Economic Implications of Conventional Water Treatment Versus Desalination: A Dual Case Study

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Introduction/Objectives

The Texas Rio Grande Valley (Valley), a multi-county region in southern Texas, is experiencing rapid population growth, urban sprawl, and the sometimes contentious issue of limited water resources. According to the 2000 U.S. Census Bureau, the Valley is the fourth-fastest-growing Metropolitan Statistical Area (MSA) in the United States, with the McAllen-Edinburg-Mission area realizing a 48.5% population growth from 1990 to 2000. This growth, combined with prolonged drought, prior shortfalls in water deliveries from Mexico, and the uncertainty of future supplies, has resulted in increased competition for water, as well as a heightened awareness for planning, conservation, and capital investment.[1]

Conventional surface-water treatment is the norm for producing potable (drinkable) water for the Valley. The primary source water is the Rio Grande [River], which serves as a partial international boundary between the United States and Mexico, and provides 87% of the region's municipal and industrial water (Rio Grande Regional Planning Group 2001). With increased demand and growing concern over future potable water supplies, water managers, consulting engineers, and other state and regional stakeholders are considering, evaluating, and implementing alternatives to conventional surface-water treatment.

There are various strategies which can improve the available water supply in the region, either by increasing use efficiency or supply enhancement. Efficiency-in-use improvements

[1] As stated in Sturdivant et al. (2008), "Shortfalls in water deliveries from Mexico are in reference to The 1944 Treaty, a binational treaty in which the U.S. annually provides Mexico with 1.5 million acre feet (ac-ft) from the Colorado River, while Mexico in return annually provides the U.S. with 350,000 ac-ft from the Rio Grande. As of September 30, 2005, Mexico had paid its water debt which accumulated from 1992-2002 (Spencer 2005)."

occurring in the Valley include on-farm and municipal water-conservation measures, as well as conservation in irrigation district water-conveyance systems. Alternatives to the predominance of diverted Rio Grande water (i.e., supply) include: groundwater wells, water reuse, desalination of seawater and/or brackish groundwater, and rainwater harvesting. Historically, desalination of brackish groundwater has not been an economically feasible alternative, but through recent advancements in technology, groundwater desalination has become a viable alternative. The purpose of this study is to provide a comprehensive economic and financial analysis of the costs of producing water for two of the supply alternatives: conventional surface-water treatment and brackish groundwater desalination, which, combined, constitute about 90% of the region's total municipal supply (Rio Grande Regional Water Planning Group 2001).

Methodology

Determining an objective, economic-efficiency based, priority-ranked strategy of alternatives requires a sound and consistent methodology. Such a methodology should allow for an "apples-to-apples" comparison of alternatives as each will likely differ in initial and continued costs, quantity and quality of output, useful life, etc. An appropriate approach to determining the most cost-effective alternative is to identify and define each as a capital investment (i.e., project) and apply appropriate financial, accounting, and economic principles and techniques.

The methodology herein combines standard Capital Budgeting - Net Present Value (NPV) analysis with the calculation of annuity equivalent measures. Calculating NPV values for dollars and water allows for comparing alternatives with differing cash flows and water production output, while the use of annuity equivalents facilitates comparisons of projects (and components thereof) with different useful lives. This combined approach integrates expected years of useful life with related annual costs and outputs, as well as other financial realities, into a single comparative, comprehensive annual $/ac-ft {or $/1,000 gals} life-cycle cost.

Each analysis also incorporates an annual discount rate of 6.125% to account for inflation and the time value of money, which consists of an annual inflation rate of 2.043% for continued expenses, and a discount factor of 4.00% to account for social-time preference. Risk is ignored due to the government-entity aspect of the decision. Refer to Rister et al. (2002) for an explanation of the selection of these rates.

To facilitate Capital Budgeting - NPV analyses for both the conventional surface-water and groundwater desalination facilities, Texas AgriLife Extension Service and Texas AgriLife Research agricultural economists developed two independent Microsoft® Excel® spreadsheet models. The model CITY H_2O ECONOMICS© provides life-cycle costs (e.g., $/ac-ft/year) for an entire conventional surface-water treatment facility, as well as detailed cost information for up to 12 individual functional expense areas (i.e., segments) common to conventional treatment facilities.[2] Similarly, the model DESAL ECONOMICS© provides life-cycle costs for up to twelve individual functional expense areas common to desalination facilities, as well as for the entire facility.[3]

The two models, CITY H_2O ECONOMICS© and DESAL ECONOMICS© facilitate comparisons both within and across different water treatment technologies. Beyond having the ability to compare the "bottom-line" cost results for water treatment facilities, both models have the ability to analyze individual expense areas. That is, results provided by the models allow for a breakdown of costs into facility cost types, segments, and items. Such details are useful when

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2 In this initial application of CITY H_2O ECONOMICS©, the 11th and 12th functional expense areas are unused.

3 In this initial application of DESAL ECONOMICS©, the 8th-12th functional expense areas are unused.

comparing two facilities with substantially different life-cycle costs. The ability to recognize individual item costs, beyond the standard aggregate, bottom-line, overall analysis facilitates identification of which functional cost area(s) is (are) causing the disparity.

Overview of Case Studies

The conventional surface-water treatment facility analyzed in this report is the McAllen Northwest facility, located just outside of McAllen, Texas, near the Texas-Mexico Border. The facility, which is owned and operated by McAllen Public Utilities Board (PUB), began operations in 2004. The source water for the McAllen Northwest facility is surface water originating from the Rio Grande. The water reaches the McAllen facility through a system of open-surface canals operated by various irrigation districts. Located just outside of Brownsville, Texas is the brackish groundwater desalination facility analyzed in this report, the Southmost Desalination facility. This facility is owned by the Southmost Regional Water Authority (SRWA) – a consortium of six partners which includes: Brownsville Public Utilities Board (BPUB), City of Los Fresnos, Valley Municipal Utilities District No. 2, Town of Indian Lake, Brownsville Navigation District, and Laguna Madre Water District (BPUB 2007, and SRWA 2006). BPUB manages the facility through a management contract with SRWA. The source water for the Southmost facility is brackish groundwater from the Gulf Coast aquifer, which is obtained using 20 supply wells, ranging in depth from 280-300 feet, in which 18 are primary and two serve as backup.

The construction period for the McAllen Northwest facility spanned 24 months, from January of 2002 to January of 2004; a two-year construction period is assumed for this analysis. The construction period for the Southmost desalination facility spanned 20 months, from

February of 2003 to September of 2004; for this analysis, a 1-year construction period is assumed.[4] The various civil, electrical, and mechanical components of both facilities are expected to have a wide range of useful lives, ranging from as low as two years for the anthracite component of the conventional filters, to a high of 50 years for structural items such as buildings, storage tanks, concrete, etc. For these analyses, a maximum useful life of 50 years is established for both the McAllen Northwest and Southmost facilities. Within that maximum-life limit, however, certain capital items have shorter lives. Thus, intermittent capital replacement expenses are incorporated, as appropriate, to reflect the necessary replacement of such items (e.g., membranes, pumps, motors, etc.) to insure the facility's full anticipated productive term. Non-capital expenses are captured in annual operating expenses for each of the individual facilities.

The original maximum-designed capacity of the McAllen Northwest facility is 8.25 million gallons per day (mgd). This capacity equates to an output of 9,241 ac-ft annually if the facility is operating at 100% designed capacity, 365 days per year. However, due to equipment maintenance and failure issues which require a certain amount of shut-down time in the course of a year, real flow data for fiscal year (FY) 2005-2006 indicates the facility is producing roughly 2,349,000,000 gallons for the year (or 7,208 ac-ft), averaging 6.435 mgd (Santiago 2007). This output level equates to a 78% production efficiency (PE) level which is used as the benchmark level of production in this analysis. The current maximum-designed capacity of the Southmost facility is 7.5 mgd, which is derived by combining 6.0 mgd of Reverse Osmosis (RO)-processed water with 1.5 mgd of blend source water. Using a 100% PE rate equates the 7.5 mgd production

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[4] Like other capital projects, various delays and challenges were incurred during the construction phase. These issues are discussed in further detail in Norris 2006. Without the unanticipated non-operational delays and needed phased-in start-up, Southmost facility management and consulting engineers advise construction could have been achieved in a 12-month period.

rate to 8,401 acre-feet annually. Due to required shut-down time, as well as an additional problem with incoming water quality, a 68% PE rate is considered appropriate and corresponding to levels observed in the most recent fiscal years (i.e., 2006 and 2007). The modeled 68% rate equates to 5.1 mgd average daily output, or 5,713 ac-ft annually.

Cost Data for Two Case-Study Facilities

When McAllen PUB decided to build an additional conventional surface-water treatment facility, two initial investments had to be made: (1) acquiring water rights, and (2) constructing the facility; whereas, the Southmost facility only required an initial investment of constructing the facility. Since operation of both of the facilities began, two ongoing cost categories are considered to exist: (1) continued operation & maintenance (O&M)/administrative expenses, and (2) capital replacement expenses.

Since the majority of the Valley's groundwater is brackish, desalination treatment is the only way to use the groundwater for drinking-water purposes. Therefore, to obtain additional water for subsequent treatment in conventional treatment facilities, municipalities must purchase or lease municipal water rights to Rio Grande surface water from a private individual or from an irrigation district (Stubbs et al. 2003). The McAllen Northwest facility utilizes water obtained by McAllen PUB through a purchase of permanent municipal water rights in the 1990s and early 2000s. In this analysis, the current price of permanent water rights is considered as the opportunity cost of this purchase. The reasoning for recording the cost in today's price, rather than the price at which the rights were purchased, is consistent with the economic concept of opportunity cost.[5] Through communications with local irrigation district managers, the authors determined the current (2006) price of a permanent municipal water right in the Valley to be approximately $2,300/ac-ft (Kaniger 2007; Barrera 2007). This analysis assumes a purchase of 8,872 ac-ft for the McAllen Northwest facility, which is 96% of the facility's design capacity annual output. This 96% factor was achieved by assuming a municipality would purchase enough water for maximum annual capacity less a two-week shut-down time. Consequently, the total assumed cost of water rights purchased equals $20.4 million, which is calculated by multiplying the current cost of a water right ($2,300/ac-ft) by the annual water production at 96% efficiency (8,872 ac-ft).

"Initial Construction Costs" for the McAllen Northwest facility totaled $21.30 million, in 2002 dollars (McAllen Public Utilities Water Systems 2002). For this analysis, however, the authors chose to use 2006 as the benchmark year in order to make the analysis more current; therefore, the construction costs were compounded four years (using the 2.043% annual compounding rate) to account for inflation. This conversion process resulted in an adjusted 2006 construction cost of $22.96 million. For analysis-detail and conventional treatment facility-comparison reasons, the total cost is divided into ten individual segments common to conventional water treatment facilities (Table 1). This table also includes the cost of the water rights purchase, which brings the total initial investment at McAllen Northwest to $43.37 million. Initial construction costs totaled $26.19 million (in 2006 dollars) for the Southmost

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[5] The concept of opportunity cost, in its most basic definition, is the value of the next best alternative of a resource (Perloff 2004). A more precise definition provided in Thomas and Maurice (2005) states, "opportunity cost of using an owner-supplied resource is the best return the owners of the firm could have received had they taken their own resource to market instead of using it themselves." In this report, the current price of the water rights is included, for it represents the financial capital McAllen would receive if they sold the rights on the market today.

Table 1. Initial Construction and Annual Continued Costs for the Ten Segments of the McAllen Northwest Facility, 2007 (Rogers et al. 2008).[a]

Facility Segment	Initial Construction/ Investment Costs	Continued Costs (annual)
1) Water Rights/Raw Water Intake/Reservoir	$25,142,292	$618,664
2) Pre-Disinfection	482,412	398,911
3) Coagulation/Flocculation	1,446,796	71,065
4) Sedimentation	875,574	35,838
5) Filtration/Backwash	2,677,879	36,221
6) Secondary/Disinfection	423,047	156,457
7) Sludge Disposal	747,699	107,193
8) Delivery to Municipal Line/Storage	4,683,612	212,345
9) Operations' Supporting Facilities	917,784	101,923
10) Overbuilds & Upgrades [b]	5,971,571	28,306
TOTAL	$43,368,666	$1,766,923

[a] Values are in 2006 dollars.

[b] Represents construction beyond the necessities and captures "elbow room" for future expansion.

facility (Table 2). For analysis-detail and desalination-facility-comparison reasons, the total cost is divided into seven individual functional segments common to desalination facilities (Table 2).

"Continued Costs" represent the costs incurred during ongoing operations from the time of construction completion until the end of useful life. These costs are compounded at 2.043% annually. The annual continued costs recorded for the McAllen Northwest facility are based on the FY 2005-2006 budget prepared by McAllen PUB (McAllen Public Utilities Water Systems 2007) and total $1.77 million (Table 1).[6] For analysis-detail and water treatment-facility-comparison reasons, this category in the model is divided into ten individual segments common to conventional water treatment facilities. The continued costs for the Southmost facility are based on actual expenses incurred during the 2004-2005 FY, with adjustments made to reflect 2006 dollars and anticipated increases in energy and chemical costs. For this study, the

[6] FY 2005-2006 is considered 2006 dollars, to satisfy base year requirement of 2006.

Southmost facility's continued costs total $1.73 million and are separated into seven individual functional segments common to desalination facilities (Table 2).

"Capital Replacement Costs" also facilitate the continual operations of a treatment facility. Within the useful life of a facility, certain capital items must be replaced intermittently (e.g., every 2, 5, or 10 years) due to wear and tear. Recognizing the financial reality of inflation, the costs for capital replacement items (which are based on current FY 2006 dollars) are compounded at slightly more than 2.0% annually in this study. Table 3 depicts the necessary capital replacement items, as well as their replacement occurrence and costs, for the McAllen Northwest and Southmost facilities.

Table 2. Initial Construction and Annual Continued Costs for the Seven Segments of the Southmost Desalination Facility, 2007 (Sturdivant et al. 2008). [a]

Facility Segment	Initial Construction/ Investment Costs	Continued Costs (annual)
1) Well Field	$7,768,525	$383,935
2) Intake Pipeline	1,979,682	4,283
3) Main Facility	9,554,574	994,494
4) Concentrate Discharge	57,363	3,871
5) Finished Water Line & Tank Storage	963,506	70,424
6) Delivery Pipeline	1,698,501	187,408
7) Overbuilds and Upgrades [b]	4,168,843	80,686
TOTAL	$26,190,993	$1,725,101

[a] Values are in 2006 dollars.

[b] Represents construction beyond the necessities and captures "elbow room" for future expansion.

Table 3. Capital Replacement Items, Occurrence, and Costs for the McAllen Northwest and Southmost Desalination Facilities, 2007 (Rogers et al. 2008 and Sturdivant et al. 2008).

Facility Capital Item	Frequency of Replacement	Cost per Item	No. of Items Replaced each Occurrence
McAllen Northwest (Conventional)			
SCADA Upgrades[a]	5 years	$75,000	1
Anthracite	2 years	15,000	1
High Speed Pump	18 years	45,000	3
Trucks	7 years	16,000	2
Chemical Feed Pumps	5 years	3,750	4
Turbidity Meters	6 years	2,500	6
Southmost (Desalination)			
Well / Pumps	3 years	10,000	20
Membranes	6 years	700,000	1

[a] SCADA is an acronym for 'Supervisory Control and Data Acquisition' "which is the hardware and software technology which collects data from sensors at remote locations and in real time sends the data to a centralized computer where facility management can control equipment/conditions at those locations" (Sturdivant et al. 2008).

Baseline Results

Applying the primary data reported by McAllen PUB and SRWA to the aforementioned methodology and economic models produces the following analytical results. The results cover the costs of producing and delivering potable water to a point in the distribution system, but not the costs of delivering to individual households.

The NPV of all costs over the assumed 50-year life, in real 2006 dollars, totals $79,167,566 for the McAllen Northwest facility, and $65,281,089 for Southmost (Table 4). The NPV of potable water production for the McAllen Northwest facility over the 50-year life equates to a real value of 143,164 ac-ft {46,650,165 1,000 gallons} and 118,745 ac-ft {38,693,220 1,000 gallons} for the Southmost facility (Table 4).

Extending the NPV of the costs for the McAllen Northwest facility into perpetuity, using annuity equivalent calculations, results in an estimated $5,079,864/year annuity equivalent, and an annuity equivalent of $4,201,075/year for the Southmost facility. The same calculations are conducted on the NPV of water production, resulting in an annuity equivalent for potable water production of 6,583 ac-ft/year {2,145,074 1,000 gallons/year} for McAllen Northwest and 5,460 ac-ft/year {1,779,196 1,000 gallons/year} for Southmost (Table 4). This measure represents the key critical value attained in this report.

Dividing the annuity equivalent for costs by the annuity equivalent for potable water production identifies the annualized life-cycle cost or the annuity equivalent of costs per unit. For the McAllen Northwest facility, this equates to a per unit life-cycle cost of $771.67/ac-ft/yr {$2.3682/1,000 gallons/yr} and for the Southmost facility this equates to $769.62/ac-ft/yr {$2.3619/1,000 gallons/yr} (Table 4).[7]

<u>Results by Cost Type</u>

In this section, the aggregate results reported in Table 4 are separated into specific cost types. As Table 5 demonstrates, the largest cost type for the McAllen Northwest facility is the initial construction/investment, which contributes 55% of the total costs, totaling $43,368,658 over the life of the facility. Of this 55%, 26% of the costs are attributed to the acquisition of the water rights. For the Southmost facility, the largest cost type is the continued costs, which account for 55% of total cost and $35,633,597 over the life of the facility. The least significant cost type for

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7 Section 49.507 of Senate Bill 3 passed by the Texas Legislature in 2007 states that municipalities are now only required to pay 68% of the market value for permanent water rights in the Rio Grande Valley (Texas Legislature Online 2007) for water rights converted from agriculture to municipal use after January 1, 2008. In this analysis, if the opportunity cost of water rights were valued at 68% of the original price ($2,300/ac-ft), the new price would be $1,564/ac-ft. Such an adjustment would bring the total life-cycle cost of production for the McAllen Northwest facility down from $771.67/ac-ft/yr to $708.02/ac-ft/yr.

both facilities is the capital replacement expense, accounting for only 1% of total costs for McAllen Northwest and 5% of total costs for Southmost (Table 5).

Results by Cost Item

A unique feature of both spreadsheet models is the ability to separate the operations and maintenance (O&M) costs into detailed, itemized specifics. Table 6 is a specification of the breakout of the specific O&M cost items and their contribution to the total costs. For the McAllen Northwest facility, the largest O&M cost item is the cost of moving raw water from the Rio Grande to the facility by the irrigation districts. Over the life of the facility, McAllen Utilities will spend $9,472,261 (2006 dollars) for the expense of delivering the water, which accounts for 12% of the total costs for the facility and $92.33/ac-ft/yr {$0.2833/1,000 gallons/yr}. For the Southmost desalination facility, the largest cost item is energy. Over the life of the facility, SRWA will spend $16,862,411 (2006 dollars) for the energy expense, which accounts for 26% of the total costs for the facility and $198.80/ac-ft/yr {$0.6101/1,000 gallons/yr}.

Table 4. Aggregate Results for Costs of Production at the McAllen Northwest and Southmost Facilities, 2007.[a]

Results	Units	McAllen Northwest Nominal 2006 Value (Conventional)	McAllen Northwest Real Value [b] (Conventional)	Southmost Nominal Value 2006 (Desalination)	Southmost Real Value[b] (Desalination)
Initial Construction/ Investment Costs	2006 dollars	$43,368,658	$43,368,658	$26,190,993	$26,190,993
NPV of Total Cost Stream	2006 dollars	$207,706,012	$79,167,566	$195,914,480	$65,281,089
- annuity equivalent	$/year	N/A	$5,079,864	N/A	$4,201,075
Water Production	ac-ft (lifetime)	360,406	143,164	291,349	118,745
- annuity equivalent	ac-ft/year	N/A	6,583	N/A	5,460
Water Production	1,000-gal (lifetime)	117,438,750	46,650,165	94,936,500	38,693,220
- annuity equivalent	1,000-gal/year	N/A	2,145,074	N/A	1,779,196
Cost-of-Producing Water	$/ac-ft/year	N/A	$771.67	N/A	$769.62
Cost-of-Producing Water	$/1,000-gal/year	N/A	$2.3682	N/A	$2.3619

[a] The results of this table are considered the baseline analysis of the facilities in their current operating state, i.e., using current production efficiency level (78% for McAllen Northwest and 68% for Southmost), 2006 dollars, overbuilds and upgrades are included, and a zero net salvage value is recorded for all capital items and water rights.

[b] Determined using a 2.043% compound rate on costs, a 6.125% discount factor for dollars, a 4.000% discount factor for water, and a 0% risk factor (Rister et al. 2002).

Table 5. Costs of Producing Water by Cost Type for the McAllen Northwest and Southmost Facilities, 2007.[a]

	McAllen Northwest (Conventional)					Southmost (Desalination)				
Cost Type	NPV of Cost Stream[b]	Annuity Equivalent in $/yr[b]	Annuity Equivalent in $/ac-ft/year[b]	Annuity Equivalent in $/1000-gal/year[b]	% of Total Cost	NPV of Cost Stream	Annuity Equivalent in $/yr[b]	Annuity Equivalent in $/ac-ft/year[b]	Equivalent in $/1000-gal/year[b]	% of Total Cost[b]
Initial Construction/ Investment	$43,368,658	$2,782,792	$422.72	$1.2973	54.8%	$26,190,993	$1,685,486	$308.77	$0.9476	40.1%
-Water Rights Purchase	*20,404,541*	*1,309,277*	*198.89*	*0.6104*	*25.8%*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Continued Costs	35,093,723	2,251,823	342.07	1.0498	44.3%	35,633,597	2,293,151	420.10	1.2892	54.6%
Capital Replacement	705,185	45,249	6.88	0.0211	0.9%	3,456,499	222,438	40.75	0.1251	5.3%
Total	$79,167,566	5,079,864	$771.67	$2.3682	100.0%	$65,281,089	$4,201,075	$769.62	$2.3619	100%

[a] The results of this table are considered the baseline analysis of the facilities in their current operating state, i.e., using current production efficiency level (78% for McAllen Northwest and 68% for Southmost), 2006 dollars, overbuilds and upgrades are included, and a zero net salvage value is recorded for all capital items and water rights.

[b] Determined using a 6.125% discount factor for dollars (Rister et al. 2002).

Table 6. Costs of Producing Water by Continued Cost Item for the McAllen Northwest and Southmost Facilities, 2007.[a]

Facility O&M Cost Item	NPV of Cost Stream[b]	Annuity Equivalent in $/yr[b]	Annuity Equivalent in $/ac-ft/year[b]	Annuity Equivalent in $/1,000 gal/year[b]	% of Total Cost
McAllen Northwest (Conventional)					
-Energy	$7,239,217	$464,511	$64.75	$0.1987	10.0%
-Chemicals	5,789,663	371,499	51.79	0.1589	8.0%
-Labor	7,124,847	457,173	63.73	0.1956	9.8%
-Raw Water Delivery	9,472,261	607,797	92.33	0.2833	12.0%
-All Other	3,270,998	209,887	29.26	0.0898	4.5%
Southmost (Desalination)					
-Energy	16,862,411	1,085,157	198.80	0.6101	25.8%
-Chemicals	5,090,723	327,607	60.02	0.1842	7.8%
-Labor	7,615,483	490,084	89.78	0.2755	11.7%
-All Other	4,368,142	281,106	51.50	0.1580	6.7%

[a] The results of this table are considered the baseline analysis of the facilities in their current operating state, i.e., using current production efficiency level (78% for McAllen Northwest and 68% for Southmost), 2006 dollars; overbuilds and upgrades are included; and a zero net salvage value is recorded for all capital items and water rights.

[b] Determined using a 6.125% discount factor for dollars (Rister et al. 2002).

Modified Results

The results presented above represent case analyses of the McAllen Northwest and Southmost facilities in their current operating state. While the results were determined using the Capital Budgeting Annuity Equivalent approach in conjunction with models (i.e., CITY H_2O ECONOMICS© and DESAL ECONOMICS©) that are appropriate for "apples-to-apples" comparisons, shortcomings are associated with some of the basic assumptions underlying these calculated results. More accurate comparisons require several adjustments to "level the playing field" across analyses of conventional water treatment facilities and RO-desalination facilities. The adjustments allow for a more consistent basis of comparisons and alter the base assumptions in the following ways: (1) base period of analysis – assume the construction period commenced on January 1, 2006, thereby assuring all financial calculations are determined in a common time frame; (2) level of annual production – assume a constant 85% actual rate of production relative to maximum designed capacity, thereby accommodating routine maintenance, reasonable unexpected shutdown, and complying with the Rule of 85, but avoiding the potential bias associated with operating circumstances at this particular site;[8, 9] (3) overbuilds and upgrades – assume the construction design and other initial capital investments are sufficient to maintain the reasonable operation of the facility, but ignore those costs associated with "over-the-top" features intended to facilitate other functions and/or future expansions;[10] (4) salvage of capital assets – assume that all capital assets have a net salvage value of zero, reflecting either (a) circumstances whereby costs of disposing of the assets and returning the footprint property to its original state are virtually equivalent to the asset's salvage value and/or (b) the municipality's investments are intended to be long term, with no expectations of ever salvaging the asset; and (5) quality of water – it is important that similar quality standards be imposed on each of the analyses so that quality of water produced and chemical and other operating costs are not adversely compromised in any of the comparative projects. The comparable quality standard assumed for this analysis is

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8 The Rule of 85 refers to a Texas Commission on Environmental Quality (TCEQ) mandate, 30 TAC 291.93(30), which states that "A retail public utility that possesses a certificate of public convenience and necessity that has reached 85% of its capacity as compared to the most restrictive criteria of the commission's minimum capacity requirements in Chapter 290 of this title shall submit to the executive director a planning report that clearly explains how the retail public utility will provide the expected service demands to the remaining areas within the boundaries of its certificated area" (University of North Texas 2007).

9 Some individual facilities may not be able to fully attain the expected designed operating performance, e.g., abnormal arsenic, iron, and/or other objectionable water quality attributes for which original project design was incomplete and subsequent operating conditions were adversely affected. To facilitate correct comparisons, such circumstances should be removed from the analysis calculations, thus assuming the facility operates as originally designed/intended.

10 'Overbuilds' represent the excess construction completed to leave room for potential future expansions of the facility. 'Upgrades' represent construction beyond a level deemed necessary for conventional water treatment technology.

the requirement that the product potable water pass both the maximum contaminant levels and secondary levels set by both TCEQ and Environmental Protection Agency (EPA).

Incorporating considerations of the above-noted issues with the capital budgeting/annuity equivalent calculation methodology embedded in both models for the two facilities results in calculated life-cycle cost of producing potable water of $649.67/ac-ft/yr {$1.9938/1,000 gallons/yr} for McAllen Northwest and $615.01/ac-ft/yr {$1.8874/1,000 gallons/yr} for Southmost (Table 7).[11] These results are appropriately adjusted and suitable for comparison to life-cycle costs of other alternatives for producing potable water calculated using similar assumptions. Tables 7-9 provide further demonstration of the changes to the life-cycle costs of production when the data is modified to include the benchmark comparison assumptions.

Discussion and Limitations

The tasks of responding to the need to increase water supplies and choosing among alternatives is not unique to the Valley. In order to choose the most cost-effective alternative, sound and consistent economic and financial analyses should be a consideration and constitute an extension of engineering-related tasks for capital-project alternatives involved in a regional water resource planning. Economic theory suggests the most economically efficient sources of potable water are usually developed first, with subsequent expansions of the supply available only at higher marginal costs, contributing to the upward-sloping nature of the supply curve. However,

[11] As previously stated in footnote 7, Section 49.507 of Senate Bill 3 passed by the Texas Legislature in 2007 states that municipalities are now only required to pay 68% of the market value for water rights converted from agriculture to municipal use after January 1, 2008 (Texas Legislature Online 2007). In this analysis, if the opportunity cost of water rights were valued at 68% of the original price ($2,300/ac-ft) the new price would be $1,564/ac-ft. Such an adjustment would bring the adjusted, total life-cycle cost of production for the McAllen Northwest facility in its modified operating state down from $649.67/ac-ft/yr to $591.27/ac-ft/yr {$1.8145/1,000 gallons/yr}.

Table 7. "Modified" Aggregate Results for Costs of Production at the McAllen Northwest and Southmost Facilities, 2007. [a]

Results	Units	McAllen Northwest Nominal 2006 Value (Conventional)	McAllen Northwest Real Value [b] (Conventional)	Southmost Nominal 2006 Value (Desalination)	Southmost Real Value[b] (Desalination)
Initial Construction/ Investment Costs	2006 dollars	$37,397,088	$37,397,088	$22,022,150	$22,022,150
NPV of Total Cost Stream	2006 dollars	$199,159,431	$72,633,777	$209,423,179	$65,208,300
- annuity equivalent	$/year	N/A	$4,660,618	N/A	$4,196,391
Water Production	ac-ft (lifetime)	392,750	156,012	364,187	148,431
- annuity equivalent	ac-ft/year	N/A	7,174	N/A	6,825
Water Production	1,000-gal (lifetime)	127,978,125	50,836,718	118,670,625	48,366,525
- annuity equivalent	1,000-gal/year	N/A	2,337,580		2,223,996
Cost-of-Producing Water	$/ac-ft/year	N/A	$649.67	N/A	$615.01
Cost-of-Producing Water	$/1,000-gal/year	N/A	$1.9938	N/A	$1.8874

[a] The results of this table are considered the adjusted analysis of the McAllen Northwest and Southmost facilities in their modified operating state, i.e., 85% efficiency production, 2006 dollars, overbuilds and upgrades are not included, and a zero net salvage value is recorded for all capital items and water rights.

[b] Determined using a 2.043% compound rate on costs, a 6.125% discount factor for dollars, a 4.000% discount factor for water, and a 0% risk factor (Rister et al. 2002).

Table 8. "Modified" Costs of Producing Water by Cost Type for the McAllen Northwest and Southmost Facilities, 2007.[a]

	McAllen Northwest (Conventional)					Southmost (Desalination)				
Cost Type	NPV of Cost Stream [b]	Annuity Equivalent in $/yr [b]	Annuity Equivalent in $/ac-ft/year [b]	Annuity Equivalent in $/1000-gal/year [b]	% of Total Cost	NPV of Cost Stream [b]	Annuity Equivalent in $/yr [b]	Annuity Equivalent in $/ac-ft/year [b]	Equivalent in $/1000-gal/year [b]	% of Total Cost
Initial Construction/ Investment	$37,397,088	$2,399,7621	$344.50	$1.0265	51.5%	$22,022,150	1,417,205	$207.70	$0.6374	33.8%
-Water Rights Purchase	*20,404,541*	*1,309,277*	*182.51*	*0.5601*	*28.1%*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Continued Costs	35,093,723	2,215,748	308.87	0.9479	47.5%	39,729,651	2,556,747	374.71	1.1499	60.9%
Capital Replacement	705,185	45,249	6.30	0.0194	0.9%	3,456,499	222,438	32.60	0.1000	5.3%
Total	$72,633,777	$4,660,618	$649.67	$1.9938	100.0%	$65,208,300	$4,196,391	$615.01	$1.8874	100%

[a] The results of this table are considered the adjusted analysis of the McAllen Northwest and Southmost facilities in their modified operating state i.e., 85% efficiency production, 2006 dollars, overbuilds and upgrades are not included, and a zero net salvage value is recorded for all capital items and water rights.

[b] Determined using a 6.125% discount factor for dollars (Rister et al. 2002).

Table 9. "Modified" Costs of Producing Water by Continued Cost Item for the McAllen Northwest and Southmost Facilities, 2007.[a]

O&M Cost Item	NPV of Cost Stream [b]	Annuity Equivalent in $/yr [b]	Annuity Equivalent in $/ac-ft/year [b]	Annuity Equivalent in $/1,000 gal/year [b]	% of Total Cost
McAllen Northwest (Conventional)					
-Energy	$7,239,217	$464,511	$64.75	$0.1987	10.0%
-Chemicals	5,789,663	371,499	51.79	0.1589	8.0%
-Labor	7,124,847	457,173	63.73	0.1956	9.8%
-Raw Water Delivery	9,472,261	607,797	84.72	0.2600	13.0%
-All Other	3,270,998	209,887	29.26	0.0898	4.5%
Southmost (Desalination)					
-Energy	21,078,014	1,356,447	198.80	0.6101	32.3%
-Chemicals	6,363,404	409,508	60.02	0.1842	9.8%
-Labor	7,615,483	490,084	71.83	0.2204	11.7%
-All Other	2,780,863	178,959	26.23	0.0805	4.3%

[a] The results of this table are considered the adjusted analysis of the McAllen Northwest and Southmost facilities in their modified operating state (i.e., 85% efficiency production, 2006 dollars, overbuilds and upgrades are not included, and a zero net salvage value is recorded for all capital items and water rights).

[b] Determined using a 6.125% discount factor for dollars (Rister et al. 2002).

accurate cost estimates of future water supplies must also account for new technologies which lower the cost of previously "higher-cost" sources.

This research effort is directed at providing an appropriate methodology that allows for proper prioritization of future potable water-supply alternatives capable of increasing a region's available supply. Although the Capital Budgeting/Annuity Equivalent methodology presented in this report does provide an "apples to apples" comparison of the two technologies, there is a need to level the playing field by appropriately adjusting the data to allow for a more consistent basis of comparisons. Using this methodology, the economic feasibility of the two technologies appear very competitive; however, an important limitation is that only two facilities are observed.

Analysis of additional facilities' data are important for development of future potable water supplies and as further technology refinement occurs.

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