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The Top Ten Most Successful SWRO Plants

Last week, *WDR* included a November 2012 list of its picks for the Top Ten Seawater Desal Successes, which included four thermal projects. In the past 13 years the pool of SWRO projects has increased enormously, while thermal plant seawater desal plant installations have all but disappeared. It was time to prepare an updated list.

Over the past few weeks, *WDR* conducted an informal poll among a number of veteran desalters to find out which plants they thought should be included among the most successful. The only requirement was that the plants had to be installed for four years.

It's always difficult to compare projects, and the aspect(s) of a project or plant that constitutes success are often subjective. What combination of water price, recovery, reliability, innovation, SEC, CapEx, etc, should be considered?

This issue presents *WDR*'s choices for the Most Successful Seawater Desal Plant in chronological order. What started out as a half-page story, ended up taking over this whole issue. But it was necessary to provide some context for those readers who may not be familiar with all of the projects.

In the coming weeks, a list of Honorable Mention projects that didn't make this list, but deserve some recognition, will be provided.

Dhekelia Plant, Cyprus – 1998

- Initial Capacity: 40,000 m^3/d (10.5 MGD
- EPC: Osmo Sistemi, Cadagua
- Developer: Caramondani
- Consultant NT Water Pros
- Owner: Cyprus Water Development Department (WDD)
- Offtaker: WDD

Dhekelia was Cyprus' first large SWRO plant, and was awarded to Caramondoni under a 10-year BOOT contract. It began operations in April 1997. In November 2005, 17 months before the contract expired, the client exercised its right to purchase the plant. It soon issued a tender to renovate, operate, and maintain the plant, and enter a 20-year water purchase agreement to sell water to WDD for a period of 20 years.

Caramondani won the subsequent contract, and the 20-year period began in May 2007, with the contract set to expire in 2027.

In 2008, the plant capacity was increased by 10,000 m^3/d, and in 2009, it was increased another 10,000 m^3/d; its total capacity is now 60,000 m^3/d (15.9 MGD). As SWRO technology evolved, the plant underwent several upgrades, to improve performance and reduce energy consumption.

The original DuPont Permasep B-10 hollow-fiber membranes were replaced with TFC spiral-wound membrane elements, and a partial two-pass configuration was added, followed by ion-exchange polishing with a boron selective resin. In 2001, the Frances turbine energy recovery devices (ERDs) were upgraded to Energy Recovery's PXs.

Olga Salangos, the Dhekelia plant manager—and the current president of the European Desalination Society—has overseen plant operations since 1996. Last week, she proudly told *WDR*, "The plant has had a 98% availability since it began operation, and has never had to pay a performance penalty."

As the island's current drought continues to reach new proportions, Dhekelia's reliability has become more important than ever.

Point Lisas Plant, Trinidad – 2002

- Initial Capacity:100,014 m^3/d (26.4 MGD)
- EPC: GE Water (now Suez)
- Developer: Desalcott
- Consultant: MWH (now Stantec)
- Owner: Desalcott
- Offtaker: Water and Sewer Authority (WASA)

Trinidad's Point Lisas desalination facility is owned and operated by Desalcott, Inc., a 1999 joint venture between Ionics (then GE Water, and now Suez) and Karamath

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Tom Pankratz, Editor, P.O. Box 75064, Houston, Texas 77234-5064 USA
Telephone: +1-713-397-2125, www.desalination.com/wdr, email: tp@globalwaterintel.com

Engineering of Trinidad, with a water purchase agreement between the Water and Sewage Authority (WASA) and Desalcott covering all aspects of water delivery. The first phase of the plant was operational in March 2002, and by June 2003, the Point Lisas Plant was fully commissioned.

Situated in the Gulf of Paria, on Trinidad's west coast, the plant not only experiences high silt and debris loadings from South America's Orinoco River, it is subject to algal blooms that may last two months. Despite some early problems with the underdrain of its single media, deep bed filtration system, the plant has made the necessary changes, and is gradually upgrading to membrane filtration.

The original capacity was increased four times and currently stands at 204,390 m^3/d (54 MGD), with the additional capacity allowing the plant to maintain a 98% availability. Meanwhile, Karamath Engineering increased its stake in the company, and in 2012, took 100% ownership of the plant.

After 23 years of operation, the plant continues to produce desalted seawater with a TDS of less than 85 mg/L for municipal and industrial end users, in central and south Trinidad. Its expansions help ensure that the plant is able to meet contracted production, and the plant has been reported to be considering an expansion that would increase its production to 272,520 m^3/d (72 MGD).

Ashkelon Plant, Israel – 2005

- Initial Capacity: 330,000 m^3/d (87 MGD)
- EPC: IDE-Veolia Water
- Developer: Dankner-Elran
- Consultant: ADAN
- Owner: VID (IDE-Veolia project company)
- Offtaker: Mekorot

When the Ashkelon was commissioned in 2005, it was the world's largest SWRO, and helped raise the ambitions of the entire RO industry. The combination of its size, along with innovative engineering and financing, resulted in an upgrade in SWRO's state-of-the-art and a water price of \$0.527/m^3, which was the lowest of any SWRO.

The plant was launched in response to Israel's 2000 Desalination Master Plan to address the country's chronic water shortage. It was the first of six of world-class plants that now provide 80% of the country's potable water.

Constructed by an IDE-Veolia partnership under a 25-year BOT contract, the project includes an 80 MW, combined cycle, natural gas power plant, and features a high-pressure pumping 'pressure center' and a partial two-pass, four-stage 'cascade' design to produce water with a boron concentration of less than 0.4 mg/L. The plant was expanded by 20% in 2010.

In 2014, Veolia sold its 50% equity stake in the Ashkelon plant to Oaktree Capital, and in 2020, IDE sold its holdings in the plant and operating company to the Keystone Fund and Veridis, respectively, with the original BOT contract due to expire in 2027. Last year, Israel's Water Authority issued an RFQ seeking potential developers to upgrade and expand production to 600,000 m^3/d (158.5 MGD), and extend the operations contract to 2052.

Perth Kwinana Plant, Australia – 2006

- Initial Capacity: 13,700 m^3/d (38 MGD)
- EPC: Degrémont (now Suez)
- Developer: Water Corporation
- Consultant: Fichtner, Burns & Roe Worley
- Owner & Offtaker: Water Corporation

During the early stages of Australia's Millennium Drought (1997-2009), Western Australia's Water Corporation began planning to construct a seawater desalination plant as a weather-independent water supply. In April 2005, a Degrémont-Multiplex consortium was selected to construct and operate the country's first large-scale SWRO plant, under an 'alliance agreement'—a risk-reward contracting model common for large infrastructure projects in Australia.

The plant was the first large-scale plant to employ Energy Recovery's PX ERDs. To address concerns over its carbon footprint, the plant's 185 GWh/yr energy needs are produced by wind-generated electricity, via an offset arrangement.

A site in Kwinana, south of Perth and adjacent to an existing power plant, was selected, and engineering began amidst opposition by vocal critics that the plant would have adverse environmental impacts. There was particular concern that the dissolved oxygen (DO) levels in the SWRO concentrate would adversely impact the semi-enclosed Cockburn Sound into which the brine would be discharged. Several studies correctly predicted that the plant's 40-port diffused discharge would have a negligible impact.

Extensive real-time monitoring in Cockburn Sound, together with annual marine habitat mapping, has since satisfied all environmental approval requirements and previous fears, including those that DO levels would decline and "create a vast, underwater desert". The Kwinana Plant continues to serve as an example of how a properly designed SWRO plant can co-exist with the environment.

Upon commissioning, the plant provided 17% of Perth's water supply. It has served as a model for Perth's Southern Seawater Desal Plant in Binningup and the Alkimos Desalination now under construction on Perth's north side. When the Alkimos plant is complete in 2028, seawater desalination will be able to provide up to 60% of Perth's potable water supply.

Palmachim Plant, Israel – 2007

- Initial Capacity: 82,190 m^3/d (21.7 MGD)
- EPC: Global Environemental Solutions (GES)
- Developer: Via Maris
- Consultant: GES
- Owner: BlueGen Water
- Offtaker: Mekorot

Though the Palmachim Desalination Plant has its own unique features—such as employing an innovative ion exchange arrangement to polish RO permeate and reach a 0.4 mg/L boron concentration limit, and a biofouling abatement program said to abate/remove biofilm—it made this list because of its ability to have evolved with the changing SWRO technology landscape, and its multiple expansions within a remarkably small, 3ha (7.4-acre) plant footprint.

The original 82,190 m^3/d plant was commissioned in 2007 by Via Maris, an SPV that included Tahal (lead partner) and Granite Hacarmel. Delivered under a 25-year BOO contract, it will be the only Israeli plant that will not be transferred to the government upon the contract's completion.

In 2013, NanoH2O (now LG Chem) was awarded a contract to provide its thin-film nanocomposite (TFN) membranes for the project. It was the first large-scale SWRO to use the membranes and it proved beneficial to all those involved.

The plant was originally furnished with Pelton wheel ERDs, but in order to reduce energy consumption (and save space), it was retrofit to Energy Recovery's PX ERDs when the plant was expanded. In 2010, it was expanded by 40,000 m^3/d, and another 150,000 m^3/d in 2013. The plant now has a total capacity of 272,190 m^3/d (72 MGD)

Ad Dur IWPP, Bahrain – 2012

- Initial Capacity: 218,000 m^3/d (57.6 MGD)
- EPC: Degrémont (now Suez)
- Developer: International Power
- Consultant: Deltares, Tractebel
- Owner: Bahrain Government
- Offtaker: Electricity & Water Authority

When Bahrain's original 45,000 m^3/d (12 MGD) Ad Dur Desal Plant was commissioned in early 1990, it was one of the largest SWRO plants in the world. However, the plant was beset with problems—most of which were pretreatment related—from the start. Its problems were often cited as the primary example as to why SWRO was not considered viable in the warm, highly saline Arabian Gulf waters.

The plant was rehabilitated several times, with numerous modifications to the original pretreatment system.

Fortunately, SWRO desal and pretreatment technologies have come a long way since that first Ad Dur plant was first built. One of the plants that convinced Bahrainis, and others in the Gulf, that large-scale SWRO is the technology of choice was the Ad Dur Independent Water and Power Project (IWPP).

Suez's chief desalination engineer, Sophie Bertrand, told *WDR*, "Due to the high fouling potential of the Gulf seawater, we selected a pretreatment system that includes ferric chloride dosing, coagulation, flocculation, DAF [dissolved air flotation] and dual media filtration. We then conducted a one-year pilot study, demonstrating an algae removal rate of 98 to 99.9 percent and the ability to produce RO feedwater with an SDI less than 4.0 for 85 percent of the time, and less than 5.0 for 100 percent of the time.

The plant's success was the catalyst for moving ahead with Ad Dur 2 IWPP, and the planned Ad Dur 3 IWPP.

Chennai Nemmeli Plant, India – 2013

- Initial Capacity: 100,000 m^3/d (26.4 MGD)
- EPC: VA Tech Wabag, IDE Technologies
- Developer: Chennai Municipal Water (CMWSSB)
- Consultant: Adecco, Mecon
- Owner: CMWSSB
- Offtaker: CMWSSB

Despite ongoing potable water problems, India was a little late to the SWRO show. However, since the Nemmeli SWRO plant was commissioned in 2013, nine other large-scale municipal SWRO plants were either contracted or commissioned in the country, and even more are planned. Although the Nemmeli plant in Chennai wasn't the first large-scale potable water SWRO in operation—the 2010 Chennai Minjur plant was—several of those polled for this list named the Nemelli plant as having been the more influential catalyst.

The plant is owned by Chennai Metrowater Water Supply and Sewerage Board (CMWSSB), and an EPC contract was awarded to a VA Tech Wabag-IDE consortium to deliver the project in 2010. It was commissioned in 2013, and initially suffered some undefined operational/pretreatment issues,

apparently due to algal blooms. The plant issues were eventually sorted out, and the plant is said to be operating at 93% availability.

Ghalilah Plant, Ras Al Khaimah, UAE – 2015

- Initial Capacity: 68,140 m^3/d (18 MGD)
- EPC: Aquatech
- Developer: FEWA (now EtihadWE)
- Owner: EtihadWE
- Offtaker: EtihadWE

In 2011, when the Ghalilah SWRO project was awarded to Aquatech, the company guaranteed a specific energy consumption (SEC) of 3.14 kWh/m^3 (11.9 kWh/kgal) that was 9.7% lower than the specified requirement. The bid results caused a furor among the other bidders who were worried that the selected bidder received preferential treatment or included some new, 'breakthrough' technology that violated the specification.

Aquatech insisted it had complied with the specifications, and that its LoWatt Process engineering approach allowed them to reach the low SEC value. In August 2015, after the plant was placed into commercial operation, it was confirmed that the plant had met the specified power requirements.

The success was said to be a combination of the 'right' DAF/UF pretreatment combination, an RO design optimization philosophy that models the membrane flux at best efficiency point based on plant design criteria and operating conditions, effective biofouling control, and a successful membrane cleaning strategy.

The company said that it has since employed the approach on other plants with similar results.

Marina East Plant, Singapore – 2020

- Initial Capacity: 136,380 m^3/d (36 MGD)
- EPC: Keppel
- Developer: Keppel Infrastructure
- Consultant: Black & Veatch, AECOM, ILF
- Owner: Keppel
- Offtaker: Singapore PUB

Singapore's fourth large-scale desalination plant was started up in early 2020. Keppel Infrastructure delivered the project under a 25-year DBOO contract and will supply water under a water purchase agreement with Singapore PUB.

The plant is designed to maximize the flexibility of the site, which is located near the Marina Barrage, where Marina Bay meets the Singapore Strait, and allows the plant to treat freshwater drawn from the Marina Reservoir or seawater from the Singapore Strait, depending on the prevailing weather conditions.

The plant can start up and produce full production on either seawater or fresh water in 6 hours, and can switch to/from full production of one feedwater to the other in 12 hours.

Set on a small, 3ha (7.4-acre) site, with Singapore's Central Business District as a backdrop, it is bordered by the Eastern Coastal Park Connector Network, which bridges the recreational spaces of East Coast Park and Bay East Gardens.

Much of the desal plant is located underground, and the facility's roof is a 20,000 m^2 (215,275 ft^2) garden accessible to the public. The landscaping incorporates environmentally friendly elements, including rainwater harvesting ponds and stormwater management systems to retain rainwater for irrigating the plant property and in the facility's cascading water features.

The plant shows SWRO's ability to be flexible, and be adapted to take advantage of site specific conditions.

Rabigh 3 IWP, Saudi Arabia – 2021

- Initial Capacity: 600,000 m^3/d (158.5 MGD)
- EPC: Abengoa, Veolia-Sidem
- Developer: ACWA Power, Saudi Brothers
- Consultants: Fichtner, Ayesa Group
- Owner, Operator: ACWA Power, NOMAC
- Offtaker: Saudi Water Partnership (SWPC)

Although the 'youngest' project on the list, Rabigh 3 IWPs 'success' has already been demonstrated. It was the first 'mega-SWRO" and first greenfield facility to be tendered by the Water and Electricity Company (now SWPC) under the Kingdom's wide ranging water privatization process that was unveiled in 2016 and delivered under a 25-year BOO contract at a water price of \$0.531/m^3, which sent water prices for subsequent mega-SWROs tumbling.

With a SEC well below its 3.5 kWh/m^3 energy cap—reportedly less than 3.2 kWh/m^3—the plant incorporated a new, more-flexible twist on the pressure-center concept and the use of larger trains. Membrane selection, and the optimization and configuration of membrane arrays, were based on the use of big data analytics and thousands of membrane simulations, which analyzed five years of raw water quality data.

The plant has already had an impact on the way that the new wave of mega-plants are designed and operated.