Texas Water Development Board

The Future of Desalination in Texas
Volume 1
Biennial Report on Seawater Desalination

December 2004

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The Future of Desalination in Texas
Volume 1

Section 16.060 of the Texas Water Code, directs the Texas Water Development Board to undertake or participate in research, feasibility and facility planning studies, investigations, and surveys as it considers necessary to further the development of cost-effective water supplies from seawater desalination in the state. The Texas Water Development Board shall prepare a biennial progress report on the implementation of seawater desalination activities in the state and shall submit it to the Governor, Lieutenant Governor, and Speaker of the House of Representatives not later than December 1 of each even-numbered year.

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Letter of Transmittal

December 1, 2004

To: The People of Texas
The Honorable Rick Perry, Governor of Texas
The Honorable David Dewhurst, Lieutenant Governor of Texas
The Honorable Tom Craddick, Speaker of the Texas House of Representatives

Among the many sources of water that Texans will rely upon in the future for human consumption—rivers, streams, rain, groundwater, and seawater—only seawater has the unique potential to provide an uninterruptible and limitless supply during times of drought. Droughts are a recurring theme in Texas and often have devastating effects upon the state's economy and environment.

In 2003, the Texas Legislature directed the Texas Water Development Board (TWDB) to allocate $1.5 million for feasibility and regional facility planning studies (feasibility studies) to determine the technical and economic viability of proposed demonstration seawater desalination projects. This resulted in TWDB funding studies of the Lower Rio Grande Valley-Brownsville, Corpus Christi, and Freeport project proposals. These feasibility studies are near-completion and analysis and review of the drafts has been integral to the development of this report.

Governor Rick Perry, the TWDB, and the citizens of Texas share a common vision—that one day, our great state will be a leader among states in turning seawater into drinking water—that one day, desalination of seawater and brackish groundwater will have fulfilled their potential and be counted among the primary means for meeting the state's drinking water supply needs.

On behalf of the citizens of Texas, the TWDB respectfully submits to Governor Rick Perry, the Lieutenant Governor, the Speaker of the House and members of the 79th Texas Legislature this document, consisting of a progress report of and recommendations regarding the implementation of a large-scale coastal seawater desalination plant in Texas (Volume I) and a compilation of authored papers on key desalination issues (Volume II).

Chairman

Executive Administrator

Table of Contents

Executive Summary

The 78th Texas Legislature adopted House Bill 1370 which was signed into law in May 2003. HB 1370 directs the Texas Water Development Board (TWDB) to "undertake or participate in research, feasibility and facility planning studies, investigations, and surveys as it considers necessary to further the development of cost-effective water supplies from seawater desalination in the state." In addition, the legislation directs TWDB to report biennially on the progress of seawater desalination activities in the state and to submit the report to the Governor, Lieutenant Governor, and the Speaker of the House no later than December 1 of each even-numbered year. This document constitutes the first biennial report under HB 1370.

According to the 2002 State Water Plan, the inability of current water sources to meet demands for water during drought conditions will increase from 2.4 million acre-feet per year (AFY) in 2000 to an estimated 7.5 million AFY in 2050. Of the major categories of water users in Texas—municipal, manufacturing, agricultural, and steam-electric power—municipal users is the category with the most significant unmet demands by 2050 in terms of total volume and the level of increase from today. Almost 3 million AFY in additional supplies, primarily drinking water supplies, must be secured to meet the needs of Texas cities if drought conditions occur in 2050. Meeting this exceptional need presents a tremendous challenge to the citizens of Texas. The extent to which seawater desalination can help meet this long-term challenge is one of the primary issues examined in this report.

Factors that support a continued focus on development of large-scale seawater desalination capacity in Texas include:

- The Texas Gulf Coast is home to some of the state's largest and fastest growing urban and suburban populations. According to the 2002 State Water Plan, four of the six regional water planning areas with the greatest volumetric water supply needs in 2050 will be regions that have large urban, suburban, and rural populations located on or near the Texas Gulf Coast. These populations could conceivably benefit from a new, significant, and sustainable source of high-quality drinking water.

- The Texas Gulf Coast is the site of extensive petrochemical and port industrial complexes of strategic national importance and a tourism industry of enormous economic significance to the state. Because of these vital industries, the region could benefit from a new, abundant, and sustainable source of high-quality drinking water.

- Advances in desalination technology have made its product more competitive economically relative to conventional alternatives. Today, water desalination is a viable option for providing high-quality drinking water that can meet the most stringent federal drinking water quality standards, including those for arsenic and radionuclides.

- Scientists at universities across Texas and elsewhere are investigating advances in pretreatment, methods of salt separation, disposal of brine, effects of byproducts on the environment, and management of desalination facilities. Continued development of seawater desalination offers promising opportunities for economically beneficial collaborations between the private sector and Texas universities.

- Advancing Governor Perry's vision for development of large-scale seawater desalination capacity complements other elements of the Governor's blueprint for long-term economic development in

Texas, such as the Trans-Texas Corridor Initiative, regional economic clusters, and overall water supply strategy.

The question is: can the promise of seawater desalination become the reality of a substantial and sustainable new water supply as well as a catalyst for associated economic, environmental, and academic benefits? In HB 1370, the Texas Legislature recognized that additional information was necessary to assess the implementation of and future opportunities for seawater desalination in the state. To fill the more critical information needs, TWDB funded feasibility studies of large-scale demonstration seawater desalination projects proposed for the Lower Rio Grande Valley-Brownsville, the City of Corpus Christi, and Freeport. Additionally, TWDB funded key desalination-related research studies.

The TWDB presents summaries, analyses, conclusions and associated information related to the seawater feasibility studies in Section 1 and Appendix 1 of this document. A compact disk containing executive summaries of the feasibility studies and other information under the title: *The Future of Desalination in Texas, Volume II,* is included as part of this submission. In addition, final seawater feasibility study reports for all three proposed seawater desalination demonstration projects are available electronically via the TWDB website at ***www.twdb.state.tx.us*** under the Desalination Activities link.

With respect to research activities, the TWDB is in the process of finalizing research related to the development of a permitting model for desalination projects in Texas; the feasibility of desalination of produced water from natural resource extraction activities; the potential for capacitive deionization technology; and the development of an inventory and database of desalination facilities in Texas. Additionally, the U. S. Bureau of Reclamation awarded the TWDB a federal grant to assess the potential for using oil field-related deep-well injection sites for desalination brine disposal. Volume II of this report includes a more detailed discussion of these studies, along with numerous contributed papers authored by recognized authorities on their respective subjects and related to seawater and brackish groundwater desalination.

In this report, the TWDB concludes that implementing seawater desalination in Texas is technically feasible. The construction and operation of large-scale demonstration facilities will create an effective precedent to guide the development of a new, drought-proof, and plentiful, water supply. The draft feasibility reports clearly show, however, that financial assistance will be required in order to realize the development of large-scale seawater desalination projects in Texas.

The TWDB recommends that the state continue advancing toward implementation of a large-scale demonstration seawater desalination facility in Texas. Over the next biennium, this implies implementing pilot plant studies and formulating state policy regarding the state's role in providing the financial assistance needed for future development of seawater desalination.

Key Findings and Recommendations

DEMONSTRATION SEAWATER DESALINATION PROJECTS

- **Key Finding-**

The development of large-scale demonstration seawater desalination in Texas is technically feasible but will require considerable financial assistance.

The draft feasibility reports indicate that the demonstration seawater desalination projects proposed for the Lower Rio Grande Valley-Brownsville, City of Corpus Christi, and Freeport are technically feasible. In each case, however, the estimated total costs (capital and operation and maintenance) of the proposed projects will exceed the cost of current sources of drinking water. As a result, the sponsoring entities have concluded that implementing the proposed large-scale seawater desalination projects will require substantial subsidized financial assistance to justify public and/or private investment.

- **Recommendation**

TWDB recommends that the Texas Legislature provide guidance in the establishing of a state policy for financial assistance to support further development of one or more of the proposed large-scale demonstration seawater desalination projects.

- **Key Finding-**

State funding of $2.4 million will be needed over the next biennium for advancing the proposed large-scale seawater desalination projects to pilot plant studies phase.

The draft feasibility reports indicate that a number of environmental, regulatory, cost, and other issues remain unresolved to varying degrees for each of the three proposed desalination projects. Seawater desalination planning involves addressing key issues that affect the overall viability of a project, as well as specifics associated with how it is developed and configured. A pilot study provides vital information regarding intake siting/source water selection to support pretreatment, primary treatment design and project costing, environmental and permitting considerations, and public outreach.

- **Recommendation**

TWDB recommends that the Texas Legislature consider authorizing the funding requested in the TWDB's Legislative Appropriations Request for FY 2006-07 related to seawater desalination pilot plant studies.

- **Key Finding-**

Investing in a large-scale demonstration seawater desalination project today will expedite the use and further development of large-scale seawater desalination as a drought-proof source of water.

A large-scale seawater desalination project has never been implemented in Texas. While certain planning decisions and cost estimates can be made through 'paper' or 'desktop' assessments, the actual development, construction, and use of a large-scale seawater desalination facility will provide information about funding support mechanisms, environmental concerns, public involvement, design, project delivery, and permitting that will allow public and private investment in seawater desalination to reach its market potential.

In addition, the new, substantial, and reliable supply of high-quality drinking water provided by a seawater desalination project will provide flexibility in system-and basin-wide water supply operations that may translate into economic and environmental benefits that would not otherwise be available to the beneficiaries of the projects.

- **Recommendation**

TWDB recommends that in its deliberations regarding the state's financial support for seawater desalination, the Texas Legislature consider the benefits to the state of demonstrating the feasibility of a new, substantial, sustainable, drought-proof, water supply by implementing a large-scale demonstration seawater desalination project.

RESEARCH AND OUTREACH

- **Key Finding-**

Research has and will continue to play a vital role in developing the most efficient, cost-competitive, and environmentally sound seawater desalination projects in Texas.

Reviews by the Texas Water Resources Institute[1] and the U. S. Bureau of Reclamation[2] of desalination research resources and activities at the federal level and at Texas agencies and universities indicate that there are impressive lines of research in all areas of desalination. These areas of research include pre-treatment, development of advanced and improved membranes, management and operational issues, environmental impacts, energy consumption, system optimization, and outreach activities to assist rural areas in developing cost-effective water supplies.

- **Recommendation**

TWDB recommends that the Texas Legislature continue its support of state agency and university desalination research efforts, and, work closely with our congressional delegation in Washington to secure federal funds for desalination research and development in Texas and continue the state's access to federal expertise and staff resources.

- **Key Finding-**

State funding at an estimated cost of $900,000 is needed during the next biennium for TWDB to continue facilitating water desalination activities in the state. This estimate includes $300,000 to fund two full time staff conducting technical assistance and outreach, and $600,000 for developing demonstration brackish desalination projects for small to medium size communities.

Provisions in HB 1370 directed the TWDB to include in this report the appropriations the agency anticipates will be necessary to continue investigating water desalination activities in the state during the next biennium. TWDB believes it is vital to continue progressing toward the development and implementation of seawater desalination projects in Texas. In addition, TWDB believes it is key to the state's overall water supply planning effort to explore the potential for creating new water supplies

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[1] ***Jensen, Ric and Jones, Allan, Texas Water Resources Institute, The Future of Desalination in Texas-Volume II, Desalination Research Programs of Universities in Texas, contributed paper.***

[2] ***Martella, Susan, United States Bureau of Reclamation, The Future of Desalination in Texas-Volume II, Desalination Resources, contributed paper.***

through the desalination of brackish groundwater, which recent studies indicate exists in great quantities in many regions of the state. TWDB is committed to facilitating the transfer of technology and other advances obtained pursuant to this progress and exploration to every region of Texas.

- **Recommendation**

TWDB recommends that the Texas Legislature consider authorizing the funding requested in the TWDB's Legislative Appropriations Request for FY 2006-07 related to desalination technical and outreach assistance as well as implementing model desalination facilities for treating brackish groundwater in small-to-medium-sized systems.

REGIONAL WATER PLANNING

- **Key Finding-**

The proposed seawater desalination demonstration projects would create new, abundant, drought-proof water supplies for meeting regional and interregional water supply needs.

The regional water planning groups consider all potentially feasible water management strategies when addressing regional water needs. By realizing the development of the proposed large-scale demonstration seawater desalination projects, the state will provide a new water-supply tool for regional water planners to consider in their deliberations. Now that the seawater feasibility studies are complete, affected regional water planning groups may assess the potential benefits of the proposed projects and whether they should be incorporated into their respective plans as a regional or interregional water management strategy.

- **Recommendation**

TWDB recommends that Regional Water Planning Groups G, H, K, L, M, and N consider the results of the seawater feasibility studies as potential water management strategies to be used in meeting future water supply needs.

Introduction

According to the 2002 State Water Plan, if a drought occurs in 2050 almost half (43 percent) of the municipal water demand in Texas will not be satisfied by current sources. The best response to this situation is a thoughtful, feasible, and long-term plan for acquiring new water supplies and reducing demand. With respect to the long-term plan for water supply acquisition, Governor Rick Perry has made the construction of the state's first large-scale seawater desalination plant the centerpiece of his plan for securing an abundant, drought-proof, water supply to meet Texas' future needs.

It is estimated that 50 percent of the future population growth in the nation will occur in the coastal states of California, Texas, and Florida[3]. These three states are leading the nation in pursuing seawater desalination. Seawater desalination is a technically feasible and increasingly cost-competitive tool to develop new drought-proof water supplies. A recent survey conducted by the International Desalination Association found that during the 2002-2003 period, a total of 2,115 desalination units were installed in the world with a production capacity of 1.27 billion gallons per day[4] (1.4 million acre-ft/year).

Most of the growth in desalination treatment over the last two decades has been accomplished through the use of reverse-osmosis water filtering technologies. Reverse osmosis technology uses high pressure to force water through semi-permeable membranes which in turn retain dissolved solids.

In April 2002, Governor Rick Perry tasked the TWDB, in concert with regional water planning groups and the private sector, to develop a proposal for building Texas' very first large-scale coastal desalination plant to produce drinking water using the latest technology. In 2003, the Texas Legislature enacted HB 1370, which directs the TWDB to undertake or participate in research, feasibility and facility planning studies, investigations, and surveys as needed to advance the development of cost-effective water supplies from seawater desalination in the state.

House Bill 1370 also requires the TWDB to issue a biennial report addressing the current status and future development of large-scale demonstration seawater desalination in Texas. HB 1370, now incorporated into Texas Water Code (TWC) §16.060, requires that the report address the following specific topics:

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[3] ***United States Bureau of Reclamation and Sandia National Laboratories, Desalination and Water Technology Roadmap, January 2003.***

[4] ***International Desalination Association, the International Desalination and Water Reuse Quarterly, August/September 2004, Volume 14/No. 2.***

TWC §16.060 (b):

> "(1) Results of the board's studies and activities relative to seawater desalination during the preceding biennium;
>
> (2) Identification and evaluation of research, regulatory, technical, and financial impediments to the implementation of seawater desalination projects;
>
> (3) Evaluation of the role the state should play in furthering the development of large-scale seawater desalination projects in the state; and
>
> (4) The anticipated appropriation from general revenues necessary to continue investigating water desalination activities in the state during the next biennium."

The following sections address the specific topics noted above as TWC §16.060 (b)(1) – (b)(4). As a whole, the sections describe the actions, analyses, and findings of the TWDB with respect to the development of large-scale demonstration seawater desalination projects in Texas, impediments to their implementation and the role of the state in overcoming those impediments, and the identification of next steps, including funding requirements.

SECTION 1-TWC 16.060(b)(1) Results of Studies and Activities

Key Activities Since April 2002

In April 2002, Governor Rick Perry directed the TWDB to prepare a recommendation for the development of seawater desalination in Texas. TWDB undertook the following actions (described in chronological order) to advance the development of large-scale seawater desalination.

- During the Fall 2002 the TWDB implemented a public solicitation process[5] to identify potential seawater desalination projects in Texas. The TWDB received a total of 13 proposals via this process.

- In December 2002 the TWDB issued a report to Governor Perry[6] that identified three proposals from the 13 competing proposals that exhibited the highest potential for implementation. The recommended projects and their respective sponsoring entities (in parenthesis) were:

    - Lower Rio Grande Valley-Brownsville Project (Brownsville Public Utilities Board)
    - Corpus Christi Project (City of Corpus Christi,) and
    - Freeport Project (Brazos River Authority and Poseidon Resources Inc.)

- The 78th Texas Legislature directed the TWDB to issue planning grants of up to $1,500,000 out of the Water Assistance Fund to be used for the execution of desalination projects, research, and regional studies during the biennium beginning September 1, 2003.

- In addition, the 78th Legislature passed House Bill 1370, which directs TWDB to "undertake or participate in research, feasibility and facility planning studies, investigations, and surveys as it considers necessary to further the development of cost-effective water supplies from seawater desalination in the state." HB 1370, signed into law by Governor Perry on May 15, 2003, is codified under TWC §16.060.

- In August 2003, the TWDB authorized $1,500,000 in grants for the preparation of feasibility and regional water facility planning studies to determine the technical and economic viability of the proposed demonstration seawater desalination projects in the Lower Rio Grande Valley-Brownsville, Corpus Christi, and Freeport. The goal of these studies was to better define the proposed projects by determining their technical characteristics; identifying and assessing potential customers, determining potential benefits and costs, and identifying the financial requirements to implement the projects.

- On August 30, 2004, TWDB received draft feasibility reports; and on September 30, 2004, TWDB provided comments to the respective contractors. The final feasibility reports are now complete and their results incorporated in the present report.

- Additionally, TWDB has pursued and secured federal funding in support of the Texas desalination program; organized various state wide outreach activities to inform the water community and obtain

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[5] Texas Water Development Board, request for Statements of Interest for large-scale seawater demonstration desalination facilities, October 2002.

[6] Texas Water Development Board, Large-Scale Demonstration Seawater Desalination in Texas - Report of Recommendations for the Office of Governor Rick Perry, December 17, 2002.

feedback to improve the desalination program. TWDB provided grants of $235,000 for desalination research.

Seawater Feasibility Studies

In September 2003, the TWDB authorized funding for regional water facility planning studies focusing on the feasibility of seawater desalination of large-scale demonstration seawater desalination projects proposed for the Lower Rio Grande Valley-Brownsville, Corpus Christi, and Freeport. The purpose of these studies was to assess the technical feasibility of seawater desalination at their respective locations, determine the cost of the projects, identify a target customer base for the projects, and identify the requirements for implementing the projects.

Following are key findings of these three proposed projects based on TWDB review and analysis of the feasibility studies. Appendix 1 contains summary review information, such as the projects' technical characteristics and costs breakdown.

- **Lower Rio Grande Valley-Brownsville**

The initial phase of the proposed project consists of a 25 million gallon per day[7] (mgd) reverse-osmosis plant scheduled to begin operations in the year 2010. The plant is capable of expanding to a 100 mgd production level by the year 2040 if service agreements with neighboring cities in Cameron and Hidalgo counties are executed. Certain elements of the project are sized to meet future expansions if needed. The site for the plant is the Brownsville Port Authority's complex, which is located approximately 10 miles west of the Gulf of Mexico and approximately 6 miles from the Brownsville Public Utility distribution system. The source water intake consists of a screened structure that will draw water from the Brownsville Ship Channel in the vicinity of the Port of Brownsville. The proposal calls for disposal of brine concentrate through an open ocean diffused discharge outfall line that would extend 15 miles away from the plant and approximately 3 miles into the Gulf of Mexico.

The initial 25 mgd phase of the project would serve the Brownsville Public Utility Board's (PUB) system. The project's greatest benefit is that it would add diversity to the Brownsville water supply portfolio, lessening the area's critical dependence on the Rio Grande.

The capital cost of the project is estimated at $151 million. The annual operation and maintenance (O&M) cost is estimated at $11.8 million; energy costs represent approximately 59 percent of the O&M cost and are based on an electric utility rate of 5.45 cents per kilowatt-hour (¢/kW-h).

The Brownsville PUB estimates that, in order to maintain the affordability of its water utility rate, it would need a subsidy of $13.8 million per year, equivalent to $494 per acre-ft to begin implementation of this project. This level of subsidy assumes that by the year 2010 the water utility rate for the Brownsville PUB system will be approximately $2.50/1,000 gallons; the subsidy corresponds to the difference between this projected rate and the estimated unit cost of the seawater desalination facility.

[7] ***1 million gallons per day = 1,121 acre-feet/year***

- **Corpus Christi**

The proposed project consists of a 25 mgd reverse-osmosis plant scheduled to begin operations in the year 2010. The proposed site for the desalination plant is the Barney Davis Power Plant, which is located approximately one mile from the Corpus Christi water distribution system. This proximity to the water distribution system is an asset of considerable value because it lessens the costs associated with treated water conveyance.

A potential advantage of this project is the option to co-locate with the Barney Davis Power Plant and use its intake and discharge facilities; however, at the present juncture, the study considered this option and concluded that the hyper-salinity of Laguna Madre exceeds the maximum salinity requirements for the project. The study also determined that discharge of the desalination plant's concentrate to Oso Bay is not advisable because of environmental concerns. Although use of Barney Davis' intake/discharge may be considered in the future, in its present form, the proposed project will require an open ocean intake and an open ocean concentrate disposal system.

Corpus Christi has diligently developed cost-effective water supplies to meet the needs of its customers until the year 2060. A potential benefit of the project is that, by adding seawater desalination to the Corpus Christi system, it creates a system surplus upstream in the Nueces and Lower Colorado rivers that could be offered for sale to other water users; the most likely choice is the City of San Antonio. The report assessed this possibility and concludes that San Antonio would likely defer consideration until after it concludes pursuing its current projects portfolio, even though the proposed desalination project is both technically feasible and projects costs are comparable to other approved water management strategies in Region L.

The capital cost of the project is estimated at $197 million. The annual O&M cost is estimated at $17,518,000; energy costs represent approximately 42 percent of the O&M and are based on an electric utility rate of 6.5¢/kW-h.

Corpus Christi estimates that, in order to maintain a zero impact to its customer base from the implementation of the desalination project, it would need a subsidy of $24 million per year, equivalent to $1,055 per acre-ft in order to implement this project. Additionally, the projected cash flow assumes $5 million/year from water sales to San Antonio. Additional analysis of the methodology and assumptions utilized to determine this level of subsidy is needed to ensure consistency between the three projects, and to assess alternative funding options.

- **Freeport**

The proposed project is a public-private partnership between the Brazos River Authority and Poseidon Resources Inc. The project consists initially of a 10 mgd reverse-osmosis plant scheduled to begin operations in the year 2010. The plant site is located at the Dow Chemical Complex in Freeport. The plant would be designed to take advantage of Dow Chemical's existing intake infrastructure, which provides access to both seawater and the waters of the Brazos River. The project's concept is to treat river water preferentially to lower the produced water cost and, when river water is not available, to shift to treatment of seawater. This concept results in lower production costs while still providing a demonstration facility fully capable of producing10 mgd of high quality drinking water entirely from seawater. The disposal of concentrate would also benefit from Dow Chemical's existing permitted discharge infrastructure.

The desalination project will initially serve customers of the Brazosport Water Authority (BWA) with drinking water supply levels in the 6.5 to 9.2 mgd range. A new 15-mile transmission line will convey water from the desalination plant site to the BWA distribution system. The BWA is a regional provider of surface water currently supplying water to seven communities within 25 miles of the proposed desalination plant– Lake Jackson, Freeport, Angleton, Clute, Oyster Creek, Richwood, and Brazoria. Future expansions of up to 50 mgd, and potentially greater, would expand the area served by the desalination plant to northern Brazoria and eastern Fort Bend counties as demands in those areas increase. The phased approach has the benefit of lower upfront costs relative to the competing proposed projects while still providing the state with the large-scale demonstration facility that it desires.

The capital cost of the project is estimated at $93.1 million. The annual O&M cost is estimated at $7.3 million. Energy costs represent approximately 43 percent of the O&M. The Brazos River Authority estimates that a subsidy equivalent to approximately $8 million per year, equivalent to $765 per acre-ft. The subsidy is necessary to adjust the cost of desalinated water down to the level available via alternative or existing sources of drinking water.

Other Studies

In addition to the seawater feasibility studies, TWDB has provided funding for various desalination-research studies during the biennium. These studies, and one funded by the U. S. Bureau of Reclamation Desalination Research Program, are described below.

- **Feasibility Study of Product Water Desalination[8]-Texas Engineering Extension Service, Texas A&M University (Draft report received November 2, 2004).**

Large quantities of produced water are brought to the surface in Texas as a result of oil and gas extraction activities. Often, this produced water must be re-injected in the formation as a pressure-building tool to enhance oil recovery. If there is no such need for the produced water, then it must be disposed. The proposed research will assess the economic and technological feasibility of desalting produced water resulting from these activities to develop water of sufficient quality to meet certain local water supply needs and to allow consideration of disposal options other than well injection.

This study will provide a comprehensive description of what is involved in the desalination of oil field produced brine and the technical developments and regulatory changes needed to make the concept a commercial reality. It will address where oil field brine is produced, its composition, and the volume available for treatment and desalination; the potential uses for the water resource and options for disposal of the desalination byproducts; and the cost effectiveness of desalination technology as used to treat oil field brine.

[8] ***Burnett, David, The Future of Desalination in Texas-Volume II, Potential for Beneficial Use of Oil and Gas Produced Water, contributed paper.***

- **Development of Permitting and Development Decision Model for Desalination Projects in Texas[9].-RW Beck. (Draft report received on August 30, 2004)**

Few major brackish and no seawater desalination plants have been built in Texas, and as a result the regulatory requirements for permitting such facilities are not well-defined. The growing interest in developing desalination facilities in Texas to help meet future water supply needs has greatly increased the need to address this issue. The primary purpose of this study is to fill this knowledge and guidance gap and develop a permitting and development decision model for desalination projects in Texas.

Successful completion of the research would result in more effective management of stakeholder processes in water planning and improve decisions regarding the appropriate types of facilities and arrangements to pursue. The draft report lists 20 major permits and approvals for a seawater desalination plant and associated transmission lines. According to the draft study, the amount of time required to complete a permitting process ranges from 18 to 24 months.

- **Please pass the salt[10]: Grant from the U.S. Bureau of Reclamation to the Texas Water Development Board. (Draft report completed)**

The objective of this study was to evaluate the feasibility of disposing brine concentrate from desalination plants in injection wells associated with oil and gas extraction activities. According to the study, oil and gas fields hold promise for concentrate disposal in Texas because (1) they occur in many parts of the state, (2) oil- and gas-field operators have considerable experience injecting oil field brines into these fields, and (3) the impact to the environment is negligible to non-existent relative to alternative disposal methods.

There are significant cost reduction advantages for communities that could dispose of concentrate down the same or similarly equipped wells that accept oil field brines. Unfortunately, the current permitting environment does not allow this option. Instead, desalination plant operators would be expected to apply for a Class I permit (millions of dollars and several years) instead of using a Class II permitted well (which only requires thousands of dollars and months for a permit). One of the purposes of this study is to affirm that deep well disposal of brine concentrate into oil and gas fields can be safe and reliable and to recommend changes to statute and regulations that would allow this approach to disposal of brine concentrate.

To show that oil and gas fields could accept injected concentrate from desalination plants, the project team first identified depleted oil and gas fields in Texas and selected and characterized six areas for analysis--the Anadarko, Permian, East Texas, Fort Worth, Maverick, and Southern

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[9] Steiman, Howard, The Future of Desalination in Texas-Volume II, Permitting Roadmap for Seawater Desalination Facilities in Texas, contributed paper in the availability section

[10] Mace, Robert, Nicot, Jean-Philippe; Chowdhury, Ali H.; Dutton, Alan R.; and, Kalaswad, Sanjeev, Texas Water Development Board, The Future of Desalination in Texas-Volume II, Please Pass the Salt, contributed paper.

Gulf Coast basins. Each of these basins contains oil and gas fields and sources of brackish groundwater, and include areas with identified needs for additional fresh-water supplies. After selecting the target areas, the team investigated formation pressures, analyzed water sensitivity, and modeled injectivity and the interaction of concentrate and formation fluids.

Results from the study indicate that many of the depleted oil and gas fields associated with the targeted injection wells had formation pressures that were lower than those of overlying aquifers identified as sources of drinking water. The importance of this finding is that there is no hydraulic potential for brine concentrate injected through wells into these oil and gas fields to move into overlying aquifers. Concentrate could be injected into oil and gas fields without causing the precipitation of minerals. In some cases, the concentrate would need a pre-treatment with anti-scalants to prevent precipitation. Clays would be a problem with raw concentrate in all of the basins. However, pre-treatment and operational solutions (such as adjusting the injection rate, progressive mixing with formation water, and injecting a buffer) can be used to mitigate clay issues. The median injection rate for a single well is about 10 gallons per minute (gpm) in the Anadarko, Permian, Fort Worth, and Maverick basins and about 280 and 470 gpm in the southern Gulf Coast and East Texas basins, respectively. These rates could be increased by screening more intervals and stimulating the wells. A lower injectivity would require a larger number of injection wells for the same amount of concentrate. This work suggests that injection of desalination concentrates in the formation water will likely not be a problem if the injection water and the formation are appropriately pretreated, as is done routinely by the oil industry in the injection of produced waters.

The study included a review of current statute and regulations applicable to underground well injection. This review involved coordination and discussion of alternatives with staff from the Texas Railroad Commission, the Texas Commission on Environmental Quality, and the U.S. Environmental Protection Agency (headquarters and Region 6).

Depending on the specifics of the case, a desalination plant can obtain a Class I or Class V permit for concentrate disposal. The permitting process under Class I could be made easier if Texas followed EPA's minimum requirements for a Class I municipal (non-hazardous) disposal well. Texas currently requires that non-hazardous Class I wells meet the same requirements as hazardous Class I wells. Recent legislation (HB 2567-78th Texas Legislature) has eliminated the contested case hearings process associated with applications for a Class I injection well permit.

Disposal of concentrate in a Class II well would require a dual permit: Class I-Class II or Class II-Class V. However, to attain a dual permit, the well would have to meet Class I or Class V requirements. Concentrate could be injected directly into a Class II well with no additional permits if the concentrate was used in enhanced oil recovery. However, for this to be considered a viable alternative, desalination plant operators would need assurances that oil field operators would take their volume of concentrate over the life of the desalination plant.

The permitting process under Class I could be made easier by using a general permit. The general permit would experience all of the public hearings and scrutiny of the Class I process. However, once the general permit was approved, permit applications that met the requirements of the general permit would only need an administrative review – a savings of years and perhaps millions of dollars. Because Texas has primacy of its underground injection control program, it may also be possible to create a special category of Class I permitting for the disposal of brine concentrate in Class II permitted wells.

Another option is to change the permitting process at the federal level. These changes could include creating a special category under Class V or allowing Class II disposal wells to accept concentrate. However, attempts to change these rules at the federal level have been unsuccessful.

In conclusion, the study finds that it is technically feasible to inject concentrate into oil and gas fields and, that certain changes to statute and regulations should be considered to make the permitting process more conducive to the disposal of brine concentrate from desalination plants into oil and gas fields in Texas.

- **Capacitive deionization technology: Testing of a new type of electrode being developed by CDT Inc. Texas Water Resources Institute-Texas A&M University[11] (Draft report filed August 30,' 2004)**

Capacitive deionization technology involves the desalination of brackish groundwater from saline aquifers. For the purposes of this study, laboratory tests were conducted to determine the performance efficiency, and the power and other operational costs of the technology. The draft report confirmed the ion removal capability of the technology. However, the study did expose an important drawback to this technology--the inability to adequately regenerate the cells using a minimal amount of fresh water. The research also found problems with the material selected for the cell and its flow design. These design and operation concerns, coupled with cost issues will require significant and further development before an operational cell will be available.

[11] ***Kramer, Timothy; Kim, Jinwook; and, Kim, Sahghyun, Department of Civil Engineering, Texas A&M University, Desalination Using Capacitive De-ionization: An Evaluation of the CDT Aqua-cell, August 29, 2004.***

Coordination with desalination research community

Research has played a major role in realizing the dramatic technological improvements that make desalination an increasingly more cost competitive option today. Research will continue to have a crucial role in addressing some of the more challenging aspects of seawater desalination: concentrate disposal[12] and energy consumption[13].

In 2003, the U.S. Bureau of Reclamation and Sandia National Laboratories published their vision for a national desalination research agenda entitled: *Desalination and Water Purification Technology Roadmap.* In its letter report on the Review of the Desalination and Water Purification Technology Roadmap, the National Research Council[14] states that "the potential for desalination technologies to become a major component of future water supply management throughout the United States justifies a careful research and development strategy to nurture novel ideas and facilitate technological advances." The review suggested that future research needs should address energy efficiency and air emissions associated with large-scale desalination plants, the development of membranes that are resistant to fouling, improving pretreatment methods, and developing alternative technologies that would reduce costs and be more environmentally sustainable. The review recommends that more emphasis be placed on the reuse, recycling, and management of concentrates and reject waters.

Research at Texas universities is contributing to the knowledge base required to implement reliable, cost-effective desalination technologies. A Texas Water Resources Institute review[15] of desalination research resources in Texas indicates that there is an impressive research capability in the state in all areas of desalination: pre-treatment, development of advanced and improved membranes, operational issues, environmental impacts, energy consumption and system optimization, and outreach activities to assist rural areas in developing cost-effective water supplies.

Through its participation in professional conferences and events, TWDB staff has been able to efficiently network with both desalination researchers and practitioners. The benefits of this networking have been projected to a wider audience by means of annual TWDB-sponsored workshops. In partnership with representatives from the Texas desalination research community, the TWDB held two annual workshops that were very well received and attended. Both events registered attendance in excess of 150 people.

The first workshop, which took place in April 2003, focused on the desalination research capabilities and interest of Texas universities and the U. S. Bureau of Reclamation. As a result of this activity, TWDB initiated a closer coordination with desalination researchers, identifying opportunities of mutual benefit in improving desalination technology and its transfer to the Texas water community.

The second workshop, which took place in March 2004, provided a progress report and discussion on alternative project delivery methods with a focus on the methodology known as design-build-operate

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[12] Mickley, Mike, The Future of Desalination in Texas-Volume II, Review of Concentrate Management Options, contributed paper.
[13] Callahan, Neil, The Future of Desalination in Texas-Volume II, Integration of Power Generation and Water Desalination Operations, contributed paper.
[14] National Research Council, Letter Report, June 12, 2003.
[15] Jensen and Jones, Ibid

(DBO). DBO is a predominant approach for the implementation of large-scale desalination projects around the world and many of its advocates argue that it results in cost-savings and faster project delivery. Public entities in Texas are not allowed to use DBO for water infrastructure projects. Texas procurement laws require a two-stage process that separates the design from the construction phase. The TWDB-facilitated discussion involved recognized experts and included advocates for and against DBO approaches. While there are examples of the use of DBO in Texas, its wider use would require changes in Texas procurement law.

Due in part to TWDB's outreach efforts, Texas was given a prominent role at the American Membrane Technology (AMTA) Conference held in San Antonio in August 2004. The TWDB presented progress reports on the feasibility studies and desalination research projects to a diverse national audience estimated at 500 people.

Coordination with State and Federal Agencies

Federal Assistance

TWDB staff has developed a productive and on going dialogue with representatives of key federal and state agencies to advance water desalination efforts. In addition, TWDB works closely with the Texas Congressional Delegation (Texas Delegation) by keeping them informed of desalination activities and associated financial needs in an effort to take advantage of opportunities for federal assistance. This coordination was instrumental in garnering a federal appropriation of $400,000 in 2004 in support of the proposed Freeport desalination project. As a follow up to this successful effort, the TWDB is working with the Texas Delegation on a $1 million federal appropriations request, for fiscal year 2005, to help fund pilot plant studies for all three proposed desalination projects.

TWDB staff is closely involved in the development of federal legislation to provide additional tools for the financing of large-scale desalination projects. TWDB provides support to U.S. Representative Kevin Brady and Senator Kay Bailey Hutchison on legislation to exempt water and wastewater projects from the private activity bond volume cap. TWDB staff has provided Congressman Brady's office with documentation describing the positive impact an exemption would have on the cost of financing water-related infrastructure, particularly for rural communities whose water systems are managed by water supply corporations (WSCs). Private activity bonds are often the only low-rate financing available to these WSCs since they are not eligible for tax-exempt financing generally available to municipalities.

- **Research**

During the biennium, TWDB submitted three separate applications to the U. S. Bureau of Reclamation Desalination Research Program and was successful in securing funding for one of them (*Pass the Salt*, see above description of "Other Studies") for research on concentrate disposal options.

TWDB is in the final stages of completing the Pass the Salt report under an $85,000 contract with the U.S. Bureau of Reclamation. The report evaluates the use of depleted oil fields as sites for disposal of brine concentrate from desalination plants and attempts to demonstrate that deep-well disposal of the concentrate in oil fields is safe and reliable.

In addition, TWDB has submitted other proposals in pursuit of federal research dollars for hydrodynamic modeling of concentrate disposal in Texas bays but did not receive a contract award.

- **Statutory/Regulatory Relief**

As described previously in this report, one of the most significant issues for desalination project development is the need for a solution for affordable and appropriate disposal of the desalination brine concentrate resulting from the desalination process. TWDB and others have directed considerable resources to researching the disposal issue. In addition, TWDB has pursued the possibility of regulatory or statutory relief on concentrate disposal, particularly for more rural areas of the state that could benefit greatly from brackish groundwater desalination.

The TWDB has met periodically with the EPA to discuss concentrate disposal issues, both for offshore and inland disposal. Through these discussions, TWDB determined that it must focus resources on finding solutions to inland disposal of concentrate. In many cases throughout the state, rural communities could benefit from the desalination of widely available brackish groundwater sources, but the cost of disposing the desalination concentrate make this water management strategy prohibitive for these smaller, rural communities. With EPA's input, TWDB is looking to other state agencies to help address this issue.

TWDB is currently working with the Texas Railroad Commission (RRC) and the Texas Commission on Environmental Quality (TCEQ) to review underground injection well regulations and to identify regulatory modifications that could ease the administrative burden and regulatory cost of concentrate disposal, while continuing to protect the environment. Current regulations provide for disposal of desalination concentrate in Class I injection wells. Class I injection wells require significant administrative resources to obtain operating permits and are extremely costly to construct (millions of dollars). The cost of these wells makes the prospect of desalination in rural communities unlikely. The ability to use Class II injection wells for desalination concentrate disposal would greatly reduce the cost of concentrate disposal and make the development of brackish desalination projects more attractive to rural communities, while at the same time providing the necessary protection against environmental degradation. Oil and gas brine waste is allowed to be disposed into Class II injection wells. Brine concentrate from brackish desalination facilities is considered no more of a threat to the environment than the oil and gas brines. It will generally be the case that brackish desalination concentrate will have lower levels of applicable constituents than the oil and gas brines. Just as importantly, the ability to use Class II injection wells increases the population of available and accessible disposal facilities for rural communities. The RRC has 31,000 permits for Class II injection wells, compared to only 111 permits for Class I wells permitted by TCEQ.

The TWDB, RRC, and TCEQ continue to review and identify regulatory solutions for the disposal issue. The three agencies do not foresee a need for a federal or state statutory change to the underground injection well program. The TWDB continues to inform EPA on the state's progress on this regulatory reform initiative.

Partnerships for Water Infrastructure Seminar

In August 2004 the TWDB joined the National Council for Public Private Partnerships (PPP) and the Texas Municipal League in hosting a seminar to discuss public-private partnership approaches to water infrastructure funding.

The seminar was attended by approximately 140 people. The program included nationally recognized experts in the area of PPP and funding of water infrastructure projects. Several roundtables focused on procurement, implementation, financing, legal, environmental, and risk allocation issues.

The procurement and implementation roundtable concluded that in order to gain full access to the benefits of PPP, there is a need for clear enabling legislation for PPPs, especially on design-build and design-build-operate procurement methods. This will require consensus building among all stakeholders of the benefits and downsides of the various alternative delivery methods. The initial implementation of PPP for water infrastructure will require expert assistance to public entities on procurement and implementation of alternative procurement projects. In this regard, a PPP manual focusing on Texas' issues would be a valuable tool for those interested in PPP.

Regarding financing, the roundtable identified the need for education of public and elected officials on PPP and financial alternatives; facilitation of the use of take-or-pay contract structures; and, a more aggressive use of existing finance tools such as private activity bonds and private equity.

The Legal and Environmental roundtable considered successful experiences in Texas and recommended amending procurement laws to allow "best value" procurement. Also, to facilitate PPP, the environmental permitting processes need to be aligned with the design-build and design-build-operate procurements.

Lastly, the Risk Allocation roundtable recommended the development of a risk allocation methodology/template to allow owners to think through the project development process internally and then communicate more clearly with the private sector. There is a need to educate customers/residents and other stakeholders about the values of appropriate risk allocation. This could be facilitated by developing standard agreements to help craft contract services.

SECTION 2-TWC 16.060(b)(2) Impediments to implementation of Seawater Desalination

Texas Water Code §16.060(b)(2) requires this report to address impediments to the implementation of seawater desalination projects. The TWDB considered research, regulatory, technical, and financial requirements to implement the current proposals for large-scale seawater desalination projects.

Research

The lack of research is not an impediment to the development of the proposed demonstration projects. As noted in Section 1, the TWDB coordinates research efforts with Texas universities and other desalination researchers and works closely with key representatives of research entities in identifying opportunities for research of mutual benefit. It is essential that, as appropriate, these coordinated research efforts be incorporated into all desalination activities, including outreach activities targeting rural and smaller communities throughout the state.

Additionally, there is a reasonable expectation in the desalination research community that additional breakthroughs in desalination and water treatment are on the horizon[16]. Concentrate management is an area of research that will undoubtedly have future pay-offs, and the TWDB is participating in this line of research.

Regulatory

The draft feasibility studies and the TWDB Permitting and Development Decision Model for Desalination Projects in Texas, which lays out permitting paths for all possible saline sources and concentrate disposal options, do not identify permitting as an impediment to the development of seawater desalination in Texas. However, there is no precedent in the state for large-scale seawater desalination, consequently, the proposed large-scale demonstration seawater desalination projects will test the process and provide a valuable precedent.

Technical

There are a number of technical issues that will undoubtedly require additional work. The most critical of these is the need to accurately characterize source water for each of the projects to select the appropriate pre-treatment method. The draft feasibility studies do not identify any technical impediments to the implementation of the project except technical and environmental issues that may arise for the Corpus Christi project associated with the installation of large diameter pipelines across the Upper Laguna Madre.

Financial

As demonstration projects, all three projects would require varying degrees of financial assistance to ensure that implementation of the projects will not result in an undue financial burden to the targeted water users. Both California[17] and Florida[18] have adopted performance incentives or subsidies to facilitate the development of new water supply sources by means of seawater desalination.

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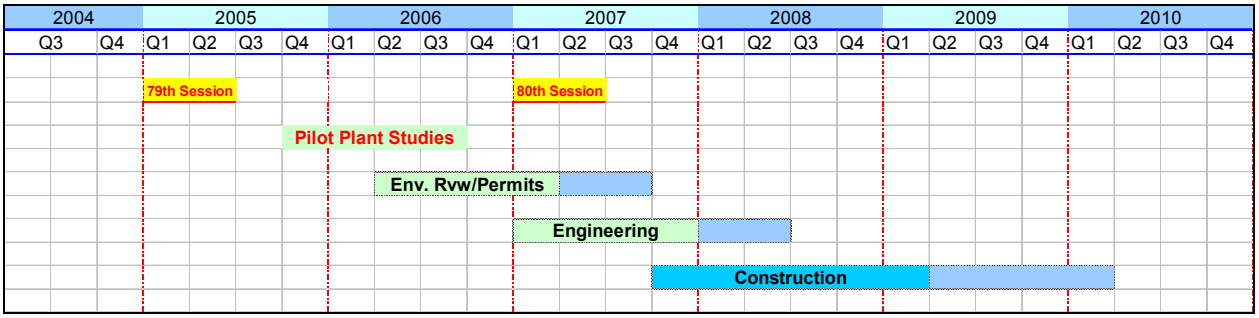
[16] United States Bureau of Reclamation and Sandia National Laboratories, Desalination and Water Technology Roadmap, January 2003.

[17] Vergara, José and Falagan, Anatole, Metropolitan Water District of California, The Future of Desalination in Texas-Volume II, Local Resources Management in Southern California, contributed paper.

[18] Schiller, Gene, Southwest Florida Water Management District, The Future of Desalination in Texas-Volume II, Successful Procurement and Finance Methods-The Southwest Florida Experience, contributed paper.

Figure 1 is representative of a conservative timeline for developing large-scale seawater desalination demonstration projects in Texas. It should be noted, however, that the timeline reflects a best-case scenario and one in which policies regarding subsidies and/or incentives for the implementation of the projects have been resolved. The absence of definitive policy may have the effect of discouraging continued pursuit of these projects by their proponents. Providing financial support for implementing pilot plant studies, as requested in the TWDB's Legislative Appropriations Request for FY 2006-07, will constitute a clear message of state support for these projects. The pilot plant studies will take an estimated 16 to 18 months to complete.

Figure 1-Large-Scale Seawater Desalination Demonstration Projects Timeline



SECTION 3-TWC 16.060(b)(3) Role of the State

Texas Water Code §16.060(b)(3) requires this report to evaluate the role the state should play in furthering the development of large-scale seawater desalination projects in the state.

The role of the state was cast by Governor Rick Perry when he expressed his vision in April 2002 that the state should proceed with the development of a large-scale demonstration seawater desalination plant to be located on the Texas Gulf Coast. The vision was anchored, ultimately, on the strategic need to add new, drought-proof water to the mix of water supply resources of the state. By characterizing the initiative as a demonstration project to be developed with the participation of the regional water planning groups and the private sector, Governor Perry provided the foundation for broad-based participation in the development of the project.

The role of the state for the next biennium should be to provide the financial support and policy guidance to encourage the continued development of the proposed Lower Rio Grande Valley-Brownsville, City of Corpus Christi, and Freeport projects. The TWDB has included in its Legislative Appropriations Request for Fiscal Years 2006-2007 an exceptional item that requests appropriations for the execution of pilot plant studies and outreach and technical assistance program activates.

TWC §16.060 provides a clear framework for the TWDB's role in advancing seawater desalination. Subsection (a) states: "The board shall undertake or participate in research, feasibility and facility planning studies, investigations, and surveys as it considers necessary to further the development of cost-effective water supplies from seawater desalination in the state."

The TWDB will continue to provide leadership as the state seeks to develop seawater desalination. Specifically, the TWDB will:

- Prepare terms of reference for the execution of the pilot plant phase of the seawater desalination program.
- Coordinate with the academic desalination research community to schedule two statewide annual desalination workshops.
- Continue informing the Texas Congressional Delegation on the status and future of the desalination program to identify appropriate opportunities to pursue federal financial assistance for desalination projects, particularly for the three proposed demonstration seawater desalination projects.
- Maintain and enhance the TWDB Desalination Web Site.
- Develop technical assistance and outreach activities that target small-to-medium size utilities.
- Continue to participate in professional organizations and conferences such as the International Desalination Association, the American Membrane Technology Association and the South Central Desalt Association, and
- Actively inform the regional water planning groups of developments in the desalination program.

SECTION 4-TWC 16.060(b)(4) Anticipated Appropriation

SECTION 4-TWC 16.060(b)(4) Anticipated Appropriation

Texas Water Code §16.060(b)(4) requires this report to convey to the legislature the appropriation from general revenues the TWDB anticipates will be necessary to continue investigating water desalination activities in the state during the next biennium.

The TWDB's Legislative Appropriations Request for Fiscal Years 2006-2007 requests $3.3 million for on-site construction of desalination pilot plants, executing as many as three feasibility studies for demonstration brackish groundwater desalination projects for small communities, and funding for two full-time equivalents (FTEs) to support desalination activities.

This request would ensure continued and effective progress toward full development of large-scale seawater desalination facilities by one or more of the entities currently pursuing seawater desalination projects. Pilot plants are a necessary step in order to collect and develop data on the source water and pilot alternative pre-treatment and reverse-osmosis membrane combinations that will ultimately lead to the most effective plant design.

The requested funding would also allow TWDB to pursue the development of demonstration brackish groundwater desalination facilities (1 to 5 mgd) suitable for use in small communities. TWDB would implement a process similar to that used in the development of large-scale demonstration seawater desalination facilities, including the issuance of a request for statements of interest from small communities and the potential selection of up-to three proposals. The preparation of feasibility contracts will have an anticipated cost not to exceed $200,000 each, or $600,000 for the biennium.

The requested funding would allow TWDB to fund two additional FTEs to adequately address the workload issues associated with the implementation of the Texas Desalination Program, including monitoring of desalination technology developments and educational outreach activities to provide technology transfer to TWDB customers considering desalination alternatives.

Appendix 1-Summary Review of Seawater Feasibility Studies

Review Seawater Feasibility Studies

This Appendix summarizes the seawater feasibility studies for the Lower Rio Grande Valley-Brownsville; the City of Corpus Christi; and Freeport. The purpose of the studies was to determine the technical feasibility of the projects, define their technical characteristics and costs, identify the targeted water users (both direct and indirect), identify permitting and environmental issues, and determine the financial requirement for their implementation.

The enclosed CD, entitled "The Future of Desalination in Texas, Volume II" includes copies of the Executive Summaries of the feasibility studies. The complete seawater feasibility reports may be accessed via the TWDB web site at ***www.twdb.state.tx.us*** under the Desalination Activities link.

Technical Characteristics

Desalination is a complex process. Its success depends on several interrelated factors: source water quality, intake, pre-treatment, treatment, energy recovery, and concentrate disposal. Source water quality, however, underpins the entire operation and determines the level of pre-treatment necessary for reverse osmosis treatment.

Typically there is not enough information about source water quality and its variability for a feasibility level study. Because it is important to determine the quality of source water for design purposes, one of the first steps in implementing a large-scale desalination project is a pilot study. The Water Treatment Engineering and Research Group of the U. S. Bureau of Reclamation remarked that "the analysis should include major ions, any species for which drinking water limitations currently exist, or are likely to exist in the future. It should also include organic, microbiological and suspended materials. Analyses should be taken over a sufficient period to disclose any annual variations and results of weather anomalies like heavy rains and tropical storms. Samples should be taken in such a way that they represent the water that will be taken into the plant intake as closely as possible."[19] Pilot studies typically extend over a 12 month period to capture the seasonal variability of the raw water quality.[20]

The information resulting from pilot studies allows the designers to confirm or revise the decisions made at the project's feasibility level regarding pre-treatment, primary treatment and concentrate disposal.

- **Lower Rio Grande Valley – Brownsville Project**

As proposed, the project consists of a screened raw water intake from the Brownsville Ship Channel, with the plant located at the Port of Brownsville. By using the Brownsville Ship Channel as the intake point, the project avoids the need for raw water pipelines from the open sea (this relative advantage may be offset by having to deal with poorer water quality). This will be a focus of the pilot study for this project. The selected pre-treatment is flocculation, dual media filtration, and cartridge filtration prior to undergoing primary treatment via reverse-osmosis with Pelton turbines as energy recovery. The plant will have an initial capacity of 25 mgd to begin production in the year 2010. Additional 25 mgd increments would be added for a final capacity of 100 mgd in 2040. The concentrate disposal systems consist of open discharge into the Gulf of Mexico via a pipeline with a diffuser array.

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[19] U. S. Bureau of Reclamation letter dated September 20, 2004 from Frank Leitz to Jorge Arroyo.
[20] Reiss, Robert, The Future of Desalination in Texas-Volume II, the importance of pilot plant studies, contributed paper.

- **Corpus Christi Project**

The City of Corpus Christi proposes a 25 mgd plant to be located at the Barney Davis Power Plant. The source water is the Gulf of Mexico. The project includes an open-ocean intake at the Gulf of Mexico and a 72-inch, 43,300 feet pipeline to the plant site. Pre-treatment will consist of air flotation and granular media filtration, followed by two-stage reverse-osmosis filtration with pressure exchangers as energy recovery. The concentrate disposal system is an open-ocean discharge via a 54-inch, 43,300 feet pipeline. The plant would begin producing water in 2010.

- **Freeport Project**

This project consists of a 10 mgd reverse-osmosis plant to be located at the Dow Chemical Complex in Freeport. To improve the economics of the project, it will be designed to treat river water preferentially and, when river water is not available, shift to seawater. Both intakes will be located within Dow Chemical complex, as would the concentrate discharge facilities. This concentrate will be disposed into the existing permitted Dow Freeport discharge infrastructure, where it will be diluted and discharged into the lower reach of the Brazos River and the Gulf of Mexico. The project will begin providing water to the Brazosport Water Authority in 2010; service will be expanded to serve areas in northern Brazoria County and Fort Bend County.

Table 1-Technical Characteristics

	Brownsville	Corpus Christi	Freeport
Source Water	Brownsville Ship Channel	Gulf of Mexico	Gulf Coast seawater or Brazos River water
Intake	Screened intake at Brownsville Ship Channel	Open sea intake, 8.2 mile 72-inch pipeline	Existing Dow Chemical seawater & Brazos River intake system
Treatment Capacity	25 mgd expandable to 100 mgd by 2040	25 mgd	10 mgd
Concentrate Disposal	Open sea discharge with diffuser array- 15 miles 36-inch concentrate transmission pipeline	Open sea discharge with diffuser array- 8.2 mile 54-inch concentrate transmission pipeline	Existing permitted Dow Freeport discharge canals and outfall

Permitting and environmental issues

Although a project may be technically feasible, it must also be permissible from a regulatory perspective. All three proposed seawater desalination projects are technically feasible and, as demonstration projects, would offer the opportunity to develop a precedent for the permitting of large-scale seawater desalination in the state. R.W. Beck[21] estimates that approximately 21 months will be needed for obtaining the estimated 20 permits required for a seawater desalination reverse-osmosis project.

From a regulatory perspective, a specific concern regarding desalination is how to safely dispose of the concentrate. The impact of concentrate discharge is determined by its temperature, salinity, and chemical

[21] ***R. W. Beck, Guidance Manual for Permitting Requirements in Texas for Desalination Facilities Using Reverse Osmosis Processes, a report prepared for the Texas Water Development Board, DRAFT September 3, 2004.***

content[22] when compared to the receiving environment. The proposed pilot plant studies will more accurately define the composition of the concentrate and its possible environmental impacts. As with the pre-treatment, the information resulting from the pilot study is a tool to confirm or adjust the concentrate disposal method selected at feasibility level.

- **Lower Rio Grande Valley – Brownsville Project**

The concentrate will be discharged off shore via an array of diffusers. This method is a fairly common and accepted approach to minimizing environmental impacts. The environmental impacts analysis will especially examine the risks of routing the concentrate discharge pipeline across areas of known environmental sensitivity.

- **Corpus Christi Project**

The open sea intake and offshore disposal will involve extensive trenches for large sized pipelines extending 8.2 miles to and from the Gulf of Mexico. The discharge pipeline will use the same trench as the raw water line. The concentrate will have to be pumped to discharge into the Gulf of Mexico. A total of about 75 mgd (50 mgd raw water line plus a 25 mgd concentrate pipeline) will have to be transported through the pipelines. There may be significant issues and delays involved in permitting and constructing of these pipelines and in addressing and resolving environmental concerns.

- **Freeport Project**

Under an approved Texas Pollutant Discharge Elimination System (TPDES) permit, the Dow Chemical plant discharges into the Brazos River within its complex. Currently, no technical information has been provided regarding the discharge; however, in response to TWDB staff questions, the project developers stated that their intent is to use Dow's permitted seawater discharge for blending and diluting the concentrate prior to discharge into the river.

Capital and Operation and Maintenance Costs

Regarding the cost of the projects, the feasibility reports provide estimates of the capital and operation and maintenance (O&M) costs. Capital costs for large-scale reverse-osmosis generally range from $3 to $8 per gallon of installed capacity[23,24] Excluding concentrate disposal, a 25 mgd (28,000 acre-feet/year) plant, treating seawater of about 35,000 milligrams/liter of dissolved solids may cost from $4 to $5 per gallon of installed capacity, for single-pass membranes with energy recovery and 50 percent produced water recovery.

For the O&M costs, the most significant cost element is power. Power costs may range between 30 to 70 percent of the total O&M costs[25,26]. Energy demand of seawater desalination projects typically ranges between 3,260 to 4,900 kilowatts-hour per acre-foot of produced water[27]. Table 1 illustrates the impact of electric rates on the power cost component for a 25 mgd seawater desalination plant.

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[22] Sagle, Alyson and Freeman, Benny, University of Texas, The Future of Desalination in Texas-Volume II Fundamentals of Membranes for Water Treatment, a contributed paper.
[23] United States Bureau of Reclamation, Desalting Handbook for Planners, 3rd Edition, July 2003.
[24] Sommariva, Corrado, Desalination Management and Economics, June 2004.
[25] Pankratz, ibid
[26] Callahan, Neil, R. W. Beck, The Future of Desalination in Texas-Volume I, Integration of Power Generation andWater Desalination Operations, a contributed paper.
[27] State of California, Department of Water Resources, Water Desalination Findings and Recommendations, October 2003.

Table 2-Energy cost as a function of power rates

	Kilo-Watt Consumption per acre-foot of water produced	
	Low-end: 3,260	High-end: 4,900
Energy rate in $/kW-hr	Annual Cost of Energy	
0.035	$3,197,653	$4,806,288
0.06	$5,481,690	$8,239,350

Table 3-Summary of capital costs

	Brownsville 25 mgd	Corpus Christi 25 mgd	Freeport 10 mgd
Intake System	$4,900,000	$7,574,800	4,200,000
Raw Water Piping	$0.00	$18,727,610	1,200,000
Transmission System	$9,600,000	$1,358,000	$19,183,000
Pre-Treatment	$10,600,000	$20,124,023	10,800,000
Reverse Osmosis	$32,600,000	$41,731,690	19,500,000
Byproduct Disposal	$30,500,000	$21,767,200	7,300,000
Site Development	$9,200,000	$0.00	6,500,000
Contingency	$13,472,000	$27,820,830	6,500,000
Total Capital Cost	$110,872,000	$139,104,153	75,183,000
Implementation Cost*	$40,516,000	$57,495,847	18,000,000
Total Project Cost	$151,388,000	$196,600,000	$93,183,000

*Includes the following costs: engineering, environmental, easement acquisition, legal, fiscal, contractors' overhead and profit, permitting, etc.

Table 4-Summary of Annual Operation and Maintenance Costs for All Projects

	Brownsville 25 mgd	Corpus Christi 25 mgd	Freeport 10 mgd
Power	$6,943,000	$7,306,000	$3,162,200
Chemicals	$1,866,000	$2,152,000	$727,000
Labor	$1,270,000	$1,199,000	$1,192,000
Miscellaneous	$397,000	$1,032,000	$1,264,900
Maintenance	$1,820,000	$5,826,000	$1,018,000
Plant Site – Lease	$179,000		
Total O&M Cost	$11,776,000	$17,500,000	$7,364,100

Table 5 -Breakdown of Power Cost

	Kilowatt-Hours	Cost Per Hour	Total Cost
Corpus Christi	112,391,661	$0.065	$7,305,458
Brownsville	127,400,000	$0.0545	$6,943,000
Freeport	N/A	N/A	$3,162,200

Anticipated Benefits

Each one of these projects would enhance existing water supplies with new, drought-proof desalinated water. An implicit benefit to the regions affected by these projects is the added reliability that new water provides. The economics of this benefit are not trivial but have not been quantified in the feasibility studies. Nevertheless, new drought-proof water supplies are perhaps the greatest benefits that these projects present.

This part of the review focuses on the apparent benefit of providing new water to each one of the target areas, as well as support for the projects, advantages of the proposed locations, and the overall demonstration value of the project.

- **Lower Rio Grande Valley – Brownsville Project**

This project is located in an area whose primary water supply source is the Rio Grande as it is administered by the Rio Grande Watermaster. The water-rights system and the long established symbiotic practice of joint transportation of river water for agricultural irrigation use and water for municipal treatment and consumption lends itself to regional marketing of any surplus water resulting from seawater desalination.

The area's great dependence on the Rio Grande is a cause of concern for all users, especially those located at the downstream of the river. The recently completed water availability model for the Rio Grande Valley indicates that available firm supplies correspond to half of the current paper demand. Additionally, the regional water plan estimates that there is a current deficit of irrigation water estimated at 1 million acre-feet/year. At the same time, the primary water management strategy to meet municipal needs is the transfer of water rights from irrigated agriculture. Because access to municipal water often is contingent upon irrigation users providing transport or "push-water," then the irrigation deficit threatens the municipalities' access to river water. The influx on new water from a seawater desalination project would help offset the imbalance of river water-rights versus river water availability.

The initial phase of the proposed project would serve the Brownsville PUB system. The relative close proximity of the treatment plant site to the point of use is advantageous as it lessens the need for costly transportation infrastructure.

The feasibility report indicates that sale or lease of surplus water rights could offset the cost of the project.

Subsequent phases are technically feasible and would shift the project from a demonstration initiative to a full fledged water supply project. The additions contemplated in the report would be contingent upon future agreements involving other cities in Cameron and Hidalgo counties. The key cities that would be targeted are Harlingen, Pharr, and McAllen, all of which have provided either letters of support and/or city council resolution in favor of the project.

- **Corpus Christi Project**

The City of Corpus Christi has diligently developed cost-effective and diversified water supplies capable of meeting the city's needs until the year 2060. Although portions of the City's supply capacity involving upstream resources are not yet connected, this in itself offers a potential advantage that the surplus capacity created by the seawater desalination project could potentially make raw water resources available for sale to the City of San Antonio from the Choke Canyon system and, possibly, from the

Lower Colorado River. These types of strategies were considered in the preparation of the 2001 South Central Texas Regional Water Plan (Region L). The feasibility report indicates, however, that the City of San Antonio is currently focused on a portfolio of projects that does not include these alternatives.

The siting of this project at the Barney Davis Power Plant is advantageous because of its proximity to the city's distribution system. The transmission costs of the desalinated seawater are lower for this project than those of the Freeport and Brownsville projects.

- **Freeport Project**

As a demonstration project, the Freeport plant is unique because it is a public-private partnership, structured to take advantage of private activity bond funding. The project team has done an excellent job of communicating the project's potential to stakeholders within the targeted area. However, in its current state, the project can only justify a 6.5 mgd demand. Although not a large-capacity facility, it would still serve its demonstration purpose by creating a precedent in Texas.

The proposed project site takes advantage of existing intake and discharge facilities at the Dow Chemical Complex. The concentrate disposal system, a significantly onerous component of the Brownsville and Corpus Christi projects, would use Dow Freeport discharge canals and outfall No. 001 for dilution and discharge to the lower reach of the Brazos River and then into the Gulf of Mexico. Although staff has not had access to the details of this information, they offer a significant advantage from an implementation perspective.

Table 6- Summary of potential benefits

	Brownsville	Corpus Christi	Freeport
Relative Need	The Rio Grande is the primary source in the region. It is over appropriated, vulnerable to droughts and subject to an International Treaty. Desalination would increase overall system reliability.	Current system is supplied by multiple sources that extend into other regions. Potentially, by providing desalinated seawater to Corpus Christi, some of the existing sources could then be made available to upstream water users.	Future subsidence penalties could accelerate the need for additional supplies of "new" water.
Customers	Brownsville system (1st Phase-25 mgd). Additional phases could serve Harlingen, Pharr, and McAllen	City of Corpus Christi system	Brazosport Water Authority (Initial 6.5 mgd). Future expansion would serve northeastern Brazoria and Fort Bend counties
Water Trade-offs	Water-rights could be leased to up stream water users within the Rio Grande Watermaster System.	Surplus raw water could be sold to San Antonio contingent upon success of efforts to implement Region L approved WMS.	To be defined at a later date.
Demonstration Value	All three projects would demonstrate technical viability of seawater desalination in Texas. Additional "new" drought-proof water would be provided. All projects would create a permitting precedent.		
	Project could deliver water in 2010.	Project could deliver water in 2010.	Project could deliver water in 2010

Financial Requirements

To determine potential markets for the proposed projects, the seawater feasibility studies prepared population and water demand for the potential service areas affected by the projects. Because the projects will become operational in the year 2010, the need for water will be greater. In all cases, however, the proposed projects will be implemented ahead of when the market strictly requires them. This results in additional costs to the implementing agencies. An example of such costs is the debt on existing facilities, which may be redundant once the seawater desalination facilities begin providing water.

As reference, considering existing and other non-desalination facilities, the projected costs of water for the targeted service areas are:

Brownsville PUB:	$2.03/1,000 gal
Corpus Christi:	$1.78/1,000 gal
Brazosport Water Authority	$1.62/1,000 gal

The following table reflects the cost of the proposed large-scale demonstration seawater desalination facilities and the degree of subsidy that is required to implement the projects.

Table 7- Summary of financial considerations

	Brownsville 25 mgd	**Corpus Christi 25 mgd**	**Freeport 10 mgd**
Capital cost	$151,388,000	$196,600,000	$93,183,000
Annual Cost of Operation & Maintenance	$11,776,000	$17,515,000	$7,364,100
Annual potential cost off-sets to O&M	$2,372,500/yr (Sale/lease of water rights)	$5,000,000/yr (Sale of raw water to San Antonio)	None
Cost of treated desalinated water delivered to the distribution system			
$/1,000 gal	2.41	3.51	3.37
$/acre-ft	778	1,133	1,088
Other costs			
$/1000 gal	1.60	0.72	.21
Total Cost to the system			
$/1000 gal	4.01	4.23	3.58
$/acre-ft	1,295	1,366	1,155
Subsidy Requirement			
Criteria	Maintain rate within estimated affordability level.	Attain "zero" cost increment to the end user with respect to existing and planned water supply infrastructure.	
Annual equivalent	$13,830,319	$24,466,335	$7,962,100
$/Acre-ft equivalent	494	865	765
$/1,000 gal equivalent	1.51	2.68	2.37