DESALINATION FACILITYS LOCATED THROUGHOUT THE WORLD

Over the last thirty years, seawater desalination has evolved into a viable drought proof water supply alternative allowing to tap the largest water reservoir in the world – the ocean. Seawater desalination technology has made great strides in many arid regions of the world such as the Middle East and the Mediterranean. Today, desalination facilities operate in more than 120 countries worldwide and some desert states, such as Saudi Arabia and the United Arab Emirates, rely on desalinated water for more than 70 percent of their water supply (See Figure 1). Spain, a country with population, climate and water challenges comparable to California, has more than 20 seawater desalination facilities with a total fresh water production capacity of over 340 MGD.

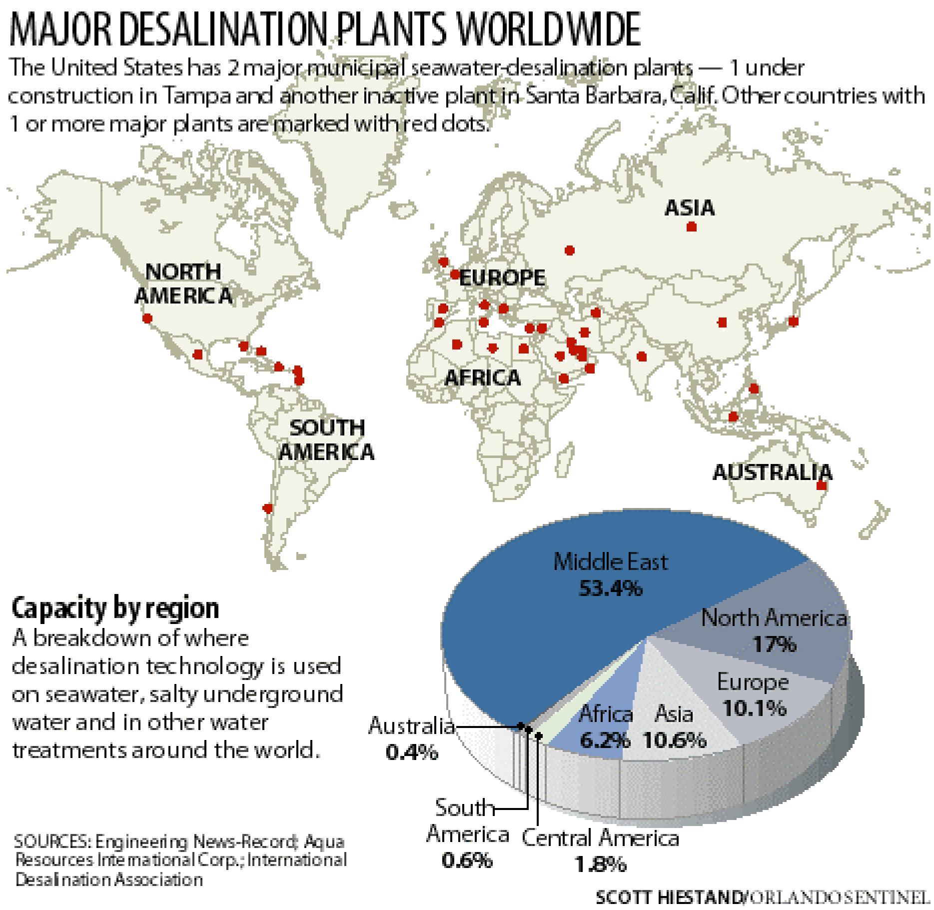


Figure 1 – Existing Desalination facilities Worldwide

Worldwide, seawater desalination facilities produce over 3.5 billion gallons of potable water a day. The installed RO desalination facility capacity has increased dramatically over the past 30 years (see Figure 2).

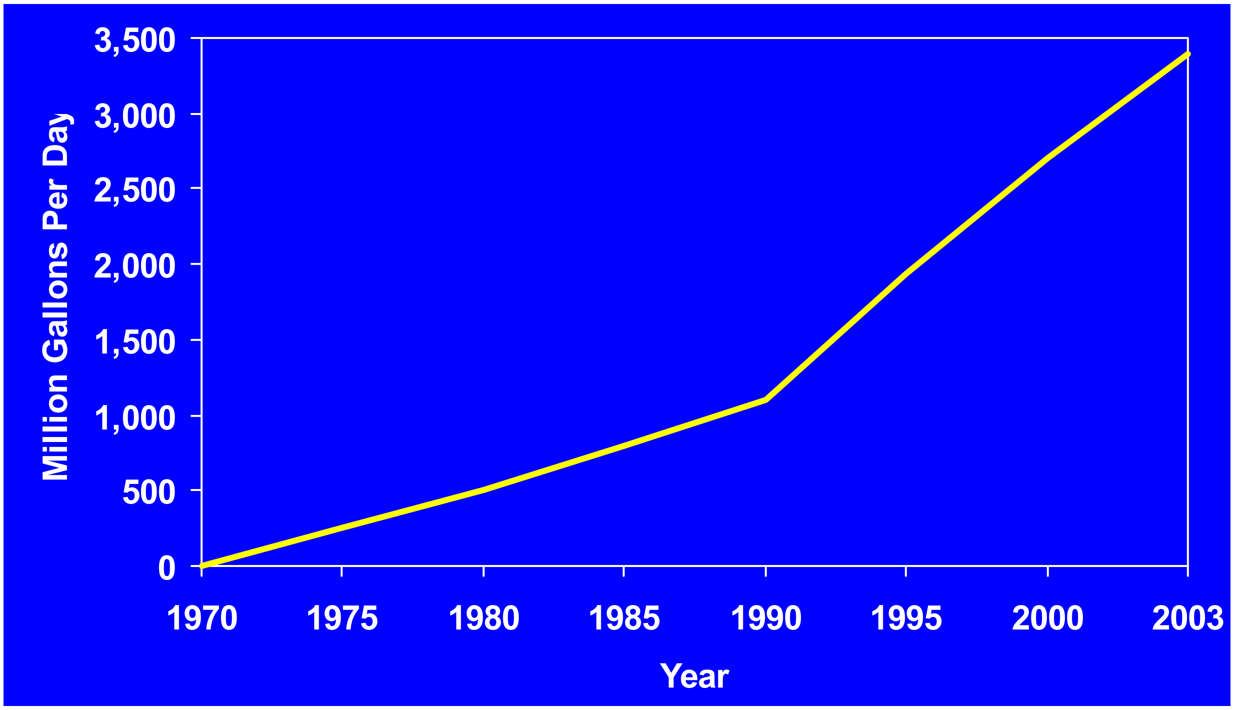


Figure 2 – Growth of Worldwide Seawater Desalination Facility Capacity

As seen on this figure, major breakthroughs in membrane technology and energy recovery equipment in the early nineties resulted in a significant acceleration of the construction of new desalination facilities. Table 1 lists the largest seawater membrane desalination facilities built over the past 10 years. Table 2 presents large desalination facilities in various stages of design and construction.

Review of Tables 1 and 2 reveals a clear trend. Most of the large seawater desalination facilities built in the past 10 years or currently undergoing construction are delivered under public-private partnership arrangement using build-own-operate-transfer (BOOT) method of project implementation. The BOOT project delivery method is preferred by municipalities and public utilities worldwide because it allows cost-effective transfer to the private sector of the risks associated with the number of variables affecting the cost of desalinated water, such as: intake water quality and its sometimes difficult to predict effects on plant performance; permitting challenges; startup and commissioning difficulties; fast-changing membrane technology and equipment market; and limited public sector experience with the operation of large seawater desalination facilities.

TABLE 1

LARGE RO SEAWATER DESALINATION FACILITYS CONSTRUCTED IN THE LAST 10 YEARS

Plant Name/Location	Capacity (mgd)	In Operation Since	Project Delivery Method
Tampa Bay Desalination facility, USA	25.0	2006	BOOT/DBO
Alikante, Spain	13.2	2003	Design-Bid-Build
Carboneras - Almeria, Spain	32.0	2002	BOOT 15-yr term
Point Lisas, Trinidad	28.8	2002	BOOT 30-yr term
Almeria, Spain	13.2	2002	Design-Bid-Build Private O&M Contractor
Las Palmas - Telde	9.2	2002	Design-Bid-Build Private O&M Contractor
Larnaca, Cyprus	14.2	2001	BOOT 10-yr term
Muricia, Spain	17.2	1999	Design-Bid-Build Private O&M Contractor
The Bay of Palma Palma de Mallorca	16.6	1999	Design-Bid-Build Private O&M Contractor
Dhekelia, Cyprus	10.6	1997	BOOT 10-yr term
Marbella - Mallaga, Spain	14.5	1997	BOOT 25-yr term

Notes: BOOT – Build-Own-Operate-Transfer; DBO – Design-Build-Operate.

TABLE 2

RO SEAWATER DESALINATION FACILITYS LARGER THAN 10 MGD IN DESIGN/CONSTRUCTION PHASE

Plant Name/Location	Capacity (mgd)	Completion Target Year	Project Delivery Method
Fujairah, UAE	45	2005	BOOT 25-yr term
Ashkelon, Israel	86	2005	BOOT 25-yr term
Singapore	36	2005	BOOT 20-yr term
Cartagena – Mauricia, Spain	17.2	2005	BOOT 15-yr term
Campo de Cartagena – Mauricia, Spain	37	2006	BOOT 15-yr term

Currently, seawater desalination is gaining popularity in the United States. Since the early spring of 2003 the first large seawater reverse osmosis (RO) desalination facility began operation in Tampa, Florida. This facility has capacity to produce 25 MGD of high-quality fresh water (Figure 3) from seawater originating form Tampa Bay. The desalination facility is co-located with the Tampa Electrical Company's Big Bend power plant and uses the power plant outfall for seawater intake and desalination byproduct discharge. After a rocky start, the Tampa desalination facility produced and delivered over 3.5 billion gallons of potable water in 2003. The plant's performance challenges have been associated with the startup and optimization of the facility's pretreatment system which includes two-stage continuous backwash sand media filters followed by 5-micron cartridge filters. Currently, the plant is producing 12 -25 MGD of drinking water every other week for a week while improvements to the facility's pretreatment system are performed. The facility's improvements are expected to be completed by 2006.

Figure 3 – Tampa Bay Seawater Desalination facility

To date, only a few small-size seawater desalination facilities have been built along the West Coast of the United States primarily because the cost of desalination has been higher than that of available alternative sources of water supply – groundwater and interstate and out-of-state imported water. Prolonged drought, dwindling traditional water sources such as Colorado River and new more stringent regulatory requirements are driving the costs of conventional water supplies up and are bringing seawater desalination back into the limelight in California.

Currently, there are over 10 seawater desalination projects in various stages of development in California. A description of the Southern California projects is provided in Section 6XX. The Metropolitan Water District of Southern California has been very supportive of the development of new local draught-proof potable water resources and has plans to subsidize the cost of water produced at four desalination facilities in Southern California with a $250/acre-foot ($0.77/1,000 gallons) credit. Compared to alternative water resources, the desalinated water planned to be produced at these facilities will be of lower salinity, and will have better overall water quality.

Most of these projects are expected to be commissioned after 2010, and to cumulatively produce over 150 MGD of fresh water for Southern California. Although this amount is locally significant, it would be adequate to satisfy only a small portion of California's commitment to reduce its use of imported fresh water sources. By year 2016, Southern California is mandated to decrease its consumption of Colorado River water by more than 700 million gallons per day, which corresponds to a volume of water used by one million households per year. In addition to seawater desalination, other alternative water sources which would be used to achieve this significant water use reduction target are: increased reliance on water reuse, conservation and development of new groundwater resources.

Cost Reduction Through Technology Development

Historically, the key concern related to the use of seawater desalination in a large scale has been the high cost of water production. Cost-saving innovations in seawater desalination technology are transforming this once expensive option of last resort into a fiscally viable water supply alternative. The "engine" of every desalination facility that turns seawater into fresh potable water is the RO membrane element (Figure 4).

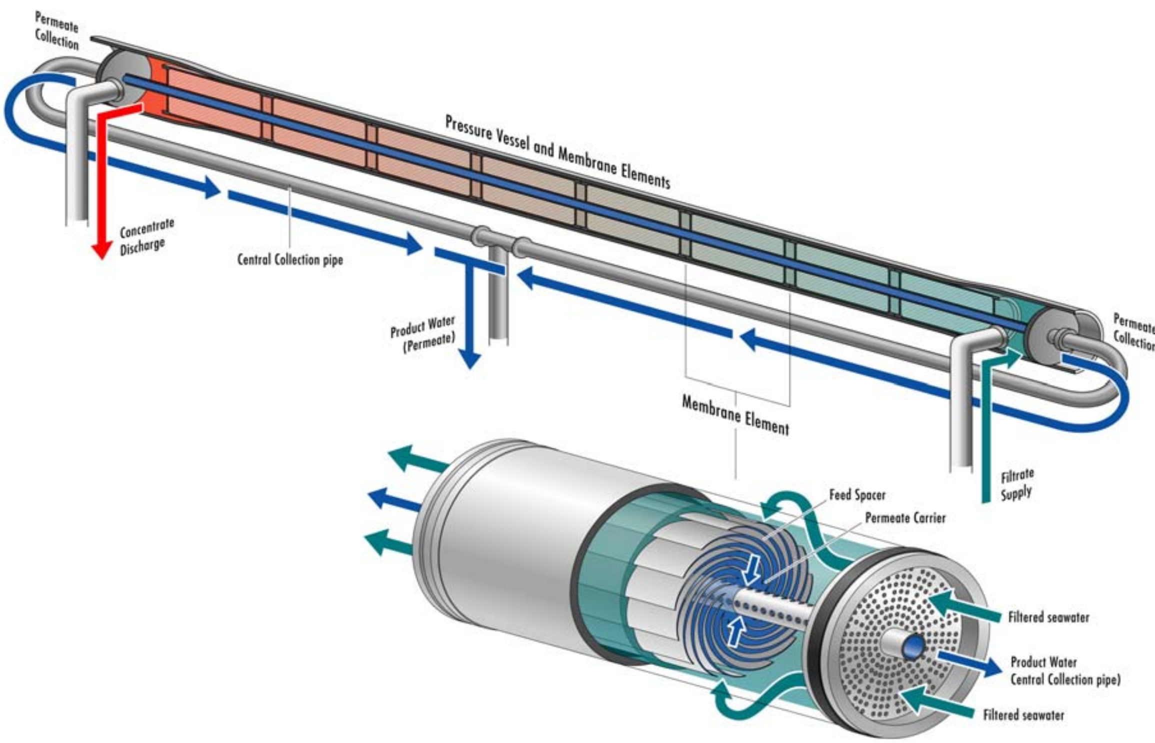


Figure 4 – Spiral-wound Reverse Osmosis Membrane Element

A large seawater desalination facility, such as the proposed Huntington Beach facility, usually has thousands of membrane elements connected into a highly automated and efficient water treatment system, which typically produces 1 gallon of fresh water from approximately 2 gallons of seawater. In particular, the 50 MGD Huntington Beach desalination facility will use over 19,000 membrane elements similar to that shown on Figure 4. The membrane productivity, energy use, salt separation efficiency, cost of production and durability of the membrane elements by large determine the cost of the desalinated water. Technological and production improvements in all of these areas in the last two decades are now rendering water supply from the ocean affordable. Membrane productivity – i.e. the amount of water that can be produced by one membrane element, has increased over two times in the last 20 years (see Figure 5).

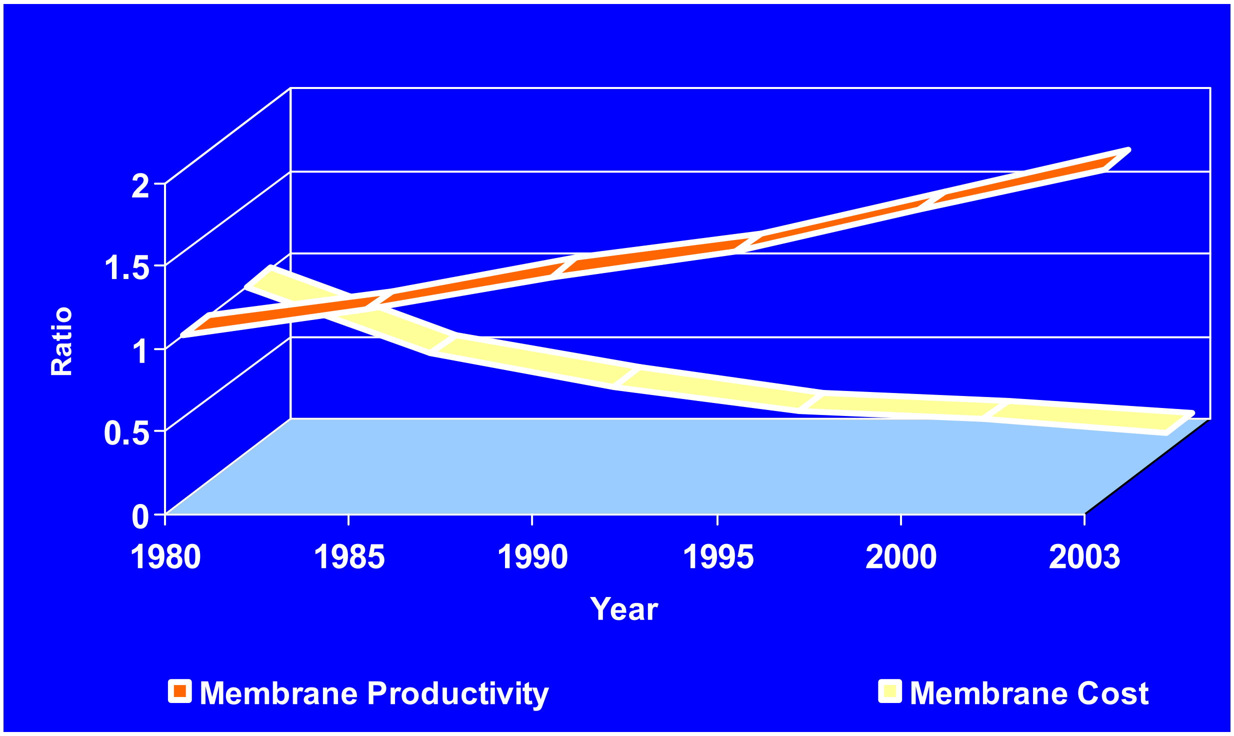


Figure 5 – Trends in Membrane Productivity and Costs

Recent introduction of spiral wound membrane elements with a larger number of membrane "leaves" and denser packing offer increased efficiency vs. older designs. Today's most efficient elements have more than twice as many membrane leaves compared to older designs. Higher productivity means that the same amount of water can be produced with significantly less membrane elements, which has a profound effect of the size of the membrane equipment, treatment plant buildings, and the footprint of the desalination facility – all of which ultimately reduce the cost of water production.

In seawater desalination facilities salts are separated from the fresh water applying pressure to the seawater, which is 60 to 70 times higher than the atmospheric pressure (typically in a range of 800 to 1,000 psi). After the salt/water separation is complete, a great portion of this energy stays with the more concentrated seawater and can be recovered, and reused to minimize the overall energy cost for seawater desalination. Dramatic improvements of the membrane element materials and energy recovery equipment over the last 20 years coupled with enhancements in the efficiency of RO feed pumps, and reduction of the pressure losses through the membrane elements have allowed to reduce the use of power to desalinate seawater to less than 14 kWh/1,000 gallons of produced fresh water today. Taking under consideration that the cost of power is typically 20 to 30 percent of the total cost of desalinated water, these technological innovations contributed greatly to the reduction of the overall cost of seawater desalination.

Novel energy recovery systems working on the pressure exchange principle (pressure exchangers) are currently available in the market and use of these systems is expected to further reduce the desalination power costs with approximately 10 to 15 %. The pressure exchangers transfer the high pressure of the concentrated seawater directly into the RO feed water with an efficiency exceeding 95 %. Future lower-energy RO membrane elements are expected to operate at even lower pressures and to continue to yield further reduction in cost of desalinated water.

Membrane performance tends to naturally deteriorate over time due to combination of material wear-and-tear and irreversible fouling of the membrane elements. Typically membrane elements have to be replaced every five years to maintain their performance in terms of water quality and power demand for salt separation. Improvements of membrane element polymer chemistry and production process over the last 10 years have made the membranes more durable and have extended their useful life. Use of elaborate conventional media pretreatment technologies and ultra and micro-filtration membrane pretreatment systems prior to RO desalination is expected to allow extending the membrane useful life to seven years and beyond, thereby reducing the costs for their replacement and the overall cost of water.

Today, the RO membrane technology and elements are highly standardized in terms of size, productivity, durability and useful life. There are number of manufacturers of high-quality seawater RO membrane elements which provide interchangeable products of excellent quality, proven track record and performance. All of the leading membrane manufacturers are dedicated to supporting the water desalination market and advancing membrane technology, and science at a pace no other water technology can compare with. The desalination facility of today is a highly automated water production factory with a number of build-in protection and safety systems allowing reduction of staffing requirements to a minimum and thereby reducing the costs of plant operation.

Cost Reduction Through Economy of Scale and Co-Location With Power Generation Stations

The recent trend of building large capacity seawater desalination facilities is driven by the cost benefits offered by the economy of scale and centralization. The economy of scale related to building fewer large capacity RO plants rather than a large amount of smaller facilities is a recent trend that has contributed greatly to the overall reduction of the cost of producing desalinated water. Typically, the economy of scale factor of desalination facilities larger than 10 MGD yields additional cost of water reduction in a range of 5 to 15 %. For example, the cost of water savings produced by building one 40 MGD plant instead of four 10 MGD plants is at least 10 %. Today, the construction of large desalination facilities is possible mainly due to the availability of large-size off-the-shelf high pressure pumps, large energy recovery systems and other auxiliary equipment with a proven track record and performance.

Co-location of desalination facilities with large power generation stations can also yield significant cost-savings and further reduce the cost of desalinated water. Co-location with a power generating station in a large scale was first introduced by Poseidon Resources for the 25 MGD Tampa Bay Seawater Desalination Project, and since than has been considered for numerous plants in the US and worldwide. For example, the desalination facilities proposed by West Basin Water District, Los Angeles Department of Water and Power, the Poseidon's

Carlsbad seawater desalination facility, and the San Diego County Water Authority and Municpal Water District of Orange County's San Onofre desalination project are all proposed to co-locate their intake and/or discharge facilities with an adjacent generating station's discharge outfall.

The intake and discharge of the Tampa Bay Seawater Desalination facility are connected directly to the cooling water discharge outfalls of the Tampa Electric (TECO) Big Bend Power Station (Figure 6). The TECO power station discharges an average of 1.4 billion gallons of cooling water per day of which the desalination facility takes 44 MGD to produce 25 MGD of fresh potable water. The desalination facility concentrate is discharged to the same TECO cooling water outfalls downstream from the point of seawater intake.

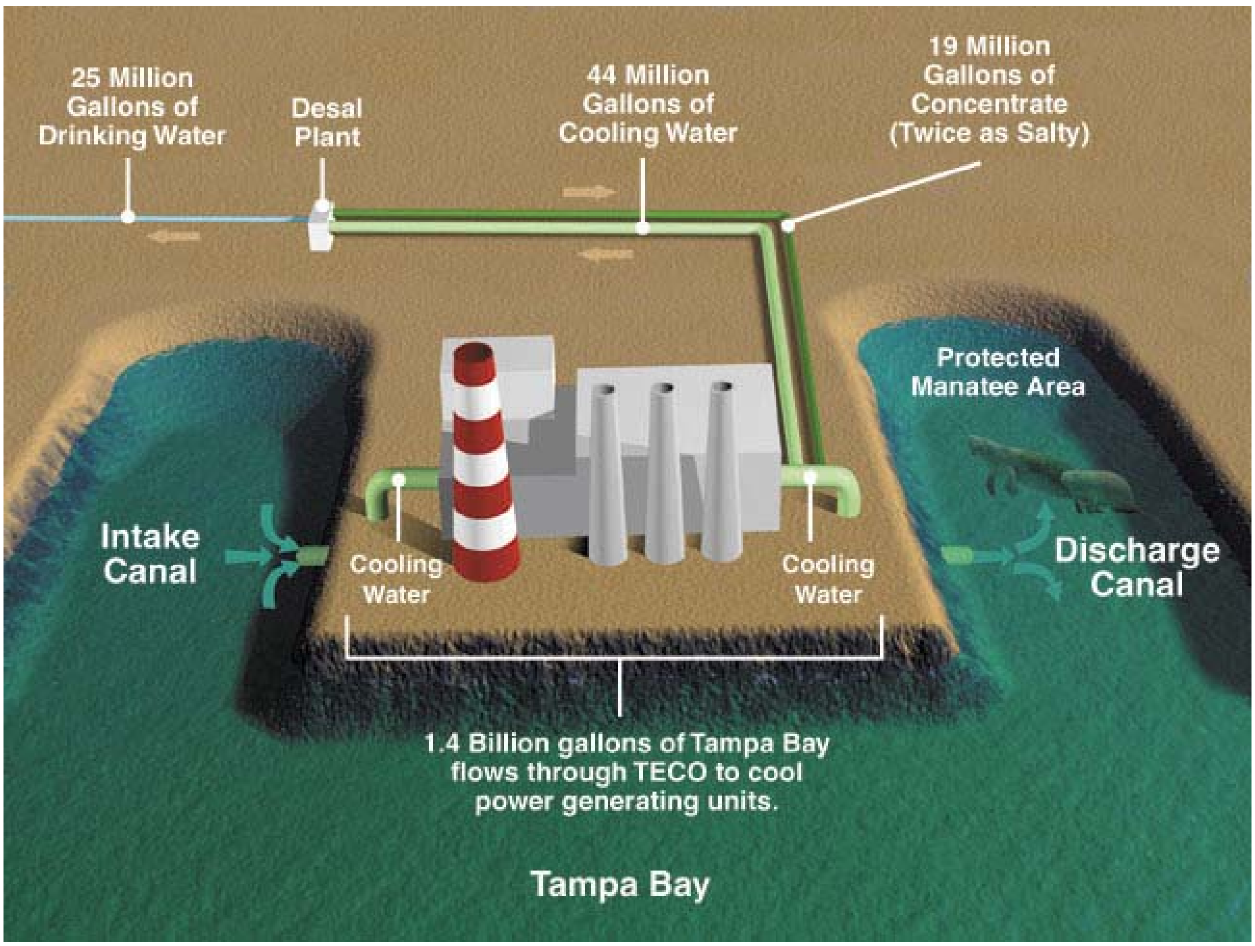


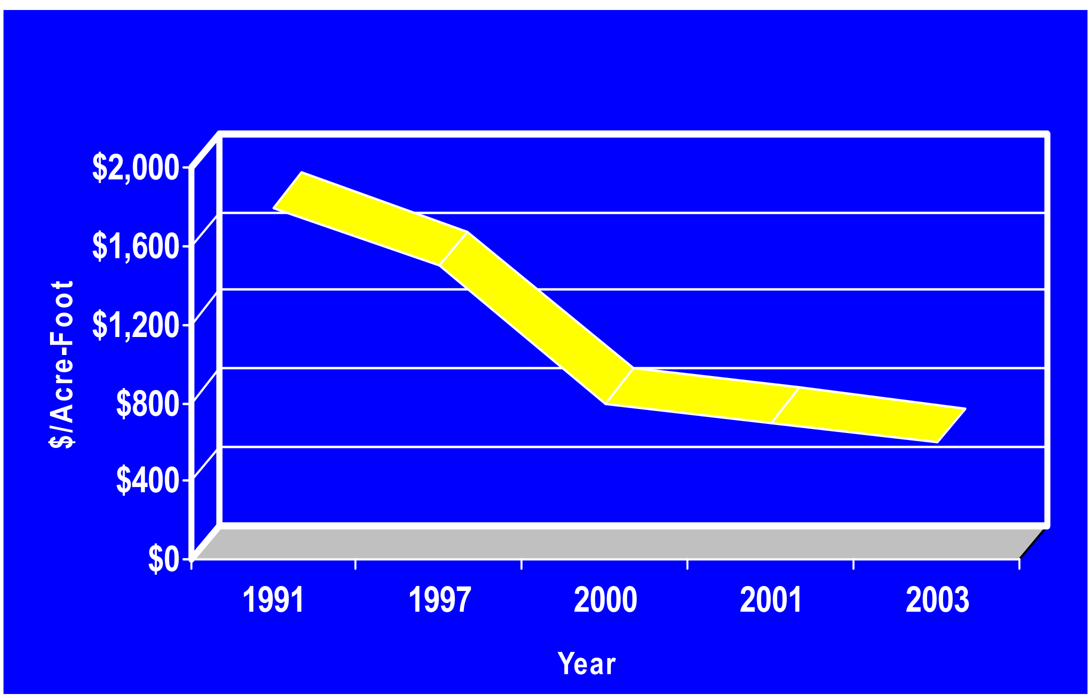
Figure 5 – Co-location of Tampa Bay Desalination facility and TECO Power Station

Co-location of desalination facilities and power generation stations has a number of advantages, including the use of the existing power generation station intake and discharge facilities which allows reducing the construction costs of the desalination facility; lowering the overall desalination facility power demand by using warmer ocean water; and minimizing the environmental impact of both the thermal discharge of the power generating station and the elevated-salinity desalination facility discharge by their blending. The power generating station's thermal discharge is lighter than the ambient ocean water because of its elevated temperature and therefore, it tends to float on the ocean surface. The heavier saline discharge from the desalination facility draws the lighter cooling water downwards and thereby engages the entire depth of the ocean water column into the heat and salinity dissipation process. As a result the time for dissipation of both discharges shortens and the area of their impact is reduced.

Another clear environmental benefit of co-location is the reduced overall entrainment, impingement and entrapment of marine organisms as compared to construction of two separate intake structures – one for the power generation station and one for the desalination facility. Combined use of the same intake and outfall structures also avoids the disturbance of ocean floor habitat which would otherwise be necessitated by the construction of separate new desalination facility intake and outfall pipelines and structures. Most desalination facilities outside the United States do not co-locate with power generating stations and have separate intake and outfall structures.

Seawater Desalination – Technology with Promising Future

The developments in seawater desalination technology during the past two decades, combined with transition to construction of large capacity plants, co-location with power plant generation facilities and enhanced competition by using Build-Own-Operate-Transfer (BOOT) method of project delivery have resulted in a dramatic decrease of the cost of desalinated water. Figure 7 indicates the trend of decreasing cost of water produced by seawater desalination based on recent large seawater RO desalination projects in the US, Israel, Cyprus, Singapore and the Middle East.



Note: $1/1000 gallons = $326/Acre-Foot

Figure 7 – Cost of Potable Water Produced Using Seawater Desalination

The advance of the reverse osmosis desalination technology is closest in dynamics to that of the computer technology. While conventional technologies, such as sedimentation and filtration have seen modest advancement since their initial use for potable water treatment several centuries ago, new more efficient seawater desalination membranes and membrane technologies, and equipment improvements are released every several years. Similar to computers, the RO membranes of today are many times smaller, more productive and cheaper than the first working prototypes. As seen on Figure 7, over the last 10 years, the cost of desalinated water dropped more than two-fold. Although, no major technology breakthroughs are expected to bring the cost of seawater desalination further down dramatically in the next several years, the steady reduction of desalinated water production costs coupled with increasing costs of water treatment driven by more stringent regulatory requirements, are expected to accelerate the current trend of increased reliance on the ocean as an environmentally friendly and competitive water source. This trend is forecasted to continue in the future and to further establish ocean water desalination as a reliable drought-proof alternative for many communities in California and worldwide.