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ONE WATER: ACHIEVING LONG-TERM WATER RESILIENCY AT DENVER WATER

BY KEN URBANEK, PE, LEED AP, ASHRAE HBDP

Water conservation, reclamation, and efficiency is fundamental to Denver Water, one of the major water providers in the West, serving 1.5 million people. When deciding to replace and renovate buildings on their campus, their mission to be an environmental steward was put into high gear.

One of the city utility's key goals was to implement a rainwater capture system and an on-site wastewater treatment system to drive overall building water use to exceedingly low levels at the new 186,000-sf, LEED Platinum, Net-Zero Energy administration building—the centerpiece of the larger Denver Water Operations Complex Redevelopment project.

Implementing such a system would take water-efficient design to the next level and would not come without challenges. This whitepaper discusses the successful solutions the IMEG team implemented while designing the water systems for this highly sustainable project.

The 35-acre Denver Water Operations Complex Redevelopment is one of the most multi-faceted sustainable projects in the U.S., boasting LEED Platinum, LEED Gold, LEED Silver, and Net-Zero Energy certifications for its buildings.

IMEG was critically instrumental in the design of the 186,000-sf, LEED Platinum, Net-Zero Energy administration building that incorporates the unique "One Water" concept.

IMEG also provided design for the campus's central utility plant and utility distribution (chilled water, hot water, potable water "condenser source," and 13.2kV medium voltage electrical); the 7,400-sf, LEED Gold certified wellness building; the 15,400-sf, LEED Gold certified renovation of the historical 3-Stones building; and the 155,000-sf parking structure.

Denver Water's One Water Framework

Prior to the redevelopment of the Operations Complex, Denver Water was already focused on conservation and the appropriate use for water, demonstrated by their development of a recycled water system and use of downstream reservoirs. The redevelopment project provided them an opportunity to use their own facility to show what was possible.

"As we began to plan the campus-wide redevelopment, we thought about how we could demonstrate best practices for water management and incorporate them into the project," says Jeremy Ross, Denver Water's Director of Engineering – Projects.

This led to the creation of the utility's One Water Plan for implementing water management and long-term resiliency strategies in the community (see figure 1). The plan views all parts of the urban water cycle—rain/stormwater, surface water, groundwater, recycled water, drinking water, and wastewater—as "One Water."

The plan encourages communication and collaboration among water management agencies, raises awareness of water use for the community, and provides a framework for state agencies, utilities, engineers, architects, contractors, and end-users to implement plans like One Water across the arid West to achieve long-term water resiliency.

The design of Denver Water's administration building was a successful implementation of the One Water framework due to the owner's years-long planning process and dedication to water resiliency.

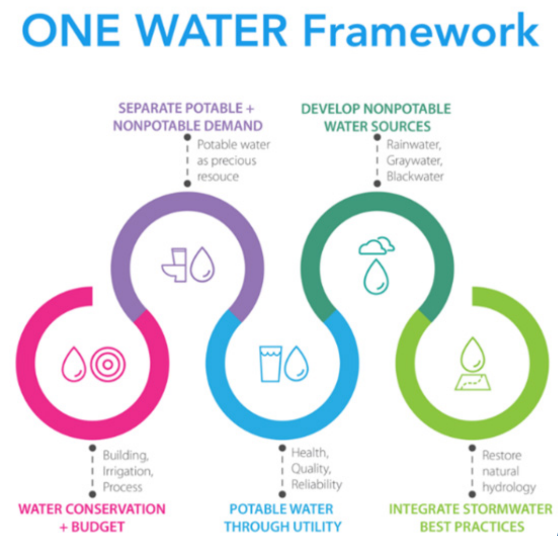


Fig. 1

Planning for water use

Critical to the overall project success was a thorough understanding of the existing water use on campus as well as a clear vision of the client's goals for water use reduction. This discovery process started very early during the master planning phase of the project—approximately eight years before the project would be completed.

Water consumption was evaluated using a water use intensity (WUI gal/sf/year) metric similar to the more common energy use intensity (EUI kBtu/sf/year) metric used to evaluate building energy performance. This evaluation started by developing a baseline model that represented the WUI of a typical set of buildings matching the master plan concept. The WUI of the existing buildings on the Denver Water campus also was determined. Additionally, the existing campus WUI was broken down across various uses—irrigation, building plumbing fixtures, cafeteria fixtures, process water, and cooling water. The typical baseline was modeled to be 38 gal/sf/year and the existing campus was performing at 29 gal/sf/year, already a 24 percent reduction in water use due to years of water efficiency measures by Denver Water.

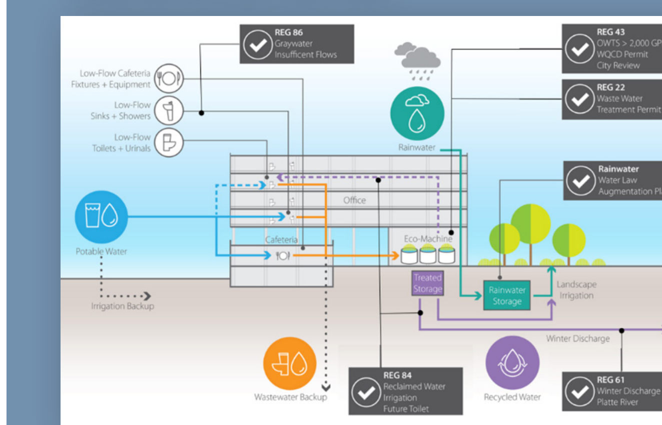
From the developed baseline and existing conditions, multiple layers of best practices were considered for the current time (2012, when the master plan phase began) and into the future (2022, when the project was to be entirely constructed and landscape established, about two years after substantial completion). Stretch goals to set leadership trends along with theoretical net-zero conditions also were evaluated.

The first step toward long-term water use reduction was a continued push on water efficiency. This included implementing more native and adaptive landscape to reduce/eliminate irrigation requirements and deploying even lower "low flow" plumbing fixtures and commercial kitchen fixtures. The flow rates for the common plumbing fixtures were 1.1 GPF for water closets, 0.125 GPF for urinals, and 0.1 gallons per cycle for lavatories; no waterless urinals or composting toilets were implemented due to the nuisance issues sometimes encountered with these devices. Extra care and attention were paid to the selection of the commercial kitchen equipment to ensure that it also utilized low flow components.

The second step was to reconsider where water was needed and whether its use could be entirely or nearly removed. As part of Denver Water's One Water concept, the campus uses water treated and provided by Denver Water for the campus's potable needs while maximizing reclamation and recycled water for non-potable uses. To conserve the critically precious potable water resource, a hybrid geothermal system (via distribution water conduit sink/source geo-exchange shown at right) coupled with air-cooled systems, was implemented to avoid using potable water for building cooling. No evaporative cooling was used, which is nearly unheard of for a campus of this size.

These best practices for eliminating and/or optimizing consumptive systems dropped the WUI to 15 gal/sf/year, a nearly 50 percent reduction over the existing campus. Further reduction also would be achieved through reuse systems, with the captured and treated water used for landscape irrigation and the flushing of plumbing fixtures. With more aggressive leadership measures, it was determined that the WUI could drop even more, to as low as 9 gal/sf/year. Further reduction, although possible, was determined not to be cost-effective and also counter to Denver Water's intent to use highly regulated utility-provided potable water for all potable water uses. The final selected target would achieve a nearly 70 percent WUI reduction over the existing campus and an over 75 percent reduction from the average building.

WATER AS AN ENERGY SOURCE/SINK



The innovative design of the Denver Water redevelopment used water to provide an energy source/sink for the campus's central heat pump system when energy recovery is not available. When Conduit #18 (a 54-inch potable water distribution conduit that serves a large portion of the Denver Metro area) was relocated to accommodate the new administrative building, taps were added into the new conduit during the move—along with a double-wall heat exchanger within the central plant—to decouple the potable water from the campus heating/cooling water systems. This cool-water, high-flow conduit could then be utilized as the heat source/sink for the campus. Since all components on the potable water side needed to maintain the high level of integrity required for a potable water source, special materials for piping, pumps, and controls were used. Additionally, there are numerous months during the year, even in the summer, where this mountain water is cool enough to provide direct "free" water-side economizer cooling.

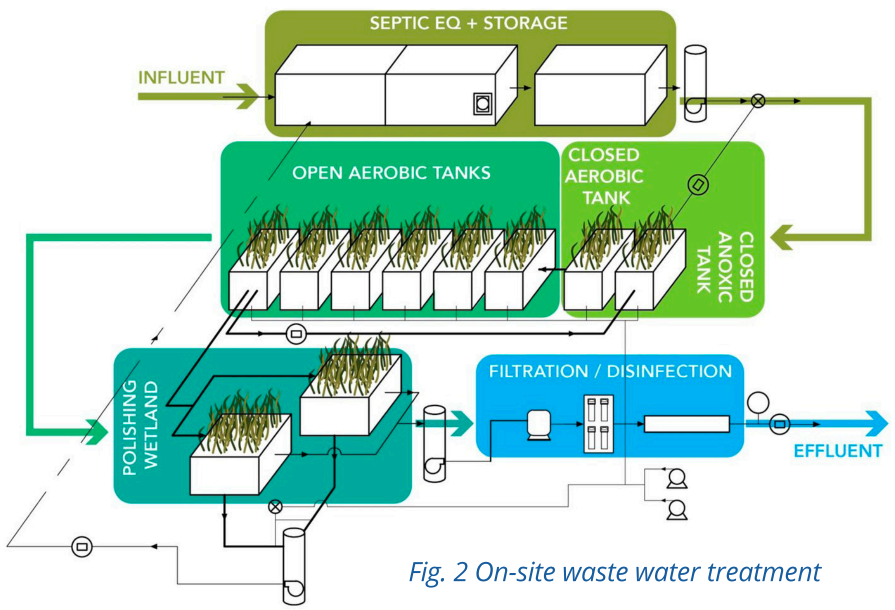


Fig. 2 On-site waste water treatment

Efficient wastewater treatment

The Denver Water administration building utilizes a plant-based blackwater on-site wastewater treatment system, a so-called ["Living Machine"] as coined by the biologist Dr. John Todd in the 1970s. (The first Living Machine, which is still in operation, was installed in 1995 at the Findhorn Ecovillage in Moray, Scotland.) This one-of-a-kind system captures and processes all black and greywater influent from the building's sanitary sewer system in multiple stages (see Figure 2, above), starting with the influent being routed to a septic tank with overflow to the municipal sewer. From this septic tank, the water is processed in closed anoxic and aerobic tanks followed by open aerobic tanks and then polishing wetlands. The open tanks and the polishing wetlands utilize plants for the treatment process; these plants are visible in the Denver Water Administration building lobby. Finally, the water is filtered and disinfected before the effluent is routed to a holding tank for use either to flush plumbing fixtures or to be utilized for irrigation of the adjacent landscaping. Additionally, aesthetically incorporating this system into the beautiful campus required numerous buried tanks and vaults.

The administration building also utilizes a rainwater system in which rainwater is captured off both the administration building roof and off the solar panels covering the top floor of the adjacent parking garage. One key aspect of implementing rainwater reuse is water scenario modeling to help determine storage tank size. For the Denver Water project, multiple scenarios with various levels of landscape quality and demand satisfaction were reviewed to ensure long-term flexible operation for annual water capture/consumption; one example of that modeling is shown in the Water Reclamation Systems section at right.

Rainwater reuse, like blackwater, is not without its share of regulatory issues. In Colorado, rainwater harvesting is significantly limited due to the water rights on this rainfall. Denver Water proposed changes to regulations that would allow indoor flushing as an approved use for recycled water and assigned water rights to the collected rainfall on this project. For these efforts, Denver Water was awarded the US Water Alliance's US Water Prize for Outstanding Public Sector Organization.

A way forward for One Water

Denver Water continues to evaluate how to best use the water resources available today, collaborating with local agencies to determine how to use the right water for the right purpose and find new opportunities to move the One Water Plan forward—such as their partnership with Colorado State University and National Western to construct the Hydro Building at the CSU Spur Campus. This project will not only house Denver Water's new Water Quality Lab, but it will also provide a hub for finding innovative ways to manage natural resources.

WATER RECLAMATION SYSTEMS

Three types of water reclamation systems are typically considered on any project: greywater (capturing water from lavatories, showers/tubs, and clothes washers), blackwater (capturing water from nearly any plumbing fixture, including those noted under greywater), and rainwater (capturing rainwater that falls on the project site, primarily into the roof drains). Of these three, greywater and rainwater tend to be the most common across the U.S. due to their more simplistic treatment requirements and reduced hazards.

For Denver Water, the team chose a plant-based blackwater system and a rainwater system. To provide a broader understanding of all the options considered, however, explanations of all systems follow.

Greywater systems: A non-potable water system that is beneficial for hotels, apartments, and other facilities with multiple showers/tubs and clothes washers.

Blackwater systems: In addition to the sources identified for greywater, blackwater systems typically add in water closets, urinals, dishwashers, kitchen sinks, and other more contaminated wastewater sources.

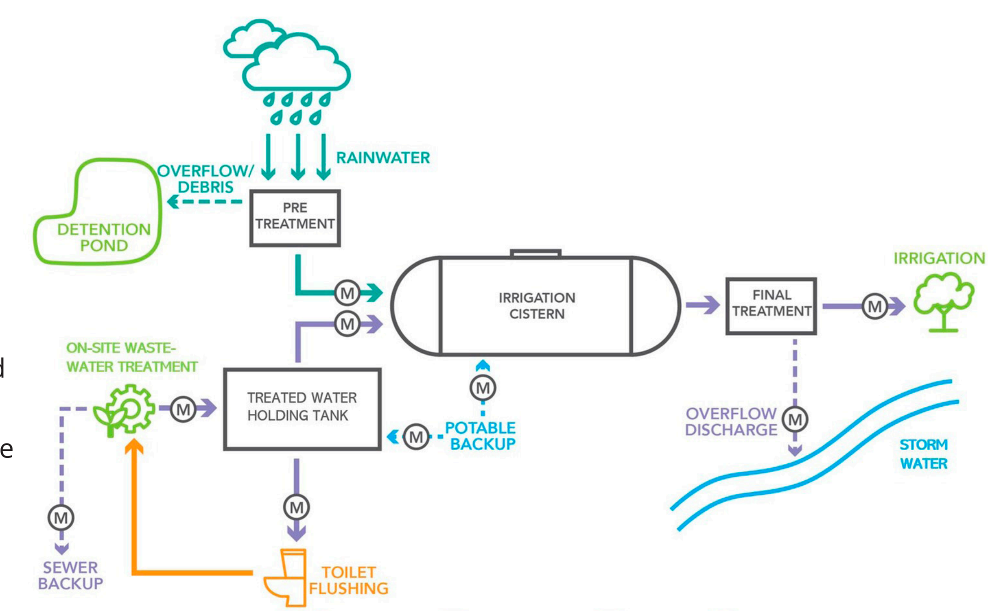
Blackwater systems take reclamation to another level since it contains significantly more pathogens and bacteria that are hazardous if not treated properly. Note: Numerous regulatory requirements must be dealt with when implementing any type of blackwater system.

Plant-based treatment: A system that uses closed anoxic and aerobic tanks followed by open aerobic tanks and polishing wetlands that utilize plants for the treatment process. Denver Water's Administration building lobby houses this type of system.

Non-plant-based treatment: These systems collect blackwater into a first stage settling tank, with overflow to the municipal sewer, and then route the blackwater into aerobic screening, biological treatment, filtration, and finally disinfection before it is collected and reused.

Rainwater systems: These systems must address debris excluders and first-flush diverters to address large contaminants, such as leaves, which may be present in the rainwater flow.

Blackwater or greywater and rainwater could potentially be combined to further enhance the diversity and resiliency of the entire system. A simple summary schematic of a combined rainwater and blackwater system is shown below.



Water Reuse Detail

Carbon reduction strategies

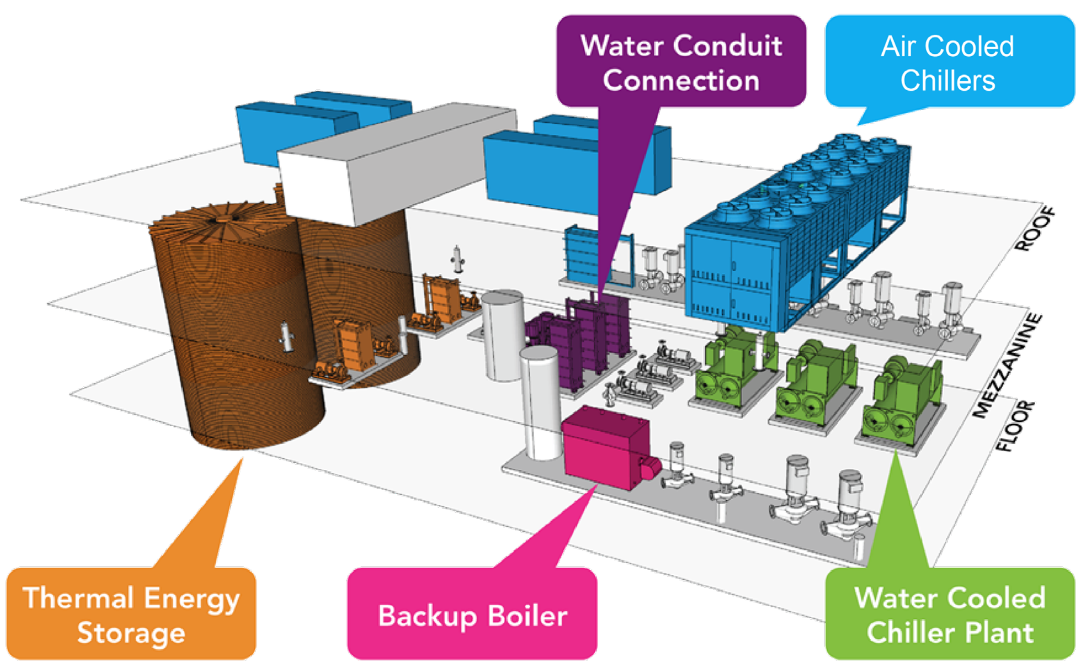
Along with achieving drastic reduction in water use, carbon emission reduction was another major sustainability goal for the Denver Water Operations Complex Redevelopment. Key technologies and strategies to achieve lower emissions included:

- **Primary heating through electrically driven heat pump compressors** eliminates on-site combustion and increases system operational efficiency.

- **Campus energy recovery** to achieve operational sustainability goals. A central heat pump system was implemented using central energy recovery and simultaneous heating/cooling water- and air-source heat pumps. The water-source heat recovery chillers are magnetic centrifugal chillers that can, under certain operational conditions, achieve COP efficiencies near 30. The air-source heat pumps can provide water heating down to ambient temperatures below zero degrees.

- **Thermal storage.** As excess energy is recovered from the campus, or as ambient conditions present optimal generation conditions, the central plant can channel chilled water or hot water into two 35,000-gallon thermal storage tanks. This stored energy can then be used to shave peak heating and cooling loads.

- **Radiant heating and cooling systems.** The central utility plant is used to calibrate water temperatures so that water at different temperatures can be sent through a vast array of tubing within concrete slabs to keep the building at a comfortable temperature year-round. The water's temperature is adjusted using energy captured from other areas in the complex. The radiant system is 30 percent to 50 percent more energy efficient than more conventional construction and best addresses human thermal comfort, as radiant transfer accounts for nearly 50 percent of human thermal regulation.



Central Utility Plant

Redefining Water Resiliency

The administration building is performing as intended, according to Ross, who has noticed a dramatic decrease in energy usage in comparison to the previous building. He also is pleased with how the project managed to meet a variety of goals and remain within budget.

"During design we had to strike a balance between providing functional, efficient spaces to complete the work, incorporate design concepts that would provide wellness and benefit to the employee, and develop these facilities within the project budget as a responsibility to the ratepayers," Ross said. "We were able to utilize the design concepts presented by the design team, garner feedback from the employees through feedback sessions and continuous improvement concepts such as 2P events, and utilize the expertise of the CMAR (construction manager at risk), Mortenson, to provide a continuous feedback loop on constructability and costs."

With the leadership and support of the water efficiency-focused Denver Water, the design and construction team was ultimately able to deliver on the client's One Water concept and achieve LEED Platinum and Net-Zero Energy certifications. Its innovative use of water reclamation via the on-site wastewater treatment and rainwater capture systems is a first-of-its-kind installation in Colorado and was a contributing factor to the project winning the [2021 ACEC EEA National Grand Conceptor Award](). The building's One Water principle has a broader social impact as Denver Water serves as a case study to push and redefine water stewardship across the arid West.

ABOUT THE AUTHOR

Ken Urbanek served as IMEG's Project Executive for the Denver Water Campus Redevelopment. He has a broad design and construction background that includes specific expertise in high-performance building design, including central utility plants, campus distribution systems, under-floor air distribution, chilled beams, geothermal, and variable refrigerant flow (VRF) systems.

Contact him at kenneth.a.urbanek@imegcorp.com