

# The Modernization of the Metropolitan Sewer System: The Deer Island Treatment Plant

David Duest<sup>1</sup>

<sup>1</sup>Wastewater Treatment, Massachusetts Water Resources Authority, Boston

E-mail: [David.Duest@mwra.com](mailto:David.Duest@mwra.com)

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## Abstract

The Massachusetts Water Resources Authority's (MWRA) inherited two failing treatment plants from its predecessor and was challenged to design, build and commission a new Clean Water Act compliant plant in their place. The Deer Island Treatment Plant was constructed at a cost of \$3.8 billion and treats wastewater flows from 2.3 million people from the metropolitan Boston area. The plant is a modern marvel that has unique site constraints and challenges which forced the selection of a number of space saving technologies to meet the end goal: protect public health and the environment. While designing and building the Deer Island Wastewater Treatment Plant, MWRA also began and continues to modernize the collection system, headworks, pumping stations and interceptors feeding the plant.

Wastewater treatment is a critical public service that protects both public health and the environment. Maintaining and upgrading those plants is incredibly important to the health of a region. This is the story of how the Massachusetts Water Resources Authority (MWRA) replaced two severely underfunded treatment plants in the Metropolitan Boston area of Massachusetts with the fully modernized new Deer Island Treatment Plant.

Keywords: wastewater, primary treatment, secondary treatment, disinfection, anaerobic digestion

## 1. What Did MWRA Inherit?

When MWRA was created in 1984, it inherited two failing primary-only wastewater treatment plants in Boston Harbor – one located on Deer Island and the other on Nut Island – and a poorly maintained combined sewer collection system. Both treatment plants suffered from decades of severe underfunding and lack of maintenance. At Deer Island alone, over one third of the pumps were non-operational when MWRA took ownership. These failures contributed to reduced capacity, poor plant performance and significant environmental impact. While the plants did provide anaerobic digestion and beneficial use of digester gas, the digested sludge was disposed with the outgoing tides directly into the harbor along with the poorly treated effluent. Overall, the plants achieved at best 25 to 30 percent solids removal when the Clean Water Act of 1972 mandated 85% removal. It is no wonder Boston Harbor was considered one of the dirtiest harbors in the nation back in the 1980s.

## 2. How Did This Change?

The MWRA was created to be financially independent from the state with bonding authority to fund its much needed capital improvements to modernize the treatment plants, along with sewer and water infrastructure. MWRA would derive its rate revenue as wholesale suppliers of water services to its water communities and wastewater services to its 43 metropolitan Boston area wastewater communities.

With the MWRA formed, design and construction of one of the most modern and advanced secondary wastewater plants in the county was completed, combining the two obsolete treatment plants into one large facility located on a very constrained Deer Island. The Nut Island Treatment Plant was

converted to a Headworks Facility and connected to Deer Island through a deep rock sewer conveyance tunnel.

In addition, MWRA's wastewater collection system is a complex network of conduits and facilities that is strongly influenced by seasonal and wet weather conditions. It includes a network of 274 miles of sewer pipelines - 19 miles of cross-harbor tunnels, 226 miles of gravity sewers, 18 miles of force mains, 7 miles of siphons; 13 pump stations; one screening facility; and four remote headworks facilities. Substantial investment in the rehabilitation and maintenance of these facilities is critical to MWRA's ability to move wastewater from the communities to Deer Island for treatment.

Since 1993, MWRA has made a commitment to assist member sewer communities to finance infiltration and inflow (I/I) reduction and sewer system rehabilitation projects within their locally owned collection systems. Funding of community projects through MWRA's I/I Local Financial Assistance Program is provided most recently as 75 percent grants and 25 percent interest-free ten year loans. To date, a total of \$760 million in grant and loan funds have been authorized by the Board and allocated to member sewer communities. The program goal is to assist member communities in improving local sewer system conditions to reduce I/I and ensure ongoing repair/replacement of the collection system.

### 3. The New Deer Island Treatment Plant

The Deer Island Treatment Plant (Figures 2 and 3) is a modern marvel and cost \$3.8 billion US dollars to design, construct and commission. It is the second largest treatment plant in the United States based on maximum capacity. Deer Island treats wastewater from 2.3 million people or 34% of the state's population. It has a design maximum capacity of 1.3 billion gallons per day (4.95 million cubic meters/day) with an average design flow of 361 million gallons per day (mgd) (1.363 million cubic meters/day). The treatment plant is at the edge of its service area and receives wastewater through five deep rock tunnels. Massive pumps in 3 pump stations at the plant lift the sewage between 80 and 150 feet (24 and 46 meters)



Figure 1. Nut Island sludge disposal to Boston Harbor. (Nut Island, 2023).



Figure 2. Deer Island Treatment Plant (MWRA, 2014).

to bring the untreated sewage to the head of the treatment works.

### 4. What Treatment Is Used at Deer Island?

Wastewater first travels through grit removal, primary treatment, and then an oxygen activated sludge treatment process before the treated water, now called effluent, is disinfected, dechlorinated and disposed. More than 94% of the solids in Deer Island's incoming wastewater are now removed using Deer Island's modernized treatment processes. Deer Island's new outfall discharges treated effluent over the last

1.25 miles of its 9.5 miles (15.3 km) outfall tunnel, in 110 foot (33.5 meter) deep ocean waters of Massachusetts Bay.

Wastewater solids (sludge and scum), removed from primary and secondary treatment, are thickened: primary sludge by gravity thickening; waste secondary sludge by centrifuges. The thickened sludge is then sent to Deer Island's iconic 12 egg-shaped digesters. These digesters, standing nearly 140 feet (43 meters) tall, hold 3 million gallons of liquid sludge (5.5% solid) for 18 to 22 days. The digesters anaerobically (without free oxygen) break down wastewater solids to a sustainable weak form of natural gas, a valuable fuel for use in Deer Island's energy recovery processes. Any remaining solids are then pumped seven miles to an MWRA-owned pelletizing plant located in Quincy, Massachusetts (Figure 4). The solids are then dewatered and thermally dried into a high quality "Class A" fertilizer, the best EPA rating available for any fertilizer. The fertilizer is sold locally as Bay State Fertilizer and is land applied throughout the eastern half of the continental United States as a great soil enhancer.

## 5. Taking Advantage of the Space It Was Given

Deer Island is a compact 210-acre site, with 150 acres dedicated to the treatment plant. The plant had to be designed to fit into this tight space and the design engineers were not allowed to "grow" the island to build the plant. The plant's design also needed to incorporate future expansion space to ensure the plant would continue to meet future permitting responsibilities should compliance goals change over time. As such, MWRA's design engineers included a number of advanced space-saving treatment technologies on Deer Island: vortex grit chambers; stacked primary and secondary clarifiers; a pure oxygen activated sludge treatment process; egg-shaped digesters and a remote pelletizing operation off-island. While a number of these technologies have been used at other treatment plants,



**Figure 3. Deer Island Treatment Plant, view from bottom to top, Cryogenic Oxygen Plant, Secondary Reactors and stacked Secondary Clarifiers (open to atmosphere). To the right, disinfection chemical storage (MWRA, 2023).**



**Figure 4. MWRA Pellet Plant, Quincy, MA (MWRA, 2023).**

Deer Island was unique in combining them all in one space-limited site to maximize treatment while preserving space for future expansion.

Given that the plant was built on land surrounded by the Atlantic Ocean, protective measures had to be built into the facility to ensure the plant would survive a direct hit from a category 3 hurricane with storm run up. A new energy

dispersing seawall was added along the Massachusetts Bay side of the plant to redirect wave run up. The plant was one of the first facilities in the nation to plan and design for sea level rise due to polar ice cap melt. As a result, all Deer Island facilities were built up from the ground while the ground level was raised an appropriate level to ensure the plant would be protected from future weather and climate conditions.

Given its remoteness, the plant was designed with 100% backup power generation capability should the primary electrical connection be compromised. The plant has designed into its systems two, 26-MW combustion turbine generators to fill this role with one unit alone capable of providing enough power to sustain plant operation up to 850 mgd. (Note: 94% of the historical operating time flows are under this level.)

The plant is highly complex and relies on its control system to oversee a majority of its operation, allowing MWRA to maintain a lean operational workforce. With over 30,000 input/output points and over 3,000 control screens within its control system, the control system is one of the largest in the country. It is estimated that over 70% of Deer Island systems are fully automated with 90% of its systems monitored. Maintenance of 70,000 critical pieces of equipment is tracked in a Maximo maintenance management database, dynamically linked to a purchasing and warehousing application for efficient operation.

And if the treatment plant wasn't improvement enough, the land surrounding it is now a public park that features five miles of public walkways and trails for walking, jogging, sightseeing, picnicking, fishing and bicycling. The public access area is open to the public year-round, from sunrise to sunset and includes 60 acres of open space, 10 landscaped overlooks, interpretive signage and dramatic views of the Boston skyline and Harbor Islands.

## 6. Building For a Sustainable Future

The conversion of wastewater solids to a renewable fuel (a "green" product) is a huge boon to the treatment plant and provides for major operational cost savings to the MWRA. Over 250 dry tons of solids per day ("dtpd" or 226,000 kg) are added to the digesters as a result of Deer Island's wastewater treatment processes. At the end of 18 to 22 days, 100 dtpd remain and this material is then

pumped seven miles to MWRA's pelletizing plant where the material is converted to fertilizer. About 150 dtpd of solids are broken down and converted to a weak form of natural gas, roughly 65% methane with a thermal value of roughly 630 BTU per cubic foot ("cuft"). 190,000 cuft per hour (5,380 cm/hr) of digester gas is produced, compressed and sent to Deer Island's thermal plant where the gas is burned in high pressure steam boilers. The resulting steam is sent through a steam topping turbine where electricity is produced and the steam is converted to high temperature water. This high temperature water is circulated around the plant for building and process heating.

In total, digester gas produces more than 95% of the plant's heating needs and 23% of the electricity needs of the plant, an equivalent value of \$18 to \$26 million US dollars annually. Digester gas is responsible for keeping Deer Island 57 to 65% "off the grid." A future project to revise Deer Island's combined heat and power process could increase, within the next 5 to 10 years, the electrical generation to 52% increasing Deer Island's off-grid percentage up to 80%.<sup>1</sup> Deer Island has an annual budget of slightly over \$60 million US dollars. Without digester gas, Deer Island's budget would be over \$80 million. In addition to the savings from use of digester gas, MWRA has diversified its green energy portfolio by installing two 1.1-MW hydroelectric generators (in its outfall conveyance tunnel), two



**Figure 5. Deer Island view from public access looking south. Egg-shaped digesters (the heart of Deer Island's green energy program), and its two wind turbines (MWRA, 2023).**

<sup>1</sup> A more detailed discussion is presented in the "Energy Matters" paper included in this issue.

600-kW wind turbines and 756 kW worth of solar panels. All in all, up to 30% of Deer Island's electricity demand are met by on-site green energy.

## 7. Motivations for Continuous Improvement

MWRA is an environmental agency that takes its role at protecting the public health and the environment very seriously. Since its inception, it has seen Boston Harbor transformed from the dirtiest harbor in the nation to a harbor with some of the cleanest urban beaches as a result of modernizing its treatment plants and collection system.

MWRA defines itself as an environmental leader and practices what it preaches in all of its daily operations. MWRA derives its funding directly from the local communities it serves. It has always felt a tight connection to its ratepayers and understands it has a fiduciary responsibility to maintain the best operation it can provide for a reasonable cost. Enhanced sustainability practices, reduced operating costs and minimizing its impact on the environment in the pursuit of its mission are key motivations.

In addition to internal motivations, the State of Massachusetts under former Governor Deval Patrick, in 2007, established Executive Order 484. This was further challenged by Massachusetts current Governor Charlie Baker under Executive Order 594, established in 2021. EO 484 and EO 594 set renewable energy and demand reduction goals for all state agencies and awards Massachusetts state agencies that meet these goals. As such, MWRA has been awarded several awards for "Leading by Example" "for outstanding environmental and energy achievement." MWRA has also received USEPA's Green Power Partnership Award as a green power leader. MWRA is also a registered with the Federal Department of Energy under its Better Plants Program which also sets goals to reduce demand and maximize green energy to maintain a sustainable operation. Under this program, MWRA has been awarded a certificate of recognition for "Water Resources Utility of the Future Today". MWRA has been an industry leader. It strives to continue to improve its operation and reduce operating costs all the while protecting public health and the environment.

## 8. Was It Worth It?

For many decades leading up to the clean-up initiative, Boston had neglected its harbor. A raised highway acted as a barrier, effectively separating the waterfront from the city, and the concept of development in the area was virtually non-existent. Only industrial and maritime industries operated near the water's edge. However, the transformation of Boston Harbor into a pristine environment has proven to be a pivotal force both as an economic driver and a valuable community asset.

Over the past two decades, development along the waterfront has seen remarkable growth, leading to a surge in private investments and economic prosperity, estimated to be worth as

much as \$80 billion. What were once vacant lots and industrial structures have now been converted into attractive and vibrant neighborhoods. The revival of Boston Harbor has not only created new economic opportunities but has also significantly improved the overall quality of life for residents.

The Boston Harbor Islands, now designated as a National Recreational Area, are teeming with activity. Regular ferry services bring residents and tourists alike to enjoy fishing, camping, and picnicking in these idyllic locations. The harbor itself has become a hub for sailboats and kayaks, while the city's beaches proudly boast the title of the cleanest urban beaches in the country.

In addition to these positive changes, the implementation of the Boston Harborwalk has been a game-changer. This 43-mile linear park gracefully stretches along Boston's shoreline, connecting waterfront neighborhoods to Boston Harbor and, in turn, fostering a stronger sense of community and recreation.

The transformation of Boston Harbor from an overlooked and polluted waterway into a thriving economic, recreational, and community resource stands as a testament to the power of determined efforts to revive and cherish the natural assets of a city.

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