Study Sponsors and shall reflect task reductions made as a result of withdrawal of any Study Sponsor.

ARTICLE XI - OBLIGATIONS OF FUTURE APPROPRIATIONS

A. Nothing herein shall constitute, nor be deemed to constitute, an obligation of future appropriations by the Non-Federal Sponsors of the State of Texas, where creating such an obligation would be inconsistent with Article 3, Section 49 of the Constitution of the State of Texas, or Article IV, Section 7 and 9 of the Charter of the City of Corpus Christi and Article XI, Section 5 of the Constitution of the State of Texas.

B. The Non-Federal Sponsors intend to satisfy their obligations under this Agreement. The Non-Federal Sponsors shall include in its budget request or otherwise propose, for each fiscal period, appropriations sufficient to cover the Non-Federal Sponsors' obligations under this Agreement for each biennium, and will use all reasonable and lawful means to secure the appropriations for that biennium sufficient to make the payments necessary to fulfill their obligations hereunder. The Non-Federal Sponsors reasonably believe that funds in amounts sufficient to discharge these obligations can and will lawfully be appropriated and made available for this purpose. In the event the budget or other means of appropriations does not provide funds in sufficient amounts to discharge these obligations, the Non-Federal Sponsors shall use their best efforts to satisfy any requirements for payments under this Agreement from any other source of funds legally available for this purpose. Further, if the Non-Federal Sponsors are unable to satisfy their obligations hereunder, the Government may exercise any legal rights it has to protect the Government's interests related to this Agreement.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement, which shall become effective upon the date it is signed by the District Engineer for the U.S. Army Corps of Engineers, Fort Worth District.

DEPARTMENT OF THE ARMY

BY ______________________
JOHN R. MINAHAN
Colonel, Corps of Engineers
District Engineer
Fort Worth District

NUECES RIVER AUTHORITY

BY ______________________
CON MIMS 9/15/04
Executive Director
Nueces River Authority

THE CITY OF CORPUS CHRISTI, TEXAS

BY ______________________
GEORGE K. NOE
City Manager
City of Corpus Christi, Texas

DATE: ______________________

SAN ANTONIO RIVER AUTHORITY

BY ______________________
GREGORY E. ROTHE, P.E.
General Manager
San Antonio River Authority

DATE: 8/31/04

Res 025931 AUTHORIZED
BY COUNCIL 9/14/04
______________________ AC
SECRETARY

ATTEST: ______________________
ARMANDO CHAPA
CITY SECRETARY

APPENDIX D-3

SAN ANTONIO WATER SYSTEM

BY ____________________
LEONARD YOUNG
Acting President/Chief Executive Officer
San Antonio Water System

DATE: August 18, 2004

GUADALUPE-BLANCO RIVER AUTHORITY

BY ____________________
W.E. WEST
General Manager
Guadalupe-Blanco River Authority

DATE: 9/2/04

Attachment: Project Management Plan

CERTIFICATE OF AUTHORITY

I, PHILIP S. HAAG, do hereby certify that I am the principal legal officer of Nueces River Authority, Texas, that Nueces River Authority is a legally constituted public body with full authority and legal capacity to perform the terms of the Agreement between the Department of the Army and Nueces River Authority, the San Antonio River Authority, the city of Corpus Christi, the San Antonio Water System, and the Guadalupe-Blanco River Authority, in connection with the Nueces River and Tributaries, Texas Feasibility Study, and to pay damages in accordance with the terms of this Agreement, if necessary, in the event of failure to perform, as required in accordance with the principles enunciated in Section 221 of Public Law 91-611 (42 U.S.C. Section 1962d-5b), and that the persons who have executed this Agreement on behalf of Nueces River Authority, Texas, have acted within their statutory authority.

IN WITNESS WHEREOF, I have made and executed this certification this 16th day of September 2004.

Philip S. Haag 08657800

Nueces River Authority Attorney
Texas State Bar License Number

CERTIFICATE OF AUTHORITY

I, Mary Kay Fischer, do hereby certify that I am the principal legal officer of City of Corpus Christi, Texas, that City of Corpus Christi, Texas is a legally constituted public body with full authority and legal capacity to perform the terms of the Agreement between the Department of the Army and Nueces River Authority, the San Antonio River Authority, the city of Corpus Christi, the San Antonio Water System, and the Guadalupe-Blanco River Authority, in connection with the Nueces River and Tributaries, Texas Feasibility Study, and to pay damages in accordance with the terms of this Agreement, if necessary, in the event of failure to perform, as required in accordance with the principles enunciated in Section 221 of Public Law 91-611 (42 U.S.C. Section 1962d-5b), and that the persons who have executed this Agreement on behalf of City of Corpus Christi, Texas, have acted within their statutory authority.

IN WITNESS WHEREOF, I have made and executed this certification this 14th day of September, 2004.

Mary Kay Fischer 07043025

City of Corpus Christi, Texas Attorney
Texas State Bar License Number 07043025

CERTIFICATE OF AUTHORITY

I, David W. Ross, do hereby certify that I am the principal legal officer of San Antonio River Authority, Texas, that San Antonio River Authority is a legally constituted public body with full authority and legal capacity to perform the terms of the Agreement between the Department of the Army and Nueces River Authority, the San Antonio River Authority, the city of Corpus Christi, the San Antonio Water System, and the Guadalupe-Blanco River Authority, in connection with the Nueces River and Tributaries, Texas Feasibility Study, and to pay damages in accordance with the terms of this Agreement, if necessary, in the event of failure to perform, as required in accordance with the principles enunciated in Section 221 of Public Law 91-611 (42 U.S.C. Section 1962d-5b), and that the persons who have executed this Agreement on behalf of San Antonio River Authority, Texas, have acted within their statutory authority.

IN WITNESS WHEREOF, I have made and executed this certification this 30th day of August, 2004.

[signature] 17285700

San Antonio River Authority Attorney
Texas State Bar License Number

CERTIFICATE OF AUTHORITY

I, Frank Stenger-Castro do hereby certify that I am the principal legal officer of San Antonio Water System, that San Antonio Water System is a legally constituted public body with full authority and legal capacity to perform the terms of the Agreement between the Department of the Army and Nueces River Authority, the San Antonio River Authority, the city of Corpus Christi, the San Antonio Water System, and the Guadalupe-Blanco River Authority, in connection with the Nueces River and Tributaries, Texas Feasibility Study, and to pay damages in accordance with the terms of this Agreement, if necessary, in the event of failure to perform, as required in accordance with the principles enunciated in Section 221 of Public Law 91-611 (42 U.S.C. Section 1962d-5b), and that the persons who have executed this Agreement on behalf of San Antonio Water System, have acted within their statutory authority.

IN WITNESS WHEREOF, I have made and executed this certification this 24th day of August, 2004.

19143500

San Antonio Water System Attorney
Texas State Bar License Number

APPENDIX D-3

CERTIFICATE OF AUTHORITY

I, BRUCE WASINGER, do hereby certify that I am the principal legal officer of Guadalupe-Blanco River Authority, Texas, that Guadalupe-Blanco River Authority is a legally constituted public body with full authority and legal capacity to perform the terms of the Agreement between the Department of the Army and Nueces River Authority, the San Antonio River Authority, the city of Corpus Christi, the San Antonio Water System, and the Guadalupe-Blanco River Authority, in connection with the Nueces River and Tributaries, Texas Feasibility Study, and to pay damages in accordance with the terms of this Agreement, if necessary, in the event of failure to perform, as required in accordance with the principles enunciated in Section 221 of Public Law 91-611 (42 U.S.C. Section 1962d-5b), and that the persons who have executed this Agreement on behalf of Guadalupe-Blanco River Authority, Texas, have acted within their statutory authority.

IN WITNESS WHEREOF, I have made and executed this certification this 3RD day of SEPT, 2004.

Bruce Wasinger 20901100

Guadalupe-Blanco River Authority Attorney
Texas State Bar License Number

CERTIFICATION REGARDING LOBBYING
NUECES RIVER AUTHORITY

The undersigned certifies, to the best of his or her knowledge and belief that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

[SIGNATURE]

CON MIMS

EXECUTIVE DIRECTOR
NUECES RIVER AUTHORITY

CERTIFICATION REGARDING LOBBYING
CITY OF CORPUS CHRISTI

The undersigned certifies, to the best of his or her knowledge and belief that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

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[SIGNATURE]

GEORGE K. NOE

CITY MANAGER
CITY OF CORPUS CHRISTI

CERTIFICATION REGARDING LOBBYING
SAN ANTONIO RIVER AUTHORITY

The undersigned certifies, to the best of his or her knowledge and belief that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

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Gregory E. Rothe

[SIGNATURE]

GREGORY E. ROTHE

EXECUTIVE DIRECTOR
SAN ANTONIO RIVER AUTHORITY

CERTIFICATION REGARDING LOBBYING
SAN ANTONIO WATER SYSTEM

The undersigned certifies, to the best of his or her knowledge and belief that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

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[SIGNATURE]

LEONARD YOUNG

ACTING PRESIDENT/CHIEF EXECUTIVE OFFICER
SAN ANTONIO WATER SYSEM

CERTIFICATION REGARDING LOBBYING
GUADALUPE-BLANCO RIVER AUTHORITY

The undersigned certifies, to the best of his or her knowledge and belief that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

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[SIGNATURE]

W.E.WEST

GENERAL MANAGER
GUADALUPE-BLANCO RIVER AUTHORITY

Appendix E

List of Utility Companies

Conventional Power

American Electric Power
Website: http://www.aep.com
Main phone: 877-373-4858
Contact: Kenneth Griffin, 361-881-5828, kwgriffin@aep.com

CPL Retail Energy
Website: http://www.cplretailenergy.com
Main phone: 866-322-5563
Contact: Zoey

Entergy Solutions Ltd.
Website: http://www.entergy-solutions.com
Main phone: 866-368-3749
Contact: Tim Weil, 281-297-5513

First Choice Power, Inc.
Website: http://www.FirstChoicePower.com
Main phone: 866-469-2464
Contact: Gary Patterson, 979-345-3596 ext. 105

Green Mountain Energy Company
Website: http://www.greenmountain.com
Main phone: 866-767-5818
Contact: Jeff Luna, 888-380-9410 ext. 6132

Reliant Energy Solutions, LLC
Website: http://www.reliant.com
Main phone: 866-660-4900
Contact: Cara Mills

TXU Energy Company
Website: http://www.txuenergy.com
Main phone: 888-398-4483
Contact: Bill Thomas, account manager in Corpus Christi, 361-904-0649

Wind Energy

Centripetal Dynamics
Website: http://www.centripetal-dynamics.com
Main phone: 602-617-9259
Contact: CEO Ken Hicks, 602-617-9259, khicks@centripetal-dynamics.com

GE Wind
Website: http://www.gewind.com
Main phone: 661-823-6700
Contact: Jill Pollyniak, 661-823-6425

NEG Micon
Website: http://www.neg-micon.com
Main phone: 847-806-9500
Contact: Philip Stiles, 847-806-6456, pstiles@negmicon-usa.com

Vestas
Website: http://www.vestas.com
Main phone: 503-327-2000
Contact: Steve Wieland, 817-437-4683, swieland@vestas-awt.com

Solar Energy

BP Solar
Website: http://www.bpsolar.com
Main phone: 707-438-3823
Contact: Sherwin McDonald, 281-542-1090

Shell Solar
Website: http://www.shellsolar.com
Main phone: 805-482-6800
Contact: Peter Denapoli, 561-477-7679, peter.denapoli@shellsolar.com

Nuclear Power

Comanche Peak Power Plant
Operator: TXU Energy
Website: http://www.txuenergy.com
Main phone: 888-398-4483
Contact: Bill Thomas, account manager in Corpus Christi, 361-904-0649

South Texas Project Electric Generating Station
Operator: South Texas Project Nuclear Operating Company
Website: http://www.stpnoc.com
Main phone: 361-972-8502
Contact: Sandy Danheart, 361-972-8328

Appendix F

Cost Model Results

Appendix F-1

No Desalination

APPENDIX F
No Desalination Scenario

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	FIRM YIELD WATER SUPPLY														
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (acre-feet)	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000	224,000
Acct #	**CONSUMPTION TREATED**														
324000	ICL Residential	5,781,550,000	5,887,545,083	5,993,540,167	6,099,535,250	6,205,530,333	6,311,525,417	6,417,520,500	6,486,899,100	6,556,277,700	6,625,656,300	6,695,034,900	6,764,413,500	6,833,792,100	6,903,170,700
324050	ICL Commercial and Other	5,075,683,000	5,168,737,188	5,261,791,377	5,354,845,565	5,447,899,753	5,540,953,942	5,634,008,130	5,694,916,326	5,755,824,522	5,816,732,718	5,877,640,914	5,938,549,110	5,999,457,306	6,060,365,502
324100	ICL Large Volume Users	821,862	836,929	851,997	867,064	882,132	897,199	912,267	922,129	931,992	941,854	951,716	961,579	971,441	981,303
324800	OCL Residential	8,443,000	8,597,788	8,752,577	8,907,365	9,062,153	9,216,942	9,371,730	9,473,046	9,574,362	9,675,678	9,776,994	9,878,310	9,979,626	10,080,942
324150	OCL Commercial and Other	534,231,000	544,025,235	553,819,470	563,613,705	573,407,940	583,202,175	592,996,410	599,407,182	605,817,954	612,228,726	618,639,498	625,050,270	631,461,042	637,871,814
324810	OCL Large Volume Users	7,950,453,000	8,096,211,305	8,241,969,610	8,387,727,915	8,533,486,220	8,679,244,525	8,825,002,830	8,920,408,266	9,015,813,702	9,111,219,138	9,206,624,574	9,302,030,010	9,397,435,446	9,492,840,882
324170	City Water Use	542,727,000	552,676,995	562,626,990	572,576,985	582,526,980	592,476,975	602,426,970	608,939,694	615,452,418	621,965,142	628,477,866	634,990,590	641,503,314	648,016,038
324850	San Patricio	1,205,710,000	1,239,871,783	1,274,033,567	1,308,195,350	1,342,357,133	1,376,518,917	1,410,680,700	1,426,354,930	1,442,029,160	1,457,703,390	1,473,377,620	1,489,051,850	1,504,726,080	1,520,400,310
324850	South Texas Water Authority	434,991,000	448,040,730	461,090,460	474,140,190	487,189,920	500,239,650	513,289,380	518,509,272	523,729,164	528,949,056	534,168,948	539,388,840	544,608,732	549,828,624
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	422,505,000	466,868,025	511,231,050	555,594,075	599,957,100	644,320,125	688,683,150	716,145,975	743,608,800	771,071,625	798,534,450	825,997,275	853,460,100	880,922,925
	Subtotal (gallons)	23,111,839,862	23,568,136,063	24,024,432,264	24,480,728,464	24,937,024,665	25,393,320,866	25,849,617,067	26,136,700,920	26,423,784,774	26,710,868,627	26,997,952,480	27,285,036,334	27,572,120,187	27,859,204,040
	Subtotal (mgd)	63.3	64.6	65.8	67.1	68.3	69.6	70.8	71.6	72.4	73.2	74.0	74.8	75.5	76.3
	Subtotal (acre-feet)	70,932	72,333	73,733	75,134	76,534	77,935	79,335	80,216	81,097	81,978	82,859	83,740	84,621	85,503
	CONSUMPTION RAW														
324820	Alice	451,854,000	456,372,540	460,891,080	465,409,620	469,928,160	474,446,700	478,965,240	481,676,364	484,387,488	487,098,612	489,809,736	492,520,860	495,231,984	497,943,108
324820	Beeville	872,287,000	878,102,247	883,917,493	889,732,740	895,547,987	901,363,233	907,178,480	908,923,054	910,667,628	912,412,202	914,156,776	915,901,350	917,645,924	919,390,498
324820	Mathis	215,179,000	214,103,105	213,027,210	211,951,315	210,875,420	209,799,525	208,723,630	208,078,093	207,432,556	206,787,019	206,141,482	205,495,945	204,850,408	204,204,871
324820	San Patricio	5,921,852,000	6,089,637,807	6,257,423,613	6,425,209,420	6,592,995,227	6,760,781,033	6,928,566,840	7,005,550,916	7,082,534,992	7,159,519,068	7,236,503,144	7,313,487,220	7,390,471,296	7,467,455,372
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,431,805,000	1,472,372,808	1,512,940,617	1,553,508,425	1,594,076,233	1,634,644,042	1,675,211,850	1,688,098,095	1,700,984,340	1,713,870,585	1,726,756,830	1,739,643,075	1,752,529,320	1,765,415,565
324820	Celanese	1,332,093,000	1,369,835,635	1,407,578,270	1,445,320,905	1,483,063,540	1,520,806,175	1,558,548,810	1,570,537,647	1,582,526,484	1,594,515,321	1,606,504,158	1,618,492,995	1,630,481,832	1,642,470,669
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	10,225,070,000	10,480,424,142	10,735,778,283	10,991,132,425	11,246,486,567	11,501,840,708	11,757,194,850	11,862,864,169	11,968,533,488	12,074,202,807	12,179,872,126	12,285,541,445	12,391,210,764	12,496,880,083
	Subtotal (acre-feet)	31,382	32,165	32,949	33,733	34,517	35,300	36,084	36,408	36,733	37,057	37,381	37,706	38,030	38,354
	Total Water Demand (gallons)	33,336,909,862	34,048,560,204	34,760,210,547	35,471,860,889	36,183,511,232	36,895,161,574	37,606,811,917	37,999,565,089	38,392,318,262	38,785,071,434	39,177,824,606	39,570,577,779	39,963,330,951	40,356,084,123
	Total Capacity (mgd)	91.3	93.3	95.2	97.2	99.1	101.1	103.0	104.1	105.2	106.3	107.3	108.4	109.5	110.6
	Total Water Demand (acre-feet)	102,314	104,498	106,682	108,867	111,051	113,235	115,419	116,624	117,830	119,035	120,241	121,446	122,651	123,857
	ON STEVENS EXPENSES														
Treated	Salaries & Wages	$ 726,362	$ 666,511	$ 683,174	$ 700,253	$ 717,759	$ 735,703	$ 754,096	$ 772,948	$ 792,272	$ 812,079	$ 832,381	$ 853,190	$ 874,520	$ 896,383
Treated	Fringe Benefits	$ 267,109	$ 247,769	$ 253,963	$ 260,312	$ 266,820	$ 273,491	$ 280,328	$ 287,336	$ 294,519	$ 301,882	$ 309,430	$ 317,165	$ 325,094	$ 333,222
Treated	Materials/Supplies/Utilities	$ 4,351,402	$ 6,288,040	$ 6,445,241	$ 6,606,372	$ 6,771,531	$ 6,940,820	$ 7,114,340	$ 7,292,199	$ 7,474,504	$ 7,661,366	$ 7,852,900	$ 8,049,223	$ 8,250,453	$ 8,456,715
Treated	Capital	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ 5,344,873	$ 7,202,320	$ 7,382,378	$ 7,566,937	$ 7,756,111	$ 7,950,014	$ 8,148,764	$ 8,352,483	$ 8,561,295	$ 8,775,328	$ 8,994,711	$ 9,219,579	$ 9,450,068	$ 9,686,320
	RAW WATER EXPENSES														
Raw	Wesley Seale Dam	$ 1,190,020	$ 1,215,144	$ 1,245,523	$ 1,276,661	$ 1,308,577	$ 1,341,292	$ 1,374,824	$ 1,409,194	$ 1,444,424	$ 1,480,535	$ 1,517,548	$ 1,555,487	$ 1,594,374	$ 1,634,234
Raw	Choke Canyon Dam	$ 503,700	$ 575,003	$ 589,378	$ 604,113	$ 619,215	$ 634,696	$ 650,563	$ 666,827	$ 683,498	$ 700,585	$ 718,100	$ 736,052	$ 754,454	$ 773,315
Raw	Environmental Studies	$ 700,000	$ 700,000	$ 717,500	$ 735,438	$ 753,823	$ 772,669	$ 791,986	$ 811,785	$ 832,080	$ 852,882	$ 874,204	$ 896,059	$ 918,461	$ 941,422
Raw	Water Supply Development	$ 864,613	$ 890,234	$ 912,490	$ 935,302	$ 958,685	$ 982,652	$ 1,007,218	$ 1,032,399	$ 1,058,208	$ 1,084,664	$ 1,111,780	$ 1,139,575	$ 1,168,064	$ 1,197,266
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 489,981	$ 573,599	$ 587,939	$ 602,637	$ 617,703	$ 633,146	$ 648,975	$ 665,199	$ 681,829	$ 698,875	$ 716,347	$ 734,255	$ 752,612	$ 771,427
Raw	Water Purchased - LNRA	$ 6,206,324	$ 6,603,854	$ 6,739,012	$ 6,834,059	$ 6,931,127	$ 7,086,677	$ 7,186,106	$ 7,314,107	$ 7,474,756	$ 7,579,286	$ 7,742,312	$ 7,849,195	$ 8,014,925	$ 8,124,511
Raw	Supplemental Water Sources - Wells	$ 35,000	$ 61,000	$ 62,525	$ 64,088	$ 65,690	$ 67,333	$ 69,016	$ 70,741	$ 72,510	$ 74,323	$ 76,181	$ 78,085	$ 80,037	$ 82,038
	Subtotal	$ 10,099,638	$ 10,728,834	$ 10,964,367	$ 11,162,298	$ 11,364,821	$ 11,628,464	$ 11,838,687	$ 12,080,253	$ 12,357,306	$ 12,581,149	$ 12,866,472	$ 13,098,709	$ 13,392,926	$ 13,634,213
	EXISTING DEBT SERVICE														
Treated	ON Stevens Debt	$ 3,649,462	$ 3,445,464	$ 3,390,714	$ 3,587,318	$ 3,589,253	$ 3,591,432	$ 3,820,568	$ 1,903,651	$ 1,902,983	$ 1,795,002	$ 1,796,673	$ 1,687,429	$ 1,448,508	$ 1,448,844
Raw	Bureau of Rec or PL Fund	$ 4,425,542	$ 4,695,363	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163
Raw	NRA Debt Service	$ 931,562	$ 970,110	$ 976,170	$ 971,375	$ 971,010	$ 974,933	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ 117,878	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ 77,458	$ 75,193	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 2,111,136	$ 2,434,132	$ 2,431,914	$ 2,873,210	$ 2,878,236	$ 2,884,445	$ 2,885,746	$ 2,322,352	$ 2,323,963	$ 1,847,992	$ 1,847,697	$ 1,846,788	$ 1,848,067	$ 1,848,266
Raw	2000 Rev Bond: portion applicable P&I	$ 466,092	$ 465,932	$ 464,821	$ 464,921	$ 464,815	$ 464,888	$ 551,554	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,548	$ 1,100,729	$ 1,101,083	$ 1,100,985	$ 1,100,503	$ 1,101,158	$ 1,100,480	$ 1,100,819	$ 1,101,196	$ 1,100,782	$ 1,100,642	$ 1,100,906	$ 1,100,906	$ 1,100,567
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ 48,350	$ 60,091	$ 85,273	$ 108,280	$ 108,819	$ 108,954	$ 74,834	$ 151,044	$ 150,809	$ 179,559	$ 180,491	$ 123,830	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,171,975	$ 8,170,875	$ 8,171,275	$ 8,172,975	$ 8,170,375	$ 8,173,288	$ 8,169,738	$ 8,173,050	$ 8,172,438	$ 8,172,638	$ 8,173,125	$ 8,173,125	$ 8,172,863	$ 8,171,063
Raw	LNRA - Pipeline Debt (Pumping Station)	$ 763,680	$ 758,430	$ 760,100	$ 760,420	$ 759,350	$ 756,850	$ 757,762	$ 756,775	$ 758,175	$ 757,925	$ 756,025	$ 757,475	$ 757,000	$ 759,600
	Subtotal	$ 21,863,684	$ 22,176,319	$ 22,376,513	$ 23,034,645	$ 23,037,524	$ 23,051,111	$ 22,355,846	$ 19,402,854	$ 19,404,727	$ 18,849,061	$ 18,849,816	$ 18,684,715	$ 18,322,506	$ 18,323,502

APPENDIX F
No Desalination Scenario

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	PLANNED DEBT SERVICE														
Treated	ON Stevens Debt	$ -	$ -	$ 23,447	$ 186,809	$ 1,635,830	$ 2,366,037	$ 2,956,244	$ 5,830,847	$ 7,010,826	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499
Raw	Raw Water Debt	$ -	$ -	$ 489,778	$ 1,271,993	$ 1,621,048	$ 1,621,048	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727
	Subtotal	$ -	$ -	$ 513,225	$ 1,458,802	$ 3,256,878	$ 3,987,085	$ 4,660,972	$ 7,535,574	$ 8,715,553	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227
	FUTURE CAPITAL PROJECTS														
Raw	Garwood - Intake and Pump Station	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Garwood - Transmission Pipeline	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Garwood - Texana Upgrade	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Garwood - Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Garwood - Engineering, Acquisition, Environmental, ID	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	ON Stevens Replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	FUTURE OPERATION & MAINTENANCE														
Raw	Garwood - Intake, Pipeline, Pump Station	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Garwood - Pumping Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Raw Cost of Water ($ per 1,000 gallons)	***$ 1.23***	***$ 1.25***	***$ 1.27***	***$ 1.30***	***$ 1.30***	***$ 1.29***	***$ 1.24***	***$ 1.20***	***$ 1.19***	***$ 1.17***	***$ 1.17***	***$ 1.17***	***$ 1.16***	***$ 1.16***
	Raw Cost of Water ($ per acre-foot)	***$ 277***	***$ 282***	***$ 285***	***$ 293***	***$ 292***	***$ 289***	***$ 278***	***$ 268***	***$ 268***	***$ 263***	***$ 263***	***$ 262***	***$ 261***	***$ 260***
	Treated Cost of Water ($ per 1,000 gallons)	***$ 0.39***	***$ 0.45***	***$ 0.45***	***$ 0.46***	***$ 0.52***	***$ 0.55***	***$ 0.58***	***$ 0.62***	***$ 0.66***	***$ 0.68***	***$ 0.68***	***$ 0.68***	***$ 0.67***	***$ 0.67***
	Treated Cost of Water ($ per acre-foot)	***$ 127***	***$ 147***	***$ 146***	***$ 151***	***$ 170***	***$ 178***	***$ 188***	***$ 201***	***$ 215***	***$ 221***	***$ 221***	***$ 220***	***$ 218***	***$ 218***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 1.82***	***$ 1.84***	***$ 1.82***	***$ 1.81***	***$ 1.86***	***$ 1.85***	***$ 1.85***	***$ 1.84***	***$ 1.83***	***$ 1.83***
	Combined Cost of Water ($ per acre-foot)	***$ 404***	***$ 429***	***$ 432***	***$ 444***	***$ 462***	***$ 467***	***$ 466***	***$ 469***	***$ 483***	***$ 484***	***$ 484***	***$ 482***	***$ 479***	***$ 478***
	Total Annual Raw Water Cost	***$ 28,313,860***	***$ 29,459,689***	***$ 30,439,944***	***$ 31,881,618***	***$ 32,434,140***	***$ 32,709,191***	***$ 32,078,693***	***$ 31,284,183***	***$ 31,563,777***	***$ 31,339,935***	***$ 31,624,343***	***$ 31,800,723***	***$ 31,971,652***	***$ 32,213,599***
	Total Annual Treatment Cost	***$ 8,994,335***	***$ 10,647,784***	***$ 10,796,539***	***$ 11,341,064***	***$ 12,981,193***	***$ 13,907,483***	***$ 14,925,576***	***$ 16,086,981***	***$ 17,475,104***	***$ 18,106,829***	***$ 18,327,883***	***$ 18,443,506***	***$ 18,435,075***	***$ 18,671,663***
	Total Annual Cost	***$ 37,308,195***	***$ 40,107,473***	***$ 41,236,483***	***$ 43,222,682***	***$ 45,415,333***	***$ 46,616,674***	***$ 47,004,269***	***$ 47,371,164***	***$ 49,038,881***	***$ 49,446,764***	***$ 49,952,226***	***$ 50,244,229***	***$ 50,406,727***	***$ 50,885,261***
	Total Annual Present Value	***$ 37,308,195***	***$ 39,612,319***	***$ 40,224,584***	***$ 41,641,524***	***$ 43,213,792***	***$ 43,809,281***	***$ 43,628,181***	***$ 43,425,900***	***$ 44,399,726***	***$ 44,216,319***	***$ 44,116,853***	***$ 43,826,908***	***$ 43,425,829***	***$ 43,296,879***
	Cumulative Present Value	***$ 37,308,195***	***$ 76,920,513***	***$ 117,145,097***	***$ 158,786,621***	***$ 202,000,413***	***$ 245,809,694***	***$ 289,437,875***	***$ 332,863,776***	***$ 377,263,502***	***$ 421,479,821***	***$ 465,596,674***	***$ 509,423,583***	***$ 552,849,411***	***$ 596,146,290***

APPENDIX F
No Desalination Scenario

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	FIRM YIELD WATER SUPPLY													
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	32,000	32,000	32,000	32,000	32,000	32,000	32,000	32,000	32,000	32,000	32,000
	Subtotal (acre-feet)	224,000	224,000	256,000	256,000	256,000	256,000	256,000	256,000	256,000	256,000	256,000	256,000	256,000
Acct #	**CONSUMPTION TREATED**													
324000	ICL Residential	6,972,549,300	7,041,927,900	7,111,306,500	7,163,340,450	7,215,374,400	7,267,408,350	7,319,442,300	7,371,476,250	7,423,510,200	7,475,544,150	7,527,578,100	7,579,612,050	7,631,646,000
324050	ICL Commercial and Other	6,121,273,698	6,182,181,894	6,243,090,090	6,288,771,237	6,334,452,384	6,380,133,531	6,425,814,678	6,471,495,825	6,517,176,972	6,562,858,119	6,608,539,266	6,654,220,413	6,699,901,560
324100	ICL Large Volume Users	991,166	1,001,028	1,010,890	1,018,287	1,025,684	1,033,081	1,040,477	1,047,874	1,055,271	1,062,668	1,070,064	1,077,461	1,084,858
324800	OCL Residential	10,182,258	10,283,574	10,384,890	10,460,877	10,536,864	10,612,851	10,688,838	10,764,825	10,840,812	10,916,799	10,992,786	11,068,773	11,144,760
324150	OCL Commercial and Other	644,282,586	650,693,358	657,104,130	661,912,209	666,720,288	671,528,367	676,336,446	681,144,525	685,952,604	690,760,683	695,568,762	700,376,841	705,184,920
324810	OCL Large Volume Users	9,588,246,318	9,683,651,754	9,779,057,190	9,850,611,267	9,922,165,344	9,993,719,421	10,065,273,498	10,136,827,575	10,208,381,652	10,279,935,729	10,351,489,806	10,423,043,883	10,494,597,960
324170	City Water Use	654,528,762	661,041,486	667,554,210	672,438,753	677,323,296	682,207,839	687,092,382	691,976,925	696,861,468	701,746,011	706,630,554	711,515,097	716,399,640
324850	San Patricio	1,536,074,540	1,551,748,770	1,567,423,000	1,583,097,230	1,598,771,460	1,614,445,690	1,630,119,920	1,645,794,150	1,661,468,380	1,677,142,610	1,692,816,840	1,708,491,070	1,724,165,300
324850	South Texas Water Authority	555,048,516	560,268,408	565,488,300	568,533,237	571,578,174	574,623,111	577,668,048	580,712,985	583,757,922	586,802,859	589,847,796	592,892,733	595,937,670
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	908,385,750	935,848,575	963,311,400	987,394,185	1,011,476,970	1,035,559,755	1,059,642,540	1,083,725,325	1,107,808,110	1,131,890,895	1,155,973,680	1,180,056,465	1,204,139,250
	Subtotal (gallons)	28,146,287,894	28,433,371,747	28,720,455,600	28,942,302,732	29,164,149,864	29,385,996,996	29,607,844,127	29,829,691,259	30,051,538,391	30,273,385,523	30,495,232,654	30,717,079,786	30,938,926,918
	Subtotal (mgd)	77.1	77.9	78.7	79.3	79.9	80.5	81.1	81.7	82.3	82.9	83.5	84.2	84.8
	Subtotal (acre-feet)	86,384	87,265	88,146	88,827	89,508	90,188	90,869	91,550	92,231	92,912	93,593	94,274	94,955
	CONSUMPTION RAW													
324820	Alice	500,654,232	503,365,356	506,076,480	507,432,042	508,787,604	510,143,166	511,498,728	512,854,290	514,209,852	515,565,414	516,920,976	518,276,538	519,632,100
324820	Beeville	921,135,072	922,879,646	924,624,220	926,368,794	928,113,368	929,857,942	931,602,516	933,347,090	935,091,664	936,836,238	938,580,812	940,325,386	942,069,960
324820	Mathis	203,559,334	202,913,797	202,268,260	201,837,902	201,407,544	200,977,186	200,546,828	200,116,470	199,686,112	199,255,754	198,825,396	198,395,038	197,964,680
324820	San Patricio	7,544,439,448	7,621,423,524	7,698,407,600	7,775,391,676	7,852,375,752	7,929,359,828	8,006,343,904	8,083,327,980	8,160,312,056	8,237,296,132	8,314,280,208	8,391,264,284	8,468,248,360
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,778,301,810	1,791,188,055	1,804,074,300	1,815,528,740	1,826,983,180	1,838,437,620	1,849,892,060	1,861,346,500	1,872,800,940	1,884,255,380	1,895,709,820	1,907,164,260	1,918,618,700
324820	Celanese	1,654,459,506	1,666,448,343	1,678,437,180	1,689,093,924	1,699,750,668	1,710,407,412	1,721,064,156	1,731,720,900	1,742,377,644	1,753,034,388	1,763,691,132	1,774,347,876	1,785,004,620
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	12,602,549,402	12,708,218,721	12,813,888,040	12,915,653,078	13,017,418,116	13,119,183,154	13,220,948,192	13,322,713,230	13,424,478,268	13,526,243,306	13,628,008,344	13,729,773,382	13,831,538,420
	Subtotal (acre-feet)	38,678	39,003	39,327	39,639	39,952	40,264	40,576	40,889	41,201	41,513	41,826	42,138	42,450
	Total Water Demand (gallons)	40,748,837,296	41,141,590,468	41,534,343,640	41,857,955,810	42,181,567,980	42,505,180,150	42,828,792,319	43,152,404,489	43,476,016,659	43,799,628,829	44,123,240,998	44,446,853,168	44,770,465,338
	Total Capacity (mgd)	111.6	112.7	113.8	114.7	115.6	116.5	117.3	118.2	119.1	120.0	120.9	121.8	122.7
	Total Water Demand (acre-feet)	125,062	126,268	127,473	128,466	129,459	130,452	131,446	132,439	133,432	134,425	135,418	136,412	137,405
	ON STEVENS EXPENSES													
Treated	Salaries & Wages	$ 918,793	$ 941,763	$ 965,307	$ 989,439	$ 1,014,175	$ 1,039,530	$ 1,065,518	$ 1,092,156	$ 1,119,460	$ 1,147,446	$ 1,176,132	$ 1,205,536	$ 1,235,674
Treated	Fringe Benefits	$ 341,552	$ 350,091	$ 358,843	$ 367,814	$ 377,010	$ 386,435	$ 396,096	$ 405,998	$ 416,148	$ 426,552	$ 437,216	$ 448,146	$ 459,350
Treated	Materials/Supplies/Utilities	$ 8,668,133	$ 8,884,836	$ 9,106,957	$ 9,334,631	$ 9,567,996	$ 9,807,196	$ 10,052,376	$ 10,303,686	$ 10,561,278	$ 10,825,310	$ 11,095,943	$ 11,373,341	$ 11,657,675
Treated	Capital	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ 9,928,478	$ 10,176,690	$ 10,431,107	$ 10,691,885	$ 10,959,182	$ 11,233,161	$ 11,513,990	$ 11,801,840	$ 12,096,886	$ 12,399,308	$ 12,709,291	$ 13,027,023	$ 13,352,699
	RAW WATER EXPENSES													
Raw	Wesley Seale Dam	$ 1,675,089	$ 1,716,967	$ 1,759,891	$ 1,803,888	$ 1,848,985	$ 1,895,210	$ 1,942,590	$ 1,991,155	$ 2,040,934	$ 2,091,957	$ 2,144,256	$ 2,197,862	$ 2,252,809
Raw	Choke Canyon Dam	$ 792,648	$ 812,464	$ 832,776	$ 853,595	$ 874,935	$ 896,808	$ 919,229	$ 942,209	$ 965,765	$ 989,909	$ 1,014,656	$ 1,040,023	$ 1,066,023
Raw	Environmental Studies	$ 964,958	$ 989,082	$ 1,013,809	$ 1,039,154	$ 1,065,133	$ 1,091,761	$ 1,119,055	$ 1,147,032	$ 1,175,707	$ 1,205,100	$ 1,235,227	$ 1,266,108	$ 1,297,761
Raw	Water Supply Development	$ 1,227,197	$ 1,257,877	$ 1,289,324	$ 1,321,557	$ 1,354,596	$ 1,388,461	$ 1,423,173	$ 1,458,752	$ 1,495,221	$ 1,532,601	$ 1,570,916	$ 1,610,189	$ 1,650,444
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 790,713	$ 810,480	$ 830,742	$ 851,511	$ 872,799	$ 894,619	$ 916,984	$ 939,909	$ 963,406	$ 987,492	$ 1,012,179	$ 1,037,483	$ 1,063,420
Raw	Water Purchased - LNRA	$ 8,335,257	$ 8,504,345	$ 8,617,689	$ 8,790,535	$ 8,964,136	$ 9,138,181	$ 9,313,153	$ 9,538,473	$ 9,715,121	$ 9,892,989	$ 10,072,188	$ 10,252,833	$ 10,491,042
Raw	Supplemental Water Sources - Wells	$ 84,089	$ 86,191	$ 88,346	$ 90,555	$ 92,819	$ 95,139	$ 97,518	$ 99,956	$ 102,454	$ 105,016	$ 107,641	$ 110,332	$ 113,091
	Subtotal	$ 13,979,951	$ 14,287,407	$ 14,542,577	$ 14,860,795	$ 15,183,403	$ 15,510,180	$ 15,841,702	$ 16,227,485	$ 16,568,609	$ 16,915,063	$ 17,267,064	$ 17,624,831	$ 18,044,590
	EXISTING DEBT SERVICE													
Treated	ON Stevens Debt	$ 1,449,133	$ 1,448,956	$ 814,516										
Raw	Bureau of Rec or PL Fund	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,208,976	$ 827,934
Raw	NRA Debt Service	$ -	$ -	$ -	$ -	$ -								
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -								
Raw	1994 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -								
Raw	1995 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -								
Raw	1999 Rev Bond: portion applicable P&I	$ 1,848,266	$ 1,847,231	$ -	$ -	$ -								
Raw	2000 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -								
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,793	$ 1,101,024	$ 1,101,143	$ 1,101,030	$ 1,100,804								
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ -	$ -	$ -	$ -	$ -								
Raw	NRA Pipeline Debt	$ 8,172,450	$ 8,169,275	$ 8,171,800	$ 8,173,925	$ 8,169,825	$ 8,168,950	$ 8,170,200	$ 8,172,475	$ 8,169,675	$ 8,012,418			
Raw	LNRA - Pipeline Debt (Pumping Station)													
	Subtotal	$ 17,565,805	$ 17,561,650	$ 15,082,622	$ 14,270,118	$ 14,265,792	$ 13,164,113	$ 13,165,363	$ 13,167,638	$ 13,164,838	$ 13,007,581	$ 4,995,163	$ 4,208,976	$ 827,934

APPENDIX F
No Desalination Scenario

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	PLANNED DEBT SERVICE													
Treated	ON Stevens Debt	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499
Raw	Raw Water Debt	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727
	Subtotal	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227
	FUTURE CAPITAL PROJECTS													
Raw	Garwood - Intake and Pump Station	$ -	$ -	$ 1,557,397	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571	$ 1,280,571
Raw	Garwood - Transmission Pipeline	$ -	$ -	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077	$ 4,737,077
Raw	Garwood - Texana Upgrade	$ -	$ -	$ 219,389	$ 180,393	$ 180,393	$ 180,393	$ 180,393	$ 180,393	$ 180,393	$ 180,393	$ 180,393	$ 180,393	$ 180,393
Raw	Garwood - Other	$ -	$ -	$ 40,132	$ 32,999	$ 32,999	$ 32,999	$ 32,999	$ 32,999	$ 32,999	$ 32,999	$ 32,999	$ 32,999	$ 32,999
Raw	Garwood - Engineering, Acquisition, Environmental, ID	$ -	$ -	$ 3,558,655	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107	$ 2,926,107
Treated	ON Stevens Replacement	$ -	$ -	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398	$ 13,377,398
	Subtotal	$ -	$ -	$ 23,490,048	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544	$ 22,534,544
	FUTURE OPERATION & MAINTENANCE													
Raw	Garwood - Intake, Pipeline, Pump Station	$ -	$ -	$ 1,114,259	$ 1,142,116	$ 1,170,669	$ 1,199,935	$ 1,229,934	$ 1,260,682	$ 1,292,199	$ 1,324,504	$ 1,357,617	$ 1,391,557	$ 1,426,346
Raw	Garwood - Pumping Costs	$ -	$ -	$ 3,389,138	$ 3,473,867	$ 3,560,714	$ 3,649,731	$ 3,740,975	$ 3,834,499	$ 3,930,361	$ 4,028,621	$ 4,129,336	$ 4,232,569	$ 4,338,384
	Subtotal	$ -	$ -	$ 4,503,398	$ 4,615,983	$ 4,731,382	$ 4,849,667	$ 4,970,908	$ 5,095,181	$ 5,222,561	$ 5,353,125	$ 5,486,953	$ 5,624,126	$ 5,764,730
	Raw Cost of Water ($ per 1,000 gallons)	$ 1.13	$ 1.13	$ 1.57	$ 1.54	$ 1.54	$ 1.51	$ 1.51	$ 1.52	$ 1.52	$ 1.52	$ 1.27	$ 1.25	$ 1.15
	Raw Cost of Water ($ per acre-foot)	$ 254	$ 254	$ 354	$ 347	$ 348	$ 340	$ 341	$ 342	$ 343	$ 343	$ 285	$ 281	$ 258
	Treated Cost of Water ($ per 1,000 gallons)	$ 0.67	$ 0.67	$ 1.12	$ 1.09	$ 1.09	$ 1.09	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.11
	Treated Cost of Water ($ per acre-foot)	$ 219	$ 220	$ 365	$ 356	$ 356	$ 356	$ 357	$ 357	$ 358	$ 359	$ 359	$ 360	$ 361
	Combined Cost of Water ($ per 1,000 gallons)	$ 1.80	$ 1.80	$ 2.69	$ 2.63	$ 2.64	$ 2.60	$ 2.61	$ 2.62	$ 2.62	$ 2.62	$ 2.37	$ 2.35	$ 2.25
	Combined Cost of Water ($ per acre-foot)	$ 473	$ 474	$ 719	$ 703	$ 704	$ 697	$ 698	$ 700	$ 701	$ 702	$ 644	$ 641	$ 619
	Total Annual Raw Water Cost	$ 31,801,350	$ 32,104,828	$ 45,131,458	$ 44,608,769	$ 45,042,450	$ 44,385,833	$ 44,839,846	$ 45,352,177	$ 45,817,881	$ 46,137,642	$ 38,611,053	$ 38,319,807	$ 35,499,127
	Total Annual Treatment Cost	$ 18,914,110	$ 19,162,145	$ 32,159,520	$ 31,605,782	$ 31,873,079	$ 32,147,058	$ 32,427,887	$ 32,715,737	$ 33,010,783	$ 33,313,205	$ 33,623,188	$ 33,940,920	$ 34,266,596
	Total Annual Cost	$ 50,715,460	$ 51,266,973	$ 77,290,978	$ 76,214,551	$ 76,915,529	$ 76,532,891	$ 77,267,734	$ 78,067,914	$ 78,828,664	$ 79,450,847	$ 72,234,241	$ 72,260,727	$ 69,765,723
	Total Annual Present Value	$ 42,619,655	$ 42,551,237	$ 63,358,997	$ 61,705,284	$ 61,504,013	$ 60,442,513	$ 60,269,493	$ 60,141,867	$ 59,978,205	$ 59,705,288	$ 53,612,042	$ 52,969,580	$ 50,509,291
	Cumulative Present Value	$ 638,765,945	$ 681,317,182	$ 744,676,179	$ 806,381,463	$ 867,885,476	$ 928,327,989	$ 988,597,482	$ 1,048,739,349	$ 1,108,717,554	$ 1,168,422,842	$ 1,222,034,884	$ 1,275,004,464	$ 1,325,513,755

Appendix F-2

Desalination BD 2 Base Alternate

APPENDIX F

Desalination BD 2 Base Alternate (Open Sea Intake and Discharge)

Acct #	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	FIRM YIELD WATER SUPPLY														
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Desal Plant	0	0	0	0	0	0	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000
	Subtotal (acre-feet)	224,000	224,000	224,000	224,000	224,000	224,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000
Acct #	**CONSUMPTION TREATED**														
324000	ICL Residential	5,781,550,000	5,887,545,083	5,993,540,167	6,099,535,250	6,205,530,333	6,311,525,417	6,417,520,500	6,486,899,100	6,556,277,700	6,625,656,300	6,695,034,900	6,764,413,500	6,833,792,100	6,903,170,700
324050	ICL Commercial and Other	5,075,683,000	5,168,737,188	5,261,791,377	5,354,845,565	5,447,899,753	5,540,953,942	5,634,008,130	5,694,916,326	5,755,824,522	5,816,732,718	5,877,640,914	5,938,549,110	5,999,457,306	6,060,365,502
324100	ICL Large Volume Users	821,862	836,929	851,997	867,064	882,132	897,199	912,267	922,129	931,992	941,854	951,716	961,579	971,441	981,303
324800	OCL Residential	8,443,000	8,597,788	8,752,577	8,907,365	9,062,153	9,216,942	9,371,730	9,473,046	9,574,362	9,675,678	9,776,994	9,878,310	9,979,626	10,080,942
324150	OCL Commercial and Other	534,231,000	544,025,235	553,819,470	563,613,705	573,407,940	583,202,175	592,996,410	599,407,182	605,817,954	612,228,726	618,639,498	625,050,270	631,461,042	637,871,814
324810	OCL Large Volume Users	7,950,453,000	8,096,211,305	8,241,969,610	8,387,727,915	8,533,486,220	8,679,244,525	8,825,002,830	8,920,408,266	9,015,813,702	9,111,219,138	9,206,624,574	9,302,030,010	9,397,435,446	9,492,840,882
324170	City Water Use	542,727,000	552,676,995	562,626,990	572,576,985	582,526,980	592,476,975	602,426,970	608,939,694	615,452,418	621,965,142	628,477,866	634,990,590	641,503,314	648,016,038
324850	San Patricio	1,205,710,000	1,239,871,783	1,274,033,567	1,308,195,350	1,342,357,133	1,376,518,917	1,410,680,700	1,426,354,930	1,442,029,160	1,457,703,390	1,473,377,620	1,489,051,850	1,504,726,080	1,520,400,310
324850	South Texas Water Authority	434,991,000	448,040,730	461,090,460	474,140,190	487,189,920	500,239,650	513,289,380	518,509,272	523,729,164	528,949,056	534,168,948	539,388,840	544,608,732	549,828,624
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	422,505,000	466,868,025	511,231,050	555,594,075	599,957,100	644,320,125	688,683,150	716,145,975	743,608,800	771,071,625	798,534,450	825,997,275	853,460,100	880,922,925
	Subtotal (gallons)	23,111,839,862	23,568,136,063	24,024,432,264	24,480,728,464	24,937,024,665	25,393,320,866	25,849,617,067	26,136,700,920	26,423,784,774	26,710,868,627	26,997,952,480	27,285,036,334	27,572,120,187	27,859,204,040
	Subtotal (mgd)	63.3	64.6	65.8	67.1	68.3	69.6	70.8	71.6	72.4	73.2	74.0	74.8	75.5	76.3
	Subtotal (acre-feet)	70,932	72,333	73,733	75,134	76,534	77,935	79,335	80,216	81,097	81,978	82,859	83,740	84,621	85,503
	CONSUMPTION RAW														
324820	Alice	451,854,000	456,372,540	460,891,080	465,409,620	469,928,160	474,446,700	478,965,240	481,676,364	484,387,488	487,098,612	489,809,736	492,520,860	495,231,984	497,943,108
324820	Beeville	872,287,000	878,102,247	883,917,493	889,732,740	895,547,987	901,363,233	907,178,480	908,923,054	910,667,628	912,412,202	914,156,776	915,901,350	917,645,924	919,390,498
324820	Mathis	215,179,000	214,103,105	213,027,210	211,951,315	210,875,420	209,799,525	208,723,630	208,078,093	207,432,556	206,787,019	206,141,482	205,495,945	204,850,408	204,204,871
324820	San Patricio	5,921,852,000	6,089,637,807	6,257,423,613	6,425,209,420	6,592,995,227	6,760,781,033	6,928,566,840	7,005,550,916	7,082,534,992	7,159,519,068	7,236,503,144	7,313,487,220	7,390,471,296	7,467,455,372
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,431,805,000	1,472,372,808	1,512,940,617	1,553,508,425	1,594,076,233	1,634,644,042	1,675,211,850	1,688,098,095	1,700,984,340	1,713,870,585	1,726,756,830	1,739,643,075	1,752,529,320	1,765,415,565
324820	Celanese	1,332,093,000	1,369,835,635	1,407,578,270	1,445,320,905	1,483,063,540	1,520,806,175	1,558,548,810	1,570,537,647	1,582,526,484	1,594,515,321	1,606,504,158	1,618,492,995	1,630,481,832	1,642,470,669
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	10,225,070,000	10,480,424,142	10,735,778,283	10,991,132,425	11,246,486,567	11,501,840,708	11,757,194,850	11,862,864,169	11,968,533,488	12,074,202,807	12,179,872,126	12,285,541,445	12,391,210,764	12,496,880,083
	Subtotal (acre-feet)	31,382	32,165	32,949	33,733	34,517	35,300	36,084	36,408	36,733	37,057	37,381	37,706	38,030	38,354
	Total Water Demand (gallons)	33,336,909,862	34,048,560,204	34,760,210,547	35,471,860,889	36,183,511,232	36,895,161,574	37,606,811,917	37,999,565,089	38,392,318,262	38,785,071,434	39,177,824,606	39,570,577,779	39,963,330,951	40,356,084,123
	Total Capacity (mgd)	91.3	93.3	95.2	97.2	99.1	101.1	103.0	104.1	105.2	106.3	107.3	108.4	109.5	110.6
	Total Water Demand (acre-feet)	102,314	104,498	106,682	108,867	111,051	113,235	115,419	116,624	117,830	119,035	120,241	121,446	122,651	123,857
	ON STEVENS EXPENSES														
Treated	Salaries & Wages	$ 726,362	$ 666,511	$ 683,174	$ 700,253	$ 717,759	$ 735,703	$ 754,096	$ 772,948	$ 792,272	$ 812,079	$ 832,381	$ 853,190	$ 874,520	$ 896,383
Treated	Fringe Benefits	$ 267,109	$ 247,769	$ 253,963	$ 260,312	$ 266,820	$ 273,491	$ 280,328	$ 287,336	$ 294,519	$ 301,882	$ 309,430	$ 317,165	$ 325,094	$ 333,222
Treated	Materials/Supplies/Utilities	$ 4,351,402	$ 6,288,040	$ 6,445,241	$ 6,606,372	$ 6,771,531	$ 6,940,820	$ 4,603,448	$ 4,746,803	$ 4,893,820	$ 5,044,595	$ 5,199,231	$ 5,357,831	$ 5,520,500	$ 5,687,348
Treated	Capital	$ -	$ -												
	Subtotal	$ 5,344,873	$ 7,202,320	$ 7,382,378	$ 7,566,937	$ 7,756,111	$ 7,950,014	$ 5,637,872	$ 5,807,088	$ 5,980,611	$ 6,158,557	$ 6,341,042	$ 6,528,187	$ 6,720,115	$ 6,916,953
	RAW WATER EXPENSES														
Raw	Wesley Seale Dam	$ 1,190,020	$ 1,215,144	$ 1,245,523	$ 1,276,661	$ 1,308,577	$ 1,341,292	$ 1,374,824	$ 1,409,194	$ 1,444,424	$ 1,480,535	$ 1,517,548	$ 1,555,487	$ 1,594,374	$ 1,634,234
Raw	Choke Canyon Dam	$ 503,700	$ 575,003	$ 589,378	$ 604,113	$ 619,215	$ 634,696	$ 650,563	$ 666,827	$ 683,498	$ 700,585	$ 718,100	$ 736,052	$ 754,454	$ 773,315
Raw	Environmental Studies	$ 700,000	$ 700,000	$ 717,500	$ 735,438	$ 753,823	$ 772,669	$ 791,986	$ 811,785	$ 832,080	$ 852,882	$ 874,204	$ 896,059	$ 918,461	$ 941,422
Raw	Water Supply Development	$ 864,613	$ 890,234	$ 912,490	$ 935,302	$ 958,685	$ 982,652	$ 1,007,218	$ 1,032,399	$ 1,058,208	$ 1,084,664	$ 1,111,780	$ 1,139,575	$ 1,168,064	$ 1,197,266
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 489,981	$ 573,599	$ 587,939	$ 602,637	$ 617,703	$ 633,146	$ 648,975	$ 665,199	$ 681,829	$ 698,875	$ 716,347	$ 734,255	$ 752,612	$ 771,427
Raw	Water Purchased - LNRA	$ 6,206,324	$ 6,603,854	$ 6,739,012	$ 6,834,059	$ 6,931,127	$ 7,086,677	$ 7,186,106	$ 7,314,107	$ 7,474,756	$ 7,579,286	$ 7,742,312	$ 7,849,195	$ 8,014,925	$ 8,124,511
Raw	Supplemental Water Sources - Wells	$ 35,000	$ 61,000	$ 62,525	$ 64,088	$ 65,690	$ 67,333	$ 69,016	$ 70,741	$ 72,510	$ 74,323	$ 76,181	$ 78,085	$ 80,037	$ 82,038
	Subtotal	$ 10,099,638	$ 10,728,834	$ 10,964,367	$ 11,162,298	$ 11,364,821	$ 11,628,464	$ 11,838,687	$ 12,080,253	$ 12,357,306	$ 12,581,149	$ 12,866,472	$ 13,098,709	$ 13,392,926	$ 13,634,213
	EXISTING DEBT SERVICE														
Treated	ON Stevens Debt	$ 3,649,462	$ 3,445,464	$ 3,390,714	$ 3,587,318	$ 3,589,253	$ 3,591,432	$ 3,820,568	$ 1,903,651	$ 1,902,983	$ 1,795,002	$ 1,796,673	$ 1,687,429	$ 1,448,508	$ 1,448,844
Raw	Bureau of Rec or PL Fund	$ 4,425,542	$ 4,695,363	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163
Raw	NRA Debt Service	$ 931,562	$ 970,110	$ 976,170	$ 971,375	$ 971,010	$ 974,933	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ 117,878	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ 77,458	$ 75,193	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 2,111,136	$ 2,434,132	$ 2,431,914	$ 2,873,210	$ 2,878,236	$ 2,884,445	$ 2,885,746	$ 2,322,352	$ 2,323,963	$ 1,847,992	$ 1,847,697	$ 1,846,788	$ 1,848,067	$ 1,848,266
Raw	2000 Rev Bond: portion applicable P&I	$ 466,092	$ 465,932	$ 464,821	$ 464,921	$ 464,815	$ 464,888	$ 551,554	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,548	$ 1,100,729	$ 1,101,083	$ 1,100,985	$ 1,100,503	$ 1,101,158	$ 1,100,480	$ 1,100,819	$ 1,101,196	$ 1,100,782	$ 1,100,642	$ 1,100,906	$ 1,100,906	$ 1,100,567
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ 48,350	$ 60,091	$ 85,273	$ 108,280	$ 108,819	$ 108,954	$ 74,834	$ 151,044	$ 150,809	$ 179,559	$ 180,491	$ 123,830	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,171,975	$ 8,170,875	$ 8,171,275	$ 8,172,975	$ 8,170,375	$ 8,173,288	$ 8,169,738	$ 8,173,050	$ 8,172,438	$ 8,172,638	$ 8,173,125	$ 8,173,125	$ 8,172,863	$ 8,171,063
Raw	LNRA - Pipeline Debt (Pumping Station)	$ 763,680	$ 758,430	$ 760,100	$ 760,420	$ 759,350	$ 756,850	$ 757,762	$ 756,775	$ 758,175	$ 757,925	$ 756,025	$ 757,475	$ 757,000	$ 759,600
	Subtotal	$ 21,863,684	$ 22,176,319	$ 22,376,513	$ 23,034,645	$ 23,037,524	$ 23,051,111	$ 22,355,846	$ 19,402,854	$ 19,404,727	$ 18,849,061	$ 18,849,816	$ 18,684,715	$ 18,322,506	$ 18,323,502

APPENDIX F
Desalination BD 2 Base Alternate (Open Sea Intake and Discharge)

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	PLANNED DEBT SERVICE														
Treated	ON Stevens Debt	-	-	23,447	186,809	1,635,830	2,366,037	2,956,244	5,830,847	7,010,826	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499
Raw	Raw Water Debt	-	-	489,778	1,271,993	1,621,048	1,621,048	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727
	Subtotal	-	-	513,225	1,458,802	3,256,878	3,987,085	4,660,972	7,535,574	8,715,553	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227
	FUTURE CAPITAL PROJECTS														
Treated	ON Stevens Replacement														
	Subtotal	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMARY OF COST FOR NON-DESAL FACILITIES														
	Raw Cost of Water ($ per 1,000 gallons)	1.23	1.25	1.27	1.30	1.30	1.29	1.24	1.20	1.19	1.17	1.17	1.17	1.16	1.16
	Treated Cost of Water ($ per 1,000 gallons)	0.39	0.45	0.45	0.46	0.52	0.55	0.74	0.80	0.86	0.88	0.88	0.87	0.85	0.85
	Combined Cost of Water ($ per 1,000 gallons)	1.61	1.70	1.72	1.77	1.82	1.84	1.98	1.99	2.06	2.05	2.05	2.03	2.01	2.01
	DESAL PLANT DEBT SERVICE														
Treated	Equipment	-	-	-	-	4,595,725	4,595,725	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131
Treated	Pipe	-	-	-	-	5,063,190	5,063,190	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086
Treated	Structures	-	-	-	-	1,803,078	1,803,078	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664
Treated	Other	-	-	-	-	485,678	485,678	738,931	738,931	738,931	738,931	738,931	738,931	738,931	738,931
	Subtotal	-	-	-	-	11,947,671	11,947,671	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811
	DESAL PLANT REPAIR AND REHABILITATION														
Treated	Reverse Osmosis & Common Elements	-	-	-	-	-	-	4,822,580	4,943,145	5,066,723	5,193,391	5,323,226	5,456,307	5,592,714	5,732,532
Treated	Pre-Treatment	-	-	-	-	-	-	1,048,727	1,074,945	1,101,819	1,129,364	1,157,598	1,186,538	1,216,202	1,246,607
	Subtotal	-	-	-	-	-	-	5,871,307	6,018,090	6,168,542	6,322,755	6,480,824	6,642,845	6,808,916	6,979,139
	DESAL PLANT OPERATION AND MAINTENANCE														
Treated	Power - Reverse Osmosis & Common Elements	-	-	-	-	-	-	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503
Treated	Power - Pre-Treatment	-	-	-	-	-	-	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291
Treated	Chemical - Reverse Osmosis & Common Elements	-	-	-	-	-	-	1,551,761	1,590,555	1,630,319	1,671,077	1,712,854	1,755,675	1,799,567	1,844,556
Treated	Chemical - Pre-Treatment	-	-	-	-	-	-	883,633	905,724	928,367	951,576	975,365	999,750	1,024,743	1,050,362
Treated	Labor - Reverse Osmosis & Common Elements	-	-	-	-	-	-	1,357,056	1,390,982	1,425,757	1,461,401	1,497,936	1,535,384	1,573,769	1,613,113
Treated	Labor - Pre-Treatment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Solids Handling - Reverse Osmosis & Common Element	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Solids Handling - Pre-Treatment	-	-	-	-	-	-	1,889,883	1,937,130	1,985,558	2,035,197	2,086,077	2,138,229	2,191,685	2,246,477
	Subtotal	-	-	-	-	-	-	12,983,127	13,125,185	13,270,795	13,420,045	13,573,026	13,729,832	13,890,558	14,055,302
	DESAL PLANT REPLACEMENT														
Treated	Equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Pipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Structures	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Subtotal	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/OUT SUBSIDIES)														
	Desal Cost of Water ($ per 1,000 gallons)	-	-	-	-	-	-	3.86	3.89	3.92	3.95	3.99	4.02	4.06	4.09
	Desal Cost of Water ($ per acre-foot)	-	-	-	-	-	-	1,256	1,267	1,277	1,288	1,299	1,310	1,322	1,334
	Combined Cost of Water ($ per 1,000 gallons)	1.61	1.70	1.72	1.77	2.15	2.16	2.44	2.45	2.50	2.50	2.50	2.49	2.48	2.48
	Combined Cost of Water ($ per acre-foot)	526	554	559	575	701	704	794	798	814	815	814	812	807	807
	REVENUES FROM SUBSIDIES AND WATER SALES														
	State Subsidy	-	-	-	-	-	-	24,466,335	24,472,924	24,479,431	24,485,858	24,492,205	24,498,474	24,504,666	24,510,781
	Water Sale Revenues	-	-	-	-	-	-	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
	Subtotal	-	-	-	-	-	-	29,466,335	29,472,924	29,479,431	29,485,858	29,492,205	29,498,474	29,504,666	29,510,781
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/ SUBSIDIES)														
	Adjusted Desal Cost of Water ($ per 1,000 gallons)	-	-	-	-	-	-	0.63	0.66	0.69	0.72	0.75	0.79	0.82	0.86
	Adjusted Desal Cost of Water ($ per acre-foot)	-	-	-	-	-	-	204	214	224	235	246	257	268	280
	Adjusted Combined Cost of Water ($ per 1,000 gallons)	1.61	1.70	1.72	1.77	2.15	2.16	1.65	1.67	1.73	1.74	1.75	1.75	1.74	1.75
	Adjusted Combined Cost of Water ($ per acre-foot)	526	554	559	575	701	704	539	545	564	567	569	569	567	569
	Total Annual Raw Water Cost	28,313,860	29,459,689	30,439,944	31,881,618	32,434,140	32,709,191	32,078,693	31,284,183	31,563,777	31,339,935	31,624,343	31,800,723	31,971,652	32,213,599
	Total Annual Treatment Cost	8,994,335	10,647,784	10,796,539	11,341,064	24,928,864	25,855,154	47,589,929	49,005,672	50,654,568	51,553,670	52,048,876	52,445,603	52,725,408	53,257,548
	Total Annual Cost	37,308,195	40,107,473	41,236,483	43,222,682	57,363,004	58,564,345	50,202,287	50,816,931	52,738,914	53,407,747	54,181,014	54,747,852	55,192,394	55,960,366
	Total Annual Present Value	37,308,195	39,612,319	40,224,584	41,641,524	54,582,291	55,037,428	46,596,502	46,584,690	47,749,731	47,758,312	47,851,638	47,755,317	47,548,722	47,615,147
	Cumulative Present Value	37,308,195	76,920,513	117,145,097	158,786,621	213,368,912	268,406,339	315,002,841	361,587,531	409,337,262	457,095,575	504,947,213	552,702,530	600,251,251	647,866,399

APPENDIX F
Desalination BD 2 Base Alternate (Open Sea Intake and Discharge)

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	FIRM YIELD WATER SUPPLY													
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0
	Desal Plant	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000
	Subtotal (acre-feet)	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000
Acct #	**CONSUMPTION TREATED**													
324000	ICL Residential	6,972,549,300	7,041,927,900	7,111,306,500	7,163,340,450	7,215,374,400	7,267,408,350	7,319,442,300	7,371,476,250	7,423,510,200	7,475,544,150	7,527,578,100	7,579,612,050	7,631,646,000
324050	ICL Commercial and Other	6,121,273,698	6,182,181,894	6,243,090,090	6,288,771,237	6,334,452,384	6,380,133,531	6,425,814,678	6,471,495,825	6,517,176,972	6,562,858,119	6,608,539,266	6,654,220,413	6,699,901,560
324100	ICL Large Volume Users	991,166	1,001,028	1,010,890	1,018,287	1,025,684	1,033,081	1,040,477	1,047,874	1,055,271	1,062,668	1,070,064	1,077,461	1,084,858
324800	OCL Residential	10,182,258	10,283,574	10,384,890	10,460,877	10,536,864	10,612,851	10,688,838	10,764,825	10,840,812	10,916,799	10,992,786	11,068,773	11,144,760
324150	OCL Commercial and Other	644,282,586	650,693,358	657,104,130	661,912,209	666,720,288	671,528,367	676,336,446	681,144,525	685,952,604	690,760,683	695,568,762	700,376,841	705,184,920
324810	OCL Large Volume Users	9,588,246,318	9,683,651,754	9,779,057,190	9,850,611,267	9,922,165,344	9,993,719,421	10,065,273,498	10,136,827,575	10,208,381,652	10,279,935,729	10,351,489,806	10,423,043,883	10,494,597,960
324170	City Water Use	654,528,762	661,041,486	667,554,210	672,438,753	677,323,296	682,207,839	687,092,382	691,976,925	696,861,468	701,746,011	706,630,554	711,515,097	716,399,640
324850	San Patricio	1,536,074,540	1,551,748,770	1,567,423,000	1,583,097,230	1,598,771,460	1,614,445,690	1,630,119,920	1,645,794,150	1,661,468,380	1,677,142,610	1,692,816,840	1,708,491,070	1,724,165,300
324850	South Texas Water Authority	555,048,516	560,268,408	565,488,300	568,533,237	571,578,174	574,623,111	577,668,048	580,712,985	583,757,922	586,802,859	589,847,796	592,892,733	595,937,670
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	908,385,750	935,848,575	963,311,400	987,394,185	1,011,476,970	1,035,559,755	1,059,642,540	1,083,725,325	1,107,808,110	1,131,890,895	1,155,973,680	1,180,056,465	1,204,139,250
	Subtotal (gallons)	28,146,287,894	28,433,371,747	28,720,455,600	28,942,302,732	29,164,149,864	29,385,996,996	29,607,844,127	29,829,691,259	30,051,538,391	30,273,385,523	30,495,232,654	30,717,079,786	30,938,926,918
	Subtotal (mgd)	77.1	77.9	78.7	79.3	79.9	80.5	81.1	81.7	82.3	82.9	83.5	84.2	84.8
	Subtotal (acre-feet)	86,384	87,265	88,146	88,827	89,508	90,188	90,869	91,550	92,231	92,912	93,593	94,274	94,955
	CONSUMPTION RAW													
324820	Alice	500,654,232	503,365,356	506,076,480	507,432,042	508,787,604	510,143,166	511,498,728	512,854,290	514,209,852	515,565,414	516,920,976	518,276,538	519,632,100
324820	Beeville	921,135,072	922,879,646	924,624,220	926,368,794	928,113,368	929,857,942	931,602,516	933,347,090	935,091,664	936,836,238	938,580,812	940,325,386	942,069,960
324820	Mathis	203,559,334	202,913,797	202,268,260	201,837,902	201,407,544	200,977,186	200,546,828	200,116,470	199,686,112	199,255,754	198,825,396	198,395,038	197,964,680
324820	San Patricio	7,544,439,448	7,621,423,524	7,698,407,600	7,775,391,676	7,852,375,752	7,929,359,828	8,006,343,904	8,083,327,980	8,160,312,056	8,237,296,132	8,314,280,208	8,391,264,284	8,468,248,360
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,778,301,810	1,791,188,055	1,804,074,300	1,815,528,740	1,826,983,180	1,838,437,620	1,849,892,060	1,861,346,500	1,872,800,940	1,884,255,380	1,895,709,820	1,907,164,260	1,918,618,700
324820	Celanese	1,654,459,506	1,666,448,343	1,678,437,180	1,689,093,924	1,699,750,668	1,710,407,412	1,721,064,156	1,731,720,900	1,742,377,644	1,753,034,388	1,763,691,132	1,774,347,876	1,785,004,620
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	12,602,549,402	12,708,218,721	12,813,888,040	12,915,653,078	13,017,418,116	13,119,183,154	13,220,948,192	13,322,713,230	13,424,478,268	13,526,243,306	13,628,008,344	13,729,773,382	13,831,538,420
	Subtotal (acre-feet)	38,678	39,003	39,327	39,639	39,952	40,264	40,576	40,889	41,201	41,513	41,826	42,138	42,450
	Total Water Demand (gallons)	40,748,837,296	41,141,590,468	41,534,343,640	41,857,955,810	42,181,567,980	42,505,180,150	42,828,792,319	43,152,404,489	43,476,016,659	43,799,628,829	44,123,240,998	44,446,853,168	44,770,465,338
	Total Capacity (mgd)	111.6	112.7	113.8	114.7	115.6	116.5	117.3	118.2	119.1	120.0	120.9	121.8	122.7
	Total Water Demand (acre-feet)	125,062	126,268	127,473	128,466	129,459	130,452	131,446	132,439	133,432	134,425	135,418	136,412	137,405
	ON STEVENS EXPENSES													
Treated	Salaries & Wages	$ 918,793	$ 941,763	$ 965,307	$ 989,439	$ 1,014,175	$ 1,039,530	$ 1,065,518	$ 1,092,156	$ 1,119,460	$ 1,147,446	$ 1,176,132	$ 1,205,536	$ 1,235,674
Treated	Fringe Benefits	$ 341,552	$ 350,091	$ 358,843	$ 367,814	$ 377,010	$ 386,435	$ 396,096	$ 405,998	$ 416,148	$ 426,552	$ 437,216	$ 448,146	$ 459,350
Treated	Materials/Supplies/Utilities	$ 5,858,485	$ 6,034,024	$ 6,214,083	$ 6,392,164	$ 6,574,911	$ 6,762,444	$ 6,954,890	$ 7,152,374	$ 7,355,029	$ 7,562,988	$ 7,776,388	$ 7,995,372	$ 8,220,084
Treated	Capital													
	Subtotal	$ 7,118,830	$ 7,325,878	$ 7,538,233	$ 7,749,418	$ 7,966,096	$ 8,188,409	$ 8,416,503	$ 8,650,528	$ 8,890,637	$ 9,136,986	$ 9,389,737	$ 9,649,054	$ 9,915,108
	RAW WATER EXPENSES													
Raw	Wesley Seale Dam	$ 1,675,089	$ 1,716,967	$ 1,759,891	$ 1,803,888	$ 1,848,985	$ 1,895,210	$ 1,942,590	$ 1,991,155	$ 2,040,934	$ 2,091,957	$ 2,144,256	$ 2,197,862	$ 2,252,809
Raw	Choke Canyon Dam	$ 792,648	$ 812,464	$ 832,776	$ 853,595	$ 874,935	$ 896,808	$ 919,229	$ 942,209	$ 965,765	$ 989,909	$ 1,014,656	$ 1,040,023	$ 1,066,023
Raw	Environmental Studies	$ 964,958	$ 989,082	$ 1,013,809	$ 1,039,154	$ 1,065,133	$ 1,091,761	$ 1,119,055	$ 1,147,032	$ 1,175,707	$ 1,205,100	$ 1,235,227	$ 1,266,108	$ 1,297,761
Raw	Water Supply Development	$ 1,227,197	$ 1,257,877	$ 1,289,324	$ 1,321,557	$ 1,354,596	$ 1,388,461	$ 1,423,173	$ 1,458,752	$ 1,495,221	$ 1,532,601	$ 1,570,916	$ 1,610,189	$ 1,650,444
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 790,713	$ 810,480	$ 830,742	$ 851,511	$ 872,799	$ 894,619	$ 916,984	$ 939,909	$ 963,406	$ 987,492	$ 1,012,179	$ 1,037,483	$ 1,063,420
Raw	Water Purchased - LNRA	$ 8,335,257	$ 8,504,345	$ 8,617,689	$ 8,790,535	$ 8,964,136	$ 9,138,181	$ 9,313,153	$ 9,538,473	$ 9,715,121	$ 9,892,989	$ 10,072,188	$ 10,252,833	$ 10,491,042
Raw	Supplemental Water Sources - Wells	$ 84,089	$ 86,191	$ 88,346	$ 90,555	$ 92,819	$ 95,139	$ 97,518	$ 99,956	$ 102,454	$ 105,016	$ 107,641	$ 110,332	$ 113,091
	Subtotal	$ 13,979,951	$ 14,287,407	$ 14,542,577	$ 14,860,795	$ 15,183,403	$ 15,510,180	$ 15,841,702	$ 16,227,485	$ 16,568,609	$ 16,915,063	$ 17,267,064	$ 17,624,831	$ 18,044,590
	EXISTING DEBT SERVICE													
Treated	ON Stevens Debt	$ 1,449,133	$ 1,448,956	$ 814,516	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Bureau of Rec or PL Fund	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,208,976	$ 827,934
Raw	NRA Debt Service	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 1,848,266	$ 1,847,231	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2000 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,793	$ 1,101,024	$ 1,101,143	$ 1,101,030	$ 1,100,804	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,172,450	$ 8,169,275	$ 8,171,800	$ 8,173,925	$ 8,169,825	$ 8,168,950	$ 8,170,200	$ 8,172,475	$ 8,169,675	$ 8,012,418	$ -	$ -	$ -
Raw	LNRA - Pipeline Debt (Pumping Station)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ 17,565,805	$ 17,561,650	$ 15,082,622	$ 14,270,118	$ 14,265,792	$ 13,164,113	$ 13,165,363	$ 13,167,638	$ 13,164,838	$ 13,007,581	$ 4,995,163	$ 4,208,976	$ 827,934

APPENDIX F
Desalination BD 2 Base Alternate (Open Sea Intake and Discharge)

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	PLANNED DEBT SERVICE													
Treated	ON Stevens Debt	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499	7,536,499
Raw	Raw Water Debt	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727	1,704,727
	Subtotal	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227	9,241,227
	FUTURE CAPITAL PROJECTS													
Treated	ON Stevens Replacement			11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788
	Subtotal	-	-	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788	11,370,788
	SUMMARY OF COST FOR NON-DESAL FACILITIE													
	Raw Cost of Water ($ per 1,000 gallons)	1.13	1.13	1.06	1.07	1.07	1.03	1.04	1.04	1.05	1.04	0.79	0.77	0.67
	Treated Cost of Water ($ per 1,000 gallons)	0.85	0.84	1.39	1.35	1.34	1.34	1.33	1.33	1.33	1.33	1.32	1.32	1.32
	Combined Cost of Water ($ per 1,000 gallons)	1.98	1.97	2.45	2.41	2.41	2.37	2.37	2.37	2.37	2.37	2.11	2.09	1.99
	DESAL PLANT DEBT SERVICE													
Treated	Equipment	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	6,992,131	-
Treated	Pipe	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086	6,334,086
Treated	Structures	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664	2,255,664
Treated	Other	738,931	738,931	738,931	738,931	738,931	738,931	738,931	738,931	738,931	738,931	738,931	738,931	-
	Subtotal	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	16,320,811	8,589,750
	DESAL PLANT REPAIR AND REHABILITATION													
Treated	Reverse Osmosis & Common Elements	5,875,845	6,022,742	6,173,310	6,327,643	6,485,834	6,647,980	6,814,179	6,984,534	7,159,147	7,338,126	7,521,579	7,709,618	7,902,359
Treated	Pre-Treatment	1,277,772	1,309,716	1,342,459	1,376,021	1,410,421	1,445,682	1,481,824	1,518,869	1,556,841	1,595,762	1,635,656	1,676,548	1,718,461
	Subtotal	7,153,617	7,332,458	7,515,769	7,703,664	7,896,255	8,093,662	8,296,003	8,503,403	8,715,988	8,933,888	9,157,235	9,386,166	9,620,820
	DESAL PLANT OPERATION AND MAINTENANCI													
Treated	Power - Reverse Osmosis & Common Elements	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503	7,236,503
Treated	Power - Pre-Treatment	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291	64,291
Treated	Chemical - Reverse Osmosis & Common Elements	1,890,670	1,937,937	1,986,385	2,036,045	2,086,946	2,139,120	2,192,598	2,247,413	2,303,598	2,361,188	2,420,218	2,480,723	2,542,741
Treated	Chemical - Pre-Treatment	1,076,621	1,103,537	1,131,125	1,159,403	1,188,388	1,218,098	1,248,550	1,279,764	1,311,758	1,344,552	1,378,166	1,412,620	1,447,936
Treated	Labor - Reverse Osmosis & Common Elements	1,653,441	1,694,777	1,737,146	1,780,575	1,825,089	1,870,717	1,917,485	1,965,422	2,014,557	2,064,921	2,116,544	2,169,458	2,223,694
Treated	Labor - Pre-Treatment	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Solids Handling - Reverse Osmosis & Common Element	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Solids Handling - Pre-Treatment	2,302,639	2,360,205	2,419,210	2,479,690	2,541,683	2,605,225	2,670,355	2,737,114	2,805,542	2,875,680	2,947,572	3,021,262	3,096,793
	Subtotal	14,224,165	14,397,249	14,574,661	14,756,507	14,942,900	15,133,953	15,329,782	15,530,506	15,736,249	15,947,136	16,163,294	16,384,857	16,611,958
	DESAL PLANT REPLACEMENT													
Treated	Equipment	-	-	-	-	-	-	-	-	-	-	-	11,457,420	11,457,420
Treated	Pipe	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Structures	-	-	-	-	-	-	-	-	-	-	-	-	-
Treated	Other	-	-	-	-	-	-	-	-	-	-	-	1,210,824	1,210,824
	Subtotal	-	-	-	-	-	-	-	-	-	-	-	12,668,244	12,668,244
	UMMARY OF COSTS FOR DESAL FACILITIES (W/OUT SI													
	Desal Cost of Water ($ per 1,000 gallons)	4.13	4.17	4.21	4.25	4.29	4.33	4.38	4.42	4.47	4.52	4.56	6.00	5.21
	Desal Cost of Water ($ per acre-foot)	1,346	1,359	1,372	1,385	1,399	1,412	1,427	1,441	1,456	1,471	1,487	1,956	1,696
	Combined Cost of Water ($ per 1,000 gallons)	2.46	2.46	2.84	2.81	2.82	2.79	2.80	2.81	2.81	2.82	2.62	2.89	2.64
	Combined Cost of Water ($ per acre-foot)	801	802	925	916	918	910	912	915	917	918	853	942	861
	REVENUES FROM SUBSIDIES AND WATER SALE													
	State Subsidy	24,516,821	24,522,786	24,528,677	24,534,496	24,540,243	24,545,919	24,551,525	24,557,062	24,562,530	24,567,931	24,573,265	24,578,534	24,583,737
	Water Sale Revenues	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
	Subtotal	29,516,821	29,522,786	29,528,677	29,534,496	29,540,243	29,545,919	29,551,525	29,557,062	29,562,530	29,567,931	29,573,265	29,578,534	29,583,737
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/ SUB													
	Adjusted Desal Cost of Water ($ per 1,000 gallons)	0.90	0.93	0.97	1.01	1.05	1.10	1.14	1.18	1.23	1.28	1.32	2.76	1.96
	Adjusted Desal Cost of Water ($ per acre-foot)	292	305	317	330	344	357	371	386	400	415	431	899	640
	Adjusted Combined Cost of Water ($ per 1,000 gallons)	1.73	1.74	2.13	2.11	2.12	2.10	2.11	2.12	2.13	2.14	1.95	2.23	1.98
	Adjusted Combined Cost of Water ($ per acre-foot)	565	568	694	686	690	683	687	691	695	698	634	725	646
	Total Annual Raw Water Cost	31,801,350	32,104,828	30,515,410	30,835,641	31,153,922	30,379,020	30,711,792	31,099,850	31,438,174	31,627,371	23,966,954	23,538,534	20,577,251
	Total Annual Treatment Cost	53,803,056	54,361,852	65,671,278	65,437,687	66,033,350	66,644,122	67,270,387	67,912,537	68,570,973	69,246,108	69,938,365	83,316,420	76,313,168
	Total Annual Cost	56,087,585	56,943,893	66,658,011	66,738,832	67,647,028	67,477,223	68,430,654	69,455,325	70,446,617	71,305,548	64,332,054	77,276,420	67,306,682
	Total Annual Present Value	47,134,217	47,263,043	54,642,661	54,033,495	54,092,637	53,290,721	53,376,495	53,506,911	53,600,574	53,584,304	47,747,062	56,646,255	48,728,984
	Cumulative Present Value	695,000,616	742,263,658	796,906,319	850,939,814	905,032,451	958,323,171	1,011,699,666	1,065,206,577	1,118,807,151	1,172,391,455	1,220,138,516	1,276,784,771	1,325,513,755

Appendix F-3

Optimized Desalination Alternate BD A2

APPENDIX F
Desalination Alternate BD A2 (Barney Davis Intake and Open Sea Discharge)

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	FIRM YIELD WATER SUPPLY														
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Desal Plant	0	0	0	0	0	0	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000
	Subtotal (acre-feet)	224,000	224,000	224,000	224,000	224,000	224,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000
Acct #	**CONSUMPTION TREATED**														
324000	ICL Residential	5,781,550,000	5,887,545,083	5,993,540,167	6,099,535,250	6,205,530,333	6,311,525,417	6,417,520,500	6,486,899,100	6,556,277,700	6,625,656,300	6,695,034,900	6,764,413,500	6,833,792,100	6,903,170,700
324050	ICL Commercial and Other	5,075,683,000	5,168,737,188	5,261,791,377	5,354,845,565	5,447,899,753	5,540,953,942	5,634,008,130	5,694,916,326	5,755,824,522	5,816,732,718	5,877,640,914	5,938,549,110	5,999,457,306	6,060,365,502
324100	ICL Large Volume Users	821,862	836,929	851,997	867,064	882,132	897,199	912,267	922,129	931,992	941,854	951,716	961,579	971,441	981,303
324800	OCL Residential	8,443,000	8,597,788	8,752,577	8,907,365	9,062,153	9,216,942	9,371,730	9,473,046	9,574,362	9,675,678	9,776,994	9,878,310	9,979,626	10,080,942
324150	OCL Commercial and Other	534,231,000	544,025,235	553,819,470	563,613,705	573,407,940	583,202,175	592,996,410	599,407,182	605,817,954	612,228,726	618,639,498	625,050,270	631,461,042	637,871,814
324810	OCL Large Volume Users	7,950,453,000	8,096,211,305	8,241,969,610	8,387,727,915	8,533,486,220	8,679,244,525	8,825,002,830	8,920,408,266	9,015,813,702	9,111,219,138	9,206,624,574	9,302,030,010	9,397,435,446	9,492,840,882
324170	City Water Use	542,727,000	552,676,995	562,626,990	572,576,985	582,526,980	592,476,975	602,426,970	608,939,694	615,452,418	621,965,142	628,477,866	634,990,590	641,503,314	648,016,038
324850	San Patricio	1,205,710,000	1,239,871,783	1,274,033,567	1,308,195,350	1,342,357,133	1,376,518,917	1,410,680,700	1,426,354,930	1,442,029,160	1,457,703,390	1,473,377,620	1,489,051,850	1,504,726,080	1,520,400,310
324850	South Texas Water Authority	434,991,000	448,040,730	461,090,460	474,140,190	487,189,920	500,239,650	513,289,380	518,509,272	523,729,164	528,949,056	534,168,948	539,388,840	544,608,732	549,828,624
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	422,505,000	466,868,625	511,231,050	555,594,075	599,957,100	644,320,125	688,683,150	716,145,975	743,608,800	771,071,625	798,534,450	825,997,275	853,460,100	880,922,925
	Subtotal (gallons)	23,111,839,862	23,568,136,063	24,024,432,264	24,480,728,464	24,937,024,665	25,393,320,866	25,849,617,067	26,136,700,920	26,423,784,774	26,710,868,627	26,997,952,480	27,285,036,334	27,572,120,187	27,859,204,040
	Subtotal (mgd)	63.3	64.6	65.8	67.1	68.3	69.6	70.8	71.6	72.4	73.2	74.0	74.8	75.5	76.3
	Subtotal (acre-feet)	70,932	72,333	73,733	75,134	76,534	77,935	79,335	80,216	81,097	81,978	82,859	83,740	84,621	85,503
	CONSUMPTION RAW														
324820	Alice	451,854,000	456,372,540	460,891,080	465,409,620	469,928,160	474,446,700	478,965,240	481,676,364	484,387,488	487,098,612	489,809,736	492,520,860	495,231,984	497,943,108
324820	Beeville	872,287,000	878,102,247	883,917,493	889,732,740	895,547,987	901,363,233	907,178,480	908,923,054	910,667,628	912,412,202	914,156,776	915,901,350	917,645,924	919,390,498
324820	Mathis	215,179,000	214,103,105	213,027,210	211,951,315	210,875,420	209,799,525	208,723,630	208,078,093	207,432,556	206,787,019	206,141,482	205,495,945	204,850,408	204,204,871
324820	San Patricio	5,921,852,000	6,089,637,807	6,257,423,613	6,425,209,420	6,592,995,227	6,760,781,033	6,928,566,840	7,005,550,916	7,082,534,992	7,159,519,068	7,236,503,144	7,313,487,220	7,390,471,296	7,467,455,372
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,431,805,000	1,472,372,808	1,512,940,617	1,553,508,425	1,594,076,233	1,634,644,042	1,675,211,850	1,688,098,095	1,700,984,340	1,713,870,585	1,726,756,830	1,739,643,075	1,752,529,320	1,765,415,565
324820	Celanese	1,332,093,000	1,369,835,635	1,407,578,270	1,445,320,905	1,483,063,540	1,520,806,175	1,558,548,810	1,570,537,647	1,582,526,484	1,594,515,321	1,606,504,158	1,618,492,995	1,630,481,832	1,642,470,669
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	10,225,070,000	10,480,424,142	10,735,778,283	10,991,132,425	11,246,486,567	11,501,840,708	11,757,194,850	11,862,864,169	11,968,533,488	12,074,202,807	12,179,872,126	12,285,541,445	12,391,210,764	12,496,880,083
	Subtotal (acre-feet)	31,382	32,165	32,949	33,733	34,517	35,300	36,084	36,408	36,733	37,057	37,381	37,706	38,030	38,354
	Total Water Demand (gallons)	33,336,909,862	34,048,560,204	34,760,210,547	35,471,860,889	36,183,511,232	36,895,161,574	37,606,811,917	37,999,565,089	38,392,318,262	38,785,071,434	39,177,824,606	39,570,577,779	39,963,330,951	40,356,084,123
	Total Capacity (mgd)	91.3	93.3	95.2	97.2	99.1	101.1	103.0	104.1	105.2	106.3	107.3	108.4	109.5	110.6
	Total Water Demand (acre-feet)	102,314	104,498	106,682	108,867	111,051	113,235	115,419	116,624	117,830	119,035	120,241	121,446	122,651	123,857
	ON STEVENS EXPENSES														
Treated	Salaries & Wages	$ 726,362	$ 666,511	$ 683,174	$ 700,253	$ 717,759	$ 735,703	$ 754,096	$ 772,948	$ 792,272	$ 812,079	$ 832,381	$ 853,190	$ 874,520	$ 896,383
Treated	Fringe Benefits	$ 267,109	$ 247,769	$ 253,963	$ 260,312	$ 266,820	$ 273,491	$ 280,328	$ 287,336	$ 294,519	$ 301,882	$ 309,430	$ 317,165	$ 325,094	$ 333,222
Treated	Materials/Supplies/Utilities	$ 4,351,402	$ 6,288,040	$ 6,445,241	$ 6,606,372	$ 6,771,531	$ 6,940,820	$ 4,603,448	$ 4,746,803	$ 4,893,820	$ 5,044,595	$ 5,199,231	$ 5,357,831	$ 5,520,500	$ 5,687,348
Treated	Capital	$ -	$ -												
	Subtotal	$ 5,344,873	$ 7,202,320	$ 7,382,378	$ 7,566,937	$ 7,756,111	$ 7,950,014	$ 5,637,872	$ 5,807,088	$ 5,980,611	$ 6,158,557	$ 6,341,042	$ 6,528,187	$ 6,720,115	$ 6,916,953
	RAW WATER EXPENSES														
Raw	Wesley Seale Dam	$ 1,190,020	$ 1,215,144	$ 1,245,523	$ 1,276,661	$ 1,308,577	$ 1,341,292	$ 1,374,824	$ 1,409,194	$ 1,444,424	$ 1,480,535	$ 1,517,548	$ 1,555,487	$ 1,594,374	$ 1,634,234
Raw	Choke Canyon Dam	$ 503,700	$ 575,003	$ 589,378	$ 604,113	$ 619,215	$ 634,696	$ 650,563	$ 666,827	$ 683,498	$ 700,585	$ 718,100	$ 736,052	$ 754,454	$ 773,315
Raw	Environmental Studies	$ 700,000	$ 700,000	$ 717,500	$ 735,438	$ 753,823	$ 772,669	$ 791,986	$ 811,785	$ 832,080	$ 852,882	$ 874,204	$ 896,059	$ 918,461	$ 941,422
Raw	Water Supply Development	$ 864,613	$ 890,234	$ 912,490	$ 935,302	$ 958,685	$ 982,652	$ 1,007,218	$ 1,032,399	$ 1,058,208	$ 1,084,664	$ 1,111,780	$ 1,139,575	$ 1,168,064	$ 1,197,266
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 489,981	$ 573,599	$ 587,939	$ 602,637	$ 617,703	$ 633,146	$ 648,975	$ 665,199	$ 681,829	$ 698,875	$ 716,347	$ 734,255	$ 752,612	$ 771,427
Raw	Water Purchased - LNRA	$ 6,206,324	$ 6,603,854	$ 6,739,012	$ 6,834,059	$ 6,931,127	$ 7,086,677	$ 7,186,106	$ 7,314,107	$ 7,474,756	$ 7,579,286	$ 7,742,312	$ 7,849,195	$ 8,014,925	$ 8,124,511
Raw	Supplemental Water Sources - Wells	$ 35,000	$ 61,000	$ 62,525	$ 64,088	$ 65,690	$ 67,333	$ 69,016	$ 70,741	$ 72,510	$ 74,323	$ 76,181	$ 78,085	$ 80,037	$ 82,038
	Subtotal	$ 10,099,638	$ 10,728,834	$ 10,964,367	$ 11,162,298	$ 11,364,821	$ 11,628,464	$ 11,838,687	$ 12,080,253	$ 12,357,306	$ 12,581,149	$ 12,866,472	$ 13,098,709	$ 13,392,926	$ 13,634,213
	EXISTING DEBT SERVICE														
Treated	ON Stevens Debt	$ 3,649,462	$ 3,445,464	$ 3,390,714	$ 3,587,318	$ 3,589,253	$ 3,591,432	$ 3,820,568	$ 1,903,651	$ 1,902,983	$ 1,795,002	$ 1,796,673	$ 1,687,429	$ 1,448,508	$ 1,448,844
Raw	Bureau of Rec or PL Fund	$ 4,425,542	$ 4,695,363	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163
Raw	NRA Debt Service	$ 931,562	$ 970,110	$ 976,170	$ 971,375	$ 971,010	$ 974,933	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ 117,878	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ 77,458	$ 75,193	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 2,111,136	$ 2,434,132	$ 2,431,914	$ 2,873,210	$ 2,878,236	$ 2,884,445	$ 2,885,746	$ 2,322,352	$ 2,323,963	$ 1,847,992	$ 1,847,697	$ 1,846,788	$ 1,848,067	$ 1,848,266
Raw	2000 Rev Bond: portion applicable P&I	$ 466,092	$ 465,932	$ 464,821	$ 464,921	$ 464,815	$ 464,888	$ 551,554	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,548	$ 1,100,729	$ 1,101,083	$ 1,100,985	$ 1,100,503	$ 1,101,158	$ 1,100,480	$ 1,100,819	$ 1,101,196	$ 1,100,782	$ 1,100,642	$ 1,100,906	$ 1,100,906	$ 1,100,567
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ 48,350	$ 60,091	$ 85,273	$ 108,280	$ 108,819	$ 108,954	$ 74,834	$ 151,044	$ 150,809	$ 179,559	$ 180,491	$ 123,830	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,171,975	$ 8,170,875	$ 8,171,275	$ 8,172,975	$ 8,170,375	$ 8,173,288	$ 8,169,738	$ 8,173,050	$ 8,172,438	$ 8,172,638	$ 8,173,125	$ 8,173,125	$ 8,172,863	$ 8,171,063
Raw	LNRA - Pipeline Debt (Pumping Station)	$ 763,680	$ 758,430	$ 760,100	$ 760,420	$ 759,350	$ 756,850	$ 757,762	$ 756,775	$ 758,175	$ 757,925	$ 756,025	$ 757,475	$ 757,000	$ 759,600
	Subtotal	$ 21,863,684	$ 22,176,319	$ 22,376,513	$ 23,034,645	$ 23,037,524	$ 23,051,111	$ 22,355,846	$ 19,402,854	$ 19,404,727	$ 18,849,061	$ 18,849,816	$ 18,684,715	$ 18,322,506	$ 18,323,502

APPENDIX F
Desalination Alternate BD A2 (Barney Davis Intake and Open Sea Discharge)

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	PLANNED DEBT SERVICE														
Treated	ON Stevens Debt	$ -	$ -	$ 23,447	$ 186,809	$ 1,635,830	$ 2,366,037	$ 2,956,244	$ 5,830,847	$ 7,010,826	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499
Raw	Raw Water Debt	$ -	$ -	$ 489,778	$ 1,271,993	$ 1,621,048	$ 1,621,048	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727
	Subtotal	$ -	$ -	$ 513,225	$ 1,458,802	$ 3,256,878	$ 3,987,085	$ 4,660,972	$ 7,535,574	$ 8,715,553	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227
	FUTURE CAPITAL PROJECTS														
Treated	ON Stevens Replacement														
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	SUMMARY OF COST FOR NON-DESAL FACILITIES														
	Raw Cost of Water ($ per 1,000 gallons)	***$ 1.23***	***$ 1.25***	***$ 1.27***	***$ 1.30***	***$ 1.30***	***$ 1.29***	***$ 1.24***	***$ 1.20***	***$ 1.19***	***$ 1.17***	***$ 1.17***	***$ 1.17***	***$ 1.16***	***$ 1.16***
	Treated Cost of Water ($ per 1,000 gallons)	***$ 0.39***	***$ 0.45***	***$ 0.45***	***$ 0.46***	***$ 0.52***	***$ 0.55***	***$ 0.74***	***$ 0.80***	***$ 0.86***	***$ 0.88***	***$ 0.88***	***$ 0.87***	***$ 0.85***	***$ 0.85***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 1.82***	***$ 1.84***	***$ 1.98***	***$ 1.99***	***$ 2.06***	***$ 2.05***	***$ 2.05***	***$ 2.03***	***$ 2.01***	***$ 2.01***
	DESAL PLANT DEBT SERVICE														
Treated	Equipment	$ -	$ -	$ -	$ -	$ 3,988,628	$ 3,988,628	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467
Treated	Pipe	$ -	$ -	$ -	$ -	$ 4,389,312	$ 4,389,312	$ 5,491,060	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630
Treated	Structures	$ -	$ -	$ -	$ -	$ 1,566,310	$ 1,566,310	$ 1,959,466	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179
Treated	Other	$ -	$ -	$ -	$ -	$ 418,897	$ 418,897	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328
	Subtotal	$ -	$ -	$ -	$ -	$ 10,363,147	$ 10,363,147	$ 14,156,321	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604
	DESAL PLANT REPAIR AND REHABILITATION														
Treated	Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,310,438	$ 4,418,199	$ 4,528,654	$ 4,641,870	$ 4,757,917	$ 4,876,865	$ 4,998,787	$ 5,123,756
Treated	Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,048,727	$ 1,074,945	$ 1,101,819	$ 1,129,364	$ 1,157,598	$ 1,186,538	$ 1,216,202	$ 1,246,607
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,359,165	$ 5,493,144	$ 5,630,473	$ 5,771,235	$ 5,915,515	$ 6,063,403	$ 6,214,988	$ 6,370,363
	DESAL PLANT OPERATION AND MAINTENANCE														
Treated	Power - Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951
Treated	Power - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291
Treated	Chemical - Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,551,761	$ 1,590,555	$ 1,630,319	$ 1,671,077	$ 1,712,854	$ 1,755,675	$ 1,799,567	$ 1,844,556
Treated	Chemical - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 883,633	$ 905,724	$ 928,367	$ 951,576	$ 975,365	$ 999,750	$ 1,024,743	$ 1,050,362
Treated	Labor - Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,357,056	$ 1,390,982	$ 1,425,757	$ 1,461,401	$ 1,497,936	$ 1,535,384	$ 1,573,769	$ 1,613,113
Treated	Labor - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Reverse Osmosis & Common Element	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,889,883	$ 1,937,130	$ 1,985,558	$ 2,035,197	$ 2,086,077	$ 2,138,229	$ 2,191,685	$ 2,246,477
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,701,575	$ 12,843,633	$ 12,989,243	$ 13,138,493	$ 13,291,474	$ 13,448,280	$ 13,609,006	$ 13,773,750
	DESAL PLANT REPLACEMENT														
Treated	Equipment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Pipe	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Structures	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/OUT SUBSIDIES)														
	Desal Cost of Water ($ per 1,000 gallons)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 3.53***	***$ 3.48***	***$ 3.52***	***$ 3.55***	***$ 3.58***	***$ 3.61***	***$ 3.65***	***$ 3.68***
	Desal Cost of Water ($ per acre-foot)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 1,151***	***$ 1,135***	***$ 1,146***	***$ 1,156***	***$ 1,167***	***$ 1,177***	***$ 1,189***	***$ 1,200***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 2.11***	***$ 2.12***	***$ 2.36***	***$ 2.35***	***$ 2.40***	***$ 2.41***	***$ 2.40***	***$ 2.40***	***$ 2.38***	***$ 2.38***
	Combined Cost of Water ($ per acre-foot)	***$ 526***	***$ 554***	***$ 559***	***$ 575***	***$ 687***	***$ 690***	***$ 769***	***$ 766***	***$ 783***	***$ 784***	***$ 784***	***$ 781***	***$ 777***	***$ 777***
	REVENUES FROM SUBSIDIES AND WATER SALES														
	State Subsidy	$ -	$ -	$ -	$ -	$ -	$ -	$ 22,020,247	$ 21,847,157	$ 21,676,205	$ 21,507,363	$ 21,340,605	$ 21,175,906	$ 21,013,241	$ 20,852,584
	Water Sale Revenues	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ 27,020,247	$ 26,847,157	$ 26,676,205	$ 26,507,363	$ 26,340,605	$ 26,175,906	$ 26,013,241	$ 25,852,584
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/ SUBSIDIES)														
	Adjusted Desal Cost of Water ($ per 1,000 gallons)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 0.57***	***$ 0.54***	***$ 0.59***	***$ 0.64***	***$ 0.69***	***$ 0.74***	***$ 0.80***	***$ 0.85***
	Adjusted Desal Cost of Water ($ per acre-foot)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 186***	***$ 177***	***$ 193***	***$ 209***	***$ 226***	***$ 243***	***$ 260***	***$ 277***
	Adjusted Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 2.11***	***$ 2.12***	***$ 1.64***	***$ 1.64***	***$ 1.71***	***$ 1.72***	***$ 1.73***	***$ 1.74***	***$ 1.73***	***$ 1.74***
	Adjusted Combined Cost of Water ($ per acre-foot)	***$ 526***	***$ 554***	***$ 559***	***$ 575***	***$ 687***	***$ 690***	***$ 534***	***$ 536***	***$ 556***	***$ 561***	***$ 565***	***$ 566***	***$ 565***	***$ 568***
	Total Annual Raw Water Cost	***$ 28,313,860***	***$ 29,459,689***	***$ 30,439,944***	***$ 31,881,618***	***$ 32,434,140***	***$ 32,709,191***	***$ 32,078,693***	***$ 31,284,183***	***$ 31,563,777***	***$ 31,339,935***	***$ 31,624,343***	***$ 31,800,723***	***$ 31,971,652***	***$ 32,213,599***
	Total Annual Treatment Cost	***$ 8,994,335***	***$ 10,647,784***	***$ 10,796,539***	***$ 11,341,064***	***$ 23,344,341***	***$ 24,270,630***	***$ 44,631,745***	***$ 45,333,967***	***$ 46,969,739***	***$ 47,855,389***	***$ 48,336,807***	***$ 48,719,402***	***$ 48,984,721***	***$ 49,502,013***
	Total Annual Cost	***$ 37,308,195***	***$ 40,107,473***	***$ 41,236,483***	***$ 43,222,682***	***$ 55,778,480***	***$ 56,979,821***	***$ 49,690,191***	***$ 49,770,993***	***$ 51,857,312***	***$ 52,687,962***	***$ 53,620,545***	***$ 54,344,218***	***$ 54,943,132***	***$ 55,863,028***
	Total Annual Present Value	***$ 37,308,195***	***$ 39,612,319***	***$ 40,224,584***	***$ 41,641,524***	***$ 53,074,578***	***$ 53,548,329***	***$ 46,121,187***	***$ 45,625,862***	***$ 46,951,529***	***$ 47,114,665***	***$ 47,356,643***	***$ 47,403,237***	***$ 47,333,981***	***$ 47,532,325***
	Cumulative Present Value	***$ 37,308,195***	***$ 76,920,513***	***$ 117,145,097***	***$ 158,786,621***	***$ 211,861,199***	***$ 265,409,528***	***$ 311,530,715***	***$ 357,156,577***	***$ 404,108,106***	***$ 451,222,772***	***$ 498,579,414***	***$ 545,982,651***	***$ 593,316,631***	***$ 640,848,956***

APPENDIX F
Desalination Alternate BD A2 (Barney Davis Intake and Open Sea Discharge)

Acct #	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	FIRM YIELD WATER SUPPLY													
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0
	Desal Plant	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000
	Subtotal (acre-feet)	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000
Acct #	**CONSUMPTION TREATED**													
324000	ICL Residential	6,972,549,300	7,041,927,900	7,111,306,500	7,163,340,450	7,215,374,400	7,267,408,350	7,319,442,300	7,371,476,250	7,423,510,200	7,475,544,150	7,527,578,100	7,579,612,050	7,631,646,000
324050	ICL Commercial and Other	6,121,273,698	6,182,181,894	6,243,090,090	6,288,771,237	6,334,452,384	6,380,133,531	6,425,814,678	6,471,495,825	6,517,176,972	6,562,858,119	6,608,539,266	6,654,220,413	6,699,901,560
324100	ICL Large Volume Users	991,166	1,001,028	1,010,890	1,018,287	1,025,684	1,033,081	1,040,477	1,047,874	1,055,271	1,062,668	1,070,064	1,077,461	1,084,858
324800	OCL Residential	10,182,258	10,283,574	10,384,890	10,460,877	10,536,864	10,612,851	10,688,838	10,764,825	10,840,812	10,916,799	10,992,786	11,068,773	11,144,760
324150	OCL Commercial and Other	644,282,586	650,693,358	657,104,130	661,912,209	666,720,288	671,528,367	676,336,446	681,144,525	685,952,604	690,760,683	695,568,762	700,376,841	705,184,920
324810	OCL Large Volume Users	9,588,246,318	9,683,651,754	9,779,057,190	9,850,611,267	9,922,165,344	9,993,719,421	10,065,273,498	10,136,827,575	10,208,381,652	10,279,935,729	10,351,489,806	10,423,043,883	10,494,597,960
324170	City Water Use	654,528,762	661,041,486	667,554,210	672,438,753	677,323,296	682,207,839	687,092,382	691,976,925	696,861,468	701,746,011	706,630,554	711,515,097	716,399,640
324850	San Patricio	1,536,074,540	1,551,748,770	1,567,423,000	1,583,097,230	1,598,771,460	1,614,445,690	1,630,119,920	1,645,794,150	1,661,468,380	1,677,142,610	1,692,816,840	1,708,491,070	1,724,165,300
324850	South Texas Water Authority	555,048,516	560,268,408	565,488,300	568,533,237	571,578,174	574,623,111	577,668,048	580,712,985	583,757,922	586,802,859	589,847,796	592,892,733	595,937,670
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	908,385,750	935,848,575	963,311,400	987,394,185	1,011,476,970	1,035,559,755	1,059,642,540	1,083,725,325	1,107,808,110	1,131,890,895	1,155,973,680	1,180,056,465	1,204,139,250
	Subtotal (gallons)	28,146,287,894	28,433,371,747	28,720,455,600	28,942,302,732	29,164,149,864	29,385,996,996	29,607,844,127	29,829,691,259	30,051,538,391	30,273,385,523	30,495,232,654	30,717,079,786	30,938,926,918
	Subtotal (mgd)	77.1	77.9	78.7	79.3	79.9	80.5	81.1	81.7	82.3	82.9	83.5	84.2	84.8
	Subtotal (acre-feet)	86,384	87,265	88,146	88,827	89,508	90,188	90,869	91,550	92,231	92,912	93,593	94,274	94,955
	CONSUMPTION RAW													
324820	Alice	500,654,232	503,365,356	506,076,480	507,432,042	508,787,604	510,143,166	511,498,728	512,854,290	514,209,852	515,565,414	516,920,976	518,276,538	519,632,100
324820	Beeville	921,135,072	922,879,646	924,624,220	926,368,794	928,113,368	929,857,942	931,602,516	933,347,090	935,091,664	936,836,238	938,580,812	940,325,386	942,069,960
324820	Mathis	203,559,334	202,913,797	202,268,260	201,837,902	201,407,544	200,977,186	200,546,828	200,116,470	199,686,112	199,255,754	198,825,396	198,395,038	197,964,680
324820	San Patricio	7,544,439,448	7,621,423,524	7,698,407,600	7,775,391,676	7,852,375,752	7,929,359,828	8,006,343,904	8,083,327,980	8,160,312,056	8,237,296,132	8,314,280,208	8,391,264,284	8,468,248,360
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,778,301,810	1,791,188,055	1,804,074,300	1,815,528,740	1,826,983,180	1,838,437,620	1,849,892,060	1,861,346,500	1,872,800,940	1,884,255,380	1,895,709,820	1,907,164,260	1,918,618,700
324820	Celanese	1,654,459,506	1,666,448,343	1,678,437,180	1,689,093,924	1,699,750,668	1,710,407,412	1,721,064,156	1,731,720,900	1,742,377,644	1,753,034,388	1,763,691,132	1,774,347,876	1,785,004,620
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	12,602,549,402	12,708,218,721	12,813,888,040	12,915,653,078	13,017,418,116	13,119,183,154	13,220,948,192	13,322,713,230	13,424,478,268	13,526,243,306	13,628,008,344	13,729,773,382	13,831,538,420
	Subtotal (acre-feet)	38,678	39,003	39,327	39,639	39,952	40,264	40,576	40,889	41,201	41,513	41,826	42,138	42,450
	Total Water Demand (gallons)	40,748,837,296	41,141,590,468	41,534,343,640	41,857,955,810	42,181,567,980	42,505,180,150	42,828,792,319	43,152,404,489	43,476,016,659	43,799,628,829	44,123,240,998	44,446,853,168	44,770,465,338
	Total Capacity (mgd)	111.6	112.7	113.8	114.7	115.6	116.5	117.3	118.2	119.1	120.0	120.9	121.8	122.7
	Total Water Demand (acre-feet)	125,062	126,268	127,473	128,466	129,459	130,452	131,446	132,439	133,432	134,425	135,418	136,412	137,405
	ON STEVENS EXPENSES													
Treated	Salaries & Wages	$ 918,793	$ 941,763	$ 965,307	$ 989,439	$ 1,014,175	$ 1,039,530	$ 1,065,518	$ 1,092,156	$ 1,119,460	$ 1,147,446	$ 1,176,132	$ 1,205,536	$ 1,235,674
Treated	Fringe Benefits	$ 341,552	$ 350,091	$ 358,843	$ 367,814	$ 377,010	$ 386,435	$ 396,096	$ 405,998	$ 416,148	$ 426,552	$ 437,216	$ 448,146	$ 459,350
Treated	Materials/Supplies/Utilities	$ 5,858,485	$ 6,034,024	$ 6,214,083	$ 6,392,164	$ 6,574,911	$ 6,762,444	$ 6,954,890	$ 7,152,374	$ 7,355,029	$ 7,562,988	$ 7,776,388	$ 7,995,372	$ 8,220,084
Treated	Capital													
	Subtotal	$ 7,118,830	$ 7,325,878	$ 7,538,233	$ 7,749,418	$ 7,966,096	$ 8,188,409	$ 8,416,503	$ 8,650,528	$ 8,890,637	$ 9,136,986	$ 9,389,737	$ 9,649,054	$ 9,915,108
	RAW WATER EXPENSES													
Raw	Wesley Seale Dam	$ 1,675,089	$ 1,716,967	$ 1,759,891	$ 1,803,888	$ 1,848,985	$ 1,895,210	$ 1,942,590	$ 1,991,155	$ 2,040,934	$ 2,091,957	$ 2,144,256	$ 2,197,862	$ 2,252,809
Raw	Choke Canyon Dam	$ 792,648	$ 812,464	$ 832,776	$ 853,595	$ 874,935	$ 896,808	$ 919,229	$ 942,209	$ 965,765	$ 989,909	$ 1,014,656	$ 1,040,023	$ 1,066,023
Raw	Environmental Studies	$ 964,958	$ 989,082	$ 1,013,809	$ 1,039,154	$ 1,065,133	$ 1,091,761	$ 1,119,055	$ 1,147,032	$ 1,175,707	$ 1,205,100	$ 1,235,227	$ 1,266,108	$ 1,297,761
Raw	Water Supply Development	$ 1,227,197	$ 1,257,877	$ 1,289,324	$ 1,321,557	$ 1,354,596	$ 1,388,461	$ 1,423,173	$ 1,458,752	$ 1,495,221	$ 1,532,601	$ 1,570,916	$ 1,610,189	$ 1,650,444
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 790,713	$ 810,480	$ 830,742	$ 851,511	$ 872,799	$ 894,619	$ 916,984	$ 939,909	$ 963,406	$ 987,492	$ 1,012,179	$ 1,037,483	$ 1,063,420
Raw	Water Purchased - LNRA	$ 8,335,257	$ 8,504,345	$ 8,617,689	$ 8,790,535	$ 8,964,136	$ 9,138,181	$ 9,313,153	$ 9,538,473	$ 9,715,121	$ 9,892,989	$ 10,072,188	$ 10,252,833	$ 10,491,042
Raw	Supplemental Water Sources - Wells	$ 84,089	$ 86,191	$ 88,346	$ 90,555	$ 92,819	$ 95,139	$ 97,518	$ 99,956	$ 102,454	$ 105,016	$ 107,641	$ 110,332	$ 113,091
	Subtotal	$ 13,979,951	$ 14,287,407	$ 14,542,577	$ 14,860,795	$ 15,183,403	$ 15,510,180	$ 15,841,702	$ 16,227,485	$ 16,568,609	$ 16,915,063	$ 17,267,064	$ 17,624,831	$ 18,044,590
	EXISTING DEBT SERVICE													
Treated	ON Stevens Debt	$ 1,449,133	$ 1,448,956	$ 814,516	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	Bureau of Rec or PL Fund	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,208,976	$ 827,934
Raw	NRA Debt Service	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 1,848,266	$ 1,847,231	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2000 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,793	$ 1,101,024	$ 1,101,143	$ 1,101,030	$ 1,100,804	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,172,450	$ 8,169,275	$ 8,171,800	$ 8,173,925	$ 8,169,825	$ 8,168,950	$ 8,170,200	$ 8,172,475	$ 8,169,675	$ 8,012,418	$ -	$ -	$ -
Raw	LNRA - Pipeline Debt (Pumping Station)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ 17,565,805	$ 17,561,650	$ 15,082,622	$ 14,270,118	$ 14,265,792	$ 13,164,113	$ 13,165,363	$ 13,167,638	$ 13,164,838	$ 13,007,581	$ 4,995,163	$ 4,208,976	$ 827,934

APPENDIX F
Desalination Alternate BD A2 (Barney Davis Intake and Open Sea Discharge)

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	PLANNED DEBT SERVICE													
Treated	ON Stevens Debt	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499
Raw	Raw Water Debt	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727
	Subtotal	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227
	FUTURE CAPITAL PROJECTS													
Treated	ON Stevens Replacement			$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788
	Subtotal	$ -	$ -	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788
	SUMMARY OF COST FOR NON-DESAL FACILITIE													
	Raw Cost of Water ($ per 1,000 gallons)	***$ 1.13***	***$ 1.13***	***$ 1.06***	***$ 1.07***	***$ 1.07***	***$ 1.03***	***$ 1.04***	***$ 1.04***	***$ 1.05***	***$ 1.04***	***$ 0.79***	***$ 0.77***	***$ 0.67***
	Treated Cost of Water ($ per 1,000 gallons)	***$ 0.85***	***$ 0.84***	***$ 1.39***	***$ 1.35***	***$ 1.34***	***$ 1.34***	***$ 1.33***	***$ 1.33***	***$ 1.33***	***$ 1.33***	***$ 1.32***	***$ 1.32***	***$ 1.32***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.98***	***$ 1.97***	***$ 2.45***	***$ 2.41***	***$ 2.41***	***$ 2.37***	***$ 2.37***	***$ 2.37***	***$ 2.37***	***$ 2.37***	***$ 2.11***	***$ 2.09***	***$ 1.99***
	DESAL PLANT DEBT SERVICE													
Treated	Equipment	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ 6,068,467	$ -
Treated	Pipe	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630	$ 4,974,630
Treated	Structures	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179	$ 1,775,179
Treated	Other	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ 637,328	$ -
	Subtotal	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 13,455,604	$ 6,749,809
	DESAL PLANT REPAIR AND REHABILITATION													
Treated	Reverse Osmosis & Common Elements	$ 5,251,850	$ 5,383,146	$ 5,517,725	$ 5,655,668	$ 5,797,060	$ 5,941,986	$ 6,090,536	$ 6,242,799	$ 6,398,869	$ 6,558,841	$ 6,722,812	$ 6,890,883	$ 7,063,155
Treated	Pre-Treatment	$ 1,277,772	$ 1,309,716	$ 1,342,459	$ 1,376,021	$ 1,410,421	$ 1,445,682	$ 1,481,824	$ 1,518,869	$ 1,556,841	$ 1,595,762	$ 1,635,656	$ 1,676,548	$ 1,718,461
	Subtotal	$ 6,529,622	$ 6,692,863	$ 6,860,184	$ 7,031,689	$ 7,207,481	$ 7,387,668	$ 7,572,360	$ 7,761,669	$ 7,955,711	$ 8,154,603	$ 8,358,468	$ 8,567,430	$ 8,781,616
	DESAL PLANT OPERATION AND MAINTENANCI													
Treated	Power - Reverse Osmosis & Common Elements	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951	$ 6,954,951
Treated	Power - Pre-Treatment	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291
Treated	Chemical - Reverse Osmosis & Common Elements	$ 1,890,670	$ 1,937,937	$ 1,986,385	$ 2,036,045	$ 2,086,946	$ 2,139,120	$ 2,192,598	$ 2,247,413	$ 2,303,598	$ 2,361,188	$ 2,420,218	$ 2,480,723	$ 2,542,741
Treated	Chemical - Pre-Treatment	$ 1,076,621	$ 1,103,537	$ 1,131,125	$ 1,159,403	$ 1,188,388	$ 1,218,098	$ 1,248,550	$ 1,279,764	$ 1,311,758	$ 1,344,552	$ 1,378,166	$ 1,412,620	$ 1,447,936
Treated	Labor - Reverse Osmosis & Common Elements	$ 1,653,441	$ 1,694,777	$ 1,737,146	$ 1,780,575	$ 1,825,089	$ 1,870,717	$ 1,917,485	$ 1,965,422	$ 2,014,557	$ 2,064,921	$ 2,116,544	$ 2,169,458	$ 2,223,694
Treated	Labor - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Reverse Osmosis & Common Element	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Pre-Treatment	$ 2,302,639	$ 2,360,205	$ 2,419,210	$ 2,479,690	$ 2,541,683	$ 2,605,225	$ 2,670,355	$ 2,737,114	$ 2,805,542	$ 2,875,680	$ 2,947,572	$ 3,021,262	$ 3,096,793
	Subtotal	$ 13,942,613	$ 14,115,697	$ 14,293,109	$ 14,474,955	$ 14,661,348	$ 14,852,401	$ 15,048,230	$ 15,248,954	$ 15,454,697	$ 15,665,584	$ 15,881,742	$ 16,103,305	$ 16,330,406
	DESAL PLANT REPLACEMENT													
Treated	Equipment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,943,891	$ 9,943,891
Treated	Pipe	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Structures	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,044,336	$ 1,044,336
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 10,988,226	$ 10,988,226
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/OUT SU													
	Desal Cost of Water ($ per 1,000 gallons)	***$ 3.72***	***$ 3.76***	***$ 3.79***	***$ 3.83***	***$ 3.87***	***$ 3.91***	***$ 3.95***	***$ 4.00***	***$ 4.04***	***$ 4.09***	***$ 4.13***	***$ 5.38***	***$ 4.70***
	Desal Cost of Water ($ per acre-foot)	***$ 1,212***	***$ 1,224***	***$ 1,236***	***$ 1,249***	***$ 1,262***	***$ 1,275***	***$ 1,288***	***$ 1,302***	***$ 1,317***	***$ 1,331***	***$ 1,346***	***$ 1,754***	***$ 1,530***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 2.37***	***$ 2.37***	***$ 2.75***	***$ 2.72***	***$ 2.73***	***$ 2.70***	***$ 2.71***	***$ 2.72***	***$ 2.72***	***$ 2.73***	***$ 2.53***	***$ 2.77***	***$ 2.54***
	Combined Cost of Water ($ per acre-foot)	***$ 771***	***$ 772***	***$ 895***	***$ 886***	***$ 888***	***$ 880***	***$ 882***	***$ 885***	***$ 888***	***$ 889***	***$ 824***	***$ 901***	***$ 827***
	REVENUES FROM SUBSIDIES AND WATER SALE													
	State Subsidy	$ 20,693,910	$ 20,537,194	$ 20,382,414	$ 20,229,545	$ 20,078,563	$ 19,929,445	$ 19,782,168	$ 19,636,710	$ 19,493,046	$ 19,351,156	$ 19,211,019	$ 19,072,611	$ 18,935,913
	Water Sale Revenues	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000
	Subtotal	$ 25,693,910	$ 25,537,194	$ 25,382,414	$ 25,229,545	$ 25,078,563	$ 24,929,445	$ 24,782,168	$ 24,636,710	$ 24,493,046	$ 24,351,156	$ 24,211,019	$ 24,072,611	$ 23,935,913
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/ SUB													
	Adjusted Desal Cost of Water ($ per 1,000 gallons)	***$ 0.90***	***$ 0.96***	***$ 1.01***	***$ 1.07***	***$ 1.12***	***$ 1.18***	***$ 1.24***	***$ 1.30***	***$ 1.36***	***$ 1.42***	***$ 1.48***	***$ 2.74***	***$ 2.07***
	Adjusted Desal Cost of Water ($ per acre-foot)	***$ 294***	***$ 312***	***$ 330***	***$ 348***	***$ 366***	***$ 385***	***$ 403***	***$ 422***	***$ 442***	***$ 462***	***$ 482***	***$ 894***	***$ 676***
	Adjusted Combined Cost of Water ($ per 1,000 gallons)	***$ 1.74***	***$ 1.75***	***$ 2.14***	***$ 2.12***	***$ 2.13***	***$ 2.12***	***$ 2.13***	***$ 2.15***	***$ 2.16***	***$ 2.17***	***$ 1.98***	***$ 2.22***	***$ 2.00***
	Adjusted Combined Cost of Water ($ per acre-foot)	***$ 566***	***$ 570***	***$ 696***	***$ 690***	***$ 694***	***$ 689***	***$ 694***	***$ 699***	***$ 704***	***$ 708***	***$ 645***	***$ 724***	***$ 653***
	Total Annual Raw Water Cost	***$ 31,801,350***	***$ 32,104,828***	***$ 30,515,410***	***$ 30,835,641***	***$ 31,153,922***	***$ 30,379,020***	***$ 30,711,792***	***$ 31,099,850***	***$ 31,438,174***	***$ 31,627,371***	***$ 23,966,954***	***$ 23,538,534***	***$ 20,577,251***
	Total Annual Treatment Cost	***$ 50,032,301***	***$ 50,575,497***	***$ 61,868,933***	***$ 61,618,953***	***$ 62,197,816***	***$ 62,791,369***	***$ 63,399,984***	***$ 64,024,043***	***$ 64,663,936***	***$ 65,320,064***	***$ 65,992,838***	***$ 77,670,906***	***$ 71,672,452***
	Total Annual Cost	***$ 56,139,741***	***$ 57,143,130***	***$ 67,001,929***	***$ 67,225,049***	***$ 68,273,175***	***$ 68,240,944***	***$ 69,329,608***	***$ 70,487,183***	***$ 71,609,064***	***$ 72,596,279***	***$ 65,748,774***	***$ 77,136,829***	***$ 68,313,791***
	Total Annual Present Value	***$ 47,178,047***	***$ 47,428,408***	***$ 54,924,587***	***$ 54,427,149***	***$ 54,593,322***	***$ 53,893,876***	***$ 54,077,687***	***$ 54,301,833***	***$ 54,485,042***	***$ 54,554,255***	***$ 48,798,548***	***$ 56,543,929***	***$ 49,458,114***
	Cumulative Present Value	***$ 688,027,004***	***$ 735,455,412***	***$ 790,379,998***	***$ 844,807,148***	***$ 899,400,470***	***$ 953,294,346***	***$ 1,007,372,033***	***$ 1,061,673,866***	***$ 1,116,158,908***	***$ 1,170,713,163***	***$ 1,219,511,711***	***$ 1,276,055,640***	***$ 1,325,513,755***

Appendix F-4

Optimized Desalination Alternate BD B2

APPENDIX F
Desalination Alternate BD B2 (Barney Davis Intake and Discharge)

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	FIRM YIELD WATER SUPPLY														
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Desal Plant	0	0	0	0	0	0	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000
	Subtotal (acre-feet)	224,000	224,000	224,000	224,000	224,000	224,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000
Acct #	**CONSUMPTION TREATED**														
324000	ICL Residential	5,781,550,000	5,887,545,083	5,993,540,167	6,099,535,250	6,205,530,333	6,311,525,417	6,417,520,500	6,486,899,100	6,556,277,700	6,625,656,300	6,695,034,900	6,764,413,500	6,833,792,100	6,903,170,700
324050	ICL Commercial and Other	5,075,683,000	5,168,737,188	5,261,791,377	5,354,845,565	5,447,899,753	5,540,953,942	5,634,008,130	5,694,916,326	5,755,824,522	5,816,732,718	5,877,640,914	5,938,549,110	5,999,457,306	6,060,365,502
324100	ICL Large Volume Users	821,862	836,929	851,997	867,064	882,132	897,199	912,267	922,129	931,992	941,854	951,716	961,579	971,441	981,303
324800	OCL Residential	8,443,000	8,597,788	8,752,577	8,907,365	9,062,153	9,216,942	9,371,730	9,473,046	9,574,362	9,675,678	9,776,994	9,878,310	9,979,626	10,080,942
324150	OCL Commercial and Other	534,231,000	544,025,235	553,819,470	563,613,705	573,407,940	583,202,175	592,996,410	599,407,182	605,817,954	612,228,726	618,639,498	625,050,270	631,461,042	637,871,814
324810	OCL Large Volume Users	7,950,453,000	8,096,211,305	8,241,969,610	8,387,727,915	8,533,486,220	8,679,244,525	8,825,002,830	8,920,408,266	9,015,813,702	9,111,219,138	9,206,624,574	9,302,030,010	9,397,435,446	9,492,840,882
324170	City Water Use	542,727,000	552,676,995	562,626,990	572,576,985	582,526,980	592,476,975	602,426,970	608,939,694	615,452,418	621,965,142	628,477,866	634,990,590	641,503,314	648,016,038
324850	San Patricio	1,205,710,000	1,239,871,783	1,274,033,567	1,308,195,350	1,342,357,133	1,376,518,917	1,410,680,700	1,426,354,930	1,442,029,160	1,457,703,390	1,473,377,620	1,489,051,850	1,504,726,080	1,520,400,310
324850	South Texas Water Authority	434,991,000	448,040,730	461,090,460	474,140,190	487,189,920	500,239,650	513,289,380	518,509,272	523,729,164	528,949,056	534,168,948	539,388,840	544,608,732	549,828,624
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	422,505,000	466,868,625	511,231,050	555,594,075	599,957,100	644,320,125	688,683,150	716,145,975	743,608,800	771,071,625	798,534,450	825,997,275	853,460,100	880,922,925
	Subtotal (gallons)	23,111,839,862	23,568,136,063	24,024,432,264	24,480,728,464	24,937,024,665	25,393,320,866	25,849,617,067	26,136,700,920	26,423,784,774	26,710,868,627	26,997,952,480	27,285,036,334	27,572,120,187	27,859,204,040
	Subtotal (mgd)	63.3	64.6	65.8	67.1	68.3	69.6	70.8	71.6	72.4	73.2	74.0	74.8	75.5	76.3
	Subtotal (acre-feet)	70,932	72,333	73,733	75,134	76,534	77,935	79,335	80,216	81,097	81,978	82,859	83,740	84,621	85,503
	CONSUMPTION RAW														
324820	Alice	451,854,000	456,372,540	460,891,080	465,409,620	469,928,160	474,446,700	478,965,240	481,676,364	484,387,488	487,098,612	489,809,736	492,520,860	495,231,984	497,943,108
324820	Beeville	872,287,000	878,102,247	883,917,493	889,732,740	895,547,987	901,363,233	907,178,480	908,923,054	910,667,628	912,412,202	914,156,776	915,901,350	917,645,924	919,390,498
324820	Mathis	215,179,000	214,103,105	213,027,210	211,951,315	210,875,420	209,799,525	208,723,630	208,078,093	207,432,556	206,787,019	206,141,482	205,495,945	204,850,408	204,204,871
324820	San Patricio	5,921,852,000	6,089,637,807	6,257,423,613	6,425,209,420	6,592,995,227	6,760,781,033	6,928,566,840	7,005,550,916	7,082,534,992	7,159,519,068	7,236,503,144	7,313,487,220	7,390,471,296	7,467,455,372
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,431,805,000	1,472,372,808	1,512,940,617	1,553,508,425	1,594,076,233	1,634,644,042	1,675,211,850	1,688,098,095	1,700,984,340	1,713,870,585	1,726,756,830	1,739,643,075	1,752,529,320	1,765,415,565
324820	Celanese	1,332,093,000	1,369,835,635	1,407,578,270	1,445,320,905	1,483,063,540	1,520,806,175	1,558,548,810	1,570,537,647	1,582,526,484	1,594,515,321	1,606,504,158	1,618,492,995	1,630,481,832	1,642,470,669
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	10,225,070,000	10,480,424,142	10,735,778,283	10,991,132,425	11,246,486,567	11,501,840,708	11,757,194,850	11,862,864,169	11,968,533,488	12,074,202,807	12,179,872,126	12,285,541,445	12,391,210,764	12,496,880,083
	Subtotal (acre-feet)	31,382	32,165	32,949	33,733	34,517	35,300	36,084	36,408	36,733	37,057	37,381	37,706	38,030	38,354
	Total Water Demand (gallons)	33,336,909,862	34,048,560,204	34,760,210,547	35,471,860,889	36,183,511,232	36,895,161,574	37,606,811,917	37,999,565,089	38,392,318,262	38,785,071,434	39,177,824,606	39,570,577,779	39,963,330,951	40,356,084,123
	Total Capacity (mgd)	91.3	93.3	95.2	97.2	99.1	101.1	103.0	104.1	105.2	106.3	107.3	108.4	109.5	110.6
	Total Water Demand (acre-feet)	102,314	104,498	106,682	108,867	111,051	113,235	115,419	116,624	117,830	119,035	120,241	121,446	122,651	123,857
	ON STEVENS EXPENSES														
Treated	Salaries & Wages	$ 726,362	$ 666,511	$ 683,174	$ 700,253	$ 717,759	$ 735,703	$ 754,096	$ 772,948	$ 792,272	$ 812,079	$ 832,381	$ 853,190	$ 874,520	$ 896,383
Treated	Fringe Benefits	$ 267,109	$ 247,769	$ 253,963	$ 260,312	$ 266,820	$ 273,491	$ 280,328	$ 287,336	$ 294,519	$ 301,882	$ 309,430	$ 317,165	$ 325,094	$ 333,222
Treated	Materials/Supplies/Utilities	$ 4,351,402	$ 6,288,040	$ 6,445,241	$ 6,606,372	$ 6,771,531	$ 6,940,820	$ 4,603,448	$ 4,746,803	$ 4,893,820	$ 5,044,595	$ 5,199,231	$ 5,357,831	$ 5,520,500	$ 5,687,348
Treated	Capital	$ -	$ -												
	Subtotal	$ 5,344,873	$ 7,202,320	$ 7,382,378	$ 7,566,937	$ 7,756,111	$ 7,950,014	$ 5,637,872	$ 5,807,088	$ 5,980,611	$ 6,158,557	$ 6,341,042	$ 6,528,187	$ 6,720,115	$ 6,916,953
	RAW WATER EXPENSES														
Raw	Wesley Seale Dam	$ 1,190,020	$ 1,215,144	$ 1,245,523	$ 1,276,661	$ 1,308,577	$ 1,341,292	$ 1,374,824	$ 1,409,194	$ 1,444,424	$ 1,480,535	$ 1,517,548	$ 1,555,487	$ 1,594,374	$ 1,634,234
Raw	Choke Canyon Dam	$ 503,700	$ 575,003	$ 589,378	$ 604,113	$ 619,215	$ 634,696	$ 650,563	$ 666,827	$ 683,498	$ 700,585	$ 718,100	$ 736,052	$ 754,454	$ 773,315
Raw	Environmental Studies	$ 700,000	$ 700,000	$ 717,500	$ 735,438	$ 753,823	$ 772,669	$ 791,986	$ 811,785	$ 832,080	$ 852,882	$ 874,204	$ 896,059	$ 918,461	$ 941,422
Raw	Water Supply Development	$ 864,613	$ 890,234	$ 912,490	$ 935,302	$ 958,685	$ 982,652	$ 1,007,218	$ 1,032,399	$ 1,058,208	$ 1,084,664	$ 1,111,780	$ 1,139,575	$ 1,168,064	$ 1,197,266
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 489,981	$ 573,599	$ 587,939	$ 602,637	$ 617,703	$ 633,146	$ 648,975	$ 665,199	$ 681,829	$ 698,875	$ 716,347	$ 734,255	$ 752,612	$ 771,427
Raw	Water Purchased - LNRA	$ 6,206,324	$ 6,603,854	$ 6,739,012	$ 6,834,059	$ 6,931,127	$ 7,086,677	$ 7,186,106	$ 7,314,107	$ 7,474,756	$ 7,579,286	$ 7,742,312	$ 7,849,195	$ 8,014,925	$ 8,124,511
Raw	Supplemental Water Sources - Wells	$ 35,000	$ 61,000	$ 62,525	$ 64,088	$ 65,690	$ 67,333	$ 69,016	$ 70,741	$ 72,510	$ 74,323	$ 76,181	$ 78,085	$ 80,037	$ 82,038
	Subtotal	$ 10,099,638	$ 10,728,834	$ 10,964,367	$ 11,162,298	$ 11,364,821	$ 11,628,464	$ 11,838,687	$ 12,080,253	$ 12,357,306	$ 12,581,149	$ 12,866,472	$ 13,098,709	$ 13,392,926	$ 13,634,213
	EXISTING DEBT SERVICE														
Treated	ON Stevens Debt	$ 3,649,462	$ 3,445,464	$ 3,390,714	$ 3,587,318	$ 3,589,253	$ 3,591,432	$ 3,820,568	$ 1,903,651	$ 1,902,983	$ 1,795,002	$ 1,796,673	$ 1,687,429	$ 1,448,508	$ 1,448,844
Raw	Bureau of Rec or PL Fund	$ 4,425,542	$ 4,695,363	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163
Raw	NRA Debt Service	$ 931,562	$ 970,110	$ 976,170	$ 971,375	$ 971,010	$ 974,933	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ 117,878	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ 77,458	$ 75,193	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 2,111,136	$ 2,434,132	$ 2,431,914	$ 2,873,210	$ 2,878,236	$ 2,884,445	$ 2,885,746	$ 2,322,352	$ 2,323,963	$ 1,847,992	$ 1,847,697	$ 1,846,788	$ 1,848,067	$ 1,848,266
Raw	2000 Rev Bond: portion applicable P&I	$ 466,092	$ 465,932	$ 464,821	$ 464,921	$ 464,815	$ 464,888	$ 551,554	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,548	$ 1,100,729	$ 1,101,083	$ 1,100,985	$ 1,100,503	$ 1,101,158	$ 1,100,480	$ 1,100,819	$ 1,101,196	$ 1,100,782	$ 1,100,642	$ 1,100,906	$ 1,100,906	$ 1,100,567
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ 48,350	$ 60,091	$ 85,273	$ 108,280	$ 108,819	$ 108,954	$ 74,834	$ 151,044	$ 150,809	$ 179,559	$ 180,491	$ 123,830	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,171,975	$ 8,170,875	$ 8,171,275	$ 8,172,975	$ 8,170,375	$ 8,173,288	$ 8,169,738	$ 8,173,050	$ 8,172,438	$ 8,172,638	$ 8,173,125	$ 8,173,125	$ 8,172,863	$ 8,171,063
Raw	LNRA - Pipeline Debt (Pumping Station)	$ 763,680	$ 758,430	$ 760,100	$ 760,420	$ 759,350	$ 756,850	$ 757,762	$ 756,775	$ 758,175	$ 757,925	$ 756,025	$ 757,475	$ 757,000	$ 759,600
	Subtotal	$ 21,863,684	$ 22,176,319	$ 22,376,513	$ 23,034,645	$ 23,037,524	$ 23,051,111	$ 22,355,846	$ 19,402,854	$ 19,404,727	$ 18,849,061	$ 18,849,816	$ 18,684,715	$ 18,322,506	$ 18,323,502

APPENDIX F
Desalination Alternate BD B2 (Barney Davis Intake and Discharge)

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	PLANNED DEBT SERVICE														
Treated	ON Stevens Debt	$ -	$ -	$ 23,447	$ 186,809	$ 1,635,830	$ 2,366,037	$ 2,956,244	$ 5,830,847	$ 7,010,826	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499
Raw	Raw Water Debt	$ -	$ -	$ 489,778	$ 1,271,993	$ 1,621,048	$ 1,621,048	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727
	Subtotal	$ -	$ -	$ 513,225	$ 1,458,802	$ 3,256,878	$ 3,987,085	$ 4,660,972	$ 7,535,574	$ 8,715,553	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227
	FUTURE CAPITAL PROJECTS														
Treated	ON Stevens Replacement														
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	SUMMARY OF COST FOR NON-DESAL FACILITIES														
	Raw Cost of Water ($ per 1,000 gallons)	***$ 1.23***	***$ 1.25***	***$ 1.27***	***$ 1.30***	***$ 1.30***	***$ 1.29***	***$ 1.24***	***$ 1.20***	***$ 1.19***	***$ 1.17***	***$ 1.17***	***$ 1.17***	***$ 1.16***	***$ 1.16***
	Treated Cost of Water ($ per 1,000 gallons)	***$ 0.39***	***$ 0.45***	***$ 0.45***	***$ 0.46***	***$ 0.52***	***$ 0.55***	***$ 0.74***	***$ 0.80***	***$ 0.86***	***$ 0.88***	***$ 0.88***	***$ 0.87***	***$ 0.85***	***$ 0.85***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 1.82***	***$ 1.84***	***$ 1.98***	***$ 1.99***	***$ 2.06***	***$ 2.05***	***$ 2.05***	***$ 2.03***	***$ 2.01***	***$ 2.01***
	DESAL PLANT DEBT SERVICE														
Treated	Equipment	$ -	$ -	$ -	$ -	$ 2,992,989	$ 2,992,989	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660
Treated	Pipe	$ -	$ -	$ -	$ -	$ 3,302,608	$ 3,302,608	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586
Treated	Structures	$ -	$ -	$ -	$ -	$ 1,177,768	$ 1,177,768	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397
Treated	Other	$ -	$ -	$ -	$ -	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690
	Subtotal	$ -	$ -	$ -	$ -	$ 7,789,056	$ 7,789,056	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333
	DESAL PLANT REPAIR AND REHABILITATION														
Treated	Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,231,589	$ 4,337,379	$ 4,445,813	$ 4,556,959	$ 4,670,882	$ 4,787,655	$ 4,907,346	$ 5,030,030
Treated	Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,048,727	$ 1,074,945	$ 1,101,819	$ 1,129,364	$ 1,157,598	$ 1,186,538	$ 1,216,202	$ 1,246,607
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,280,316	$ 5,412,324	$ 5,547,632	$ 5,686,323	$ 5,828,481	$ 5,974,193	$ 6,123,548	$ 6,276,636
	DESAL PLANT OPERATION AND MAINTENANCE														
Treated	Power - Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116
Treated	Power - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291
Treated	Chemical - Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,551,761	$ 1,590,555	$ 1,630,319	$ 1,671,077	$ 1,712,854	$ 1,755,675	$ 1,799,567	$ 1,844,556
Treated	Chemical - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 883,633	$ 905,724	$ 928,367	$ 951,576	$ 975,365	$ 999,750	$ 1,024,743	$ 1,050,362
Treated	Labor - Reverse Osmosis & Common Elements	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,357,056	$ 1,390,982	$ 1,425,757	$ 1,461,401	$ 1,497,936	$ 1,535,384	$ 1,573,769	$ 1,613,113
Treated	Labor - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Reverse Osmosis & Common Element	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,889,883	$ 1,937,130	$ 1,985,558	$ 2,035,197	$ 2,086,077	$ 2,138,229	$ 2,191,685	$ 2,246,477
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,467,740	$ 13,609,798	$ 13,755,408	$ 13,904,658	$ 14,057,639	$ 14,214,445	$ 14,375,171	$ 14,539,915
	DESAL PLANT REPLACEMENT														
Treated	Equipment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Pipe	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Structures	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/OUT SUBSIDIES)														
	Desal Cost of Water ($ per 1,000 gallons)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 3.20***	***$ 3.23***	***$ 3.26***	***$ 3.30***	***$ 3.33***	***$ 3.36***	***$ 3.39***	***$ 3.43***
	Desal Cost of Water ($ per acre-foot)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 1,044***	***$ 1,053***	***$ 1,063***	***$ 1,074***	***$ 1,084***	***$ 1,095***	***$ 1,106***	***$ 1,118***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 2.04***	***$ 2.05***	***$ 2.28***	***$ 2.29***	***$ 2.34***	***$ 2.35***	***$ 2.35***	***$ 2.34***	***$ 2.33***	***$ 2.33***
	Combined Cost of Water ($ per acre-foot)	***$ 526***	***$ 554***	***$ 559***	***$ 575***	***$ 664***	***$ 667***	***$ 743***	***$ 746***	***$ 763***	***$ 764***	***$ 764***	***$ 762***	***$ 758***	***$ 758***
	REVENUES FROM SUBSIDIES AND WATER SALES														
	State Subsidy	$ -	$ -	$ -	$ -	$ -	$ -	$ 19,256,124	$ 19,080,123	$ 18,906,293	$ 18,734,611	$ 18,565,048	$ 18,397,578	$ 18,232,176	$ 18,068,816
	Water Sale Revenues	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ 24,256,124	$ 24,080,123	$ 23,906,293	$ 23,734,611	$ 23,565,048	$ 23,397,578	$ 23,232,176	$ 23,068,816
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/ SUBSIDIES)														
	Adjusted Desal Cost of Water ($ per 1,000 gallons)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 0.54***	***$ 0.59***	***$ 0.64***	***$ 0.69***	***$ 0.74***	***$ 0.80***	***$ 0.85***	***$ 0.90***
	Adjusted Desal Cost of Water ($ per acre-foot)	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ 177***	***$ 193***	***$ 210***	***$ 226***	***$ 243***	***$ 259***	***$ 276***	***$ 294***
	Adjusted Combined Cost of Water ($ per 1,000 gallons)	***$ 1.61***	***$ 1.70***	***$ 1.72***	***$ 1.77***	***$ 2.04***	***$ 2.05***	***$ 1.63***	***$ 1.66***	***$ 1.72***	***$ 1.73***	***$ 1.74***	***$ 1.75***	***$ 1.75***	***$ 1.76***
	Adjusted Combined Cost of Water ($ per acre-foot)	***$ 526***	***$ 554***	***$ 559***	***$ 575***	***$ 664***	***$ 667***	***$ 532***	***$ 540***	***$ 560***	***$ 565***	***$ 568***	***$ 569***	***$ 569***	***$ 572***
	Total Annual Raw Water Cost	***$ 28,313,860***	***$ 29,459,689***	***$ 30,439,944***	***$ 31,881,618***	***$ 32,434,140***	***$ 32,709,191***	***$ 32,078,693***	***$ 31,284,183***	***$ 31,563,777***	***$ 31,339,935***	***$ 31,624,343***	***$ 31,800,723***	***$ 31,971,652***	***$ 32,213,599***
	Total Annual Treatment Cost	***$ 8,994,335***	***$ 10,647,784***	***$ 10,796,539***	***$ 11,341,064***	***$ 20,770,249***	***$ 21,696,539***	***$ 41,637,073***	***$ 43,038,041***	***$ 44,671,793***	***$ 45,555,372***	***$ 46,034,667***	***$ 46,415,086***	***$ 46,678,174***	***$ 47,193,181***
	Total Annual Cost	***$ 37,308,195***	***$ 40,107,473***	***$ 41,236,483***	***$ 43,222,682***	***$ 53,204,389***	***$ 54,405,730***	***$ 49,459,642***	***$ 50,242,101***	***$ 52,329,276***	***$ 53,160,696***	***$ 54,093,962***	***$ 54,818,230***	***$ 55,417,650***	***$ 56,337,963***
	Total Annual Present Value	***$ 37,308,195***	***$ 39,612,319***	***$ 40,224,584***	***$ 41,641,524***	***$ 50,625,267***	***$ 51,129,257***	***$ 45,907,197***	***$ 46,057,734***	***$ 47,378,846***	***$ 47,537,394***	***$ 47,774,755***	***$ 47,816,706***	***$ 47,742,782***	***$ 47,936,435***
	Cumulative Present Value	***$ 37,308,195***	***$ 76,920,513***	***$ 117,145,097***	***$ 158,786,621***	***$ 209,411,889***	***$ 260,541,145***	***$ 306,448,342***	***$ 352,506,077***	***$ 399,884,922***	***$ 447,422,316***	***$ 495,197,071***	***$ 543,013,777***	***$ 590,756,559***	***$ 638,692,994***

APPENDIX F
Desalination Alternate BD B2 (Barney Davis Intake and Discharge)

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	FIRM YIELD WATER SUPPLY													
	CCR/LCC System	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160	182,160
	Lake Texana Contract	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840	41,840
	Garwood Water	0	0	0	0	0	0	0	0	0	0	0	0	0
	Desal Plant	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000
	Subtotal (acre-feet)	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000	252,000
Acct #	**CONSUMPTION TREATED**													
324000	ICL Residential	6,972,549,300	7,041,927,900	7,111,306,500	7,163,340,450	7,215,374,400	7,267,408,350	7,319,442,300	7,371,476,250	7,423,510,200	7,475,544,150	7,527,578,100	7,579,612,050	7,631,646,000
324050	ICL Commercial and Other	6,121,273,698	6,182,181,894	6,243,090,090	6,288,771,237	6,334,452,384	6,380,133,531	6,425,814,678	6,471,495,825	6,517,176,972	6,562,858,119	6,608,539,266	6,654,220,413	6,699,901,560
324100	ICL Large Volume Users	991,166	1,001,028	1,010,890	1,018,287	1,025,684	1,033,081	1,040,477	1,047,874	1,055,271	1,062,668	1,070,064	1,077,461	1,084,858
324800	OCL Residential	10,182,258	10,283,574	10,384,890	10,460,877	10,536,864	10,612,851	10,688,838	10,764,825	10,840,812	10,916,799	10,992,786	11,068,773	11,144,760
324150	OCL Commercial and Other	644,282,586	650,693,358	657,104,130	661,912,209	666,720,288	671,528,367	676,336,446	681,144,525	685,952,604	690,760,683	695,568,762	700,376,841	705,184,920
324810	OCL Large Volume Users	9,588,246,318	9,683,651,754	9,779,057,190	9,850,611,267	9,922,165,344	9,993,719,421	10,065,273,498	10,136,827,575	10,208,381,652	10,279,935,729	10,351,489,806	10,423,043,883	10,494,597,960
324170	City Water Use	654,528,762	661,041,486	667,554,210	672,438,753	677,323,296	682,207,839	687,092,382	691,976,925	696,861,468	701,746,011	706,630,554	711,515,097	716,399,640
324850	San Patricio	1,536,074,540	1,551,748,770	1,567,423,000	1,583,097,230	1,598,771,460	1,614,445,690	1,630,119,920	1,645,794,150	1,661,468,380	1,677,142,610	1,692,816,840	1,708,491,070	1,724,165,300
324850	South Texas Water Authority	555,048,516	560,268,408	565,488,300	568,533,237	571,578,174	574,623,111	577,668,048	580,712,985	583,757,922	586,802,859	589,847,796	592,892,733	595,937,670
324840	Parks Use	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000	1,154,725,000
324860	Port Aransas	908,385,575	935,848,575	963,311,400	987,394,185	1,011,476,970	1,035,559,755	1,059,642,540	1,083,725,325	1,107,808,110	1,131,890,895	1,155,973,680	1,180,056,465	1,204,139,250
	Subtotal (gallons)	28,146,287,894	28,433,371,747	28,720,455,600	28,942,302,732	29,164,149,864	29,385,996,996	29,607,844,127	29,829,691,259	30,051,538,391	30,273,385,523	30,495,232,654	30,717,079,786	30,938,926,918
	Subtotal (mgd)	77.1	77.9	78.7	79.3	79.9	80.5	81.1	81.7	82.3	82.9	83.5	84.2	84.8
	Subtotal (acre-feet)	86,384	87,265	88,146	88,827	89,508	90,188	90,869	91,550	92,231	92,912	93,593	94,274	94,955
	CONSUMPTION RAW													
324820	Alice	500,654,232	503,365,356	506,076,480	507,432,042	508,787,604	510,143,166	511,498,728	512,854,290	514,209,852	515,565,414	516,920,976	518,276,538	519,632,100
324820	Beeville	921,135,072	922,879,646	924,624,220	926,368,794	928,113,368	929,857,942	931,602,516	933,347,090	935,091,664	936,836,238	938,580,812	940,325,386	942,069,960
324820	Mathis	203,559,334	202,913,797	202,268,260	201,837,902	201,407,544	200,977,186	200,546,828	200,116,470	199,686,112	199,255,754	198,825,396	198,395,038	197,964,680
324820	San Patricio	7,544,439,448	7,621,423,524	7,698,407,600	7,775,391,676	7,852,375,752	7,929,359,828	8,006,343,904	8,083,327,980	8,160,312,056	8,237,296,132	8,314,280,208	8,391,264,284	8,468,248,360
324820	Choke Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0
324820	Koch	1,778,301,810	1,791,188,055	1,804,074,300	1,815,528,740	1,826,983,180	1,838,437,620	1,849,892,060	1,861,346,500	1,872,800,940	1,884,255,380	1,895,709,820	1,907,164,260	1,918,618,700
324820	Celanese	1,654,459,506	1,666,448,343	1,678,437,180	1,689,093,924	1,699,750,668	1,710,407,412	1,721,064,156	1,731,720,900	1,742,377,644	1,753,034,388	1,763,691,132	1,774,347,876	1,785,004,620
	Additional Nueces County Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0
	Subtotal (gallons)	12,602,549,402	12,708,218,721	12,813,888,040	12,915,653,078	13,017,418,116	13,119,183,154	13,220,948,192	13,322,713,230	13,424,478,268	13,526,243,306	13,628,008,344	13,729,773,382	13,831,538,420
	Subtotal (acre-feet)	38,678	39,003	39,327	39,639	39,952	40,264	40,576	40,889	41,201	41,513	41,826	42,138	42,450
	Total Water Demand (gallons)	40,748,837,296	41,141,590,468	41,534,343,640	41,857,955,810	42,181,567,980	42,505,180,150	42,828,792,319	43,152,404,489	43,476,016,659	43,799,628,829	44,123,240,998	44,446,853,168	44,770,465,338
	Total Capacity (mgd)	111.6	112.7	113.8	114.7	115.6	116.5	117.3	118.2	119.1	120.0	120.9	121.8	122.7
	Total Water Demand (acre-feet)	125,062	126,268	127,473	128,466	129,459	130,452	131,446	132,439	133,432	134,425	135,418	136,412	137,405
	ON STEVENS EXPENSES													
Treated	Salaries & Wages	$ 918,793	$ 941,763	$ 965,307	$ 989,439	$ 1,014,175	$ 1,039,530	$ 1,065,518	$ 1,092,156	$ 1,119,460	$ 1,147,446	$ 1,176,132	$ 1,205,536	$ 1,235,674
Treated	Fringe Benefits	$ 341,552	$ 350,091	$ 358,843	$ 367,814	$ 377,010	$ 386,435	$ 396,096	$ 405,998	$ 416,148	$ 426,552	$ 437,216	$ 448,146	$ 459,350
Treated	Materials/Supplies/Utilities	$ 5,858,485	$ 6,034,024	$ 6,214,083	$ 6,392,164	$ 6,574,911	$ 6,762,444	$ 6,954,890	$ 7,152,374	$ 7,355,029	$ 7,562,988	$ 7,776,388	$ 7,995,372	$ 8,220,084
Treated	Capital													
	Subtotal	$ 7,118,830	$ 7,325,878	$ 7,538,233	$ 7,749,418	$ 7,966,096	$ 8,188,409	$ 8,416,503	$ 8,650,528	$ 8,890,637	$ 9,136,986	$ 9,389,737	$ 9,649,054	$ 9,915,108
	RAW WATER EXPENSES													
Raw	Wesley Seale Dam	$ 1,675,089	$ 1,716,967	$ 1,759,891	$ 1,803,888	$ 1,848,985	$ 1,895,210	$ 1,942,590	$ 1,991,155	$ 2,040,934	$ 2,091,957	$ 2,144,256	$ 2,197,862	$ 2,252,809
Raw	Choke Canyon Dam	$ 792,648	$ 812,464	$ 832,776	$ 853,595	$ 874,935	$ 896,808	$ 919,229	$ 942,209	$ 965,765	$ 989,909	$ 1,014,656	$ 1,040,023	$ 1,066,023
Raw	Environmental Studies	$ 964,958	$ 989,082	$ 1,013,809	$ 1,039,154	$ 1,065,133	$ 1,091,761	$ 1,119,055	$ 1,147,032	$ 1,175,707	$ 1,205,100	$ 1,235,227	$ 1,266,108	$ 1,297,761
Raw	Water Supply Development	$ 1,227,197	$ 1,257,877	$ 1,289,324	$ 1,321,557	$ 1,354,596	$ 1,388,461	$ 1,423,173	$ 1,458,752	$ 1,495,221	$ 1,532,601	$ 1,570,916	$ 1,610,189	$ 1,650,444
Raw	Nueces River Authority	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000	$ 110,000
Raw	Lake Texana Pipeline	$ 790,713	$ 810,480	$ 830,742	$ 851,511	$ 872,799	$ 894,619	$ 916,984	$ 939,909	$ 963,406	$ 987,492	$ 1,012,179	$ 1,037,483	$ 1,063,420
Raw	Water Purchased - LNRA	$ 8,335,257	$ 8,504,345	$ 8,617,689	$ 8,790,535	$ 8,964,136	$ 9,138,181	$ 9,313,153	$ 9,538,473	$ 9,715,121	$ 9,892,989	$ 10,072,188	$ 10,252,833	$ 10,491,042
Raw	Supplemental Water Sources - Wells	$ 84,089	$ 86,191	$ 88,346	$ 90,555	$ 92,819	$ 95,139	$ 97,518	$ 99,956	$ 102,454	$ 105,016	$ 107,641	$ 110,332	$ 113,091
	Subtotal	$ 13,979,951	$ 14,287,407	$ 14,542,577	$ 14,860,795	$ 15,183,403	$ 15,510,180	$ 15,841,702	$ 16,227,485	$ 16,568,609	$ 16,915,063	$ 17,267,064	$ 17,624,831	$ 18,044,590
	EXISTING DEBT SERVICE													
Treated	ON Stevens Debt	$ 1,449,133	$ 1,448,956	$ 814,516	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-
Raw	Bureau of Rec or PL Fund	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,995,163	$ 4,208,976	$ 827,934
Raw	NRA Debt Service	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1990 Refunding: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1994 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1995 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	1999 Rev Bond: portion applicable P&I	$ 1,848,266	$ 1,847,231	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2000 Rev Bond: portion applicable P&I	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2002 Rev. Bond: portion applicable P&I (Garwood)	$ 1,100,793	$ 1,101,024	$ 1,101,143	$ 1,101,030	$ 1,100,804	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	2003 Rev. Bond: portion applicable P&I (Garwood)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw	NRA Pipeline Debt	$ 8,172,450	$ 8,169,275	$ 8,171,800	$ 8,173,925	$ 8,169,825	$ 8,168,950	$ 8,170,200	$ 8,172,475	$ 8,169,675	$ 8,012,418	$ -	$ -	$ -
Raw	LNRA - Pipeline Debt (Pumping Station)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Subtotal	$ 17,565,805	$ 17,561,650	$ 15,082,622	$ 14,270,118	$ 14,265,792	$ 13,164,113	$ 13,165,363	$ 13,167,638	$ 13,164,838	$ 13,007,581	$ 4,995,163	$ 4,208,976	$ 827,934

APPENDIX F
Desalination Alternate BD B2 (Barney Davis Intake and Discharge)

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	PLANNED DEBT SERVICE													
Treated	ON Stevens Debt	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499	$ 7,536,499
Raw	Raw Water Debt	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727	$ 1,704,727
	Subtotal	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227	$ 9,241,227
	FUTURE CAPITAL PROJECTS													
Treated	ON Stevens Replacement			$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788
	Subtotal	$ -	$ -	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788	$ 11,370,788
	SUMMARY OF COST FOR NON-DESAL FACILITIE													
	Raw Cost of Water ($ per 1,000 gallons)	***$ 1.13***	***$ 1.13***	***$ 1.06***	***$ 1.07***	***$ 1.07***	***$ 1.03***	***$ 1.04***	***$ 1.04***	***$ 1.05***	***$ 1.04***	***$ 0.79***	***$ 0.77***	***$ 0.67***
	Treated Cost of Water ($ per 1,000 gallons)	***$ 0.85***	***$ 0.84***	***$ 1.39***	***$ 1.35***	***$ 1.34***	***$ 1.34***	***$ 1.33***	***$ 1.33***	***$ 1.33***	***$ 1.33***	***$ 1.32***	***$ 1.32***	***$ 1.32***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 1.98***	***$ 1.97***	***$ 2.45***	***$ 2.41***	***$ 2.41***	***$ 2.37***	***$ 2.37***	***$ 2.37***	***$ 2.37***	***$ 2.37***	***$ 2.11***	***$ 2.09***	***$ 1.99***
	DESAL PLANT DEBT SERVICE													
Treated	Equipment	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ 4,553,660	$ -
Treated	Pipe	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586	$ 4,131,586
Treated	Structures	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397	$ 1,473,397
Treated	Other	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ 315,690	$ -
	Subtotal	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 10,474,333	$ 5,604,983
	DESAL PLANT REPAIR AND REHABILITATION													
Treated	Reverse Osmosis & Common Elements	$ 5,155,780	$ 5,284,675	$ 5,416,792	$ 5,552,211	$ 5,691,017	$ 5,833,292	$ 5,979,124	$ 6,128,603	$ 6,281,818	$ 6,438,863	$ 6,599,835	$ 6,764,831	$ 6,933,951
Treated	Pre-Treatment	$ 1,277,772	$ 1,309,716	$ 1,342,459	$ 1,376,021	$ 1,410,421	$ 1,445,682	$ 1,481,824	$ 1,518,869	$ 1,556,841	$ 1,595,762	$ 1,635,656	$ 1,676,548	$ 1,718,461
	Subtotal	$ 6,433,552	$ 6,594,391	$ 6,759,251	$ 6,928,232	$ 7,101,438	$ 7,278,974	$ 7,460,948	$ 7,647,472	$ 7,838,659	$ 8,034,625	$ 8,235,491	$ 8,441,378	$ 8,652,413
	DESAL PLANT OPERATION AND MAINTENANCI													
Treated	Power - Reverse Osmosis & Common Elements	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116	$ 7,721,116
Treated	Power - Pre-Treatment	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291	$ 64,291
Treated	Chemical - Reverse Osmosis & Common Elements	$ 1,890,670	$ 1,937,937	$ 1,986,385	$ 2,036,045	$ 2,086,946	$ 2,139,120	$ 2,192,598	$ 2,247,413	$ 2,303,598	$ 2,361,188	$ 2,420,218	$ 2,480,723	$ 2,542,741
Treated	Chemical - Pre-Treatment	$ 1,076,621	$ 1,103,537	$ 1,131,125	$ 1,159,403	$ 1,188,388	$ 1,218,098	$ 1,248,550	$ 1,279,764	$ 1,311,758	$ 1,344,552	$ 1,378,166	$ 1,412,620	$ 1,447,936
Treated	Labor - Reverse Osmosis & Common Elements	$ 1,653,441	$ 1,694,777	$ 1,737,146	$ 1,780,575	$ 1,825,089	$ 1,870,717	$ 1,917,485	$ 1,965,422	$ 2,014,557	$ 2,064,921	$ 2,116,544	$ 2,169,458	$ 2,223,694
Treated	Labor - Pre-Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Reverse Osmosis & Common Element	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Solids Handling - Pre-Treatment	$ 2,302,639	$ 2,360,205	$ 2,419,210	$ 2,479,690	$ 2,541,683	$ 2,605,225	$ 2,670,355	$ 2,737,114	$ 2,805,542	$ 2,875,680	$ 2,947,572	$ 3,021,262	$ 3,096,793
	Subtotal	$ 14,708,778	$ 14,881,862	$ 15,059,274	$ 15,241,120	$ 15,427,513	$ 15,618,566	$ 15,814,395	$ 16,015,119	$ 16,220,862	$ 16,431,749	$ 16,647,907	$ 16,869,470	$ 17,096,571
	DESAL PLANT REPLACEMENT													
Treated	Equipment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 7,461,702	$ 7,461,702
Treated	Pipe	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Structures	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Treated	Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 787,035	$ 787,035
	Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8,248,737	$ 8,248,737
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/OUT SI													
	Desal Cost of Water ($ per 1,000 gallons)	***$ 3.47***	***$ 3.50***	***$ 3.54***	***$ 3.58***	***$ 3.62***	***$ 3.66***	***$ 3.70***	***$ 3.74***	***$ 3.79***	***$ 3.83***	***$ 3.88***	***$ 4.83***	***$ 4.34***
	Desal Cost of Water ($ per acre-foot)	***$ 1,129***	***$ 1,141***	***$ 1,153***	***$ 1,166***	***$ 1,179***	***$ 1,192***	***$ 1,205***	***$ 1,219***	***$ 1,233***	***$ 1,248***	***$ 1,263***	***$ 1,573***	***$ 1,414***
	Combined Cost of Water ($ per 1,000 gallons)	***$ 2.31***	***$ 2.31***	***$ 2.69***	***$ 2.66***	***$ 2.67***	***$ 2.65***	***$ 2.65***	***$ 2.66***	***$ 2.67***	***$ 2.67***	***$ 2.48***	***$ 2.65***	***$ 2.47***
	Combined Cost of Water ($ per acre-foot)	***$ 753***	***$ 754***	***$ 877***	***$ 868***	***$ 870***	***$ 863***	***$ 865***	***$ 868***	***$ 870***	***$ 871***	***$ 806***	***$ 864***	***$ 804***
	REVENUES FROM SUBSIDIES AND WATER SALE													
	State Subsidy	$ 17,907,473	$ 17,748,121	$ 17,590,736	$ 17,435,296	$ 17,281,774	$ 17,130,146	$ 16,980,392	$ 16,832,485	$ 16,686,406	$ 16,542,129	$ 16,399,634	$ 16,258,898	$ 16,119,899
	Water Sale Revenues	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000
	Subtotal	$ 22,907,473	$ 22,748,121	$ 22,590,736	$ 22,435,296	$ 22,281,774	$ 22,130,146	$ 21,980,392	$ 21,832,485	$ 21,686,406	$ 21,542,129	$ 21,399,634	$ 21,258,898	$ 21,119,899
	SUMMARY OF COSTS FOR DESAL FACILITIES (W/ SUB													
	Adjusted Desal Cost of Water ($ per 1,000 gallons)	***$ 0.95***	***$ 1.01***	***$ 1.06***	***$ 1.12***	***$ 1.18***	***$ 1.23***	***$ 1.29***	***$ 1.35***	***$ 1.41***	***$ 1.47***	***$ 1.53***	***$ 2.50***	***$ 2.03***
	Adjusted Desal Cost of Water ($ per acre-foot)	***$ 311***	***$ 329***	***$ 347***	***$ 365***	***$ 383***	***$ 401***	***$ 420***	***$ 439***	***$ 459***	***$ 479***	***$ 499***	***$ 813***	***$ 660***
	Adjusted Combined Cost of Water ($ per 1,000 gallons)	***$ 1.75***	***$ 1.76***	***$ 2.15***	***$ 2.13***	***$ 2.14***	***$ 2.13***	***$ 2.14***	***$ 2.16***	***$ 2.17***	***$ 2.18***	***$ 1.99***	***$ 2.17***	***$ 1.99***
	Adjusted Combined Cost of Water ($ per acre-foot)	***$ 569***	***$ 573***	***$ 700***	***$ 694***	***$ 698***	***$ 693***	***$ 698***	***$ 703***	***$ 708***	***$ 711***	***$ 648***	***$ 708***	***$ 650***
	Total Annual Raw Water Cost	***$ 31,801,350***	***$ 32,104,828***	***$ 30,515,410***	***$ 30,835,641***	***$ 31,153,922***	***$ 30,379,020***	***$ 30,711,792***	***$ 31,099,850***	***$ 31,438,174***	***$ 31,627,371***	***$ 23,966,954***	***$ 23,538,534***	***$ 20,577,251***
	Total Annual Treatment Cost	***$ 47,721,125***	***$ 48,261,919***	***$ 59,552,894***	***$ 59,300,391***	***$ 59,876,667***	***$ 60,467,569***	***$ 61,073,467***	***$ 61,694,740***	***$ 62,331,778***	***$ 62,984,980***	***$ 63,654,755***	***$ 72,590,260***	***$ 68,425,099***
	Total Annual Cost	***$ 56,615,003***	***$ 57,618,626***	***$ 67,477,568***	***$ 67,700,736***	***$ 68,748,815***	***$ 68,716,443***	***$ 69,804,867***	***$ 70,962,105***	***$ 72,083,546***	***$ 73,070,223***	***$ 66,222,076***	***$ 74,869,896***	***$ 67,882,451***
	Total Annual Present Value	***$ 47,577,442***	***$ 47,823,067***	***$ 55,314,490***	***$ 54,812,277***	***$ 54,973,659***	***$ 54,269,405***	***$ 54,448,393***	***$ 54,667,702***	***$ 54,846,061***	***$ 54,910,412***	***$ 49,149,831***	***$ 54,882,190***	***$ 49,145,832***
	Cumulative Present Value	***$ 686,270,436***	***$ 734,093,502***	***$ 789,407,992***	***$ 844,220,269***	***$ 899,193,929***	***$ 953,463,334***	***$ 1,007,911,727***	***$ 1,062,579,430***	***$ 1,117,425,491***	***$ 1,172,335,902***	***$ 1,221,485,733***	***$ 1,276,367,923***	***$ 1,325,513,755***

Appendix G

Public Outreach

Appendix G-1

Public Meeting Summary

FINAL

Public Meeting Summary
Corpus Christi Large-Scale Desalination Feasibility Study
Corpus Christi Main Public Library
September 9, 2004 - 5:30 P.M.

The City of Corpus Christi hosted a public meeting to present the findings of the Large-Scale Desalination Feasibility Study. The meeting was held at 5:30 p.m. in the Retama Room at the Corpus Christi Main Public Library (803 Comanche). Invitations for the meeting were mailed to more than 280 individuals and organizations in the City's service area, including local governments, area federal and state legislators, water, navigation, and other special districts, supply corporations, well owners, petrochemical companies, environmental groups, and others that attended the project kick-off meeting in January. The invitations included meeting information and the locations where copies of the draft report were available for public viewing. .A copy of the draft report was available at: the Corpus Christi Main Public Library (803 Comanche); Corpus Christi City Hall (1201 Leopard); Coastal Bend Region Planning Group office at Texas A&M University – Corpus Christi (6300 Ocean, NRC 3300); Nueces County Library in Robstown (710 E. Main, #2); and the Sinton Public Library (100 N. Pirate Boulevard). The draft reports were available for public review from September 1 through September 17. Copies of the draft report were also available for review at the public meeting. The project team accepted written comments until September 17th, but no written comments were received.

A press release was distributed to the local news media. Mr. Eduardo Garaña P.E., the Director of the City of Corpus Christi's Water Department gave television interviews at the meeting with Channel 10-CBS and Spanish station KORO. A camera man from Channel 6-KRIS also took footage of the meeting.

Four people attended the public meeting, including Ralph Boeker from the Texas Water Development Board and Jim Tolan from the Texas Parks Wildlife Department. City staff in attendance included Eduardo Garaña and Max Casteneda. Project team members in attendance included Mark Lowry, Stan Williams from Turner Collie & Braden¸ John Seifert from LBG-Guyton Associates, Larry VandeVenter from Metcalf Eddy, and Leah Olivarri and Marco Castillo from Olivarri & Associates, Inc.

Mr. Lowry welcomed the audience at approximately 5:35 p.m. The presentation outlined the study's tasks and some of the key findings and recommendations. Following the presentation, Mr. Lowry opened the discussion for questions from the audience.

Mr. Bruce Taylor asked about the impact of trace metals in the desalination process. Mr. Lowry said the process takes a lot of the trace metals out, but removal of some trace metals are more trouble than others. Mr. Lowry deferred to Mr. VandeVenter to add to the response. Mr. VandeVenter stated that trace metals are removed in the desalination process, but the concern is with the levels of trace metals that can possibly foul up the system. Mr. Lowry added that another issue is that if the concentration of that metal is doubled then there might be problems in the by-product discharge. He noted that while a particular metal may be present in the seawater used to feed the desalination plant, it might be at a level, which would not cause a problem. Doubling the concentration through the desalination facility could produce levels that would be harmful.

Public Meeting Summary
Corpus Christi Large-Scale Desalination Feasibility Study
Corpus Christi Main Public Library
September 9, 2004 - 5:30 P.M.

Mr. Taylor also asked about impacts of aeromatic hydrocarbon in the desalination system. He asked if it was bad for the system. Mr. VandeVeter said that was correct; that an aeromatic hydrocarbon spill would be a problem for the desalination system. Mr. Lowry followed up by stating that prescribed pre-treatment process is dissolved air flotation. He said the air moving through the dissolved air flotation system is one of the better ways of driving those aeromatic hydrocarbons off, but it is still an issue.

There were no other questions. Mr. Lowry thanked the audience and the meeting concluded at approximately 6:00 p.m.

A similar presentation was given to the Corpus Christi City Council on August 24, 2004. A story that included information about the public meeting was published in the Corpus Christi Caller Times on August 25, 2004.

The same presentation was also given to the Coastal Bend Region N Water Planning Group earlier in the day on September 9.

Appendix G-2

Summary of Public Outreach Activities

Large-Scale Desalination Facility
Feasibility Study
Summary of Public Outreach Activities
September 2004

Public outreach activities have been an on-going part of the Large-Scale Desalination Facility Feasibility Study even prior to the City of Corpus Christi receiving a grant from the Texas Water Development Board (TWDB) to conduct the study. Local entities were notified of the City's grant application using a database the project team developed and used throughout the study for distributing public meeting notices. Outreach activities continued during the study, including public meetings at the study's beginning, at the 50% completion point, and at the 90% completion point, and other presentations. Additional activities included development of a project fact sheet and project information for the City's website, and media outreach. These activities are discussed below in more detail.

One element of outreach activities has been distinguishing this project from the City's Padre Island Desalination Feasibility Analysis and Siting Plan (PIDP). (The PIDP was a City-funded desalination study completed in June 2004 that assessed the feasibility and costs of constructing a three to five million gallons per day (mgd) desalination facility on North Padre Island.) While the two projects independently proceeded, information from the PIDP was used in the Large-Scale Study. As will be discussed later, information on the Large-Scale project was included in many of the public information materials distributed as part of the PIDP.

PUBLIC MEETINGS/PRESENTATIONS

Kick-Off Meeting

The City hosted a public kick-off meeting to present an overview of the Large-Scale Desalination Feasibility Study on January 8, 2004. The meeting was held at 5:30 p.m. in the City Council Chambers at City Hall (1201 Leopard Street) in Corpus Christi, Texas. Invitations for the meeting were mailed to more than 250 individuals and organizations in the City's service area, including the Region N mailing list; local governments; water, navigation, and other special districts; supply corporations; well owners; petrochemical companies; and environmental groups. Area federal and state legislators and regulatory agencies were also notified of the meeting. A press release was distributed to the local news media and other informational sources, including the Corpus Christi Chamber of Commerce and the Coastal Bend Bays Foundation. There was discussion of the meeting on a local public radio morning show, including an interview with Ron Massey, on the morning of January 8, 2004. A similar presentation on the project was also given to the Coastal Bend Region N Planning Group and the City of Corpus Christi Water Advisory Committee earlier in the day.

There was television coverage of the meeting on January 8th and 9th, including stories on all four TV channels at 10 p.m. and some at 6 p.m. Channel 28 produced its story in Spanish for its audience.

Approximately 35 people attended the meeting, including Mayor Loyd Neal, Councilman Mark Scott, and State Representative Jamie Capelo. City staff in attendance included Ron Massey, Eduardo Garaña, Scott Dunakey, and Max Casteneda. Project team members in attendance included Mark Lowry, Jerry Newell, and Stan Williams from Turner Collie & Braden; Patrick

Veteto from RVE, Inc.; and Leah Olivarri and Marco Castillo from Olivarri & Associates, Inc. Jorge Arroyo, Yujuin Yang, and Ralph Boeker, Jr. from the TWDB, and Richard Tomlinson of the U.S. Army Corps of Engineers also attended.

The following comments and questions were raised after the presentation:

- Whether the latest technology was being used and if the City was talking about treating wastewater for the project.
- Questioning the approach in the Nueces River Basin Reconnaissance Report that proposed to use desalination for mitigation for diversion of water from the Edwards Aquifer to the Gulf of Mexico.
- A comment questioning why the City needs a desalination plant.
- Mr. Arroyo, of the TWDB, discussed the impetus and process the state used to provide the grants to conduct the study. He said were there were four proposals from the area and the City was one of the three top ranked proposals and sites, along with two other sites in the state. He said the Legislature provided a framework to do this work after the Governor's report on desalination.
- A comment that this project may provide benefits to the state, but not to Corpus Christi or the Coastal Bend.
- A comment that the City seems to be in a situation where water is already taken care of. The gentleman said it seems like the desalination plant was about nine years late.
- Discussion about Tampa Bay's desalination facility.

50% Completion Point Meetings

To meet the 50% completion point meeting requirement in the City's desalination contract, the following public meetings were held:

Presentation at the Coastal Bend Bays Foundation Oso Watershed and Land Use Workshop – May 6, 2004

The Coastal Bend Bays Foundation is a public organization dedicated to the conservation of freshwater and coastal natural resources. Its members include scientists, local businesses, and representatives from environmental groups, educational institutions, local governments, and state and federal agencies. CBBF hosted a public workshop focusing on Oso Bay, including potential impacts from actions, such as the closure of the Barney Davis plant.

Since the Barney Davis plant was a site considered for the City's Large Scale Desalination Plant Feasibility Study, the CBBF invited the City/project team to create a display board for the workshop and prepare project information for the moderator's presentation. In addition to the members of the CBBF, the workshop sponsors sent invitations to landowners and homeowners near the Oso Bay, petrochemical companies, elected officials, and environmental organizations.

Approximately 50 people attended the day-long workshop, which was held at the Kings Crossing Country Club in Corpus Christi. The project team's display board was one of several boards on display at the workshop. The project manager attended and was available to answer questions about the project. A flyer with information on the additional 50% completion point meetings, which are described below, was available at the workshop.

Presentation at a Corpus Christi City Council Meeting – May 11, 2004

An additional meeting scheduled to fulfill the 50% public meeting requirement for this study included a presentation at the May 11th regularly scheduled Corpus Christi City Council meeting. The meeting began at 10:00 a.m. and was held in the City Hall Council Chambers at 1201 Leopard Street in Corpus Christi.

The presentation was posted as a meeting agenda item, and public comments were called for following the presentation. There were no public comments following the project manager's presentation.

A press release was distributed prior to the City Council meeting. The meeting was televised live on public access television the day of the meeting with repeat showings during the same week. The meeting was also available on live streaming video on the City's website for a number of days the following week.

The presentation was posted to the City's website following the City Council meeting and has remained available throughout the study. The same presentation was made at the May 13th regularly scheduled Coastal Bend Regional Water Planning Group meeting, which is discussed below.

Presentation at Region N Regional Water Planning Group Meeting – May 13, 2004

As noted above, the same presentation given at the May 11th City Council meeting was presented at the regularly scheduled Region N Regional Water Planning Group meeting on May 13, 2004. The meeting began at 1:30 p.m. and was held at the Johnny Calderon County Building at 710 E. Main Street in Robstown. Max Castaneda and Ed Garaña from the City attended the meeting. Project team members in attendance included Mark Lowry with TCB and Marco Castillo with Olivarri & Associates.

Attendees asked questions about the study's purpose and the by-product and feed source options. Preliminary cost estimates were discussed and how the study's preliminary estimates compared to costs of the Tampa Bay desalination facility. The project manager noted that the information was preliminary and additional cost data still needed to be collected.

90% Completion Point Meetings

The following meetings were held at the 90% completion point to allow public comment on the project's draft report:

Presentation at a Corpus Christi City Council Meeting – August 24, 2004

A presentation was given at the August 24th regularly scheduled Corpus Christi City Council meeting. The meeting began at 10:00 a.m. and was held in the City Hall Council Chambers at 1201 Leopard Street in Corpus Christi.

The presentation was posted as a meeting agenda item, and public comments were called for following the presentation. There were no public comments following the project manager's presentation.

A press release was distributed prior to the City Council meeting. The Corpus Christi Caller Times published a story on August 25th describing the study and the City's water supply options. The story included a side bar graphic on the public meeting held on September 9th, which is discussed in more detail below. A copy of the newspaper article and all other articles published throughout the study are attached to this summary.

The meeting was televised live on public access television the day of the meeting with repeat showings during the same week. The meeting was also available on live streaming video on the City's website for a number of days the following week.

Presentation at Region N Regional Water Planning Group Meeting – September 9, 2004

As noted above, the same presentation given at the August 24th City Council meeting was presented at the regularly scheduled Region N Regional Water Planning Group meeting on September 9, 2004. The meeting began at 1:30 p.m. and was held at the Johnny Calderon County Building at 710 E. Main Street in Robstown.

Public Meeting – September 9, 2004

A public meeting was held on September 9, 2004 to present the findings of the Large-Scale Desalination Feasibility Study. The meeting was held at 5:30 p.m. in the Retama Room at the Corpus Christi Main Public Library (803 Comanche). The purpose of the meeting was to allow the public to comment on the project findings before the final report was distributed to the TWDB.

Invitations for the meeting were mailed to more than 280 individuals and organizations in the City's service area, including local governments, area federal and state legislators, water, navigation, and other special districts, supply corporations, well owners, petrochemical companies, environmental groups, and others that attended the project kick-off meeting in January. The invitations included meeting information and the locations where copies of the draft report were available for public viewing. A copy of the draft report was available at: the Corpus Christi Main Public Library (803 Comanche); Corpus Christi City Hall (1201 Leopard); Coastal Bend Region Planning Group office at Texas A&M University – Corpus Christi (6300 Ocean, NRC 3300); Nueces County Library in Robstown (710 E. Main, #2); and the Sinton Public Library (100 N. Pirate Boulevard). The draft reports were available for public review from September 1st through September 17th. Copies of the draft report were also available for review at the public meeting, and the report was posted to the City's website. The project team accepted written comments until September 17th, but no written comments were received.

A press release was distributed to the local news media prior to the public meeting. Mr. Eduardo Garaña P.E., the Director of the City of Corpus Christi's Water Department gave television interviews at the meeting with Channel 10-CBS and Spanish station KORO. A cameraman from Channel 6-KRIS also took footage of the meeting.

Four people attended the public meeting, including Ralph Boeker from the Texas Water Development Board and Jim Tolan from the Texas Parks Wildlife Department. City staff in attendance included Eduardo Garaña and Max Casteneda. Project team members in attendance included Mark Lowry, Stan Williams from Turner Collie & Braden¸ John Seifert from LBG-Guyton Associates, Larry VandeVenter from Metcalf Eddy, and Leah Olivarri and Marco Castillo from Olivarri & Associates, Inc.

Following the presentation, a gentleman asked about the impact of trace metals and the impact of aeromatic hydrocarbons in the desalination process.

Other Presentations

Additional presentations to different groups throughout the project provided valuable feedback. The public involvement team helped set up presentations for City staff at the Coastal Coordination Council (CCC) Executive Committee meeting in October 2003 and at the full CCC meeting in December 2003. City staff provided an overview of the Large-Scale study, the Padre Island Study, and a third desalination study that the City of Corpus Christi is partnering with other local government entities to conduct.

In January 2004, at the request of City staff, the public involvement team updated the City's Water Resources Advisory Committee on the public outreach activities for the Large-Scale project and the City's Padre Island Desalination Study. Presentations were also made at the Texas Water Development Board's (TWDB) Workshop on Desalination in Texas on March 25, 2004, in Austin and at the General Land Office Coastal Issues Conference on March 10, 2004, in Corpus Christi.

PROJECT FACT SHEET

A project fact sheet was developed shortly after the study began. The two-sided, one page fact sheet provides an overview of the study and project tasks and an expected timeline. Information distinguishing this study from the City's Padre Island Desalination project was included to help distinguish the two projects.

MEDIA OUTREACH

Media outreach has helped provide information to the public at key project milestones. As previously noted, press releases were distributed to the media before all public meetings and City Council presentations. As a result, local newspapers published multiple project-related stories throughout the study. And, as previously noted, there were multiple news stories throughout the project on major local news stations in English and Spanish. Some non-local newspapers also published stories during the study. As previously noted, attached to this summary are copies of the newspaper articles that were published throughout the study.

CITY WEBSITE

Project information was developed and posted to the City's website under a desalination link in the Water Department's information page. This section also includes links to desalination information available on the Texas Water Development Board's website.

The City website was one of the outreach tools used to help differentiate this study from the City's Padre Island desalination study. The information was updated at project milestones and progress reports were added as they became available. And, as previously noted, the draft report on the study's findings was posted to the website in September 2004 for public review. The website can be accessed at: www.cctexas.com/?fuseaction=main.view&page=1790.

Appendix G-3

Newspaper Clippings

City explores water supply options

Colorado River may be major source in future

By Neal Falgoust Caller-Times

August 25, 2004

With the Gulf of Mexico at Corpus Christi's doorstep, it might seem like the city would never have to worry about its source of drinking water.

But the city still is exploring the best ways to use gulf water as part of the city's water supply.

City officials already have dismissed the construction of a small, locally owned desali-nation plant as too expensive, but they continue to examine the possibility of securing money through a special ini-tiative by Gov. Rick Perry to build a much larger plant.

Public hearing on desalination

A hearing will be held on the city's study of a large desalination plant at 5:30 p.m. Sept. 9 in the Retama Room of the Corpus Christi Central Library, 805 Comanche St. Comments also may be sent to Mark Lowry, P.O. Box 130089, Houston, TX 77219-0089, or by e-mail to mark.lowry@tcb.aecom.com.

Perry, in Corpus Christi Tuesday to discuss tort reform, took some time to dis-cuss potential water sources for the Texas Gulf Coast.

"The fact is that all along the Texas Gulf Coast, the possi-bility for 'desal' is excellent and we could be looking for-ward to years ahead for a sub-stantial supply of potablewa-ter that comes from the Gulf of Mexico."

City Council members on Tuesday reviewed the various efforts they are taking to secure reliable sources of water for the city.

Those efforts include tap-ping into the Colorado River, cooperating with other agen-cies to get that water to Cor-pus Christi and working with the state to build a large desalination plant on Padre Island.

Having a secure source of water is essential to econom-ic development and growth. If there is no reliable supply of water, businesses will not move into a community, and the city will not be able to sup-port a growing population.

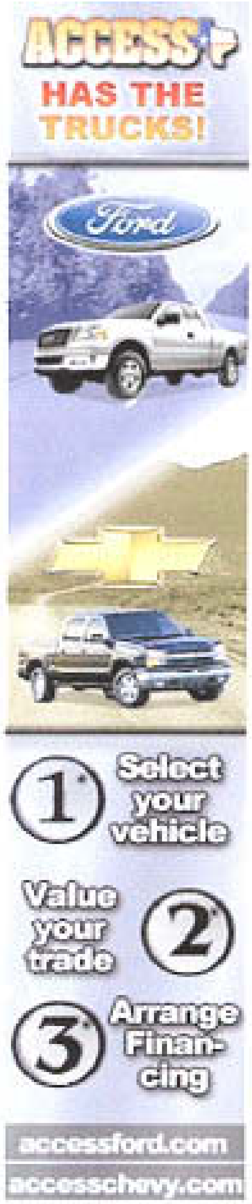
Consultant Mark Lowry told the council that every 1,000 gallons of water from the Gulf of Mexico would cost about $5 to clean and send to customers for home use.

Using pipelines to tap into other sources, such as the Col-orado River, would cost half as much, he said.

Council members also met with the Lower Colorado River Authority to discuss ways they could cooperate to move water from the Colorado River to Lake Texana, where the 101-mile Mary Rhodes Pipeline begins its journey to Corpus Christi.

"It is in our best interest to work together," Mayor Loyd Neal said.

LCRA general manager Joe Beal said it doesn't matter how much water Corpus Christi



has the right to in the Colorado River if it has no way to get it to city residents.

"It's one thing to have the paper water rights," he said. "It's another thing to try to move that water."

The city staff will continue working on both the state desalination project and the effort to tap into the Colorado River.

Alison Beshur contributed to this report. Contact Neal Falgoust at 886-4334 or falgoustn@caller.com

Caller.com

URL: http://www.caller.com/ccct/state_texas_news/article/0,1641,CCCT_876_3089137,00.html

Governor calls for big water desalination project

August 5, 2004

SAN ANTONIO- Texas should take the lead in converting seawater to freshwater by building the nation's first big coastal desalination plant, Gov. Rick Perry said Thursday.

Perry, addressing the American Membrane Technology Association, said the state's water supply is in good shape, but future population growth, economic development and fickle weather will require Texas to find new and reliable supplies.

"The question to me is not, 'Are we going to use salt water as a source of potable water in the state of Texas?'" Perry said. "My question is, 'When and where is it going to occur?'"

The trade group comprises companies that develop technologies for treating water and wastewater.

In 2002 Perry began pushing for testing of the idea of large-scale water desalination along the Gulf of Mexico. Experimental projects are in their early phases in Corpus Christi, Freeport and Brownsville.

Texas already has dozens of inland desalination units that can process up to 40 million gallons of brackish water per day into usable water for industry and municipalities, according to the Texas Water Development Board's Web site.

A state water plan issued in 2002 states that hundreds of communities in Texas could face water shortages in the next 50 years unless demand is cut or new sources found.

"Why wait until the need is the greatest?" Perry told the trade group. "Now is the time to be addressing all of these issues."

Caller.com

URL: http://www.caller.com/ccct/kris_tv/article/0,1641,CCCT_995_2878473,00.html

Corpus Christi Hopes to Lure Desal Plant

By Aaron Drawhorn, KRIS-TV
May 11, 2004

Three Texas cities, including Corpus Christi, are in the running to land a desal plant.

The facility would be a huge boost to our local economy and allow the City of Corpus Christi to sell water to other cities and counties in Texas.

The city hopes to soon be in the business of converting seawater to freshwater.

Water woes would not be as much a problem if salt water could be converted to fresh water.

Having a desal plant in Corpus Christi would bring millions of gallons of flowing water and along with it a nice cash flow for the city.

"This is a big opportunity for Corpus Christi to be one of the key players with water over the next 50 to 100 years," said city councilman Mark Scott.

This is a complex $130 million project, but the idea behind it is very simple.

Basically you take salt water. Then the water goes through a powerful filtration process.

What you end up with is pure water that's good enough to drink, as well as salty water that's saltier than before. As a byproduct, it has to go back into the ocean ten miles.

The Barney Davis plant in Flour Bluff is one possible location for the desal plant.

Everything is contingent upon the state legislature and funding.

But Corpus Christi has some competition.

Brownsville and Freeport also want to build a desal plant, and there's only enough money for one.

"We probably have come further in water planning than those two areas, so I think we have a real opportunity to succeed here," Scott said.

If this becomes a reality in Corpus Christi, the city likely will sell water to San Antonio, Laredo, central Hays County, and southern Williamson County.

First they must get the word from Austin, and now they must wait.

"If a suitable subsidy is found to make the project cost effective, then construction could conceivably start in about two years," said a water expert Mark Lowry.

If Corpus Christi gets the desal plant, construction would last about five years.

This story is written and published by KRIS Communications. Please send your comments to newsroom@kristv.com.

San Antonio Express-News
Sunday
April 18, 2004
Section B

Brownsville tests the waters of desalination

By Jerry Needham
Express-News Staff Writer

BROWNSVILLE — With a sea of salty water at its doorstep, there's no mystery why this fast-growing region is embracing desalination as a new source of drinking water.

But instead of diving in, Texas' southernmost city is dipping a toe.

A new 7.5-million-gallon-a-day treatment plant, which was dedicated earlier this month, is not tackling the saline water of the Gulf of Mexico.

It's taking a cheaper route — tapping into an underground aquifer whose salt levels are a tenth of those found in seawater.

And Brownsville is not alone.

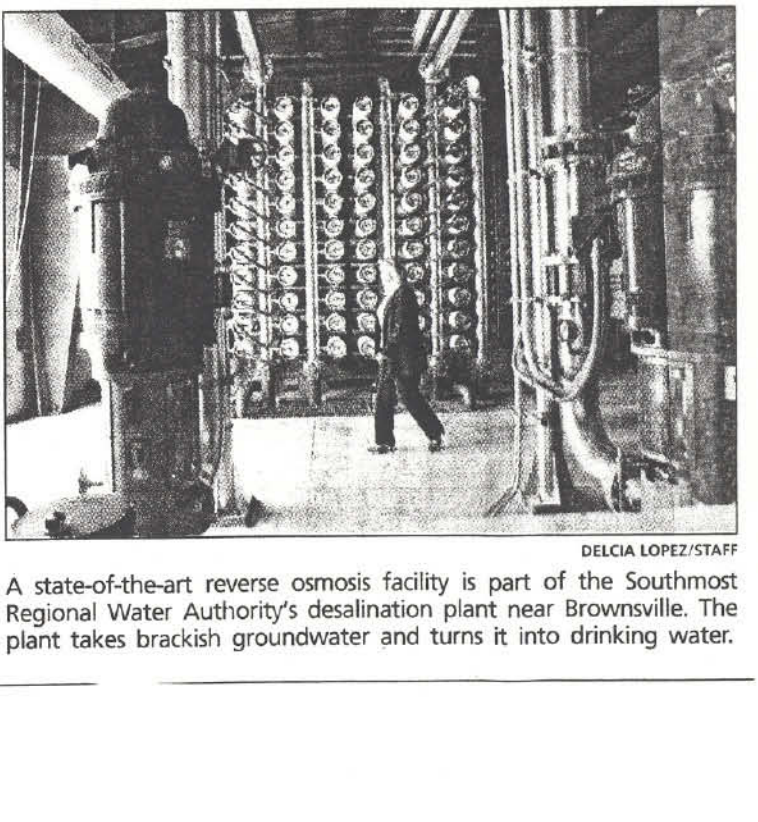
Dozens of similar plants have sprung up across Texas in recent years as growth has outpaced traditional water sources and the cost of desalination technology has dropped.

Even San Antonio is studying the idea.

"Up to now, the technology has been expensive," said Hari Krishna, a senior engineer and desalination specialist at the Texas Water Development Board. "It's only now that desalination is becoming more affordable and competing in cost with other sources. As other sources get depleted, the alternatives become fewer."

Brownsville for years has depended only on the meandering flows of the increasingly strained Rio Grande and the 10 days worth of water the city could

See BROWNSVILLE/8B

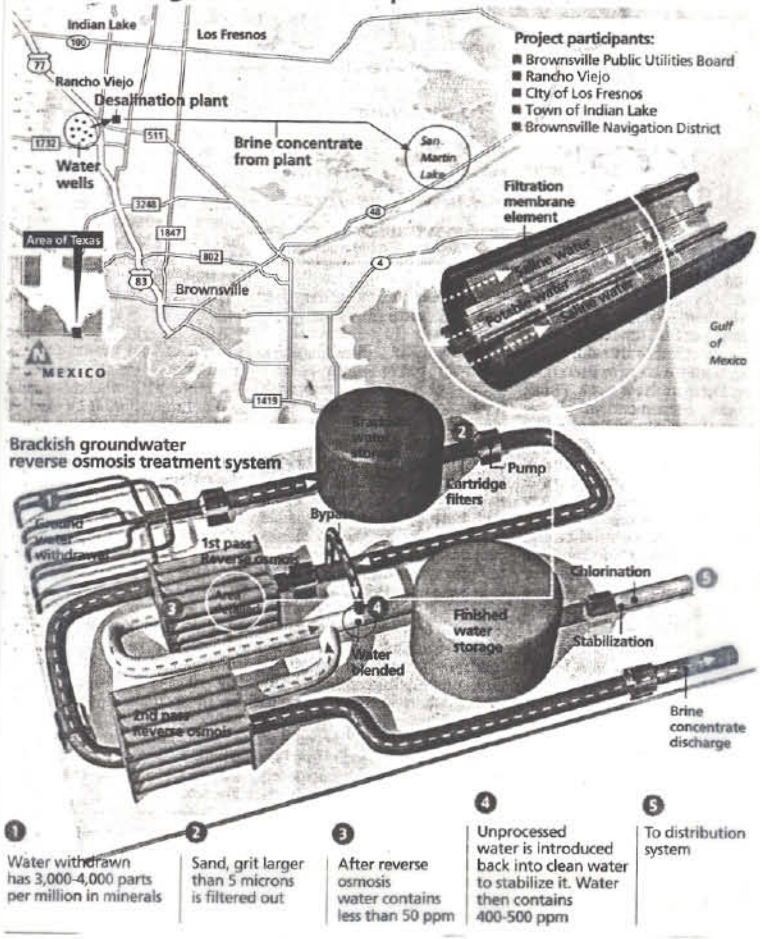


DELCIA LOPEZ/STAFF

A state-of-the-art reverse osmosis facility is part of the Southmost Regional Water Authority's desalination plant near Brownsville. The plant takes brackish groundwater and turns it into drinking water.

Page 1 of 2

Southmost Regional desalination plant



FELIPE SOTO/STAFF

Brownsville tries desalination

CONTINUED FROM 1B

sock away in its two tiny riverside reservoirs during times of high water.

The problem with that approach became painfully clear when the drought-stressed river quit flowing into the gulf for several months in 2001 and 2002.

With the new $21.1 million plant up and running, the city finally has a drought-proof source of water.

Twenty wells now pump from 350 feet deep in the salty edge of the Gulf Coast Aquifer.

Brownsville, which is a partner in the project with Rancho Viejo, Los Fresnos, Indian Lake and the Port of Brownsville, is only the latest to tap into brackish water previously thought unusable.

Krishna said officials expect to see more cities and industries desalinating groundwater, even as the state moves toward its first seawater desalination plant.

More than 100 plants in Texas now desalinate water, all of them using either brackish groundwater or surface water, Krishna said.

Among Texas municipal suppliers that get at least part of their water from desalinating groundwater are the El Paso County Water Authority, Fort Stockton, Electra, Kenedy and Seadrift.

In addition, Sherman, Lake Granbury, Granbury and Robinson treat salty river water or lake water.

The amounts aren't inconsequential — Sherman treats 26.4 million gallons a day, Lake Granbury 14.2 million and Fort Stockton 12.7 million.

Dozens of smaller systems are in place at schools, churches, convenience stores and other small businesses where municipal water is not available.

El Paso Water Utilities, which also depends chiefly on the overworked Rio Grande, is planning a plant with Fort Bliss that will process 29 million gallons a day.

The San Antonio Water System is studying whether it's feasible to withdraw and treat saline water from the Edwards Aquifer.

The concern is whether pulling water from the salty portion of the limestone formation would lower water levels in the freshwater portion, from which San Antonio gets most of its water supply.

In Texas, there's plenty of brackish groundwater, defined as water with salinity between 3,000 and 10,000 parts of minerals per million parts of water.

A year-old study commissioned by the water development board concluded there are 2.7 billion acre-feet in the state.

In 2000, 17 million acre-feet were used in the state for all purposes.

The Brownsville plant is desalinating and distributing its water at a cost of $1.60 per 1,000 gallons — just below the $1.66 it was already charging customers.

The piping for the system was oversized so the plant capacity can be tripled, and the cost for additional production could be as low as $1.20 per 1,000 gallons, said John Bruciak, general manager of both the Brownsville Public Utilities Board and the Southmost Regional Water Authority, which owns the plant.

Three coastal communities — Brownsville, Corpus Christi and Freeport — are proposing 25-million-gallon-a-day seawater desalination plants.

The state, which provided the three with $500,000 grants to refine their proposals, is expected by year's end to announce continuing financial support for one of them.

But taking salt out of seawater is more expensive because of the higher salt concentrations and the environmental problems of disposing of the brine produced as waste.

The brackish groundwater that Brownsville is tapping into has salinity levels between 3,000 and 4,000 parts per million, said Michael Myers, project manager for NRS Consulting Engineers, which designed and oversaw construction of the project.

The salt levels in seawater range from 30,000 to 40,000 ppm.

"A lot of people say 'Why don't you just go to seawater? There's an unlimited supply.'" Myers said. "They don't understand the economics and the difference in treatment and discharge."

The current costs to treat seawater range from $2.60 per 1,000 gallons to $4 per 1,000, depending on power for the facility and the difficulty in disposing of the brine, officials said.

The warmer the water, the more efficient the salt-removal process, so the cheapest plants work in tandem with electricity-generating plants, treating the warm water used to cool power plant turbines.

The $21.1 million cost of the Brownsville project was more than the $16.8 million it would have cost to buy the river rights necessary to produce the same amount of water.

"Of course, even if you buy the water rights, if the water supply's not available you cannot get the water," said Genoveva Gomez, operations director for the Brownsville utility. "We couldn't depend on that."

But most importantly, Bruciak said, the project diversifies the region's water sources and "conserves for the Rio Grande region more than 7.5 million gallons of surface water per day, flows that will go far to helping maintain instream flows and protecting habitat."

The plant, scheduled to hit full production by June, will provide 40 percent of the water now used by each of the partners.

To the 6 million gallons of purified water the Brownsville plant produces daily, it will add back in 1.5 million gallons of brackish water to stabilize the product before it mixes with the treated river water now circulating in the city's pipes, Myers said.

It will daily send about 1.5 million gallons of brine into a nearby drainage ditch that runs 6 miles to a lake that drains into the Brownsville Ship Channel.

jneedham@express-news.net

Page 2 of 2

CALENDAR

around theAREA

Public meeting will focus on desalination

The city of Corpus Christi will have a public meeting at 5:30 p.m. Jan. 8 to provide an overview of a study on the feasibility of a large desalination plant.The meeting will be in the Council Chambers at City Hall, 1201 Leopard St.

The study is being funded by a grant the city received in 2003 from the Texas Water Development Board. The study envisions a 25-million-gallon-per-day desalination on the mainland. Locations for the plant will be analyzed in the study.

The city was one of three sites awarded a $500,000 state grant in 2003 to conduct studies as part of Gov. Rick Perry's initiative to assess the potential desalination of seawater to help meet the state's regional water needs, city officials said.

Corpus Christi Caller-Times
10/29/03

SECTION

B

around the AREA

CORPUS CHRISTI

Council votes to use grant for desalination

The Corpus Christi City Council voted 8-0 Tuesday to accept a Regional Facility Planning Grant and use the funds to further study the possibility of a large-scale seawater desalination demonstration project.

The grant, awarded in September by the Texas Water Development Board, was awarded to help communities prepare regional water facility plans focusing on seawater desalination projects.

The Council also voted to contract Turner, Collie & Braden Inc., a Houston engineering firm, to develop a plan for the project.

Corpus Christi gets a $500,000 water grant

Luna believes city is the best location in Texas for a desalination facility

By Ty Meighan Scripps Howard Austin Bureau
September 17, 2003

AUSTIN - The Texas Water Development Board on Wednesday approved three $500,000 grants, including one for Corpus Christi, to help communities prepare regional water facility plans focusing on seawater desalination projects.

In addition to Corpus Christi, the Brazos River Authority and the Brownsville Public Utility Board received grants.

The money is intended to assist the communities in identifying the need for the projects, cost-effectiveness and whether there are buyers for the water. The study also will determine requirements for implementing the seawater desalination projects.

Corpus Christi's proposed project is in the Coastal Bend Regional Water Planning area with primary emphasis on the retail and wholesale customer service area of the city.

State Rep. Vilma Luna, D-Corpus Christi, was the author of a bill last session that directed the water development board to study the feasibility of seawater desalination in Texas.

"I believe Corpus Christi is the best location in Texas for a seawater desalination plant," Luna said. "We have easy access to bay waters, an established water-delivery infrastructure, and excellent institutions of higher education that can conduct the research essential to maintaining a technologically advanced desalination plant."

Luna has been working with the governor's office and the water development board to make the case that Corpus Christi is the ideal site for a desalination plan.

"Our state's long-term prosperity depends on our ability to ensure a supply of water that is safe, easily replenished and drought proof," Gov. Rick Perry said Wednesday. "These grants move us one step closer to that goal."

Meanwhile, the water development board also approved 32 nominees for membership to a statewide group that will examine water conservation efforts in Texas.

State lawmakers created the Water Conservation Implementation Task Force this year in a bill sponsored by state Sen. Robert Duncan, R-Lubbock. Task force members include environmentalists to higher education officials.

The task force will recommend optimum levels of water use and conservation for Texas.

The group will compile a best management practices guide for regional water planning groups and political subdivisions responsible for water delivery service no later than Nov.1, 2004.

Specifically, the group will:

"TRY KEEPING 280 ARMS AND LEGS IN TOTAL CONTROL ALL THE TIME."

- CATHY WHEAT, DIRECTOR, HIGHLAND BELLES TXU ENERGY CUSTOMER

n Identify, evaluate and select best management practices for municipal, industrial, and agricultural water uses and evaluate the costs and benefits of these practices.

n Evaluate the proper role for state funding of incentive programs to facilitate the implementation of these practices.

n Evaluate the implementation of water conservation strategies recommended in regional and state water plans.

n Consider a possible statewide public awareness program for water conservation.

n Recommend a standard methodology for reporting and using per capita water use data

n Evaluate the appropriate state oversight and support of any conservation initiatives adopted by the Legislature

Appendix H

Comments to the Draft Report and Responses

Attachment A

Copy of Comments Provided Electronically on September 23, 2004

Comment

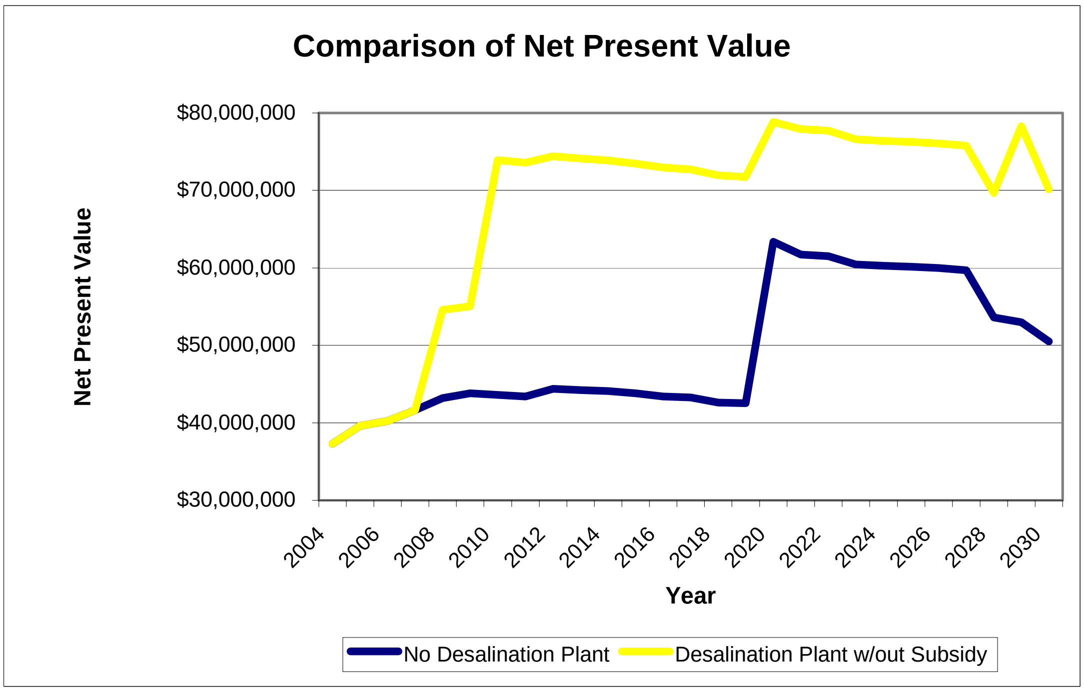
1. For comparative consistency between the three proposed projects, please provide the total cost difference between implementing the currently approved water management strategies and seawater desalination.

   a. Provide the net present value of this cost differential over the life of the first phase of the project.

   Response to 1.a

   The differential of net present value varies significantly over time when comparing a proposed desalination alternative versus a no desalination alternative. *Figure 1* illustrates the differential in net present value over the study period between the desalination and no desalination alternatives.

Figure 1



In addition, *Table A* below summarizes the differential in net present value between the desalination and no desalination alternatives for each planning decade over the study period. As indicated, the differential in net present value ranges from a high of approximately $30 million in 2010 to a low of approximately $15 million in 2020.

Table A

	Year			
	2004	**2010**	**2020**	**2030**
Net Present Value No Desalination	$37,308,195	$43,628,181	$63,358,997	$50,509,291
Net Present Value Desalination	$37,308,195	$73,946,414	$78,848,686	$70,147,146
Net Present Value Differential	$0	$30,318,233	$15,489,689	$19,637,855
Net Present Value Differential (per acre-foot)	$0	$1,083	$553	$701

b. Identify and consider any offsetting income resulting from sales related to surplus water rights and/or surplus water resources generated by the desalination project.

Response to 1.b

The analysis assumed an offsetting income of $5 million annually from the sale of surplus water supplies of an equal volume to that being treated at the proposed desalination facility (i.e., 28,000 acre-feet per year). *Table 10-4-3* in *Chapter 10* of the draft feasibility report provides a summary of projected subsidies required to make desalination costs neutral compared to a no desalination alternative for the City. Of the total subsidies projected in *Table 10-4-3*, $5 million is assumed to be derived from the sale of excess water supplies. *Table B* provides details regarding projected subsidies and surplus water supply sales.

It is noted that the projected subsidy reported in *Table B* was calculated using the cost model developed for this study. The subsidy was determined by calculating the subsidy required to make the total cumulative net present value for both the desalination and no desalination alternatives equal. By doing this, the amount of subsidy required was more equally distributed over the entire study period as opposed to varying significantly for each planning year or decade. This methodology provides a more effective comparison of the three proposed desalination projects.

Table B

	Year			
	2004	**2010**	**2020**	**2030**
Subsidy from Surplus Water Sales	$0	$5,000,000	$5,000,000	$5,000,000
Subsidy from Surplus Water (per acre-foot)	$0	$179	$179	$179
Subsidy from Other Sources	$0	$24,466,335	$24,528,677	$24,583,737
Subsidy from Other Sources (per acre-foot)	$0	$874	$876	$878
Total Subsidy	$0	$29,466,335	$29,528,677	$29,583,737
Total Subsidy (per acre-foot)	$0	$1,053	$1,055	$1,057

c. Identify and consider any other costs that would have to be addressed if the seawater desalination project is implemented; such as debt on existing facilities that may become redundant as a result of the desalination project.

Response to 1.c

Existing and projected future City debt services for water facilities were included in the cost model developed for this study in *Chapter 10* and *Appendix 10-A*. The current situation with the City of Corpus Christi is that they have adequate water facilities in the near term. The addition of the desalination facility would allow the City to avoid the future costs of constructing facilities to convey Colorado River water from the Colorado River to the Intake Pump Station at Lake Texana. The spreadsheet model shows the cost of the conveyance in the No Desalination alternative and it is deleted from the Desalination alternative.

d. Calculate and report the corresponding cost differential as dollars per acre-foot.

Response to 1.d

See responses to 1.a and 1.b above.

Additional Comment and Information

In a phone conversation between the consultant team and the Texas Water Development (TWDB), the TWDB requested that cost information be calculated in a manner similar to other consultants working on other related projects, so that costs and required subsidies can be easily compared. TCB held extensive conservations with the other consultant team members to determine their calculation methodology and as a result has prepared the following for comparison to other related reports. All of these costs in the following table are based on present worth costs for the year 2004.

PROJECTED COSTS AND SUBSIDIES

PROJECTED COSTS	
Projected Cost of Water (Current System – No Desal)	$1.78 / 1000 gallons
	$580 / Acre-Foot
Projected Cost of Desalted Water	$3.51 / 1000 gallons
	$1,142 / Acre-Foot
Project Cost of Combined System	$2.61 / 1000 gallons
	$851 / 1000 gallons
PROJECTED SUBSIDIES REQUIRED	
Equivalent Annual Subsidy	$24.5 million
Equivalent Unit Subsidy ($ / 1000 gallons)	$2.69 / 1000 gallons
Equivalent Unit Subsidy ($ / Acre-Foot)	$876 / Acre-Foot

Comment

2. Please provide a breakdown of the water production and transmission cost (net present value) in dollars per acre-foot, as follows:

    a. Treatment
        i. Debt service
        ii. Operations and maintenance costs
            - Chemical
            - Membrane replacement
            - Power costs
            - Miscellaneous
            - Labor

    b. Transmission
        i. Debt service
        ii. Operations and maintenance costs

Response to 2.a – 2.b

Please note that the costs provided in *Table C* do not include costs associated with future major system replacement costs at the end of the service life. The significantly lower present value indicated for year 2030 is due to the reduction in debt service as the original capital expenditures and associated principal and interest are paid off. The 2030 net present value on a per acre-foot basis would likely be more in line with the 2010 and 2020 unit costs if these future replacement costs were included.

Table C

Cost Component	Year			
	2004	**2010**	**2020**	**2030**
Treatment				
Debt Service	$0	$9,269,427	$8,186,581	$1,633,065
Debt Service (per acre-foot)	$0	$331	$292	$58
Chemical	$0	$2,283,447	$2,518,658	$2,778,097
Chemical (per acre-foot)	$0	$82	$90	$99
Membrane Replacement	$0	$1,095,588	$1,208,441	$1,332,919
Membrane Replacement (per acre-foot)	$0	$39	$43	$48
Power	$0	$6,680,731	$5,756,567	$4,960,245
Power (per acre-foot)	$0	$239	$206	$177
Miscellaneous	$0	$5,355,972	$5,907,674	$6,516,206
Miscellaneous (per acre-foot)	$0	$191	$211	$233
Labor	$0	$1,271,646	$1,402,634	$1,547,115
Labor (per acre-foot)	$0	$45	$50	$55
Transmission				
Debt Service	$0	$5,879,140	$5,192,344	$4,585,779
Debt Service (per acre-foot)	$0	$210	$185	$164
Operations and Maintenance	$0	$834,532	$898,434	$990,979
Operations and Maintenance (per acre-foot)	$0	$30	$32	$35
Total Combined System				
Total Combined	$0	$1,167	$1,109	$869

A breakout of the costs by plant component and O&M component is provided for FY 2004 and FY 2010 in the following table.

Table D

Capital Costs	2004	2010	Annual O&M	2004	2010
Raw Water	$39,453,000	$40,439,325	Labor/Subcontract Services	$1,199,000	$1,228,975
Pre-Treatment	$30,186,000	$30,940,650	Power	$7,306,000	$7,488,650
Primary Treatment	$61,874,000	$63,420,850	Chemicals	$2,152,000	$2,205,800
Concentrate Disposal	$26,923,000	$27,596,075	Miscellaneous	$5,826,000	$5,971,650
Transmission	$2,037,000	$2,087,925	Total Annual O&M	$16,483,000	$16,895,075
Implementation Costs	$36,192,000	$37,096,800	Membrane Replacement	$1,032,000	$1,057,800
Total Cost	$196,665,000	$201,581,625	Total Annual Operating Costs	$17,515,000	$17,952,875

Comment

3. Regarding the subsidy requirements described in the draft report; please confirm the amount of subsidy, length over which it would be applied, and what would be the equivalent amount in dollars per acre-foot when considered over the life of the initial phase of the project.

Response to 3

As discussed in responses to 1.a and 1.b above, the annual subsidies required to make a desalination project cost neutral to the City of Corpus Christi consisted of an assumed $5 million revenue source from the sale of 28,000 acre-feet per year of surplus water supply plus approximately $24 million in subsidies from other, not specified, sources. From review of *Table A* provided in response to 1.a above, the net present value differential (or required subsidy) varies significantly over the planning period. For purposes of a more effective comparison of the three proposed desalination projects, the spreadsheet cost model developed for this study utilized a program routine to solve for the annual subsidy based on the constraint that the total cumulative present value over the study period for both the desalination and no desalination alternatives would be equal. This methodology provides for a more equally distributed subsidy over the study period (i.e., approximately $1,055 per acre-foot) and allows for the development of a single subsidy amount based on net present value that can be used to more easily compare the three proposed projects.

Comment

4. The draft feasibility report mentions recent discussions with Topaz Power Partners regarding conditions under which desalination could occur at the Barney Davis facility; it indicates that a letter from the power company was expected. What is the status of the letter?

Response to 4

A letter was provided by William Nelson, Project Development Manager, Sempra Energy Resources, on behalf of Topaz Power Partners, dated July 29, 2004. This letter details the areas in which Sempra and Topaz are interested in further discussions with the City of Corpus Christi concerning the development of a desalination facility on the Barney Davis Plant Site. The letter expresses a willingness to discuss a number of issues including provision of a site for the desalination facility, allowable discharge to the cooling ponds, and consideration of modifications to the existing intake and discharge permits to facilitate a desalination plant. The letter notes that all of these items are subject to the development of a suitable contract between the City of Corpus Christi and Topaz Power Partners. A copy of this letter will be included in the final report. **See Appendix D-1.**

Comment

5. Regarding the intake and pretreatment system, please indicate clearly what options were evaluated, the selected system(s), and why they were chosen.

Response to 5a

a. Intakes

Three intake concepts were evaluated for this project. The optimized alternatives used the existing intake structure at the Barney Davis Power Plant. Other intake concepts considered included open sea intakes and infiltration intakes. All intake options must allow the transport of the raw water to the treatment plant site. For any option that uses the Gulf of Mexico as the raw water source, the raw water line must cross Padre Island and Laguna Madre. This raw water line is an expensive pipe that would be constructed through an environmentally sensitive area. The selection of the intake must be based on the raw water source location and consider quality, environmental impacts, the intake technology, and costs. Therefore, the intake selection is only a component of the entire alternate of which it is a part. No single intake option is optimum for all alternates.

i. Existing Barney Davis Intake

The primary alternative developed for the project did not initially include the use of the existing intake at the Barney Davis Power Plant because of the uncertainty regarding ownership of the facility. The original owner was attempting to sell the power plant and did not want to encumber the site with any commitments that might inhibit the sale of the property. Also, the long-term operation of the Barney Davis Power Plant was in question.

In addition to the questions regarding ownership, the design team had developed a desired baseline water quality of 35,000 mg/l as a target for raw water to be treated. The Laguna Madre water used at the Barney Davis Power Plant for cooling has extended periods of time when salinities are above 35,000 mg/l, and efforts were directed at determining the availability of either brackish groundwater to blend with the Laguna Madre water to meet the 35,000 mg/l salinity limitation. These efforts were unsuccessful due to the lack of availability of groundwater with appropriate levels of total dissolved solids.

For all of the reasons noted above, the primary alternatives were developed based on not using the existing intake at the Barney Davis Power Plant.

Several days before the project was finalized, it was learned that the sale of the Barney Davis Power Plant had been consummated and the new owners intended to be cooperative with the concept of co-locating a desalination facility onsite including use of the existing intake facilities. As a result of change in ownership status, the recommended Barney Davis site alternate was optimized to include the use of the existing intake facilities. For the optimized alternates, all modifications necessary to obtain raw water were included in other on-site facilities and no changes or modifications are anticipated for the intake. The benefits of using the existing intake are somewhat offset by the necessity of increasing the plant size to handle the higher salinities during dry weather conditions.

ii. Open Sea Intake

The open sea intakes consist of an onshore fine screen and a pipeline from the shore to the appropriate intake location terminating at the open sea inlet structure.

The open sea inlet structure has coarse screens with very low screen velocities, debris intake, and impingement, and it is constructed of concrete. This structure will be located on the sea floor and extend vertically to rise above the height of vegetation in the area. A 7-foot structure height was chosen for the analysis.

The pipeline between the open sea intake and the onshore fine screens uses high density polyethylene (HDPE) pipe. The sea bottom floor will be wet dredged to a sufficient depth to fully bury the pipe. A granular bedding and backfill will be provided to support the pipe, and a protective rock barrier and anchor will be placed over the top of the pipe. After construction, the finished grade of the sea floor will be returned to its original grade with the rock protective barrier as the finished grade material.

A fine screen assembly will be located onshore to screen finer particles from the intake stream. Multiple isolated screen assemblies will be used to allow periodic maintenance of these screens without affecting intake operations. Periodically these fine screens will be purged with a violent blast of air. The purged material will then be drained and the solid material removed from the purge stream. The cleansed purge stream will be returned to the open sea. The fine screens are located in a structure onshore to facilitate maintenance operations and shield the violent purging operations from sea traffic. If uncontained, the magnitude of the air blast could cause harm to small boats. Also, locating the fine screen onshore eliminates the need for the raw water pipeline to be designed for the high pressures required to deliver the air purge.

iii. Infiltration Intakes

Infiltration Galleries

Infiltration gallery intakes generally consist of drawing water through the existing or constructed soils to an onshore receptor, then pumping the water to the point of use. With infiltration galleries, the soils surrounding the collector pipes act as the screening device. The passageways through the soils have very small openings that remove nearly all of the particulate matter from the seawater, thus producing a relatively high quality raw water stream. The alternates that use the infiltration gallery intake concept have a greatly reduced pre-treatment requirement because of the high degree of filtering provided by soils surrounding the collector pipes. Three types of infiltration gallery intakes were considered: caissons, linear collection wells, and Ranney collectors.

Caissons

Caisson infiltration galleries, also called vertical beach wells, are vertical shafts constructed as close to the shore as feasible to be close to the water source. These shafts could be 60 feet or more in depth with a spacing of 300 or more feet. The number of vertical beach wells would need to be developed based on the soils structure in the area, but it is estimated that at least 40 wells would be required. The 55-mgd intake capacity required for this desalination facility is more than twice the capacity of the largest known vertical beach well plant intake system in the world. This intake concept was not used in the development of any alternates because of questionable long-term reliability, cost, high maintenance requirements, and large onshore land area requirements.

Linear Collection Wells

Linear collection wells are an enhanced version of the vertical beach well. Vertical caissons are constructed, but the collection system is enhanced by horizontal collector pipes being buried parallel to the shoreline. All construction is performed onshore. Water is still drawn through the indigenous soils, and the capacity of the system is dependent on the soils structure. This option used six caissons and 39,000 linear feet of horizontal collector pipes. This intake concept was not used in the development of any alternates because of questionable long-term reliability, cost, high maintenance requirements, and large onshore land area requirements.

Ranney Collectors

The Ranney collector infiltration gallery is an enhanced version of the linear collection well. Caissons are constructed onshore and horizontal collector pipes are constructed under the seabed. Each caisson can accommodate multiple collection legs to reduce the number of caissons. The Ranney collector configuration was used in the alternatives because it significantly reduced the amount of shoreline required to be dedicated to the intake system. The collector pipes could either be constructed by jacking techniques or could be wet dredged in a manner described in the open sea intake. If the collector pipes are jacked into place, the permeability of the existing soils would be the limiting factor on the number as well as the size and length of the collector pipes. If the collector pipes are installed with wet dredging techniques, the backfill and bedding materials can be manufactured and constructed to optimize intake performance. The alternates that used infiltration galleries for the intake are based on using the Ranney collector type infiltration gallery. The size and length of the collector pipes are based on using the jacking techniques for installation. The costs for this intake system were estimated using 39,000 linear feet of collector pipe.

Intakes Summary

The intake options that were used in the development of alternates included the existing Barney Davis intake, the open sea intake, and the Ranney collector intake. The Vertical Beach Well and Linear Infiltration Wells were eliminated for the reasons previously stated.

The existing Barney Davis intake is the optimal intake choice because it already exists, it is permitted, and its configuration is compatible with the desalination facility. This intake does not require the construction of an expensive raw water line through Laguna Madre and Padre Island or into the Gulf of Mexico. However, the water available at this location is from Laguna Madre and is hypersaline. The hypersalinity of the water increases the capital and operating costs of the system, which partially offsets the savings from using the existing facilities. However, even accounting for these offsetting factors, the use of the existing Barney Davis intake is the recommended intake concept if a final agreement can be reached with the property owners.

The open sea intake is considered the next most viable intake primarily because of the long-term reliability compared to the Ranney collector system. The cost of the open sea intake is less than the cost of constructing the Ranney collector, but the reduction in pre-treatment requirements makes the Ranney collector less costly on a total life cycle basis for the evaluation of a complete alternate.

Response to 5b

b. Pre-Treatment

Seven candidate pre-treatment options were identified for consideration including:

1. Direct filtration (eliminated prior to prescreening as not applicable)
2. Conventional flocculation, sedimentation, and filtration
3. Solids contact clarification (Accelator) and filtration
4. Plate or tube settler clarification and filtration
5. Pulsator or Superpulsator clarification and filtration
6. Dissolved air flotation (DAF) clarification and filtration
7. Micro-sand enhanced clarification and filtration
8. Ultrafiltration using immersed membranes (Zenon)
9. Infiltration galleries

After the prescreening process, which is described in detail in the feasibility report, four pre-treatment options were selected for detailed evaluation:

Option 1 – Plate or tube settler clarification with filtration
Option 2 – Dissolved air flotation clarification with filtration
Option 3 – Ultrafiltration using immersed membranes (Zenon)
Option 4 – Infiltration galleries using the Ranney collector

Option 4 is more precisely referred to as an intake system as described in the response for 5a, but the screening process inherent to the system greatly reduces the pre-treatment requirements on the plant site.

Option 1 – Plate or Tube Settler Clarification and Filtration

Plate or tube settlers followed by granular media filtration are well proven in drinking water treatment. These systems have been used in seawater reverse osmosis and can be considered as a base-line approach capable of treating worst-case water quality. The enhancements of the tube or plate settlers results in a much smaller process footprint than for conventional sedimentation. Tube and plate settler clarified turbidity may be slightly higher than for conventional sedimentation, but low turbidities are still achieved through subsequent filtration. Residuals concentrations are in the range of 0.1-0.5 percent solids. Plate and tube settlers are susceptible to rapid changes in water temperature and have limitations in treating high turbidity and algae. The tube openings in tube settlers can become blocked with algae and solids which creates short-circuiting and deterioration in clarifier performance. Plate and tube settlers are being replaced with more advanced and innovative technologies as described under the following options 1-4. Because tube settlers have been used effectively for seawater reverse osmosis (SWRO), they are included in the feasibility analysis as a "baseline" alternative of accepted practice.

Option 2 – Dissolved Air Flotation (DAF) Clarification and Filtration

DAF can achieve very low clarifier effluent turbidities of <0.5 NTU. DAF can achieve a high level of performance even without using a polymer, which can be an advantage in pre-treatment ahead of reverse osmosis (RO). DAF is not susceptible to thermal variation and has demonstrated significant advantages in treating very cold (dense) water, thus DAF may be very effective in treating high density seawater. Another important advantage of DAF clarification is that it has proven to be the premier clarifier for treating large concentrations of algae, which are notoriously difficult to settle. This may be a distinct advantage in treatment of seawater where red tides or algae may be of concern. DAF followed by granular media filtration can easily treat the expected worst-case raw seawater quality.

Another potentially important advantage of DAF is that it can produce a residual concentration of up to 2 percent solids when mechanical extraction is used. This sludge concentration is about 4 times the maximum solids concentration achievable with plate, tube, Accelator, or sludge blanket clarifiers. Mechanically extracted DAF residuals can be fed directly to dewatering processes such as belt filter presses or centrifuges without further thickening.

DAF is extremely well proven from pilot tests conducted for large plants as indicated by designs for Boston, Massachusetts at 450 mgd and the New York City Croton Water Treatment Plant at 290 mgd. When the DAF is located above the filtration units, the maximum surface loading rate of both the DAF and the filter must be limited to less than 5 gpm/sf. For the reasons above, DAF clarification followed by granular media filtration is included as the most robust and favorable high rate clarification technology to be considered in this analysis. The "stacked" DAF is evaluated in the feasibility report and is the most advantageous configuration for reducing plant footprint.

Option 3 – Ultrafiltration Using Immersed Membranes

Membrane microfiltration (MF) and ultrafiltration (UF) (low pressure hollow fiber membrane treatment) technologies have developed rapidly over the last 5 years. In immersed UF systems, the membrane fibers are immersed in the raw or coagulated water, and a vacuum is applied to the lumen of the fibers to draw the water through the membrane and into the lumen.

UF membranes provide physical removal of solids, particles, algae, and physical disinfection by removal of pathogens such as *Giardia*, *Cryptosporidium* and some viruses. Unless a coagulant is used, UF membranes do not remove color or organics. MF and UF have demonstrated effectiveness for providing low silt density indices (SDI) ahead of high-pressure membrane processes such as nanofiltration (NF) and reverse osmosis (RO), resulting in greater NF and RO process efficiency. There is some limited experience for MF and UF in seawater pre-treatment.

Because of the high degree of benefit that can be realized by using the Zeeweed process as a full replacement for both clarification and filtration and the proven robustness of the process, the Zenon Zeeweed 500D UF was selected for analysis as the immersed ultrafiltration process for comparison to the conventional pre-treatment approach using tube settler clarification and filtration and DAF and filtration. Other approaches using other types of UF as a "filtration" replacement may be considered in the future when the plant is sited, water quality is confirmed, and residuals disposal options are known.

Option 4 – Infiltration Galleries

Bank filtration without pre-treatment was included in this feasibility study to capture the potential least cost process alternative with assumed worst-case water quality. A bank infiltration system is conceptualized to provide "physical" pre-treatment ahead of the RO. The Infiltration galleries considerations are presented in the previous section on "Intakes."

Summary of Pretreatment Options

Four alternates for each treatment site were developed based on selecting compatible combinations of intakes, off-site pipeline, pre-treatment, and common elements (common elements included the reverse osmosis components). A weighted prioritization method was used to evaluate the alternatives using total life cycle cost, reliability, and complexity of implementation as the decision criteria.

The intake pre-treatment combination using infiltration galleries was the least cost alternative, but this option received low marks for reliability and complexity of implementation. Tube and plate settlers and the DAF system have similar life cycle costs, but the DAF pre-treatment was determined to be more reliable than the tube and plate settler options. The immersed UF membrane was the most costly of the pre-treatment options, but it scored favorably in the reliability of treatment and complexity of implementation.

Based on the information available, the alternatives using DAF appeared to be the optimum pre-treatment options for the Corpus Christi Desalination project. It should be noted that in view of the cost competitive nature of this application and the long-term trend of decreasing costs of micro- and ultra-filtration membranes, the immersible membrane should also be considered for any future developments.

Comment

6. Please include site maps to clearly show intake location, desalination plant operations and outfall location.

Response to 6

A site map showing the intake location, desalination plant and outfall location is presented in *Figure 8-1.4-1* attached at the back of this document.

Comment

7. Please summarize the options/locations considered for concentrate disposal, and what was the basis for selecting an outfall at a two-mile distance?

Response to 7

Several potential options for concentrate (byproduct) disposal were considered including deep well injection, evaporative lagoons, offshore discharge, membrane-thermal zero liquid discharge, beneficial reuse, and dilution and discharge to Oso Bay.

Deep Well Injection

Deep well injection required the construction of a minimum of 25 to 30 widely spaced wells with an estimated capacity of 1 mgd each. In addition to the wells, well distribution lines and high pressure injection pumps operating at approximately 1000 psi are required. The cost of this byproduct disposal option was very high and was eliminated from further consideration.

Evaporative Lagoons

Evaporative lagoons were considered. In this option, large lagoons are constructed to contain the water until it is evaporated to atmosphere leaving only the salts behind. To evaporate 25 to 30 mgd of byproduct water would require a land area of 38,000 acres. The estimated cost for purchasing the land and constructing a lined lagoon system is over $2 billion, and therefore is not considered a feasible solution.

Offshore Discharge

Offshore discharge is considered the most straightforward and reliable method of byproduct disposal. Although significant and important environmental concerns will have to be addressed, it is intuitively apparent that discharging to the Gulf of Mexico offers the greatest opportunity for environmental support. The byproduct stream will have a TDS concentration of twice the ambient conditions, but proper design of diffusion outfalls should minimize environmental impacts. The final location of the outfall will require further investigation.

The design of the outfall is important to assure that environmental impacts are minimized and that the discharged material does not migrate back to the intake area at concentrations higher than normal ambient conditions. To accomplish these features, the outfall needs to be located at the proper depth and distance from shore and sufficiently remote from the intake. To minimize cost, most of the discharge outfall pipe is constructed in the same trench as the intake line, but diverges at the appropriate location to attain the proper separation distances.

The relative locations of the outfall and discharge pipes must be determined by detailed hydraulic modeling during subsequent design phases. For this assessment, an estimate of ¼ mile (1400 feet) separation distance was determined to be reasonable for planning purposes.

The byproduct outfall needs to be located in water deep enough to avoid conflicts with marine traffic but also shallow enough to benefit from mixing that results from surface wave action. For mixing and diffusion, a maximum water depth of 40 feet was chosen.

Two types of currents predominate in the Gulf of Mexico in this area, riptides and wind driven currents. Riptides predominate along the coast and are generally contained within one-half mile of the shoreline. Riptides close to shore must be avoided to prevent the discharge from recirculating and possibly concentrating toward the shore. The wind driven current in the area is known as the Texas Coastal Current. The Texas Coastal current will aid in the mixing and dispersion of the byproduct stream and prevent the discharge from reaching the intake structure.

The 2-mile offshore distance was chosen as the optimum location in consideration of depth and currents in the area as described above and to ensure that riptides do not interfere.

Discharge to a Wastewater Treatment Plant

Discharging the byproduct to a wastewater treatment plant was considered but quickly determined not to be viable. The byproduct stream will have a flow of approximately 25 mgd and a total dissolved solids concentration of 70,000 mg/l. The largest wastewater plant in the area, the Oso Treatment Plant, has a rated capacity of 16.2 mgd, and the effluent is used to dilute the hypersaline conditions in the bay. If the plant could be made to accommodate the proposed byproduct stream, the resultant dissolved solids concentration would be approximately 49,000 mg/l and would negatively impact the Oso Bay salinity. This option was determined not to be feasible due to the negative salinity impact, and therefore was eliminated.

Membrane-Thermal Zero Liquid Discharge (ZLD)

Zero liquid discharge technologies involve concentrating the byproduct stream to essentially dry salts and disposal of the dried cake residue. Research indicates that this technology is the most expensive of all byproduct disposal options, and is only considered viable when a valuable byproduct can be recovered. Due to the cost of this option and the lack of a reliable, long-term customer for the concentrated byproduct salts, this option was eliminated.

Beneficial Reuse

During the site selection investigations, a potential customer for concentrated seawater salts was found near the Oxychem site. The customer is currently trucking in concentrated saltwater at a concentration of 300,000 mg/l to use as a feedstock for their manufacturing facility. The processes to concentrate the byproduct to the desired concentration are similar to but not as extensive as the previously mentioned ZLD technology. In addition to the high cost of this option, the entire operations of the desalination facility would be dependent on the economic viability of the product being manufactured by the byproduct concentrate customer. This option was determined not to have satisfactory reliability to be the sole disposal method for the byproduct stream, and therefore was eliminated from consideration.

Dilution and Discharge to Oso Bay

The Barney Davis Power Plant currently has the ability and permits to withdraw over 500 mgd of water from Laguna Madre for cooling and then discharging the warmed water through cooling ponds and released into Oso Bay. Oso Bay is a flow limited body of water, and the continued circulating flow from the cooling tower operations is considered highly beneficial, even though the salinity of the discharge is higher than background conditions in Oso Bay. The byproduct stream from the desalination facility is approximately 25 mgd with a salinity of

70,000 mg/l. Combining the cooling water discharge with the byproduct stream would increase the salinity of the discharge to Oso Bay by approximately 5 percent. This option represents a significant cost savings from all other options and should be considered in all future discussions and evaluations.

Summary

Of all the options for byproduct stream disposal, the open sea outfall is determined to be the most reliable. Diluting the byproduct stream with the cooling water and discharging the blended stream to Oso Bay offers a potentially significant cost savings but faces environmental issues that must be addressed. Both of these options are carried forward in the detailed evaluations and cost modeling performed for the Corpus Christi Desalination Demonstration Study.

Comment

8. TWDB will likely include the Executive Summary of your report as part of the Future of Desalination in Texas report that will be submitted in response to the TWDB's statutory requirements contained in Texas Water Code §16.060. We would like to suggest that the current summary contained in your report be enhanced to a level of quality similar to that employed in the City of Corpus Christi report entitled *Padre Island Desalination Plant, Feasibility Analysis and Siting Plant*, dated June 2003 and prepared by Carollo Engineers.

Response to 8

TCB's practice is to provide a true executive summary document and to hold that document to a minimum length. Based on what is contained in the report cited above, we understand that you want a stand-alone project summary that provides significantly more detail than a true executive summary provides. We will modify our summary to include the desired additional details. **See Executive Summary.**

Attachment B

Texas Water Development Board Staff Review Comments

The following comments are those of TWDB staff. They are broken down by category (contract compliance and technical) and represent the formal comments of the TWDB and should be addressed by the contractor before producing a finished product. Additionally and without any performance obligation, there are some suggestions that the contractor may want to consider. These are listed separately and are meant to help provide a more thorough or readable product.

CONTRACT COMPLIANCE COMMENTS

Comment

1. Consistent with Scope of Services, Task I "Site Selection," Item A, describe the buffer zone requirements for a desalination facility.

Response

Buffer zone requirements for a desalination facility are similar to other types of water plants. Buffer zones are generally included in the design of a treatment plant to be respectful of the surrounding land uses typically in regard to noise, odor, visual nuisances, prevention of contamination and for the protection of environmental resources. The facilities in the feasibility report were developed in regard to the buffer zone concepts as described in the following list.

a. Noise. All large, high-speed rotating equipment and other potentially noisy facilities are enclosed so that significant noise levels do not extend offsite.
b. Odor. The desalination plant is not anticipated to have any odor causing processes, chemicals, or substances.
c. Visual. The visual plant components are anticipated to be treatment structures such as tanks, and buildings. These components are similar to other facilities in the surrounding areas and are not anticipated to cause a visual concern or distraction to neighbors. If determined to be necessary during subsequent project phases, visual barriers can be constructed to address visual concerns, though this is not anticipated at this time.
d. Contamination. All water streams on the plant site after the pretreatment step is contained within covered tanks and equipment or sealed within pipes. Contamination from offsite sources is not anticipated.
e. Environmental. The sites reviewed during the siting analysis were all located on industrial sites that have been at least partially developed and maintained. No known environmental concerns requiring buffer zones were identified during these investigations. Environmental studies will be conducted in future project phases.

The proposed desalination facilities are not anticipated to be required to comply with any more stringent buffer zone requirements than that required under the Texas Commission on Environmental Quality Chapter 290 *Rules for Public Drinking Water Systems.* A review of the TCEQ Chapter 290 regulations did not reveal any specific buffer zone requirements for Public Water Treatment Systems. If during future development stages, buffer zone requirements are identified, the site layout may have to be modified to accommodate these issues, though none are anticipated at this time. Therefore, anticipated buffer zones are anticipated to be designed for perimeter maintenance and vehicular access to all facilities on site.

Comment

2. Consistent with Scope of Services, Task 2, "Selection of Primary Treatment and Concentrate Disposal Processes," Item F, discuss the likely impacts on use of the potential desalination source waters on other water resources, including other management strategies.

Response

The development of new water from a desalination facility on the coast has a number of potential impacts on other water resources. Desalinated seawater is the ultimate drought proof supply, provided that the environmental issues associated with management of the byproduct water can be overcome. Use of desalinated seawater as the base flow for the City of Corpus Christi allows the City to maximize its use of interruptible supplies upstream and to conserve stored water for a longer period of time. This allows the system to use water from more high flow periods where the withdrawal is less of an environmental concern for instream and bay and estuary flows. Such a facility would potentially reduce the stress on inland rivers and streams by developing more water from the coastal areas.

Corpus Christi and its regional customers have an adequate supply of water for the next 50 years, although not all of the necessary infrastructure is in place to deliver that water.

The financial analysis of the desalination facility versus no desalination facility assumes that the City would contract some of their surplus water, with the obvious choices being either from the Garwood rights on the Colorado River or the Choke Canyon rights in the Nueces Basin. Water could be diverted from the Colorado River at Bay City and sent to the Greater San Antonio area as a part of the larger LCRA/SAWS agreement identified in the Region L and Region K regional plans. Pipelines that are already proposed for this project could be enlarged to carry the additional 35,000 acre feet of water from the City's Garwood rights. The impact on other water resources of this diversion would be a positive impact on the in stream flows of the Colorado River as this water would be in the river all of the way to Bay City, and then a decrease in the flow going into Matagorda Bay equivalent to the amount of water diverted. If diverted, this water would be treated and used in the San Antonio area and at least a portion of it would probably end up as wastewater effluent discharged into the San Antonio River basin and would contribute to instream flows in that basin after discharge.

A second option for contract sales of surplus water would be diversion from Choke Canyon Reservoir and a pipeline to the Greater San Antonio area from there. In this instance, there would be a reduction in instream flows in the Nueces Basin below Choke Canyon Dam as a result of the movement of this water out of the basin. There would also be some reduction in losses of water in the streambed of the Nueces between Choke Canyon and Lake Corpus Christi as a result of the earlier diversion.

There are some direct impacts on management strategies for the Corpus Christi area and Region N that would be felt if a desalination facility were built. The Garwood pipeline that would move water from the Bay City area to the Lake Texana pump station would not have to be built by Corpus Christi as a management strategy to deliver the Garwood water. As an alternative, this pipeline might be constructed by San Antonio and water diverted from the Bloomington Pump Station to be mixed with water from the Lower Guadalupe Diversion for delivery to the San Antonio area. This would constitute an impact on both the Region N and Region L plans. The financial analysis of the desalination facility assumed that the costs of this pipeline, currently scheduled tentatively for the 2020 time period, would be avoided by Corpus Christi.

A second alternative would be to include the water from the Garwood rights in the pipeline and pump stations further upstream that might be developed as a part of the LCRA/SAWS Water Sharing Plan. Under this plan, water may be diverted from the Colorado River as far upstream as the Bastrop area. Again, the costs would be avoided in the Region N plan and would be covered in the Region L plan along with the estimated raw water contract costs.

Comment

3. Consistent with Scope of Services, Task 4, "Identification and Assessment of Project Partnerships," Item D, describe the key aspects of the proposed partnership with Topaz Power. List any meetings or any other type of direct communications with San Antonio representatives concerning potential water supply partnerships.

Response

Topaz Power Partners has purchased the Barney Davis plant and intends to continue to run the plant as a power generation facility. As a result of that purchase, representatives for Topaz have indicated that they are willing to provide a site for the desalination facility on the Barney Davis Plant property. They have also indicated that they are willing to work with the City and the desalination plant project developers to amend the withdrawal permit to include municipal use in addition to the once through cooling currently permitted. In addition, they have agreed in principal to the discharge of the desalination plant byproduct water into the main cooling ponds for the power plant, and the amendment of the discharge permit for those ponds to include the byproduct. The issues of the intake and discharge permits may be a moot point if intake and discharge takes place in the Gulf as the primary desalination plant configuration option assumes at present.

However, location of the desalination facility at the Barney Davis site benefits from a controlled access facility, proximity to power lines and gas lines for plant use, and other features common to industrial facilities, even without the intake and discharge issues. It should be noted that all of the above items are subject to the development of a suitable agreement between the City of Corpus Christi and Topaz Power Partners.

There have been a number of direct interactions between City of Corpus Christi and SAWS staff related to the development of scope items and shared participation in the costs of a Corps of Engineers Feasibility Study of the Nueces Basin. Staff from both entities have participated in this process, which includes some aspects of desalination facility resource management issues. These negotiations have resulted in a Federal Cost Sharing Agreement among the Department of the Army, the Nueces River Authority, the City of Corpus Christi, the San Antonio Water System, the San Antonio River Authority, and the Guadalupe Blanco River Authority. This agreement was executed on September 24, 2004. A copy of the agreement is included as a part of the response to questions. In addition, there is an ongoing dialogue between the two entities related to the current recharge dams in the San Antonio area, as well as proposed recharge dams that SAWS is looking at as a management strategy for enhancing recharge to the Edwards Aquifer. Discussions have been held at the staff level concerning the potential reduction in the surface water flows that belong to the City of Corpus Christi through the recharge dam projects. Corpus Christi staff have noted that there will be mitigation required if surface water flows that comprise the City's water rights are reduced. One of the mitigation options that has been put on the table is the possibility that SAWS would pay a portion of the desalination plant facility costs in exchange for the reduced surface water flows caused by the recharge dams. As additional information is learned from the feasibility study of the Nueces and the studies on the Aquifer Recharge projects, then additional attention will be paid to the issue of potential water sales from Corpus Christi to SAWS and how the potential mitigation will factor into those sales agreements.

Comment

4. Consistent with Scope of Services, Task 5, "Identification and Assessment of Potential Customers," Item D, address potential benefits to upstream water users resulting from seawater desalination in the Corpus Christi area.

Response

The City of Corpus Christi and its regional customers currently rely on supplies that are a considerable distance from Corpus Christi. Some of those supplies are strategically located in such that upstream customers could benefit by diverting water supplies that would have otherwise been used by Corpus Christi. Development of reliable supplies of freshwater from seawater brings a new source of supply that does not involve flooding prime bottomland hardwood habitat and taking land away from farm families who have lived on it for generations. Many of the potential inland reservoir sites that are left for development of surface water supplies will have limited yield and significant environmental concerns, so the development of new water that does not add to the development pressures of inland sites is a significant benefit. Although costly at present, desalinated water costs are comparable to or less than many new inland reservoir costs when the costs for surface water treatment are included.

If Gulf water desalination is viable, the existing pipeline operated by the City of Corpus Christi could even be operated in a reverse flow situation, and water delivered from new desalination plants all along the coastline back towards Lake Texana. Finally, the more interest and attention that desalination receives in full scale operations, the more innovation and improvements are likely. Lessons learned in full scale seawater desalination plants can be used in brackish groundwater desalination as well, which will further benefit upland water users.

Comment

5. The Scope of Services, Task 8, "Cost model to include funding shortfalls and the need for supplemental funding" includes a subtask to "Assemble cost indexes of estimated prices of natural gas and other items that impact the operational cost of the facilities." Include a discussion in the report of the expected cost trends based on this information.

Response

Prices of commodities that have an impact on the desalination industry were determined in two ways. For most of the chemicals, materials, supplies, etc, the costs were projected based on the recent historic inflation of approximately 2.5 percent per year. This percentage was applied uniformly by year to project future costs.

The cost of electricity is a significant portion of the operations and maintenance costs for a desalination facility. In addition, the cost of electricity does fluctuate in response to market pressures and fuels costs. The United States Energy Information Agency website was reviewed to determine the long term forecast for natural gas prices as a surrogate for electricity costs for the desalination industry. This forecast runs through 2025, and shows a mild fluctuation in gas prices, with a very slight upward trend. Forecast fuel prices for electricity generators were shown as $5.01/1000 cubic feet in 2025, as compared to $5.73 in 2003 and $4.59 in 2004. Forecast prices fall as low as $4.12/1000 cubic feet and are as high as $5.10 during the forecast period.

In addition to the information reviewed above, the TCB team was provided with a confidential document by Topaz Power Partners as a part of their assistance to the City of Corpus Christi on this project. Officials for Topaz required that TCB staff sign a confidentiality agreement concerning release of this material. However, they did agree to discussion of the results in the report. The document was a report on wholesale power prices from now until 2025 that Topaz had paid an independent consulting firm to perform for them as a part of their investigation into the purchase of the Barney Davis Plant. This projection provided a reasonably flat outlook for wholesale power prices which was similar to the natural gas price prediction. In addition, the power cost used by the TCB team assumed a separate retail power provider being responsible for retail power provision to the City of Corpus Christi. The City of Corpus Christi is still exploring the option of setting up their own retail power firm, or of encouraging the South Texas Aggregation Project (STAP) to apply for status as a power retailer. In either event, the cost of the retailing of power could be less than estimated by the TCB team. For all of the above noted reasons, the power cost used was flat throughout the life of the desalination facility.

The above text is proposed for inclusion in the final report.

TECHNICAL COMMENTS

Comment

6. The executive summary should include information on the selected water intake for the plant, and the selected pre-treatment process.

Response

The Executive Summary has been modified to include this information.

Comment

7. Pretreatment options are discussed Chapter 4 from page 39-93, pages 120-127, and pages 136-137. The report should include a clear statement on what pre-treatment option was selected and why.

Response

This comment and others suggest that the techniques used in the development of recommendations for the proposed desalination facility be explained in greater detail. The major facilities comprising the desalination facility were determined to be the intake, the pretreatment system, the reverse osmosis system, and the byproduct disposal method. Several options were described in detail in the report for the intake, pretreatment and byproduct disposal systems. Advantages, disadvantage, and costs of each option were explained in the appropriate report sections. Pipeline corridors, as opposed to detailed routing studies, connecting the facilities were identified and appropriate costs and concerns detailed. It was determined that no one option was universally the best option for the intake or the pretreatment available options. Each of the options would impact other components comprising a complete system. Therefore, it was not possible to select the most appropriate or cost effective intake or pretreatment option without considering the impacts on the entire desalination program.

Based on the foregoing considerations, the analysis technique that was used is based on selecting various combinations of compatible facility components for each site, taking advantage of the potential synergies of the selected combinations. For example, the report clearly points out that the infiltration intake systems are more expensive than open sea intakes. However, the infiltration impact options result in a drastic reduction in the onsite pretreatment requirements. Therefore, eliminating the infiltration intake based on a stand-alone analysis against other intake systems would not have been appropriate. As a result, we developed a comprehensive list of total project alternatives that encompassed the potential synergies of combining various components. The resulting Alternatives evaluations analyzed complete alternatives, not individual components.

The selected alternative was Alternate BD 2, which is located at the Barney Davis Power Plant and consists of an open sea intake, dissolved air flotation pretreatment, reverse osmosis system, and offshore byproduct disposal. This was not the lowest cost option. The open sea intake was chosen in combination with the dissolved air flotation pretreatment primarily because of the reliability of these options. A detailed explanation of the evaluation techniques used in selecting the Alternate is contained in Section 6 of Chapter 4 beginning on page 147. The presented prioritization of alternates should be frequently evaluated in future project phases as more information becomes available.

Therefore, within the context of the above explanation, dissolved air flotation (DAF) is the selected pretreatment option. The DAF process is the most robust of the treatment options evaluated, provides the best removal efficiencies of algae (including red-tide), has the smallest footprint, and the lowest cost for the onsite treatment options. The lowest cost alternate that included infiltration galleries and limited onsite pretreatment was marked down in the analysis because of low long-term reliability and the massive shoreline requirements for construction and maintenance.

Comment

8. In the body of the report, through Chapter 4, page 118, it is still difficult to determine what type of intake is being recommended. This should be discussed early in the report, followed by pre-treatment.

Response

The response to the previous question provides a detailed explanation of the analysis techniques used in the development of Alternates for this project. It is suggested that the reader review the previous comment-response to develop an understanding of the evaluation techniques used in this study before continuing with the review of this response.

The Commenter suggests that the selection of the intake can be made purely on the merits of the various intakes options without regard to the impacts that the intake has on other components comprising a complete system. The analysis technique chosen and presented in the report develops several complete Alternatives comprising all of the facility components. By using this technique, the reliability and cost of the entire facility is not dictated by the individual components but instead allows the synergy of the combination of components to be realized.

The selected Alternate BD 2 uses an open sea intake with a DAF pretreatment system. This was not the lowest costs system. The bank infiltration intake with limited plant-site pretreatment, Alternate BD 4, was the lowest costs system but was marked down due to low reliability of long-term performance and a large shoreline area required for construction and maintenance. A detailed explanation of the evaluation techniques used in selecting the Alternate is contained in Section 6 of Chapter 4 beginning on page 147.

The presented prioritization of alternates should be frequently evaluated in future project phases as more information becomes available. It is noted in the report that a few days before the report was completed, it was learned that the sale of Barney Davis Power Plant was consummated and that the new owners would be willing to consider sharing resources of the site, including the existing intake facility. This late change affects the overall viability of the project and offers the potential savings of millions of dollars associated with the construction of the open sea intake, raw water pipeline, and raw water pump station. A brief analysis of the impacts was developed and included in the report beginning on Chapter 4 page 155.

If the project goes forward to subsequent phases, the recommended Alternate BD 2 including the open sea intake should be carried forward as the principle Alternate, however, significant consideration should be provided to the development of the same alternate using the existing Barney Davis Intake and Pumping Facilities as described in optimized Alternates BD A2 and BD B2.

Comment

9. The report should provide additional details on the recommended desalination system. The system is indicated as a two-pass system, reverse osmosis plus nanofiltration. List other options considered and describe why this option was decided to be the best. Include figures or drawings explaining the layout of the five skids (RO system), and how they would be linked to the rest of the system.

Response

Reverse osmosis is the state of the art in seawater desalination facilities. Other systems, such as mechanical, charged, or heat based systems are appropriate only in very limited applications such as low salinity applications, or where energy is significantly cheaper than in the United States. The Desalting Planners Guide supports reverse osmosis as the least cost seawater desalination technology for all plant sizes. This is a conceptual level feasibility study. Sufficient level of detail has been developed upon which to base comparative cost estimates. See additional responses below on the selection of a two-pass approach.

A Process flow diagram of the reverse osmosis system is provided in *Figure 4-3.2.5-1* on page 105 of Chapter 4 and attached at the end of this document. This process flow diagram begins with the product water stream from the pretreatment facility as it enters the intermediate transfer clearwell. This diagram also shows the transfer pumps from the intermediate clearwell, chemical feed systems in the transfer line, in-line static mixer, a pre RO cartridge filter system, the high pressure RO feed pumps, the 1st and 2nd pass desalination facilities, byproduct disposal and recycle streams, post treatment chemical feed systems and in-line mixers, the disinfection and finished water storage tanks and the high service pumps to the distribution system. Additional labeling of these facilities will be provided to enhance the clarity of this diagram.

Because this is a feasibility study and not a detailed design, the level of detail provided by the process flow diagram was determined to be adequate at this stage of the project.

Comment

10. Include detailed site maps, plans or drawings to show the conceptual project, starting with intake, and ending with finished water storage.

Response

These drawings are already contained in the Report. The system in the recommended alternate consists of an open sea intake, a raw water pump station, plant site improvements, byproduct disposal, and interconnecting piping and pumping for a complete and working system. The drawings of the proposed recommended facilities are shown as indicated below.

Intake	see attached ”Profile of Sea Intake” “Sea Intake Pipe Section”
Raw Water Pump Station	see “Raw Water Pump Station Typical Section” “Raw Water Pump Station Plan”
Plant Site (All site components)	See attached “Pre-Treatment Option 2 DAF FlowFilters”
Overall plan (All components)	see 1st figure attached at end of this document

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Comment

11. Please note that Figure 4-2.2-1 does not match its description.

Response

Noted. The final report will be modified to include the correct figure.

Comment

12. On page 145 of Chapter 4, following cost analysis, four alternate choices are indicated for the two preferred sites. Two of them are "recommended for further evaluation." Clarify if these two were selected based only on cost or other considerations.

Response

Chapter 4 - Section 6 – pages 147 to 156 present a detailed description of the evaluation techniques including the identification and prioritization of the evaluation criteria and all eight evaluated Alternates. The procedure used is based on a Multidimensional Weighted Evaluation Matrix technique.

Comment

13. The total present worth of the desalination project is estimated at $415.6 million in Chapter 4, and as $1.835 billion in Section 10 (2030). Clarify the difference between the two numbers.

Response

The numbers reported in Chapters 4 and Chapters 10 are not intended to be compared. The costs reported in Chapter 4 are developed as a mechanism to compare various alternatives. The Chapter 4 costs are the capital costs and the annual and present worth of the annual O&M costs. As project directives required the costs are reported in 2004 dollars and this is done in Chapter 4. The costs identified in Chapter 4 are only a component of the costs presented in Chapter 10.

The costs presented in the Chapter 10 reflect the complete cost model for the recommended Alternate(s) including non-desalination related costs. The Chapter 10 Cost Model reflects the desalination project starting in 2008 with construction completion in 2010. The annual costs presented in Chapter 10 reflect the financing costs as annual payments, including debt service and annual O&M costs for each year during the life of the facilities. The annual costs for each alternative (i.e., no desalination and desalination) also include, where applicable, the projected costs for capital, debt service, and inflation related to existing treatment facilities (i.e., O. N. Stevens Treatment Plant) and other future non-desalination facilities (i.e., Garwood Pipeline). The cost model(s) developed in Chapter 10 were designed to capture all costs associated with a given alternative (i.e., non-desalination and desalination) and therefore the numbers reported in Chapter 10 include costs associated with facilities not directly related to desalination processes.

The value reported in *Table 10-4-2* of the report represents the total costs for the desalination alternative through the year 2030 of $1.8 billion. This number represents the total cumulative present value of this alternative including current and projected capital costs, debt service, and inflation over the study period for desalination facilities as well as facilities not directly related to the desalination process.

Comment

14. The report provides general information on alternative source water intake structures and sites, alternative discharge sites, environmental requirements for permitting, and cost of environmental compliance. The report does not provide sufficient detail on these issues to adequately compare the feasibility of the selected site or alternative scenarios within this site regarding potential environmental impacts.

Response

Concur. The feasibility analysis presented is conceptual in nature and not intended to be an exhaustive study of all considerations including the environmental impacts. Project construction footprints, pipeline alignments, discharge sites, and construction methods need to be identified before a comparative environmental impact analysis can be performed. However, a list of potential environmental issues for each site (Barney Davis vs Oxychem) will be provided in Chapter 8. A detailed environmental impact analysis will be performed during subsequent phases of the project as alternatives are defined in more detail. The results of pilot scale studies are needed to take this process to the next step in further refining the costs and the impacts.

Comment

15. The report provides three potential sources of seawater supply for the proposed project in Chapter 4, pages 20-36. These include use of an existing intake at the Barney Davis Power Plant, construction of new intake, and construction of bank filters along the coastline. Provide documentation supporting the conclusions on about environmental impacts (page 35).

Response

The conclusions noted on page 35 are based on general information about the various intake systems and the manner in which they are constructed. The greater the amount of disturbance to the beach and/or the seabed, the greater the potential for environmental consequences that must be mitigated. In the case of infiltration galleries, the impact is general and all along the beach in a significant areal impact. It takes up a considerable amount of beach front property and requires exclusion zones for protection of the supply. The potential for revisiting the site to renew the capacity of the sands to prefilter the seawater also leads to a greater potential for disruption and construction activity on the beach.

The Ranney type well system has a lesser impact to the beach front, as much of the collector portion of the process is obtained though lateral drilling under the sea floor without disturbing the floor or the water column itself. This option is likely to have the least effect on plant and animal life in proximity to the intake. The smaller number of wells and the elimination of the need for open trenching contribute to a smaller environmental impact. The Ranney wells also have the potential for requiring some means of restoring the filtration capacity of the sands if it becomes plugged during operations, and that restoration activity could require disturbance of the sea floor and beach areas. The uncertainty of the long term efficacy of this type of treatment is a key component in looking at a more conventional Gulf intake

The conventional intake into the Gulf represents a considerable disturbance of the sea floor, but in a narrow band and for a relatively short period of time. Once installed, the sea floor can be restored to a condition similar to that existing prior to the construction, with only the single pump station located on the beachfront. The intake will be designed to meet all existing requirements for impingement and entrainment to exclude marine organisms to the greatest extent possible. While it is the opinion of the consultant team that this option will have the lowest environmental impact during construction, we have no studies to point to for documentation. As a result, that sentence will be removed from the report.

Comment

16. The report states that the infiltration gallery installation would have the greatest construction impact, the Ranney type well system the least environmental impact of the bank filtration options, and the construction of the seawater intake would have only a short impact on marine life. Reference or explain these conclusions.

Response

See response to previous comment

Comment

17. The report provides some information regarding byproduct management in Chapter 5, pages 1-22, including discharge of the byproduct stream to the open sea and Oso Bay discharge through the Barney Davis Power Plant cooling water discharge. Discuss how the conclusion was reached in the report that discharge to Oso Bay would not be feasible.

Response

During the development of the report, the Barney Davis Power Plant was in the process of being sold and its long-term operation was in question. The future of the Barney Davis site was in question including the cooling water flows from the intake at Laguna Madre to the outfall at Oso Bay. The Alternatives were developed to have reliable performance under all anticipated conditions, and at the time, it was felt that reliance on the Barney Davis facilities would be questionable. We felt very strongly that a byproduct stream with salinity levels always exceeding 70,000 mg/l into Oso Bay would not be permittable without the dilution of the cooling water flows.

Several days before the completion of the feasible report, the sale of the Barney Davis facilities was completed and a letter was received from the new Owners that expressed interest in co-locating a desalination facility on the site, including sharing the intake and outfall facilities. The statement in the report that indicates that the Oso Bay discharge would not be feasible was based on not having the Barney Davis facilities available. Pages 155 through 169 of Chapter 4 were added to re-introduce the impacts of shared resources with the Barney Davis facilities.

The original conclusion to not use the Oso Bay discharge was based almost entirely on the potential negative reaction of the environmental community to any increase in the salinity level of water being discharged into Oso Bay. There is a portion of the environmental community that wants the cooling water from the Barney Davis Plant to continue to flow into the Oso to relieve stagnation conditions that occur in that reach during summertime low flow conditions. In addition, Oso Creek is effluent dominated from the discharges from several wastewater treatment plants and the Laguna Madre water that cools the Barney Davis Plant provides some dilution of that effluent. On the other hand, the bays in the Corpus Christi area are largely hypersaline and the introduction of a more concentrated cooling water from the Barney Davis Plant will be seen as contributing to the hypersalinity problem.

As a point of fact, the actual impact on the cooling water stream coming from the Barney Davis Plant with all cooling pumps running is an increase in salinity of approximately 5 percent. This discharge will cause a very slight increase in the Oso Creek when mixed with the water already in the creek. The increase in salinity in Oso Creek will probably not be measurable beyond a few feet from the outfall of the cooling water. For this reason, the discharge into Oso Creek is not discounted entirely and is in fact recommended for further study as a part of any pilot plant work that would be done. The cost analysis presented in Chapter 4, Section 6.1, pages 155 through 169 for this alternative is based on running the full capacity of the cooling water pumps even if the Barney Davis Power Plant is not operating for any reason. The desalination facility will pay for the electricity to operate that pump when it is not being used by the power plant.

Comment

18. The waste stream is to be discharged two miles out to sea. The report should answer the following questions: Could a closer discharge location be selected to reduce pipeline costs without adverse effects on the environment? What was the basis for selecting the 2-mile distance? How does the discharge point relate to the intake location?

Response

The criteria that was used to select the waste stream discharge was a depth of water of 30 feet. This concentrated solution is more dense than the water in which it is being discharged and will tend to sink. If the water into which it is discharged is too shallow, it is more likely to have significant bottom growing communities that are not able to move away from such an effluent plume.

Discharging into a greater depth gives a large water column for dilution effects. However, it is possible that a closer discharge location could be selected, but that would be part of a more intensive study of the circulation patterns and water column effects. The depth and location of the intake also takes into account wave action, riptides, impacts of boat traffic and other conditions that could have a detrimental effect on consistent water quality.

The discharge point relates to the intake location only to the extent that it is desirable to minimize short circuiting of the byproduct discharge to prevent it from increasing the feed water dissolved solids concentration. The current in this location apparently has the potential to reverse direction depending upon the time of year. The location of the byproduct discharge line in relation to the intake is based upon predominant current patterns and will be defined in greater detail as the project progresses. Currently, the separation distance is estimated to be 1,400 feet.

Comment

Chapter 8, pages 7-11, provides pipeline routing information on the various concepts, and states that pipeline routing studies would be needed to identify routes that would minimize impacts to the sensitive natural environment of Laguna Madre, Padre Island, Redfish Bay, Mustang Island, and Aransas Pass. The report should provide information on those resources or potential impacts.

Response

A summary paragraph describing potential environmental impacts related to pipeline installation will be developed and inserted at the end of this section of the feasibility report. More detailed descriptions of potential environmental impacts would be developed during subsequent phases of the project.

The estimated cost for environmental compliance was developed as an average percentage of construction costs based on similar projects documented in the *Coastal Bend Regional Water Plan* dated January 2001.

Comment

19. Provide additional information or documentation on the basis for the estimated cost of environmental compliance.

Response

As noted above and as discussed in the report, the costs of environmental compliance are estimated based on the construction costs of the various facilities. In addition to these specific costs, all of the estimates include a 30 percent contingency to cover any excess costs of environmental compliance that are not covered by the standard percentage. Percentages used for environmental compliance are consistent with those used in the Region N planning process to ensure comparability among the alternatives.

Comment

20. The capital cost of the proposed project ($196.6, Table 4-5.5-1) equates to $7.9 per gallon of production capacity. This is almost twice the current international trend that estimates $4-5 of capital cost per gallon. Please comment on the reasons why this project might be far more expensive than the average.

Response

When considering 'typical' costs for desalination systems, evaluation of the over-all scope of the project and site specific factors is critical. Many systems installed overseas are co-located with power generation facilities and experience substantial reductions in capital costs relating to intake and outfall facilities. In many areas of the world, use of a direct surface discharge is common. These approaches can be less expensive than the intake and outfall structures required for Corpus Christi. When the intake and outfall costs are excluded from the capital costs (over 30 percent of the total capital cost) the capital cost per gallon is reduced to approximately $5.25/gpd.

A review of several major desalination projects in development or production indicates that a more typical range for capital cost is $4 to $6 per gallon per day of capacity (*Table A*). These projects are predominately being constructed using a BOO procurement model. Most of these projects have progressed beyond Corpus Christi, with a site selected and conceptual design completed allowing cost estimates with lower levels of contingency than applied for Corpus Christi. The costs developed for this project assumed a conventional design, bid, build procurement model, with typical conservative contingency factors applied (30 percent).

In the absence of a defined source of water and comprehensive water quality data, other than TDS, robust pretreatment alternatives were considered that could treat high turbidity, red tide, and organics. If water quality at a selected site is of higher quality and requires less robust pretreatment, then the total project cost may be accordingly reduced. Pilot testing of a specific candidate water will better inform the process design and conceptual cost estimates. Following a pilot study, a more site and water quality specific conceptual design and cost estimate can be developed.

Plant	Capacity cu.m./d	Capacity (-mgd)	Cost ($M, high)	Cost ($M, low)	Project Structure	Cost $/gal, high	Cost $/gal, low
Algiers (East)/Cap Djinet, Algeria	100000	26.42	140	100	Build, Own, Operate	5.30	3.79
Algiers (West)/Zeralda, Algeria	100000	26.42	140	100	Build, Own, Operate	5.30	3.79
Hamma, Algeria	200000	52.84	225		Build, Own, Operate	4.26	
Oran/Beni Saf, Algeria	150000	39.63	170	165	Build, Own, Operate	4.29	4.16
Oran II/Mostagenem, Algeria	100000	26.42	140	100	Build, Own, Operate	5.30	3.79
Kwinana (Perth), WA, Australia	150000	39.63	250			6.31	
Antofagasta, Chile	52000	13.74	54		BOOT	3.93	
Tianjin (Dagnang), China	100000	26.42	90		20 year BOOT	3.41	
Palmahim, Israel	82190	21.71	90	60	BOO	4.14	2.76
Taweelah, UAE	225000	59.45	300	250	BOOT	5.05	4.21
London, UK (surface water)	150000	39.63	340			8.58	
Brockton, MA (surface water)	19000	5.02	40			7.97	
Huntington Beach, CA, USA	189000	49.93	240		30 year BOO	4.81	
Moss Landing, Duke Energy	45000	11.89	176			14.80	
Marin County, CA	57000	15.06	100	60		6.64	3.98
Tampa Bay, FL, USA	94640	25.00	125		BOOT	5.00	
El Segunda (Scattergood, CA)	94640	25.00	140		Design, Bid, Build	5.60	
Corpus Christi, TX, USA	94640	25.00	197		Design, Bid, Build	7.88	
Corpus Christi, TX, USA	94640	25.00	130.9		Design, Bid, Build	5.24	

SUGGESTIONS

21. To make it easier to locate key information within the report, the following changes are recommended:

a. Include tabs between the chapters,

Response

Accepted

b. Label all pages of the report with a chapter or appendix number,

Response

The original draft report already contains this information.

c. When detailed analyses of various alternatives that were not selected are documented, highlight the summary analysis of the selected option,

Response

Concur

d. Place all appendices at the end of the report.

Response

Accepted

22. Chapter 6, page 11 of the draft report includes a reference to cost information on a potential Choke Canyon to San Antonio transfer to be included in Appendix 6-A, however this appendix only lists research needs.

Response

The referenced information was inadvertently omitted from the Appendix and will be added to the Report.

23. The subsidy needed is documented in the Executive Summary and elsewhere in the report. As a basis for comparison, the report could list alternative water management strategies, including costs per acre-foot, available to the Corpus Christi service area based on information from page 5.1-2 of the Coastal Bend Regional Water Plan dated January 2001. Additionally, the report could document desalination subsidies provided in other states ($250 per acre-foot being provided by MWD in California, and about $180 per acre-foot in Florida).

Response

A review of the alternative management strategies that were included in the 2001 regional plans was conducted and strategies that produced approximately the same or slightly higher amounts of water were compared to the cost of desalination. *Table 5.1-1* of the 2001 Region N plan includes 9 strategies that produce amounts of water greater than 10,000 acre feet per year. The costs of these strategies range from a low of $268 per acre-foot for an Aquifer Storage and Recovery Strategy along the South Texas Water Authority Pipeline to $930 per acre-foot for Stage II of Lake Texana, to $1168 per acre-foot for desalination of seawater. All of these costs are in Second Quarter 1999 dollars.

There is currently a significant interest in desalination of seawater nationally, with specific subsidies being provided in at least two states. The Metropolitan Water District of Southern California has approved a subsidy of $250 per acre-foot to any of its sponsoring member agencies who successfully implement a seawater desalination project to augment the District's scarce supplies of water. In addition, the South Florida Water Management District has provided $85 million of the capital cost for the Tampa Bay Desalination Facility owned by Tampa Bay Water. Eighty-five million dollars reduced to an annual payment over 20 years and with a 6 percent interest rate would be approximately $7.4 million annually for a throughput of 28,005 acre feet annually. This results in a potential subsidy of $265 per acre-foot.

There is also federal legislation, HR 3834 that is moving through Congress. This bill, entitled the Desalination Energy Assistance Act of 2004, is intended to provide a national subsidy for desalination projects. This bill initially provides for a subsidy of $0.62 per1000 gallons, or a subsidy of approximately $200 per acre-foot for a period of ten years. Subsequent discussions have considered the possibility of removing the 10-year limitation but that has not occurred at this date.

The preceding text will be added to the final report document in Chapter 10.

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24. Chapter 8, page 15, includes a statement that "The TWDB, TPWD, and the TCEQ cooperatively administer the SB 1 process." TWDB is lead agency for SB 1 administration. Other state agencies provide technical assistance to the regions. Texas Parks & Wildlife and the Texas Department of Agriculture also are represented as non-voting members on the regional water planning groups.

Response

Comment is accepted and modifications will be made to the text.

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25. This report assumes financing through the TWDB regular Development Fund program. It would be difficult to recommend a loan commitment without contracts in place to sell water and subsidies guaranteed.

Response

The plant costs were calculated using the rates currently used in the TWDB regular Development Fund program to provide a common measurement between the projects unless special financing was arranged. This was our understanding of one of the outcomes of the Board's costing methodology workshop on April 16, 2004, with each of the project consultants. Development of this project is likely to take place with some form of alternative project delivery and the rates will be those prevailing to the commercial market at that time. However, we concur that guaranteed subsidies and water contracts would be needed in order to obtain a loan commitment.

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26. Total costs are based on a design-build-operate (DBO) project delivery approach, which assumes 10-20% cost reduction. TWDB cannot currently finance DBO. Does this increase costs by 10-20%?

Response

Costs in the report are developed assuming a conventional design, bid, build delivery method. The report indicates that if an alternative delivery method is allowed by the Legislature at some time in the future, the costs could potentially be reduced by 10 to 20 percent.

27. The report could describe the City of Corpus Christi's recent study on feasibility of desalination on the island, including conclusions of this study.

Response

The recent desalination project that the City conducted on Padre Island examined the feasibility of a brackish groundwater desalination facility potentially combined with an Aquifer Storage and Recovery project. The primary motivation behind this study is the need to increase the reliability of potable water service to Padre Island. This area is served by a single, aging line that is submerged in a harsh environment. The cost of a second line to Padre Island has specific and significant environmental challenges and the purpose of this study was to determine whether water could be produced on the Island at a lesser cost than completing a second pipeline.

Brackish groundwater desalination is generally much less costly than seawater desalination because of the difference in dissolved solids concentration of the two sources. This study, however, found that after a short period of pumping, the water quality increased in total dissolved solids concentration to such an extent that the treatment costs were more similar to those for seawater desalination. As a result, the City has determined that it is not cost effective to construct such a plant at the present time.

Attachment C

Comments from Texas Parks & Wildlife Department

General Comments Regarding Seawater Desalination Plants

Comment

Cooling Water Intake Structure rules, adopted under the Clean Water Act Section 316(b), already exist for power plants, and are anticipated for all other large facilities in the future. These rules will require certain facilities to use technology to minimize impingement and entrainment of larval and juvenile fish. These rules will be implemented in the TPDES permitting process.

Response

Concur. The appropriate details will be included in the design of the intake. The referenced legislation was reviewed during the development of this feasibility study and we are confident that the cost estimates will accommodate the appropriate design details.

Comment

Each of the facilities would have a pretreatment waste stream of relatively low volume, compared to a 25-mgd brine discharge. Having a low volume, this waste stream could go to a local wastewater treatment plant, or it could be commingled with the brine.

Response

Concur. The residuals disposal method used in the report was based on a self-sufficient program wherein the residuals are processed on site then hauled offsite for disposal. This was felt to be the most reliable form of residuals processing though potentially not the most cost effective. Sending these residuals to a wastewater treatment plant would add a treatment load to the existing facilities, reseparation of the residuals from the waste stream, additional treatment and solids processing costs at the wastewater treatment plant, and the cost of pumps and pipes to transport the residuals to the nearest collection system line of adequate capacity. To determine if transporting the residuals to a local wastewater plant is cost effective, a long-term analysis of the impacts to the capacity and O&M costs at the wastewater plant would have to be performed. Developing residual treatment facilities on the desalination site provides a very reasonable estimate of these costs. Going forward, the disposal of residuals to a wastewater treatment plant will be discussed with appropriate entities.

Comment

Facilities operating water pipelines typically periodically use some sort of antifouling chemicals to clean their lines. As part of the TPDES application process for brine disposal, the facilities would have to specify what they plan to use, to ensure that TCEQ can properly regulate to prevent environmental harm.

Response

Concur. Usually the supply line is treated with a weak oxidant such as chloramine to prevent growth and accumulation of marine organisms on the inside of the pipe. In this case, the chemicals would be drawn into the pipe and brought to the plant site. Dechlorination would eliminate the chloramines prior to contact with the RO system.

Because of the pretreatment processes, the byproduct disposal pipeline is not likely to require routine treatment with chemicals. In the event that further analysis or full scale operations determine that cleaning of the pipeline is required, the environmental impacts of the various maintenance options will be coordinated with TPDES and TCEQ.

Comment
Specifics of Gulf disposal of brine, relevant to Brownsville and Corpus Christi, would have to be worked out. This would focus, from a water quality perspective, on outfall location and depth, prevailing currents, and design of a diffuser system.

Response

Concur

Corpus Christi Proposal

Comment
Department staff has several comments regarding ecologically sensitive habitat types occurring within the Barney Davis Power Plant project area. According to information contained in the draft feasibility study, reverse osmosis is the only primary treatment process being considered in this feasibility analysis. The report further indicates that the feasibility screening process has identified the open sea in the Gulf of Mexico as being the only raw water source with reliable and consistent water quality by having a total dissolved solids (TDS) concentration of 35,000 mg/l or less. The other potential water sources such as the Laguna Madre, Oso Bay, and Nueces Bay routinely exceed the 35,000 mg/l criteria or are subject to other significant water quality deficiencies. Therefore, as stated on Page 118 (Chapter 4) of the feasibility report, the Gulf of Mexico raw water source is compatible with all intake, treatment, and plant site options and subsequently will be carried forward in the development and evaluation of alternatives. The 54-inch diameter raw water line would extend from the Barney Davis Plant, east across the Laguna Madre and Padre Island, and out into the Gulf. It would have a capacity of 55 million gallons per day.

Response

Page 118 of the report will be modified to retain the option of using water from Laguna Madre through the existing Barney Davis intake and pump station.

Comment

Although the draft feasibility report briefly addresses impacts on marine life during pipeline construction, this environmental section of the report only discusses potential impacts as a result of pipeline installation in the Gulf. The report does not address pipeline construction across the Laguna Madre. The Laguna Madre is characterized as one of the most ecologically sensitive and productive lagoonal ecosystems in the world. The Laguna Madre contains dense seagrass beds which are one of the most ecologically important habitat types occurring on the Texas Coast, and also one of the most difficult habitat types to mitigate. As stated earlier, the draft feasibility study gives the reader the impression that the raw water source would be obtained from the Gulf of Mexico. This is further reinforced by information contained on page 155 (Chapter 4) which states that the Barney Davis Power Plant already has an intake system in the Laguna Madre, however, this intake could not be used for the desalinization project because the total dissolved solids concentration in the Laguna Madre is often significantly well above the project goal upper limit of 35,000 mg/l.

The following section of the draft report (Section 6.1.2 Development of Optimized Alternatives) is very confusing to the reader. As stated earlier, the report contains several references identifying the raw water intake source for the Barney Davis Project Site as being the Gulf of Mexico. This section of the draft feasibility report focuses on reducing the total life cycle costs of the proposed desalination facility using two specific areas of optimization: (1) the use of the Barney Davis Raw Water Intake and Circulation Water and (2) the use of the Barney Davis Cooling Water Outfall and mixing of the desalinization byproduct stream with the cooling water discharge. The report further states that, with this optimization, the raw water intake into the Gulf of Mexico, the raw water pump station, and the construction of the water line across the Laguna Madre would be eliminated. The draft feasibility report is very confusing at this point because the report previously stated that the Laguna Madre intake water could not be utilized for numerous reasons.

Response

Project goals were established at the start of the report. These goals were based at least in part on the fact the owners of the Barney Davis Power Plant were trying to sell the facility and they were not willing to encumber the site with commitments to a desalination facility. Furthermore, documentation form ERCOT indicated that it was not likely that the Barney Davis Power Plant would be a viable long-term electric generating facility. For reliability reasons, a decision was made not to use the resources, other than available land, of the Barney Davis site. The report was essentially completed on this basis.

In a confidential letter dated July 29, 2004, it was learned that the sale of the Barney Davis Power Plant was completed and that the new owners were willing to consider and cooperate with the siting of a large-scale desalination facility at the Barney Davis site, including shared use of the intake and outfall facilities. This development at the very end of the project injected a completely new set of circumstances and potential cost savings measures to the project.

The analyses to this point had indicated that the Barney Davis site was the best site evaluated for the desalination facility and that dissolved air flotation is the optimum pretreatment facility. Therefore, the introduction of the use of the Barney Davis resources did not impact the selected site or the treatment components. However, it was recognized that substantial savings available from using the Barney Davis intake and outfall facilities could further optimize project costs and potentially offset the reasons for not using Laguna Madre as the water source or Oso Bay as the discharge location. The potential savings associated with using these shared resources changes the economic dynamics of the analyses.

To analyze the economic impacts of the sharing of Barney Davis resources, Section 6.1 of Chapter 4 was developed. Section 6.1 indicates that the cost savings associated with not having to build separate raw water intake, piping and pumping facilities or an open sea byproduct outfall will more than offset the cost for upgrading the onsite facilities required for the additional treatment of the hypersaline water. Also, it was surmised that the continued Barney Davis cooling water flows to Oso Bay would be an environmental benefit compared to the elimination of these flows. Therefore, if the desalination facility could financially support the continued flow of water through Oso Bay in the amount of 475 to 500 mgd on a continuous basis even during shutdown of the power station, there is at least a possibility that some members of the environmental community may support the concept of including the byproduct in this stream.

For these reasons the optimized alternates are presented in Chapter 6. Further negotiations are required with both the owners of the Barney Davis Power Plant and the environmental community to determine the viability, desire, and costs for implementing the optimized alternates. It is our recommendation that the optimized alternates be carried forward as well as the recommended base alternate for any future studies and project development.

Comment

From a water quality viewpoint, disposal by pipeline to the Gulf is preferred from either the Barney Davis or Oxychem locations. The Executive Summary does not specifically mention Oso Bay as a possible disposal location, although this is discussed in Chapters 3, 5 and 8. A discharge to Oso Bay would need a thorough review before comments could be given. The proposal is to commingle the brine and the power plant waste. More information is needed regarding the location, volume and chemical makeup of the Barney Davis plant intake, as well its discharge. It is not clear from the proposal if the plant will use seawater for cooling and discharge that to Oso Bay. The proposal indicates that commingling the brine would increase the salinity of the discharge in the same proportion as the water volume. This will depend critically on the circulation and residence times in Oso Bay and connecting bays. Additional information is needed to determine the impact this would have to habitat and salinity levels in Oso Bay.

Response

Concur. As a point of clarification, the Barney Davis intake uses water from Laguna Madre. The water is used for cooling purposes, thus heating the water. The water is discharged to cooling ponds before being discharged to Oso Bay. Therefore the source of this water is Laguna Madre, not the Gulf of Mexico. The Barney Davis intake and discharge is already a permitted activity. Permit amendments would be required to share these resources with the desalination facility. Appropriate environmental studies will be performed prior to submitting an application for these permit modifications.

Comment

Department staff recommends that the feasibility report be clarified regarding the raw water source. As mentioned earlier, seagrass beds occur throughout this portion of the Laguna Madre and if intake and/or discharge lines are to be installed across the Laguna Madre, then the feasibility report should include seagrass impacts as a major factor in siting the proposed desalinization facility and the cost analysis associated with the project. The draft feasibility report cost analysis (Concept Design O & M Costs Section) indicates that the raw water intake and discharge pipelines would be installed across the Laguna Madre using wet dredging methods. Department staff has been involved in many pipeline projects in the Laguna Madre and strongly recommends that impacts to seagrass beds be avoided and minimized as much as possible. Although there have been a few pipeline projects which have impacted seagrasses in this area of the Laguna Madre, those pipeline projects were much smaller than the proposed 54-inch raw water intake line. Department staff anticipates that the raw water intake pipeline installation process (using open trench dredging) would involve significant impacts when considering the pipeline trench and work corridors that would be needed. The Laguna Madre is a very shallow lagoon and installation of a pipeline of this size may require dredging work channels as well as the pipeline trench. The issue of constructing large pipelines across the Laguna Madre is of such environmental importance that it should be addressed as a separate section in the report. Furthermore, Department staff recommends that methods to avoid and minimize seagrass impacts (such as directional drilling the pipelines or using existing channels) also be included in the feasibility report.

Response

Concur. The construction methodologies employed for the pipeline installation will have to be detailed. It was premature to perform detailed environmental studies during this feasibility study that was intended to identify the facilities and approximate locations. Detailed environmental studies can be performed concurrently or subsequent to the development of additional details and finalization of pipeline locations and routing.

Comment

As stated earlier, Department staff has been involved in several pipeline projects that have resulted in seagrass impacts in this area of the Laguna Madre. The natural resource agencies consistently recommend that seagrass impacts be avoided and minimized, and then compensatory mitigation be performed for unavoidable and justifiable impacts. Seagrass mitigation is typically performed at a 3:1 ratio; that is 3 acres of seagrass created for every one acre that is damaged. These ratios, which have been adopted and used by the resource agencies for many years, require higher ratios of created habitat because of the poor success associated with seagrass mitigation. The higher ratios also consider the "down time," or amount of time it takes before the newly created seagrass bed will become functionally equivalent to natural seagrass beds. One of the difficult challenges associated with seagrass mitigation in this area of the Laguna Madre is the significant lack of areas to use as mitigation sites. This is particularly true for large projects. Therefore, it is recommended that seagrass impacts and subsequent mitigation also be addressed in the siting alternatives and cost analysis sections of the feasibility report.

Response

Pipeline routing studies have been recommended by the feasibility report so that seagrass bed and other environmental resources are identified and avoided to the extent possible. During subsequent investigations and environmental studies, as desalination alternatives are defined and clarified, construction issues associated with project components and sensitive environments, including the Laguna Madre, will be fully explored.

A statement to the effect that pipeline installation methods will be investigated so that opportunities to (1) avoid and (2) minimize impact to seagrass beds will be added to the report. **See Chapter 8 page 8.**

Comment

Department staff also notes that the Oxychem Plant site, which has not been identified as the preferred alternative, may also involve seagrass impacts. The Oxychem site is located on the north side of Corpus Christi Bay. According to information contained in the draft feasibility report, Corpus Christi Bay does have reasonable average water quality to use as a raw water source, however, the shallow depth of the bay (14 feet maximum) was not considered to be adequate for a 55 mgd intake design. A low profile intake system would have to be constructed in Corpus Christi Bay in order to use the bay water as a raw water supply. The Barney Davis Power Plant site is identified as the preferred alternative over the Oxychem site for several reasons, including the presence of a major water distribution line in the area of the Barney Davis Plant. Although most of the feasibility report focuses on the Barney Davis Power Plant site, the Concept Design

O & M Costs – Offsite Piping Systems Section of the report states that a raw water intake pipeline (54-inch) would also be installed in the Gulf of Mexico to service the Oxychem site. The pipeline would extend from the existing Oxychem Plant east across Harbor Island and Redfish Bay, across Mustang Island, and out into the Gulf of Mexico. Redfish Bay contains large areas of dense seagrass beds as well as oyster reefs, mangrove marshes, and colonial waterbird nesting islands. According to information contained in this section of the report, the raw water intake pipeline would be installed across Redfish Bay using dredging methods. Department staff cannot provide site specific comments regarding potential impacts to these sensitive habitats because the pipeline alignments have not been provided for review. However, Department staff would like to point out the fact that Corpus Christi Bay is a fairly deep bay and subsequently does not contain the ecologically important habitat features that Redfish Bay does. Therefore, it appears that the Oxychem site does provide better options to locate a raw water pipeline in deeper bay areas that would result in significantly less impacts to sensitive habitat types including seagrass beds.

Response

Pipeline routing studies have been recommended in order to evaluate and avoid impacts to sensitive environments, including seagrass beds. Environmental mitigation costs provided by the feasibility report are based on the conceptual design alternatives identified by the feasibility report and will be refined during subsequent engineering design phases of the project.

Comment

Department staff cannot provide site specific habitat-related comments until proposed project footprints, pipeline alignments, and construction methods are provided for review. In general, however, topics for consideration should include seagrass beds, oyster reefs, emergent marshes, tidal flats, colonial waterbird nesting islands, State and Federally listed species (particularly sea turtles), and sensitive habitats located within Mustang Island State Park and the Padre Island National Seashore. Department staff is available to provide guidance and review of the various project components which may affect these important resources.

Response

Comment noted. Subsequent environmental impact analyses will include significant, ongoing natural resource agency coordination in order to identify and address important resources and how those resources would be affected by project components.

Attachment D

Comments from the Water Treatment Engineering and Research Group of the United States Bureau of Reclamation

Comment

Much of the work in this report has been carefully done. While there might appear to be an undue emphasis on pretreatment (Chap. 4), this is in fact totally appropriate as much of the success or failure of the plant depends on this issue.

Response

We totally agree

Comment

The selection of 50% recovery is on the upper edge, but consistent with, current practice for seawater reverse osmosis (Summary, p.2).

Response

We agree that this is an appropriate value.

Comment

The decision not to use groundwater dilution (Summary, p. 2) has the advantage, in addition to those stated, that this allows a more consistent plant operation, given that the salinity of seawater is fairly constant, depending on the location of the intake and the absence of hurricanes, and its availability is high.

Response

We concur that this advantage is significant.

Comment

Discharge to the open ocean (Summary, p.3) appears to be a reasonable choice of the alternatives considered.

Response

We concur that it appears to be a reasonable choice.

Comment

The process of assembling a complete water analysis from different sources (Table 4-2.2.2-2) is an unusual one; although, the authors credit for publishing their sources. It is not clear how much time the authors of this report had, but it should have been enough to take a sample or samples and at the selected location and have them analyzed.

Response

To make meaningful decisions about selection of pretreatment processes, at least a year of water quality data would be required in order to have confidence that water quality variations have been captured. Even if one sample of each potential source had been taken, available water quality data was limited essentially to TDS. Other water quality parameters such as turbidity, algae (red tide), and total organic carbon could have a significant impact on the selection of pretreatment process. There was insufficient time and budget to gather additional water quality data. Therefore a "simulated" sea water quality was used and assumptions were included to cover worst case variations. We concur that such data is needed, and that a pilot plant study which would collect data as well as pilot treatment processes is the next logical step in the process.

Comment

To the equations on Chap. 4, p. 36, one can add

$$TDS_f = 5000 + 600\,Q \geq 29{,}000.$$

Response

After review, we do not understand the applicability of this additional equation and need additional information to include it in the Report.

Comment

As suggested by the discussion in Chapter 4, selection of an appropriate pretreatment system is not a simple matter. It is suggested that the study carried out near Corpus Christi, by Aqua Resources, sponsored in part by the Bureau of Reclamation, be carefully considered.

Response

As noted by other commenters, the report focuses heavily on the pretreatment issues. This is particularly true in view of the experiences at Tampa Bay and others. The report in question has not yet been released in final form, but the primary authors were at one time in the employ of Metcalf and Eddy during this project and they have provided the summary results of this investigation for consideration by the team.

Comment

The issue of initial screening of water at the intake (except in the case of beach wells where it is inherent) does not appear to have been given any consideration.

Response

The initial screening of water at the intake involves several issues that make it problematic. If clogging of the intake screens is experienced at a location 2 miles offshore and 30 feet deep, it is a much more difficult situation to remedy. At the same time, the screens chosen are cleaned by an air burst. As the report states this air burst must provide significant velocity and the line would experience tremendous stress if this air burst had to be delivered two miles offshore. The dewatering of the line during the air burst process would present significant strain on the rock rip rap that is anchoring the line to the sea floor. Finally, a small craft that is in the area when an air burst is taking place two miles offshore could be easily swamped or overturned. As it is, there will be very little surface impact at the location of the intakes.

Comment
Throughout Chapter 4, reference is periodically made to "worst case water quality." The only definitions of this relate to TDS. Things like TOD, biological species, suspended solids and other foulant materials should be considered if one wants a real “worst case.”

Response

It is recognized that the worst case water quality identified in the report is an assumed worst-case condition based on available data. The assumed “worst case water quality” included high turbidity, possibility of algae (red tide), and total organic carbon as constituents that would require a robust pretreatment process. A long-term (at least one year of data) water sampling program is required to develop a true worst case scenario and this program is recommended for future project phases.

Comment
The reference to the solids, dewatered to 17%, as "dry" (Figure 4-3.1.3-5 and other places) is questionable. The cake may be firm, but it is not dry.

Response

We concur with this comment. This figure will be modified.

Comment
In membrane filtration, it is important to make sure that the hypochlorite dosed to prevent fouling (Chap. 4, p. 84) does not get to the RO membranes.

Response

Dechlorination was included in the conceptual design for this purpose.

Comment

Apparently the seawater analysis given in Table 4-2.2.2-2 was compiled after the discussion on membrane selection beginning on Chap. 4, p. 94 was written. It is not clear where the limiting product TDS of 300 mg/L came from.

Response

The seawater analysis provided is a model seawater (35,000 mg/l TDS) drawn from several sources. Since no one source provides a complete data set for the desired parameters, multiple sources were required. The model seawater analysis was used in the simulations performed.

The value of 300 mg/l is independent of the feed water analysis. Most water systems incorporating seawater desalination select a target distribution system TDS lower then the secondary water quality standard of 500 mg/l. A review of the literature indicates values of approximately 350 mg/l for final desalination plant effluent quality. The stabilization process of lime/CO_2 typically adds about 40 to 50 mg/l of TDS to the water. To meet an effluent TDS of 350 mg/l, the blended permeate TDS cannot exceed 300 mg/l.

Comment

In Figure 4-3.2.3-2, the second pass is described as "softening membranes." I would expect most of the calcium and magnesium to have been removed in the first pass.

Response

The second pass membranes would be more appropriately referred to as low pressure, high output membranes

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Comment

The second pass appears to have about 2% of the volumetric flow of the first pass. Thus it seems that the product of the first pass was not much greater that 300 mg/L TDS. An alternative method of reducing the product TDS would be by reducing the recovery from 50% to a slightly lower value. This should not require much reduction and would produce considerable operating simplicity in the plant.

Response

As membranes age in service, the rejection of salt decreases, resulting in higher permeate TDS values. The second pass RO system is typically utilized to mitigate the long-term effects of membrane aging, and short-term temperature effects, and continue to produce water of acceptable water quality. The size need for a second pass will be further evaluated following pilot testing.

Comment

There is something wrong in the calculations in the middle of Chap. 4, p. 104. You can't save 49% of the energy in a 50% recovery plant with energy recovery. The energy savings claimed is too high.

Response

Use of DWEER technology permits substantial savings in the over-all operating costs. Although 49 percent is somewhat optimistic, values of 47.5 percent are feasible. Based on a reevaluation, 47.5 percent is the efficiency at this time for these conditions. This analysis was originally developed and then internally questioned and verified on two separate occasions. The manufacturer of the technology was also included in the evaluation and reevaluation processes. During the reevaluation process, the recovery was reduced from 49 percent to 47.5 percent and the economic analysis modified to reflect the 47.5 percent recovery. All references in the body of the report to a 49 percent recovery were inadvertently overlooked.

Comment

Although Figure 4-3.2.5-1 is highly simplified, it should include a pump for the second pass RO system.

Response

Agreed

Comment

The intermediate clearwell described in Table 4-3.2.5-1 appears to be too large. US BoR used half an hour storage time in Yuma, (73 mgd). Two hours seems too much unless time is being allowed for dechlorination, in which case it may be best to provide baffling to limit short-circuiting.

Response

In this application, the intermediate storage is also a reservoir for backwash supplies for the pretreatment filters as well as equalization for the RO feed. Standard design approaches were used for operating storage and backwash water supply for conventional pre-treatment.

Comment
In the list on Chap 4, p. 108, the last bullet contains no factors that are not in the first bullet.

Response

Concur. The last bullet will be eliminated

Comment
It would be preferable to aim for a Langelier Index of the product water slightly above 0 (Chap. 4, p. 109). To avoid difficulties when introducing water from a new source into existing distribution piping, the Langelier Index of the current water should be investigated and possibly matched.

Response

We concur with this comment and the preliminary engineering process for this project should include this evaluation.

Comment
It is disappointing that there is not an overall cost of product water in dollars per thousand gallons in the main part of the report. This would have made it simpler to compare this project to other seawater projects.

Response

The estimated cost of water produced from the proposed desalination facility is $4.23 per 1000 gallons. This sentence will be added to Chapter 10.