Desalination Database Updates for Texas

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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).

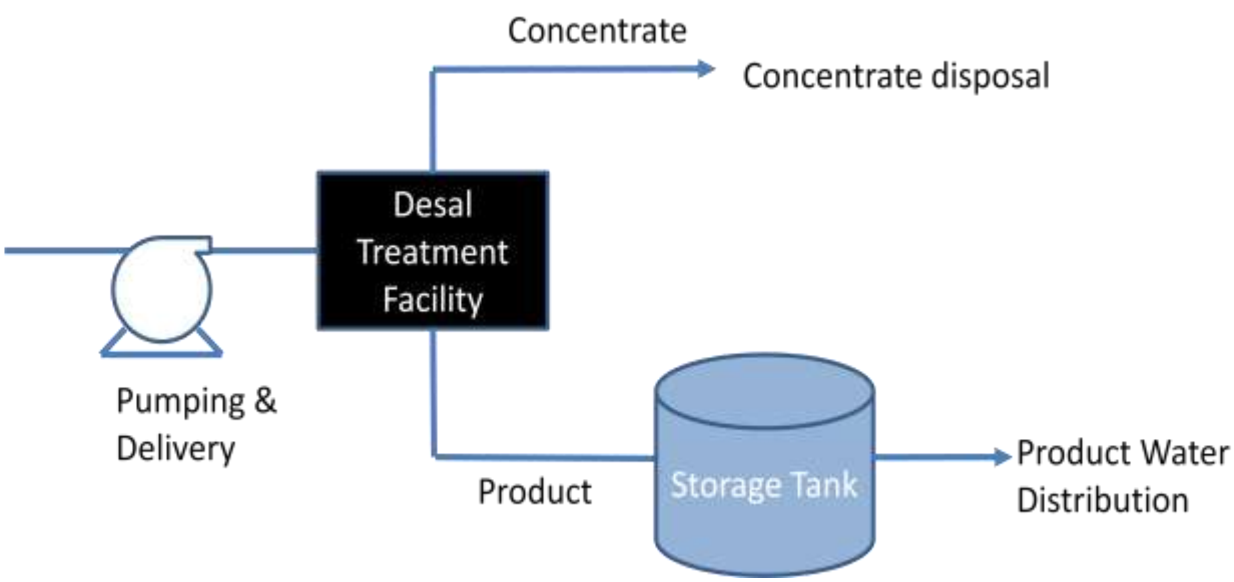

Figure 1-1: Primary components of a desalination facility

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 Free port, 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"

- Global Water Intelligence's Desal Database
- American Membrane Technology Association's database
- Personal contacts

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).

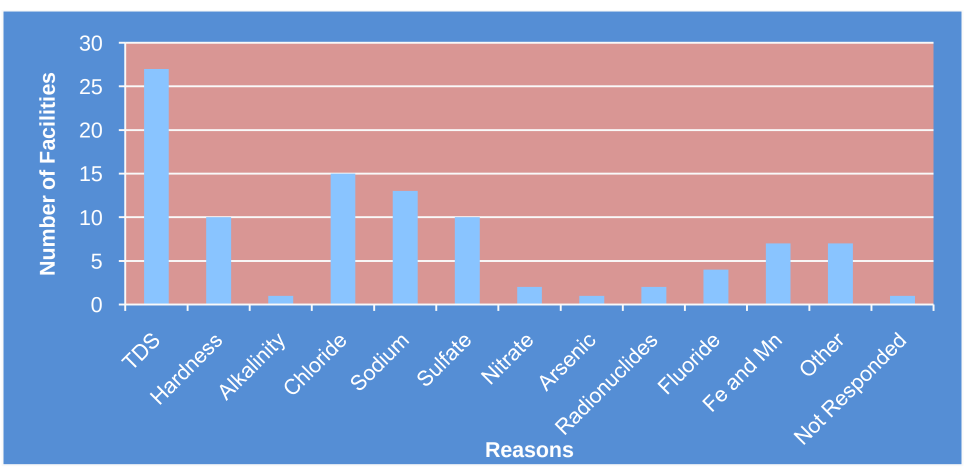

Figure 3-1: Reasons for building desalination facilities in Texas

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.

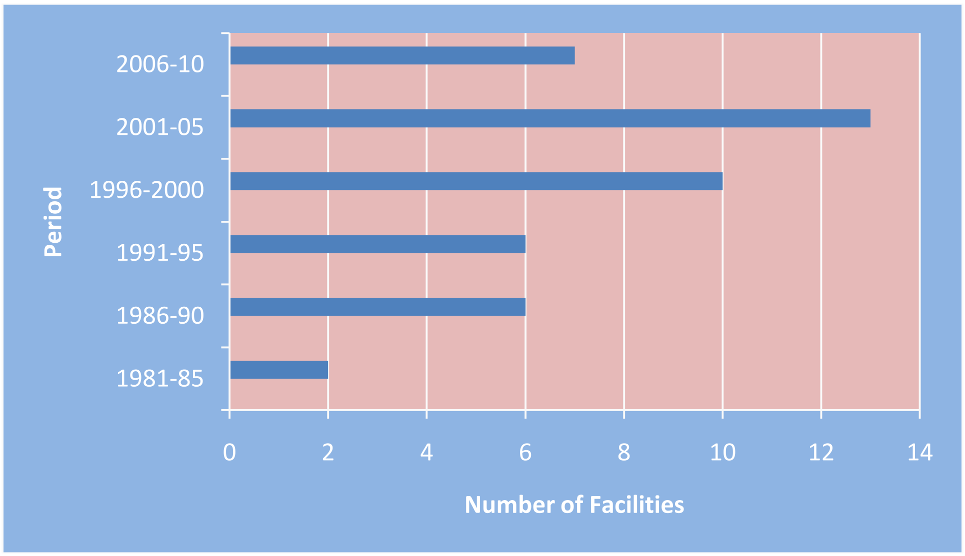

Figure 3-2: Start-up year for desalination facilities in Texas

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)

Facility Name	Status	Desalination Facility Start Up Year	Source Water	Process
Big Bend Motor Inn	Operating	1989	GW	RO
City of Abilene (Hargesheimer Treatment Plant)	Operating	2003	SW	RO
City of Bardwell	Operating	1990	GW	RO
City of Bayside	Operating	1990	GW	RO
City of Beckville	Operating	2004	GW	RO
City of Brady	Operating	2005	SW	RO
City of Clarksville City	Operating	2006	GW	RO
City of Evant	Operating	2010	GW	RO
City of Fort Stockton	Operating	1996	GW	RO
City of Granbury	Idle	Original EDR Plant was built in 1984; in 2007 RO Plant was mounted in trailer	SW	RO
City of Hubbard	Operating	2002	GW	RO
City of Kenedy	Operating	1995	GW	RO
City of Laredo	Operating	1996	GW	RO
City of Los Ybanez	Idle	1991	GW	RO
City of Robinson	Operating	1994	SW	RO
City of Seadrift	Operating	1998	GW	RO
City of Seymour	Operating	2000	GW	RO
City of Sherman	Operating	1993	SW	EDR
City of Tatum	Operating	1999	GW	RO
Cypress Water Treatment Plant	Operating	2008	SW	RO
Dell City	Operating	1997	GW	EDR
DS Waters of America, LP	Operating	1997	GW	RO
Esperanza Fresh Water Supply	Operating	1990	GW	RO
Holiday Beach WSC	Operating	2002	GW	RO

Facility Name	**Status**	**Desalination Facility Start Up Year**	**Source Water**	**Process**
Horizon Regional MUD	Operating	2001	GW	RO
Kay Bailey Hutchison Desalination Plant	Operating	2007	GW	RO
Lake Granbury Surface Water Advanced Treatment System	Operating	2003	SW	RO
Longhorn Ranch Motel	Operating	1990	GW	RO
Midland Country Club - fairways & greens	Operating	2004	GW	RO
North Alamo Water Supply Corporation (Lasara)	Operating	2005	GW	RO
North Alamo Water Supply Corporation (Owassa)	Operating	2008	GW	RO
North Alamo (Doolittle)	Operating	2008	GW	RO
North Cameron Regional Water Supply Corporation	Operating	2006	GW	RO
Oak Trail Shores	Operating	EDR was installed in 1998; RO replaced EDR in 2007	SW	RO
Possum Kingdom Water Supply Corporation	Operating	2003	SW	RO
River Oaks Ranch	Operating	1987	GW	RO
Southmost Regional Water Authority	Operating	2004	GW	RO
Sportsmans World MUD	Operating	1984	SW	RO
Study Butte Terlingua Water System	Operating	2000	GW	RO
The Cliffs (Double Diamond Utilities)	Operating	1991	SW	RO
Valley MUD #2	Operating	2000	GW	RO
Veolia Water Treatment Plant	Idle	1992	SW	RO
Water Runner, Inc.	Operating	2001	GW	RO
Windermere Water System	Idle	2003	GW	RO

NOTE:
EDR: Electrodialysis reversal
GW: Groundwater
MUD: Municipal Utility District
RO: Reverse osmosis
SW: Surface water
WSC: Water Supply Corporation

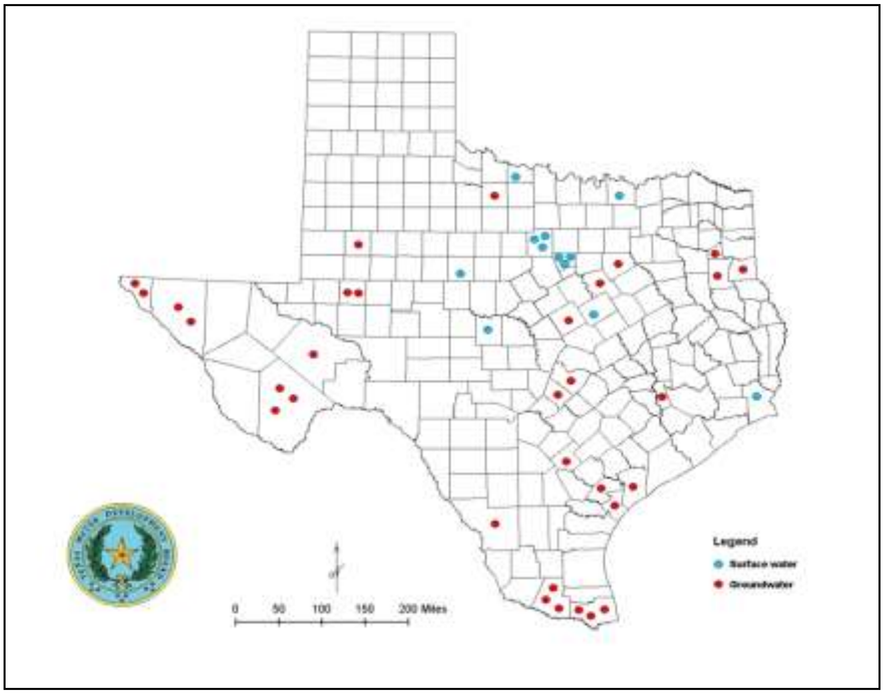

Figure 3-3: Locations of desalination facilities in Texas

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).

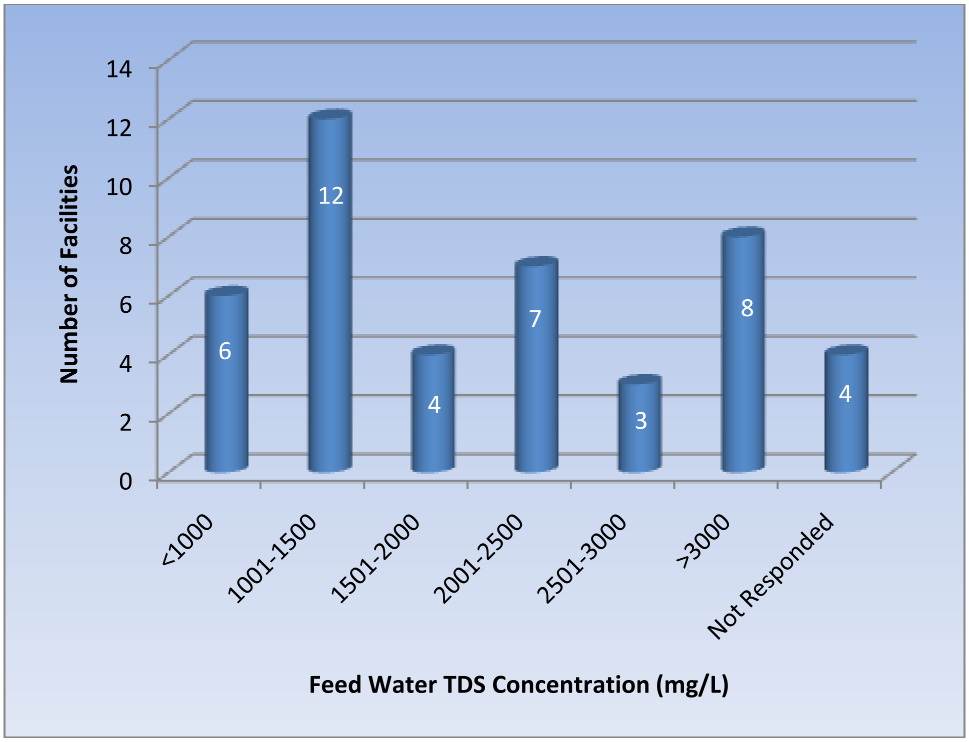

Figure 3-4: Total dissolved solids concentration in feed water

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).

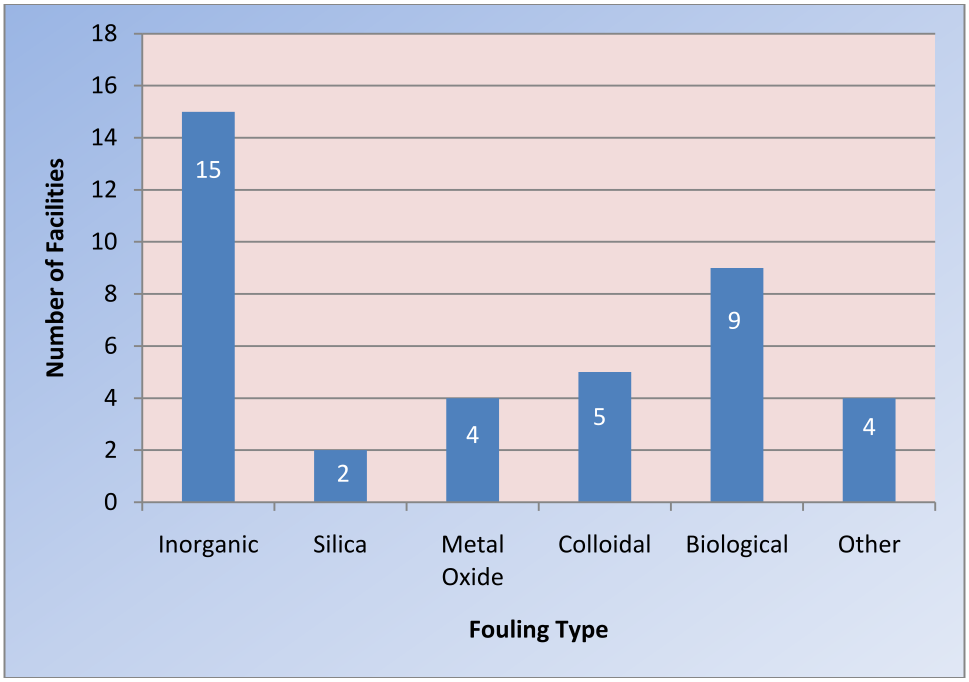

Figure 3-5: Membrane fouling in desalination facilities of Texas

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).

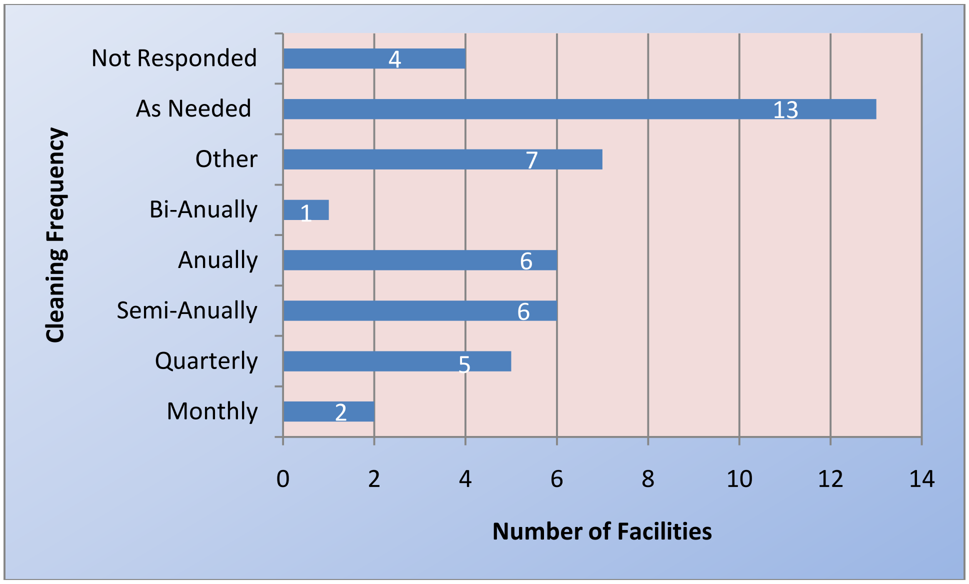

Figure 3-6: Membrane cleaning frequency in desalination facilities of Texas

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).

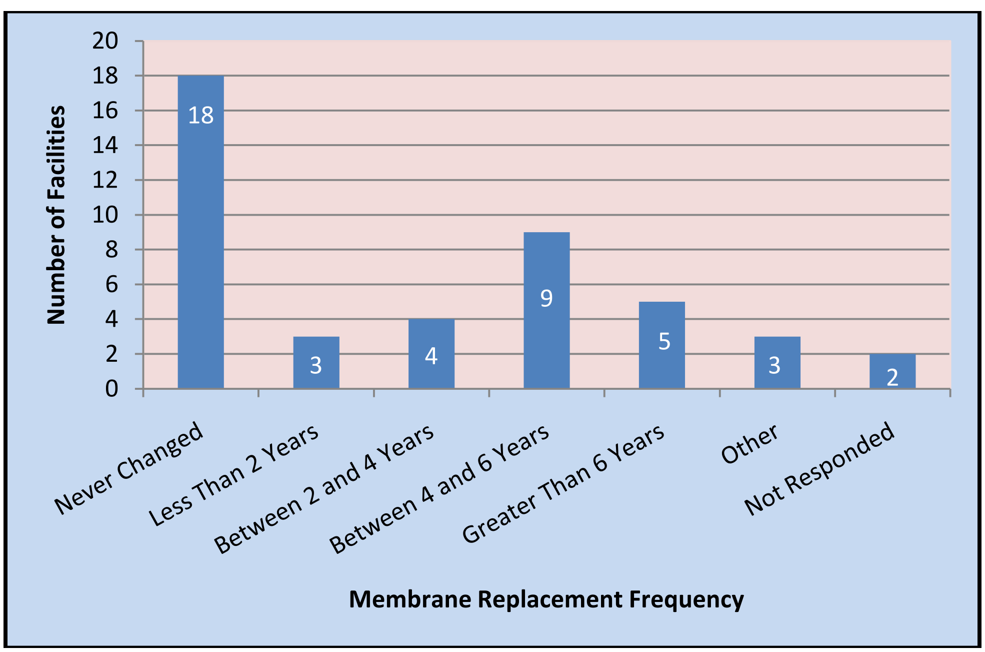

Figure 3-7: Membrane replacement frequency in desalination facilities of Texas

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).

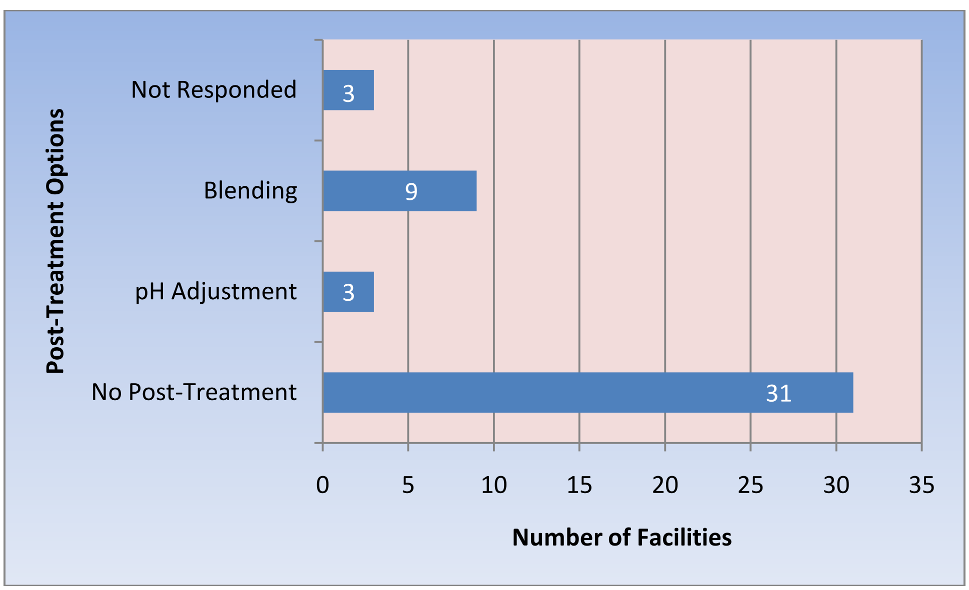

Figure 3-8: Post-treatment of concentrate

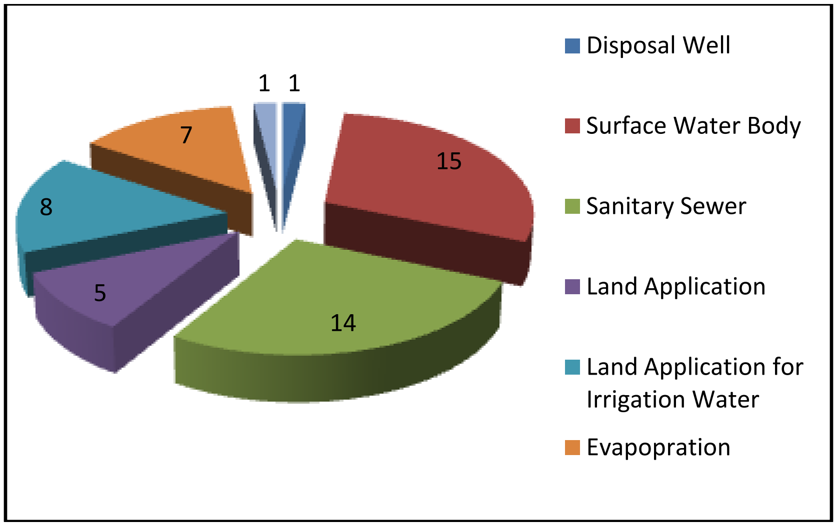

Figure 3-9: Concentrate disposal methods in desalination facilities of Texas

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 4-1: Capital cost of desalination facilities of Texas (when they were built)

Desalination Facility	Facility Start Up Year	Capital Cost When the Facility was Built ($)	Plant Design Capacity (including blending) MGD
Big Bend Motor Inn	1989	26,000	0.057
City of Abilene (Hargesheimer Treatment Plant)	2003	NA	7.95
City of Bardwell	1990	100,000	0.252
City of Bayside	The original unit was installed in 1990. In 2010, the City has replaced the old unit with the new one.	NA	0.045
City of Beckville	2004	400,000	0.216
City of Brady	2005	9,000,000	3
City of Clarksville City	2006	1,539,000,000	0.288
City of Evant	2010	250,000	0.1
City of Fort Stockton Osmosis/Desalination Facility	1996	6,000,000	6.5
City of Granbury	1984 Original EDR Plant, 2007 - RO Plant mounted in trailer	600,000	0.462
City of Hubbard	2002	NA	0.648
City of Kenedy	1995	NA	2.858
City of Laredo Santa Isabel R.O.	1996	NA	0.1
City of Los Ybanez	1991	300,000	
City of Robinson	1994	6,000,000	2.3
City of Seadrift	1998	1,200,000	0.61
City of Seymour	2000	4,500,000	3
City of Sherman	1993	NA	11
City of Tatum	1999	NA	0.324
Cypress Water Treatment Plant	2008	NA	10
Dell City	1997	NA	0.1
DS Waters of America, LP	1997	NA	0.09
Esperanza Fresh Water Supply	1990	NA	0.023
Holiday Beach WSC	2002	450,000	0.15

Desalination Facility	Facility Start Up Year	Capital Cost When the Facility was Built ($)	Plant Design Capacity (including blending) MGD
Horizon Regional MUD	2001	6,800,000	6
Kay Bailey Hutchison Desalination Plant	2007	87,000,000	27.5
Lake Granbury Surface Water Advanced Treatment System	2003	36,600,000	12.5
Longhorn Ranch Motel	1990	34,149	0.023
Midland Country Club - fairways & greens	2004	90,000	0.023
North Alamo Water Supply Corporation (Lasara)	2005	2,000,000	1.2
North Alamo Water Supply Corporation (Owassa)	2008	8,000,000	1.5
North Alamo Water Supply Corporation (Doolittle)	2008	NA	3.75
North Cameron Regional Water Supply Corporation	2006	1,783,651	2.5
Oak Trail Shores	1998	NA	1.584
Possum Kingdom Water Supply Corporation	2003	NA	1
River Oaks Ranch	1987	NA	0.14
Southmost Regional Water Authority	2004	13,090,000	7.5
Sportsmans World MUD	1984	3,500,000	0.083
Study Butte Terlingua Water System	2000	1,348,000	0.14
The Cliffs		NA	0.25
Valley MUD #2	2000	800,000	1
Veolia Water Treatment Plant	1992	NA	0.245
Water Runner, Inc.	2001	NA	0.028
Windermere Water System	2003	1,500,000	2.88

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

Name of the Future Facility	Location
North Alamo Water Supply Corporation (Donna) [under construction]	Donna, TX
Central Texas Water Supply Corporation	Bell, TX
Fort Hancock Water Control and Improvement District	Hudspeth, TX
Sylvester-McCaulley Water Supply Corporation	Fisher, TX

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

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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:______

□ 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 † H_2S † 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 adjustement:† 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

† Adjustment of pH † Aeration † Blending † Corrosion control † Dechlorination

† Disinfection † Gas removal † Scaling control † Other:_________________

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: ____

____

☐ Permitting: ____

____

☐ Posttreatment of concentrate: ____

____

☐ Posttreatment of permeate: ____

____

☐ Pretreatment: ____

____

☐ Pump/Valves: ____

____

☐ Well/Intake: ____

____

10- COST ISSUES

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

☐ Not available ☐ <1¢ /kWh ☐ >1¢ and ≤3¢ /kWh

☐ >3¢ and ≤5¢ /kWh ☐ >5¢ and ≤10¢ /kWh ☐ >10¢ /kWh

Average cost of water production:____

Average cost of desalinated water production:___________________________________

Operation and Maintenance costs:

☐ Not available

Feed water cost ____

Labor cost ____

Membrane replacement cost ____

Chemical cost ____

Energy cost ____

Concentrate disposal cost ____