CAROLLO ENGINEERS | VOL 3. 2018 | SPECIAL EDITION

currents

WASTEWATER SYSTEMS

INTENSIFICATION

BIG OPPORTUNITY IN SMALL PACKAGES

PLUS—

TRENDING NOW in the Wastewater Industry

WHAT'S HAPPENING TODAY WILL SHAPE TOMORROW

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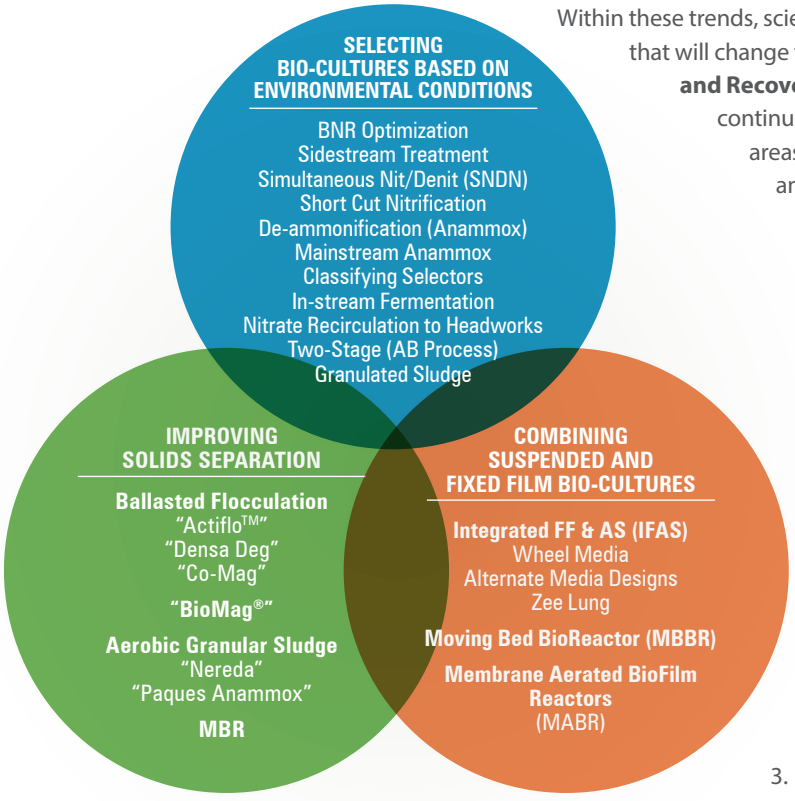
Carollo Engineers monitors industry trends to keep abreast of changing perspectives, hot topics, and new technical developments that allow us to better resolve future wastewater challenges. Our ongoing review of hundreds of research and engineering publications has identified five major trends, illustrated by interconnected rings.

TOP FIVE WASTEWATER TRENDS



NUTRIENT REMOVAL
INNOVATIVE AND EMERGING TECHNOLOGY

Within these trends, scientific and engineering advances are producing technology that will change the industry as we know it. The trend of **Nutrient Removal and Recovery** is a great example. As shown in the figure to the left, continued research and applied technology development in the areas of bio-culture selection, enhanced liquid/solids separation, and combined fixed film and suspended growth biology have created a long list of new processes. The most exciting breakthroughs, however, will happen where multiple areas of advancement overlap.

With that in mind, a team of Carollo's top wastewater engineers and scientists recently convened a wastewater summit to seek out specific topics where current trends, scientific exploration, and applied engineering converge. The goal is to drive innovation by focusing our creative thinking, R&D investment, and leadership toward the highest impact areas.

After two days of intense discussion and debate, four areas of **wastewater innovation leadership** opportunity emerged. These are:

1. Big Data Management and Smart Water Process Automation and Control
2. Advanced Carbon and Energy Management
3. Mainstream Anaerobic Treatment
4. Ballasted Activated Sludge

This issue of *Currents* describes some of our work related to the top five industry trends, the overlapping areas of innovation in nutrient removal and recovery, and Carollo's four focus areas for wastewater innovation leadership.

FLY, FLOAT, OR FALL?

IT'S ALL ABOUT THE BALLAST

Toshio Shimada, Ph.D., P.E. (tshimada@carollo.com) | Jon DeArmond | Andrew DeVries | Katy Rogers, P.E. | John Fraser, P.E.

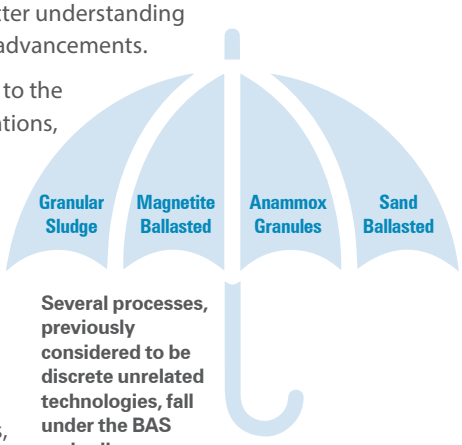
WHAT IS BALLASTED ACTIVATED SLUDGE ANYWAY?

In Ballasted Activated Sludge (BAS), high concentrations of biomass surround heavy ballast particles, allowing biological treatment and clarification to occur in a reduced footprint. The three current nutrient reduction advancements described on page 2 converge with BAS to create a powerful synergy. The wastewater industry often looks at processes such as BioMag®, Aerobic Granular Sludge (AGS), and deammonification using Anammox as discrete, unrelated technologies. However, at Carollo, we believe these processes fall under the same umbrella due to some very important common ground. First, each process ballasts the mixed liquor to improve settling and liquid/solids separation. Second, each process provides a core ballast granule for biomass attachment that allows micro-environments to support a diverse bio-population capable of efficient nitrogen and phosphorus removal. Combine this with advanced control of anaerobic, anoxic, and aerobic environmental conditions, and true innovation will emerge.

In ballooning, ballast helps stabilize the craft and helps the pilot better control altitude and speed. Operationally, wastewater treatment is not so different. When a utility's goal is to be faster, better, and cheaper, all in a smaller footprint, then, like a balloon pilot, we must look to the ballast—in this case, Ballasted Activated Sludge (BAS). BAS just may represent process intensification at its best, and a commitment to better understanding BAS will open the door to a variety of R&D-related advancements.

Enhancing our knowledge of BAS requires answers to the following questions: What are the microbial populations, pathways, and biokinetics of various BAS systems? What ballast material works best? How does an artificial ballast, such as sand, magnetite, or other material, compare to the naturally formed granules in AGS or anammox? What is the most effective way to separate ballasted mixed liquor from effluent liquid, and how is the ballast best recovered?

Working with several well-known industry partners, Carollo has started to find the answers.



Several processes, previously considered to be discrete unrelated technologies, fall under the BAS umbrella.

BALLAST OPPORTUNITIES MAY BE RIGHT IN FRONT OF US

Biological Phosphorus Removal (BPR) tends to increase struvite formation potential. Struvite and other precipitates, such as vivianite, can create significant challenges for any operations and maintenance team. Thus, some agencies are reluctant to implement BPR just to avoid dealing with struvite. In recent years, processes designed to sequester, remove, or recover phosphorus in the form of struvite have been developed. Rather than discarding the struvite, we ask if recovered struvite can be used as a naturally occurring ballast in a BAS system.

To answer this question, Carollo partnered with Ostara Nutrient Recovery Technologies, Inc., to explore the use of struvite as a ballast. Both firms are currently testing the concept to evaluate several additional unanswered questions:

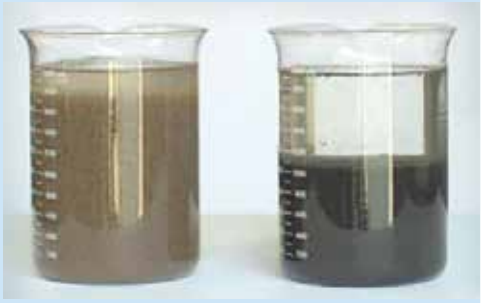
- What is the most effective struvite particle size and distribution for ballasting?
- What is the most effective roughness to encourage bio attachment?
- What is the appropriate ratio of struvite particles to Mixed Liquor Suspended Solids (MLSS)?
- Will phosphorus dissolution occur when ballasting with struvite?
- How and where do we separate struvite from the treatment train?

The ability to discover creative and innovative ballast materials does not stop here. In addition to finding answers to the above questions, the Carollo team is actively exploring multiple types of potential ballast materials that could further leverage BAS as a more efficient, effective, and intensified nutrient removal approach.

Recovered phosphorus in the form of struvite might serve as a natural ballast material.

(Continued on page 4)

Conventional Activated Sludge | Aerobic Granular Sludge



Conventional Activated Sludge | Magnetite Ballasted Activated Sludge

SIDE-BY-SIDE SETTLING OF CONVENTIONAL ACTIVATED SLUDGE MIXED LIQUOR COMPARED TO BOTH AEROBIC GRANULAR SLUDGE AND MAGNETITE BALLASTED ACTIVATED SLUDGE SHOWS SUPERIOR LIQUID/SOLIDS SEPARATION FOR BOTH BALLAST MATERIALS.

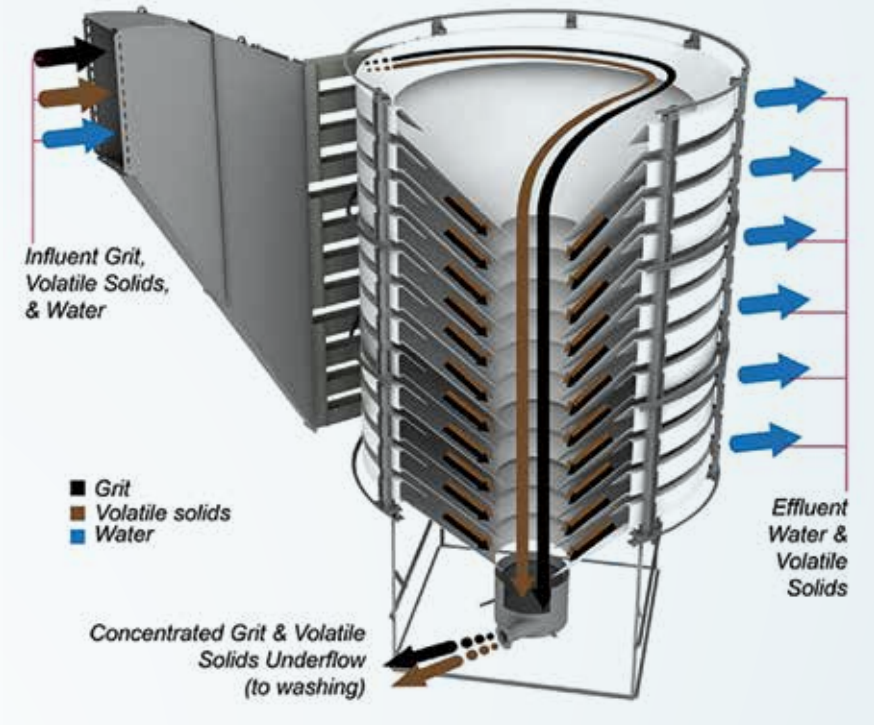
IF BAS SETTLES LIKE A ROCK - WHY SETTLE IT LIKE A FLOC?

Simply put, fast settling ballasted mixed liquor deserves a high-rate separation technology. Settling tests for AGS, and magnetite ballasted MLSS show significant improvement when compared to settling of conventional MLSS. In those tests, high settling rates and superior supernatant quality are obvious. Therefore, ballasted and rapidly settling mixed liquor does not need large conventional final clarifiers designed for a surface overflow rate (SOR) of 400 to 600 gpd/sf. Much higher surface overflow rates and smaller footprints are possible using a more suitable clarifier configuration.

To explore a different way of thinking, Carollo has teamed with industry giants Evoqua Water Technologies and Hydro International to perform demonstration-scale testing of high-rate heavy solids separation of magnetite ballasted activated sludge. The high MLSS concentrations associated with Evoqua's BioMag® system allow for smaller aeration basins. Wastewater facilities already have vast experience in separating heavy grit particles in our headworks. So, our team asked Hydro International: "Can stacked tray HeadCell® grit removal technology be adapted to fit downstream of BAS and used as a clarifier for heavy ballasted MLSS?"

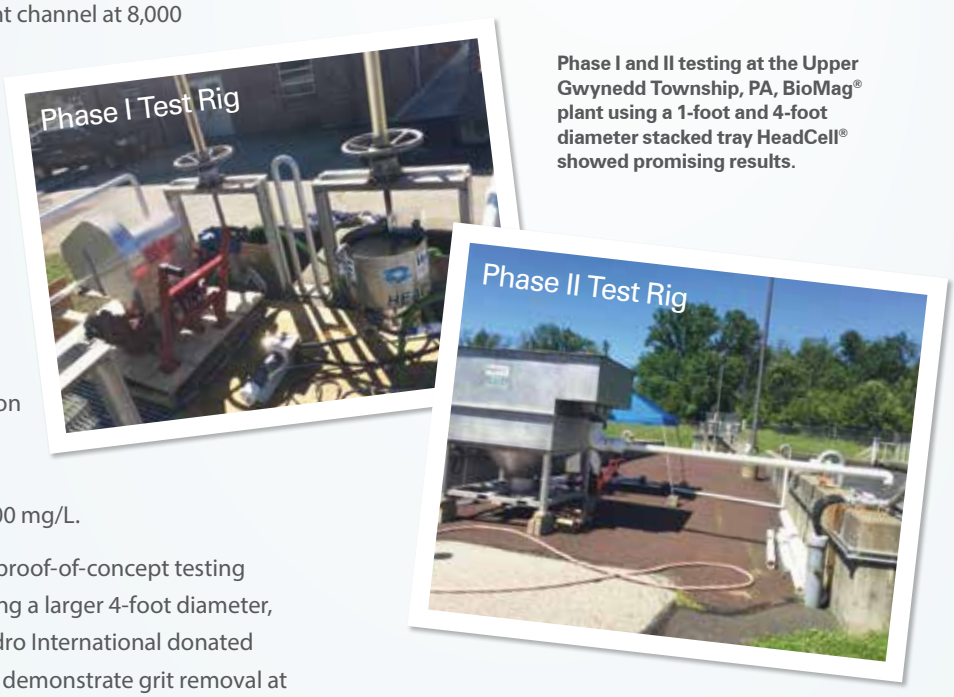
The concept is no different than a big city intensifying their land use by building up. The stacked tray HeadCell® uses a similar approach, by stacking multiple trays to create a "vertical clarifier" thereby reducing the footprint required for high-rate separation of heavy solids. We decided to test it out.

Upper Gwynedd Township, Pennsylvania, has been using the well-established BioMag® system for many years and served as the ideal site for BioMag® and HeadCell® separation testing. Two phases of testing were conducted.



Grit removal technology, such as the HeadCell®, can provide high-rate liquids/solids separation of ballasted mixed liquor.

During the initial Phase I proof-of-concept testing, BioMag® MLSS was withdrawn from the plant's aeration basin effluent channel at 8,000 to 10,000 mg/L with a 0.7 to 1.0 lb ballast/lb of MLSS magnetite load and routed through a 1-foot diameter bench-scale HeadCell®. The unit was able to separate ballasted MLSS at an equivalent SOR of about 1,500 gpd/sf of effective tray surface area. This hydraulic loading rate is about two to three times higher than the SOR of a conventional final clarifier.

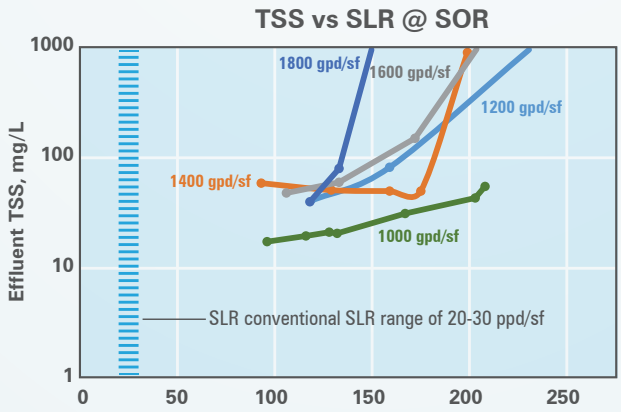


Phase I and II testing at the Upper Gwynedd Township, PA, BioMag® plant using a 1-foot and 4-foot diameter stacked tray HeadCell® showed promising results.

However, the test was not without its challenges. The bench-scale HeadCell® was subject to vibration effects that re-suspended and swept outsettled magnetite MLSS, resulting in effluent Total Suspended Solids (TSS) between 100 mg/L and 200 mg/L.

Nonetheless, the team persisted. With the initial proof-of-concept testing complete, the test team moved on to Phase II using a larger 4-foot diameter, three-stacked-tray pilot-scale HeadCell® unit. Hydro International donated the trailer-mounted pilot unit commonly used to demonstrate grit removal at various plant sites around the country.

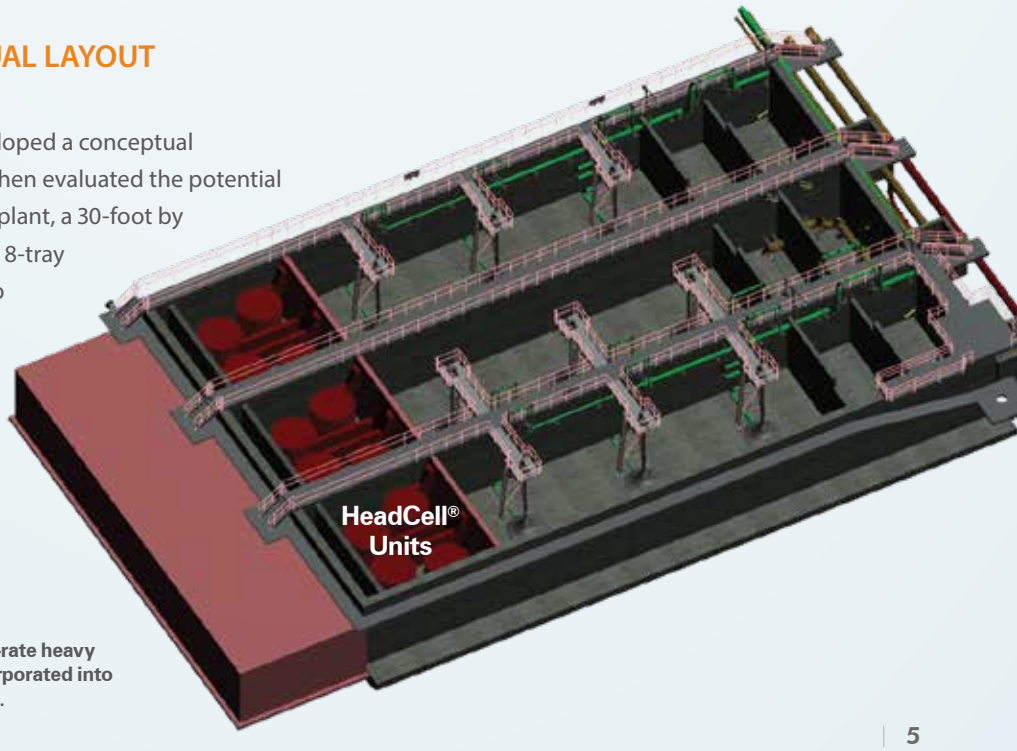
The larger pilot-scale unit was used to further evaluate high-rate separation and intensification of a new wave of BAS thinking. Protocol for Phase II of the test program refined performance expectations, loading criteria, and underflow pumping requirements. Phase II testing indicated that the pilot-scale HeadCell® unit can provide effluent quality between 20 and 60 mg/L TSS when operating over a range of SORs from 1,000 to 1,600 gpd/sf and solids loading rates (SLR) from 100 to 175 ppd/sf.



The SOR and SLR of ballasted activated sludge on a stacked tray HeadCell® grit removal unit was two to three times higher than typical conventional clarifier loading.

BIOMAG® AND HEADCELL® CONCEPTUAL LAYOUT AND COST SAVINGS

Based on the success of the pilot test, Carollo developed a conceptual HeadCell® layout for BioMag® aeration basins. We then evaluated the potential cost and footprint savings. For a 5.0-mgd BioMag® plant, a 30-foot by 30-foot settling section using four 8-foot diameter, 8-tray HeadCell® units at each aeration basin replaces two 90-foot diameter conventional final clarifiers. The HeadCell® would operate at 1,000 gpd/sf and produce effluent TSS of less than 30 mg/L. The system could also be constructed at about half of the cost of conventional clarifiers, splitter boxes, and piping and requires only 50 percent of the space of a non-ballasted biological nutrient removal system using conventional clarifiers.



A conceptual layout of a high-rate heavy solids HeadCell® system incorporated into BioMag® BAS aeration basins.

A FUTURE THAT **WORKS:** OPERATIONS, AUTOMATION, AND MACHINE LEARNING

Vincent Roquebert, P.E. (vroquebert@carollo.com) | Alex Ekster, PhD, P.E., BCEE | Monte Richard, P.E. | Scott Parker, P.E. | Beverly Hann, P.E.

INTRODUCTION

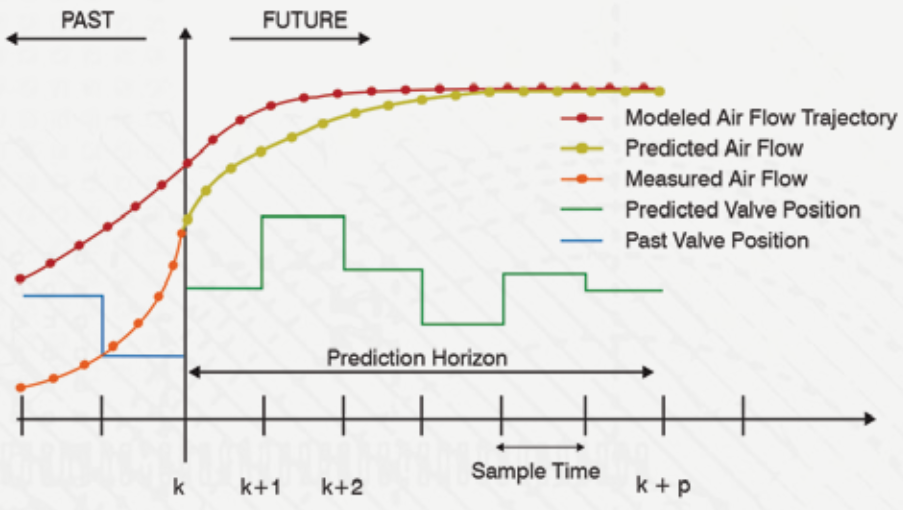
Operators have used automation for decades to help monitor and control wastewater treatment processes. More recently, process models such as BioWin™ have been embedded into control logic to provide advanced process control. Today, accurate and fast field instruments, combined with advanced analytics tools, enable us to go one step further and use Model Predictive Control (MPC) and Machine Learning (ML) techniques to meet regulatory requirements safely, reliably, and efficiently.

CASE STUDY DEMONSTRATION

The City of Chico, California, operates and maintains a 12-mgd activated sludge secondary treatment plant. To optimize the treatment process Carollo implemented a two-step approach to incorporate MPC and ML into plant operations:

1 SRTmaster™

The SRTmaster™ control system, developed by Ekster and Associates, Inc. (Ekster), was installed at the plant in 2014. SRTmaster™ is part of a new generation of automatic solids retention time (SRT) controllers that use both MPC and ML to optimize SRT. Once installed, the SRTmaster™ reduced the effluent turbidity that had caused disinfection issues and stabilized the sludge settleability.



THE MPC AND ML BASED MODEL PROVIDES RELIABLE AIR FLOW CONTROL

2 DO/NH_3master™

Based on the SRTmaster™ success, the City decided to replace its outdated dissolved oxygen (DO) control system in 2016 with new valve actuators, new air flow meters, and Ekster's DO/NH_3master™.

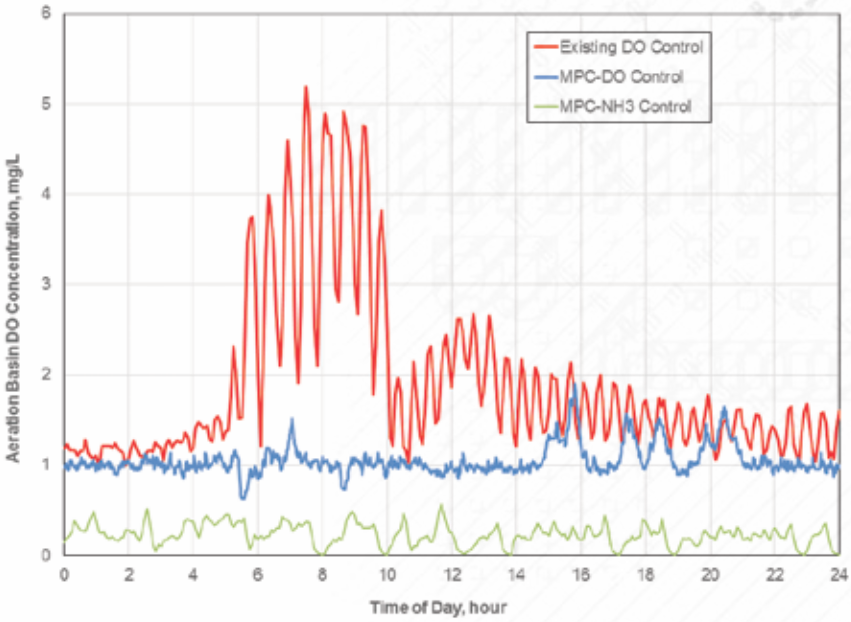
DO/NH_3master™ has three interconnected control loops: air flow, DO, and ammonia (NH_3) that work together instead of fighting each other.

Each control loop is built on MPC and ML concepts. The software generates models from empirical operational data. These models predict the valve actuators and blower vane positions. Similarly, airflow and DO targets are predicted by the models.

This is a large step forward compared to the independent Proportional-Integral-Derivative (PID) controllers.

RESULTS

The innovative control logic provided precise control. The standard deviation measured for ammonia was 0.34 mg/L. The standard error for the DO control was 10 to 20 percent. If intermittent aeration at low air flow demand was not required to meet the diffuser manufacturer's minimum membrane flux rate, the standard error could be further reduced. The overall incorporation of MPC and ML cut energy use by 50 percent, resulting in savings of $110 per million gallons.



THE DO/NH_3 MODEL ENABLES OPERATORS TO USE A LOWER DO SETPOINT AND PROVIDE MORE PRECISE CONTROL

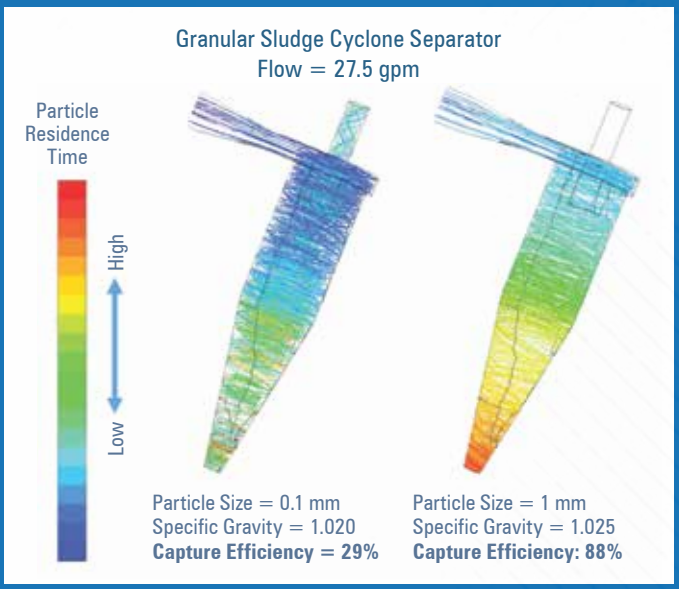
HOW DO **HYDROCYCLONES** SEPARATE GRANULAR ACTIVATED SLUDGE?

Ed Wicklein, P.E. (ewicklein@carollo.com) | Tanja Rauch-Williams, Ph.D., P.E. | William Mancell-Egala, Ph.D. | Nigel Beaton

Hydrocyclones are one method to separate granular activated sludge (GAS) from common activated sludge flocs. Hydrocyclone geometry and size, hydraulic loading rate, pressure setpoints, and nozzle geometry are all factors that need to be properly designed to achieve a consistent, high degree of granular sludge recovery efficiency.

Carollo has undertaken the first of its kind Computational Fluid Dynamics (CFD) modeling of hydrocyclones for GAS separation.

Any facility that is interested in modeling their specific GAS and hydrocyclone characteristics please contact: Tanja Rauch-Williams, Ph.D., P.E., Carollo Wastewater Innovation Lead, trauch-williams@carollo.com.



Energy Neutrality Analysis
FOR THE UNION SANITARY DISTRICT

Scott Parker, P.E. (sparker@carollo.com) | Rashi Gupta, P.E. | Becky Gherini, P.E. | Katherine Eve, P.E. | Ron Appleton, P.E.

Our nation's wastewater treatment plants are transforming into resource recovery facilities, with energy being one of the prime resources sought for recovery. The number of energy neutral, or even energy positive, facilities is growing: East Bay Municipal Utility District in California, Gresham in Oregon, and Strass in Austria. Many others are well on their way to fully offsetting energy consumption with energy efficiency initiatives and onsite energy production. The push toward energy neutrality is the result of these drivers:

- Recognition of the energy intensity of water/wastewater treatment
- A need to reduce operating costs in the face of rising energy prices
- Regulatory and legislative changes to produce more renewable energy and reduce greenhouse gas emissions
- A desire to fully leverage our treatment infrastructure to support sustainability goals

Push towards energy neutrality — How do we get there from here?

CASE STUDY: UNION SANITARY DISTRICT

The Union Sanitary District (District) in Union City, California, sought to answer this question for their Alvarado Wastewater Treatment Plant. The District had already made incremental progress in reducing energy consumption and increasing onsite energy production by installing high-efficiency turbo blowers, solar panels, and cogeneration engines. After installing these assets, the District wanted to know how they could achieve complete energy neutrality under current and future conditions. Like other facilities that have met this goal, the District was particularly interested in evaluating co-digestion of external feedstock to increase digester gas production and subsequent power generation.

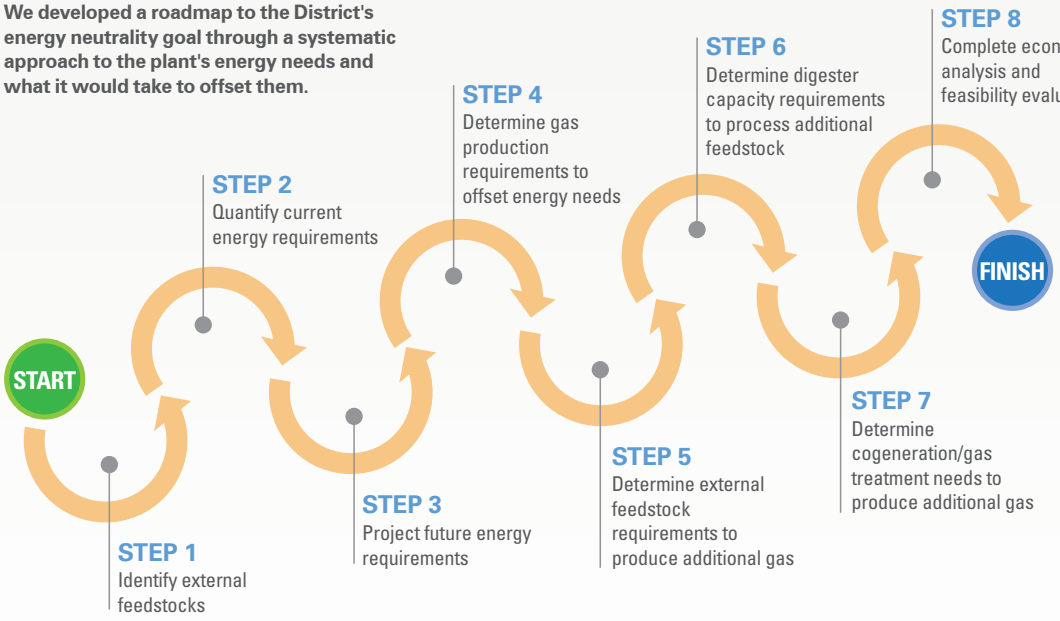
ROADMAP TO ENERGY NEUTRALITY

Our project team developed a roadmap to energy neutrality for the District through a systematic analysis of the plant's energy needs and the actions required to offset them. The graphic below shows our stepwise approach.

To assess infrastructure and feedstock needs, we considered current and future conditions, including projections of increasing municipal biosolids and energy demand. Carollo first worked with the District to determine the treatment capacity required for the plant's core objective: maintaining permit compliance for increasing loads. To do this, we defined redundancy requirements for the solids processes to accommodate regular operational and maintenance tasks, such as taking digesters out of service for cleaning. The team then developed a timeline for additional digester construction that would meet the municipal treatment needs and the District's redundancy requirements.

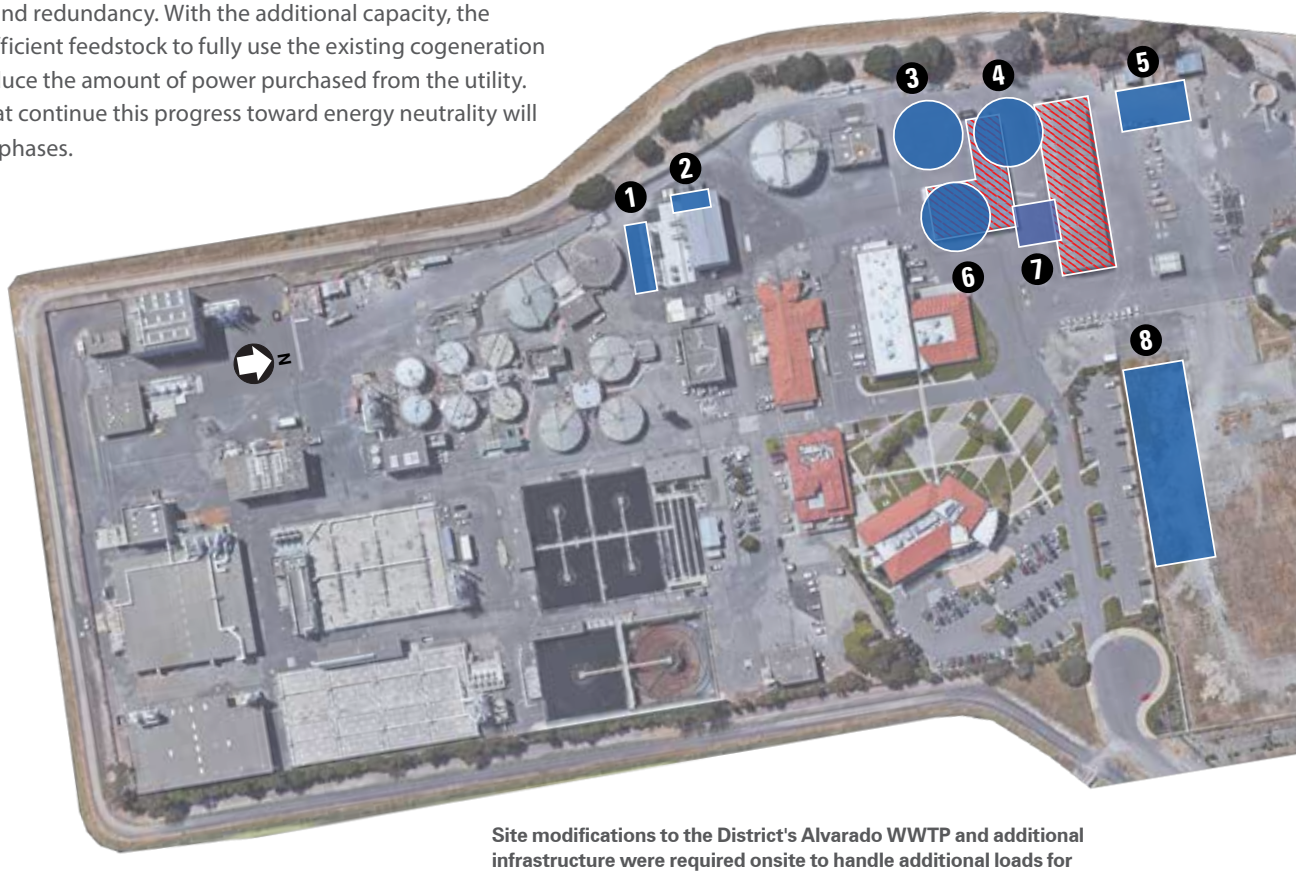
Having determined the plant's core capacity needs, we evaluated how much excess digestion capacity would be available for co-digestion of external feedstock. We also assessed the supporting infrastructure required to convert the increased digester gas into energy. Shown on the next page is an image of the site modifications and additional infrastructure required onsite to handle the additional loads for future conditions and remain energy neutral.

We developed a roadmap to the District's energy neutrality goal through a systematic approach to the plant's energy needs and what it would take to offset them.



IMPLEMENTATION PLAN

Knowing what the plant needed to achieve energy neutrality, the District began a phased implementation plan, starting with the construction of a new digester for additional capacity and redundancy. With the additional capacity, the District could accept sufficient feedstock to fully use the existing cogeneration capacity and further reduce the amount of power purchased from the utility. Subsequent projects that continue this progress toward energy neutrality will be considered in future phases.



LEGEND

- New Facilities
- Demolition
- 1 Expand Gas Conditioning System
- 2 Cogeneration Engine 3
- 3 Additional Digester
- 4 Additional Digester
- 5 Feedstock Receiving Station
- 6 Additional Digester
- 7 Additional Heating and Mixing Building
- 8 Relocate Covered Maintenance Storage and Solar Panels

Site modifications to the District's Alvarado WWTP and additional infrastructure were required onsite to handle additional loads for future conditions and to remain energy neutral.

INCREASING DIGESTER CAPACITY WITH HIGH-SOLIDS DIGESTION

Rick Chan, P.E. (rchan@carollo.com) | Daniel Chien, P.E. | Rashi Gupta, P.E.
Brian Schumacker [City of South San Francisco]

THE CITIES OF SOUTH SAN FRANCISCO AND SAN BRUNO own and operate a Water Quality Control Plant (WQCP) with a permitted average dry weather flow capacity of 13 mgd. The WQCP has five conventional anaerobic digesters that stabilize primary and thickened waste activated sludge. The two oldest digesters, each 70 feet in diameter with a volumetric capacity of approximately 830,000 gallons, have been in operation since the 1950s and have reached the end of their useful lives.

To address the age and condition of these digesters, Carollo worked with the City to evaluate two alternatives for their replacement:

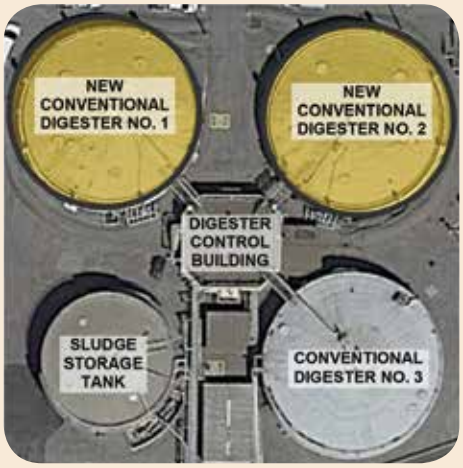
REPLACEMENT ALTERNATIVE 1: Replace both existing digesters with two 70-foot diameter conventional digesters to handle the traditional digester solids content of 2 to 3 percent.

REPLACEMENT ALTERNATIVE 2: Replace both existing digesters with one 70-foot diameter high-solids digester that increases the digester solids content to 5 or 6 percent, coupled with one recuperative thickening system.

(Continued on page 10)

REPLACEMENT ALTERNATIVE 1:

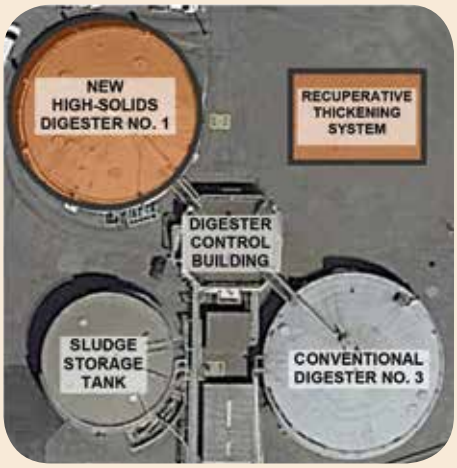
Site Layout with Two New Conventional Digesters



This alternative would provide two new conventional digesters with the same diameter and volumetric capacity as the existing digesters. To improve mixing of the digester contents and reduce energy and maintenance costs, a linear motion mixer would be provided for each digester to replace the existing gas mixing system. Sludge distribution to the new and existing conventional digesters would be the same as for current operations.

REPLACEMENT ALTERNATIVE 2:

Site Layout with One New High-Solids Digestion System



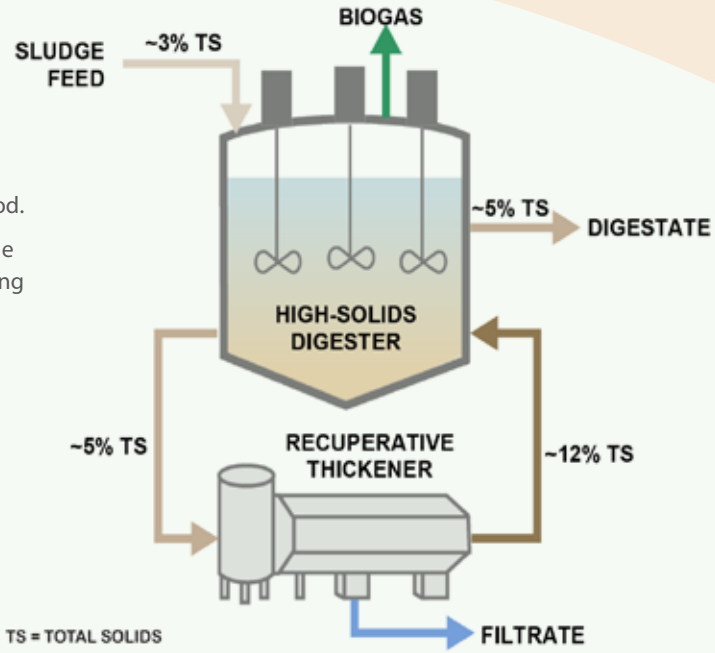
This alternative would provide one new digester, which has the same diameter and volumetric capacity as one of the existing digesters, with Anaergia's Omnivore™ high-solids digestion system. To produce and operate the digester at a solids content of 5 to 6 percent, a portion of the digester's sludge would be continuously recirculated through an external recuperative thickener to thicken the sludge to approximately 12 percent solids and maintain a higher solids content. By doubling the solids content and controlling the Solids Retention Time (SRT) separately from the Hydraulic Retention Time (HRT), the operating capacity of a single high-solids digester increases to that of two conventional digesters. To provide uniform mixing of the higher solids content inside the digester, three high-torque, low-speed submersible mixers would be provided. Sludge fed to the new high-solids digester would be twice that of the existing conventional digester.

SELECTED ALTERNATIVE

After evaluating both economic and non-economic factors, the City decided to implement the high-solids digestion system (Alternative 2) for the following reasons:

- **Lower capital and operation and maintenance (O&M) costs,** which resulted in over 12 percent savings in life-cycle cost over a 10-year period.
- **Operating at a higher SRT** improves the potential for increased volatile solids destruction, increased biogas production, and reduced dewatering O&M costs.
- **Provides flexibility** for future external high-strength organic waste (fats, oils, grease, and food waste) to the WQCP without needing additional digestion capacity.
- **Aligns well with the WQCP's vision** to embrace process innovation and efficiency to protect public health.

Design of the high-solids digestion system was completed in March 2018. **Construction will begin in late October 2018**, and start-up and commissioning of the Omnivore™ digester will commence in 2020.



THE RECUPERATIVE THICKENING PROCESS ALLOWS SEPARATE CONTROL OF THE DIGESTER'S SRT AND HRT TO MAINTAIN A HIGHER SOLIDS CONTENT IN ORDER TO INCREASE DIGESTION CAPACITY.

Conventional
HRT=SRT=~25 DAYS

High Solids Digester
SRT>HRT
SRT=~30 DAYS
HRT=~14 DAYS

Wish you could stop paying those monthly electricity bills?

WELL, WHY DON'T YOU?

Andrew Carroll | Mary Beth Sullivan, Ph.D., P.E. | Tanja Rauch-Williams, Ph.D., P.E. (trauch-williams@carollo.com)

OTHER THAN YOUR EMPLOYEES, ELECTRICITY BILLS ARE LIKELY ONE OF YOUR HIGHEST RUNNING MONTHLY COSTS. MORE FACILITIES ARE STARTING TO INCREASE THEIR ELECTRICAL SELF-SUFFICIENCY BY LOWERING THE AMOUNT OF EXTERNALLY PURCHASED ELECTRICITY AND DECREASING TOTAL UTILITY ELECTRICAL DEMAND.

Know Your Numbers

Not many staff members know or have daily access to the amount of real-time, daily, or annual electricity their utility consumes. Energy consumption tracking and billing often take place in departments outside of the end-user and are separate from daily operational decisions.

More and more utilities are starting to take energy conservation seriously and set targeted strategic goals to increase their self-sufficiency. In the United States, several facilities have achieved or are very close to achieving electrical neutrality. In over one year, these utilities will produce as many kWhs on average as they consume within the fence. Achieving this goal has taken facilities about 10 to 15 years of dedicated and focused decision making and investment.

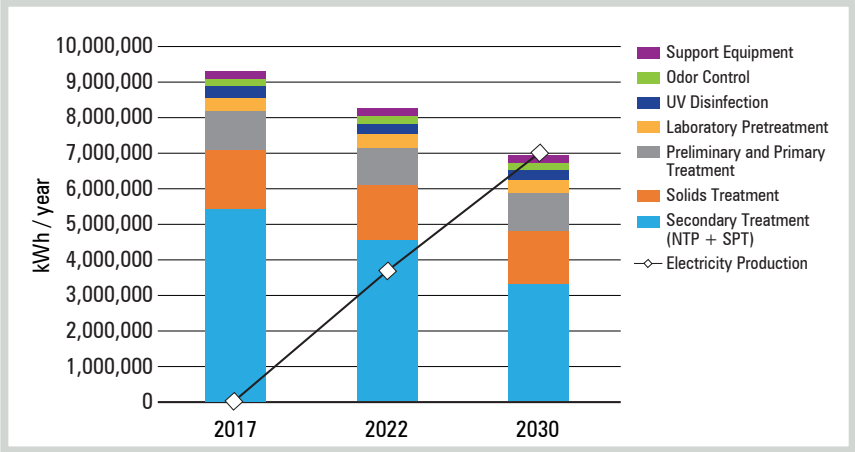
What Is Your Facility's 10-Year Roadmap?

Carollo recently completed a 20-year Wastewater Treatment Master Plan for the City of Fort Collins Utilities in Colorado. The City is making successful strides toward their ambitious goal of being carbon neutral by 2050. Wastewater treatment is one key component in achieving this goal.

As part of the City's master planning effort, Carollo presented a potential roadmap for obtaining electrical neutrality by 2030 for wastewater treatment. The roadmap is based on a list of recommendations for no-cost electricity reductions and suggested upgrades for increased energy production and reduced energy usage. Over the coming years, implementing the master plan's recommendations will require thoughtful planning and coordination with future capital improvement projects and new regulatory requirements.

Electricity Neutrality Requires a Plan

Carollo has supported a number of utilities in the United States in their electrical neutrality planning and implementation efforts. This work is similar to planning for retirement: start now, develop reasonable goals, get your advisors on board, benchmark, and track progress often.



The City of Fort Collins' wastewater facility can become electricity neutral through a combination of plant-wide optimization and energy-conscious capital improvement projects. A roadmap like this can serve as a benchmark for tracking progress through 2030.

Carollo Selected to Support WEF in Setting

NATIONAL RESOURCE RECOVERY GOALS

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The Water Environment Federation (WEF) encourages wastewater treatment plants to transition into Water Resource Recovery Facilities (WRRFs) to better serve sustainability and community objectives. With challenges such as population pressures, climate change, aging infrastructure, and funding shortfalls, water resources are being stressed at unprecedented levels. To address these challenges, we must take bold action.

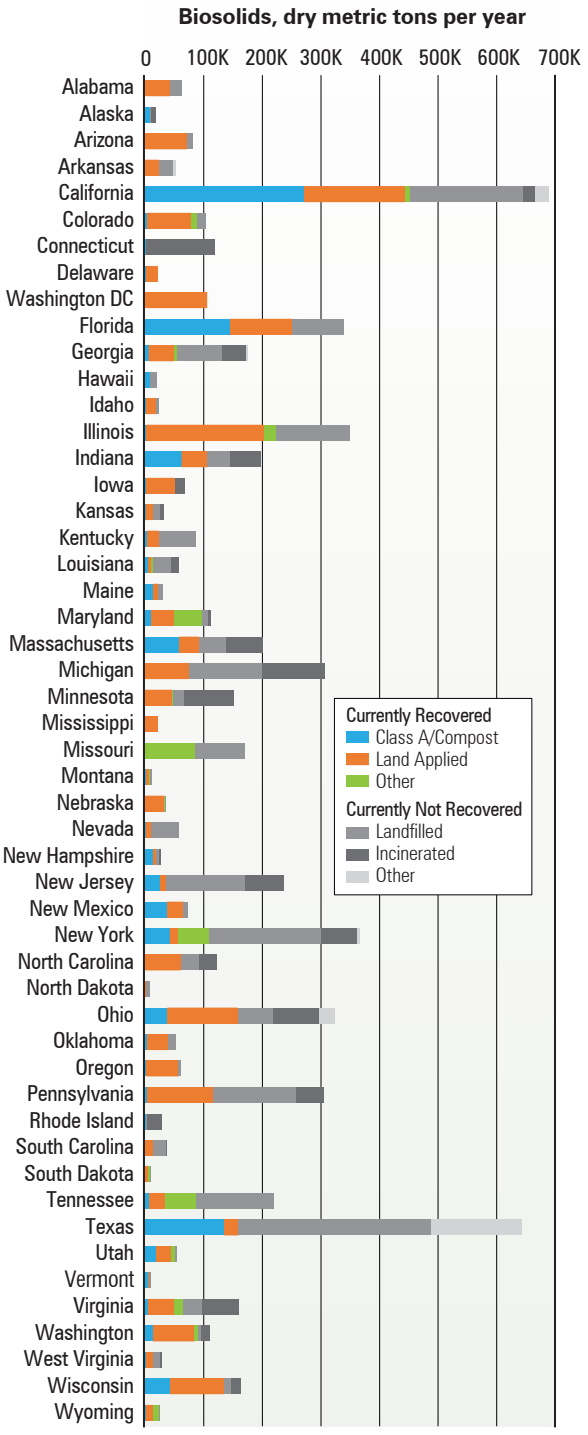
Wastewater treatment plants can no longer operate as waste disposal facilities. Instead, they must operate as WRRFs that produce clean reused water, recover nutrients such as phosphorus and nitrogen, and help reduce the nation's dependence on fossil fuels by producing and using renewable energy.

To help wastewater treatment plants transition to WRRFs, WEF selected Carollo to set strategic resource recovery goals for the North American water sector. Recovery goals will be developed specifically for water reuse, nutrient, biosolids, and energy recovery. WEF wishes to encourage the water sector to adopt a resource recovery mindset by quantifying and publicizing progress toward these goals.

However, before the goals could be set, Carollo had to understand the current state of the industry. To do this, Carollo teamed with Stantec and the University of Colorado-Boulder to develop baseline data that established the current amount of resource recovery at WRRFs in the United States and Canada. WEF will publish the results of this effort at the Water Environment Federation Technical Exhibition and Conference (WEFTEC) 2018.

As part of this study, Carollo developed a resource recovery survey for WEF that helps define where utilities are standing with current recovery practices, their potential, and how they compare to their industry peers. Benchmarking utility achievements and tracking progress over time are critical for setting achievable and defensible goals and communicating them to community leaders.

For WEF, Carollo is summarizing the current state of resource recovery in North America for water, biosolids, nutrients, and energy. The figure on the right shows the annual amount of recovered and non-recovered biosolids by state.



Current state of resource recovery in the U.S. – Annual amount of recovered and non-recovered biosolids by state.

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