Cost of Brackish Groundwater Desalination in Texas

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Purpose of paper

To provide sample water production costs of brackish groundwater desalination in Texas.

Summary of Results

The capital cost of desalination plants is site specific. Factors such as depth, location and quality of the source water, and concentrate disposal method have the potential to substantially impact the capital cost of a project. Operation and maintenance will also vary from plant to plant in response to factors such as source water quality, power costs, age of the plant, and personnel allocated to the plant. Nevertheless, the cost of completed plants is a useful reference to estimate the cost of future projects with similar characteristics.

In collaboration with various utilities and consultants, we examined six brackish groundwater desalination plants completed in the last decade and arrived at the following conclusions:

- Capital cost range from $2.03 to $3.91 per gallon of installed capacity;
- Operation and maintenance costs range from $0.53 to $1.16 per 1,000 gallons of water produced; and
- Total production cost of water ranges from $1.09 to $2.40 per thousand gallons or $357 to $782 per acre-foot.

Background

In 1961 one of the first seawater desalination demonstration plants to be built in the United States was located at the Dow Chemical Complex in Freeport, Texas (The Dow Chemical Company, 1960; The Dow Chemical Company, 1961; Lomax, 2008). The first community desalting plant in Texas, designed to provide a public water supply, was installed at Port Mansfield in 1965. The plant had a design capacity of 250,000 gallons per day and used electrodialysis as the primary method of desalination (U.S. Department of Interior, 1966). Currently, there are 44 municipal brackish water desalination facilities in Texas, with a design capacity of about 120 million gallons per day or about 134,400 acre-feet per year.

In spite of this history and current status, desalination is relatively new when compared to other better-known water management strategies in Texas, and this lack of familiarity prompts questions about its costs. Desalination costs vary considerably by location based on a number of issues including feed water source, feed water quality, plant size, process type and design, intake type, pre- and post-treatment processes, concentrate disposal method, regulatory issues, land costs, and conveyance of water to and from the plant.

There are cost estimating tools that incorporate some of these variables. One such tool is the U.S. Bureau of Reclamation planning level estimating procedures for seawater and surface water brackish desalination facilities. Estimating procedures include nomographs to calculate the impact of selected variables, such as the cost of power, in the cost of desalination projects (U.S. Bureau of Reclamation, 2003). Another of Reclamation's products is WTCost©, a database and computer program with cost algorithms for different types of desalination pre-treatment and treatment technologies.

This paper provides a cost reference for brackish groundwater desalination in Texas on the basis of recently completed projects and projects currently under construction.

Cost Factors

The total production cost of desalinated water includes the cost of capital or debt service and operation and maintenance costs. Debt service costs are a function of the total capital cost of the project, the interest on the capital, and the loan payback period. The operation and maintenance costs are a function of chemical, power, equipment replacement, and labor costs. There are several approaches to calculate and report the cost of water. One approach assigns the debt service to the actual production volume (Wilf, 2007). Another alternative is to calculate the debt service load on the basis of a life-cycle analysis and use an efficiency factor [also known as plant operating factor] to estimate actual production volume instead of the design production capacity (Sturdivant and others, 2009). In this paper, the unit production cost (UPC) of desalinated water is calculated as follows:

Equation 1 - Unit Production Cost

$$UPC = \frac{Annual\ Debt\ Service}{Plant\ Design\ Capacity \times Plant\ Operating\ factor} + \frac{Operation\ and\ Maintenance}{Production\ Volume}$$

Many factors affect the capital and operational costs of desalination facilities (Graves & Choeffel, 2004; Younos, 2005). Below is an illustration of commonly recognized cost factors for desalination systems (Figure 1).

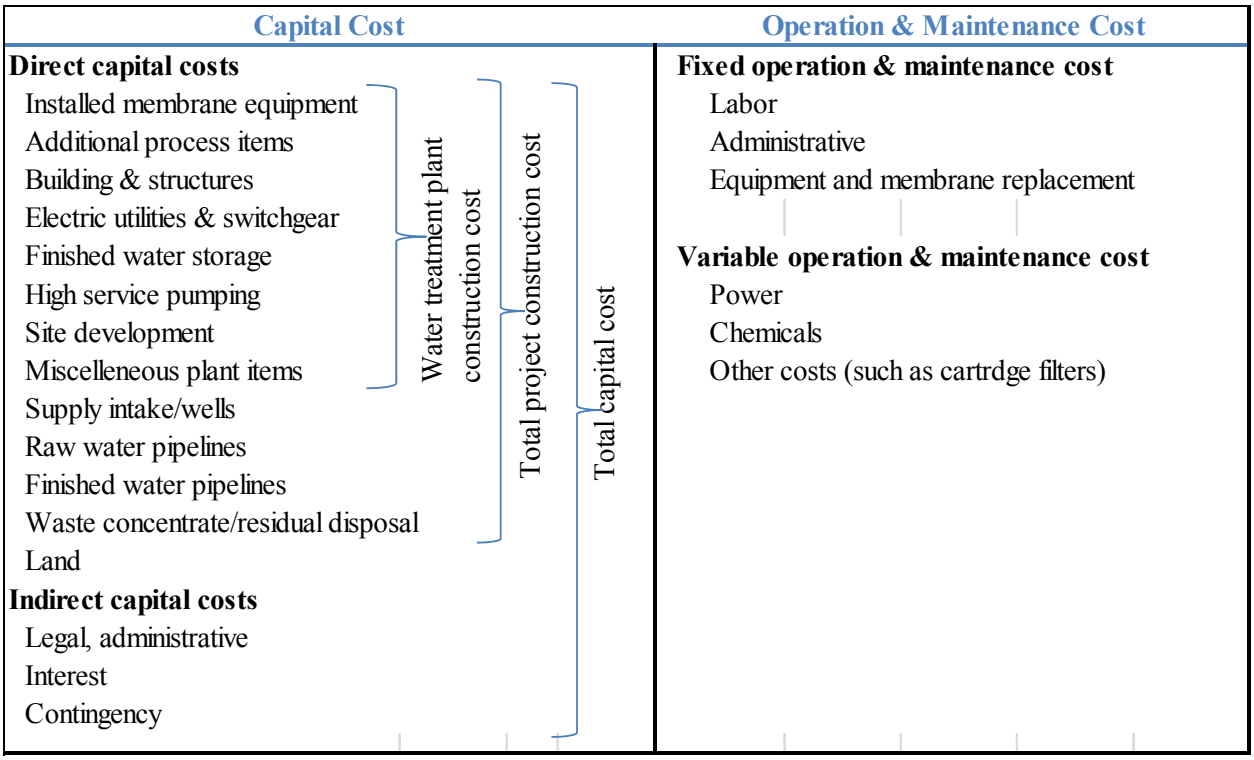

Figure 1 - Key factors for capital and operation and maintenance costs of a desalination facility (Bergman, 2012).

Projects Samples and Costs Analysis

Project Samples

Our review of brackish groundwater desalination costs considered two sets of samples. In the first set, we collected data from a sample of recently completed brackish groundwater desalination plants in Texas. In the second set, we collected data from a sample of brackish groundwater desalination projects that are currently under construction in Texas.

The sample of recently completed brackish groundwater desalination projects consists of six facilities (year of installation noted in brackets):

- North Alamo Water Supply Corporation, three facilities:
    - Lasara, Willacy County (2005)
    - Owassa, Hidalgo County (2008)
    - Doolittle, Hidalgo County (2008)
- North Cameron Regional Water Supply Corporation, Cameron County (2007)
- Southmost Regional Water Authority, Cameron County (2004)
- El Paso Water Utilities' Kay Bailey Hutchison Brackish Groundwater Desalination Plant. El Paso County (2007)

The sample of projects currently under construction consists of three projects:

- North Alamo Water Supply Corporation- Donna, Hidalgo County
- City of Roscoe, Nolan County

- Fort Hancock Water Conservation Improvement District, Hudspeth County

Costs Analysis

Our estimates of production cost do not include any infrastructure to connect the facility to the distribution system. The cost, thus, should reflect extracting and delivering the source water to the treatment plant, treating and conditioning the water for delivery, and discharging the concentrate for disposal. We worked with representatives from the respective utilities and used TWDB records to obtain relevant capital and operation and maintenance cost information.

The completed projects have different plant start dates. To facilitate the comparison of capital costs, we normalized the capital costs for all projects to 2011 dollar equivalents. We used the Engineering News Record (ENR) construction average annual indices to estimate the trended capital costs for each project.

Equation 2 – Capital Costs Trending Formula

$$Capital\ Cost_{\$2011} = Capital\ Cost_{\$installation\ year} \times \frac{ENR\ Index_{2011}}{ENR\ Index_{installation\ year}}$$

The [trended] annual debt service was calculated by amortizing the trended capital cost over a 20-year period (n) and a 5.5 percent interest rate (i), as follows:

Equation 3 - Annual Debt Service

$$Annual\ Debt\ Service = Capital\ Cost \times \left(\frac{i}{1-(1+i)^{-n}}\right)$$

Where,

i= annual interest rate for capital borrowing

n= number of year to repay the debt

Results

Table 1 reports the unit production cost of desalinated brackish groundwater for the sample of recently completed projects. These costs are estimates of what the production cost of water would be if the plants had been built in the year 2011 and if the unit operation and maintenance costs observed on the basis of actual operation to-date were maintained. Unit production cost of desalinated brackish groundwater ranges from $357 per acre-foot (North Alamo Water Supply Corporation plant at Doolittle) to $782 per acre-foot (North Cameron Regional Water Supply Corporation).

Table 1 - Trended water production costs of a sample of existing brackish groundwater desalination facilities.

Brackish Groundwater Desalination Plant	Desalination Design Capacity (MGD)[3]	Water Treatment Construction cost ($)		Capital Cost $$_{2011}$/gal	Capital Cost $$_{2011}$/AF	Power cost (¢/Kw-hr)	Production cost ($) per 1,000 Gallons			Water Production Cost ($ per Acre-Foot)
[Source water salinity; start-up year]	[Reverse osmosis treatment capacity; raw water blending capacity]	Original Cost	Trended Cost 2011				O&M	Debt	Total cost	
Lasara [2,500-3,000 mg/l; 2005]	1.2 [1; 0.2]	2,000,000	2,436,180	2.03	661.53	7.2	1.13	0.46	1.59	518
Doolittle [2,500-3,000 mg/l; 2008]	3.5 [3; 0.5]	8,000,000	8,731,736	2.49	812.93	6.9	0.53	0.56	1.09	357
Owassa [2,500-3,000 mg/l; 2008][1]	2 [1.5; 0.5]	5,850,000	6,385,082	3.19	1,040.29	5.9	0.6	0.72	1.32	431
North Cameron Regional WSC [3,500 mg/l; 2007][2]	1.25 [1; 0.25]	7,033,554	8,008,327	6.41	2,087.62	8	0.95	1.45	2.40	782
	2.5 [2; 0.5]	8,033,554	9,146,916	3.66	1,192.21	8	0.95	0.83	1.78	579
Southmost Regional Water Authority [3,500 mg/l; 2004]	7.5 [6; 1.5]	23,000,000	29,319,404	3.91	1,273.84	7.49	1.16	0.88	2.04	666
Kay Bailey Hutchison El Paso-Ft. Bliss [4,365 mg/l; 2007]	27.5 [15; 12.5]	91,000,000	103,611,599	3.77	1,227.71	8.35	0.65	0.85	1.50	489

Notes:

[1]Current production capacity of the plant is only 2 MGD. The plant will be capable of producing 3.5 MGD with the addition of a well. The capital cost includes expansion capabilities.

[2]The plant currently operates with only one well and produces as much as 1.25 MGD of product water. The plant will produce as much as 2.5 MGD with the addition of a well. The plant's capital cost includes expansion capabilities for up to 5 MGD of product water.

[3]The cost analysis used "1" as the plant operating factor.

AF = acre-foot, Kw-hr = kilowatt-hour, mg/l = milligrams per liter, MGD = millions of gallons per day, O&M = operation and maintenance, TDS = total dissolved solids, WSC = water supply corporation.

The capital cost in 2011 dollar equivalents of the sample of completed facilities ranges from $2.03 (North Alamo Water Supply Corporation Lasara) to $3.91 (Southmost Regional Water Authority) per gallon of installed capacity (Figure 2).

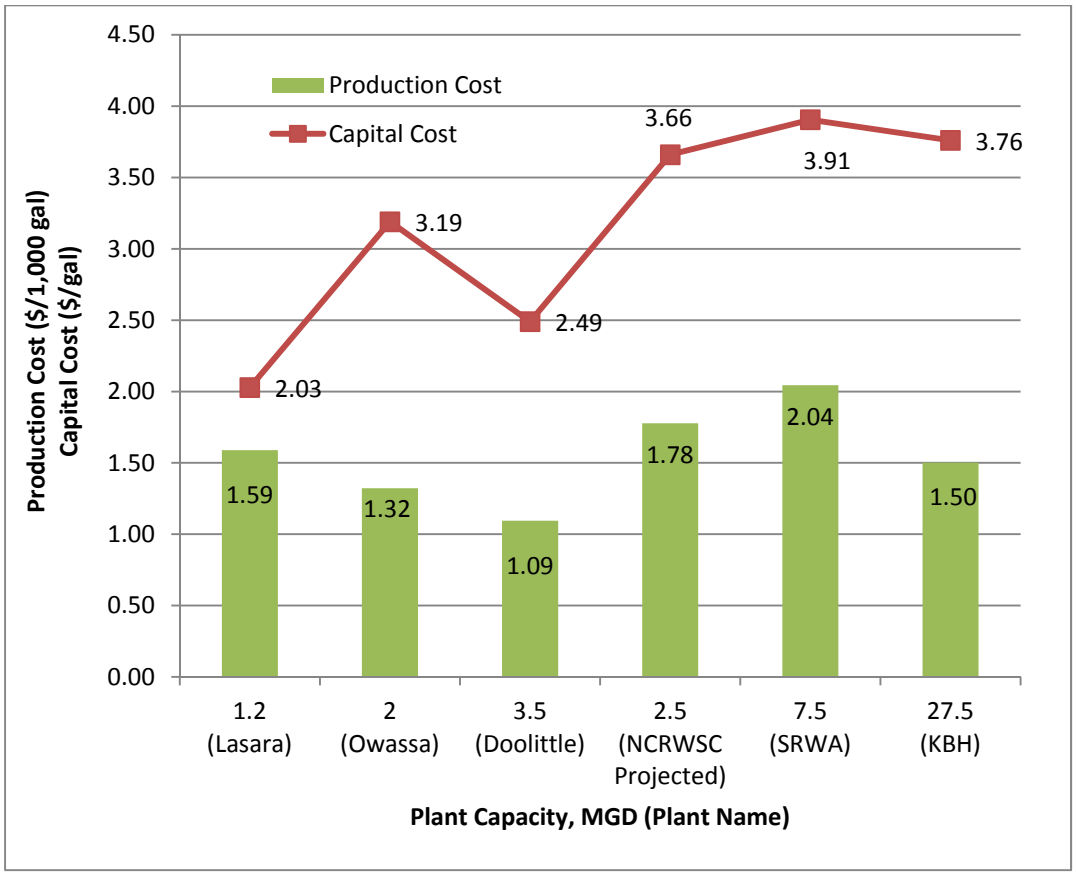

Figure 2 - Capital and Operational Costs (2011 dollar equivalents) of sample completed facilities

The projected total production cost of desalinated brackish water for a sample of projects that are currently under construction in Texas ranges from $280 per acre-foot to $1,064 per acre-foot (Table 2). The capital costs for the plants under construction were amortized on a 20-year 5.5 percent interest basis. Because these plants have not begun operation yet, the unit operation and maintenance costs were estimated on the basis of engineering analysis of the projects.

Although the desalination design capacities for the City of Roscoe and Forth Hancock Water Control and Improvement District (WCID) are almost same, the unit capital cost as well as the total production cost for these facilities is significantly different (Table 2). One of the primary reasons for such a significant difference in cost is that Forth Hancock WCID installs evaporation ponds to dispose the concentrate, while the City of Roscoe disposes the concentrate by surface water discharge. Construction cost of evaporation ponds increases the unit capital cost and the total production cost of desalinated water for Fort Hancock WCID.

Table 2 - Estimated water production cost of brackish groundwater desalination facilities under construction.

Brackish Groundwater Desalination Plant [Source water salinity]	Desalination Design Capacity (MGD)[1]	Water Treatment Plant's Capital Cost ($)	Unit Capital Cost		Power Cost (¢/Kw-hr)	Cost ($) per 1,000 Gallons			Water Production Cost ($ per Acre-Foot)
			$\$_{2011}$/gal	$\$_{2011}$/AF		O&M[2]	Debt	Total Production Cost	
Fort Hancock WCID [1,600-2,400 mg/l]	0.4	3,375,000	8.44	2,749	8.2	1.36	1.91	3.27	1,064
City of Roscoe [3,800 mg/l]	0.5	974,000	2.25	735	7	0.42	0.44	0.86	280
North Alamo WSC Donna [3,800 mg/l]	2.5	6,700,000	2.68	873	7	0.8	0.61	1.41	458

Notes:

[1]The cost analysis used "1" as the plant operating factor.

[2]O&M costs for these projects are estimated.

AF = acre-foot, Kw-hr = kilowatt-hour, mg/l = milligrams per liter, MGD = millions of gallons per day, O&M = operation and maintenance, TDS = total dissolved solids, WSC = water supply corporation.

Additional Considerations

Several methodologies researched for this paper provide a valuable reference for a systematic planning-level water production cost estimating for desalination facilities (U.S. Bureau of Reclamation, 2003; Wilf, 2007; Sturdivant and others, 2009). TWDB and Reclamation are in the process of applying Reclamation's WaterCost (WTCost©) estimating software to a larger sample of facilities completed in the state since 2000. This application will account for cost factors such as source water chemistry and location, recovery rate, blending ratio, energy recovery, power tariff, concentrate management strategy, and projected plant availability. A deliverable of this effort will be a set of cost curves to guide cost estimating of brackish groundwater desalination facilities in Texas.

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