Desalination Database Updates for Texas
Saqib Shirazi and Jorge Arroyo
Innovative Water Technologies
Texas Water Development Board
Austin, TX 78701

Abstract
The Texas Water Development Board (TWDB) in collaboration with the Bureau of Economic Geology developed a desalination database for Texas in 2005 to provide support for desalination supply alternatives in the state. Recently, TWDB updated the database by collecting information on desalination facilities from the Texas Commission on Environmental Quality, South Central Membrane Association, International Desalination Association, and by conducting a survey of desalination facilities in Texas.

In the past five years, total brackish water desalination capacity in Texas (including blending) increased from 75 million gallons per day (MGD) to 120 million gallons per day. The updated database contains information on 44 desalination facilities; 12 of these facilities use surface water as the feed water source, 32 other facilities use groundwater as the feed water source. The Kay Bailey Hutchison Desalination Plant is the largest desalination facility in the state with a design capacity of 27.5 MGD.

The desalination database will be updated periodically in the future to provide utilities, water planners, policy makers, and other interested stakeholders a resource for obtaining information on desalination facilities in Texas.
1.0 Introduction
Desalination is the process of removing total dissolved solids (TDS) from raw water (or source water) to produce water that is suitable for its intended purposes (Henthorne, 2009; American Water Works Association, 2007). Desalting devices generally use either evaporation or membrane filtration to remove salts from water.

Although every desalination project is unique, four primary components are common to all desalination facilities (Figure 1-1); the pumping and delivery of source water, the treatment facility where the source water is desalted, the disposal of concentrate, and the delivery of the potable water to customers (TWDB, 2008).

Figure 1-1: Primary components of a desalination facility

Desalination is not a new technology in Texas. One of the first seawater desalination demonstration plants of the United States was built at the Dow Chemical Complex in Freeport, Texas (The Dow Texan, 1961). Twenty years later, in 1981, Haciendas del Notre Water Improvement District first built a full-scale brackish water desalination plant for public water supply in Texas. Since then, a number of desalination plants of various sizes were built in Texas.

To inventory the desalination facilities in Texas, and to provide support for water desalination supply alternatives in the state, the Texas Water Development Board (TWDB) in collaboration with the Bureau of Economic Geology developed a desalination database for Texas in 2005. The database is thought to
be the first at the state level to include all public water supplies with a desalination design capacity of greater than 25,000 gallons per day (TWDB, 2005). However, it has not been updated since it was first developed.

In the past few years, several full-scale desalination plants were commissioned in Texas, and several more are in the process of being commissioned. Some of the desalination plants that were in operation five years ago have been decommissioned in the mean time. To incorporate these changes into the desalination database, an amendment of the database was made.

During the process of updating the database, the TWDB collected information on various sequences of desalination that include feed water source, pretreatment, membrane process, post-treatment, and concentrate disposal. We also collected information on the production cost of desalinated water.

The primary objective of this report is to provide an analysis of the data obtained from various desalination facilities in Texas.

2.0 Methods

In the first step of the process, the 2005 desalination database was reviewed. In the second step, desalination facilities with a design capacity of greater than 25,000 gallons of water per day were identified. In the third step, facility operators or managers of each of the selected desalination facilities were contacted and requested to fill out a survey form. In the final step, information obtained from the facility managers/operators were entered into a Microsoft Access Database, which was ultimately imported into a SQL server database.

2.1 Sources of Information

Several sources were used to collect information on desalination facilities in Texas. A detailed discussion on the sources that were used to collect information is provided below.

a. One of the primary sources of information was Texas Commission on Environmental Quality’s (TCEQ) Water Utility Database (WUD). One of the major limitations of the WUD database is that the database is updated by TCEQ field inspections. Therefore, more recent facilities not yet inspected are not included in the WUD.

b. Several other sources were used to collect information on facilities that are not present in the WUD. These sources include

- TWDB’s drinking water “State Revolving Loan Program’s Priority List”
2.2 Collection of Information
The primary method of collecting information on desalination facilities was to interview facility operators and to request them to fill out a survey form. The survey form included a number of questionnaires for the facility operators/managers, which include information on plant’s name and address, plant’s design and production capacities, raw water supply source, pretreatment, post-treatment, concentrate management, and production cost of desalinated water. A sample survey form is attached in Appendix A of this report.

Analysis of the survey revealed that a total of 10 desalination facilities that provided information on their plants in 2005, did not respond to the latest survey. Information for these desalination facilities remains unchanged in the desalination database.

3.0 Results
3.1 Reasons for Building Desalination Facilities
The survey identified that the primary reason for building desalination facilities in Texas is to remove dissolved solids from water. Other reasons for which desalination plants in Texas were built include the removal of high concentration of nitrate, arsenic, fluoride, and perchlorate from water (Figure 3-1).

Figure 3-1: Reasons for building desalination facilities in Texas
3.2 Desalination Facilities
The survey identified that Texas currently has 44 desalination facilities. Most of these facilities were built between 1996 and 2010 (Figure 3-2). The survey also identified that three facilities (the City of Electra, Haciendas Del Notre Water Improvement District, and the City of Primera) decommissioned their desalination plants in the past five years. Total design capacities of these three facilities were about 3 MGD.

![Figure 3-2: Start-up year for desalination facilities in Texas](image)

3.3 Desalination Capacities
Depending on the source, desalination is divided into two major categories; seawater desalination (total dissolved solids concentration is greater than 25,000 mg/L) and brackish water desalination (total dissolved solids concentration varies from 1,000 – 10,000 mg/L). Brackish water source is further divided into two sub categories; brackish surface water and brackish groundwater.

Currently, Texas does not have any full-scale seawater desalination facility. There are 44 brackish water desalination facilities in Texas, with a design capacity of approximately 120 MGD (including blending). Four of these facilities are currently sitting idle (City of Granbury, City of Los Ybanez, Veolia Water, and Windermere Water System). Table 3-1 provides a list of the desalination facilities in Texas that have the capacity of producing more than 25,000 gallons of water per day.

Twelve of forty four facilities use surface water as a source of raw water, which accounts for design capacity of 50 MGD. Thirty two facilities use groundwater as a raw water source, which accounts for the design capacity of 70 MGD. Figure 3-3 shows the location of brackish surface water and brackish
groundwater desalination facilities in Texas. El Paso Water Utility’s Kay Bailey Hutchison Desalination facility has the highest design capacity in the State (27.5 MGD).

Table 3-1: Summary of desalination facilities in Texas (with a design capacity of greater than 25,000 gallon per day)

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Status</th>
<th>Desalination Facility Start Up Year</th>
<th>Source Water</th>
<th>Process</th>
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<tbody>
<tr>
<td>Big Bend Motor Inn</td>
<td>Operating</td>
<td>1989</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Abilene (Hargesheimer Treatment Plant)</td>
<td>Operating</td>
<td>2003</td>
<td>SW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Bardwell</td>
<td>Operating</td>
<td>1990</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Bayside</td>
<td>Operating</td>
<td>1990</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Beckville</td>
<td>Operating</td>
<td>2004</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Brady</td>
<td>Operating</td>
<td>2005</td>
<td>SW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Clarksville City</td>
<td>Operating</td>
<td>2006</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Evant</td>
<td>Operating</td>
<td>2010</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Fort Stockton</td>
<td>Operating</td>
<td>1996</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Granbury</td>
<td>Idle</td>
<td>Original EDR Plant was built in 1984; in 2007 RO Plant was mounted in trailer</td>
<td>SW</td>
<td>RO</td>
</tr>
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<td>City of Hubbard</td>
<td>Operating</td>
<td>2002</td>
<td>GW</td>
<td>RO</td>
</tr>
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<td>City of Kenedy</td>
<td>Operating</td>
<td>1995</td>
<td>GW</td>
<td>RO</td>
</tr>
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<td>City of Laredo</td>
<td>Operating</td>
<td>1996</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Los Ybanez</td>
<td>Idle</td>
<td>1991</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Robinson</td>
<td>Operating</td>
<td>1994</td>
<td>SW</td>
<td>RO</td>
</tr>
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<td>City of Seadrift</td>
<td>Operating</td>
<td>1998</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>City of Seymour</td>
<td>Operating</td>
<td>2000</td>
<td>GW</td>
<td>RO</td>
</tr>
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<td>City of Sherman</td>
<td>Operating</td>
<td>1993</td>
<td>SW</td>
<td>EDR</td>
</tr>
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<td>City of Tatum</td>
<td>Operating</td>
<td>1999</td>
<td>GW</td>
<td>RO</td>
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<td>Cypress Water Treatment Plant</td>
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<td>2008</td>
<td>SW</td>
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<td>Dell City</td>
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<td>1997</td>
<td>GW</td>
<td>RO</td>
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<td>Esperanza Fresh Water Supply</td>
<td>Operating</td>
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<td>RO</td>
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<td>Holiday Beach WSC</td>
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<td>RO</td>
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<td>Facility Name</td>
<td>Status</td>
<td>Desalination Facility Start Up Year</td>
<td>Source Water</td>
<td>Process</td>
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<tr>
<td>---------------------------------------------------</td>
<td>----------------</td>
<td>-------------------------------------</td>
<td>--------------</td>
<td>---------</td>
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<td>Horizon Regional MUD</td>
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<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>Kay Bailey Hutchison Desalination Plant</td>
<td>Operating</td>
<td>2007</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>Lake Granbury Surface Water Advanced Treatment System</td>
<td>Operating</td>
<td>2003</td>
<td>SW</td>
<td>RO</td>
</tr>
<tr>
<td>Longhorn Ranch Motel</td>
<td>Operating</td>
<td>1990</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>Midland Country Club - fairways &amp; greens</td>
<td>Operating</td>
<td>2004</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>North Alamo Water Supply Corporation (Lasara)</td>
<td>Operating</td>
<td>2005</td>
<td>GW</td>
<td>RO</td>
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<td>North Alamo Water Supply Corporation (Owassa)</td>
<td>Operating</td>
<td>2008</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>North Alamo (Doolittle)</td>
<td>Operating</td>
<td>2008</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>North Cameron Regional Water Supply Corporation</td>
<td>Operating</td>
<td>2006</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>Oak Trail Shores</td>
<td>Operating</td>
<td>EDR was installed in 1998; RO replaced EDR in 2007</td>
<td>SW</td>
<td>RO</td>
</tr>
<tr>
<td>Possum Kingdom Water Supply Corporation</td>
<td>Operating</td>
<td>2003</td>
<td>SW</td>
<td>RO</td>
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<td>River Oaks Ranch</td>
<td>Operating</td>
<td>1987</td>
<td>GW</td>
<td>RO</td>
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<td>Southmost Regional Water Authority</td>
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<td>2004</td>
<td>GW</td>
<td>RO</td>
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<td>Sportsmans World MUD</td>
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<td>RO</td>
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<td>Study Butte Terlingua Water System</td>
<td>Operating</td>
<td>2000</td>
<td>GW</td>
<td>RO</td>
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<tr>
<td>The Cliffs (Double Diamond Utilities)</td>
<td>Operating</td>
<td>1991</td>
<td>SW</td>
<td>RO</td>
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<tr>
<td>Valley MUD #2</td>
<td>Operating</td>
<td>2000</td>
<td>GW</td>
<td>RO</td>
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<tr>
<td>Veolia Water Treatment Plant</td>
<td>Idle</td>
<td>1992</td>
<td>SW</td>
<td>RO</td>
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<tr>
<td>Water Runner, Inc.</td>
<td>Operating</td>
<td>2001</td>
<td>GW</td>
<td>RO</td>
</tr>
<tr>
<td>Windermere Water System</td>
<td>Idle</td>
<td>2003</td>
<td>GW</td>
<td>RO</td>
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</tbody>
</table>

NOTE:
EDR: Electrodialysis reversal  
RO: Reverse osmosis  
GW: Groundwater  
SW: Surface water  
MUD: Municipal Utility District  
WSC: Water Supply Corporation
Figure 3-3: Locations of desalination facilities in Texas

3.4 Desalination Operation and Maintenance

The survey asked various operational and maintenance questions to the facility operators and managers. These questions include feed water source and quality, desalination treatment method, membrane scaling type, membrane cleaning frequency, membrane replacement frequency, product water post-treatment, concentrate post-treatment, and concentrate disposal. A summary of the outcome of the survey is provided below.

a) Feed Water Quality: Feed water quality is a critical design criterion for desalination. Low TDS concentration in feed water requires less energy for treatment compared to high TDS in feed water. Additionally, low TDS allows for higher conversion rates and the plant can operate with less dosing of antiscalant chemicals.

In Texas, total dissolved solids concentration in desalination facilities varies from less than 1,000 mg/L to greater than 3,000 mg/L (Figure 3-4).
b) Treatment Method: Two major types of desalination technologies are available worldwide; membrane based and thermal. In Texas, the vast majority of desalination facilities rely on reverse osmosis. Only two facilities (City of Sherman and Dell City) use electrodialysis reversal for desalting water. Design capacities for electrodialysis reversal and reverse osmosis in Texas are 11.1 and 108.9 MGD, respectively. Two facilities (City of Granbury and Oak Trail Shores) shifted the treatment method from EDR to RO in the past few years.

c) Membrane Fouling: Membrane fouling, caused by the deposition of dissolved materials on the membrane surface, is one of the major limitations of reverse osmosis technology. Membrane fouling increases feed pressure, decreases water production, and shortens membrane life.

Desalination facilities in Texas reported various types of membrane fouling including inorganic, organic, colloidal, silica, and biological fouling. Among them, inorganic scaling is the most predominant. 15 of 44 desalination facilities reported inorganic scaling as one of the major operational problems (Figure 3-5).
d) Membrane Cleaning: Cleaning is the process of removing mineral scale, organic matter, biological growth, colloidal particles, or insoluble constituents which build up on the surface of the membrane. The optimum cleaning procedure restores the membrane production back to its original or near original state. A number of factors affect membrane cleaning including raw water quality, type of foulants, and type of membrane.

Generally, membrane cleaning frequency may vary from once a month to once a year. Most of the desalination facility operators in Texas reported that they clean membranes as needed (Figure 3-6).
Membrane Cleaning frequency in desalination facilities of Texas

e) Membrane Replacement: After several years of operation, membranes’ water production and salt rejection capacities decrease, and they need to be replaced with new ones. Generally, the life span of a membrane varies from 6 to 9 years. Because many desalination facilities in Texas were built in the past fifteen years, a large number of these facilities have not changed membranes since they started their operation (Figure 3-7).
f) Concentrate Management and Disposal: All desalination processes generate a concentrated salt solution or brine by-product that must be managed in an environmentally sound manner. Concentrate management options include volume minimization, post-treatment, beneficial reuse, and concentrate disposal.

Most of the desalination facilities in Texas do not treat concentrate prior to disposal (Figure 3-8). They use one or more methods for concentrate disposal. These methods include discharge in the sanitary sewer or in the surface water body, evaporation, land application, deep well injection and zero discharge desalination. Most of the desalination facilities in Texas use only one method; however, some facilities use more than one method for concentrate disposal.

A majority of the desalination facilities in Texas discharge their concentrate either in the sanitary sewer or in the surface water body. Thirteen facilities use desalination concentrate for land application, seven facilities use evaporation ponds to treat desalination concentrate, one facility (Veolia Water System) use zero discharge desalination and one facility (Kay Bailey Hutchison Desalination Plant) use injection well to discharge the concentrate underground (Figure 3-9).

Figure 3-8: Post-treatment of concentrate
Figure 3-9: Concentrate disposal methods in desalination facilities of Texas

4.0 Cost of Desalination

Historically, the high cost of desalination has been a limiting factor for its broader use. However, over the past two decades, increased efficiency and lower cost of reverse osmosis membranes have lowered the cost of desalination to competitive levels. A recent TWDB review of desalination costs in Texas indicated that the cost of brackish groundwater desalination ranges between $410 per acre-foot and $847 per acre-foot (TWDB, 2009)

The cost of desalination depends on various factors including the source water type and quality, pre-treatment requirement, post-treatment requirement of product water, post-treatment of concentrate, and concentrate disposal.

Water production cost depends on the capital cost as well as the operation and maintenance cost of a plant. The survey collected information from 27 facilities on the capital cost of desalination plants when they were built. The capital cost data of these plants is shown in Table 4-1. Data for operation costs are too disparate for a statistical study to be undertaken; therefore, operation costs are not shown in the Table.
<table>
<thead>
<tr>
<th>Desalination Facility</th>
<th>Facility Start Up Year</th>
<th>Capital Cost When the Facility was Built ($)</th>
<th>Plant Design Capacity (including blending) MGD</th>
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<td>The original unit was installed in 1990. In 2010, the City has replaced the old unit with the new one.</td>
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<td>Capital Cost When the Facility was Built ($)</td>
<td>Plant Design Capacity (including blending) MGD</td>
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<td>-----------------------------------------------------------</td>
<td>------------------------</td>
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<tr>
<td>Horizon Regional MUD</td>
<td>2001</td>
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<td>2004</td>
<td>13,090,000</td>
<td>7.5</td>
</tr>
<tr>
<td>Sportsmans World MUD</td>
<td>1984</td>
<td>3,500,000</td>
<td>0.083</td>
</tr>
<tr>
<td>Study Butte Terlingua Water System</td>
<td>2000</td>
<td>1,348,000</td>
<td>0.14</td>
</tr>
<tr>
<td>The Cliffs</td>
<td>NA</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Valley MUD #2</td>
<td>2000</td>
<td>800,000</td>
<td>1</td>
</tr>
<tr>
<td>Veolia Water Treatment Plant</td>
<td>1992</td>
<td>NA</td>
<td>0.245</td>
</tr>
<tr>
<td>Water Runner, Inc.</td>
<td>2001</td>
<td>NA</td>
<td>0.028</td>
</tr>
<tr>
<td>Windermere Water System</td>
<td>2003</td>
<td>1,500,000</td>
<td>2.88</td>
</tr>
</tbody>
</table>

NOTE:

NA: Not available
5.0 Future Desalination Facilities
Texas has significant future needs for additional water, a portion of which could be met through desalination. The regional water planning groups have been active in evaluating opportunities for both seawater and brackish water desalination. In the course of this study we informally collected information about future desalination facilities in Texas. A list of these facilities is presented in Table 5-1.

### Table 5-1: Future desalination facilities in Texas

<table>
<thead>
<tr>
<th>Name of the Future Facility</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Alamo Water Supply Corporation (Donna) [under construction]</td>
<td>Donna, TX</td>
</tr>
<tr>
<td>Central Texas Water Supply Corporation</td>
<td>Bell, TX</td>
</tr>
<tr>
<td>Fort Hancock Water Control and Improvement District</td>
<td>Hudspeth, TX</td>
</tr>
<tr>
<td>Sylvester-McCaulley Water Supply Corporation</td>
<td>Fisher, TX</td>
</tr>
</tbody>
</table>

6.0 Conclusion
The desalination database was updated to keep track of the growth of desalination industry in Texas. In the past five years, brackish water desalination design capacity increased from 75 MGD to 120 MGD in the state. This staggering growth is a combined result of increased need for new water supplies, growing scarcity of freshwater sources, and the significant advances in membrane desalination technology that have resulted in lower costs to desalt water. In the future, the database will be updated periodically to monitor the progress of desalination capacities in Texas.

7.0 References


The Dow Texan (1961, July 5). Beutel terms phone call a shocker.

8.0 Acknowledgements
The authors gratefully acknowledge the help from Marlo Berg of TCEQ for retrieving data from the Water Utility Database of TCEQ. The authors would also like to thank the desalination facility operators and managers who spent their valuable time for filling out the survey forms.
Appendix A: SURVEY FORM FOR DESALINATION FACILITIES

(Use one form for each plant)

Data entered on: ________________

1- GENERAL INFORMATION:

Plant Name and Address:

Official Name: ____________________________________________________________

Address: __________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

County: ________________________________________________________________

Water/Ground Water Conservation District (if applicable): ______________________

Public Water System No (if applicable): _____________________________________

Contact Name: ____________________________________________________________

Contact Title: _____________________________________________________________

Phone: ___________________________________________________________________

Fax: _____________________________________________________________________

Email: ___________________________________________________________________

Web site: __________________________________________________________________

Plant Designer: ____________________________________________________________________

Contact_____________________________________________________________

Plant Owner: __________________________________________________________________

______________________________________________

Plant Operator: __________________________________________________________________

2- PLANT INFORMATION:

Plant status in the past few months:
- Operating; 
- Idle since ______; 
- Closed since ______

Year of plant start-up:__________________

Is desalination unit start-up year different? 
- No 
- Yes :______________

Cost of desalination plant when it was built:______________

Plant Category (check all that applies):
- Drinking water production; 
- Waste water treatment; 
- Landfill leachate treatment 
- Industrial: 
  - Power; 
  - Electronics; 
  - Beverage; 
  - Pharma.; 
  - Chemical; 
- Other:______

Plant Capacity

Design plant capacity including bypass (MGD): ________________________________

Permitted plant production including bypass (MGD): _____________________________

Average plant production including bypass (MGD): _____________________________

Strong seasonal variation in production (>25%)?: 
- No 
- Yes

Process Type (check all that applies):
- RO (Reverse Osmosis) 
- EDR (Electrodialysis Reversal) 
- ED (Electrodialysis)
- NF (Nanofiltration) 
- ME (Multi-effect Evaporation)
- MSF (Multi-Stage Flash) 
- VC (Vapor Compression) 
- Other:_________________

Desalination Unit Capacity

- Same as plant capacity, there is no blending

Blend water source:
- same as membrane feed water; 
- other:_________________

Design production (MGD): _________________________________
Permitted production (MGD): _______________________________________

Average production (MGD): ______________________________________

Average concentrate production (MGD): ___________________________

Power Source:† Grid; † Collocation; † Generated on site; † Other: _______________________

Reasons for building desalination plant (check all that apply):

† High TDS  † High hardness  † High alkalinity  † High chloride
† High sodium  † High sulfate  † High nitrate  † High arsenic
† High radionuclides  † High fluoride  † High Fe/Mn  † Other: __________

Is an expansion of the plant being considered? † No † Yes

3- RAW WATER SUPPLY SOURCE:

† Ground water; † Surface water; † Reclaimed water; † Seawater; † Other: __________

Average/Range of TDS of the membrane feed water: _________________

Is turbidity an operational problem? † No † Yes: ___NTU; ____SDI

Are the following operational problems present?

† Fe/Mn  † H₂S  † Organic matter/TOC  † Variability in raw water composition

Distance from supply source to plant: _______________________________________

If ground water:

Well field location: ______________ Withdrawal zone: _______________________

Screened interval: _______ ft to _______ ft below land surface

If surface/sea water, intake location: __________

If reclaimed water, water source __________

4- PRETREATMENT OF DESALINATION UNIT FEED

Filtration (check all that apply):
Gravity filter  Media filter  Bag filter
Cartridge filter. Manufacturer if applicable:_______________________________
Membrane (MF/UF). Manufacturer if applicable:_______________________________
Other___________
Coagulation/flocculation: No  Yes
Alum  Ferric chloride  Ferric sulfate  Polymer  Other:________________
Clarification: No  Yes
Oxidation: No  Yes Why?______________________________________________
Aeration; K permanganate; Green sand; same as disinfection; Other___________
Softening: No  Yes
Lime addition  Membrane (NF)  Ion exchange
Disinfection: No  Yes
Chlorination/chloramination  Ozonation  UV  Other
Dechlorination: No  Yes
Activated carbon: No  Yes: to remove________________
pH adjustment: No  Yes  Acidification: what pH?:__ Addition of caustic?: what pH?:___
Scaling control: No  Yes.

5- MEMBRANE INFORMATION:
No membrane, go to Section 6
Manufacturer/Model of membrane elements:__________________________________________
Years in service: _____________years
Feed pressure: _________________psi
Membrane recovery: _____________%
Target TDS of the final permeate: _________________mg/L
Problems encountered:
Scaling: calcite; gypsum; silica; Metal oxide/sulphides; other: don’t know nature of scales

Colloidal fouling: biological fouling

Membrane replacement frequency:

Never been changed ≤ 2 years
> 2 and ≤ 4 years > 4 and ≤ 6 years
> 6 years: Other:

Current membrane cleaning frequency:

Monthly; bimonthly; quarterly; semi-annually; annually
Every 2 years; other:

Membrane cleaning triggered by:

Decreased production; Increased pressure; Time elapsed: hours

Disposal method of cleaning waste:

Mixed with concentrate Sewer, Waste water treatment plant
Hauled from the site other:

Average TDS of the concentrate:

6- POSTTREATMENT OF THROUGHPUT

No posttreatment before distribution, go to Section 7

Activated carbon Adjustment of pH Adjustment of alkalinity Aeration
Blending Corrosion control Disinfection Fluoridation
Gas removal Ion exchange Other:

7- POSTTREATMENT OF CONCENTRATE

No posttreatment of concentrate, go to Section 8
8- CONCENTRATE DISPOSAL

Co-disposal with neighboring facility: No / Yes

- Disposal well: Distance to well: ______________________________
  - Permit type: Class I / Class II / Class V

- Surface water body: Distance to water body: ______________________________
  - Permit type: TPDES / Other: ____________

- Land application: on-site waste water (i.e., septic) / irrigation water

- Sanitary sewer, waste water treatment plant name: ______________________________

- Evaporation pond. Ultimate fate of dry residue: ______________________________

- Zero-discharge

9- PROBLEMS

- Chemicals: ______________________________

- Disposal of concentrate: ______________________________

- Electronics: ______________________________

- Feed water: ______________________________

- Membrane: ______________________________

- Operating costs: ______________________________
10- COST ISSUES

Average rate/cost of power as of 2008 if applicable:

<table>
<thead>
<tr>
<th>Cost Range</th>
<th>Rate / Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>&lt;1¢ /kWh</td>
<td></td>
</tr>
<tr>
<td>&gt;1¢ and ≤3¢ /kWh</td>
<td></td>
</tr>
<tr>
<td>&gt;3¢ and ≤5¢ /kWh</td>
<td></td>
</tr>
<tr>
<td>&gt;5¢ and ≤10¢ /kWh</td>
<td></td>
</tr>
<tr>
<td>&gt;10¢ /kWh</td>
<td></td>
</tr>
</tbody>
</table>

Average cost of water production:______________________________

Average cost of desalinated water production:_________________________

Operation and Maintenance costs:

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>Feed water cost</td>
<td></td>
</tr>
<tr>
<td>Labor cost</td>
<td></td>
</tr>
<tr>
<td>Membrane replacement cost</td>
<td></td>
</tr>
</tbody>
</table>
Chemical cost ____________________________________________________________

Energy cost _____________________________________________________________

Concentrate disposal cost ________________________________________________