Cost Guidance for Seawater Desalination Facilities in Texas

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Introduction

Planning a seawater desalination treatment facility in Texas faces numerous challenges, including generating meaningful costs estimates for the planning, construction and operation of the plant. Cost estimates require, at its most basic, knowledge of feedwater conditions and finished water quality and distribution requirements, to a thorough knowledge of the proposed water treatment plant, facility shared resources as it impacts site planning and operations, water demand allocation, and the costs basis and assumptions that may vary between costing sources. Costing sources are one tool in the planner/designer's toolbox, and a typical planning approach could incorporate use of computer programs, established cost curves, other bid costs for comparison, and other like resources for comparison purposes. In any situation, the planners, managers and engineers best serve the needs of the expected consumers through an awareness of the design and expected operating conditions of the proposed water treatment plant, as well as the validity and accuracy of the costing sources.

Identification of Costing Tools and Resources Available on the Market

This section considers the available cost estimating reference tools available on the market for any agencies or planners and decision makers that are into the cost development phase for membrane desalination water treatment facilities. Although the process would generally take the same basic approach in the United States, differences as related to Texas, are identified.

Costing Model Availability and Indices on the Market

Most of costing models for desalination plants have been developed by agencies such as USEPA and by the US department of Interior. Engineer-consultants have contributed to general industry knowledge certain project cost experience gained from select clients; and this information is typically a bit generalized and available in industry trade journals and is usually specific to the application, end-user, and their (specific) challenges.

USEPA published in 1979 the *Estimating Water Treatment Costs* and though dated, is still used by some as a reference to compute cost estimates for pretreatment, post-treatment, and conventional treatment technologies. The Department of Interior developed in 1967 and 1969 the *Guideline for Uniform Presentation of Desalting Costs Estimates* (Research and Development Progress Report No. 264) and the *Development of Mathematical Model and Computer Program for Optimization of VTE (Vertical Turbine Evaporator) Saline Water Plants* (Research and Development Progress Report No. 404). Then the Department of Interior, Bureau

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of Reclamation developed the *Water Treatment Evaluation Routine* program and manual in 1999 based on the USEPA *Estimating Water Treatment Costs.*

The most recent and comprehensive cost estimate computer program was jointly developed by I. Moch & Associates and USBR (WTCost©, a Water Treatment Cost Estimation Program, I. Moch & Associates, Boulder Research Enterprises, US Bureau of Reclamation - with the sponsorship of the American Membrane Technology Association, April 2002). This is a Visual Basic application to estimate costs and is partially based on updated cost curves generated by USEPA (*Estimating Water* Treatment *Costs*, EPA-600/2-79-162a, EPA-600/2-79-162b, EPA-600/2-79-162c, August 1979) and is an upgraded version of the WaTER (Water Treatment Estimation Routine) excel spreadsheet developed by the US Bureau of Reclamation in 1999.

The most recent costing tool, WTCost©, incorporates consideration of pretreatment disinfection, chemical feed systems (coagulants, PAC, lime, caustic and antiscalant), filtration (GAC, gravity filtration, MF/UF), dechlorination, desalting processes (Reverse Osmosis, Ion Exchange, Electrodialysis), post-treatment and miscellaneous ancillary equipment such as intake/outfall, clearwell, and pumps. Water quality of the source water as well as key design criteria and costs assumptions are entered into this program to generate capital and operating costs. This program has some default values that need to be checked and/or adjusted before using the program to obtain accurate cost estimates for a specific project. This program can be used to compile a very detailed cost estimate and requires the user to be very familiar with the proposed seawater plant for which cost estimated are computed and as well be very familiar with the program and assumptions.

There is also a dose of common sense necessary in using these tools insofar as each particular application may have some unique components that may cannot be modeled in a computer program.

Numerous cost references can be also researched on Desalnet - Advanced Water Treatment Database; a cooperative project of the US Bureau of Reclamation and the American Water Works Association. For example, *Desalination for California--Technical and Cost Overview* (Horne, Wiley Argo, David Elder, Douglas Morin, O.J., 1988), on Desalnet, is a report prepared to be used as the basis for evaluating the technical aspects and projecting desalination costs for California in the 1990s. This report reviewed and analyzed the operation of 22 desalination facilities in the United States and the Caribbean area. This information is updated to 1991 with the addition of a number of desalination facilities built in the interim. Processes included in the comparison were reverse osmosis (RO) for the treatment of brackish water and seawater, and thermal distillation processes for the treatment of seawater-multistage flash (MSF) & multiple effect (ME) distillation. The basic cost information is taken from the plants described in the report. These costs are then adjusted for time of construction, and estimates are prepared for construction in California. Cost trends are then adjusted and predicted for time of construction, and estimates are prepared for construction in California. This could be a helpful resource from a technical/cost perspective (after adjusting for inflation); however use caution since issues specific to siting and permitting still need to be accounted for.

Considering inflation and other factors that cause plant costs to rise, older cost curves can be adjusted using indices, including those found in Engineering News-Record (ENR). From a process perspective, the major component cost of a seawater treatment plant in Texas will be similar in virtually any another State in the continental United States in terms of raw equipment and material cost, such as with large pumps and membrane elements. However, ENR escalations and regional-specific impacts, such as those influenced by labor rates (and the impact on operating costs) will vary from one state to another. Construction costs generated from costs curves that were computed in another State than Texas should therefore be adjusted with wage by area and occupation data from the U.S. Bureau of Labor Statistics, U.S. Department of Labor.

Regarding the ENR component, construction costs indices (CCI) and building costs indices (BCI) are compiled for 20 individual US cities (Table 1). These cost indexes use the same components and weighting factor as those for the 20-city national indexes. The city indexes use local prices for Portland cement, 2 X 4 lumber, and the national average price for structural steel. The city's BCI uses local union wages, plus fringes, for carpenters. The difference between the CCI and BCI is in their labor component. These indexes measure how much it costs to purchase a hypothetical package of goods compared to what it cost in the base year. The city's CCI uses the same union wages for laborers.

Table 1 Engineer News-Record Cost Indices

	BCI Index*	**CCI Index***
Dallas, TX	4,315.96	3,034.85
Atlanta, GA	4,644.05	3,354.55
New York, NY	6,140.78	11,690.77
San Francisco, CA	4,486.89	8,193.77

** September 2004 Cost Indices*

As it can be seen, the cost indices can vary greatly from one city to another, and the difference is only due to labor rates in each city, since these indices use 20-city average price for the material component.

Discussion of Assumptions

Prior to applying cost modeling or data base information to estimate the costs of a desalination water treatment plant, the planners, managers and engineers should be aware of key operating parameters and design criteria for the facility. Specific cost models that reflect specific geographic area or state-wide policy decisions are not generally available; however Texas projects will minimally require an understanding of the Texas Commission on Environmental Quality Source Water Assessment Program and sanitary survey information.

Primary Feasibility Assessment

Technical Feasibility.

The number of identified components used to support cost estimates of any desalination facility, will have a direct impact on the accuracy of the cost estimate. A basic "seawater versus brackish groundwater versus surface water" selection is based on feedwater availability and to a certain degree a policy and perhaps water rights issues. Other components for a feasibility "litmus test" include water quality (feed and finished) and the proximity of the source water and residuals management/discharge. The co-location with a power plant can allow access to existing intake/discharge infrastructure, and a warmer source water to enhance water production efficiency and unit cost of water. In addition a feasibility assessment would evaluate local finished water distribution systems already in-place (if any).

Economic Feasibility.

Financing and funding must be considered to ensure that the cost of the seawater treatment plant can be covered by the parties involved in the project. For example, Texas State Programs include drinking water state revolving funds (DWSRF), water/wastewater (W/WW) Loan Program, Regional W/WW Facilities Program, and Private Activity Bonds. Other sources could include local Government Bonds, and Private Capital.

1.2.1.3. Project Delivery Mechanisms.

Although beyond the purview of this Chapter, Project delivery mechanisms ultimately influence the cost of any project and bear discussion. Three different contracting methods are generally available to municipalities to permit, design, construct, own, and operate a desalination facility:

1. The Design-bid-build (DBB) method. In the DBB the Municipality is the owner of the plant and the Engineer represents the municipality. Typically the Engineer prepares the technical specifications of the plant and any general contractors can bid on the project. This is a very common practice for water plant project procurement in the United States.

2. The Design/build/operate (DBO) method. As for DBB, the Municipality is the owner of the water treatment plant. The Owner's Engineer defines performance specifications and a team composed of an Engineer, Contractor and Operator is selected by the municipality to design, build and operate the plant. DBO's are increasingly common in the United States on large-scale (and cost) projects. It contributes to optimizing the design/procurement process and offers lower costs, typically, compared to traditional DBB projects.

3. The Design/build/own/operate/transfer (D/BOOT) method. The Municipality is a "bulk purchaser" of water at their specified quantity and quality. A developer/private entity is the owner of the plant, and the contractor/engineers are hired by the developer to build and operated the plant according to the design of the Engineer representing the developer and contractor. This delivery mechanism is popular outside of the United States for large water projects that are not necessarily as straight-forward to permit, design or construct. This includes most seawater desalination projects.

Facility Design Approach

Prior performing costs estimates, all the components of the facility should be identified and key design criteria are established for each process. The source water quality as well as the finished water quality goals will have to be known and defined in order to select the treatment process that will meet the water quality goals. The list of significant design criteria which influence capital and operation and maintenance (O&M) costs include:

1. Intake and discharge structures for seawater or surface water. For example, awareness of the recently EPA-updated Section 316 (b) of the Clean Water Act (intended to limit the level of fish mortality caused by water intake at power plants) may impact facility cost upwards of several million dollars for seawater desalination plants proposed along the Texas coast;

2. Wells for brackish ground water or beach/shallow bank wells for seawater;

3. Feed (raw) water pre-screening, flocculation/sedimentation/settling and solids handling;

4. Advanced pretreatment requirements including media filtration or microfiltration and ultrafiltration;

5. Chemical additions, types, and doses;

6. Reverse Osmosis system - number of passes, throughput (flux) and pressure requirements;

7. Recovery for the reverse osmosis system as this will impact pump and membrane array size (capital) and operating costs;

8. Post treatment and stabilization requirements;

9. Finished Water Storage and blending; and

10. Permitting requirements which are imposed on 1-5 above.

Performance-driven design parameters include feedwater turbidity, total suspended solids, bromide, boron, radionuclides, chlorides, dissolved oxygen, iron/metals, silt density index (SDI), possible organism retention/preservation impacts, red tide impacts/toxins, and finished water compatibility with receiving water/distribution system.

Selection of the treatment processes would have to be performed via a desktop assessment to be confirmed by performing a recommended pilot study.

Identification of Market Trends which Impact Seawater Desalination Costs

Planners, decision makers and engineers should be armed with an awareness of market trends as these influence costs. The following sections are an overview of market supplier trends as well as a discussion of the different areas of the project that will impact desalination facility costs.

Membrane Elements

Within the same category of element type, the cost of a membrane element is similar from one manufacturer to another. In addition, the differences between membranes (within each classification of element type) generally are minimal with very similar ion rejection qualities and interchangeable dimensionally. The key membrane manufacturers in the US that can provide seawater membranes are Hydranautics, Dow/Filmtec, Trisep, Ionics, Koch (distributing Fluid Systems membranes), Osmonics and Toray. Minute differences in membrane element rejection between manufacturers become important (as it will impact facility costs) when a specific ion such as boron has high removal requirements, (of which are not regulated as a part of the EPA primary or secondary maximum contaminant levels (MCL)). For example, if a reduction from a 0.5 to 0.6 mg/L boron limit, or about 100 to 125 mg/L chloride limit in the permeate stream is required, this usually triggers the necessity for a second pass membrane array. Depending on the final concentration and membrane rejection capabilities, the capital impact can range from 10-percent to 25-percent or more. O&M costs will increase as well due to additional pump requirements; however less significantly so at 3 to 10-percent of the membrane-associated power costs.

The average cost of a membrane element has dropped since the introduction of reverse osmosis in the drinking water industry. Where a typical cost for seawater membrane elements would vary from $800 to $1,000 in the early 1990's, this cost has dropped to $500-$600. In addition, during the same period permeate production from an RO membrane has typically increased by a factor of three. Membrane element manufacturers have increased active surface area (one as much as 20-percent since 1994); which directly lowers capital costs; increased production capacity, and decreased the required pressure necessary to produce the same quantity of water. A 1 million gallon per day (MGD) membrane array in 1988 would be 25 percent larger versus today's standards.

It takes approximately 0.6 MW of power to produce 1 MGD of potable water; and between 65 and 85 percent of the power at desalination plant is used in the reverse osmosis process. For perspective, today, the amount of power used to produce desalinated water for one family per year is the same as that used by the family refrigerator.

Energy Recovery Systems

Since power has a significant impact on the production cost of desalinated water, any process or practices that can reduce power consumption will significantly decrease the costs of a seawater plant. Energy recovery systems that serve such a purpose should be evaluated as the inclusion of these systems will drive the water cost down by varying amounts, based on the type of energy recovery device chosen.

Figure 1 shows how the energy recovery system (turbines in the Figure) significantly reduces the energy consumption of a seawater plant. The energy consumption was reduced from approximately 10 kWh/m3 to 6 kWh/m3 by selecting this particular energy recovery system.

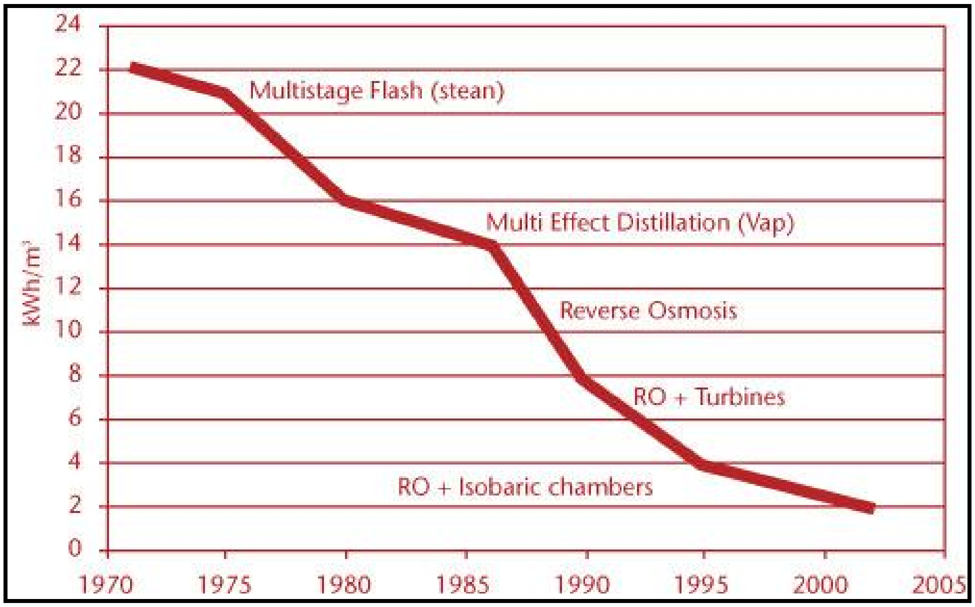

Figure 1-Evolution of energy consumption for the desalination of seawater over the last 30 years (authors estimation based on historical records). Note 1k m3/hr = 6.3 mgd; 75 bar = 1,090 psi

Energy recovery devices can effect an energy recapture range from 85 to 98 percent of the power consumed by the high-pressure reverse osmosis pump. For most large-scale applications (skid capacities greater than 3 mgd), Pelton turbines with efficiencies of approximately 91 to 93 percent are typical; though other alternative systems are increasing in size to close the gap. For other systems, lowest efficiencies are reverse running centrifugal pumps (~85 percent); positive displacement systems with pistons (88 to 92 percent), and piston-free pressure exchange systems (up to 98 percent). The principle behind energy recovery device is to use the energy of the brine (only 10 to 25 pounds per square inch (psi) less than the feed pressure that can reach 1,000 psi in seawater desalination) and transfer this energy back into the system to cause a net decrease in power consumption.

There are two classes of classes of energy recovery devices which most significantly impact costs. The first class converts hydraulic energy found in the membrane concentrate stream into rotational energy, which is delivered in the form of mechanical shaft power. The PEI (Pump Engineering, Inc.) Turbo™ or the Calder Energy Recovery Turbine (ERT) recovers hydraulic energy from the high pressure concentrate stream in membrane processes and transfers this energy via a turbine to any other stream in the process, usually the feed stream. This design reduced the feed pump discharge pressure and therefore has an impact on feed pump capital and operating costs. The Turbo™ was developed and first installed in seawater plant in the late 1980's. The second class of energy recovery devices uses positive displacement systems to transfer the energy via a piston or barrier. In the Calder Dual Work Exchanger Energy Recovery (DWEER) the high pressure brine is directed to a work exchanger vessel filled with seawater and pressurizes that seawater to brine pressure. The first work exchanger was installed in the mid seventies in Bermuda. Energy Recovery, Inc.'s Pressure Exchanger (PX) uses the principle of positive displacement and isobaric chambers to achieve extremely efficient energy transfer from a high-pressure waste stream, such as brine from a reverse osmosis desalination unit, to an incoming feed process stream.

The efficiency of these energy recovery devices varies from 50 to 95 percent. Choice of one of those devices is site specific and depends on the configuration of the membrane system and pressure requirements; and a return in investment analysis should be performed prior to selection; and should calculate power consumed with and without the energy recovery devices, accounting for all power consuming components. In most cases, the calculated net power needed is lower with Class II than the Class I energy recovery devices, though capital costs of the Class II devices are generally more expensive than the Class I. For example, a pressure exchanger PX would cost approximately $500,000 for a 5 MGD seawater plant operating at 800 psi and 50 percent recovery, whereas the cost for a Turbo, under the same conditions, would be approximately $200,000. Therefore, the capital cost of such energy recovery systems represents about 5 to 10 percent of the equipment costs for a seawater reverse osmosis system. For this hypothetical seawater plant, the return in investment could be from 6 to 18 months depending on the power cost using the PX device, and as low as 4 months using the Turbo. However, particularly with devices that are “newer” on the market, the expected life of the device will require manufacturer corroboration and additional research is suggested until a greater installed base can substantiate life expectancy.

Physical

A critical process and impacted cost of a desalination facility is regarding pretreatment to the membrane process. Pretreatment, sometimes to very high prefiltration levels, is necessary prior to membranes in order to remove suspended solids from seawater.

Reverse osmosis membrane manufacturers require high water quality water feeding the membranes in order to satisfy membrane manufacturer warranty requirements. Although membrane manufacturers require turbidity of less than 1 NTU and SDI of less than 5, feed water (particularly sea water and feedwater high in organics and particles) should have at least a turbidity of less than 0.3 NTU. In the absence of pilot or other data indicating otherwise, a silt density index (SDI) of no greater than 3 or 4 should be required to help ensure the membranes will not plug due to particles. These constraints may be more stringent and/or other constraints may be applicable depending on the specific seawater reverse osmosis project and if pilot or other feasibility work has been performed, since constraints result in increased costs. For example, since filtered water suspended particles become more challenging to remove with lower SDI and turbidity requirements, the association between these parameters and pretreatment costs is directly related.

Pretreatment may include dual stage media filtration or diatomaceous earth (pre-coat) filtration or membrane filtration (microfiltration (MF) or ultrafiltration (UF)). Costs of MF/UF membrane filtration has been decreasing in the last decade and becoming more competitive with media/conventional filtration. A trend may ultimately shift from dual stage media filtration to MF/UF filtration, however this is highly location-specific to the source feedwater and yet to be seen in the industry. The prefiltration component costs range from 15 to 20 percent (conventional) to 25 to 30 percent (with membrane pretreatment) or more, of the capital cost of a facility.

Chemical

Another important aspect of a seawater treatment plant cost is the chemical feed systems necessary to achieve better efficiency of the processes and also to treat the water to meet regulatory requirements. Chemical feed systems may include pre-chlorination to prevent biogrowth in the intake structure and feed piping, coagulant injection to optimize media filtration or MF/UF membrane filtration, acid and antiscalant injections to prevent seawater reverse osmosis membrane fouling, post-chlorination for disinfection, caustic and corrosion inhibitor for post-stabilization of the finished water. Chemical costs will usually represent between 50 and 75-percent of the operation and maintenance costs that remain after power costs are accounted for.

Chemical costs are directly related to the dose of the chemicals injected in the different streams of the seawater treatment plant. By reducing the dose or eliminating all together a chemical, large chemical costs can be saved. A pilot study provides an opportunity to optimize the dose of any chemicals utilized at the plant, and as well, demonstrate sustained productivity of an RO system without the need for acid and antiscalant; whereas computer projections and calculations on paper may show otherwise.

Cost savings related to chemical feed systems could be realized by simplifying the design and operation. An effective way to control certain chemical feed systems is to design for one chemical pump per seawater RO train, assuming that each train produces permeate under consistent operating conditions and also design the chemical feed systems such as the systems are close to the injection points. This avoids capital investment in flow controllers and PID loops and piping. In addition operation and maintenance of the feed systems is simplified and therefore result in reducing costs.

In addition, acid injection prior pretreatment may have multiple advantages. It may enhance the coagulation process, if a coagulation step is included in the process train, and also prevent seawater membranes from calcium carbonate scaling. By improving the coagulation process, filtration may be more efficient and therefore SWRO may sustain productivity for a longer time and therefore saving operating costs. These benefits would be understood by completing a pilot study.

Mechanical/Electrical

Construction material must be resistant to corrosion and failure in a seawater environment. There are a number of different alloys available on the world market suitable for seawater service. The common alloys used in seawater application are Allegheny-Ludlum's AL-6XN®, Weir Materials' Zeron 100® and Avesta Sheffield's 254 SMO®. Corrosion resistance, tensile/strength and existing service duty should be evaluated by an engineer as alloys can vary widely.

The austenitic alloys, such as AL6XN and SMO 254, are approximately 10 to 15 percent higher capital cost than the super duplex Zeron 100 since they are higher in Nickel and Molybdenum contents. The cost of austenitic is approximately $8 to $10 per pound and varies daily due to the market value of nickel that composes 25 percent of these alloys.

Costs vary with diameter of piping, thickness and quantity, fitting types, and fabrication labor. For the United States' largest seawater RO AL6XN is used for J-Bends and manifolds, and Zeron 100 is used for large diameter high pressure lines. The other large seawater facility in the

Western Hemisphere, Trinidad, mainly uses AL6XN. Pacific Gas and Electric's Diablo Canyon SWRO uses SMO 254, though initially some 316L was used but had a severely limited service life. Regarding all other non-exotic transmission pipe materials that are used to support the facility operation, a wide range of material and costs are available and competitive throughout the North American market.

Based on feedwater salinity (which in turn impacts required feedwater pressure and power requirements), power savings may be realized by investing in pumps that utilize adjustable frequency drives (AFD). For example, a salinity range from 20,000 mg/L to 32,000 mg/L results in delta pressure variations of between 300 and 400 psig. The AFD allows operating a high pressure pump on an infinite number of speed curves depending on the required operating conditions, in lieu of "burning off" excess pressure (and power cost) that may not be necessary to produce the required volume of water.

Other electrical issues that any designer would need to be aware of (as it impacts costs) include voltage sag on a transformer feeding the plant, and the possible need for motor soft-starts and electrical/control noise cancellation or vibration/isolation software and hardware to ensure trouble-free operation. Depending on the size of the facility, high pressure feed pump soft starts alone can range from 5 to 15 percent of a pump/afd package.

Costing Roadmap and Steps Necessary to Obtain Accurate Facility Costs

Today there are about 1,200 desalination plants in the U.S., mainly treating brackish ground water. The Tampa Bay Water Desalination facility is the largest and first seawater with 25 MGD treatment capacity in North America. The Tampa Bay Water Desalination plant treats approximately 25,000 mg/l TDS water to less than 500 mg/l using seawater reverse osmosis technology and is co-located with a Power plant. Specific energy consumption for the process is about 11 kWh / 1,000 gallons at 4 cents/kWh. Pelton wheel technology is used as energy recovery system. The cost of product water is estimated at $2.02 / 1,000 gallons ($658/AF) for the first year including distribution. Average cost of treated water over a 30-year period is estimated as $2.49 / 1,000 gallons ($811/AF). In California, even though earlier desalination was thought to be very expensive, technological developments in this arena have encouraged many water districts to consider seawater desalination as part of their future water supplies. In addition to many small inland and coastal desalination plants, five large seawater desalination plants are planned to come on line in the next few years including one 50 MGD for the San Diego County Water Authority. The current cost estimates of potable water from these plants are in the range of $2.18 to $3.59 / 1,000 gallons including distribution expenses and before any rebate. These costs, however, are expected to decrease from further technological improvements in this field by the time these plants come on line.

Today, the typical unit cost of desalted water falls in the following ranges[2]:

Seawater	Large Plants (> 10 MGD)	1.52 – 3.80 $/1,000 gallons
	Medium Plants (1—10 MGD)	3.80 – 5.70 $/1,000 gallons
	Small Plants (< 1MGD)	Over 5.70 $/1,000 gallons
Brackish Water		0.40 – 3.80 $/1,000 gallons

Costing Classification Discussion

The levels of accuracy to develop costs estimates for a seawater treatment plant project are dependent on the end purpose of using this cost estimates and the degree of effort invested in estimating costs. Five estimate classes are presented in Table 1 in relationship to the identified characteristics.

Table 1. Cost Estimate Classification Matrix for Process Industries

	Primary Characteristic	***Secondary Characteristic***			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATIO N EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored. Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to + 100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to + 50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to + 30%	3 to 10
Class 2	30% to 70%	Control or Bid/Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to + 20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Estimate	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to + 15%	5 to 100

[a] The state of process technology and availability of applicable reference cost data affect the range markedly.

The +/- value represents typical percentage variation of actual cost estimate after application of contingency (typically at a 50 percent level of confidence) for given scope

[b] If the range index value of "1" represents 0.005 percent of project costs, then an index value of 100 represents 0.5 percent. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

[2] Adil A. Bushnak – Bushnak Water Group, Jeddah, Saudi Arabia

Costing Classification Considerations:

Class 5 estimates are prepared for conceptual planning purposes such as market studies, project screening, project location studies, gage public interest level, etc. These estimates are generated with limited information and the accuracy range may vary from -50 to +100 percent. At this stage of the project, the site locations and the source waters have been identified and selection can be made. General regulatory issues have been identified.

Class 4 estimates are prepared for detailed strategic planning, business development, confirmation of economic and/or technical feasibility and preliminary budget approval or approval to proceed to next stage of the project. Typically engineering for the seawater plant would be 1 percent complete. And therefore these estimates are generated with pre-study information and the accuracy range may vary from -30 to 50 percent. At this stage of the project, plant capacity, block schematics, layout and process flow diagram with key design parameters would be the basis of the cost estimates. A pilot study data would contribute data to confirm feasibility of the treatment process for the project; identify the key design parameters; and compute costs estimates. Processes, process operation, chemical feed systems for pretreatment and post treatment related to disinfection and blending of the treated seawater with groundwater will be identified during a pilot and will be the basis of the seawater plant design and capital and operating cost estimates. Operating costs estimates mostly consists of chemical costs and power besides labor and they would have to be computed using local prices and rates. In terms of chemicals, the planners will have to select the chemical company that would provide the most economical chemicals that meet the specifications of the seawater treatment plant.

Other influences at this stage include land acquisition cost/options, preliminary hydro/geological subsurface assessment, identification of site environmental impacts, site access issues, and power connection/transformer substation reliability, substation power quantity and quality.

Class 3 estimates are prepared to support full project funding requests and become the first and in some cases the last of the project phase "control estimates". Typically the engineering for the seawater plant would be from 10 to 40 percent complete. Tariff impacts are also evaluated.

Power is regulated in the State of Texas by the Public Utility Commission (PUC) of Texas. In addition consumers can choose the power provider they want to obtain the lowest rates. Rates from power companies still must be approved by the PUC (http://www.puc.state.tx.us/index.cfm). Significant power savings could be accomplished by selecting a less expensive power rate schedule that would result in some down time during the day compared to a more expensive power rate schedule that would guarantee power delivered 24hour/day. However, larger finished water storage facilities would be designed to take into account facility power-peak downtime and still be able to provide the required water demand. If this option is desired, an economic study would have to be performed (such as at the next lower cost Class 3) to determine the number years necessary to recover the capital cost by saving power.

These estimates are generated based on the preliminary engineering design and the accuracy range may vary from -20 to +30 percent. At this stage of the project, detailed process flow diagrams, preliminary piping and instrumentation diagrams are the basis of the costs estimates.

Class 2 estimates are prepared as the detailed control baseline against which all actual costs and resources will be monitored for variations to the budget. These estimates are generated based on engineering design that is 30 to 70 percent complete and the accuracy range may vary from -15 to 20 percent.

Class 1 estimates are prepared as the final control estimate against which all actual costs and resources will be monitored for variations to the budget. These estimates may be used to evaluate bid, to support vendor/contractor negotiations. These estimates are generated based on engineering design that is 50 to 100 percent complete and the accuracy range may vary from -10 to 15 percent.

Specific to Class 1-4, cost differentiators should be understood during the cost compilation process and are mainly attributed to the following factors:

1. Capacity of the plant: in general, production costs decrease with capacity

2. Site specific conditions and impacts

3. Pretreatment, post treatment and concentrate disposal may be different from one site to another and therefore significantly impact the cost of the project.

4. Land, permitting and engineering costs can also be the basis for discrepancy in costs

Although facility costs can be very site specific, a cost estimate should be clear regarding treatment of influences to account for differences in site locations, such as transmission/delivery costs - including pumping and storage, to the potential customers; concentrate disposal costs - including pumping, transmission and outfall structure; electrical power costs - document power costs and include the normal rate off the grid and consider any special rates/tariffs; depreciation/replacement costs – pumps (15+ years), pipelines/structures (50+ years); membranes (5 years); include the replacement costs of any item with a life of less than 20 years; facility utilization (on-line time); and financing terms, inflation, interest rate, and adjustment indices.

Conclusions

Costs of any membrane desalination plant require sufficient market, process understanding and an awareness of the assumptions associated with the various costing sources if employed. Varying degrees of knowledge are necessary based on the Class level and accuracy level desired in the estimates.

One overall observation of the market is that similarly sized facilities do not result in similar costs, due to variations in feedwater quality and finished water quality goals.

Capital cost and O&M cost influences will continue to progress both inside and outside the facility "fenceline". These "inside the fenceline" issues include pretreatment optimization, membrane surface area, process island approach (common headers, etc), use of more efficient energy recovery devices, minimizing concentrate volume, and enhancing intra-plant "electrical net" such as soft starts, and variable frequency motor drives. "Outside the fenceline" areas will also trend toward focusing on transformer substation design as it relates to voltage/quality/sag/transients and facility cost, finished water quality dial-in capability, and power rate structure.

Regardless of trends; time and money should be invested methodologically in the front-end planning of these projects to help ensure reasonable, logical decisions are made - which ensure realistic expectations from the treatment facility at an acceptable cost and quality level.

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