NOTICE OF SPECIAL MEETING
OF THE
SOUTH ORANGE COUNTY WASTEWATER AUTHORITY

PC-2 / PC-17 COMMITTEES
TELECONFERENCE MEETING

TELECONFERENCE PHONE NUMBER: (213) 279-1455
TELECONFERENCE ID: 809 980 820

September 29, 2020
9:00 a.m.

NOTICE IS HEREBY GIVEN that a Special Meeting of the South Orange County Wastewater Authority (SOCWA) PC-2/PC-17 Committees was called to be held by Teleconference on **September 29, 2020** at **9:00 a.m.** SOCWA staff will be present and conducting the call at the SOCWA Administrative Office located at 34156 Del Obispo Street, Dana Point, California. This meeting is being conducted via Teleconference pursuant to the California Governor Executive Order N-29-20.

MEMBERS OF THE PUBLIC ARE INVITED TO PARTICIPATE IN THIS TELECONFERENCE MEETING AND MAY JOIN THE MEETING VIA THE TELECONFERENCE PHONE NUMBER AND ENTER THE ID CODE. THIS IS A PHONE CALL MEETING AND NOT A WEB-CAST MEETING SO PLEASE REFER TO AGENDA MATERIALS AS POSTED WITH THE AGENDA ON THE WEB-SITE WWW.SOCWA.COM. ON YOUR REQUEST, EVERY EFFORT WILL BE MADE TO ACCOMMODATE PARTICIPATION. IF YOU REQUIRE ANY SPECIAL DISABILITY RELATED ACCOMMODATIONS, PLEASE CONTACT THE SOUTH ORANGE COUNTY WASTEWATER AUTHORITY SECRETARY'S OFFICE AT (949) 234-5452 AT LEAST TWENTY-FOUR (24) HOURS PRIOR TO THE SCHEDULED MEETING TO REQUEST DISABILITY RELATED ACCOMMODATIONS. THIS AGENDA CAN BE OBTAINED IN ALTERNATE FORMAT UPON REQUEST TO THE SOUTH ORANGE COUNTY WASTEWATER AUTHORITY'S SECRETARY AT LEAST TWENTY-FOUR (24) HOURS PRIOR TO THE SCHEDULED MEETING.

AGENDA EXHIBITS AND OTHER WRITINGS THAT ARE DISCLOSABLE PUBLIC RECORDS DISTRIBUTED TO ALL, OR A MAJORITY OF, THE MEMBERS OF THE SOUTH ORANGE COUNTY WASTEWATER AUTHORITY PC-2/PC-17 COMMITTEES IN CONNECTION WITH A MATTER SUBJECT FOR DISCUSSION OR CONSIDERATION AT AN OPEN MEETING OF THE PC-2/PC-17 COMMITTEES ARE AVAILABLE BY PHONE REQUEST MADE TO THE AUTHORITY ADMINISTRATIVE OFFICE AT 949-234-5452. THE AUTHORITY ADMINISTRATIVE OFFICES ARE LOCATED AT 34156 DEL OBISPO STREET, DANA POINT, CA ("AUTHORITY OFFICE"). IF SUCH WRITINGS ARE DISTRIBUTED TO MEMBERS OF THE FINANCE COMMITTEE LESS THAN TWENTY-FOUR (24) HOURS PRIOR TO THE MEETING, THEY WILL BE SENT TO PARTICIPANTS REQUESTING VIA EMAIL DELIVERY. IF SUCH WRITINGS ARE DISTRIBUTED IMMEDIATELY PRIOR TO, OR DURING, THE MEETING, THEY WILL BE AVAILABLE IMMEDIATELY ON VERBAL REQUEST TO BE DELIVERED VIA EMAIL TO REQUESTING PARTIES.

AGENDA

1. **Call Meeting to Order**

2. **Public Comments**

   THOSE WISHING TO ADDRESS THE PC-2/PC-17 COMMITTEE ON ANY ITEM LISTED ON THE AGENDA WILL BE REQUESTED TO IDENTIFY AT THE OPENING OF THE MEETING AND PRIOR TO THE CLOSE OF THE MEETING. THE AUTHORITY REQUESTS THAT YOU STATE YOUR NAME

WHEN MAKING THE REQUEST IN ORDER THAT YOUR NAME MAY BE CALLED TO SPEAK ON THE ITEM OF INTEREST. THE CHAIR OF THE MEETING WILL RECOGNIZE SPEAKERS FOR COMMENT AND GENERAL MEETING DECORUM SHOULD BE OBSERVED IN ORDER THAT SPEAKERS ARE NOT TALKING OVER EACH OTHER DURING THE CALL.

3. **Review Innovative Solids Objectives and Proposals – PC-2/PC-17**

   Recommended Action: Information Item

4. **Project Committee 2 Innovative Biosolids Options Discussion for the JB Latham Treatment Plant**

   Recommended Action: Staff recommends the PC-2 Board table the Innovative Biosolids initiative at this point in time.

5. **Project Committee 17 Innovative Biosolids Options Discussion for the Regional Treatment Plant**

   Recommended Action: Staff recommends the PC-17 Board award the 30% design contract to Lystek.

Adjournment

I hereby certify that the foregoing Notice was personally emailed or mailed to each member of the SOCWA Finance Committee at least 24 hours prior to the scheduled time of the Special Meeting referred to above.

I hereby certify that the foregoing Notice was posted at least 24 hours prior to the time of the above-referenced Finance Committee at the usual agenda posting location of the South Orange County Wastewater Authority and at www.socwa.com.

Dated this 23rd day of September 2020.

B. Burnett

Betty Burnett, General Manager/Secretary
SOUTH ORANGE COUNTY WASTEWATER AUTHORITY

Agenda Item 3

Board of Directors Meeting	
Meeting Date: September 29, 2020	

TO: Project Committee 2 and 17 Board of Directors

FROM: Betty Burnett, General Manager

STAFF CONTACT: Jason Manning, Director of Engineering

SUBJECT: Review Innovative Solids Objectives and Proposals

Overview

Attached (Exhibit 1) are slides summarizing the proposals and answers from each of the proposers. There were initially five companies that proposed on the Innovative Biosolids Request for Proposal. During review sessions with the Engineering Committee, the list of proposers was narrowed down to three. The information submitted by each of the three proposers has been included in this packet as indicated below:

Exhibit 2 - Genifuel:
- Proposal
- Answer to Engineering Committee Questions

Exhibit 3 - Lytek:
- Proposal
- Answer to Engineering Committee Questions

Exhibit 4 - NEFCO:
- Proposal
- Answer to Engineering Committee Questions

Financial Status

Both Innovative Biosolids Projects 5204-000(a) for PC 2 Solids and 5204-000(b) for PC 17 Solids have cash already collected in the amount of $149,998 ($74,999 per PC).

Table 1 – Proposal Costs for 30% Design

Genifuel	Lystek	NEFCO
$146,850	$116,866	$176,520

Table 2 – Cost Breakdown by Agency for Each Proposal Including a 50/50 Split Between PC 2 and PC 17

	Genifuel	Lystek	NEFCO
	$146,850	*$116,866*	*$176,520*
CLB	$8,238	$6,556	$9,903
CSJC	$22,028	$17,530	$26,478
EBSD	$433	$345	$521
ETWD	$14,986	$11,926	$18,014
MNWD	$59,064	$47,004	$70,998
SCWD	$21,264	$16,922	$25,560
SMWD	$20,837	$16,582	$25,047

Table 3 – Cost Breakdown by Agency for Each Proposal for Only PC 2

	Genifuel	Lystek	NEFCO
	$146,850	*$116,866*	*$176,520*
CSJC	$44,055	$35,060	$52,956
MNWD	$31,751	$25,268	$38,166
SCWD	$29,370	$23,373	$35,304
SMWD	$41,674	$33,165	$50,094

Table 4 – Cost Breakdown by Agency for Each Proposal for Only PC 17

	Genifuel	Lystek	NEFCO
	$146,850	*$116,866*	*$176,520*
CLB	$16,477	$13,112	$19,806
EBSD	$866	$690	$1,041
ETWD	$29,972	$23,852	$36,028
MNWD	$86,377	$68,741	$103,829
SCWD	$13,158	$10,471	$15,816

Also, as noted in the presentation provide in Exhibit 1, both PC 2 Solids and PC 17 Solids have and will continue to receive funds from the respective cogeneration SGIP grants annually over the next several years. This calendar year, PC 2 received $148,623 and PC 17 received $165,541. The initial 50% payments for each PC have already been refunded to the member agencies. Table 5 below shows the schedule of funds that have been received or are expected to be received through the grant.

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Table 5 – SGIP Grant Funds Received and Anticipated

	JBL (PC 2)	Date	RTP (PC 17)	Date
	SD-SGIP-2014-0747		SCE-SGIP-2014-0986	
Maximum Total Incentive	$982,176		$1,759,680	
Initial 50% Payment[1]	$491,088	6/2019	$879,840	4/2019
1st Annual Payment	$148,623	8/2020	$165,541	5/2020
2nd Annual Payment[2]	$140,000	8/2021	$176,000	5/2021
3rd Annual Payment[2]	$130,000	8/2022	$176,000	5/2022
4th Annual Payment[2]	$72,465	8/2023	$176,000	5/2023
5th Annual Payment[2]	$0 [3]	8/2024	$176,000	5/2024

Notes:

1 - The initial 50% payments were refunded to the member agencies

2 - Estimated payment amount. The actual amount depends on digester gas production and actual cogeneration run-time and electrical output.

3 - The JBL Cogeneration System has performed above what was anticipated when the final grant approval was issued. We are therefore currently earning more than was calculated each year.

If one or both of the Project Committees choose to move forward with one or more of the proposers, the funds from the first annual payment are available to be used.

Recommended Action

Informational related to recommended actions in Items 4 and 5 of the agenda.

SOCWA Innovative Solids/ Biosolids Technologies

Project Committees 2 & 17

Exhibit 1

September 29, 2020

South Orange County Wastewater Authority

Agenda

- Project Objectives
- Technologies Proposed
- Potential Impacts to Goals
- Updates from Proposers
- Funding
- Next Steps
- Staff Recommendation

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Project Objectives

- Objectives:
  - Select one or more firms to provide a 30% design of an innovative biosolids technology
  - Provide a second proposal to better define the technology, site location, cost, and other details based on the 30% design
- Project Drivers
  - Address potential ban on biosolids landfilling
  - Defer capital investments
  - Minimize neighborhood impacts
  - Provide additional reliability
  - Maximize renewable energy production

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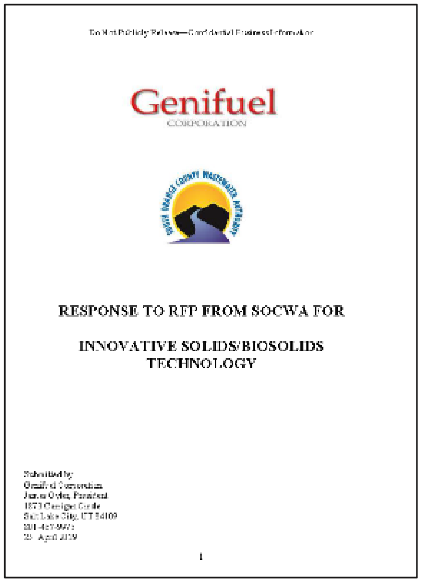
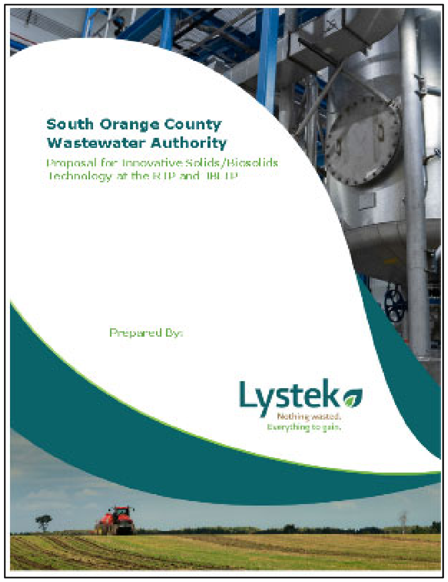
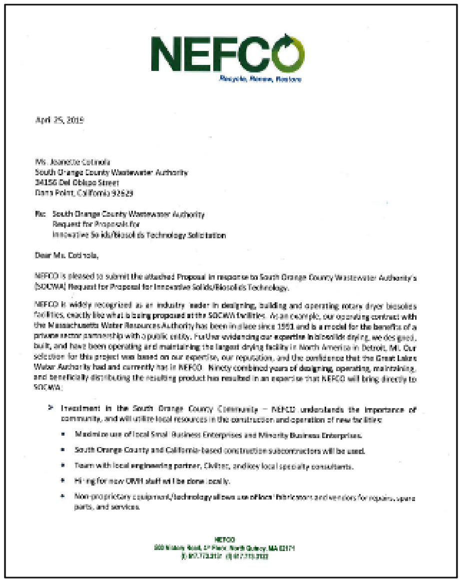
Proposals for Consideration

- Genifuel
- Lystek
- NEFCO







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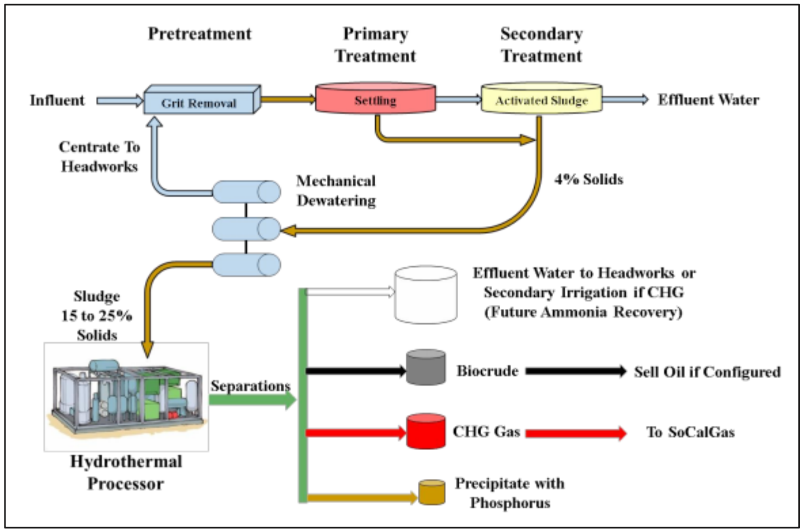
Technologies Proposed

- Catalytic Hydrothermal Gasification *(Genifuel)*
  - Undigested or digested sludge is exposed to high temperature and pressure to beak down all organic compounds to biocrude and/or methane.
- Thermal Hydrolysis *(Lystek)*
  - Undigested sludge is boiled at a high pressure followed by a rapid decompression to break down cellular material and sterilize the sludge.
- Dryer *(NEFCO)*
  - Undigested or digested sludge is heated to remove the majority of moisture. This is usually done to 95% solids. Current cake from SOCWA centrifuges is about 24% solids.

Genifuel

Process	Feedstock	% of Solids Proposed	Products
Hydrothermal Processing	Undigested sludge preferred or possibly digested sludge	30% to 100% of JBLTP or RTP	Methane, effluent water (from hydrothermal process), precipitate with phosphorus

Process Schematic:

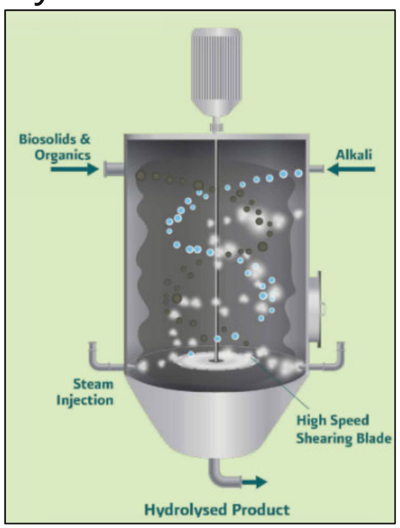


Example Skid:

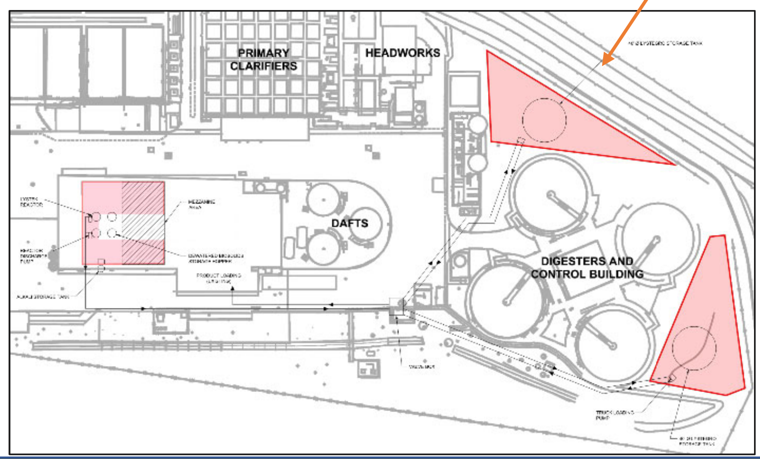
Lystek

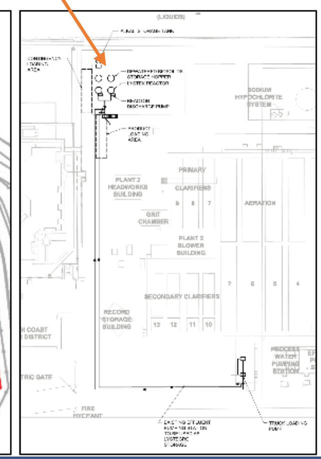
Process	Feedstock	% of Solids Proposed	Products
Thermal Hydrolysis Process	Digested sludge preferred or undigested sludge	100% of JBLTP or RTP	LysteGro (liquid fertilizer), LysteMize (product to be used in digesters to enhance biogas production – JBLTP only)

Lystek THP® Reactor



Proposed Locations at RTP & JBLTP

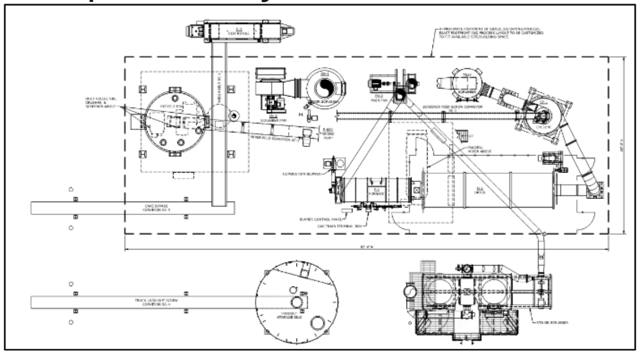




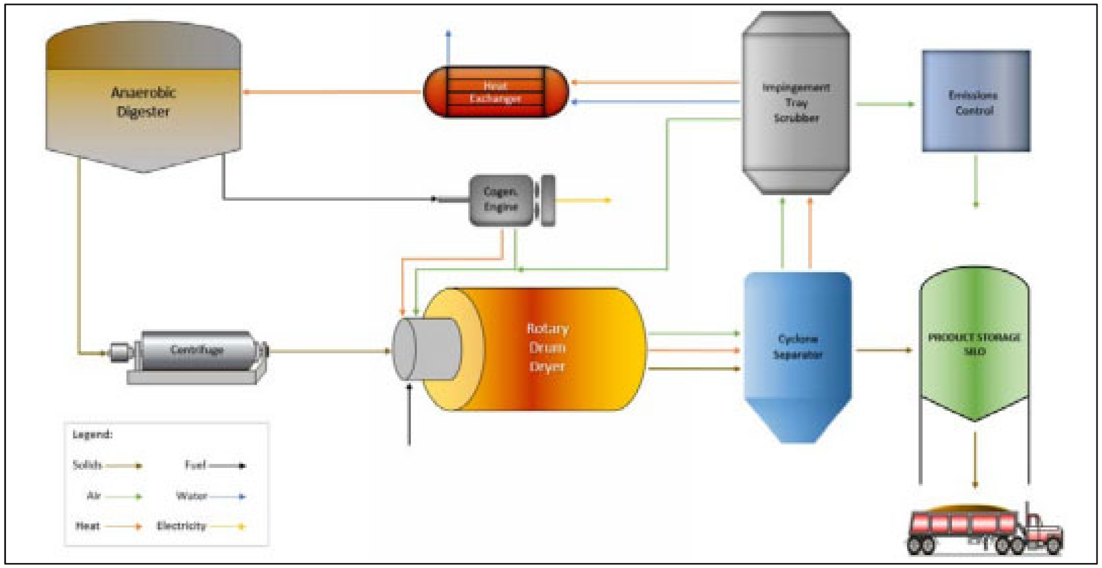
NEFCO

Process	Feedstock	% of Solids Proposed	Products
Rotary Drum Dryer	Digested preferred or undigested sludge	Not Listed	Dried granules, condensate water from dryer

Proposed Layout at JBLTP:

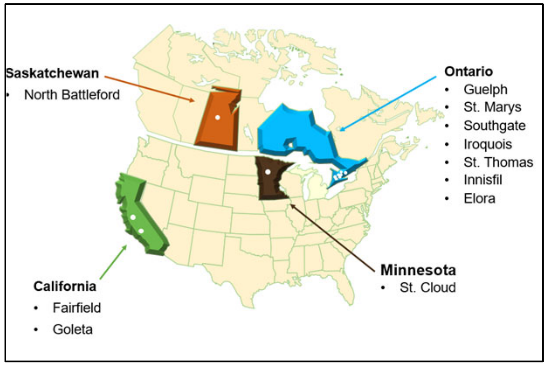


Process Schematic:



Existing Installations

Genifuel	Lystek	NEFCO
Hydrothermal	*Thermal Hydrolysis*	*Dryer*
No facility running on WWTP sludge currently operational, but two facilities planned in US and Canada.	Multiple facilities existing in US and Canada.	Multiple facilities existing in US and Canada.



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Potential Impacts to RFP Goals

	Genifuel	Lystek	NEFCO
	Hydro-thermal	*Thermal Hydrolysis*	*Dryer*
Potential Ban on Landfilling			
Defer Capital Expenses			
Minimize Neighborhood Impacts (Truck Traffic)			
Minimize Neighborhood Impacts (Odor)			
Maximize Energy Potential			

Positive Impact | **Potential Positive Impact** | **No or Negative Impact**

South Orange County Wastewater Authority

Additional Process Information

	Genifuel	Lystek	NEFCO
	Hydrothermal	*Thermal Hydrolysis*	*Dryer*
PFAS Destroyed in Process	Yes	No	No
End Product	Biocrude and/or biogas (main product), phosphorus compounds, inorganic solids, effluent water with dissolved salts and ammonia	LysteGro: Fertilizer product Lystek would be responsible for marketing and selling LyteMize: Biosolids that can be reintroduced to the digesters to increase gas production	Class A biosolids that can be used as fuel, fertilizer, and other soil amendments
Maximum Height of Structure	12 feet	30 feet	70 feet
Impact on Methane Production	Estimated up to 80% increase	Estimated up to 40% increase	None

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Funding

- PC 2 and 17 each have provided $74,999 totaling $149,998
- PC 2 and PC 17 are currently receiving SGIP Grant funds as indicated in the table below. These funds could be used to fund additional proposals if desired by the Board.
- All three proposers have indicated continued interest and that the 30% design cost would either stay the same or would require minor modifications

	JBL (PC 2)	Date	RTP (PC 17)	Date
Grant ID	SD-SGIP-2014-0747		SCE-SGIP-2014-0986	
Maximum Total Incentive	$982,176		$1,759,680	
Initial 50% Payment[1]	$491,088	6/2019	$879,840	4/2019
1st Annual Payment	$148,623	8/2020	$165,541	5/2020
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4th Annual Payment	$72,465	8/2023	$165,000	5/2023
5th Annual Payment	$0	8/2024	$165,000	5/2024

Note: 1 – The initial 50% payments were refunded to the member agencies.

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Next Steps

- Identify vendor or vendors to award the 30% design project
- Clarify any cost changes from the chosen vendor(s)
- Bring the final award to the Board with any updated costs for Board approval

-OR-

- Stop here until other options are more mature

Staff Recommendation

- Given the constraints at our facilities and the maturity of each technology, staff is recommending PC 17 move forward with the Lystek 30% design.

Benefits	Drawbacks
Mature technology with product end use	Mechanical dewatering and digestion still needed
Can increase biogas production	Cost per wet ton is estimated at $140-$170 (current options are $50-60 per wet ton)
Will help prepare SOCWA for this or other biosolids technologies that may be considered in the future	Increased truck traffic
Will provide numbers in the Ten-Year Capital Improvement Program for this or other similar biosolids handling technology	
This design will supplement the two existing preliminary dryer designs for each facility	

SOCWA
South Orange County Wastewater Authority

RESPONSE TO RFP FROM SOCWA FOR

INNOVATIVE SOLIDS/BIOSOLIDS TECHNOLOGY

Submitted by:
Genifuel Corporation
James Oyler, President
1873 Carrigan Circle
Salt Lake City, UT 84109
801-467-9976
25 April 2019

A. INFORMATION REQUIREMENTS

This Section 1 addresses each of the required information items listed in the RFP. Section B provides the cost information for the Scope of Services described in the RFP under separate cover.

1. Understanding of Scope of Services

Task	Task Description	Description of Work	Approach	Potential Problems
1	Progress Meetings	At least four onsite meetings at Dana Point, including kick-off meeting, meeting with Engineering Committee, and at least two additional meetings. Genifuel will provide agenda, action item list, and decision log	Meetings will include Genifuel president, program manager, and engineering manager	Scheduling of all personnel needs to be done well in advance
2	Document Review and Staff Interviews	Prepare Technical Memorandum with five copies for review, response to comments, and final Memorandum. The TM will be based on a review of existing plans and condition assessments, drawings, and site visit(s). Existing drawings will be verified as required. Genifuel will review project needs and develop an integration plan with existing facilities for construction, operation, and maintenance. The findings and plans will be reviewed with SOCWA O&M personnel.	a. Identify and collect all existing documents and drawings b. Visit JBLTP and validate drawings and facility utilization against actuals c. Develop site layout and integration plan for new equipment d. Review plans with O&M personnel e. Prepare TM	a. Unknown state of drawings and documents b. Validation may require physical measurement s and site work
3	Safety Assessment	Prepare a Technical Memorandum with five copies for review, response to comments, and final Memorandum. Genifuel will evaluate proposed site with NEC, OSHA, and other pertinent requirements. Work with SOCWA for safety requirements and design of new equipment.	a. Identify site requirements and location b. Work with SOCWA to identify approach and design c. Verify against relevant regulations	Genifuel equipment may be unfamiliar to SOCWA with little prior experience for safety evaluation

4	30% Submittal	Submittal will include drawings, specifications, and costs for the following, with sufficient detail for a DBOO negotiation a. Site/civil drawings b. Plan/section of major equipment c. One-line electrical drawings d. Process flow diagram e. Piping and instrumentation drawing f. List of major equipment g. Cut sheets h. Odor control plan i. Noise control plan j. Visual plan	a. Normal front-end engineering package at a 30% level b. After preliminary submittal, Genifuel and SOCWA will meet to review and agree on the package c. SOCWA will provide comments within two weeks	Will need good understanding of site and odor, noise, and visual sensitivities
5	Implementation Plan	a. Develop schedule for 100% design and plan for implantation while plant is in operation. b. Develop plan and schedule for obtaining permits and environmental compliance under Coastal Commission permits. c. Develop Technical Memorandum with similar process described above.	a. Normal work scheduling requirements b. Environmental and regulatory plan needs careful coordination with SOCWA personnel who are familiar with all aspects of regulatory requirements	Regulatory matters can be very complex and need to be performed without endangering compliance or current approvals for SOCWA
6	Proposal #2	a. Prepare second proposal with greater detail to allow SOCWA to make an award for fabrication, site construction, installation and commissioning of the equipment b. Same TM requirements as above.	Address the following requirements: a. Technology b. Facility work c. Capacity d. Site location e. Cost f. O&M impact	Not clear who will ultimately own the installation and their role in evaluation of Proposal #2.

2. Previous experience

   Genifuel has built one system which is currently in operation, and two which are in the engineering phase. The operational system is smaller than the system to be proposed for SOCWA, while the two systems in engineering are larger.

   a. System One: This system is processing two metric tons per day of 20% algae slurry to produce oil and gas in India.

Photo of System	Contact Information
	Mr. Ramesh Bhujade VP Process Engineering Reliance Industries, Ltd. ramesh.bhujade@ril.com +91 2244783424 Reliance Corporate Park Thane Belapur Road Ghansoli, Navi Mumbai 400701 Maharashtra, India

b. System Two: This system is in engineering for Metro Vancouver in Canada. It will process 10 wet metric tons per day of 20% mixed PS and WAS sludge. It will be operational in Q2 2020.

Photo of Installation Site	Contact Information
	Mr. Paul Kadota Sr. Program Manager Metro Vancouver Paul.Kadota@metrovancouver.org (604) 432-6437 4730 Kingsway Burnaby B.C. V5H 0C6

c. System Three: This system is in engineering for Central Contra Costa Sanitary District ("Central San") in Martinez, CA. It will process 15 wet metric tons per day of 20% mixed PS and WAS sludge. It will be operational in Q2 of 2021.

Photo of Installation Site	Contact Information
	Mr. Dan Frost Senior Engineer Central Contra Costa Sanitary District dfrost@centralsan.org (925) 229-7259 5019 Imhoff Place Martinez, CA 94553

3. Genifuel is an equipment supplier for Hydrothermal Processing equipment, providing the technology, front-end design, and support for commissioning, operation, and maintenance. We use various engineering and fabrication companies to do the detailed design and fabrication, as well as site demolition, construction, and integration. We have worked with

two companies for various projects (including those above). These two companies are as follows:

Company 1	Zeton, Inc. www.zeton.com Mr. Adam Whalley VP Business Development awhalley@zeton.com (905) 632-3123 x235 Burlington, Ontario L7L 6A9 Canada
Company 2	Merrick & Company www.merrick.com Mr. Chris Biondolilo Sr. Project Manager chris.biondolilo@merrick.com (303) 353-3876 5970 Greenwood Plaza Blvd. Greenwood Village, CO 80111

4. Technology

The technology is Hydrothermal Processing, which uses temperature (350°C), pressure (200 bar), and water to convert wet organic material into biocrude oil, methane, or both. For SOCWA the feedstock will be a mix of PS and WAS. It would be possible to process biosolids after digestion, but by processing the sludge the load on the digesters can be reduced, and correspondingly the amount of biosolids reduced.

Since the process has not been implemented widely yet, we propose to install a system of similar size to the Metro Vancouver and Central San systems described above. The system will be installed at JBLTP in Dana Point. The specific size will be 1.5 dry metric tons per day, which is app. 24% of the load at JBLTP. The footprint of the system will be app. 1,500 square feet, which would allow it to fit between the DAF and AD systems at JBLTP.

We propose to configure the system to produce only methane, rather than a mix of oil and gas. The reason for this is that we have an extensive working relationship with the Southern California Gas Company, and have already built one system together with SoCalGas. Their interest is to meet California requirements to increase the amount of renewable natural gas in their pipeline system, and they have concluded that Hydrothermal Processing is the most viable technology to achieve this goal. Below is a recent press release for the Central San project in which SoCalGas has received $3 million in support from the California Energy

SoCalGas Awarded $3 Million California Energy Commission Grant to Advance New Technology that Creates Twice as Much Renewable Natural Gas from Wastewater than Current Anaerobic Digestion Process

Hydrothermal processing technology also reduces greenhouse gas emissions by three times that of anaerobic digestion, and creates twice the useable energy from wastewater solids at half the cost

Apr 11, 2019

LOS ANGELES, April 11, 2019 /PRNewswire/ -- Southern California Gas Co. (SoCalGas) today announced the California Energy Commission (CEC) has awarded the company a $3 million grant to fund the next phase of development of a new technology that doubles the amount of renewable energy created from the decomposition of organic material at wastewater treatment plants. The new process, known as Hydrothermal Processing (HTP), reduces greenhouse gas emissions by three times that of traditional anaerobic digestion and costs about half. HTP is highly efficient, using heat and pressure to capture 86 percent of the energy in the waste and using only 14 percent to process it. A pilot project, to be located at the Central Contra Costa Sanitary District ("Central San") Wastewater Treatment Plant in Martinez, California. The work is being funded in part by the California Energy Commission, SoCalGas and other private participants.

"Technological advances, like hydrothermal processing, are an important part of SoCalGas' vision to be the cleanest natural gas utility in North America and will help us meet our commitment of to deliver renewable natural gas to homes and businesses," said Ron Kent, Technology Development Manager at SoCalGas. "This new technology holds the potential to convert not only wastewater, but landfill, forestry and food waste into carbon-neutral renewable energy that displaces fossil fuels and helps California meet its climate goals."

"The best thing about HTP is how simple it is," said Corinne Drennan, who is responsible for bioenergy technologies research at the Department of Energy's Pacific Northwest National Laboratory. "The reactor is literally a hot, pressurized tube. We've really accelerated hydrothermal conversion technology over the last seven years to create a continuous, and scalable process which allows the use of wet wastes like sewage sludge without the need for drying it first. And we're excited to see HTP piloted beyond the lab, at an actual waste treatment plant."

"The project will lay the groundwork for full-scale commercial hydrothermal processing plants that could revolutionize the way renewable energy is produced at wastewater treatment plants," said James Oyler, president of Genifuel Corporation, which produces the HTP equipment patented by PNNL. "Unlike anaerobic digestion, this technology completely eliminates leftover biosolids. Getting rid of the biosolids hauled to landfills would significantly reduce costs for wastewater treatment facilities."

The project team is comprised of a number of industry leaders, including: SoCalGas, the Water Research Foundation, Central San, PNNL, Genifuel Corporation, Merrick & Company, Black & Veatch, Brown and Caldwell, MicroBio Engineering, Leidos, and others.

Earlier this month, SoCalGas announced a broad, inclusive and integrated plan to help achieve California's ambitious environmental goals in a paper titled California's Clean Energy Future: Imagine the Possibilities. The plan embraces an all-of-the-above approach to fight climate change, keeps energy affordability as a key focus, calls for developing long-term renewable energy storage using existing infrastructure, and can aid in promoting rapid consumer adoption. The new strategy comes one month after SoCalGas announced its vision to be the cleanest natural gas utility in North America, delivering affordable and increasingly renewable energy to its customers.

As part of that vision, SoCalGas committed to replace 20 percent of its traditional natural gas supply with renewable natural gas (RNG) by 2030. Research shows that replacing about 20 percent of California's traditional natural gas supply with RNG would lower emissions equal to retrofitting every building in the state to run on electric only energy and at a fraction of the cost. Using RNG in buildings can be two to three times less expensive than any all-electric strategy and does not require families or businesses to purchase new appliances or take on costly construction projects.

In California, scientists at the University of California, Davis estimate that the state's existing organic waste could produce enough RNG to meet the needs of 2.3 million homes.

The contact at SoCalGas is as follows:
Mr. Ron Kent
Southern California Gas Company
Technology Development Manager
RKent@semprautilities.com
(213) 244-3764
555 West 5th Street
GT15A4
Los Angeles, CA 90013-1037

The involvement of SoCalGas could come in various ways, including application for state support similar to Central San, or simply as an offtake partner for the methane produced at SOCWA. This approach has been discussed with SoCalGas and they have expressed interest. If the methane is inserted into the SoCalGas pipeline at JBLTP, it would be eligible for RINs and LCFS credits, which substantially improves the economics of the project. We would work with SoCalGas to design and build the interconnection to their pipeline. Gas conditioning would be minimal because the output of Hydrothermal Processing is clean, with no sulfur or siloxanes in the gas. The output gas contains only methane, carbon dioxide (in a 70/30 ratio), and a small amount of water vapor. The CO_2 and water vapor are easily removed.

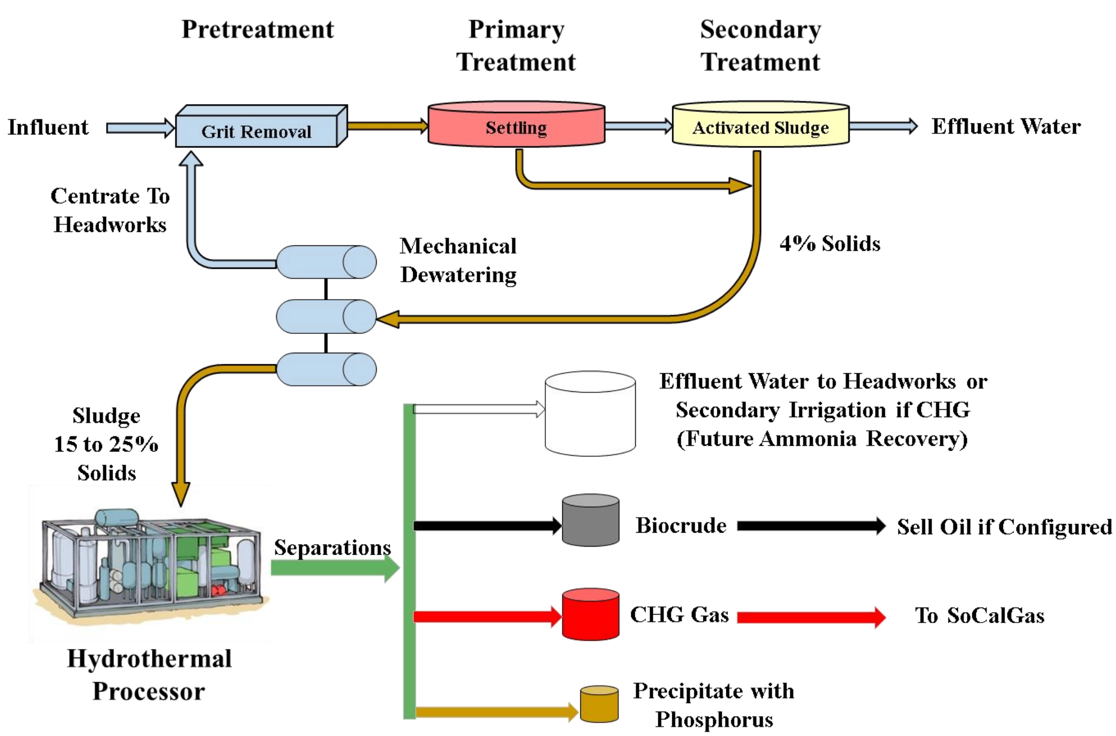
The preliminary plan is to install two identical systems at SOCWA, which would provide redundancy. The systems would have sufficient size and turn-up/turn-down capability to meet the load of 1.5 dry metric tons per day even if one system was down for maintenance or during low flow periods.

The system would include a centrifuge to dewater the input sludge from app. 4% solids to app. 20% solids, which is the preferred concentration for the Hydrothermal System. It is possible that by reducing the load on the digesters an existing centrifuge could be repurposed to the Genifuel system, but more likely a new centrifuge and polymer system will be needed.

Given the climate in Southern California, we propose that the system would have a roof but would not otherwise be contained in a building. Piping would be needed to bring PS and WAS to the system and thence to a blend tank and the centrifuge.

Below is a block diagram of the system in the SOCWA facility.

Wastewater Process Flow with Hydrothermal Processing



5. <u>Emissions</u>
   All emissions have been accounted for in the system. The system is completely sealed so there is no risk of leads of gas or odors. However, in the let-down from pressure, some off-gas can occur which contains a small H_2S. This gas would be routed to a filter for capture. The effluent water is clear and clean, and contains no biological material. It also contains no pharmaceuticals (such as estrogen), pathogens, pesticides, PFOS or PFOA, etc. since all large

molecules are broken down. The water may contain some ammonia, and we will have to work with SOCWA to determine limits and options for the ammonia.

6. Rates and Costs
We anticipate that our rates and costs will be quite competitive. We are a small company and all of our partners are small to medium size, with low overheads.

7. Rating of technology with respect to SOCWA Goals

GOAL	RATING	EXPLANATION
Potential ban on land application of biosolids	High	Completely eliminates organic solids
Defer capital investment	High	System can be sized for any proportion, or all, of the solids. The proposed system would process app. 24% of JBLTP load, thus eliminating any need to address current processes at a relatively low cost.
Minimize neighborhood impacts	High	Elimination of biosolids means truck traffic reduced by app. 24%. No odors, system is essentially silent, and is small.
Provide additional reliability	High	Proposed system would have two identical modules to provide redundancy, and enough turn-up capacity to run with only one module. The removal of 24% of the load on existing facilities means less storage of solids even if the existing facility is down.
Maximize renewable energy	High	As shown in the SoCalGas press release above, the solids processed in the proposed system would produce app. 2x as much gas as the equivalent AD

8. Project team
Genifuel is currently expanding its headcount and will be adding a new Project Manager shortly. The name and background will be supplied as soon as employment is confirmed. In the meantime the project will be managed directly by James Oyler, president of Genifuel. Mr. Oyler's CV is attached. Mr. Oyler is intimately familiar with the technology and system design, having managed the three systems listed above. Mr. Oyler also holds 24 issued or pending patents, including those licensed from the US Department of Energy.

9. Table of Effort

SCOPE ITEM	PERSONNEL	HOURS
Progress Meetings	Sr. Executive Program Manager Design Engineer Engineer/Report Writer	50 80 80 40
Doc Review and Interviews	Sr. Executive Program Manager Design Engineer Engineer/Report Writer	60 60 100 40
Safety Assessment	Sr. Executive Program Manager Design Engineer Engineer/Report Writer	20 20 40 40
30% Submittal	Sr. Executive Program Manager Design Engineer Engineer/Report Writer	60 80 200 80
Implementation Plan	Sr. Executive Program Manager Design Engineer Engineer/Report Writer	40 80 80 40
Proposal #2	Sr. Executive Program Manager Design Engineer Engineer/Report Writer	60 80 120 60

Summary by Classification

CLASSIFICATION	HOURS
Sr. Executive Program Manager Design Engineer Engineer/Report Writer	290 400 620 300
TOTAL	**1610**

10. Fee

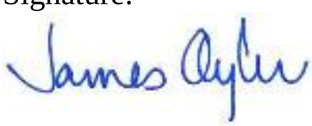
This item is supplied in a separate envelope.

11. Project Schedule
Genifuel is currently closing on new funding, which will enable addition of the staff required for this project. Funding is anticipated to be complete in the next four months and staffing shortly thereafter with most personnel already identified. App. 50% of the work will actually be performed by the firms described above, who could start in less time if that is desired by SOCWA. Therefore the work could start within the next four to six months and be completed in four months.

12. Financial Strength
Genifuel will be closing on funding of app. $3 million for corporate growth, and $12 million for project finance, some of which could be applied to this job. In the meantime Genifuel currently has contracts valued at more than $30 million and is in good standing on these contracts.

13. SOCWA Standard Engineering Contract
Genifuel will maintain the required insurance levels and agrees to the contract language.

Signature:



Typed: James R. Oyler, President, Genifuel Corporation

Date: 25 April 2019

James R. Oyler

President, Genifuel Corporation

Education and Training

1963-1967 | Lehigh University, Bethlehem, PA; BS, Electrical Engineering
1967-1969 | Cambridge University, Cambridge, UK; MA, Economics

Research and Professional Experience

2006 - present	Founder & President, Genifuel Corporation	*Hydrothermal Processing*
1994 - 2006	President and CEO, Evans & Sutherland Corporation	*Advanced electronics*
1993 - 1994	VP Systems Group, Simplex Corporation	*Building efficiency products*
1992 - 1993	Founder & President, AMG Corporation	*High-purity delicate drying*
1976 - 1992	Sector President, Harris Corporation	*Secure communications products*
1972 - 1976	Energy Lead, Booz, Allen & Hamilton Consultants	*Power generation*
1969 - 1972	First Lieutenant, U.S. Army	*Army Commendation Medal*

Publications

Genifuel Hydrothermal Processing Bench Scale Technology Evaluation Project, Published by the Water Environment & Reuse Foundation, June 2016, 185 pp
Hydrothermal Processing: Use in Water Resource Recovery Facilities; James Oyler and Paul Kadota; Watermark, Volume 24 Number 3, Fall 2015, 26-29
Harvesting and extraction technology contributions to algae biofuels economic viability; Richardson, Oyler, et al; Algal Research 5 (2014) 70–78

Intellectual Property

Mr. Oyler holds more than 24 patents or patents pending, plus exclusive licenses, for technology related to hydrothermal processing of wet waste materials, especially wastewater solids, wood, algae, and other organic matter, including processing and use of hydrothermal output products.

Synergistic Activities

- 04/2019 | Genifuel in team awarded $3 million by CEC for Central San project
- 01/2017 | Genifuel and nine other partners are selected by US Department of Energy for project to build utility-scale plant to process wastewater sludge into biocrude oil and gas
- 06/2017 | Genifuel selected to build first utility-scale HTP system for Vancouver, BC
- 09/2016 | Genifuel processing of wastewater solids is presented in the Innovation Pavilion of the annual WEFTEC Conference for the water and wastewater industries
- 03/2016 | Water Environment Research Foundation completes major report on successful use of Hydrothermal Processing to treat wastewater sludge
- 12/2015 | Genifuel ships first pilot-scale Hydrothermal Processing system to Reliance Industries Ltd for use in producing biocrude oil and methane gas from algae
- 11/2015 | Genifuel and PNNL are selected for a joint R&D 100 Award for Hydrothermal Processing
- 04/2015 | Genifuel awarded contract by California Energy Commission for use of Hydrothermal Processing to convert dairy cow manure into biocrude oil and methane

Questions for Genifuel:

1. **What are the potential barriers to operating a high temperature/pressure system in an urban environment (i.e., residents closeby)? How are these resolved or mitigated? Is there additional operator certification required? Are there additional staff hours required for operation of the system?**

   (1) Every Genifuel HTP system has multiple levels of protection to protect against out-of-spec temperature or pressure. The system is highly automated and can run safely unattended. Monitored conditions include numerous pressure and temperature sensors, which trigger an automated response depending on the condition. One response might be to shut off all power inputs (heat and pressure) and trip an alarm. Another might be to open a pressure reduction valve and dump pressure to a relief tank vented to an odor containment system. A passive response would be from a number of rupture disks which drop pressure without electronic control to the same relief tank. The system also alerts operators by remote message (internet or cell) if a process variable is moving out of range, even if it is not yet critical. None of these relief events pose a fire hazard since the material in the system is at least 80% water. In operation the system is almost completely silent so noise would not be a problem for nearby neighbors. In addition every system design is submitted for an independent Process Hazard Analysis, such as HAZOP, in the engineering phase and before fabrication begins. Another mitigation factor is the failure mode of the vessels and pipes. The failure mode has been studied by the DOE national laboratories for the materials of construction of the system (specialty stainless steel). To summarize this, the vessels and pipes do not fail suddenly or explosively, but rather by the formation of a leak or crack which can gradually grow. This failure mode creates significant venting noise and is immediately noticeable either by an operator or by the drop in pressure detected by sensors, which then take action as noted above.

   (2) There is no special operator certification required in California or anywhere in the USA as far as we know. For the system in Vancouver, there is a Canadian requirement for a boiler operator certificate which is relatively simple. This certificate is required for any vessel operating above the boiling point of water, even though we are not generating steam in normal operation.

   (3) We have based our OpEx models for moderate-size systems on the assumption of staffing during the prime shift five days a week with automatic operation on the off shifts and weekends. For small systems we would budget one person, on large systems two persons primarily to check and monitor automated run logs from other shifts and especially feedstock delivery and processing. Since the feed will be arriving by pipe and will be relatively uniform feedstock problems should be minimal. Some maintenance tasks can also be performed by these staff. On the off-shifts, in addition to automated monitoring we would ask that the utility watchman include the system in his rounds, or at least check a SCADA monitor which could have a remote screen in an existing operations room.

2. **What are potential byproducts of the system besides methane?**

   Here are the system outputs and their disposition:

   (1) In the liquefaction section there is a precipitation vessel which precipitates phosphorus compounds and any inorganic solids such as sand or grit. These solids are periodically blown down into a receiving vessel and can then be taken to a

fertilizer manufacturer to capture the phosphorus for conversion to commercial fertilizer.

(2) In the pressure let-down stage a small amount of off-gas is released. This gas is 98% carbon dioxide, a small amount of methane, less than 1% H_2S. Because of the H_2S this off-gas is routed to an odor control system or (for large systems) a thermal oxidizer.

(3) In the gasification section, the product is app. 70% methane and 30% carbon dioxide. There is no H_2S or siloxane in this stage. The gas can be burned directly (the same as AD biogas) or can be cleaned by removing the CO_2 and then sent into a natural gas pipeline (SoCalGas is very interested in taking the pure methane). The CO_2 is vented to atmosphere.

(4) Finally, the effluent water is captured. The effluent water is clear and sterile, with BOD close to zero and COD of about 50 mg/L. In terms of volume, the water in is the water out—we don't use water and we don't add water. This water will contain most of the metals in the feed sludge, in the form of salts. Of course, the dominant form is simply salt (NaCl). There are also small amounts of other salts, such as potassium, iron, zinc, boron, etc. Almost all of the nitrogen in the original sludge will also be in the water in the form of ammonia, at about 0.5% to 0.7% concentration.

We would like to have a discussion with you to understand which of several options would be most desirable to handle the ammonia. For the next level of investigation I can provide a complete detailed mass balance at each step in the process flow.

3. **Would the system require delivery off-site of methane gas or flaring at JBL, RTP? Would the system require storage of methane for the proposed size?**

The methane can be burned in an engine of the same type used for biogas from AD. The gas from hydrothermal processing has somewhat more energy than biogas, but otherwise burns the same. If you don't burn it onsite, you can insert it into a SoCalGas pipeline. This requires additional equipment to remove CO_2, but that equipment is conventional and readily available. There is no sulfur or siloxane in the hydrothermal gas, so it is much easier to purify than biogas. If you want to do this, you can generate RINs at the Federal level and LCFS credits at the state level for the gas produced. We should talk to SoCalGas to see if they would pay for the equipment to interconnect your gas output to their pipeline. If neither of these options turns out to be attractive you could certainly flare it, but that is definitely a second-level choice. I would not recommend storing it unless SoCalGas would help with the storage. It causes additional regulations and is probably more trouble than it's worth.

4. **Proposal addresses approximately 25% of solids at JBL – would you consider managing the remainder of the biosolids? If so, how would you recommend it be utilized or managed?**

We were thinking in terms of taking the biosolids from one of the anaerobic digesters (approximately) as an initial project. However, we could certainly process the entire output of biosolids if that is what you want to do. The 25% size was intended as an incremental approach, but there is no technical requirement to proceed incrementally. I think we need to discuss with you further what your strategy is relative to replacing existing equipment vs. adopting a hybrid or incremental approach.

5. **Do you have any data on PFAS/PFOS/PFOA destruction in the process? If not, do you plan to collect data or do you expect destruction? If you don't expect destruction, how do you expect it to partition?**

   PNNL performed a study on these materials two years ago when they were emerging as an issue. The report indicates that these compounds partition to the solids and stay in the water through the liquefaction stage. The study indicated that the compounds were destroyed in the liquefaction stage, but there was some difficulty in actually determining how to measure very low levels of these compounds. In any event, if the system included the gasification stage all such compounds would definitely be destroyed. In other words, preliminary study indicated all PFAS etc. are destroyed in both the liquefaction and gasification stages. Because of the difficulty in measurements two years ago, PNNL decided to repeat the study with the current EPA/California methods for measurement. This study is nearly finished but I don't have the report yet. The preliminary finding is that these substances are destroyed by hydrothermal processing.

6. **What is the maximum height of proposed structures/stacks installed with this system?**

   The dimensions of the system currently in progress at Metro Vancouver in Canada are 76'L x 24'W x 12'H. We could rearrange the equipment to give different dimensions (e.g. a more square footprint) if that is better for the location.

7. **If there is a disruption operations or in the supply chain, what is the plan for managing the biosolids?**

   This goes back to question 4 depending on the overall strategy. If there is still remaining capacity for AD that could be factored into the discussion. If the entire biosolids output is handled by the hydrothermal system, then the best answer would be to include a certain amount of redundancy. These systems have a substantial capability for turn-up and turn-down, so the redundancy would not need to be completely 2x in order to handle the total flow long enough to return an off-line system to full service after a repair. In a complete failure it might be necessary to truck dewatered solids to another site or even to landfill. It's hard to evaluate these options without more information, but we would be very interested in exploring possibilities based on the long term plan and anticipated budgets.

Exhibit 3

South Orange County Wastewater Authority

Proposal for Innovative Solids/Biosolids Technology at the RTP and JBLTP

Prepared By:

Lystek

Nothing wasted.
Everything to gain.

Lystek

1014 Chadbourne Road, Fairfield, California 94534-9700
T. 707.430.5500 TF. 888.501.6508 E. infoUSA@lystek.com

April 25, 2019

South Orange County Wastewater Authority
Administration Building
34156 Del Obispo Street
Dana Point, CA 92629
949-234-5411

Attention: Ms. Jeanette Cotinola

We thank you for the opportunity to propose an innovative biosolids management solution for SOCWA. This approach will enhance the Authority's biosolids handling and management with a sustainable, long-term solution that is well suited to accommodate future growth.

Our veteran team of industry professionals are excited to offer our patented and proven, multi award winning, turnkey biosolids management and digester enhancement technology.

The proposed systems for the JBLTP and RTP facilities, respectively, will produce a high quality, Class A biosolids product. This solution also offers substantial polymer savings, requires minimal energy inputs, and will have negligible impacts on the neighboring community with fully enclosed conveyance, treatment, storage, and transportation systems. Further, this proposed solution has exceptional process redundancy complete with contingency treatment and storage options for each plant all with processing equipment and on-site storage that can be accommodated within the existing site footprints.

This solution also includes comprehensive product management for the marketing of the LysteGro fertilizer product, all delivered by an experienced team of service-oriented professionals. With market value expected to increase, this represents a built-in hedge against rising commodity prices, particularly those currently seen in the Class B management market, likely to occur in the future.

We look forward to helping SOCWA address its biosolids management challenges with our Lystek THP technology to transform the JBLTP and RTP into a comprehensive resource recovery facility.

Thank you for your consideration of this innovative biosolids management option. We look forward to future discussions.

Jim Dunbar, P.E.

General Manager, Fairfield OMRC
Business Development Manager, Western US

T. 707-419-0084
jdunbar@lystek.com

Frederick (Rick) Mosher, P. Eng

Chief Technology Officer

T. 226-444-0186 x 103
rmosher@lystek.com

Lystek
Nothing wasted.
Everything to gain.

South Orange County Wastewater Authority

Proposal for Innovative Solids/Biosolids Technology at the RTP and JBLTP

Prepared For:

South Orange County Wastewater Authority
Attention: Ms. Jeanette Cotinola

Administration Building
34156 Del Obispo Street
Dana Point, CA 92629

T. (949) 234-5411

Prepared By:

Lystek International Ltd.

1014 Chadbourne Road
Fairfield, California 94534

Contact Person:

Jim Dunbar, P.E.

General Manager, Fairfield OMRC
Business Development Manager, Western US

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jdunbar@lystek.com

Submitted: April 25, 2019

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EXECUTIVE SUMMARY

We understand the South Orange County Wastewater Authority (SOCWA) is currently evaluating innovative and market proven technologies capable of transforming biosolids produced at both their JB Latham and Regional Treatment Plants (JBLTP and RTP) into value added products with sustainable market demand over the long term. SOCWA is also intending to retain a firm that will own the product and be responsible for its beneficial use and prefers a technology provider with operations experience in the U.S. or Canada.

We are excited to offer SOCWA a proven low-pressure Thermal Hydrolysis Process (Lystek THP®) that leverages an innovative and proprietary combination of thermal, physical, and alkali processes to transform biosolids into a high quality, high-solids liquid fertilizer at low life cycle costs compared to alternatives. The Lystek THP technology has a small footprint, which can easily and cost effectively be adapted to fit existing infrastructure constraints.

The Lystek process is energy efficient and produces a marketable product in compliance with federal, state and local regulations. Our approach and technology represent a proactive leading edge solution that meets and exceeds all current regulations. This removes any market or regulatory risks to the Authority, thereby ensuring a cost effective long-term solution.

Our technology can become an important augment to both the RTP and JBLTP to help SOCWA develop and implement a sustainable and cost effective option for long-term biosolids management. This technology will transition these sites to innovative resource recovery facilities that produce an in-demand, high solids liquid Class A biosolids fertilizer. This solution also offers operational redundancy, substantial polymer savings (up to 40%) when compared to existing cake dewatering operations, requires minimal energy inputs when compared to drying technologies, and will have negligible impacts on the neighboring community with fully enclosed conveyance, treatment, storage, and transportation systems.

The proposed solution includes the installation of a turnkey biosolids processing and management solution with (optional) product marketing services and best practice use of the Class A LysteGro® biofertilizer.

The proposed solution for SOCWA – inclusive of equipment list, conceptual layout, price quotation, and competitive advantages associated with this – is described in detail below.

One System. Multiple Benefits.

- Transition to an innovative resource recovery facility
- Production of an in demand, high-solids liquid, Class A biosolids fertilizer – LysteGro®
- Comprehensive product management services
- Small processing footprint with ability to retrofit into existing infrastructure
- Substantial polymer savings
- Effective odour mitigation with enclosed system

"The use of biosolids provides a valuable renewable source of nutrients and soil structure enhancement for the agricultural industry. Treatment of biosolids into a liquid fertilizer, with sub-surface application at computer system-controlled loading rates, allows for an additional level of management of nutrient loadings and for ensuring compliance with US EPA regulations. We support innovative technologies such as this which provide benefits to generators and enhance the quality of the product for end-users."

Lauren Fondahl, Biosolids Coordinator, US-EPA, Region 9 San Francisco, California

1 INTRODUCTION AND PROJECT UNDERSTANDING

The South Orange County Wastewater Authority (SOCWA) is currently evaluating innovative and market proven technologies capable of transforming biosolids produced at both their JB Latham and Regional Treatment Plants (JBLTP and RTP) into value added products with sustainable market demand over the long term. SOCWA is also intending to retain a firm that will own the product and be responsible for its beneficial use and prefers a technology provider with operations experience in the U.S. or Canada.

Currently both the JBLTP and RTP manage their biosolids residuals by hauling offsite for disposal at local landfills or for further management at composting facilities, both practices that are under increasing regulatory and financial pressure.

We understand the current California State regulations (AB 1594 / SB 1383) seek to limit the disposal of organic materials in landfills and are putting pressure on utilities to seek new and innovative technologies to more sustainably manage their organic residuals, in which biosolids are a key constituent.

This document proposes a sustainable, cost-effective, and environmentally friendly on-site processing solution with comprehensive product management services with an understanding that SOCWA is evaluating possible solutions capable of taking on these coming challenges. We understand SOCWA is currently favouring a Design-Build-Own-Operate (DBOO) agreement, which we have responded to as our primary option. As an alternative, we are also including information related to a proposed Design-Built-Transfer (DBT) agreement and project configuration that may be of interest to the Authority.

1.1 SCOPE OF SERVICES

We have a clear understanding of each project task and the necessary effort to complete the requested task. Below we detail how each task will be performed and address potential challenges that may arise during the execution of the work.

1.1.1 Task I: Progress Meetings

We will conduct monthly progress meetings during the course of the project duration; we expect this to last no more than 5 months. Meetings will be scheduled in advance with the SOCWA team and will be held at the SOCWA offices or treatment plants. Lystek will be flexible with SOCWA staff when coordinating meetings to meet the needs and availability of SOCWA staff. If additional meetings are needed or requested by SOCWA, Lystek will address the added effort prior to establishing a revised meeting schedule.

Our Project Manager will prepare a meeting agenda in collaboration with SOCWA to address the necessary topics to keep the project on schedule. Lystek's Project Manager will conduct the meeting and invite applicable team members as needed to address specific agenda items. At the conclusion of each meeting, Lystek will prepare detailed meeting minutes, inclusive of action items and corresponding due dates, and distribute for review.

1.1.2 Task II: Document Review and Staff Interviews

The Project Team will conduct the review of existing documents and interviews with applicable SOCWA staff. The purpose of this work will allow the project team to better understand the existing conditions and the ability to shape a project to best serve each treatment plant site. Questions and examples will be developed to enable understanding of the integration of the proposed Lystek technology and how this will benefit each facility. Depending of the specific work function, this could involve the use of diagrams and/or simple modeling to show the potential benefits. We will document each of these items as part of the project record in Technical Memorandums.

1.1.3 Task III: Safety Assessment

Lystek and GHD will perform the required safety assessment of the proposed technology and its integration into the existing facilities. The safety components will include review of seismic requirements, health and safety issues, existing infrastructure performance, and construction/operational safe-work practices. We understand the sensitivity of each site to the surrounding environment and will ensure we address any perceived issues. GHD has safety-specific expertise in the area of code/standard requirements that will be used to develop the Technical Memorandum for this task.

1.1.4 Task IV: 30% Submittal

We will prepare and submit a 30% design submittal to SOCWA for review. This design package will include basic civil drawings, major equipment plans/cross-sections, single line electrical drawings, P&ID drawings, a major process equipment listing and manufacturer cut-sheets. Additional items will include the environmental impact components, including odor, noise, aesthetics, safety, and traffic. The intent of this submittal stage is that both SOCWA and Lystek will have enough information to negotiate a complete DBOO agreement with specific definition of all of the "Owner's Requirements" for inclusion in that agreement. It is critical that the 30% submittal complete the conceptual design development with all mass and heat balances. Any/all subsequent detailed design development will be based on the approved concept and all of the Client supplied inputs that are used for the development of the conceptual design.

1.1.5 Task V: Implementation Plan

After the acceptable completion of Tasks II, III, and IV, Lystek will prepare an implementation plan with schedule for completion of the 100% design and construction project. One of the main elements of this plan will be the coordination of activities to ensure that existing plant operations are maintained to the acceptance standards of SOCWA. The implementation plan will include an identification of permit requirements, including any CEQA upgrades and submission to the Coastal Commission as required. Efforts will be made to reduce project impacts such that regulatory involvement can/will be kept to a minimum. The summary of this work will be recorded in a Technical Memorandum for submission to SOCWA.

1.1.6 Task VI: Proposal #2

At the completion of the above tasks (II thru V), we will prepare a detailed proposal (Proposal #2) defining the technology and facility components, capacity, site location(s), cost and other details as an outcome of the 30% design submission (Task IV). The proposal will have enough detail such that the project partners (SOCWA and Lystek) can come to an understanding of the scope and cost of a final project. We will present this information in a Technical Memorandum and make this a key topic for one of the progress meetings.

2 ABOUT LYSTEK

Lystek is a multi-award-winning company, with locations in the United States and Canada. We provide a patented, multiple benefit thermal hydrolysis solution, Lystek THP®, for biosolids and organics management. We work in partnership with municipalities, wastewater treatment plants, and private sector clients to recover valuable nutrients from biosolids and other similar organic feedstock.

OUR MISSION:

To set the pace as a market leader in the development and delivery of proven solutions for the complete, end-to-end management and re-use of biosolids and organics through the provision of advanced, safe, cost effective, sustainable technologies, and industry best practices.

Founded in 2000 by industrial microbiologists at the University of Waterloo, Lystek spent its early years focused on laboratory research and development of the technology until its first successful pilot in 2004 at the City of Guelph Wastewater Treatment Plant. Following a successful two-stage demonstration, we began operation of our first commercial full-scale facility at the City of Guelph WWTP in 2008.

2.1 LYSTEK THP®

The Lystek Thermal Hydrolysis Process (Lystek THP) is a unique physical-chemical thermal hydrolysis process employing high-speed shearing, alkali, and low-pressure steam injection. The system is modular, scalable, and cost effective. This technology can be implemented without any impediment to normal operations of existing facilities. The modular design of Lystek THP permits easy expansion and integration as future demand requires.

Implementation of this system provides operational flexibility. The technology has the ability to process digested, raw, or waste activated sludge to produce a multi-purpose, hydrolyzed product, with multiple benefits for full-cycle resource recovery. (See Appendix A for US EPA Region 9 classification letter)

The Lystek THP solution is experiencing a high level of interest and demand due to its operational flexibility and multi-value applications in resource recovery and facility optimization, including LysteGro, LysteMize, and LysteCarb. For an overview of how this technology compares with alternative technologies, see Appendix B.

Our process and existing deployments in both the U.S. and Canada have been recognized with numerous regional, national, and international awards.

For a list of our awards and honors, see Appendix C.

We are also fully committed to ongoing Research and Development. We collaborate with renowned institutions such as University of California Davis, Purdue University, Manhattan College, Western University, University of Waterloo, McGill University, and WERF LIFT, among others.

We are committed to long-term partnerships and leverage our expertise to offer comprehensive technology, product management, and communications and engagement support.

2.2 PROJECT AND OPERATIONS EXPERIENCE

Our current installations include a range of small, medium, and large communities throughout North America, including our most recent U.S. deployment in St. Cloud, Minnesota. In total, we have 11 operating full-scale THP installations. Within these 11 deployments, we wholly own two Regional Organic Material Recovery Centers (OMRCs), which provide resource recovery solutions to over 40 municipalities.

2.2.1 Description of Installations

We currently own and operate two large-scale regional OMRCs in Fairfield, California and Southgate, Ontario, Canada. The remainder of our installations were deployed as design-build-transfer (DBT) projects in existing wastewater and resource recovery facilities. Our team offers operations support as needed and product management services.

Lystek's Proven Deployments:

Total: 11
Regional DBOO: 2

Installation: Fairfield Suisun Sewer District Regional Organics Materials Recovery Center (FSSD OMRC)
Facility contact information:
Greg Baatrup, PE General Manager, Fairfield Suisun Sewer District 1010 Chadbourne Rd. Fairfield CA 94534-9700 T. 707-429-8930 | E. gbaatrup@fssd.com

Project scope:
A public-private-partnership (P3) project, the FSSD-OMRC services San Francisco Bay Area municipalities and agencies and has the capacity to process 150,000 wet tons annually. The facility receives a variety of dewatered biosolids, both digested and undigested, and transforms these materials into a Class A biofertilizer product (LysteGro) with the Lystek THP technology. We retain ownership of the fertilizer, and then markets and sells it to area farmers – 100% of biosolids received by the facility are beneficially used. We are responsible for land applying the LysteGro to agricultural lands, and contracts with local farmers and ranchers as our customers. In our initial two years of production, we have successfully applied approximately 18 million gallons of biofertilizer to over 5,000 acres of crop/range land in Solano County. Our success is indicated by our facility experiencing far greater demand for LysteGro than we had supply.
Annual site capacity: 150,000 wet tons
Description of the project:
This regional facility processes biosolids from the FSSD district and receives third-party material from outlying communities such as San Francisco, Benicia, Petaluma, Santa Rosa, and Palo Alto.
Timing and duration of role in project:
The facility began receiving biosolids in August 2016 under the commercial scheme of Design–Build–Own–Operate (DBOO). Under this arrangement, we will continue O&M activities for 20 years per the existing agreement with an option to extend for an additional 10 years.

Installation: Southgate Organics Materials Recovery Center (Southgate OMRC)	
Facility contact information:	
Simon Meulendyk B.E.S., P. Ag. Plant Manager Dundalk, Ontario, Canada T: 519-923-3539 | M: 519-503-2189	David Millner, Chief Administrative Officer Township of Southgate T. 888-560-6607 x 210 | E. *dmilliner@southgate.ca*
Project scope:	
The Southgate OMRC is our showcase facility, which we own and operate. The OMRC is located in a productive rural environment and accepts municipal and suitable industrial organic materials feedstock. All material received is processed through our LY10 Modules to produce Class A biofertilizer. We own, market, and sell the fertilizer to local farmers under the LysteGro registered trademark and have sold 100% of all materials received and processed by the facility for beneficial use. We were entirely responsible for the Design-Build-Own-Operate process, inclusive of permitting and community consultations. We have operated this facility in its entirety since commissioning, with an average of ten operations personnel at this facility.	
Annual site capacity: 150,000 wet tons	
Duration of the relationship: Lystek wholly owned facility, Commissioned in 2012	
Description of the project:	
The Southgate OMRC is located in Dundalk, Ontario in the Township of Southgate. It is an independent "off-plant" Lystek regional facility, which we own and operates. This facility has a total capacity to accept and process 150,000 wet tons of organic material per year. Inbound customers at the Southgate OMRC include both industrial and municipal customers. Municipal customers include Toronto, Guelph, and Hamilton, among others. Other types of	

organic feedstock materials are also accepted and include: anaerobic food waste digestate, alcohol and beverage wastes, and by-products of biofuel processes. Currently, the OMRC processes 90,000 - 100,000 wet tons per year. The Southgate OMRC has two lined and covered reservoirs for LysteGro storage, with a total capacity of approximately 90,000 m^3 (23.4 million gallons).
Timing and duration of role in project:
The life span design of the facility is for 30 years. Current contracts with feedstock stakeholders range from one month to five years.

Installation: St. Cloud Nutrient, Energy & Water Recovery Facility
Facility contact information:
Patrick Shea Public Services Director, City of St. Cloud 400 Second St. South St. Cloud MN 56301 T. 320-255-7225 | E. Patrick.shea@stcloud.mn.us
Project scope:
This facility was developed under the commercial scheme of Design-Build-Transfer (DBT). The City's biosolids storage capacity was under increasing pressure due to community growth, increased flows, and wet weather events shortening the land application season. There was a need to produce a high-solids liquid Class A product due to anticipated regulatory changes and substantial storage pressures. There was also the City's desire to retain and utilize as much of the existing treatment infrastructure as possible. The solution was the integration of Lystek THP in a major Nutrient Recovery & Reuse (NR2 Project) plant upgrade.
Annual site capacity: 15,000 wet tons
Commissioned: 2018
Description of the project:
Solids at St. Cloud are anaerobically digested and dewatered prior to being processed with the Lystek system. This technology was implemented by the City to produce a Class A biosolids fertilizer product, with the potential to add LysteMize to enhance their digestion efficiency in the future (they currently achieve high VSR).
Timing and duration of role in project:
Project construction began in 2017 and the Lystek THP system commissioned successfully in September 2018. City staff complete operations and maintenance activities. The plant is designed for a life of 20 years or more.

We have successfully performed Design-Build-Own-Operate (DBOO) projects over the last 10 years. The two main projects under the DBOO category are the FSSD OMRC in California and the Southgate OMRC in Ontario, Canada. The ability to use the DBOO format allowed us to custom fit the project to the specific needs and limitations of the site. The flexibility of the DBOO format also allowed us to make project adjustments as construction and operational demands changed.

We are very comfortable submitting a final project proposal to SOCWA under the DBOO format. Our intent is to work with SOCWA to satisfy individual site requirements without diminishing project performance. We would expect SOCWA to provide institutional knowledge about each site (along with historical documents). This will enable us to implement a tailor-made project. Throughout the development of the project scope, we will work together with SOCWA as our partner to establish and understand objectives and meet these with engineering and operational controls.

2.2.2 Descriptions of Operations Experience

We have proven itself in the marketplace as a reliable and customer focused facility operator throughout our over 10 years of DBOO experience. Our operations in Southgate and Fairfield have consistently provided environmentally sustainable biosolids management solutions to the over 40 utilities that retain our services.

Our organization's operational excellence is founded upon three layers of proficiencies within our structure: (1) educated, skilled, invested, and highly motivated front line equipment operators and facility managers; (2) a senior management team with more than 100 years of collective experience in the waste management and resource recovery industries; and (3) the Tomlinson Group's more than 35 years of company experience operating high value facilities such as major aggregate quarries, asphalt plants, and landfills.

3 PROPOSED LYSTEK SOLUTION FOR SOCWA

We understand that you are interested in an innovative and market proven technology capable of transforming waste into value added products with sustainable market demand. We also understand you are prioritizing solutions that address potential bans on Class B land application, have the capacity to defer capital investments, minimize neighbourhood impacts, all while providing additional reliability and maximizing renewable energy production.

This proposed solution has been developed using the assumptions noted in Table 3-1.

Table 3-1 Project Assumptions (DBOO Configuration)

JBLTP	
Yearly biosolids generation rate:	2,008 dry tons per year
Operating hours per year:	2,080 (8 hours per day, 5 days per week)
LysteGro fertilizer per year:	13,384 wet tons (assumed 15% solids)
RTP	
Yearly biosolids generation rate:	3,283 dry tons per year
Operating hours per year:	2,080 (8 hours per day, 5 days per week)
LysteGro fertilizer per year:	21,888 wet tons (assumed 15% solids)

3.1 PROPOSED PROJECT APPROACH

We propose Lystek THP be installed as an augment to your existing solids trains at both the RTP and JBLTP facilities. This corresponding project approach has numerous benefits.

- Processing equipment and associated on-site storage can be accommodated within the existing site footprints.
- Eliminates the need for cake-receiving infrastructure and the additional operational and logistical expenses associated with this approach.
- Eliminates the need to double-haul residuals or products. This minimizes neighbourhood impacts as no additional truck traffic or odour impacts associated with transporting and off-loading cake solids to a centralized facility.
- Exceptional process redundancy complete with contingency treatment and storage options for each plant.

Integrating this technology at both facilities will provide substantial benefits to SOCWA by transitioning the RTP and JBLTP to innovative resource recovery facilities that produce an in-demand, high solids liquid Class A biosolids fertilizer. This solution also offers substantial polymer savings (up to 40%) when compared to existing cake operations, requires minimal energy inputs when compared to dry technologies, and will have negligible impacts on the neighboring community with fully enclosed conveyance, treatment, storage, and transportation systems.

3.2 INTEGRATION OF THE LYSTEK MODULE

The Lystek THP system is installed post-dewatering as an extension to the existing biosolids program at both JBLTP and RTP. This configuration allows for relatively simple upgrades to existing process trains. The system will be integrated into each plant in such a fashion as to maintain existing cake loading capabilities, as a contingency option.

A Block Diagram showing Lystek integration at JBLTP and RTP is included below (page 12).

Note also that a key and important feature is that the Lystek processing train addition can be done with essentially no loss of operational time at the facility and can be undertaken with minimal disruption to existing operations. None of the existing plant systems or processes will be negatively impacted because of this addition. This will provide added redundancy for plant operations and ensure contingency management options are available.

3.3 FACILITY LAYOUT

At this stage, we recommend the installation of two LY10 Modules at both JBLTP and RTP facilities. Two LY10 Modules will accommodate future growth in the region and offers additional redundancy to ensure ongoing process operations. Each Module includes the Reactor as well as the associated pumps and hopper.

Conceptual site plans for both JBLTP and RTP have been created (included on page 13 and 14) to demonstrate the compact and modular nature of the Lystek solution. Note that this layout is a conceptual starting point, with substantial refinement expected to take place during the 30% design phase. We have extensive experience retrofitting existing buildings to accommodate our equipment.

The overall processing equipment footprint is approximately 2,400 ft^2 at each plant.

3.4 PROCESS DESCRIPTION

Dewatered biosolids at 16 – 18% total solids are fed into the storage hopper and then pumped using progressive cavity feed pumps into the Reactor(s). This system is able to process feedstock at lower solids content compared to current cake operations and other Class A biosolids technologies. This can yield a substantial reduction of polymer consumption and the associated cost savings.

Within the Reactor, the combination of heat (added by injecting low-pressure steam), pH increase (by addition of KOH), and physical shearing (using a high-speed mechanical blade) transforms the material into a homogeneous high-solids, liquid product. The Reactor operates at atmospheric pressure and it is insulated to reduce heat loss during processing and stand-by times. The liquid product is pumped to an on site above ground storage tank.

The concurrent combination of the three process inputs (heat, alkali, and physical shearing) allows the product to attain USEPA Class A biosolids classification, with reduced operational expenses when compared to competing technologies.

Further information detailing the operating inputs of the Lystek THP solution can be found on the attached Technical Specifications Sheet, provided as Appendix F.

Once the biosolids have been processed and transformed into Class A LysteGro product, it can then be either pumped into storage or a portion is re-fed to the anaerobic digesters for enhanced volatile solids destruction and increased biogas generation.

Table 3-2 Processing Equipment Components

Element	Quantity		Function
	RTP	JBLTP	
Dewatered Biosolids Storage Hoppers	2	2	Receives and stores dewatered biosolids from centrifuges for processing within the Lystek Reactor
Dewatered Biosolids Feed Pumps	2	2	Progressive cavity pump feeds the semi-continuous Lystek Reactor
Lystek THP Reactors and Dispersers	2	2	Transforms biosolids into LysteGro fertilizer
Reactor Discharge Pumps	2	2	Rotary lobe pump transports LysteGro from the Reactor to storage
Alkali Storage Tank	1	1	Double walled storage tank to store 45% KOH solution
Alkali Dosing Pumps	2	2	Pumps KOH to Lystek Reactor
Steam Boiler	2	2	Low pressure boiler (<15 PSI) provides steam heat to the Lystek Reactors
LysteGro Storage Tank(s)	2	1	Above ground storage tanks for storage of the LysteGro fertilizer between application seasons
Truck Loading Pumps	2	2	Pumps LysteGro fertilizer from the storage tank to tanker loading port

3.5 PRODUCT STORAGE

Once the biosolids are processed and transformed into LysteGro fertilizer, the product is pumped into storage tanks. Options for compatible storage systems include the use of above grade concrete or steel storage tanks.

This closed-system protects the material quality to optimize value for the end-user.

We intend to retrofit the existing effluent pumping station at JBLTP for LysteGro storage. This will capitalize on existing infrastructure and reduce the capital investment required for LysteGro production. Due to the tight footprint at RTP, we plan to install two above grade storage tanks (40' in diameter) on the East and South side of the existing Digesters and Control Building. This will provide both sites with approximately one month of product storage capacity.

The homogenous nature of the LysteGro product ensures settling does not occur and the material is easily pumped into and out of enclosed storage tanks. The truck loading pumps will be located adjacent to the storage tank.

3.6 LYSTEMIZE DIGESTER ENHANCEMENT

With an understanding that one of SOCWA's major goals is to enhance renewable energy production, we propose employing the LysteMize Digester Enhancement option at JBLTP. With the digesters currently operating at 54% VSR, the LysteMize process presents the opportunity to improve digester kinetics and increase VSR well beyond 60% when refeeding up to 50% of the processed material. With this approach, we anticipate SOCWA will achieve a total additional 20-25% VSR in their digesters. With the additional projected VSR, we can conservatively estimate JBLTP will produce approximately 30% more biogas.

Lystek hydrolyzed biosolids contain high concentrations of VFAs and soluble COD. This easily digested matrix allow for a quicker conversion to biogas, and also facilitates digestion of the recalcitrant compounds not consumed during the first pass through the digesters.

With an average volatile solids destruction of 70% at RTP, we do not recommend employing this option as the digesters are already performing very efficiently and any further enhancement will not outweigh the additional capital required at this site.

A sample of third-party research validating the LysteMize process is included in Appendix G.

3.7 SYSTEM RELIABILITY

The Lystek THP technology is reliable and can be operated with a minimal staffing level. The system operates at ambient pressure and only a slightly elevated temperature (168 °F/75 °C) so it does not create the thermal stresses on treatment equipment. The technology does not generate dust or potential explosive environments that require complicated monitoring equipment and dust control programs. This system uses reliable progressive cavity pumps.

Once the process transforms dewatered cake into a high solids liquid product in the Reactor, the product can be easily pumped to storage to the product loading facility. The ability to produce a high solids liquid product from a dewatered cake is one reason why our systems are much simpler, easy to operate and reliable. Benefits of a liquid product:

- It is much easier to pump a liquid product than to convey a solid product;
- By operating in fully enclosed environment (pipes, processing reactors and tanks) there are no issues with dust or offsite odors during processing, storage, transportation and land application;
- Short waiting times; loading generally occurs within 20 minutes, or less;
- Accurate loading rates; it is easier to measure exact volumes with liquids; and,
- More cost effective and timely field application with better and more even distribution of fertilizer/nutrients into the field.

Reliability of the system is further ensured through the provision of redundant equipment for critical components such as the boiler and progressive cavity feed pumps. In an infrequent event that either the boiler or one of the progressive cavity pumps experiences a breakdown during operation, backup equipment can be installed quickly to put the system back online.

3.8 EASE OF MAINTENANCE

The maintenance activities for the facility are straightforward and readily manageable given the nature of the system and its operation. Prolonged downtime is extremely rare. The basis for the proposed system has been developed and refined over the past decade at our existing installations.

The system operating program is fully automated, simple and easy to monitor and maintain. The proprietary software is an element of the technology and is simple and straightforward with relatively few items requiring regular repair and maintenance.

3.9 POTENTIAL ENVIRONMENTAL IMPACTS

3.9.1 Air

Due to advantages associated with wet processing, there are minimal air emissions associated with this process. The low-pressure steam boilers required to heat the fertilizer product may require approval for their combustion exhaust, but this is not expected to be a significant approval item.

3.9.2 Water

There are no side streams associated with our process, excepting a very small warm water flow associated with routine boiler blow-down. Simply put, all the feedstock materials entering the Reactor leave in a single stream for off-site fertilizer application.

3.9.3 Noise

This process does not employ any equipment that generates excessive noise. Given SOCWA's experience with noisy items such as CHP engines, we expect this will not be a significant consideration when evaluating an on-site Lystek installation. Regardless, all equipment with potential to generate noise (i.e. motor whine, steam crackle, etc.) will be housed inside existing buildings well suited to noise containment.

3.9.4 Odor

From the point of production to application in the field, the product is completely contained within enclosed reactors, piping systems, storage, tanker trucks, and finally the soil. This is a significant advantage when managing and mitigating odor concerns throughout the life cycle of the process. This technology generates minimal process air compared to dry alternatives that require the evaporation of water, and the liberation of odorous compounds that must be captured and treated.

A small exhaust line will be pulled from the dewatered biosolids hoppers and the Reactors. This air will be treated using either existing onsite odour treatment filtration or a small dedicated unit.

3.10 ANTICIPATED RANGE OF PROPOSED RATES AND COSTS FOR A DBOO MODEL

The range of expected costs for the proposed SOCWA facilities provided below are based on: (1) our continued operation experience in Fairfield, CA; (2) our comprehensive site tours and technical assessment of the SOCWA facilities with senior project staff; and (3) an in-depth, on the ground evaluation of local fertilizer markets.

Following this analysis, our range of expected rate fall within **US $140 to $170 per ton** for the two DBOO facilities. Life-cycle costs are inclusive of all contingency allowances, overhead and profit margins, financial carrying costs etc. for the facilities assuming the DBOO model is applied.

In addition, Note that the above price does not factor in any savings SOCWA would realize from (1) up to 40% reduction in dewatering polymer, and (2) additional biogas generated from a LysteMize re-feed process.

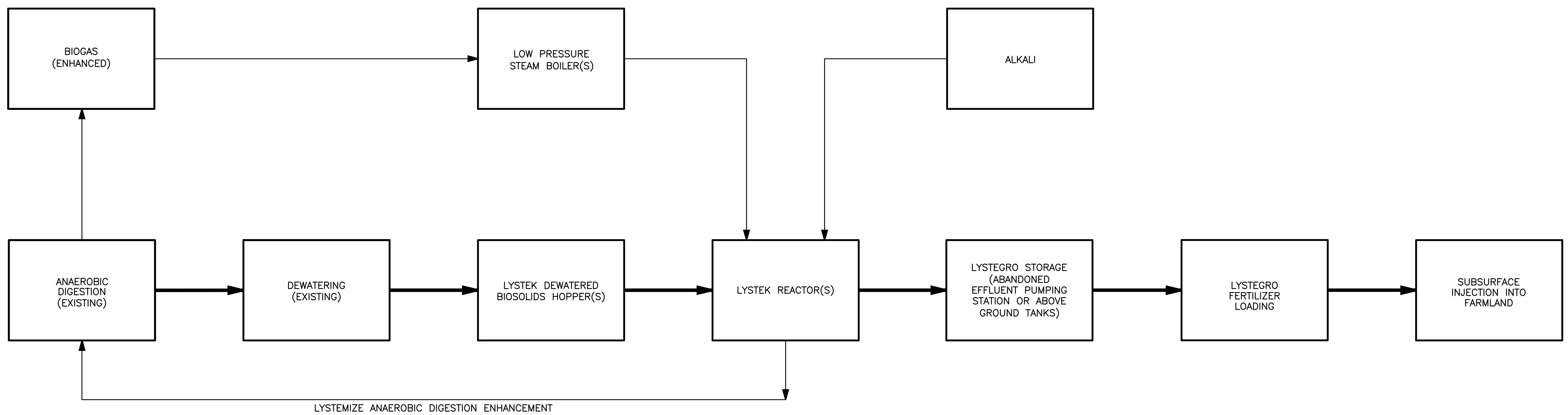
The above means that the net life-cycle costs to SOCWA will actually be significantly below the unit prices noted when these recovery factors are incorporated. Note also that future energy price structures are expected to increase at rates considerably above inflation. Additionally, fertilizer prices are expected to increase similarly in future providing additional potential for fiscal benefits to the project. Both of these factors can provide further life cycle cost benefit to SOCWA in the coming years to further reduce the net unit cost base provided.

3.11 ALTERNATIVE DESIGN-BUILD-TRANSFER OPTION

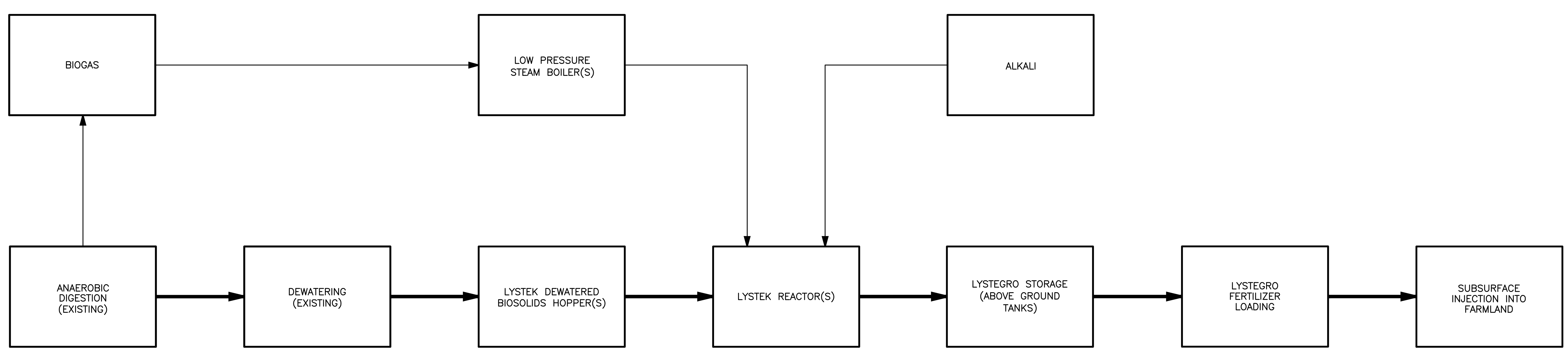
With the user friendly and easy to operate nature of this system, SOCWA could operate this technology with no additional operators beyond your existing staff. Typically, the Lystek processing is tied most appropriately to the dewatering operations and the staff operating these systems are naturally linked and compatible with this part of the operations. Further, no specialized operator qualifications or certifications are required. This approach has been proven throughout our many existing in-plant deployments.

A Design-Build-Transfer (DBT) option at both the JBLTP and RTP would offer substantial savings to SOCWA by eliminating the additional operations expenses associated with a Lystek operated DBOO facility, including but not limited to the overhead and profit margins as well as the finance recovery costs, which would be at higher rates than available to SOCWA. Further, by increasing operating hours (which we understand is feasible, as dewatering operations have extended hours of operations) SOCWA could reduce the capital investment required for a DBT agreement. This is very significant when establishing a unit price for processing activities. By limiting operations to a 40-hour workweek, capital costs substantively increase as this requires an oversized system to accommodate the restricted operating hours. There is opportunity to develop a system that SOCWA would be comfortable operating that would enhance the project and reduce the cost base.

J.B. LATHAM TREATMENT PLANT



REGIONAL TREATMENT PLANT



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NOT FOR CONSTRUCTION

Automated Engineering Technologies Ltd.
91A Duke Street, Guelph, Ontario N1E 5L1 (519)821-8644
397 Romeo Street S., Stratford, ON, N5A 4V1 (519)273-9318 WEB: www.autoengtech.on.ca

No.	REVISION	DATE

APPROVED BY:

LYSTEK PROCESSING SOLUTION

CONCEPTUAL BLOCK DIAGRAMS

SOUTH ORANGE COUNTY
WASTEWATER AUTHORITY

Lystek International Inc.
125 McGovern Dr., Unit 1
Cambridge, Ont., Can., N3H 4R7
Phone: 1-888-501-6508
Fax: 1-888-501-7429
Web: www.lystek.com
Lystek www.lystek.com

DESIGNED BY:	REVIEWED BY:	DRAWN BY:	DATE:
M.B.	R.M.	K.T.	APRIL 2019
SCALE: N.T.S.	PROJECT No.	DRAWING No. P001	

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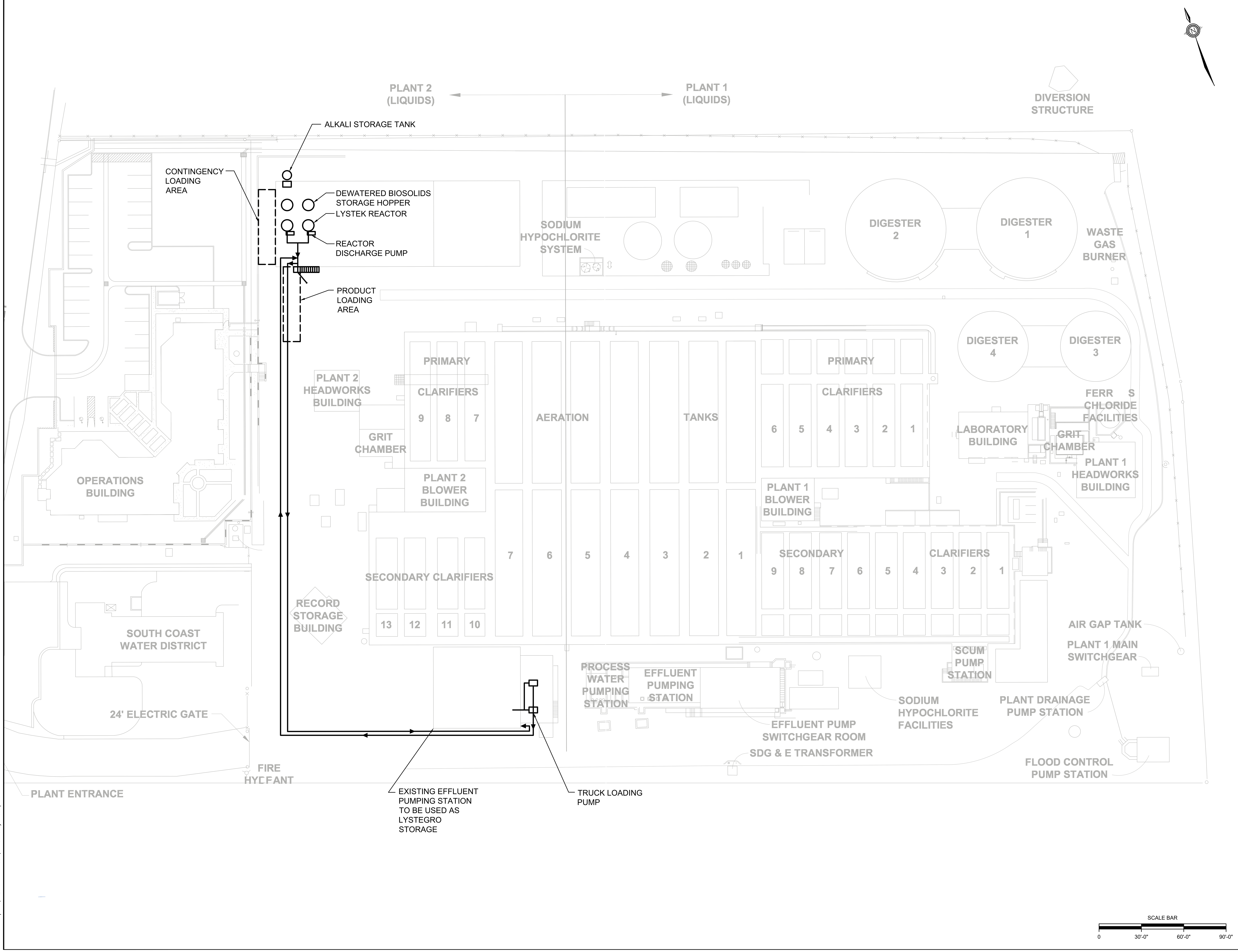

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No.	REVISION	DATE

APPROVED BY:

LYSTEK PROCESSING SOLUTION

CONCEPTUAL SITE LAYOUT
J.B. LATHAM TREATMENT PLANT

SOUTH ORANGE COUNTY
WASTEWATER AUTHORITY

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DESIGNED BY:	REVIEWED BY:	DRAWN BY:	DATE:
M.B.	R.M.	K.T.	APRIL 2019
SCALE: AS SHOWN	PROJECT No.	DRAWING No. C101	

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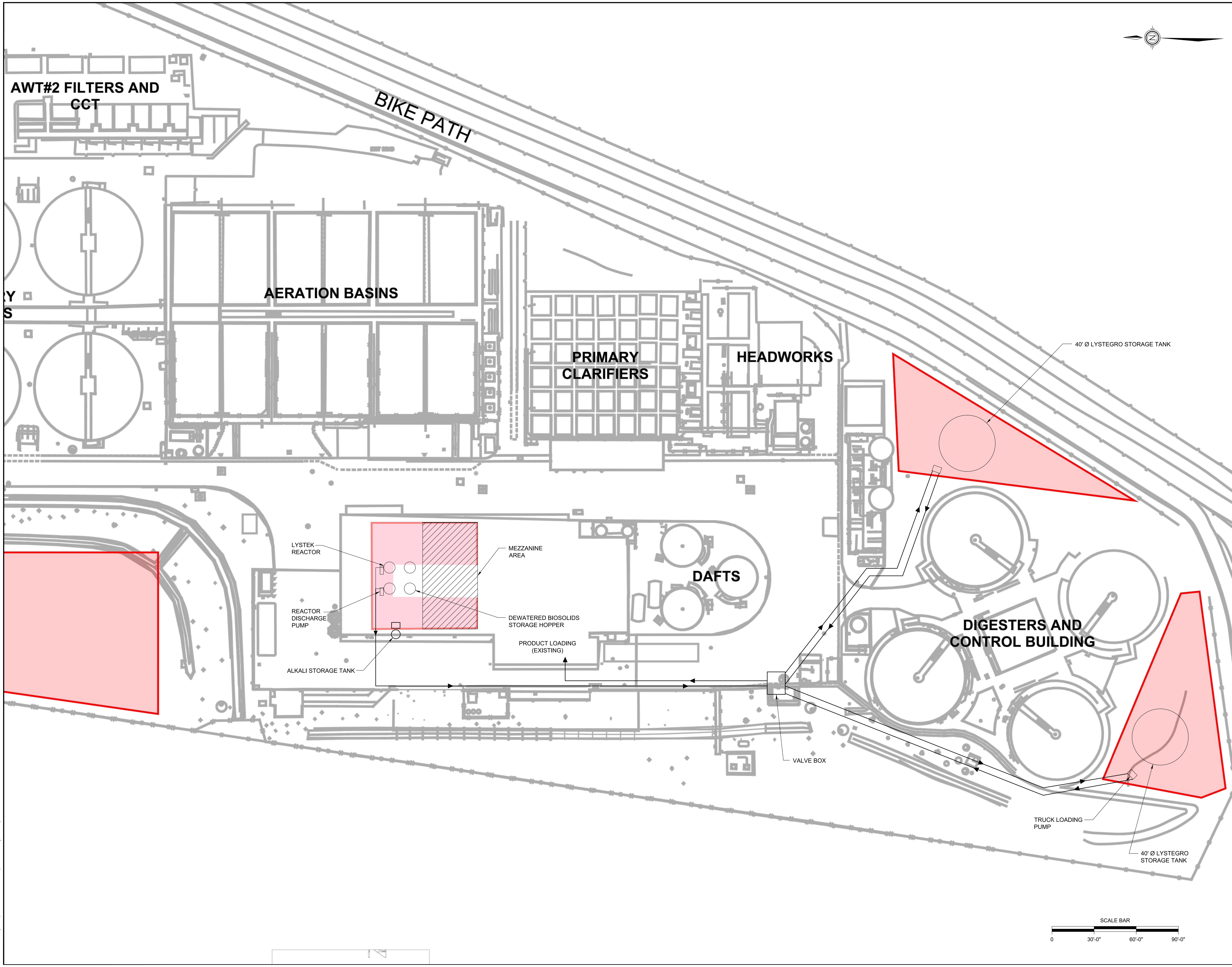

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No.	REVISION	DATE

APPROVED BY:

LYSTEK PROCESSING SOLUTION

CONCEPTUAL SITE LAYOUT
REGIONAL TREATMENT PLANT

SOUTH ORANGE COUNTY
WASTEWATER AUTHORITY

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DESIGNED BY:	REVIEWED BY:	DRAWN BY:	DATE:
M.B.	R.M.	K.T.	APRIL 2019
SCALE:	PROJECT No.	DRAWING No.	
AS SHOWN		C102	

4 PRODUCT MANAGEMENT

Part of our strategic approach is to provide a complete, turnkey product and service offering to our customers. This includes taking responsibility for and management of the LysteGro product and the associated costs if preferred. Our team effectively manages large and small-scale LysteGro marketing, sales and application programs in the San Francisco Bay Area of California and across Canada.

Our experiences in markets across North America provides us with the expertise needed to develop and manage an effective and professional fertilizer management program.

This section will provide an outline of the benefits of producing Class A biosolids and the approach we will use to manage the marketing, sales, and distribution of the product.

4.1 LYSTEGRO® CLASS A BIOSOLIDS

This THP system transforms biosolids and residuals into a pathogen free, Class A biosolids fertilizer product that is in high demand by the end customer. *The multi purpose product meets/exceeds all criteria for Class A biosolids fertilizer as classified by the US EPA.* LysteGro has also received state registration as a bulk fertilizer from the California Department of Food and Agriculture (CDFA). The combination of macro- and micro-nutrients as well as organic carbon provide a valuable cost-effective resource to customers who want an alternative fertilizer source to improve long-term soil health.

The Lystek THP system transforms biosolids and residuals into a Class A biosolids product that is pathogen free and in high demand.

This process produces a valuable fertilizer with predictable Nitrogen, Phosphorus, and Potassium (NPK) values that is high in solids (13%-16%) and remains pumpable with conventional liquid handling and application equipment (see Appendix H for example photos).

The processing system and methods of management of the final product have been designed and proven to maximize the value of the product for both the end-user and manufacturer of the product. Through the process, the inherent value in the biosolids feed stock is preserved, while odors are reduced and pathogens are eliminated. In addition to the macronutrient value, the LysteGro product is beneficial to farmers for several reasons, specifically:

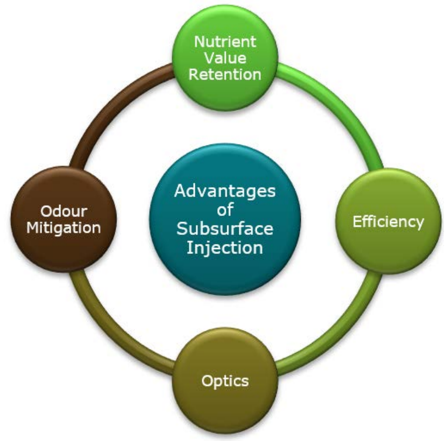
Cost Savings: We will market the material to the agricultural sector at an affordable price based on the NPK content of the material. By using the processed material, farmers will save on the input costs that they would normally pay when purchasing inorganic fertilizer. They will also see multiple year value from LysteGro due to the slow release nature of the nutrients in the product and improvements in soil health.

Micronutrients: Micronutrients important for crop growth, including Calcium, Sulfur, Zinc, Copper, and several others inherent in biosolids, provide the farmer with an affordable option for these nutrients that are expensive to purchase in the commercial fertilizer form.

Organic matter: The addition of organic matter to soils will help to improve overall soil health, including improved water holding capacity, soil structure and tilth, increased microbial activity as well as increased resilience to severe weather conditions (excess water or drought conditions).

In order to ensure maximum nutrient use efficiency, limit odor concerns, and the potential for run-off, LysteGro is injected into the soil subsurface during application. Additionally, the in-field aesthetics and cleanliness of the injection operation that we employ is superior to surface application methods. Further, the liquid nature of LysteGro allows for loading and off-loading efficiencies, as well as odor mitigation at the plant and throughout transportation.

The sub-surface injection of LysteGro further increases soil contact, and essentially removes the risk of run-off. Additionally, because the material is concentrated, there is a reduction in the overall volume that must be applied per acre versus traditional liquid programs. The advantages of producing a liquid product and our approach to product management are described further in Appendix I.



We will work with local farmers and contractors to haul and apply the material based on our internal specifications and requirements. These requirements will meet state and federal regulations for Class A biosolids, but will also be based on best management practices standard for the agricultural industry.

In 2013, a Water Environment Federation (WEF) workshop report stated *"due to concerns with pathogens and odors, there is a distinct shift away from Class B land application and towards more advanced, Class A treatment options."* It is also well known that global supplies of phosphorus, a key ingredient in the manufacture of chemical fertilizers, are being rapidly depleted. There is therefore a role for SOCWA to play in helping to ensure that organic resources, such as biosolids, are beneficially utilized for agricultural sustainability.

4.2 MARKETING AND SALES

We have developed a proven and successful marketing program for LysteGro in Northern California and Canada, and we can do the same for Southern California. We are capable and willing to assume full responsibility for the fertilizer distribution program and are currently performing this service for the majority of our customers.

In our experience, the combination of our cost-effective technology and our ability to offer product management provides a turnkey, risk-free, solution to our customers.

We have put significant effort into developing a professional product management team and the resources required to facilitate this. Our team consists of agricultural professionals (Certified Crop Advisors, Professional Agrologists, etc.) with an educational background in environmental science, and as a result, we understand and focus on both the needs of our agricultural customers and the importance of environmental stewardship.

*We have sold over **800,000 tons** of LysteGro in North America to date!*

It is our intention to sell the product, which we have successfully accomplished for all of our customers and at all of our locations. In fact, to date, we have sold all LysteGro fertilizer produced from all of our facilities, and will surpass 1,000,000 tons in 2019.

For example, in the areas surrounding Fairfield, CA we have built a strong and growing market demand for the LysteGro product. In this market, we have achieved fertilizer price increases (paid by the farmers) of almost 200% since our program started in 2016, representing the strong and growing demand for LysteGro in California. We are confident we will establish the market value of our product in the Southern California.

In summary, our approach to product management is to ensure that the material is handled and applied in the most effective manner possible. To optimize the value of the material while also engaging the local agricultural community to demonstrate and prove product value. This long-term strategy is proven to effectively develop a stable market of loyal customers who understand the value of the product and are willing to pay for it. With Lystek as its partner, SOCWA would have the option to leverage our proven successful approach or simply request our assistance, where required, to manage the product.

5 CONSIDERATION OF THE PROPOSED TECHNOLOGY WITH RESPECT TO SOCWA'S GOALS

Goal	Proposed Technology Rating	Explanation
Address potential ban on biosolids land application	**High**	LysteGro is a Class A commercial quality fertilizer (with CDFA bulk fertilizer registration) that addresses many of the challenges associated with Class B biosolids land application (handling difficulties, storage, odor, and incomplete nutrient profile).
Defer capital investments	**High**	Our solution leverages existing structures for both processing footprint and storage. No new buildings will require construction.
Minimize neighborhood impacts	**High**	The fully enclosed Lystek solution essentially eliminates any risk of off-site odor impact. Truck traffic within the neighbourhood will be limited to sealed tanker trucks. Further, by integrating Lystek THP into each site, this will minimize the additional truck traffic associated with a centralized solution.
Provide additional reliability	**High**	Duplicate processing trains ensure reliable solids management. Contingency cake loading options are included in initial site plan concepts.
Maximize renewable energy production	**High**	The use of a Lystek system not only allows for additional energy generation via optimization of onsite anaerobic digesters, but also allows for efficient use of excess onsite biogas for use as boiler fuel.

6 PROPOSED PROJECT DEPLOYMENT

6.1 PROJECT TEAM

Please see Appendix J for Project Team member's curriculum vita.

JAMES DUNBAR, P.E., MBA – GM / BUSINESS DEVELOPMENT MANAGER – (PROJECT MANAGER)

Mr. Dunbar is a Professional Engineer (in six U.S. states) with over 25 years experience in the management of solid waste and treatment of liquid wastes in the U.S. and Europe. Jim has worked within the regulatory levels at the federal, state and local levels dealing with permitting and environmental compliance. Jim is an active member in the California Association of Sanitation Agencies (CASA) and the Northwest Biosolids Management Association. Mr. Dunbar will serve as Project Manager. Responsibilities include conducting monthly progress meetings, scheduling internal tasks, and providing client liaison.

RICK MOSHER, P.ENG. – CHIEF TECHNOLOGY OFFICER

Mr. Mosher is a Professional Engineer with over 40 years of technical and executive level management experience in the areas of water, wastewater, and solid waste management, which also includes large site assessments and all aspects of construction services. Mr. Mosher has an established record of accomplishment in the successful completion of projects in accordance with all applicable regulations and environmental approvals. Mr. Mosher will bring this expertise to his role as Technical Manager; duties include review of all aspects of the existing infrastructure, design and conformance to Lystek technology standards.

AJAY SINGH, PH.D. – CO-FOUNDER & TECHNICAL DIRECTOR

Dr. Singh has over 25 years of international experience in managing industrial operations and R & D with a background in applied & environmental microbiology, and bioprocessing technology. He is one of the original founders of Lystek. Dr. Singh has developed numerous bioreactor-based processes related to water/wastewater environment, biotechnology, and fermentation & food industries. Dr. Singh has acquired regulatory knowledge in various countries across different continents. He is our internal expert, who deals with US EPA and Canadian regulators on a regular basis related to Lystek technologies and products; project duties include reviewing performance data on plant operations and integration with the Lystek technology.

MICHAEL BESWICK, P.ENG., M.A.SC. – DIRECTOR OF R&D APPLICATIONS – (DESIGN MANAGER)

Mr. Beswick is a Professional Engineer whose career has focused on the development of environmental engineering technologies in the wastewater, water, and waste management sectors. Mr. Beswick is instrumental in designing and managing both in-plant deployments and Lystek owned merchant facilities. Mr. Beswick will be Design Manager. Duties include organizing appropriate task functions and dictating subcontractor (primarily GHD) support work.

SAMANTHA HALLORAN, M.SC, P.AG. – LYSTEGRO PRODUCT MANAGER

Samantha is a Professional Agrologist, with a background in agriculture and environmental compliance. Her MSc research assessed nutrient availability and examined the fate of emerging contaminants in alkaline stabilized biosolids. Samantha has managed large-scale agriculture trials for industry and academia and has experience developing agronomy plans for farmers. She oversees product management at Lystek, which includes new product and market development, fertilizer registrations, land application and agricultural research projects. Project duties will include investigation into market availability and pricing.

GHD Inc.

GHD Inc. is an experienced multi-disciplinary environmental engineering firm with offices throughout North America. Their nearest office to the project site is in Irvine, Orange County, California. Expertise in this office will be used on structural, code compliance, and process engineering support roles to Lystek. GHD was the primary engineering consultant for Lystek in the development of the successful FSSD OMRC project in Fairfield, CA. The GHD staff is well versed in wastewater plant operations, and will be a team partner to help gather the necessary infrastructure and operational elements for the project.

6.2 ACCEPTANCE OF STANDARD ENGINEERING CONTRACT

We understand that SOCWA has proposed the use of its standard engineering contract (as presented in the RFP document). Lystek also understand that this document can be modified as requested by either party. Lystek does not have any restriction in executing this form of contract for the initial phase of the project development and will work with SOCWA to fully define the final scope of work as presented in the RFP. Lystek will assign a California registered engineer to serve as Project Manager during the duration of the work. Lystek is also fully capable of satisfying the insurance requirements of the contract terms.

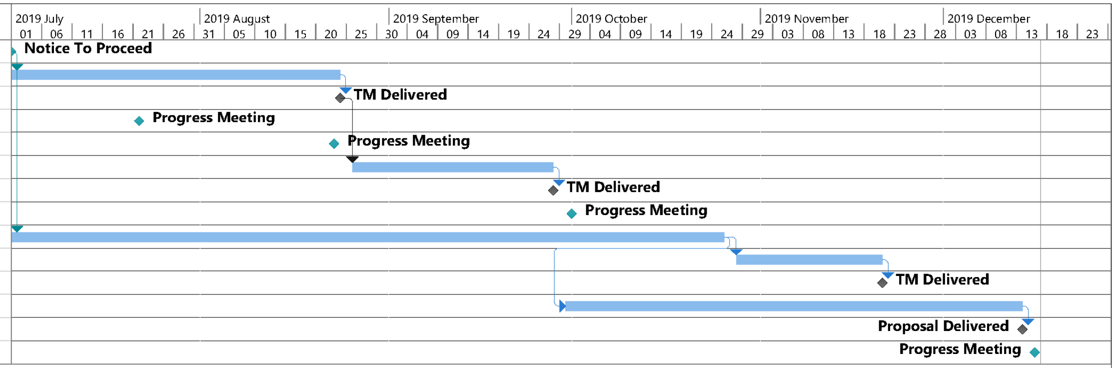
Table 6-1 Table of Effort

SOCWA Innovative Biosolids Management	Staff, Role, Designation	Lystek 1 Project Manager	Lystek 2 Process	Lystek 3 Mechanical (Lystek equipment)	Lystek 4 / Sub Electrical	Lystek 5 Modeler / Drafting	GHD - Chris Hertle Project Director	GHD - Coenraad Pretorius Project Manager and Process	GHD - Kim Domptail Design Coordinator	Dan Reiter Mechanical (Plant integration)	Scott Schumeyer Mechanical - Modeler / Drafting	GHD - Sarmad Farjo Civil - Senior	GHD - Frederick Tack OSHA - Senior	GHD - Francisco Andrade Structural - Senior	GHD - Mike Cattabiani Civil & Struct - Modeler /	GHD - Mehdi Mardi Electrical - Senior	GHD - Andrew Cole Electrical - Modeler / Drafting	GHD - Michael Masschaele Noise	GHD - Wallid Youssef Fire Protection	GHD - Dave Boggs Permitting / Environmental	Subtask total hours	TOTAL HOURS
		KEY PERSONNEL																			HOURS	
1 Progress Meetings																						**36**
1.1 Kick off meeting (at DPAB or RTP)		4					4	4	4												**16**	
1.2 Kick off meeting (with SOCWA Eng Committee)		2					2	2	2												**8**	
1.3 Monthly progress meetings (x4)		4						4	4												**12**	
2 Document Review and Staff Interviews																						**114**
2.1 Review planning and condition assessment docs		4	4					8	8												**24**	
2.2 On site verification of as-built drawing information													24				24				**48**	
2.3 Operation and maintenance staff workshop / interviews		2						6	6	2						2					**18**	
2.4 Existing Operations TM - Draft		2					1	2	12							4					**21**	
2.5 Existing Operations TM - Final		1							2												**3**	
3 Safety Assessment																						**75**
3.1 Code review (CBC, NFPA, NEC, OSHA)														6	8	6		6	6		**32**	
3.2 New equipment safeguarding		2	2	2	2									2	4	4		4	4		**26**	
3.3 Safety Assessment TM - Draft		2					1	4	8												**15**	
3.4 Safety Assessment TM - Final		1							1												**2**	
4 30% Submittal																						**313**
4.1 Calculations and drawings		4	16	16	16	40	1	4	8	8	24		20		8	8	20	8	6		**207**	
4.2 Specifications			8	8	8				1	4					4	4			2		**39**	
4.3 Equipment list		2	4	4	4				1	4						4					**23**	
4.4 Preliminary cost estimate		8	8	8	8		1	2	1	2		2			2	2					**44**	
5 Implementation Plan																						**61**
5.1 Schedule for 100% design and construction sequence plan		4	4	2				2	4	2		8									**26**	
5.2 Schedule for permitting and Environmental compliance		8							2											16	**26**	
5.3 Implementation Plan TM - Draft		2						1	4												**7**	
5.4 Implementation Plan TM - Final		1							1												**2**	
6 Proposal #2																						**66**
6.2 Detailed project description		8	8	8			1	3	8												**36**	
6.1 Revised drawings, as needed						4					4		4				4				**16**	
6.2 Revised cost estimate, as needed		4	4	4					2												**14**	
Total Hours/Person		65	58	52	38	44	11	42	79	22	28	10	48	8	26	34	48	18	18	16	665	
Percent of Project Time		10%	9%	8%	6%	7%	2%	6%	12%	3%	4%	2%	7%	1%	4%	5%	7%	3%	3%	2%		

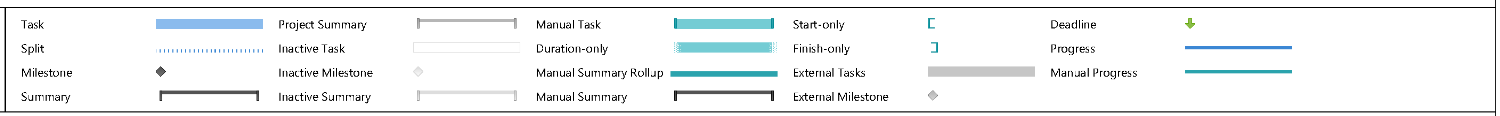
6.3 PROJECT SCHEDULE

The Project Schedule is outlined below with the corresponding Table of Effort included in Table 6-1. The project team is available for the duration of this proposed work and anticipates no conflicts with the proposed schedule.

ID	Task Name	Duration	Start	Finish
1	Notice to Proceed	0 days	Mon 19-07-01	Mon 19-07-01
2	Summary of Existing Operations	40 days	Mon 19-07-01	Fri 19-08-23
3	TM Delivered	0 days	Fri 19-08-23	Fri 19-08-23
4	Progress Meeting #1	0 days	Mon 19-07-22	Mon 19-07-22
5	Progress Meeting #2	0 days	Fri 19-08-23	Fri 19-08-23
6	Safety Assessment	25 days	Mon 19-08-26	Fri 19-09-27
7	TM Delivered	0 days	Fri 19-09-27	Fri 19-09-27
8	Progress Meeting #3	0 days	Tue 19-10-01	Tue 19-10-01
9	30% Design	85 days	Mon 19-07-01	Fri 19-10-25
10	Implementation Plan	18 days	Mon 19-10-28	Wed 19-11-20
11	TM Delivered	0 days	Wed 19-11-20	Wed 19-11-20
12	Proposal #2	55 days	Mon 19-09-30	Fri 19-12-13
13	Proposal Delivered	0 days	Fri 19-12-13	Fri 19-12-13
14	Progress Meeting #5	0 days	Mon 19-12-16	Mon 19-12-16



Project: SOCWA - Proposal
Date: Thu 19-04-18



7 FINANCIAL STRENGTH AND STABILITY

The Tomlinson Group of Companies is the sole owner of Lystek International. The significant investment made by Tomlinson in 2011 and the ongoing financial strength and stability this offers has enabled our company to continue to prove ourselves as a leading technology provider in biosolids and organics treatment and management.

Tomlinson's divisions deliver more than $300,000,000 in projects annually. The company maintains an eight-figure revolving line of credit. Tomlinson's strength as an Organization is rooted in its integrated business structure that combines expertise across multiple divisions in environmental technology and construction services that is collectively backed by a strong financial capacity. This structure allows Tomlinson to provide high value, low risk project solutions by providing a one-stop-solution for the delivery of projects from under $1,000,000 to projects in excess of $150,000,000.

ADDENDUMS

SOUTH ORANGE COUNTY WASTEWATER AUTHORITY

ADDENDUM No.1
TO REQUEST FOR PROPOSALS
FOR TECHNOLOGY SOLICITATION OF

INNOVATIVE SOLIDS/BIOSOLIDS TECHNOLOGY PROJECT

THE PROPOSER SHALL EXECUTE THE CERTIFICATION AT THE END OF THE ADDENDUM AND SHALL ATTACH THE ADDENDUM TO THE PROPOSAL (NOT TO BE INCLUDED AS PART OF THE PAGE COUNT).

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1. The proposal due date was originally March 21, 2019 at 2:00 pm. The due date has been changed to **April 18, 2019 at 2:00 pm**. All other dates for the project will remain unchanged.

DATED: __March 6, 2019__

Jason Manning

Jason Manning, Sr. Engineer

BIDDER'S CERTIFICATION

I acknowledge receipt of the foregoing Addendum No. 1 and accept all conditions contained herein.

DATED: April 22, 2019

BIDDER: Lystek International

BY: Rick Mosher and James Dunbar

Rick Mosher - P.Eng.
Chief Technology Officer

James Dunbar - P.Eng.
General Manager/
Business Development Manager - California

SOUTH ORANGE COUNTY WASTEWATER AUTHORITY

ADDENDUM No.2
TO REQUEST FOR PROPOSALS
FOR TECHNOLOGY SOLICITATION OF

INNOVATIVE SOLIDS/BIOSOLIDS TECHNOLOGY PROJECT

THE PROPOSER SHALL EXECUTE THE CERTIFICATION AT THE END OF THE ADDENDUM AND SHALL ATTACH THE ADDENDUM TO THE PROPOSAL (NOT TO BE INCLUDED AS PART OF THE PAGE COUNT).

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1. The proposal due date was revised to April 18, 2019 at 2:00 pm by Addendum No. 1. The due date has been changed to **April 25, 2019 at 2:00 pm**. All other dates for the project will remain unchanged.

DATED: __April 8, 2019__ Jason Manning

Jason Manning, Sr. Engineer

BIDDER'S CERTIFICATION

I acknowledge receipt of the foregoing Addendum No. 1 and accept all conditions contained herein.

DATED: April 22, 2019 BIDDER: Lystek International

BY: Rick Mosher and James Dunbar

Rick Mosher - P.Eng.
Chief Technology Officer

James Dunbar - P.Eng.
General Manager/
Business Development Manager - California

APPENDICES

APPENDIX A

US EPA Classification of Lystek as a Class A Sludge Management Facility

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

Certified Mail # P 432 844 924
Return Receipt Requested
In response reply to: WTR-2-3

1/4/17

James Dunbar
General Manager for California Operations
Lystek International
1014 Chadbourne Road
Fairfield, CA 94534

Re: Classification of Lystek Fairfield-Suisun Facility as a Class 1 Sludge Management Facility

Dear Mr. Dunbar:

Pursuant to authority delegated to me from the Regional Administrator of the U.S. Environmental Protection Agency, Region 9, I have classified the Lystek Fairfield-Suisun Facility as a "Class I Sludge Management Facility".

EPA Region 9 classifies as Class I those facilities which blend and/or treat more than 290 metric tons (dry weight basis) of sewage sludge per year prior to land application. EPA is making these classifications under its regulations at 40 CFR 503, "Standards for the Use or Disposal of Sewage Sludge". The regulations at 40 CFR 503.9 provide that Class I facilities are either publicly owned treatment works (POTWs) required to have a pretreatment program, or other Treatment Works Treating Domestic Sewage (TWTDS) classified by the Regional Administrator as Class I due to their having the potential to affect public health or the environment because of their sewage sludge use or disposal practice.

EPA Region 9 has determined that facilities other than POTWs which blend or treat more than 290 dry metric tons of sewage sludge per year prior to land application should be classified as Class I sludge management facilities. In order to track compliance with the requirements under 40 CFR 503 needed to protect public health and the environment, Class I Sludge Management Facilities are required to submit annual reports to EPA demonstrating compliance with the requirements for land application. See 503.18. When a POTW sends sludge to another TWTDS for further treatment and/or blending, EPA must receive information regarding the final sludge product's quality in order to determine if the requirements of 40 CFR 503 for protecting public health and the environment are being met. EPA Region 9 is classifying these TWTDs as Class I in order to receive the needed reports.

Based upon presently available information, I have determined that the Lystek Fairfield-Suisun Facility is a TWTDS which treats more than 290 dry metric tons of sewage sludge per year for the purpose of land application. Please register into EPA's CDX system for electronic submission of biosolids reports, and submit an annual report by February 19 of each year for the period covering the previous calendar year, beginning with calendar year 2016, to EPA's NeT electronic reporting system.

If you have any questions on this classification, please contact Lauren Fondahl at 415 972-3514.

Sincerely,

Tomas Torres, Director
Water Division

Cc: Royan Teter, US EPA Region 7

APPENDIX B

Why Choose Lystek THP

Comparing Lystek THP to Alternative Class A Treatment Technologies

	Heat Dried Pelletized Product	Alkaline Stabilized Dry Product	Compost	High Pressure THP	Lystek THP®
OPERATING BENEFITS					
No additional operators required	✗	✗	✗	✗	✓
Does not disrupt upstream processes	✓	✓	✓	✗	✓
Small processing footprint	✗	✗	✗	✗	✓
Rapid processing time	✗	✗	✗	✓	✓
Fully enclosed system, minimal process air	✗	✗	✗	✓	✓
No potential for dust generation	✗	✗	✗	✓	✓
Digester enhancement	✗	✗	✗	✓	✓
Multiuse carbon source for nutrient removal	✗	✗	✗	✗	✓
FERTILIZER PRODUCT BENEFITS					
Market ready fertilizer	✓	✓	✓	✓	✓
High solids liquid advantage	✗	✗	✗	✗	✓
Sub-surface injected	✗	✗	✗	✗	✓
Full NPK nutrient value	✗	✓	✗	✗	✓
Suitable for precision agriculture	✓	✗	✗	✗	✓
ECONOMIC BENEFITS					
Low capital cost	✗	✗	✓	✗	✓
Meaningful revenue sharing agreement	✗	✗	✗	✗	✓
Reduced dewatering polymer consumption	✗	✗	✗	✗	✓
ENVIRONMENTAL BENEFITS					
Contributing to the circular economy	✓	✓	✓	✓	✓
Reduced energy inputs	✗	✗	✓	✗	✓

APPENDIX C

Examples of Awards and Honors

Examples of Awards and Honors

2018	**California Association of Sanitation Agencies** *Excellence in Innovation & Sustainability* **Fairfield Organic Materials Recovery Center & Fairfield-Suisun Sewer District**
2018	Canadian Construction Association ***Sustainable Management of Biosolids & Organics*** International Business Award
2017	California Environmental Protection Agency ***Governor's Environmental & Economic Leadership Award*** Fairfield Organic Material Recovery Center
2017	Water Canada/Water's Next ***Wastewater Technology*** National Award
2017	Water Canada/Water's Next ***Company of the Year*** National Award
2015	Canadian Association of Municipal Administrators ***CAMA Environmental – Biosolids Management*** City of North Battleford, Saskatchewan
2013	Water Environment Association of Ontario ***Exemplary Biosolids Management – Technology Development*** Southgate Organic Material Recovery Center
2008	Water Environment Association of Ontario ***Exemplary Biosolids Management - Integrated BNR System*** St Marys Ontario
2005	National Research Council of Canada ***Sustainable Development*** Ontario Region

**Click on each award title to link to the full award details.*

APPENDIX D

Summary of Current Installations

Summary of Current Installations – Design, Build, Transfer Deployments

Location (Commissioned)	Site Capacity (WT/Y)	Site Details	Lystek Products / Processes	Feedstock	LysteGro Storage
Guelph, ON (2008)	18,000	On-Site - Retrofit	LysteGro, LysteMize	Anaerobic Digested Biosolids	Modular Transportable Above-Ground Storage Tanks
St. Marys, ON (2010)	3,500	On-Site - Retrofit	LysteGro, LysteMize, LysteCarb	Originally: Anaerob. Dig. Biosolids Current: Aerobic. Dig. Biosolids	Below Ground Concrete Tank
Elora, ON (2014)	3,500	On-Site - Retrofit	LysteGro	Aerobic Digested Biosolids	Below Ground Concrete Tank
North Battleford, SK (2014)	3,500	On-Site - Retrofit	LysteGro	Aerobic Digested Biosolids	Reservoir – lined & covered
St. Thomas, ON (2018)	5,600	On-Site - New Build	LysteGro	Undigested Residuals	Above ground tank
St. Cloud, MN (2018	15,000	On-Site - Retrofit	LysteGro	Anaerobic Digested Biosolids	Repurpose - below ground concrete tank
Innisfil, ON (2019)	5,500	On-Site - New Build	LysteGro	Aerobic Digested Biosolids	Retrofit - above ground tank w/ floating cover
Goleta, CA (2019)	Demo / R&D	On-Site - Skid	LysteMize	Food Waste from UC Santa Barbara and Biosolids from Goleta Sanitary District	N/A

**Customer references available upon request*

Lystek
Nothing wasted.
Everything to gain.

Summary of Current Installations – Regional Facilities

Location (Commissioned)	Site Capacity (WT/Y)	Site Details	Deployment Structure	Lystek Products/ Processes	Feedstock	LysteGro Storage
Southgate, ON (2012)	150,000	Off-Site - Regional Facility, Greenfield	DBOO	LysteGro	Undigested / Digested Biosolids & Organics from various municipalities	Reservoirs – lined & covered
Serving utilities such as: - Toronto, Halton, Hamilton, Kitchener, Guelph, Niagara, Orangeville, Tay Township, West Grey, Gravenhurst, Peterborough, Huntsville, Mississauga, Brantford, Arthur, Innisfil, Meaford, Owen Sound, Midland, Walkerton, Centre Wellington, Mono						
Iroquois, ON (2012)	40,000	Off-Site - Regional Facility Upgrade	DBT	LysteGro	Undigested / Digested Biosolids from various municipalities	Below Ground Concrete Tank
Serving utilities such as: - Ottawa, Toronto, Peterborough, among others						
Fairfield, CA (2016)	150,000	On-Site - P3 Regional Facility	P3 - DBOO	LysteGro, LysteMize	Undigested / Digested Biosolids from various municipalities	Retrofit Reservoir – lined & covered
Serving utilities such as: - Fairfield-Suisun Sewer District, City and County of San Francisco, East Bay Municipal Utility District, Santa Rosa, Central Marin Sanitation Agency, Petaluma, Benicia, Palo Alto, City of South San Francisco						

**Customer references available upon request*

APPENDIX E

Case Studies

Retrofit Creates Sustainable Biosolids Management Solution

Fairfield-Suisun Sewer District, California

Lystek
Nothing wasted.
Everything to gain.

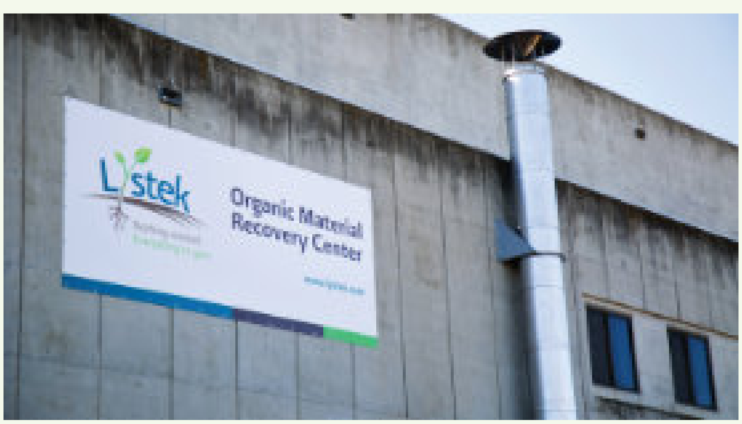
Fairfield-Suisun Sewer District enters into a unique Public-Private Partnership (P3) with Lystek to bring first, comprehensive biosolids management solution to the San Francisco Bay Area.

ABOUT

Located north-east of San Francisco, the Fairfield-Suisun Sewer District (FSSD) serves over 135,000 and operates 70 miles of sewer with 13 pumping stations within 48 square miles in central Solano County. **www.fssd.com**

CHALLENGES

- Sensitive natural environment and tightening regulations
- Under-utilized assets/infrastructure
- Odors, pathogens, and potential run-off issues related to the historical use of Class B biosolids
- High and rising costs of historical biosolids management
- Lack of a comprehensive biosolids management solution for the Bay Area



SOLUTION

- Construction and retrofit of a new state-of-the-art, 150,000 (U.S. ton) Organic Material Recovery Center (OMRC) designed, built, owned and operated by Lystek
- Conversion of Class B biosolids material into a sale-able Class A EQ biofertilizer product
- Product that can help offset rising cost of fertilizers and be stored in any suitable location
- Comprehensive air handling and process for advanced odor and vector control
- Alignment with California's Healthy Soils Initiative, the Clean Water Act and organics diversion regulations
- Unique P3 solution converting a traditional WWTP into a Wastewater Resource Recovery Center (WRRC)

RESULTS

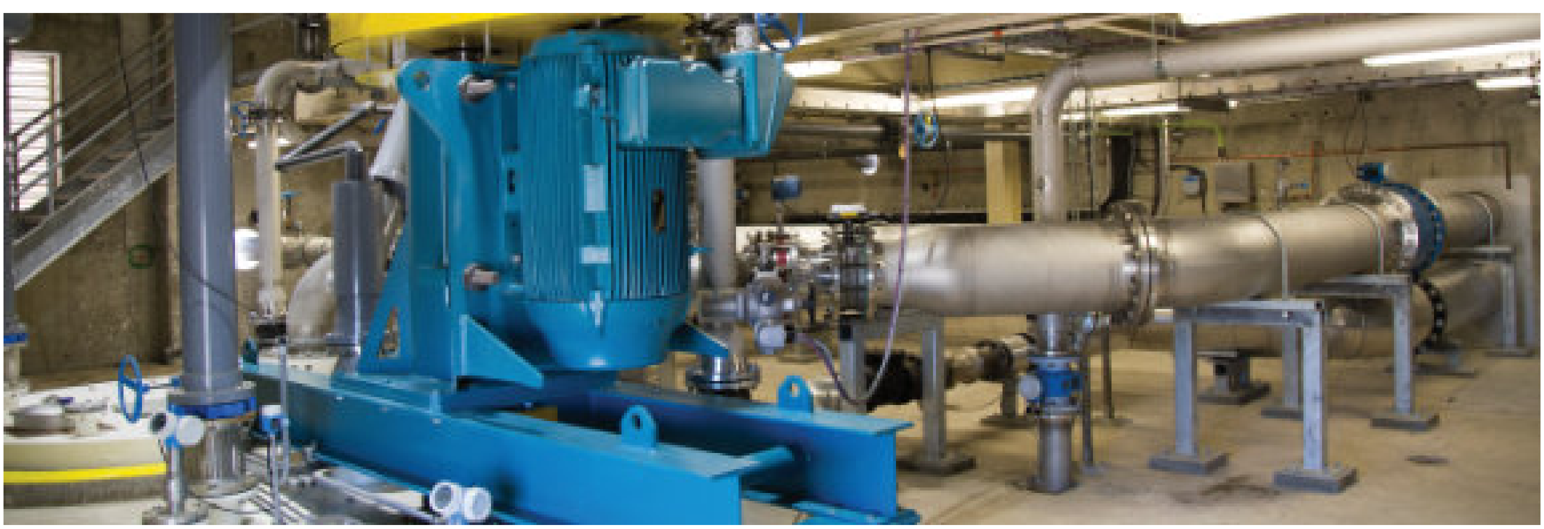
- Provides the FSSD with cost certainty in biosolids management for the next twenty (+) years
- Elimination of historical odors, pathogens, and potential run-off issues from Class B biosolids
- Opportunity to increase diversion rates for organic "waste" from Bay Area landfills
- Reduces Greenhouse Gas (GHGs) emissions and contributes to the "circular economy"
- Introduction of LysteGro®, a Class A EQ (Exceptional Quality) product, recognized by the California Department of Food and Agriculture as a licensed fertilizer

ALIGNMENT WITH PROGRAMS & POLICIES

The FSSD serves more than 135,000 residential, commercial and industrial customers, overseeing wastewater management and sanitary sewers in California's Solano County.

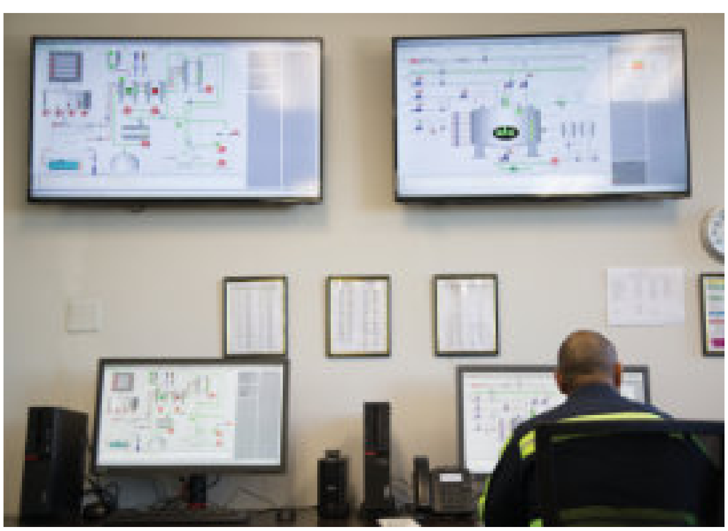
For thirty years, the District had been sending their biosolids to landfll, to be used as daily cover. This historical practice came with clear drawbacks; Class B biosolids that still contained pathogens, unpleasant odor, higher GHG emissions and the potential for "run-off" into local waterways.

The State of California is acutely aware of both the value and sensitivity of their natural environment and the inherent challenges associated with wasting valuable organic material in landflls. The State has been passing down ever-tightening regulations such as the banning of organics from landflls, the Healthy Soils Initiative and the Clean Water Act. All of these state-wide measures are designed to preserve the natural environment and improve resource management practices. With a desire to continue in its own, award-winning tradition of being proactive and with the certainty of stricter regulations on the horizon, the District understood that innovation was going to be required to invoke change. FSSD staff was also fortunate to have the support of a visionary board and local, political leadership. "We live in an area that is very sensitive to the environment and we're very much concerned about the Clean Water Act and the treatment of our "waste" products. Lystek allows us to be the utility of the future," says Harry Price, Mayor of Fairfeld.



A FULLY-INTEGRATED SOLUTION

Management at FSSD also knew they wanted to work with an organization that shared their philosophy of taking a long-term view by looking beyond just the immediate challenges. They wanted a true partner. They found this with Lystek International. The company was able to demonstrate that they had developed a patented and proven, sustainable solution for biosolids and organics management. The multi-purpose, Lystek Thermal Hydrolysis Process (Lystek THP) was already successfully diverting hundreds of thousands of these potentially valuable materials from landfills and producing LysteGro®, a Class A EQ (Exceptional Quality) product that is high in organic matter and nutrients and that has been recognized by the California Department of Food and Agriculture as a licensed fertilizer. In addition to offering long-term pricing stability and a source of additional revenue for FSSD, the new Organic Material Recovery Center (OMRC) could also be retrofitted, to make better use of existing infrastructure and under-utilized assets. For example, it provides the District with enhanced operation of its digesters to increase biogas production for green energy and local growers with a nutrient-rich, organically-based biofertilizer product that is also affordable. "We're seeing more and more benefits of the project," shares Greg Baatrup, FSSD General Manager. The OMRC has the capability to recycle organics and produce alternative energy, thereby converting the traditional treatment plant into a Wastewater Resource Recovery Center (WRRC) and playing an important role in a more sustainable, circular economy.



"We gained a long-term solution, not only a management option, but a structure that makes pricing very certain over the next twenty years to help us manage our costs and deliver valuable services to our rate payers."

– Greg Baatrup, FSSD General Manager

SUCCESSFUL P3 PROJECT

After a decade of experimenting with a range of unreliable or incomplete solutions, this unique, Public-Private Partnership is already proving to be the perfect fit. Lystek's record of success and numerous operating facilities checked several boxes for FSSD. The ability to retrofit into under-utilized infrastructure, long term cost control and regulatory compliance, checked several more.

The twenty-year (+) partnership not only provides mutual peace of mind for FSSD and Lystek but, in fact, for all stakeholders, be it local or at the state level. "This is just (another) great example of what the power of creating partnerships is, partnerships between Suisun City and the City of Fairfield, the Sewer District, and Lystek. Let's talk about public-private partnerships. We all know how important these P3's are, because the government cannot do this stuff by itself. It never will be able to," states California State Assembly member, Bill Dodd.

COMPELLING EXAMPLE

At this point (2017), the partnership is in its early stages and already, the FSSD has a compelling story to share. The stakeholders are excited because the many benefts of the project are already clear. Everyone can see how, over the long term, they will go far beyond the simple conversion of biosolids into a Class A quality fertilizer product. This ground-breaking initiative is being viewed as a major step forward in reliable and sustainable, year-round organics management for the larger, Bay Area community and a successful model that supports the Healthy Soils Initiative, the Clean Water Act, and the evolving landscape of organics diversion in the state of California. It's about taking action and doing something tangible to eliminate needless "waste" – and it is a story others are eager to hear about and watch, including other agencies, associations and the State itself.

"This project is fast becoming the beach head for the United States (and a model) for the development of other, similar projects," says Baatrup.

About Lystek International

Lystek is a leading provider of Thermal Hydrolysis solutions for the sustainable management of biosolids and organics. The multi-use, award-winning Lystek system reduces costs, volumes and GHG's by converting municipal and industrial wastewater treatment facilities into resource recovery centers. This is achieved by transforming organic waste streams into value-added products and services, such as the patented LysteMize® process for optimizing digester performance, reducing volumes and increasing biogas production; LysteGro®, a high-value, nutrient-rich biofertilizer and LysteCarb®, an alternative source of carbon for BNR systems.

Nutrient Recovery & Reuse (NR2) Project

City of St. Cloud, Minnesota, USA

Lystek
Nothing wasted.
Everything to gain.

"The biggest, driving force behind the various upgrades to our biosolids program was that we were running out of storage," says Brian Shoenecker, Wastewater Services Manager for the City of St. Cloud

ABOUT

The City of St. Cloud is the 10th largest city in Minnesota. It is centrally located in the heart of the Midwest along the banks of the mighty Mississippi River. The City is the first municipality to use the Mississippi River as its drinking water source. Maintaining high water quality standards and preserving the integrity of the receiving waters is of the highest priority to the City.

CHALLENGES

- Biosolids storage capacity was under increasing pressure due to continued community growth, increased flows, and wet weather events shortening the land application season
- Anticipated future regulatory pressures to produce a Class A product for recycling to land
- Desire to retain and utilize as much existing treatment infrastructure as possible

SOLUTION

- Integration of the Lystek Thermal Hydrolysis Process (Lystek THP®) in a major (NR2 Project) plant upgrade

RESULTS

- A 70% decrease in biosolids volume significantly extending the capacity of the City's existing storage
- Production of a liquid, Class A quality biosolids product, which can be managed with the City's existing transportation and land application equipment
- $12 million in estimated cost savings over a 20 year life cycle as compared to alternative solutions

LOCATION & BACKGROUND

The St. Cloud Nutrient, Energy & Water (NEW) Recovery Facility is located in southern St. Cloud. The center services a population of about 120,000, including the City of St. Cloud and several area cities such as St. Augusta, St. Joseph, Sartell, Sauk Rapids, and Waite Park.

In 2014, the City began developing a Resource Recovery and Energy Efficiency Master Plan (R2E2) to remain well positioned to exceed future regulatory requirements and continue to be an innovative and sustainable utility. The primary goals of the R2E2 Master Plan were resiliency, cost-efficiency, innovation, excellence, and continuous improvement.

As a forward-looking utility, the St. Cloud NEW Recovery Facility had already been recognized as a leader in resource recovery. In fact, in 2017, the facility was one of only 25 water utilities in the United States to be named a "Utility of the Future Today", in recognition of its "leadership in community engagement, watershed stewardship, and recovery of resources such as water, energy, and nutrients", by the National Association of Clean Water Agencies (NACWA).

Armed with a notification in July 2017 from the Minnesota Public Facilities Authority that $6.6 million dollars in funds from a Point Source Implementation Grant had been made available to St. Cloud, the City embarked on an ambitious initiative, known as the Nutrient Recovery and Reuse (NR2) Project, to further advance their efforts in resource recovery. The grant was made possible by the Clean Water Legacy Act. Two of the primary goals of the NR2 initiative were to recover phosphorous and produce a fertilizer product at its facility.

PROJECT DRIVERS

Prior to the implementation of the Lystek THP solution, the City had already established a highly successful, Class B, liquid biosolids management program. However, as the community around the facility continued to grow, it became obvious there would be increasing pressure on the existing storage capacity at the center. This was a challenge that needed to be addressed. Simply put, City staff understood that, in the near future, they would run out of capacity to store their liquid (3-4% solids) material. Therefore, they needed to implement a plan that would reduce the volume of their low solids content product.

In addition, St. Cloud wanted to achieve a Class A quality product to prepare for possible changes in future regulatory requirements. With the Lystek THP system, St. Cloud was able to find a solution to address both of these key project challenges/drivers, while continuing to utilize and maximize the value of their existing infrastructure.

"We were trying to find a way – a process or a technology – where we could continue to provide a liquid fertilizer product to our agricultural customers. That's what they like, that's what they ask for, so we evaluated a number of alternatives to find a solution that would be a good fit."

– Tracy Hodel, Public Utilities Assistant Director for the City of St. Cloud.

LYSTEK THP SELECTED

The solution also had to align with the St. Cloud's commitment to innovation in nutrient reuse and recovery and be as cost effective as possible for its ratepayers.

Evaluation included several options, such as producing a dewatered cake.

According to Hodel, "We were in our facility planning phase when we first heard about Lystek. The timing was perfect. We were looking at various solutions and we are known for being innovative and taking some (measured) risk in our approach, including different technologies. It started with a conference call and evolved into a detailed review of the Lystek THP system. What really impressed us was how well it fit with our exsiting infrastructure and equipment. Plus it enabled us to continue providing the type of end product our agricultural customers prefer and ask for."

Bench scale testing was initiated in 2015 to evaluate the effect of the Lystek THP approach on St. Cloud's biosolids. The process features a patented and proven combination of low temperature heat (167° F/75°C) via low-pressure steam, alkali addition (to pH 9.5), and high-speed shearing to achieve a variety of benefits for wastewater treatment facilities. Results of this initial testing showed that St. Cloud's biosolids could be dewatered and processed through the Lystek THP system, achieving a Class A quality, liquid biofertilizer product (LysteGro®) that is also high in essential nutrients and vital, organic matter.

Ultimately, Lystek was selected by the city of St. Cloud. Project construction began in 2017 and the Lystek THP system was successfully commissioned and being independently operated by City staff by September, 2018.

COST SAVINGS

Utilizing existing infrastructure also contributed significantly to overall cost savings for St. Cloud.

"Not only did it meet our sustainability goals and our customer's needs in terms of the liquid product, but it also saved us on capital money because we didn't have to build a new cake storage building. We didn't have to change our injection or our recycling equipment. So, as far as the total project goes, we are projecting approximately $12 million in lifecycle savings over 20 years." **– says Tracy Hodel**

The ability for the City to advance their successful land application program, while reducing and controlling costs, were key selling features of the project.

In addition to the benefits of the City being able to continue using their existing liquid land application trucks and equipment, they were also able to utilize existing plant infrastructure, such as liquid storage tanks, buildings, and the truck loading station. The City was also able to improve efficiencies. The concentrated nature of the LysteGro product dramatically extended the capacity of St. Cloud's existing storage, thus solving this challenge.

Further, the high solid, liquid properties of the product maintained pumping, loading, and unloading efficiencies, while also dramatically decreasing the amount of road time and wear and tear on trucks, overtime, and the number of passes the application equipment must undertake, per field.

"The cost savings alone on this project are significant with reduced maintenance on equipment, staff overtime and so forth. Not to mention the advantages of being able to move the product from storage to the fields and into the ground when it's timely for our agricultural customers."

– Brian Shoenecker

SUMMARY OF SUCCESSES

Overall, implementation of the Lystek solution as part of St. Cloud's vision and leadership in innovation and sustainability in biosolids management was an efficient, affordable, and seamless transition.

The system was deployed within the City's existing infrastructure and has reduced the volume of material going to storage by 70%, thereby significantly extending operational capacity to accommodate future growth. Plus, St. Cloud's land application program was able to proceed without interruption, and they are now producing a Class A biosolids product that their customers want and need.

Additionally, in terms of forward planning, because the Lystek THP system is modular and flexible, it can be further leveraged in the future to integrate with other components of the plant and provide further value, such as the LysteMize® approach to digester optimization for increased biogas production. Or, should the City ever require additional carbon for its BNR system, this could be achieved through the provision of LysteCarb®. On-site research has also shown the ability for the Ostara WASSTRIP process (also implemented as part of the NR2 project), to utilize this material as a carbon source for additional nutrient removal at the plant.

One system = Multiple benefits

Patrick Shea, Director of Public Utilities for the City, sums up the project this way; "One of the aspects that makes me smile when I reflect on the NR2 Project as a whole is the culture of wastewater treatment going from sewage to sewer plant to wastewater treatment facility and now to full-blown resource recovery. This is an industry game changer. We're reusing the organic material, we're reusing the nutrients, and we're converting these materials back into useful products that can help rebuild our soils while benefitting the environment over the long-term."

About Lystek International

Lystek is a leading provider of low temperature Thermal Hydrolysis solutions for the sustainable management of biosolids and organics. The multi-use, award-winning Lystek system reduces costs, volumes and GHG's by converting wastewater treatment facilities into resource recovery centers. This is achieved by transforming organic waste streams into value-added products and services, such as the patented LysteMize® process for optimizing digester performance, reducing volumes and increasing biogas production; LysteGro®, a high-value, nutrient-rich biofertilizer and LysteCarb®, an alternative source of carbon for BNR systems. **www.lystek.com**

Organic Materials Recovery Centre Delivers Innovation and Sustainability

Lystek
Nothing wasted.
Everything to gain.

Southgate Township benefits from Lystek's state-of-the-art facility and the production of a Class A biofertilizer product

Southgate wanted to become an environmental leader by embracing green technologies and innovative, sustainable organics management solutions.

ABOUT

Located in western Ontario with close proximity to Guelph and Orangeville, Southgate Township is a thriving agricultural community that contains some of the finest farmland in Canada. **www.southgate.ca**

CHALLENGES

- Odors, pathogens, on-site storage and potential run-off issues related to the historical practice of applying Class B biosolids to farmland
- High and rising costs of chemical/commercial fertilizers
- Underserviced market – particularly in the surrounding, small to medium-sized communities
- Undeveloped 'Eco Park' with no anchor tenant and limited tax revenue

SOLUTION

- Construction and commissioning of a new state-of-the-art Organic Materials Recovery Center (OMRC) designed, built, owned and operated by Lystek
- Conversion of Class B biosolid material into a safe, affordable, quality controlled, federally registered, Canadian Food Inspection Agency biofertilizer product
- Product can be stored anywhere (as suitable) and helps to offset rising costs of fertilizers
- Comprehensive air handling and redundant bio-filtration systems for advanced odor control

RESULTS

- Created 11 full time jobs for the community of Southgate to staff the new OMRC
- Elimination of pathogens, odors and run-off issues associated with Class B biosolids
- Creation of a federally registered Class A product that has all the of nutrient values of chemical/commercial fertilizers as well as being rich in organic matter
- Significant boost in new tax revenues from the first, major tenant in the Eco Park
- Diversion of organic "waste" from Ontario landfills reduces Green House Gas emissions and contributes to the "circular economy"

ORGANIC "WASTE" AS A RESOURCE

When Southgate Township was formed through amalgamation of the Village of Dundalk, the Township of Proton, and the Township of Egremont in 2000, the new Council was faced with a number of challenges. Waste management was one of them.

At the time of amalgamation, Dundalk's landfll was closed and the town was paying to have waste trucked to a neighboring municipality. Proton's landfll site was approaching capacity. Egremont had roughly ten years of volume remaining. A new landfll site would cost millions and was considered an unsupportable option due to cost – even if the Province were to approve such a proposal.

In addition to landfll issues, Council was also dealing with mounting community concerns about the application of Class B biosolids on farmland. "Biosolids were good for the soil, and they were given [by the Municipality] to area farms for free," says former Mayor, Brian Milne.

While application of partially treated, Class B biosolids was an accepted agricultural practice, some members of the community were voicing concerns about the potential for environmental and health issues as a result of run-off. While there were never any cases of ground water contamination from pathogens, there was no disputing the unpleasantness of the odor. "That material was extremely smelly when spread and not well received by some members of the community," recalls Milne.

The confuence of waste management issues and mounting environmental and health concerns resulting from the application of Class B biosolids produced a perfect storm for the newly formed council of Southgate. Yet, from this looming crisis emerged an entrepreneurial vision and plan for the Township: to position Southgate as an environmental leader by embracing green technologies and innovative, sustainable waste management solutions.

Rather than thinking "old landfll technology", Southgate invested in a three-bin curbside pick-up system that diverted organic waste from the landfll. This immediately enabled the Township to extend the life expectancy of the Egremont site to 80 plus years. However, curbside pick-up was just the beginning of the eco revolution that was beginning to take shape. Community leaders in Southgate recognized there was money to be made in the emerging, circular economy or the recycling of materials that some considered "waste". "Our Mayor at that time was Don Lewis," says Milne. "He didn't like the word "waste". He called these materials "resources" – and I wholeheartedly agreed with him – and still do."

ATTRACTING NEW, GREEN BUSINESSES

Prior to amalgamation, the town of Dundalk purchased approximately 150 acres of land - on the edge of town and immediately adjacent to the townships own sewage lagoons, that had existed for approximately 40 years. This site became the inspiration and vision for an Eco Park that could, with a supporting infrastructure, attract new green businesses to the area. In doing so, this Eco Park could help diversify the local economy while becoming a "hub of excellence."

"The whole idea was to become more environmentally conscious," confrms Dave Milliner, Chief Administrative Officer for Southgate. The move to separate organics from waste and recycled materials in 2003 was a start. "We wanted to build on that momentum by attracting more businesses and projects that would complement and supplement those practices and make us an environmental leader," he adds.

"The OMRC has had a very positive impact on our community. In addition to making Southgate part of the new, green economy, we have shown how Lystek's investment in the Eco Park is paying real dividends to the benefit of all citizens of our community, and beyond."
confirms Milne.

OPEN FOR GREEN BUSINESS

The Township made it known through its Economic Development office that it was receptive to ideas and business proposals from potential tenants for the Eco Park. Lystek, a leading organic materials recovery frm, saw a perfect ft between the vision for the Park, the Township's need for a better way to manage biosolids and organics – and its own, award-winning, patented and proven, Thermal Hydrolysis technology.

The simple, low cost, Lystek Thermal Hydrolysis process involves a combination of low heat through steam injection, the addition of alkali, and high-speed shearing. The patented process literally disintegrates microbial cell walls and hydrolyses complex macromolecules into simpler compounds. The result is a high-solid, pathogen-free, nutrient-rich liquid biofertilizer registered with the CFIA (Canadian Food Inspection Agency) that is also recognized as a Class A EQ biofertilizer by the US EPA. Also, because the process is essentially a closed loop solution from beginning to end, the potential for odor complaints during processing, transportation and end use are dramatically reduced. And, to add to the value and versatility of this remarkable technology, the same, innovative system can also be used to optimize the performance of digesters and BNR systems, while reducing overall volumes and increasing biogas production for green energy. These exciting breakthroughs are allowing Lystek to work in partnership with municipalities and other generators of organic "waste" across North America, thus transforming wastewater treatment plants (WWTP's) into Wastewater Resource Recovery Centers.

ORGANIC MATERIALS RECOVERY CENTRE

In the case of Southgate, Lystek came forward with a compelling proposal for the Township; to completely fnance, design, construct and commission a state-of-the-art Organic Materials Recovery Center (OMRC) in the Dundalk Eco Park focusing on the production of Class A quality, CFIA registered, biofertilizer products. The facility would be owned and operated by Lystek, and would be able to provide much needed tax revenues and excellent employment opportunities to the local community.

The proposal presented to Southgate council was a defnite win-win. Lystek would have a home for its regional organic materials recovery center, becoming the frst, true, anchor tenant in the Eco Park, and would produce a pathogen free, affordable, biofertilizer product high in nutrients and organic matter. The product would be sold under the brand name, LysteGro®. The community of Southgate would gain much-needed jobs and additional tax revenues plus, though a unique revenue share agreement, the Township would also be paid a royalty for every tonne of material processed at the OMRC by Lystek. The vision would fnally become a reality.

"We were quite impressed," says Milliner. "We could see there was a lot of expertise behind the project, not only academic but also operational with people who knew how to get things done on the ground. We felt there was a good ft because of our farming background in this area. And we knew this was a far better process than the previous practice of spreading Class B biosolids."

KICK-START THE ECO PARK

The agreement with Lystek, and the commitment to build the OMRC, gave the Township the confidence it needed to invest in the infrastructure that was required to turn the Eco Park from a vision into reality. "We felt confident about putting the road in, the sewage, and everything else that was required back to the property line," confirms Milne. "The OMRC provided us with a real opportunity to kick-start the Eco Park," he adds.

Lystek was given approval to move forward with construction of the OMRC in October 2012. Odor was one of the biggest factors considered throughout the development and construction process. "One-third of the approximately $12 million that Lystek invested into this center was spent on odor control and air handling," confirms Rick Mosher, Chief Technology Officer for Lystek. "The facility uses a closed-loop design that minimizes the chances of compromising quality of life for the surrounding community," he adds. As a result, once material is received at the plant, it moves immediately into a process of transformation from its original state. The material is transferred from the receiving hall into one of three, Lystek Thermal Hydrolysis reactors where it is treated with the patented process and converted into LysteGro®. Upon completion of that process, the finished product is pumped underground to one of two, lined and covered storage lagoons until it is sold and shipped into the marketplace. The center also features a testing, research and development laboratory where both incoming feedstock and the market-bound, LysteGro® product is continually sampled and analyzed and then sent to independent, third-party laboratories to ensure compliance with regulatory guidelines for health and safety.

Lystek began operations of the OMRC in May of 2013, in the Southgate Eco Park. "The OMRC has had a very positive impact on our community," confirms Milne. In addition to making Southgate part of the new, green economy, we have shown how Lystek's investment in the Eco Park is paying real dividends to the benefit of all citizens of our community, and beyond."

About Lystek International

Lystek is a leading provider of Thermal Hydrolysis solutions for the sustainable management of biosolids and organics. The multi-use, award-winning Lystek system reduces costs, volumes and GHG's by converting municipal and industrial wastewater treatment facilities into resource recovery centers. This is achieved by transforming organic waste streams into value-added products and services, such as the patented LysteMize® process for optimizing digester performance, reducing volumes and increasing biogas production; LysteGro®, a high-value, nutrient-rich biofertilizer and LysteCarb®, an alternative source of carbon for BNR systems.

APPENDIX F

Technical Specifications Sheet

Lystek
Nothing wasted.
Everything to gain.

Lystek THP® Technical Specifications

About the Technology

The Lystek low temperature Thermal Hydrolysis Process (Lystek THP®) is an innovative, award-winning, proven biosolids and organics management solution.

Lystek transforms raw or digested feedstock into multi-use products that help wastewater treatment plants produce more biogas while reducing volumes, costs, odors, and greenhouse gases (GHGs). It also produces an exceptional quality biofertilizer product.

Operating parameters are based on low pressure steam, high speed shearing, and alkali, all applied simultaneously in an enclosed Reactor.

Advantages

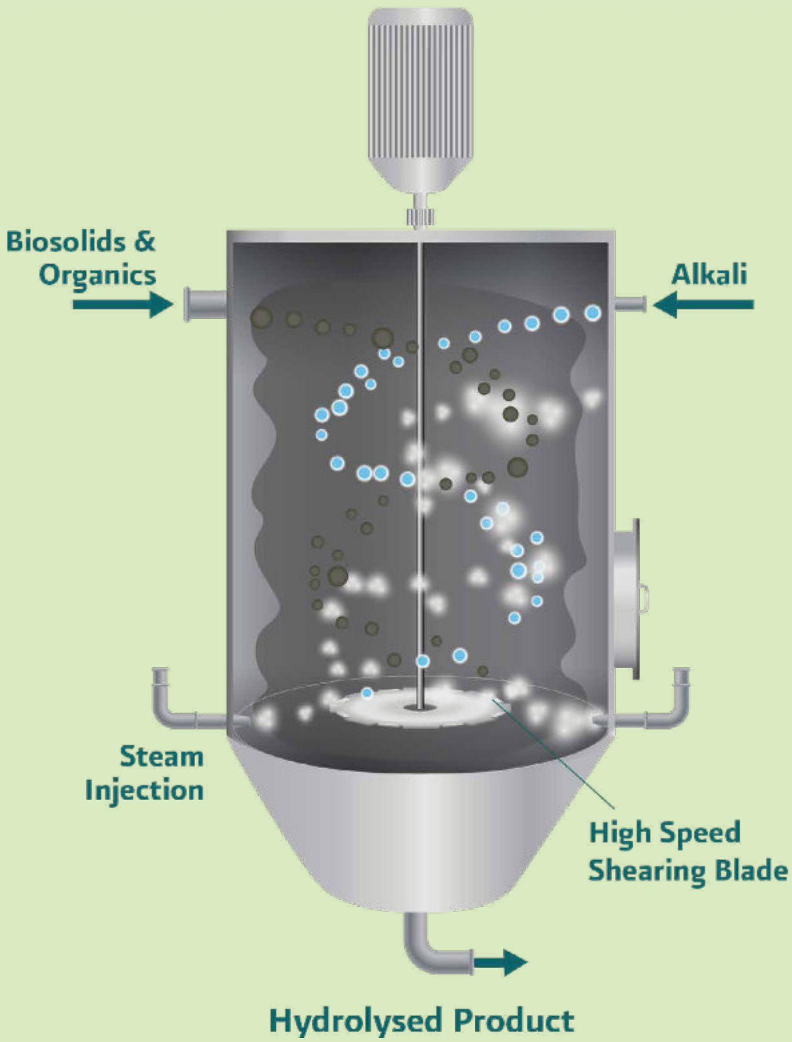
The Lystek system has a small footprint, is cost effective, fast, ef f cient, reliable, and proven.

Modular design makes it scalable and easy to deploy (or retro f t). The system is fully automated and simple to operate and maintain.

Some additional advantages of the solution are:

- Creates a marketable, high-solids liquid Class A biosolids
- Lystek offers comprehensive product management services
- Optimizes anaerobic digesters; increasing biogas production for green energy while decreasing residual volumes through improved volatile solids reduction (VSR)
- Produces a safe, cost-effective alternative source of carbon for biological nutrient removal (BNR) systems
- Can process raw, WAS, or aerobically digested residuals, or can be combined with anaerobic digestion in a pre- or post-digestion con f guration
- Augment to existing plants - does not disrupt process f ow
- Ease of integration with multiple resource recovery technologies

Lystek THP® Reactor



LysteGro® - Class A biofertilizer

LysteMize® - Anaerobic digester optimization

LysteCarb® - Alternative carbon source

Module[i] Sizing

Module size	LY3	LY6	LY10
Processing rate (dry tons per hour)	0.3	0.6	1.0
Typical processing footprint[ii] (ft^2)	800	1,250	1,600

Key Operating Parameters[iii]

Electrical consumption	61 kw-h per dry ton
Heat requirement[iv]	1100 MBtu per dry ton
45% caustic potash[v]	240 - 280 lb per dry ton
Operating temperature	167°F / 75°C
Solids content - processed product	13 - 16%
Viscosity - processed product	5,000 – 10,000 cP

End Product Value/Options

LysteGro® biofertilizer	Meets/exceeds Class A biosolids criteria
LysteMize® digester optimization	Increase biogas production by up to 40% and volatile solids reduction by up to 25%
LysteCarb® alternative carbon source	Eliminate use of costly chemicals (i.e. methanol, glycerol)

i Module includes the THP Reactor, associated pumps and hopper.

ii Minimum space required for processing equipment (Module, alkali storage, boiler) only. Product storage and air treatment system requirements will vary by site conditions.

iii Operating parameters are estimates only and will vary according to site conditions, feed stock characteristics, and intended use of hydrolysed end product.

iv Dependent upon biosolids feed temperature into the Reactor. Heat requirements estimated based upon an average feed temperature of 60°F.

v For larger facilities, lower cost alkali sources are available.

+ Modular and scalable to any size population

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APPENDIX G

Third Party Research and Development Validating LysteMize

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Impact of alkaline-hydrolyzed biosolids (Lystek) addition on the anaerobic digestibility of TWAS in lab – And full-scale anaerobic digesters

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ABSTRACT

The effect of different Lystek biosolids doses on the anaerobic digestability of thickened waste activated sludge (TWAS) was evaluated in a lab- and full-scale anaerobic digester. The overall findings of this study emphasize the beneficial impact of Lystek addition to the lab- and full-scale anaerobic digesters in terms of enhanced biogas production and increased volatile suspended solids reduction (VSSR) efficiency. Lystek added at 4% by volume to TWAS increased the methane yield from 0.22 to 0.26 L CH_4/g VSS_{added} at an solids retention time (SRT) of 10 days, and from 0.27 to 0.29 L CH_4/g VSS_{added} at an SRT of 15 days. Furthermore, the VSSRs of 37% and 47% were observed for the TWAS, and the TWAS with 4% Lystek, while at an SRT of 15 days, the observed VSSR were 49% and 58%, respectively. The lab-scale study showed that the influence of Lystek addition on methane yield and solids destruction efficiencies was more pronounced at the shorter SRT, 20% enhancement (SRT of 10 d) vs. 9% enhancement (SRT of 15 d) for methane yield, and 27% (SRT of 10 d) vs. 22% (SRT of 15 d) for VSS destruction efficiency improvement. Furthermore, addition of 4% of Lystek to the feed of the full-scale anaerobic digester at St. Marys wastewater treatment plant (WWTP) resulted in a 50% increase in the average specific methanogenic activity and 23% increase in methane yield of the biochemical methane potential tests after eight months. The results showed that Lystek degradation kinetics were 40% faster than the TWAS, as reflected by first order kinetic coefficients of 0.053 d^{-1} and 0.073 d^{-1} for TWAS and Lystek at an SRT of 10 days.

1. Introduction

Considerable efforts have been put on municipal waste recycling and recovery because of recognized problems of health issues and limited landfill space, and thus its management has become an environmental and social concern (Arsova, 2010). For beneficial recycling and agriculture utilization of municipal sludge, a high level of stabilization of organic matter in the biosolids is required to maintain, soil, water and air quality (Singh et al., 2006). Different stabilization methods include chemical treatment, aerobic or anaerobic digestion and composting (Dumontet et al., 1999). Among biological processes, anaerobic treatment process is considered to be the most promising and meets the desired criteria of environmental friendliness, and sustainability (McCarty et al., 2011; Lettinga et al., 1997). With vast quantities of waste being produced nowadays, resource and energy recovery is an integral component of an efficient waste management program. Biogas production from various organic wastes via anaerobic digestion (AD) is an environmentally friendly cost-effective waste management strategy (Khanal et al., 2007). Although AD is a very old process, significant research efforts are still underway to enhance the methane production. Pretreatment prior to the digestion is a widely used approach to enhance AD performance by improving the rate limiting hydrolysis rate through the solubilization of particulate organics (Pérez-Elvira et al., 2006). However, the rate of solubilization during pretreatment primarily depends on the nature and concentration of the particulates in the waste to be treated (Elbeshbishy et al., 2011). Most of the pretreatment studies showed enhanced digestion performance in terms of sludge solubilization followed by improved methane production (Nah et al., 2000; Lin et al., 1997; Elbeshbishy et al., 2011; Bougrier et al., 2008). The main purposes of any pretreatment technologies are to increase the soluble chemical oxygen demand (SCOD) and reduce the particle size of the particulate matter.

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0956-053X/

An innovative commercial biosolids thermo-alkaline hydrolysis treatment and processing technology, involving optimum application of heat, alkaline hydrolysis and mixing in a batch or semi-continuous system was developed primarily to facilitate land application of biosolids by reducing the viscosity of the dewatered biosolids from >2,000,000 cP, to that of a pumpable liquid with a viscosity of <1800 cP (Singh et al., 2007). Although the goal of the thermo-alkaline-hydrolysis process was mainly to produce a low-pathogen product (Lystek) that can be used as a soil conditioner, the characteristics of the treated biosolids showed a significant increase in biochemical oxygen demand (BOD), rendering the Lystek be more biodegradable compared to the digestate or the sludge cake. The recycle of the Lystek biosolids to anaerobic digesters may potentially enhance biogas production and overall volatile solids reduction. Thus, the main objectives of this project were to (a) assess the anaerobic biodegradability of the Lystek in a lab-scale anaerobic digester, (b) evaluate the effect of different volumetric Lystek additions on the anaerobic digestability of TWAS in a lab-scale anaerobic digester at two SRTs of 10 and 15 days, and (c) evaluate the effects of Lystek addition on the anaerobic digestability of TWAS in the full-scale AD at St. Marys WWTP (St. Marys, Ontario, Canada).

2. Materials and methods

2.1. Lab-scale continuous stirred-tank reactors (CSTRs)

Continuously stirred tank reactors (CSTRs) each with an operating liquid volume of 10 L and a headspace volume of 4 L were used for the anaerobic biodegradability studies of TWAS, Lystek, and TWAS with Lystek at two SRTs of 10 and 15 days. When the Lystek was used alone, it was diluted to match the TWAS solids prior to feeding. The characteristics of the different feeds are shown in Table 1. The systems used in this study were operated in completely-mixed continuous-flow mode. At the beginning, anaerobic sludge collected from the primary anaerobic digester at St. Marys wastewater treatment plant (St. Marys, Ontario) was used to seed the digesters. The total suspended solids (TSS) and volatile suspended solids (VSS) concentrations of the sludge were 11 and 9 g/L, respectively. The headspace was flushed with nitrogen gas at 5–10 psi for a period of 5 min before start-up. All the digesters were maintained at a constant temperature of 37 ± 1 °C. The continuous-flow experiments were divided into two stages: in the first stage, three reactors were run at an SRT of 10 days and fed with TWAS, Lystek, and TWAS + 4% Lystek. In the second stage, four reactors were run at an SRT of 15 days and fed with TWAS, TWAS + 4% Lystek, TWAS + 6% Lystek, and TWAS + 8% Lystek.

2.2. St. Marys full-scale AD

A schematic flow diagram for the St. Marys wastewater treatment plant (WWTP) and the thermo-alkaline-hydrolysis process are presented in Fig. 1. Lystek was added prior to the primary digester (AD1) at 4% by volume of the feed. The working volumes of AD1 and AD2 are 817 m^3 and 925 m^3, respectively with an average TWAS (3–4% solids) flow rate of about 90 m^3/d, and thus the SRT in AD1 is about 9 days. To evaluate the effects of Lystek addition on the anaerobic digestability of TWAS in the full-scale AD at St. Marys WWTP, eight specific methanogenic activities (SMA) and seven biochemical methane potential (BMP) tests were conducted using different samples (TWAS and seed from AD1) collected monthly. The sampling locations of the TWAS and the digestate are shown in Fig. 1.

2.3. Lystek technology

Thermo-alkaline-hydrolysis biosolids processing technology involves a combination of heat, alkali, and high shear mixing to convert biosolids and other organics into a homogeneous liquid product with a high solid content of 14–17% and fertilizer value. A schematic flow diagram for the St. Marys wastewater treatment plant (WWTP) and the thermo-alkaline-hydrolysis process are presented in Fig. 1. As shown in the figure, to operate the thermo-alkaline-hydrolysis process, the dewatered biosolids were pumped from the biosolids storage tank with a progressive cavity pump to the mixing tank that is equipped with a high-speed mixer. An ca alkali solution (KOH) was added to adjust the pH to 10–11 and the mixture was heated using a steam generator. The high-shear mixing contributes to particulate and solids disintegration, as well as creation of homogeneous conditions including pH and temperature. Process time for each batch was typically 30–60 min. The relative simplicity of the thermo-alkaline-hydrolysis process and the small footprint (1000–1500 square feet) facilitates retrofitting into any existing WWTP (Singh et al., 2007). The detailed characteristics of Lystek processed biosolids are presented in Table 1.

2.4. Biochemical methane potential (BMP) and specific methanogenic activities (SMA) tests

The BMP tests were conducted using TWAS from St. Mary's WWTP as a feed and St. Mary's digested sludge as a seed at four different initial substrate-to-biomass (S/X) ratios of 0.25, 0.5, 1, and 2 on mass COD/mass VSS basis, with each test condition run in duplicates in 250 mL glass bottles. The total liquid volume of the test bottles comprising both the seed and feed was 200 mL. The seed VSS and feed TCOD concentrations were measured prior to the initiation of the batch test (12 h prior to the test). The volumes of digestate and the feed (TWAS) required to maintain the S/X ratios were determined for each sample. Two bottles were used as blank (seed only) which contained 200 mL of seed without any feed. The pH was adjusted to 6.8–7.2 using 1 NaOH and HCl. The volumes of digestate and feed (TWAS) were then added to the batch test bottle (total liquid volume of 200 mL and headspace volume of 60 mL). No additional buffer was added due to the high alkalinity in both

Table 1
Characteristics of the TWAS and Lystek.

Parameter	Units	Raw Lystek	Raw TWAS	Diluted Lystek	TWAS + 4% Lystek	TWAS + 6% Lystek	TWAS + 8% Lystek
TCOD	mg/L	107500 ± 8400[a]	33600 ± 2000	34400 ± 1600	38600 ± 2270	41100 ± 2480	43500 ± 2650
sCOD	mg/L	56000 ± 4100	710 ± 40	17850 ± 1690	2900 ± 210	4600 ± 280	6100 ± 360
TSS	mg/L	104600 ± 9800	34100 ± 2080	36500 ± 2020	38700 ± 2500	40900 ± 2630	43200 ± 2980
VSS	mg/L	56000 ± 7300	30400 ± 1130	20280 ± 1750	33100 ± 1260	35600 ± 1480	36600 ± 1520
BOD	mg/L	16000 ± 2400	490 ± 70		1120 ± 140	1620 ± 190	1900 ± 180
sBOD	mg/L	11800 ± 700	110 ± 20		520 ± 70	810 ± 50	980 ± 90
Ammonia	mg/L	430 ± 80	128 ± 32	160 ± 30	150 ± 36	180 ± 28	190 ± 32
pH		10.3 ± 0.2	6.6 ± 0.2	7.9 ± 0.4	7.6 ± 0.2	7.9 ± 0.3	8.3 ± 0.3
Alkalinity	mg $CaCO_3$/L	10500 ± 860	1300 ± 110	3300 ± 120	1540 ± 140	1920 ± 160	2100 ± 170

[a] Average and STD of 10 samples.

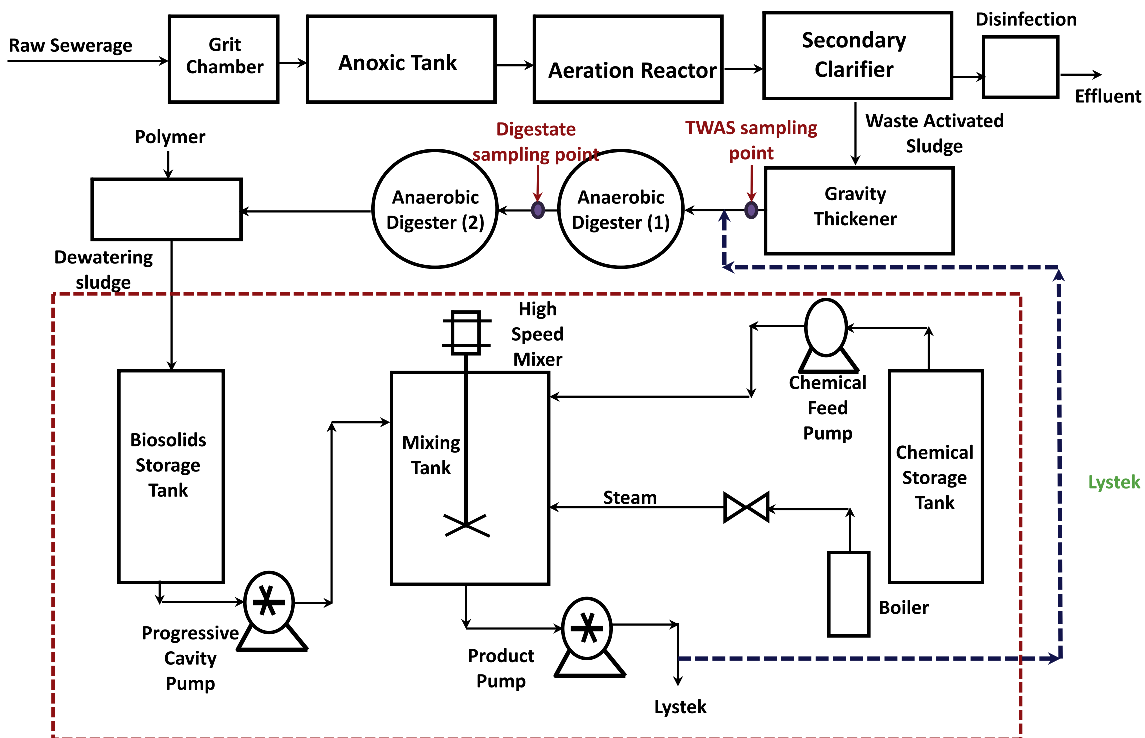

Fig. 1. Process flow diagram of St. Marys WWTP and Lystek system.

TWAS (1300 mg $CaCO_3$/L) and the digestate (3000 mg $CaCO_3$/L). A sample of the mixture was then collected for initial analysis. The headspace was flushed with nitrogen gas at 5–10 psi for a period of 5 min prior to closing the cap. The bottles were then placed in a swirling-action shaker (Max Q4000, Incubated and Refrigerated Shaker, Thermo Scientific, CA) operating at 180 rpm and maintained at a temperature of 37 °C. The volume of the gas produced was measured by releasing the bottles headspace pressure, using appropriately sized glass syringes (Perfektum; Popper & Sons Inc., NY, USA) in the 5–100 mL range to equilibrate with the ambient pressure, as recommended by Owen et al. (1979). The gas composition was analyzed every day for the first 6 days and then every 2–3 days until the test was completed i.e. cumulative gas curve reached a plateau. At the end of the experiment, the samples were analyzed for TCOD, SCOD, TSS, and VSS.

The SMA tests were conducted to evaluate the activity of the acetotrophic methanogens in the digestate from the St. Mary's full-scale digester using acetate as substrate. The digestate or the seed was collected from the full-scale digester once every month for eight months. The volumes of digestate and the acetate were calculated to maintain four different S/X ratios of 0.25, 0.5, 1.0 and 2.0, on mass COD/mass VSS. One (1) mL of a nutrient stock solution, with the following composition in 1 L, was added to each bottle: 280 g NH_4Cl, 250 g of K_2HPO_4, 100 g of $MgSO_4 \cdot 7H_2O$, 10 g of $CaCl_2 \cdot 2H_2O$, 2 g of $FeCl_2 \cdot 4H_2O$, 0.05 g of H_3BO_3, 0.05 g of $ZnCl_2$, 0.03 g of $CuCl_2$, 0.5 g of $MnCl_2 \cdot 4H_2O$, 0.05 g of $(NH_4)_6Mo_7O_{24}$, 0.05 g of $AlCl_3$, 0.05 g of $CoCl_2 \cdot 6H_2O$, and 0.05 g of $NiCl_2$. Furthermore, 1 g $NaHCO_3$ was added to each bottle to maintain buffering capacity. The volumes of digestate, nutrients, and acetate were then added to the batch test bottle (total liquid volume of 200 mL and headspace volume of 60 mL). All other conditions and procedures were similar to the BMP test.

2.5. Analytical methods

Samples were analyzed for total suspended solids (TSS), volatile suspended solids (VSS), total and soluble biochemical oxygen demand (TBOD, SBOD), and alkalinity using standard methods (APHA, 1995). Total and soluble chemical oxygen demand (TCOD, SCOD) were measured using HACH methods and test kits (HACH Odyssey DR/2500). Soluble parameters were determined after filtering the samples through 0.45 μm sterile membrane filter paper (Whatman, Cole-parmer, Montreal, Canada). Biogas production was collected by wet tip gas meters (Gas meters for Laboratories, Nashville, TN). The gas meter consisted of a volumetric cell for gas–liquid displacement, a sensor device for liquid level detection, and an electronic control circuit for data processing and display. Biogas composition including hydrogen, methane, and nitrogen was determined by a gas chromatograph (Model 310, SRI Instruments, Torrance, CA) equipped with a thermal conductivity detector (TCD) and a molecular sieve column (Molesieve 5A, mesh 80/100, 6 ft × 1/8 in). The temperatures of the column and the TCD detector were 90 and 105 °C, respectively. Argon was used as the carrier gas at a flow rate of 30 mL/min. The concentrations of volatile fatty acids (VFAs) were analyzed after filtering the sample through 0.45 μm using a gas chromatograph (Varian 8500, Varian Inc., Toronto, Canada) with a flame ionization detector (FID) equipped with a fused silica column (30 m × 0.32 mm). Helium was used as the carrier gas at a flow rate of 5 mL/min. The temperatures of the column and detector were 110 and 250 °C, respectively.

3. Results and discussion

3.1. Anaerobic biodegradability of TWAS, Lystek, and TWAS plus Lystek

The anaerobic biodegradability of TWAS, Lystek, and TWAS plus 4% by volume Lystek was evaluated using continuous stirred-tank reactors (CSTRs) at two SRTs of 10 and 15 days. For the Lystek feed, the raw Lystek was diluted, based on COD, prior to feeding in order to achieve the same OLR for the TWAS of about 3.3 kg COD/m^3 d. Fig. 2a shows the methane production rates of the TWAS, Lystek, and TWAS with 4% Lystek at an SRT of 10 days. Average steady-state methane production rates of 4.1, 7.0, and 4.9 L CH_4/d were observed for the TWAS, Lystek, and TWAS with 4% Lystek, respectively. When

4% Lystek by volume was added to the TWAS, the methane production rate increased by about 20%, from 4.1 to 4.9 L CH_4/d. Fig. 2b and c show the methane yields of the different feeds. As shown in Fig. 2b, a methane yield of 7 L/L_{feed} was observed for Lystek, 70% higher than 4.1 L/L_{feed} for TWAS. Moreover, the methane yield from TWAS with 4% Lystek at 4.9 L CH_4/L_{feed} was 20% higher than that the methane yield from TWAS only. This increase was not only due to the higher SCOD of the Lystek feed of 18,000 mg/L (after dilution to maintain the same OLR of 3.1–3.3 kg COD/m^3.d) compared to TWAS of 710 mg/L, but also due to the effect of the steam-aided alkaline hydrolysis pretreatment which reduces the particle size resulting in increased specific surface area, and hence enhanced digester performance (Sanders et al., 2000). As shown in Table 1, the SCOD to TCOD ratios in the Lystek and TWAS were 48% and 2%, respectively. On the other hand, 4% Lystek addition to the TWAS increased the methane yield by only 20%, from 4.1 L CH_4/L_{feed} to 4.9 1 L CH_4/L_{feed}. This increase in methane yield after adding 4% Lystek was expected due to the increase in the SCOD from 710 mg/L for TWAS only to 2900 mg/L for the TWAS with 4% Lystek. The increase in the SCOD due to 4% Lystek addition of 2200 mg/L is equivalent to about 0.8 L methane (identical to the observed), suggesting that the increase in the methane yield of the TWAS with Lystek addition was mainly due to the increase in the SCOD. On the other hand, as shown in Fig. 2c, methane yields of 0.22, 0.26, and 0.32 L CH_4/g VSS_{added} were observed for the TWAS, Lystek, and TWAS with 4% Lystek feed, respectively. The aforementioned increase in the methane yield per g VSS_{added} represents a 20% enhancement compared to the TWAS only. Furthermore, there were no differences in the methane yields based on the TCOD added, 0.122 and 0.127 L CH_4/g $TCOD_{added}$ for TWAS, and TWAS with 4% Lystek, respectively. Furthermore, as shown in Fig. 3a, the VSS destruction efficiency for Lystek of 52% was 27% higher than that of TWAS only (41%) and 11%

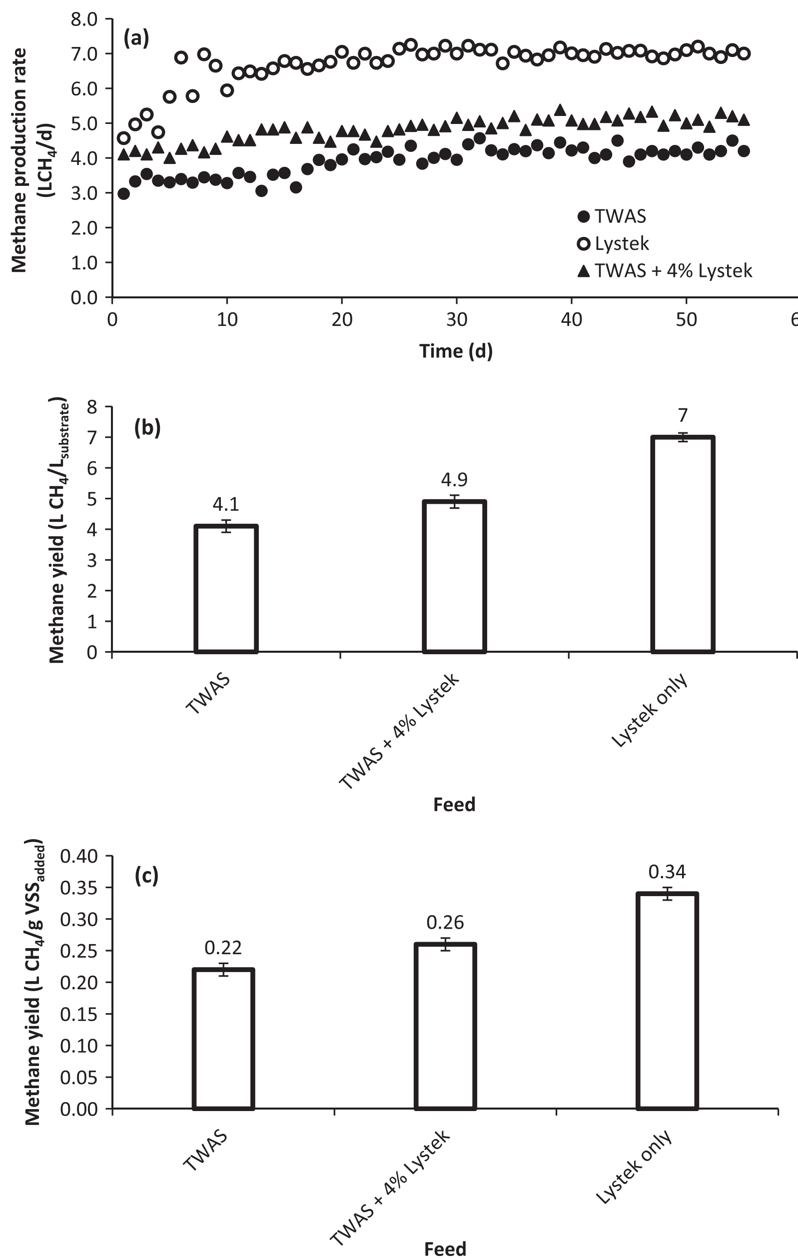

Fig. 2. Average methane production rate and yields of the different feeds at SRT of 10 days (a) methane production rate, (b) methane yield as $LCH_4/L_{substrate}$ and (c) methane yield as LCH_4/g VSS_{added}.

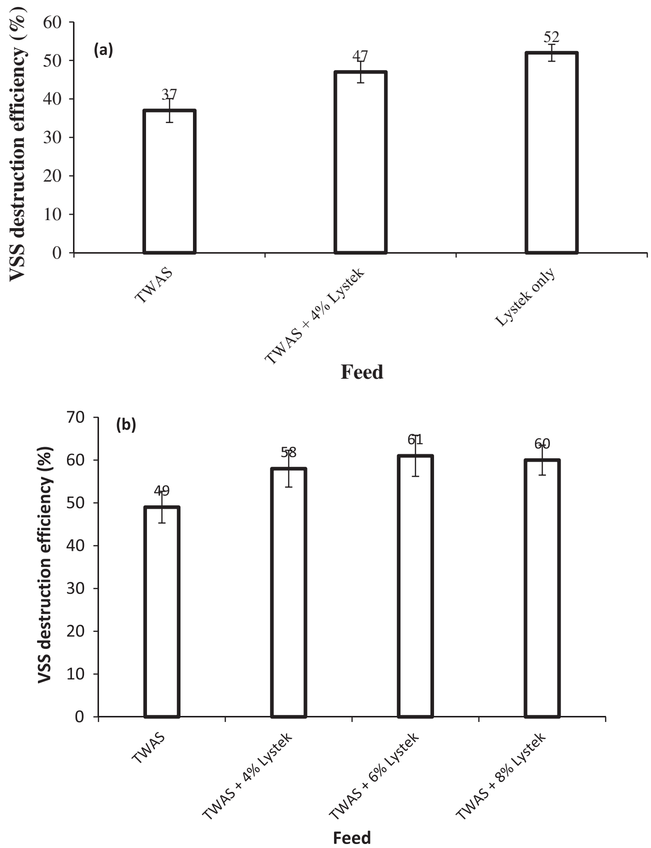

Fig. 3. Average volatile suspended solids (VSS) destruction efficiencies of the different feeds at (a) SRT of 10 days and (b) SRT of 15 days.

higher than that of TWAS plus 4% Lystek (47%). The increase in VSS destruction due to 4% Lystek addition to TWAS feed was 27% compared to TWAS only (47% vs. 37%, see Fig. 3a). Based on the aforementioned results, it was obvious that adding 4% Lystek by volume to the TWAS in a CSTR at SRT of 10 days resulted in 20% and 27% increase in methane yield and VSS destruction efficiency, respectively. The findings of this study are comparable with some thermal pretreatment processes. Bishnoi (2012) reported a 10% increase in the VS destruction efficiency and 18% increase in methane production compared to the control digester when the TWAS was pretreated at 170 °C for 3 h contact time prior to feed to CSTR at an SRT of 15 days. Furthermore, EXELYS by Kruger Inc., a subsidiary of Veolia Water developed a thermal pretreatment system which produced 20–40% more biogas compared to the control digester (Bishnoi, 2012). Furthermore, Tiehm et al. (1997) applied ultrasonication in a pilot plant using a high performance ultrasound reactor (3.6 kW, 31 kHz) for 64 s on a mixture of primary sludge and WAS (53% primary sludge and 47% WAS) with average VSS of 25 g/kg, and observed a 10% increase in VS removal efficiency of sonicated waste over the conventional AD process at an SRT of 22 days. It must be asserted, however, that the performance of the post-AD thermo-alkaline biosolids treatment is indeed superior to the two aforementioned thermal and ultrasonication technologies, despite treating a less biodegradable waste stream.

3.2. Impact of Lystek addition doses on the anaerobic biodegradability of TWAS

The effect of different doses of Lystek addition on the anaerobic biodegradability of TWAS from St. Marys WWTP was evaluated in a CSTR at an SRT of 15 days using three different doses of 4%, 6%, and 8% by volume. The OLR varied from 2.6 kg COD/m^3 d for the TWAS only and increased gradually with Lystek addition to 3.4 kg COD/m^3 d for the TWAS with 8% Lystek. Fig. 3b shows the VSS destruction efficiency of the TWAS only, and the TWAS with Lystek addition. A VSS destruction efficiency of 49% was observed for TWAS only compared to about 58–61% for TWAS with Lystek. The increase in VSS destruction efficiency was 18% when 4% of Lystek was added and about 24% when 6% or 8% of Lystek was added. Based on the abovementioned results, it was clear that increasing the Lystek dose from 4% to 6% or 8% did not have a significant effect on either methane production or solids destruction, as the difference between the absolute methane yields was less than 10%.

Fig. 4a shows the methane production rates of the TWAS, and TWAS with the different Lystek doses. As shown in the Figure, an average steady-state methane production rate of 4.3 L CH_4/d was achieved for TWAS only, increasing to 4.9 L CH_4/d at 4% Lystek, and to 5.1 and 5.4 L CH_4/d at 6% and 8% Lystek addition, respectively.

Fig. 4b and c show the methane yields of the TWAS and the TWAS with different Lystek doses. As shown in Fig. 4b, the methane yield increased from 5.8 L/L_{feed} for TWAS only to 6.3, 6.9, and 7.2 L/L_{feed} when Lystek was added at doses of 4%, 6%, and 8%, respectively. The volumetric methane yield at an SRT of 15 days increased by only 8% at 4% Lystek and to 19% and 24% at 6% and 8% Lystek addition, respectively. It should be noted that the incremental methane production with Lystek was about 90% of the theoretical methane production based on the increased SCOD only. For example, as shown in Table 1, the SCOD increased from 710 mg/L for TWAS only to 2900 mg/L for TWAS with 4% Lystek, while the increase in methane production rate was 0.54 L/d.

Interestingly, there were no significant differences between the yields of the TWAS only and the TWAS with Lystek at any dose when normalized per mass of VSS added, with methane yields of 0.27–0.29 L CH_4/g VSS_{added} observed for all feeds (see Fig. 4c). The paired *t*-test results confirmed that there were no statistically significant differences at the 95% confidence level.

3.3. Comparison between CSTRs's Performance at SRT of 10 days and 15 days

Based on the aforementioned results, the methane yield of TWAS only increased by 40% when the SRT increased from 10 days to 15 days, to 5.8 L CH_4/L_{feed}. Furthermore, the increase in methane yield due to the increase in the SRT from 10 to 15 days was less pronounced for the TWAS plus 4% Lystek, as the methane yield increased by 30%, (4.7 vs. 6.3 L CH_4/L_{feed}). The increase in volatile solids destruction efficiencies with the longer SRT were 32% and 23% for TWAS only, and TWAS plus 4% Lystek, respectively.

On the other hand, the influence of Lystek addition on methane yield and solids destruction efficiencies was more pronounced at the shorter SRT (20% at an SRT of 10 d vs. 9% at an SRT of 15 d for methane yield) and 27% at an SRT of 10 d) compared to 22% at an SRT of 15 d for VSS destruction efficiency.

The paired t-test was used to test the hypothesis of equality at the 95% confidence level. The null hypothesis was defined as no difference between the two groups tested vs. the alternative hypothesis that there is a statistical difference between the two groups. Based on the results of the *t*-test presented in Table 4, it was evident that for the SRT of 10 days, there were statistically significant differences between the methane produced from different substrates. Furthermore, for SRT of 15 days, there were statistically significant differences between the methane produced from TWAS and the other substrates i.e. TWAS plus Lystek at any dose. On the other hand, comparing the methane produced from the TWAS plus 4% Lystek with the TWAS plus 6% or 8% Lystek, there were no statistically significant differences at 95% confidence level as displayed in Table 4.

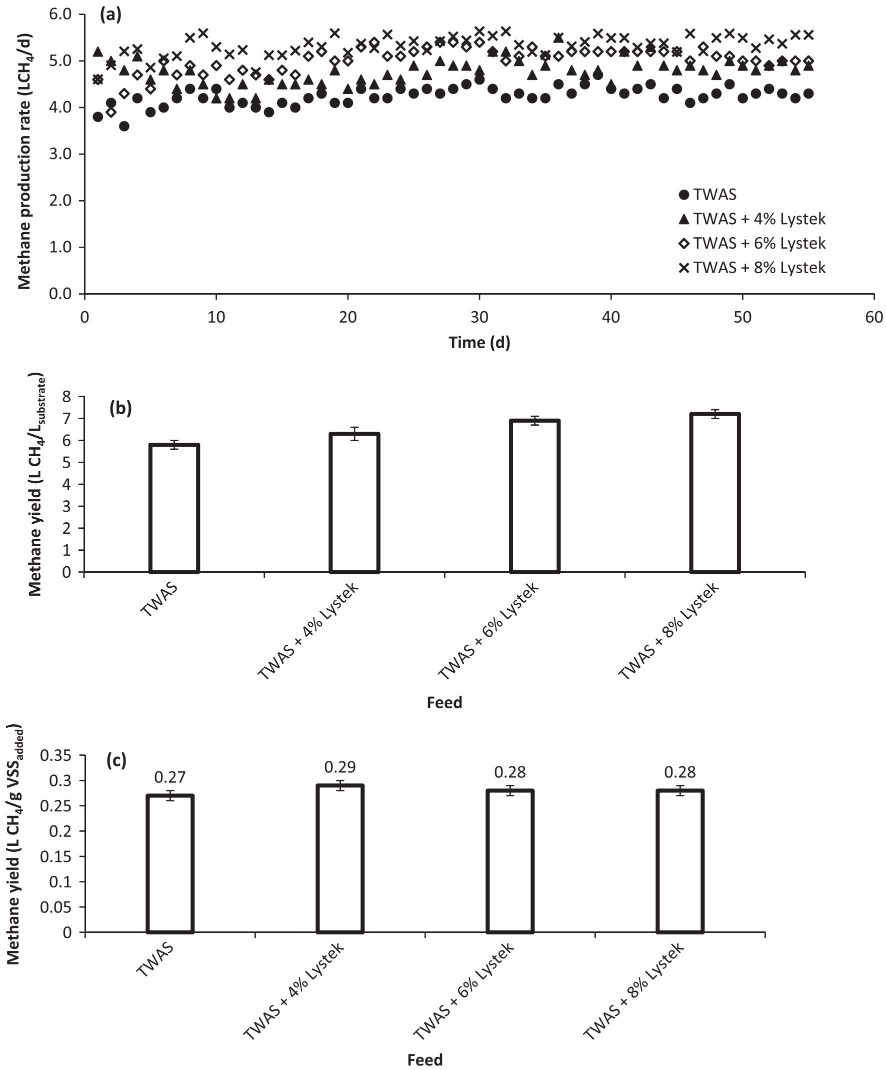

Fig. 4. Average methane production rate and yields of the different feeds at SRT of 15 days (a) methane production rate, (b) methane yield as $LCH_4/L_{substrate}$ and (c) methane yield as LCH_4/g VSS_{added}.

3.4. First order kinetic coefficients and predicted VSS destruction

The first order kinetic coefficients (k) were calculated for the different feeds based on the VSS destruction and the SRT using the following equation (Vavilin et al., 2008):

$$K = \frac{1}{t}\ln\frac{C}{C_0} \quad (1)$$

where t is the SRT (d), C is the effluent VSS concentration, and C_0 is the influent concentration or C/C_0 = (100 – VSS destruction efficiency)/100

Table 2 presenting the first order kinetic coefficients of the different feeds at different SRT, indicates that k values of 0.053 d^{-1} and 0.073 d^{-1} were observed for TWAS and Lystek at an SRT of 10 days. Thus, it is evident that Lystek degradation kinetics are 40% faster than the TWAS. For TWAS only, by increasing the SRT from 10 to 15 days, the VSS destruction efficiency increased by 20% (41% vs. 49%) and the k value decreased by 15% from 0.053 d^{-1} to 0.045 d^{-1}. The k value of the TWAS plus Lystek at an SRT of 15 days was mostly around 0.061 d^{-1}, exhibiting no sensitivity to the percentage of Lystek in the feed.

To predict the VSS destruction efficiencies for the TWAS with Lystek at the 15-days SRT, the k value of 0.045 d^{-1} (see Table 2) for TWAS only at an SRT of 15 days was used and the k value of the Lystek only at an SRT of 15 days was estimated based on the k value of Lystek only at SRT of 10 days (0.073 d^{-1}) and the 15% decrease in TWAS's k value at the longer SRT i.e. k (Lystek at SRT of 15 days) = 0.073 × (0.045/0.053) = 0.062 d^{-1}. The predicted VSS destruction efficiencies of the TWAS plus Lystek were calculated based on the k values of TWAS only and Lystek only and the SRT. As shown in Table 3, the observed (measured) VSS destruction efficiencies were higher than the predicted one by about 14–19% which emphasized that the observed VSS destruction efficiencies of the TWAS plus Lystek mixtures were not merely the cumulative VSS destruction of TWAS and Lystek solids, but that indeed there

Table 2
First order kinetic coefficients of the CSTRs.

Feed	SRT d	Measured VSS destruction eff. (%)	k d^{-1}
TWAS only	10	41	0.053
TWAS only	15	49	0.045
Lystek only	10	52	0.073
TWAS + 4% Lystek	10	47	0.063
TWAS + 4% Lystek	15	58	0.058
TWAS + 6% Lystek	15	61	0.063
TWAS + 8% Lystek	15	60	0.061

Table 3
Comparison between measured and calculated VSS destruction efficiencies for TWAS + Lystek at an SRT of 10 days.

Feed	SRT d	Lystek addition g TSS/d	TWAS addition g TSS/d	Predicted effluent VSS g VSS/d	Predicted VSS destruction efficiency (%)	Measured VSS destruction efficiency (%)
TWAS + 4% Lystek	10	2.0	21.1	9.7	42	47
TWAS + 4% Lystek	15	1.5	15.8	8.7	50	58
TWAS + 6% Lystek	15	2.3	15.5	9.0	51	61
TWAS + 4% Lystek	15	3.0	15.2	9.3	51	60

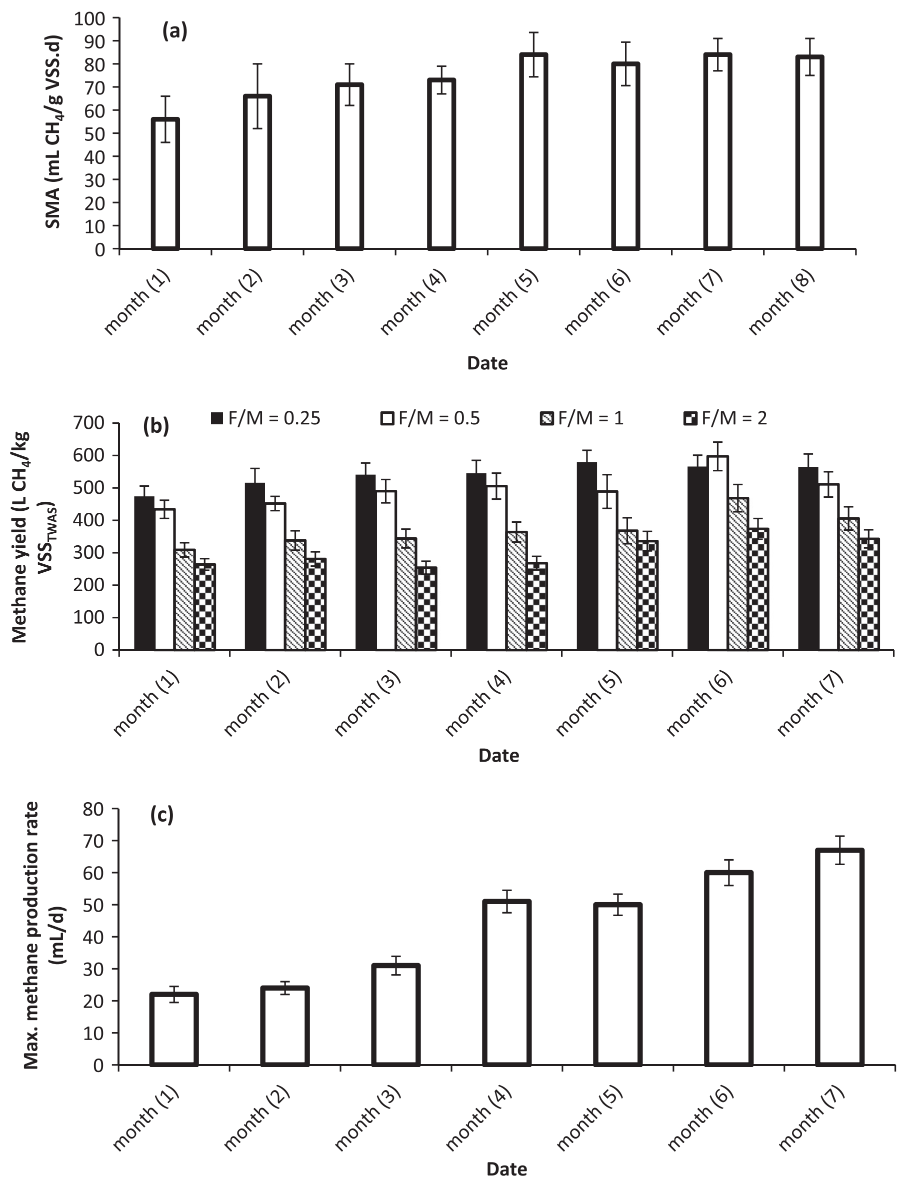

Fig. 5. Temporal variation of (a) average specific methanogenic activity of St. Marys digestate, (b) methane yields at different F/M ratio during the BMP tests and (c) Maximum methane production rate during the BMP tests.

was some synergy between Lystek and TWAS that enhanced overall VSS destruction efficiencies.

3.5. Long-term impact of recirculated Lystek on St. Marys full-scale anaerobic digester

The long-term impacts of recirculated Lystek sludges at 4% by volume to the full-scale primary anaerobic digester at St. Marys WWTP (AD1 in Fig. 1) were evaluated by monthly measurements of the activity of methanogenic bacteria as well as the BMP from the TWAS. Eight SMAs were conducted using different eight samples (seed) collected monthly from St. Marys full-scale anaerobic digester. Four different substrate to biomass' ratios (S/X) of 0.25, 0.5, 1.0, and 2.0 g COD/g VSS were used. Fig. 5a shows the average SMA of St. Marys digestate over time. It is noteworthy that the coefficient of variations (CV) of all SMA results were less than 10% except for the first two SMAs (CV was 17–20%). As depicted in Fig. 5a, the average SMA increased gradually during the first four months and then stabilized during the last four months. In the first four runs, the SMA gradually increased from 56 mL/gVSS-d for first

Table 4
Result of the paired *t*-test for the methane production.

		T-test (value)			
		TWAS	Lystek	TWAS + 4% Lystek	TWAS + 6% Lystek
CSTR 10 days	Lystek	64.12 (0.00)			
	TWAS + 4% Lystek	18.20 (0.00)	47.27 (0.00)		
CSTR 15 days	TWAS + 4% Lystek	9.82 (0.00)			
	TWAS + 6% Lystek	30.72 (0.00)		1.22 (0.12)	
	TWAS + 8% Lystek	32.57 (0.00)		0.62 (0.27)	0.26 (0.40)

month sample to 84 mL/gVSS-d for the fifth month sample, and then stabilized for the samples from months six to eight at about 83 mL/gVSS-d. Thus, it was evident that the St. Marys digestate required five months to achieve 50% enhancement in the methanogenic activity after the addition of Lystek to the digester at 4% of the feed by volume. The COD mass balance closures ranged between 88% and 103%, thus emphasizing data reliability. On the other hand, the final pH of all SMA was above 6.5, ranging from 6.5 to 7.4.

Fig. 5b shows the average net yields (after correcting for the seed sludge biogas) from the seven BMP tests as L CH_4/kg VSS_{feed} at the four different S/X ratios. As shown in Fig. 5b, the methane yield exhibited the same trend of gradual increase from the beginning to the fifth month and stabilization thereafter for the S/X ratios of 0.25, 0.5, and 1.0 g COD/g VSS. For all batches, the methane yields decreased with increasing the S/X ratio The highest methane yields were observed at S/X ratio of 0.25 g COD/g VSS with the methane yield increasing gradually from 474 L CH_4/kg VSS_{feed} for the first sample to 580 L CH_4/kg VSS_{feed} for the fifth month sample, after which, the methane yield decreased slightly to 566 L CH_4/kg VSS_{feed}. Furthermore, as shown in Fig. 5c, the maximum methane production rate (MMPR) followed the same trend of the methane yield. The MMPR increased from 22 mL/d in first month sample to a maximum of 67 mL/d in last sample. It must be emphasized that the BMP test were run for 65–88 days, The COD mass balance closures of the BMP tests ranged between 91% and 107%, thus emphasizing data reliability. On the other hand, the final pH of the BMP tests ranged from 7.3 to 7.8.

As observed from the SMA and BMP tests conducted to evaluate the long-term performance of the full scale digester, it was evident that the activity and/or number of various microbial groups i.e. acidogens, acetogens, and methanogens increased after Lystek addition. This could be due to the faster biodegradation kinetics as delineated in the side-by-side laboratory comparative testing, or microbial population dynamics, which required further testing beyond the scope of this study.

4. Conclusion

The outcome of this study emphatically revealed the positive effect of Lystek addition on the anaerobic digestability of TWAS on both lab and full-scale digesters. Based on the findings of this study, the following conclusions can be drawn:

- Adding 4% Lystek by volume to the TWAS feed in a CSTR at SRT of 10 days resulted in 20% and 27% increase in methane yield and VSS destruction efficiency, respectively.
- The volumetric methane yield at an SRT of 15 days increased by 8%, 19%, and 24% when 4%, 6%, and 8% of Lystek was added to the feed, respectively.
- The methane production rate increased from 4.3 L CH_4/d to 4.9, 5.1, and 5.4 L CH_4/d when 4%, 6%, and 8% Lystek were added to the TWAS, respectively.
- The increase in VSS destruction efficiency was 18% when 4% of Lystek was added and 24% when 6% or 8% of Lystek was added.
- At an SRT of 15 days, there were no significant differences between the yields of the TWAS only and the TWAS with Lystek at any dose when it normalized per mass of VSS added.
- The methane yield increased by 40% and 30% when the SRT increased from 10 days to 15 days for TWAS only, and TWAS with 4% Lystek, respectively.
- Lystek degradation kinetics were 40% faster than the TWAS.
- SMA results showed that Lystek addition at 4% by volume to the full-scale primary anaerobic digester at St. Marys WWTP enhanced the methanogenic activity by 50% after five months.
- BMP results showed that Lystek addition at 4% by volume to the full-scale primary anaerobic digester at St. Marys WWTP improved the methane yield by 22% after five months.

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APPENDIX H

LysteGro Product Management

LysteGro Product Management

Pictured above: Using a liquid vacuum system eliminates the need to stockpile biosolids on the field prior to application; reducing potential odor, vector attraction and loading/unloading times.

Pictured above: Standard liquid manure injection equipment is used to apply LysteGro product

APPENDIX I

Advantages of LysteGro

Lystek
Nothing wasted.
Everything to gain.

Advantages of LysteGro

Class A Quality, High Solids, Liquid Biofertilizer Product

The Lystek Thermal Hydrolysis Process (Lystek THP®) technology produces a concentrated high solids liquid product, LysteGro®, that is considered a Class A biosolids in the US and a Canadian Food Inspection Agency (CFIA) registered fertilizer in Canada. LysteGro has a solids content that generally ranges from 13 – 16% with a viscosity below 8,000 centipoise, which means that it is fully pumpable using traditional liquid manure handling and application equipment.

There are several advantages to managing a Class A quality, high solids liquid product.

Simple and Cost Effective Liquid Pumping and Storage Systems

Pumping LysteGro from processing to storage, and from storage to truck loading is completed with standard pumps proven within the industry. This allows for rapid, low maintenance pumping operations, and accurate quantif cation of the volumes. Liquid solutions offer automation that is not possible compared to solid loading operations which often required manned loading equipment. Concentrated liquid storage solutions reduce real estate footprint compared to solid options as storage tanks can be constructed with practically unlimited vertical storage capacity unbound by the slumping properties of dewatered biosolids.

Loading and Unloading Efficiencies

Depending on the site requirements and product volumes, loading of tanker trucks can be completed Extremely quickly (5 – 10 minutes at larger facilities) and accurately. Additionally, in the feld, the tankers can be unloaded in as little as 5 minutes. The result is an efficient and clean program at both the loading and feld sites with minimal staffing requirements.

Odor Management

From the point of production to application in the feld, the product is completely contained within enclosed reactors, piping systems, storage, tanker trucks, and fnally the soil. This is a signifcant advantage when managing odor concerns throughout the life cycle of the process. Lystek THP generates minimal process air compared to dry alternatives which require the evaporation of water, and the liberation of odorous compounds that must then be captured and treated.

Application Efficiency and Cost Effectiveness

Due to the loading methods at the WWTP and in the feld, LysteGro application programs are highly efficient. At the feld, the product is transferred directly from the highway tanker to the feld tanker and injected into the soil, requiring only one pass. This translates to less equipment, less human power, and less time spent on felds.

Application Accuracy and Nutrient Use Efficiency

The application rate is controlled with fow meters and GPS systems to ensure it is placed evenly and accurately throughout the feld. This provides confdence that the customer can rely on the material as a synthetic fertilizer replacement. This also creates opportunities for farmers to utilize their GPS technology to place the seed close (within 2" for example) to the band of LysteGro to optimize nutrient use efficiency of the product. The sub-surface injection of the product minimizes nitrogen loss, maximizing the effective nutrient value of the product.

Environmental Protection

LysteGro is sub-surface injected, which increases soil contact, and essentially removes the risk of run-off. Additionally, because the material is concentrated, there is a dramatic reduction in the overall volume that must be applied per acre versus traditional liquid programs. As a result, application above the hydraulic loading rate of the soil is not a concern with this product.

Improved Optics (Out of Sight, Out of Mind)

Injection of the product minimizes soil disturbance, and the outcome is a professional job with little product on the soil surface, resulting in signifcantly reduced public concern.

Value Proposition to the Modern Farmer

The value proposition to the farmer is to provide a consistent quality product they can rely on to improve yields and reduce input costs. The Lystek approach to fertilizer management is preferred by farmers compared with historical application methods, as it only requires one pass to inject and incorporate the product. Additionally, it is compatible with minimum till systems, which are rapidly growing in popularity in agricultural systems throughout North America.

LysteGro
Nothing wasted.
Everything to gain.

T. 226.444.0186
TF. 888.501.6508
E. info@lystek.com
lystek.com

water's next awards 2017 WINNER!

GEELA – Governor's Environmental & Economic Leadership Award – California

APPENDIX J

Curriculum Vitae

CURRICULUM VITAE

JAMES DUNBAR, P.E.

General Manager/
Business Development Manager – California

EDUCATION

- Bachelor of Science-Engineering (minor in environmental), University of Notre Dame, Indiana
- Associate Degree-Geology, Los Angeles Valley College, California
- Masters in Business Administration-St. Xavier University, Illinois

PROFESSIONAL QUALIFICATIONS

- Licensed Engineer in CA, AR, AZ, OK, OR, WA
- Active member of CASA, SWANA and ASCE
- Technical presenter at CASA and SWANA annual conferences
- University presenter at University of Arkansas, Fayetteville

PROFESSIONAL QUALIFICATIONS

- Served on Planning Commission, City of Fairfield, CA
- Served as Chair, Integrated Waste Management Task Force, Solano County
- Board of Director for Fairfield-Suisun Chamber of Commerce
- Board of Director for Solano Economic Development Commission
- Past President, Solano County Library Foundation
- Past President, Fairfield Police Activities League
- Past President, Fairfield-Suisun Public Education Foundation

EMPLOYMENT

Lystek International Inc. (Cambridge, Ontario)

Independent Consultant **January 2014 - Present**

- Provide professional consulting service in the solid waste, wastewater, waste-to-energy and organics management fields; maintain relationship with customers and regulatory/permitting agencies for conformance with operating permits as requested; conduct regular meetings with special districts as needed.

Potrero Hills Landfill, Republic Services, Inc. & Waste Connections, Inc.

District Manager/Project Engineer 2007-2014

- Served as District Manager/Project Engineer for regional material processing and disposal operations in Northern CA; completed major expansion project by securing permits from CalRecycle, BCDC, RWQCB, USACOE, CaDF&W, USF&WS, BAAQMD; increased revenues with 25% growth in new business and reduced non-fixed operational expenses by 35%; reduced accidents/incidents by 60+%

COACHELLA VALLEY WATER DISTRICT, Riverside County, CA

Sanitation Supervisor 2006-2007

- Served as Sanitation Supervisor within the Engineering Division; directed daily activities for professional engineering staff; oversaw technical development of four waste water treatment plants and District-wide sanitary and recycled water distribution system; completed expansion of two wastewater plants with enhanced biosolids treatment systems; developed sewer master plan for next generation of residential/commercial development

1987-1998 WASTE MANAGEMENT, INC.

(Mid-California Dist.-'87-'90, International Division-'90-'98, Arkansas-'01-'05)

District Engineer, Supervisory Group Leader 2001-2005

- Served as District Engineer, Supervisory Group Leader and State-wide Operations Manager; performed oversight of organics and landfill operations; performed technology transfer and due diligence acquisition role for International Division (Italy, France, England); served as regional manager for operations at composting, transfer and hauling locations

CITY OF NORMAN (Public Works), OKLAHOMA

Development Manager 1999-2001

- Served as development manager for all City projects; worked with residential and commercial developers on design of new housing sites and commercial buildings; oversaw design of sewer upgrades and new street construction

David Boyle Engineering, Santa Ana, CA

Project Manager 1986-1987

- Served as construction project manager for residential and commercial tract development; performed engineering calculations in support of civil design, lot layout, hydrology/hydraulic studies for drainage, and curb and gutter design.

U.S. ARMY CORPS OF ENGINEERS (Chicago District)

Chief, Maintenance & Operations Division **1978-1986**

- Served as construction inspector, Chief, Maintenance & Operations Division, and Chief, Finance Division; performed construction review and resident engineer duties for navigation and coastal development projects; responsible for $10MM annual budget for waterway and harbor improvements; managed the dredged disposal material program and development of new disposal technology

FREDERICK (RICK) A. MOSHER, P. ENG.

Chief Technical Officer

EDUCATION

B.A.Sc. - University of Waterloo (Civil Engineering), 1986

Trade Cert. - Carpentry Apprenticeship, George Brown College, 1974
(Completed with inter-provincial trade certification)

Other Courses

- Construction Law (post grad course), University of Waterloo, 1975
- Project Management (post grad course), University of Waterloo, 1975
- Construction Management, Conestoga College, 1974

EMPLOYMENT

- 2003- Chief Technology Officer, Lystek International Inc.
- 2004-2010 Vice-President, Conestoga-Rovers & Associates
- 2004-2010 Vice-President, Kane-CRA JV Ltd.
- 2005-2008 Vice-President, Orgaworld Canada Ltd.
- 1992-2003 Associate, Conestoga-Rovers & Associates
- 1995 Design Services Coordinator, Conestoga-Rovers & Associates
- 1989 Project Director & Manager, Conestoga-Rovers & Associates
- 1989-95 Branch Manager - Mississauga Office, Conestoga-Rovers & Associates
- 1988-89 Project Co-ordinator, Conestoga-Rovers & Associates
- 1986-88 Project Engineer, Conestoga-Rovers & Associates
- 1985 Field Engineer, Dufferin Construction Limited
- 1984 Research Assistant, University of Waterloo
- 1983 Construction Supervisor, Fletcher Contracting Limited
- 1980-82 Construction Manager, Westmount Engineering
- 1977-80 Partner, Manager, Estimator, Jaric General Contracting
- 1972-77 Carpenter, Surveyor, Foreman, Construction Superintendent, Whitman Contracting Limited
- 1970-72 Tradesman, Pernfuss Roofing Limited (Kitchener)

AFFILIATIONS

- Professional Engineers Ontario (PEO)
- Member of the Rotary Club (Kitchener Grand River)
- Founding Member of Landfill Gas Industry Alliance (LFGIA)
- Solid Waste Management Association of North America (SWANA)

PROFILE OF PROFESSIONAL ACTIVITIES

Management Activities

- President & CEO of Lystek International Inc., a high technology firm with a proprietary technology to process biosolids from the municipal wastewater sector and the agricultural industry for land application as a Class A biosolid (2003-)
- Vice-President of Kane-CRA JV Ltd. for development of solid waste management services in the Philippines (2005-2010)
- Vice-President of Orgaworld Canada Ltd. for development of waste processing systems in Ontario and the United States (2005-2008)
- Vice-President of CRA, with corporate responsibility for development of solid waste management services (2004-2010)
- Director of Donson Engineering Ltd., an engineering and specialty construction services firm working in cooperation with CRA to develop wastewater treatment projects in North America (1999-2002)
- Corporate Account Manager for the Suncor Energy Inc. Alliance Agreement with CRA to develop LFG to Energy Facilities in North America and internationally (1999-2004)
- Director of CRA Contracting Ltd., a fully owned subsidiary of Conestoga-Rovers & Associates (1995-2000)
- Co-ordinator for organization of corporate design services and standardization of technical drawings and specifications (1995-present)
- Corporate responsibility for Conestoga-Rovers & Associates branch office in Mississauga, Ontario. Responsibilities include all administrative, staffing and financial management of the office (1989-1995 and 1998-2000)
- Principal in Jaric General Contracting responsible for business management, bid and cost estimating, and contract administration for numerous construction projects, primarily for Ontario's Ministry of Government Services and the Federal Department of Supply and Services (DSS) (1977-1980)
- Senior project manager and cost estimator for bid preparation and cost control for Whitman Contracting Ltd. (1976-1977) Selected Clean Development Mechanism/Joint Initiative (CDM/JI) & Related Projects
- Senior Technical Advisor and Peer Reviewer for feasibility studies to assess 10 landfills for CDM projects in Mexico, Brazil and Argentina on behalf of the World Bank (2007-)
- Principal in Charge of obtaining DOE certification under the UNFCCC and obtaining status as an independent validator/verifier under various other systems such as the Chicago exchange (2005-)
- Senior Technical Advisor to FCM for its initiative to develop a carbon trading business for its member municipalities throughout Canada (2007-)
- Senior Technical Advisor and Peer Reviewer for two CDM projects in Argentina at two large landfills near Buenos Aires that are owned and operated by CEAMSE (2006-)
- Senior Technical Advisor and Peer Reviewer for CDM projects in Manaus and Belem, Brazil (2006-)

- Project Manager for development of Landfill Gas Collection System to qualify as a CDM project at the Huilango Landfill in Mexico (2004-)
- Prime author and Project Director of the Handbook for the Preparation of Landfill Gas to Energy Projects for the World Bank that includes a work plan outline for the preparation of qualifying CDM/JI projects for this market sector (2003-2004)
- Technical Advisor for feasibility study for landfill gas management at the Nanaimo Landfill, BC, which was funded as an emission reduction project under the Green Municipal Fund (2002-)
- Project Director and Peer Reviewer for development of LFG to Energy projects for development of two CEAMSE landfills in Argentina (2004-)
- Project Director for the design of an expanded landfill gas collection system for emissions reduction (as per CDM requirements) at the Canabrava Landfill, Brazil (2004-)
- Project Director for the design and construction of a landfill gas utilization system at the Eastview Landfill in Guelph, Ontario, which qualifies as an emission reduction project under the PERRL system (2002-)
- Design and installation of an expanded landfill gas collection system at the Peterborough Landfill in Peterborough, Ontario, which qualifies as an emission reduction project under the PERRL system (2002-)
- Peer Reviewer/Technical Advisor for the design and construction of a pilot landfill gas utilization facility at the Canabrava Landfill, Brazil (2000-2003)
- Peer Reviewer of feasibility assessments for development of Villa Dominica Landfill Site for CEAMSE in Argentina to determine emission reduction ad energy recovery potential for the site (1999-2001)

Selected Site Assessment Projects

- Senior Advisor and Peer Reviewer of the Himco Superfund project in Indiana for the assessment and pending remedial design (2007-)
- Due Diligence and assessment of groundwater remediation methods at the Allied Ridge Landfill (2004-2005)
- Project Advisor and technical expert to assess the Landfill Gas management system compliance issues associated with landfill gas migration at the SOCCRA Landfill Site in Michigan (2003-)
- Project Director and senior engineer for assessing and developing remedial response programs for 9 Closed Landfills for the City of Toronto (2003-)
- Project Advisor and technical expert to assess the Landfill Gas management system compliance issues associated with landfill fires at the Seneca Meadows Landfill Site in New York state (2003-)
- Project Director and technical expert for the assessment and design of landfill gas management systems at the Ciceron Landfill Site in St. Lucia (2003)
- Project Manager for Environmental Site Audit of the HHW Building in Harriston, Ontario (2003-)
- Project Director for the Site Assessment and Redevelopment Plan of the Former Rail Lands at the City of North Bay waterfront (2002-)

- Peer Reviewer and Expert Advisor for Peer Review Assessment of Site 41 in Simcoe County on behalf of the County and Tiny Township (2002-2003)
- Project Manager for a hydrogeological assessment and the site and development and implementation of an environmental management plan at Federal Industries, NEO-Mead Ave. facility in Hamilton (1991-1994)
- Project Manager for the development and implementation of an environmental management plan at CCL Industries former Conn-Chem Plant in East York (1991-1995)
- Project Manager for hydrogeological and geotechnical investigations of various TTC sites in Metropolitan Toronto (1990-1991)
- Project Manager for the design and development of a Waste Management Plan for Pan Abrasive Inc. (1990-1991)
- Project Manager for the Site Investigation for Lafarge Canada Inc. at the Francon Quarry in Montreal, Quebec (1990)
- Project Manager for the review and assessment of the wastewater treatment alternatives for Moore Business Forms production facility in Fergus, Ontario (1990)
- Project Manager for various plant and site audit services including Genstar, Federal Industries, Westinghouse, CCL Industries and Triple M Metals Ltd. (1989)

Selected Landfill/Soil Gas Management Projects

- Senior Technical and Peer Reviewer for landfill gas to energy plants for the City of Hamilton (2007-)
- Senior Technical and Peer Reviewer for development of a landfill gas to energy project for the City of Sudbury (2006-2008)
- Project Director for the design and construction of a landfill gas collection and flaring system for the City of North Bay (2006-2007)
- Project Director for the design and construction of a landfill gas collection and flaring project for the Fredericton Solid Waste Management Commission (2006-2007)
- Project Manager for the assessment of landfill gas at the Moncton Landfill, Moncton, New Brunswick (2005-)
- Project Manager for the assessment of landfill gas at the Fredericton Landfill, Fredericton, New Brunswick (2005-)
- Management of emissions reduction at the Carleton Farms landfill in Michigan, U.S.A (2004-)
- Project Advisor and Peer Reviewer for the design and construction of a landfill gas collection system, Calgary Landfill, Calgary, Alberta (2004-)
- Technical Advisor for the design of a landfill gas collection system at the Seneca Meadows Landfill, Seneca Falls, New York (2004-)
- Project Advisor for the design and construction of a number of landfill gas to energy systems for Innovative Energy, various locations across the northeastern United States (2004-)

- Peer Reviewer and Policy Advisory Support for the Alberta Environment for management of closed landfills including landfill gas emissions (2004-2005)
- Project Director and primary author of the Handbook for the Preparation of Landfill Gas to Energy Projects being prepared on behalf of the World Bank (2003-)
- Project Director and technical expert for the reassessment of Canada's baseline greenhouse gas emissions estimate from the solid waste management sector Environment Canada (2003-)
- Landfill Gas Assessment at the Aurora Landfill, Aurora, Ontario (2003-)
- Project Advisor and technical expert assisting with the preparation of the RetScreen Model being prepared by Natural Resources Canada (2003)
- Design of the Landfill Gas Control System and Blower at the Waterloo Landfill, Waterloo, Ontario (2002-2004)
- Landfill Gas Management Support at a landfill in Calgary, Alberta (2002-)
- Project Manager for the Inventory of Landfill Sites in Canada with the potential for future development for both landfill gas control and utilization for Environment Canada (1999)
- Senior Design Engineer for Air Sparge/SVE system for Mercury Marine Ltd. site in Toronto (1998)
- Peer Reviewer/Technical Advisor for the LFG systems at Yeomen Creek Landfill in Illinois (1998-99)
- Peer Reviewer/Technical Advisor for the soil gas migration issues associated with a former Ford Motor Company facility in Michigan (1998-)
- Peer Reviewer/Technical Advisor for the landfill gas issues at the Eau Claire Landfill in Wisconsin (1997-98)
- Peer Reviewer for soil gas migration issue at Valleycrest Landfill in Ohio (1998)
- Project Manager for assessment and design of a landfill gas migration control system at the Tybouts Corner Landfill in Delaware (1997-)
- Project Manager for the preparation of Landfill Gas Collection and Control Design Plans for City Management Corporation for four large landfill sites in Michigan (1997)
- Project Manager for design and construction of SVE system at VacAir facility in New York (1996-1997)
- Project Manager for the design and construction of a landfill gas control system for the Morningside Landfill in the City of Scarborough (1995-1996)
- Project Manager for the design and implementation of an active landfill gas control systems at the Regional Municipality of Waterloo Landfill Sites (1993-1997)
- Project Manager for the assessment of the landfill gas generated at the Waterloo Landfill Site as a potential fuel source for recovery and utilization (1994-1996)
- Project Manager for the design and implementation of a landfill gas collection/disposal system at the Nepean Landfill for the Regional Municipality of Ottawa-Carleton (1992-1994)
- Project Manager for the design, and construction of a landfill gas collection, control, and disposal system at the Trail Road Landfill Site of the Regional Municipality of Ottawa-Carleton (1990-1992)

- Project Manager for construction of a landfill gas control system for Waste Management of Canada Inc. in Aurora, Ontario (1990-1991)
- Project Co-ordinator for the development of a landfill gas utilization program at the Keele Valley Landfill Site for the Municipality of Metropolitan Toronto (1988-1989)
- Project Co-ordinator for the site evaluation, preliminary design and detail design of the landfill gas control system at the Upper Ottawa Street Landfill for the Regional Municipality of Hamilton-Wentworth (1988)
- Project Co-ordinator for the site evaluation, preliminary design, and detail design of the landfill gas control system at the Port Mann Landfill for the District of Surrey (1988)
- Project Co-ordinator for the design of the Stage 2 and Stage 4 Header System at the Keele Valley Landfill for the Municipality of Metropolitan Toronto (1988-1991)
- Project Engineer for the preliminary and detail design of the landfill gas control system at the Marathon County Landfill in Wisconsin (1987-1988)
- Project Engineer for the construction of the landfill gas control plant at the Keele Valley Landfill for the Municipality of Metropolitan Toronto (1987-1988)

Selected Solid Waste Management Projects

- Project Manager for the design, construction and operation of the first solid waste landfill constructed in the Philippines pursuant to a World Bank funding and joint federal and state oversight (2005-)
- Project Manager for the design and construction of a new sanitary landfill, including landfill gas and leachate collection systems, for the International Development Bank, Georgetown, Guyana (2003-)
- Design of the expansion cell of a sanitary landfill, Bradley County Landfill, Cleveland, U.S.A. (2004-)
- Project Advisor and Peer Reviewer for the CKD Waste Assessment and Remedial Design for the Lafarge Ravena site in New York State (2003-)
- Project Director and senior engineer for development and implementation of a remedial program and Site Operations and Design for the Merrick Landfill Site in North Bay (2002-)
- Project Director and senior engineer for development and implementation of a Site Closure Plan for the Keele Valley Landfill Site (2002-2004)
- Peer Reviewer and project advisor for development and implementation of a Design and Operations Plan for the Sudbury Landfill Site including the detail design of a LFG management system (2002-)
- Project Director and senior engineer for assessing and developing a remedial response program for the Curity Landfill for the City of Toronto (2001-)
- Project Director and senior engineer for assessing and developing a remedial response program for the Amesbury Park Landfill for the City of Toronto (2001-)
- Peer Reviewer/Technical Advisor for the Tomah Landfill in Wisconsin (1999-2001)

- Project Manager and Senior Design Engineer for the Leachate reinjection systems at the Trail Road Landfill in Ottawa (1999-2000)
- Project Manager and Senior Design Engineer for the Holly Disposal Landfill in Michigan (1998-2000)
- Peer Reviewer/Technical Advisor for the design of the Woodstock Landfill in Wisconsin (1997-1999)
- Senior Design Engineer for the assessment and design of a remedial program for the Rhinelander Landfill Site in Wisconsin (1997)
- Project Manager/Senior Design Engineer for the leachate management systems at the Pine Tree Acres Landfill in Michigan (1997-2000)
- Senior Technical Advisor for landfill design at various USA Waste landfills in the southern United States (1997-1999)
- Technical Reviewer and senior design engineer for new TSCA Landfill Site at the Willow Run Creek Remediation Site in Michigan (1995-1996)
- Technical Reviewer, senior engineer for preparation of Remedial Design for G&H Landfill, Michigan (1994-1995)
- Project Manager for hydrogeological site assessment and development of a remediation program at the Morningside Landfill Site for the City of Scarborough (1994-1996)
- Project Manager for the multi-disciplinary consulting team to undertake all hydrogeological and technical studies necessary to support the design of an expansion to the Keele Valley Landfill Site (1991-1995)
- Senior Engineer and technical peer reviewer acting for the PRP group for the Helen Kramer Landfill Site in New Jersey (1994-1995)
- Project Manager and senior engineer for development and implementation of a stormwater management plan for the Keele Valley Landfill Site (1989-2002)
- Project Manager for the site design, development, operations, maintenance, and monitoring programs of the Bensfort Road Landfill Site of the City of Peterborough (1990-present)
- Project Manager for the design and construction of a leachate forcemain from the Bensfort Road Landfill Site for the City of Peterborough (1992)
- Project Manager for the site investigation, design and operations plan for a waste disposal site for the cement kiln dust at the Brookfield Facility for Lafarge Canada Inc. (1989-1990)
- Project Co-ordinator for the conceptual site design, stormwater management leachate control/disposal, and gas control/utilization at a proposed landfill site for Waste Management of Canada Incorporated (1989-1990)
- Project Engineer for the preliminary design of the leachate collection and pumping system at the Waterloo Landfill for the Regional Municipality of Waterloo (1987)

Selected Site Remediation and Groundwater/Wastewater Treatment Projects

- Senior Technical Advisor and Peer Reviewer for the development of an optimized wastewater treatment facility for the Town of St. Marys that uses a proprietary new technology and state of the art BNR/Oxic/Anoxic process train to reduce costs and expand plant capacity (2006-)
- Project Director for the technology assessment and development of a biosolids management system at the City of Guelph Wastewater Treatment Plant (2002-)
- Project Advisor and Peer Reviewer of the remedial assessment and design for the low level radioactive waste cleanup program being undertaken in Port Hope by the AECL (2002-)
- Technical Reviewer, senior engineer for site assessment and remedial design of the VacAir Alloys Site for Keywell Corporation in Frewsburg, New York (1996-1997)
- Technical Reviewer, senior engineer for preparation of Remedial Design for Willow Run Creek, Michigan (1995-1997)
- Project Manager for the site investigation and design of a site remediation program for Nacan Ltd. at the Hart Chemical Site in Guelph, Ontario (1991-1994)
- Project Manager for the assessment, all design phases and construction of a wastewater treatment system at Hart Chemical Company in Guelph, Ontario (1991-1994)
- Project Co-ordinator for site evaluation, preliminary design and detail design of a coal tar collection and treatment system for Algoma Steel Corporation Ltd. and Domtar Chemicals Ltd. at their facilities in Sault Ste. Marie, Ontario (1990-1991)
- Project Engineer for the design and construction of a PCB groundwater collection and treatment system for the T.T.I. transformer plant in Guelph, Ontario (1988)
- Project Engineer for the preliminary design of a PCB treatment plant for Westinghouse, London (1987)
- Project Engineer for the design and construction of the leachate collection system at the Lees Avenue Bus Transit Station for the Regional Municipality of Ottawa-Carleton (1986-1987)
- Project Engineer for the design and construction of the treatment plant and pumping station at the Lees Avenue Bust Transit Station (1986-1987)

Selected Construction and Other Projects

- Design-Builder for Landfill Gas Control project in Newcastle Delaware for the Tybouts Corner Landfill Trust Fund (1999-2000)
- EPC Contractor to design-build the Landfill Gas to Energy Facility at the Mohawk Landfill in Brantford (2000-)
- Project Co-ordinator for the stormwater management, site operations and report preparation for the Avondale North Clay Borrow Expansion Area for the Municipality of Metropolitan Toronto (1988-1989)
- Field Engineer responsible for the management and site supervision of heavy equipment operations for the site services and land development for Dufferin Construction (1985)

- Research and produced a report examining the potential damage to forests due to acidification as a research assistant at the University of Waterloo (1984)
- Construction Manager responsible for scheduling, site supervision, and cost control on a number of projects including: Scott Medical Clinic, Peterborough (Westmount Engineering), 1982; Chemong Plaza, Peterborough (Westmount Engineering), 1980/1981; Bank of Commerce, Peterborough (Westmount Engineering), 1981; City of Peterborough - Water Pumping Station (Westmount Engineering), 1981/1982; Royal Bank, Kincardine (Whitman Contracting), 1976/1977; NCR Phase III, Waterloo (Whitman Contracting), 1975; Mohawk Race Track, Milton (Whitman Contracting), 1976; and Walker Muffler Factory, Cambridge (Whitman Contracting), 1974/1975
- Extensive field experience in most areas of light and heavy construction in various capacities, including construction superintendent, foreman, surveyor, carpenter, and apprentice

Expert Witness Services and Litigation Support

- Litigation support and expert for numerous former waste disposal sites for the City of Toronto and for the Toronto Transit Commission (2006-)
- Litigation support and expert witness in case preparation for Amesbury Landfill Site on behalf of the City of Toronto (2001-2006)
- Litigation support in case preparation for a personal injury lawsuit for Ford Motor Company related to a gas explosion (1998-1999)
- Expert witness on landfill design acting for the City of Oshawa in a hearing for a development proposal adjacent to a closed landfill site (1994-1995)
- Expert witness on landfill design acting for the Regional Municipality of Hamilton-Wentworth at the Steetley Landfill Hearing (1993-1994)
- Expert witness on lawsuit regarding the design and construction of the Coal Tar Collection System at the Lees Avenue Bus Transit Station for the Regional Municipality of Ottawa-Carleton (1986)
- Expert witness on landfill design and borrow pit operations for the Municipality of Metropolitan Toronto in its undertaking before the Consolidated Hearing Board to expropriate part Lots 29 and 30 in the Town of Vaughan for the clay resources on these properties (1988-1990)
- Expert witness on a lawsuit related to pipe supply for use in a landfill gas control system at the Keele Valley Landfill on behalf of the Municipality of Metropolitan Toronto (1994)
- Expert witness on stormwater management and landfill design in a lawsuit regarding use of lands adjacent to the Keele Valley Landfill on behalf of the Municipality of Metropolitan Toronto (1994)
- Expert witness on landfill design in a hearing for expansion of the Mountain Road Landfill in Niagara Falls (1993)

SELECTED PAPERS AND REPORTS

- "A Case History of Leachate Collection and Moisture Recirculation, Keele Valley Landfill Site, Municipality of Metropolitan Toronto" paper presented at Clayey Barriers for Mitigation of Contaminant Impact, University of Western Ontario, Faculty of Engineering Science, London, Ontario, December 1990 (with A.J. Crutcher)
- "Leachate Collection and Moisture Recirculation at the Keele Valley Landfill Site" paper presented at First Canadian Conference on Environmental Geotechnics, The Canadian Geotechnical Society, Montreal, Quebec, May 1991 (with A.J. Crutcher)
- "Reliability-Based Design for Leachate Collection Systems", presented at Sardinia '93, Fourth International Landfill Symposium, Sardinia, Italy, October 1993 (with E. McBean and F. Rovers)
- "Applications and Supporting Documentation Requirements for Industrial/Commercial Environmental Approvals" paper presented at Industrial and Commercial Environmental Approvals conference, Insight Information Inc., Toronto, Ontario, April 1994 (with A.J. Crutcher and J.R. Yardley)
- "Disposal and Utilization Technologies for Landfill Gas" paper presented at Sanitary Landfill Leachate and Gas Management seminar/workshop held jointly by EPIC Educational Program Innovations Center and University of Toronto, Toronto, Ontario, April 1994 (with M.L. Duchene)
- "Performance and Design Criteria for Landfill Gas Management", presented at Landfill Design for Long Term Performance seminar/workshop held jointly by EPIC Educational Program Innovations Centre and the University of Toronto, February 1995
- "Guidance Document for Landfill Gas Management" published by Environment Canada, Ottawa, Ontario, January 1996 (with N. MacDonald)
- "Landfill Gas Collection System Efficiencies - Facts and Fallacies", presented at the 19th Annual Landfill Gas Symposium of the Solid Waste Association of North America (SWANA), Research Triangle Park, North Carolina, March 1996 (with J. Yardley)
- "Landfill Cover System Design", presented at the Elements of Landfill Design Course for the Ministry of Environment and Energy, Toronto, Ontario, August 1996
- "Leachate Recirculation to Achieve Rapid Stabilization of Landfills - Theory and Practice", presented at the 2nd Annual Landfill Symposium of the Solid Waste Association of North America (SWANA), August 1997 (with E. McBean et al.)
- "Landfill Remediation Short Course and Papers" prepared and provided with Dr. Ed McBean to the Indiana Department of Environmental Management (IDEM), January 1997
- "Innovations In Landfill Cover System Design", presented at the Elements of Landfill Design Course for the Ministry of Environment and Energy, Toronto, Ontario, September 1998
- "Optimizing Landfills for Energy Recovery and Greenhouse Gas Reduction", presented at the 20th Canadian Solid Waste Management Congress Hamilton, Ontario September 1998
- "Landfill Remediation Short Course and Papers" prepared and provided with Dr. Ed McBean to regulators and developers from the states of Kansas, Missouri, Iowa, and Nebraska, January 1999
- "Strategy Plan for Developing Landfill Gas Resource" presented at Landfill Gas Management and Emission Reduction Ontario Workshop, May 2001

- "Design Procedure and Criteria for a Sanitary Landfill for Long-Term Performance", presented at Landfill Design and Management for Long Term Performance seminar/workshop held by EPIC Educational Program Innovations Centre, October 2002
- "Emission Reduction Principles" presented at the Canadian Waste And Recycling Exposition in Toronto on behalf of the Municipal Waste Integration Network (MWIN), December 2003
- "Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean" prepared on behalf of the World Bank for use to encourage development of projects within the target region, December 2003
- "Rapid Stabilization at a Large, Deep Landfill – Lessons Learned" presented at the SWANA conference in Boulder Colorado (June 2005)
- "Landfill Bioreactors – A New Perspectie in Solid Waste Management in the Caribbean" presented at the Caribbean Solid Waste Management conference (June 2006)
- "Carbon Credit Trading: Challenges and Opportunities Under the Kyoto Protocol" presented at the SWANA Landfill Gas conference (March 2007)
- "Lystek Biosolids Processing Technology and Beneficial Applications of the Product" presented at the WEFTEC conference in Houston, Texas (October 2006)
- "Challenges for Implementing Landfill Gas Collection and Combustion Projects in Argentina" presented at the SWANA Landfill Gas conference in Houston, Texas (March 2008)
- "Optimized Waste Management Systems" presented at the SWANA conference in Halifax, Nova Scotia (April 2008)

CURRICULUM VITAE

MIKE BESWICK, M.A.Sc., P.Eng

Director of R&D Applications

PROFESSIONAL DESIGNATIONS AND EDUCATION

- Professional Engineer (Licensed with Professional Engineers of Ontario) (Since 2015)
- Master of Environmental Systems Engineering (2017). University of British Columbia, Vancouver, BC
  Thesis: Chemically enhanced backwash as the only ultrafiltration fouling control approach in seawater applications
- Bachelor of Environmental Engineering (2011). University of Guelph, Guelph, ON

WORK EXPERIENCE

Lystek International Inc. (Cambridge, Ontario)

Director of R&D Applications **January 2018 – Present**

In this role my responsibilities are to:

- Drive the ongoing development of the core processing technologies to create operational efficiencies and lower costs.
- Evaluate and trial new complimentary technologies or approaches that allow Lystek to expand its current solutions offerings.
- Develop solutions and facility concepts for new Lystek deployments.
- Build relationships with partner organizations that can facilitate Lystek's entrance into new markets for both our feedstocks, and our fertilizer and plant optimization products.

Engineer and Project Manager **January 2014 – January 2018**

In this role my responsibilities were:

- Manage the design, construction, commissioning, and training of operators for new Lystek in-plant deployments. These projects included facilities such as the North Battleford and Centre Wellington Resource Recovery Upgrade projects using the Lystek technology.
- Prepare and manage project schedules and budget for the above projects.
- Preparation and submission of relevant regulatory applications.
- Ongoing engineering and management support for operating in-plant installations and merchant facilities.

Project Coordinator **May 2011 – January 2014**

In this role my responsibilities were:

- Coordinating the civil, electrical, process, and instrumentation design for Lystek's first stand-alone organic waste recycling facility utilizing numerous consulting firms while providing design input as needed in order to facilitate development.
- Coordinated construction activities as the General Contractor between major civil works, site servicing, mechanical, and electrical works while maintaining an aggressive project schedule
- Issued requests for quotations for pre-supplied equipment for items exceeding $300,000 in value through to minor pumps. Evaluated the submissions and made recommendations to the Senior Project Manager.
- Worked with Controls and Instrumentation consultants to develop Lystek's proprietary SCADA process automation system. This includes equipment interlocks, P&ID and GUI development.
- Coordinated and completed final checks of Ministry of the Environment Environmental Compliance Approvals (Air & Noise, Section 53, and Waste Processing) application submissions and draft approvals prior to execution.

GENIVAR Inc. (London, Ontario)

Technical Project Assistant **May 2009 – September 2009**

- Performed construction QA/QC during the Twin Creeks Landfill expansion project under the guidance of the Project Engineer. This included the installation of both the landfill liner and landfill gas pipe trenches.
- Performed field compaction and moisture tests for arterial service trenches.
- Surveyed, using TopCon GPS technology, structures and other site features for QA/QC analysis as well as final as-builts.

COMPETITIONS AND COMMITTEES

- 2011 Ontario Engineering Competition – First Place in the Consulting Engineering Category
- 2011 Canadian Engineering Competition – Third Place in the Consulting Engineering Category
- Greenhouse Gas Assurance Services Impartiality Review Committee for Conestoga Rovers and Associates – Years 2011 and 2012. Served as the Secretary in 2011, and the Chair in 2012.

PUBLICATIONS

- Beswick, M. (2017). Chemically enhanced backwash as the only ultrafiltration fouling control approach in seawater applications. University of British Columbia. Available at: https://open.library.ubc.ca/cIRcle/collections/24/items/1.0362864
- Michael Beswick, Alamgir Khan, and Richard G. Zytner (2010). Determining a bioventing scale-up factor. Studies by Undergraduate Researchers at the University of Guelph. [article published in Vol. 5, No.1. Fall 2011, 69-72]

CURRICULUM VITAE

SAMANTHA HALLORAN, MSc., P.Ag.

Product Manager

EDUCATION AND COURSES

MSc | Trent University | September 2015

- Sustainable Agriculture and Food Systems Research Group
- Thesis: Nitrogen and phosphorus bioavailability in soil amended with alkaline treated biosolids

BSc | Dalhousie University | May 2013

- Environmental Science with Major in Ecology
- Certificate in Environmental Impact Assessment

Affiliations - Professional Agrologist (Ontario Institute of Agrologist) (2018)

WORK EXPERIENCE

Lystek International Inc. (Cambridge, Ontario)

Project Coordinator — **January 2017 – Present**

Product Manager — **April 2019 - Present**

Responsibility for overseeing all aspects of product management for the company, which includes:

- overseeing product application and ensuring contractors perform based on internal best management practices and pertinent regulations;
- communicating with various stakeholders including regulators, extension personnel, customers (farmers), contractors and members of the public;
- advising customers on application rates and nutrient uptake dynamics for various crops;
- coordinating product safety and efficacy research with in-house staff, extension personnel and University professors; and,
- alternative product research and development initiatives where new product lines are researched and developed.

Quinta (Guelph, Ontario)

An Ontario company working with local farmers to produce, process and market ancient grains, including quinoa and amaranth.

Agronomy Research Technician **May 2016 – December 2016**

Responsible for managing all aspects of agronomy with the company, which included:

- Working with farmers across Canada to improve yield and profitability
- Liaising with research technician and graduate students to design relevant agronomic trials
- Developing and maintaining thorough knowledge of agronomy and relevant agriculture technology and communicate with research team and growers
- Actively marketing the benefits to growers of growing a new crop in Ontario

DuPont Pioneer/DuPont Crop Protection (Caledon, Ontario)

One of the world's largest seed and chemical companies in the world, developing and producing hybrid seed and crop protection products for row and horticultural crops.

Research and Development Intern **April 2015 – May 2016**

Responsibility for:

- Planning and managing field plots for testing new canola hybrids, and new crop protection products for row and horticultural crops
- Training and supervising summer students in planting and data collection of trials
- Completing data analysis and preparation of reports and presentations to assist regulatory staff in preparing applications to Health Canada for registration of new products

COMMITTEES

- Member of the Water Environment Association of Ontario's Students and Young Professionals Committee (2018 – present)
- Board Member at Large for the Ontario Institute of Agrologists (2018-2019)
- Chair of the Communications Committee for the Mid-Atlantic Biosolids Association (2017-2019)
- Master Gardener in Training with the Guelph-Wellington Master Gardeners

SOCWA Innovative Biosolids Technologies Project

Lystek
Nothing wasted.
Everything to gain.

Lystek
Nothing wasted.
Everything to gain.

SOCWA Innovative Biosolids Technologies Project

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South Orange County Wastewater Authority

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Prepared By:

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January 31, 2020

Overview

Lystek is pleased to respond to the questions submitted by SOCWA as part of the project evaluation process.

Please make note that the responses may involve multiple answers depending on the initial, or ultimate, scope of the project. For example, if the project being requested by SOCWA is of a limited nature (time and/or quantity), the response may be different as compared to a full-service project with long-term objectives and performance requirements. In those cases, Lystek will qualify the response or provide additional response data for SOCWA to more accurately complete its review and acceptance of our proposal.

Questions for Lystek:

1. ***With recirculation of LysteMize to the digester, what is the expected increase in biogas production? Do you have data from a similar facility?***

Response: Lystek proposes returning up to 50% of the dry solids of the hydrolyzed digestate back to the digester for additional volatile solids destruction and gas production (this is approximately 10% on a volumetric basis). Depending on the baseline efficiency of SOCWA's anaerobic digesters we would expect an increase in biogas production of up to 40%. We have peer reviewed bench-scale studies and full-scale demonstrations available from similar applications. We have included this for your review in Appendix A.

2. ***What are the expected costs to SOCWA to use the LysteMize in the digesters?***

Response: Depending on the framework of the project, i.e. Design-Build-Transfer vs. Design-Build-Own-Operate, the costs are a function of the additional processing capacity required to deliver this benefit in addition to the production of a saleable registered fertilizer product. In a Design-Build-Transfer arrangement operating costs can be as low as $130 per dry ton. If excess biogas is available onsite for use in the Lystek system this figure can be further reduced.

3. ***What is the percent solids of the end product?***

Response: LysteGro fertilizer has a percent solids typically between 12-15%. This will vary due to the characteristics of the organic feedstock and typical processing variances.

LysteMize hydrolyzed biosolids' percent solids can vary from 10-15% solids. This potential variance is due to the solid content of the delivered feedstock and the preferred operation of the anaerobic digesters. Lystek will work with SOCWA operations/engineers staff to optimize the digester processing capabilities for the best solids content.

4. ***What is the estimate of the number of trucks per day for each facility?***

Response: If LysteMize is the chosen end-product, there will be a reduction in truck traffic to/from the facility (either LTP or RTP). This is due to the destruction of biosolids within the anaerobic digesters reducing the quantity of material leaving the facility (instead being converted into biogas). Truck traffic for supporting the LysteMize technology would consist of delivering an alkali material to the site. This truck volume would be expected to be approximately one truck per week depending on the scale of the ultimate project.

If the full suite of Lystek product offerings were requested (i.e. LysteMize and LysteGro) the estimated truck volumes could increase by three or four trucks per week on average. The exact amount would depend on the dewatered biosolids feedstock delivered from the WWTP. Since any fertilizer sales activities normally occur in bulk quantities during demand seasons, truck traffic can be scheduled to avoid peak traffic periods. In other words, there would be stretches of time (weeks or months) with no truck out-hauling, and more increased truck traffic during fertilizer sales periods.

5. ***Would truck traffic occur 24/7 or only during certain hours?***

Response: Truck traffic can be scheduled to accommodate the needs of SOCWA and the community. Efforts are made to avoid truck traffic during local/regional peak periods. These peak periods normally occur during commuting hours and seasonal/tourist times. Also, off-hour truck traffic would be avoided to eliminate any added noise impacts.

6. ***Could the system operate at CTP in coordination with pumping the end product to RTP for trucking from the RTP site?***

Response: A small(er), more compact system could be operated at CTP to allow for pumping the end-product to RTP. The infrastructure required would need to be discussed in more detail. We understand the existing length of piping between CTP and RTP is quite long and we would want to understand the dynamics of pumping a higher solid content material through this pipe. An equally viable option is to continue with pumping low-solid biosolids from CTP to RTP where the Lystek technology could more efficiently process the material.

7. ***Do you have any data on PFAS/PFOS/PFOA destruction in the process? If not, do you plan to collect data or do you expect destruction? If you don't expect destruction, how do you expect it to partition?***

Response: Lystek has led the industry in attempting to elucidate the fate of these compounds within our process. Please find attached (Appendix B) an initial study (Lazcano, 2019) which details these efforts. Further collaborative work is ongoing with our academic and government partners to further our understanding of these compounds' fate.

8. ***What is the maximum height of proposed structures/stacks installed with this system?***

Response: The only structures required to implement the Lystek technology at both the JBLTP and RTP SOCWA facilities are above ground storage holding tanks for the LysteGro fertilizer product. The storage tanks proposed have a total sidewall height of 30'. This is a flexible design criteria with many potential alternate configurations. It is proposed that the Lystek THP equipment can be easily retrofitted into existing unused building spaces at both JBLTP and RTP.

9. ***If there is a disruption operations or in the supply chain, what is the plan for managing the biosolids?***

Response: For the purposes of handling only the LysteMize material, a disruption of service to the Lystek processing would result in the treatment plant returning to normal (pre-Lystek) operations for handling biosolids.

If a full-service Lystek technology was deployed (LysteGro and LysteMize), the same approach would be used as described above. Lystek would arrange with local/regional off-site outlets for dewatered biosolids to be managed in an approved manner. Service providers would be pre-contracted (including trucking services and end-users) for an un-interrupted adjustment to biosolids handling.

In a Design-Build-Own-Operate framework Lystek would post a performance bond to SOCWA to provide for financial assurance if disruptions were beyond the capabilities of Lystek.

APPENDICES

APPENDIX A

Third Party Research Validating LysteMize

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Impact of alkaline-hydrolyzed biosolids (Lystek) addition on the anaerobic digestibility of TWAS in lab – And full-scale anaerobic digesters

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ABSTRACT

The effect of different Lystek biosolids doses on the anaerobic digestability of thickened waste activated sludge (TWAS) was evaluated in a lab- and full-scale anaerobic digester. The overall findings of this study emphasize the beneficial impact of Lystek addition to the lab- and full-scale anaerobic digesters in terms of enhanced biogas production and increased volatile suspended solids reduction (VSSR) efficiency. Lystek added at 4% by volume to TWAS increased the methane yield from 0.22 to 0.26 L CH_4/g VSS_{added} at an solids retention time (SRT) of 10 days, and from 0.27 to 0.29 L CH_4/g VSS_{added} at an SRT of 15 days. Furthermore, the VSSRs of 37% and 47% were observed for the TWAS, and the TWAS with 4% Lystek, while at an SRT of 15 days, the observed VSSR were 49% and 58%, respectively. The lab-scale study showed that the influence of Lystek addition on methane yield and solids destruction efficiencies was more pronounced at the shorter SRT, 20% enhancement (SRT of 10 d) vs. 9% enhancement (SRT of 15 d) for methane yield, and 27% (SRT of 10 d) vs. 22% (SRT of 15 d) for VSS destruction efficiency improvement. Furthermore, addition of 4% of Lystek to the feed of the full-scale anaerobic digester at St. Marys wastewater treatment plant (WWTP) resulted in a 50% increase in the average specific methanogenic activity and 23% increase in methane yield of the biochemical methane potential tests after eight months. The results showed that Lystek degradation kinetics were 40% faster than the TWAS, as reflected by first order kinetic coefficients of 0.053 d^{-1} and 0.073 d^{-1} for TWAS and Lystek at an SRT of 10 days.

1. Introduction

Considerable efforts have been put on municipal waste recycling and recovery because of recognized problems of health issues and limited landfill space, and thus its management has become an environmental and social concern (Arsova, 2010). For beneficial recycling and agriculture utilization of municipal sludge, a high level of stabilization of organic matter in the biosolids is required to maintain, soil, water and air quality (Singh et al., 2006). Different stabilization methods include chemical treatment, aerobic or anaerobic digestion and composting (Dumontet et al., 1999). Among biological processes, anaerobic treatment process is considered to be the most promising and meets the desired criteria of environmental friendliness, and sustainability (McCarty et al., 2011; Lettinga et al., 1997). With vast quantities of waste being produced nowadays, resource and energy recovery is an integral component of an efficient waste management program. Biogas production from various organic wastes via anaerobic digestion (AD) is an environmentally friendly cost-effective waste management strategy (Khanal et al., 2007). Although AD is a very old process, significant research efforts are still underway to enhance the methane production. Pretreatment prior to the digestion is a widely used approach to enhance AD performance by improving the rate limiting hydrolysis rate through the solubilization of particulate organics (Pérez-Elvira et al., 2006). However, the rate of solubilization during pretreatment primarily depends on the nature and concentration of the particulates in the waste to be treated (Elbeshbishy et al., 2011). Most of the pretreatment studies showed enhanced digestion performance in terms of sludge solubilization followed by improved methane production (Nah et al., 2000; Lin et al., 1997; Elbeshbishy et al., 2011; Bougrier et al., 2008). The main purposes of any pretreatment technologies are to increase the soluble chemical oxygen demand (SCOD) and reduce the particle size of the particulate matter.

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0956-053X/

An innovative commercial biosolids thermo-alkaline hydrolysis treatment and processing technology, involving optimum application of heat, alkaline hydrolysis and mixing in a batch or semi-continuous system was developed primarily to facilitate land application of biosolids by reducing the viscosity of the dewatered biosolids from >2,000,000 cP, to that of a pumpable liquid with a viscosity of <1800 cP (Singh et al., 2007). Although the goal of the thermo-alkaline-hydrolysis process was mainly to produce a low-pathogen product (Lystek) that can be used as a soil conditioner, the characteristics of the treated biosolids showed a significant increase in biochemical oxygen demand (BOD), rendering the Lystek be more biodegradable compared to the digestate or the sludge cake. The recycle of the Lystek biosolids to anaerobic digesters may potentially enhance biogas production and overall volatile solids reduction. Thus, the main objectives of this project were to (a) assess the anaerobic biodegradability of the Lystek in a lab-scale anaerobic digester, (b) evaluate the effect of different volumetric Lystek additions on the anaerobic digestability of TWAS in a lab-scale anaerobic digester at two SRTs of 10 and 15 days, and (c) evaluate the effects of Lystek addition on the anaerobic digestability of TWAS in the full-scale AD at St. Marys WWTP (St. Marys, Ontario, Canada).

2. Materials and methods

2.1. Lab-scale continuous stirred-tank reactors (CSTRs)

Continuously stirred tank reactors (CSTRs) each with an operating liquid volume of 10 L and a headspace volume of 4 L were used for the anaerobic biodegradability studies of TWAS, Lystek, and TWAS with Lystek at two SRTs of 10 and 15 days. When the Lystek was used alone, it was diluted to match the TWAS solids prior to feeding. The characteristics of the different feeds are shown in Table 1. The systems used in this study were operated in completely-mixed continuous-flow mode. At the beginning, anaerobic sludge collected from the primary anaerobic digester at St. Marys wastewater treatment plant (St. Marys, Ontario) was used to seed the digesters. The total suspended solids (TSS) and volatile suspended solids (VSS) concentrations of the sludge were 11 and 9 g/L, respectively. The headspace was flushed with nitrogen gas at 5–10 psi for a period of 5 min before start-up. All the digesters were maintained at a constant temperature of 37 ± 1 °C. The continuous-flow experiments were divided into two stages: in the first stage, three reactors were run at an SRT of 10 days and fed with TWAS, Lystek, and TWAS + 4% Lystek. In the second stage, four reactors were run at an SRT of 15 days and fed with TWAS, TWAS + 4% Lystek, TWAS + 6% Lystek, and TWAS + 8% Lystek.

2.2. St. Marys full-scale AD

A schematic flow diagram for the St. Marys wastewater treatment plant (WWTP) and the thermo-alkaline-hydrolysis process are presented in Fig. 1. Lystek was added prior to the primary digester (AD1) at 4% by volume of the feed. The working volumes of AD1 and AD2 are 817 m^3 and 925 m^3, respectively with an average TWAS (3–4% solids) flow rate of about 90 m^3/d, and thus the SRT in AD1 is about 9 days. To evaluate the effects of Lystek addition on the anaerobic digestability of TWAS in the full-scale AD at St. Marys WWTP, eight specific methanogenic activities (SMA) and seven biochemical methane potential (BMP) tests were conducted using different samples (TWAS and seed from AD1) collected monthly. The sampling locations of the TWAS and the digestate are shown in Fig. 1.

2.3. Lystek technology

Thermo-alkaline-hydrolysis biosolids processing technology involves a combination of heat, alkali, and high shear mixing to convert biosolids and other organics into a homogeneous liquid product with a high solid content of 14–17% and fertilizer value. A schematic flow diagram for the St. Marys wastewater treatment plant (WWTP) and the thermo-alkaline-hydrolysis process are presented in Fig. 1. As shown in the figure, to operate the thermo-alkaline-hydrolysis process, the dewatered biosolids were pumped from the biosolids storage tank with a progressive cavity pump to the mixing tank that is equipped with a high-speed mixer. An ca alkali solution (KOH) was added to adjust the pH to 10–11 and the mixture was heated using a steam generator. The high-shear mixing contributes to particulate and solids disintegration, as well as creation of homogeneous conditions including pH and temperature. Process time for each batch was typically 30–60 min. The relative simplicity of the thermo-alkaline-hydrolysis process and the small footprint (1000–1500 square feet) facilitates retrofitting into any existing WWTP (Singh et al., 2007). The detailed characteristics of Lystek processed biosolids are presented in Table 1.

2.4. Biochemical methane potential (BMP) and specific methanogenic activities (SMA) tests

The BMP tests were conducted using TWAS from St. Mary's WWTP as a feed and St. Mary's digested sludge as a seed at four different initial substrate-to-biomass (S/X) ratios of 0.25, 0.5, 1, and 2 on mass COD/mass VSS basis, with each test condition run in duplicates in 250 mL glass bottles. The total liquid volume of the test bottles comprising both the seed and feed was 200 mL. The seed VSS and feed TCOD concentrations were measured prior to the initiation of the batch test (12 h prior to the test). The volumes of digestate and the feed (TWAS) required to maintain the S/X ratios were determined for each sample. Two bottles were used as blank (seed only) which contained 200 mL of seed without any feed. The pH was adjusted to 6.8–7.2 using 1 NaOH and HCl. The volumes of digestate and feed (TWAS) were then added to the batch test bottle (total liquid volume of 200 mL and headspace volume of 60 mL). No additional buffer was added due to the high alkalinity in both

Table 1
Characteristics of the TWAS and Lystek.

Parameter	Units	Raw Lystek	Raw TWAS	Diluted Lystek	TWAS + 4% Lystek	TWAS + 6% Lystek	TWAS + 8% Lystek
TCOD	mg/L	107500 ± 8400[a]	33600 ± 2000	34400 ± 1600	38600 ± 2270	41100 ± 2480	43500 ± 2650
sCOD	mg/L	56000 ± 4100	710 ± 40	17850 ± 1690	2900 ± 210	4600 ± 280	6100 ± 360
TSS	mg/L	104600 ± 9800	34100 ± 2080	36500 ± 2020	38700 ± 2500	40900 ± 2630	43200 ± 2980
VSS	mg/L	56000 ± 7300	30400 ± 1130	20280 ± 1750	33100 ± 1260	35600 ± 1480	36600 ± 1520
BOD	mg/L	16000 ± 2400	490 ± 70		1120 ± 140	1620 ± 190	1900 ± 180
sBOD	mg/L	11800 ± 700	110 ± 20		520 ± 70	810 ± 50	980 ± 90
Ammonia	mg/L	430 ± 80	128 ± 32	160 ± 30	150 ± 36	180 ± 28	190 ± 32
pH		10.3 ± 0.2	6.6 ± 0.2	7.9 ± 0.4	7.6 ± 0.2	7.9 ± 0.3	8.3 ± 0.3
Alkalinity	mg $CaCO_3$/L	10500 ± 860	1300 ± 110	3300 ± 120	1540 ± 140	1920 ± 160	2100 ± 170

[a] Average and STD of 10 samples.

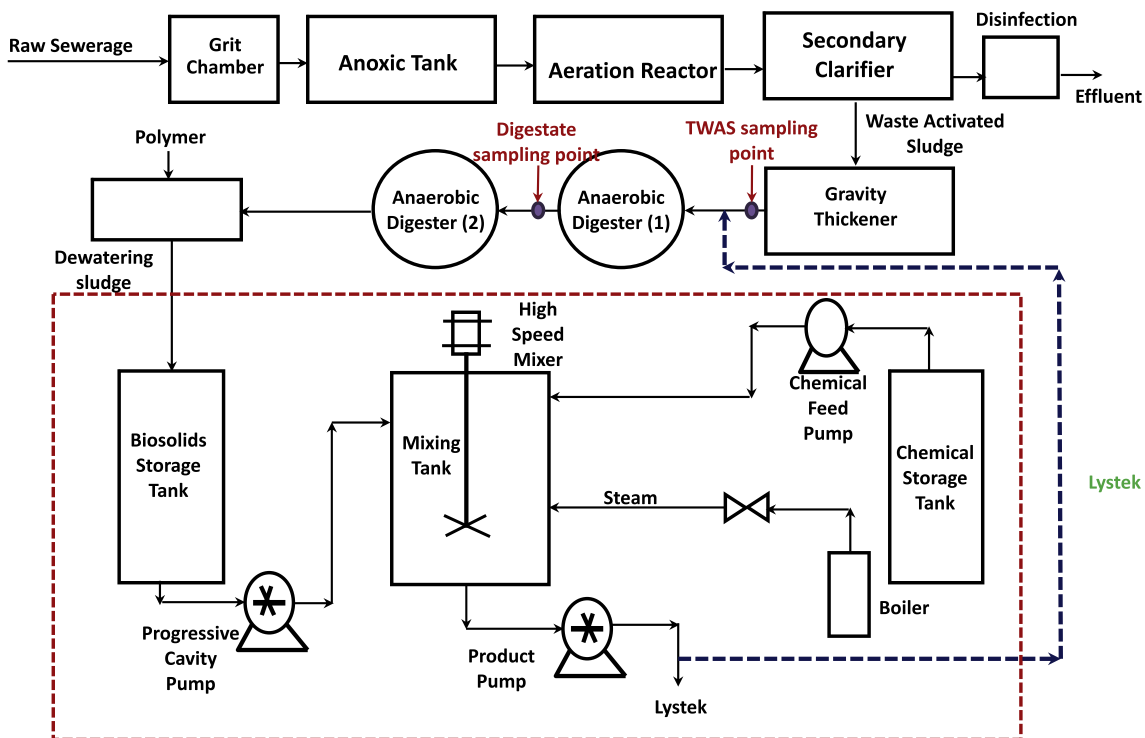

Fig. 1. Process flow diagram of St. Marys WWTP and Lystek system.

TWAS (1300 mg $CaCO_3$/L) and the digestate (3000 mg $CaCO_3$/L). A sample of the mixture was then collected for initial analysis. The headspace was flushed with nitrogen gas at 5–10 psi for a period of 5 min prior to closing the cap. The bottles were then placed in a swirling-action shaker (Max Q4000, Incubated and Refrigerated Shaker, Thermo Scientific, CA) operating at 180 rpm and maintained at a temperature of 37 °C. The volume of the gas produced was measured by releasing the bottles headspace pressure, using appropriately sized glass syringes (Perfektum; Popper & Sons Inc., NY, USA) in the 5–100 mL range to equilibrate with the ambient pressure, as recommended by Owen et al. (1979). The gas composition was analyzed every day for the first 6 days and then every 2–3 days until the test was completed i.e. cumulative gas curve reached a plateau. At the end of the experiment, the samples were analyzed for TCOD, SCOD, TSS, and VSS.

The SMA tests were conducted to evaluate the activity of the acetotrophic methanogens in the digestate from the St. Mary's full-scale digester using acetate as substrate. The digestate or the seed was collected from the full-scale digester once every month for eight months. The volumes of digestate and the acetate were calculated to maintain four different S/X ratios of 0.25, 0.5, 1.0 and 2.0, on mass COD/mass VSS. One (1) mL of a nutrient stock solution, with the following composition in 1 L, was added to each bottle: 280 g NH_4Cl, 250 g of K_2HPO_4, 100 g of $MgSO_4{\cdot}7H_2O$, 10 g of $CaCl_2{\cdot}2H_2O$, 2 g of $FeCl_2{\cdot}4H_2O$, 0.05 g of H_3BO_3, 0.05 g of $ZnCl_2$, 0.03 g of $CuCl_2$, 0.5 g of $MnCl_2{\cdot}4H_2O$, 0.05 g of $(NH_4)_6Mo_7O_{24}$, 0.05 g of $AlCl_3$, 0.05 g of $CoCl_2{\cdot}6H_2O$, and 0.05 g of $NiCl_2$. Furthermore, 1 g $NaHCO_3$ was added to each bottle to maintain buffering capacity. The volumes of digestate, nutrients, and acetate were then added to the batch test bottle (total liquid volume of 200 mL and headspace volume of 60 mL). All other conditions and procedures were similar to the BMP test.

2.5. Analytical methods

Samples were analyzed for total suspended solids (TSS), volatile suspended solids (VSS), total and soluble biochemical oxygen demand (TBOD, SBOD), and alkalinity using standard methods (APHA, 1995). Total and soluble chemical oxygen demand (TCOD, SCOD) were measured using HACH methods and test kits (HACH Odyssey DR/2500). Soluble parameters were determined after filtering the samples through 0.45 μm sterile membrane filter paper (Whatman, Cole-parmer, Montreal, Canada). Biogas production was collected by wet tip gas meters (Gas meters for Laboratories, Nashville, TN). The gas meter consisted of a volumetric cell for gas–liquid displacement, a sensor device for liquid level detection, and an electronic control circuit for data processing and display. Biogas composition including hydrogen, methane, and nitrogen was determined by a gas chromatograph (Model 310, SRI Instruments, Torrance, CA) equipped with a thermal conductivity detector (TCD) and a molecular sieve column (Molesieve 5A, mesh 80/100, 6 ft × 1/8 in). The temperatures of the column and the TCD detector were 90 and 105 °C, respectively. Argon was used as the carrier gas at a flow rate of 30 mL/min. The concentrations of volatile fatty acids (VFAs) were analyzed after filtering the sample through 0.45 μm using a gas chromatograph (Varian 8500, Varian Inc., Toronto, Canada) with a flame ionization detector (FID) equipped with a fused silica column (30 m × 0.32 mm). Helium was used as the carrier gas at a flow rate of 5 mL/min. The temperatures of the column and detector were 110 and 250 °C, respectively.

3. Results and discussion

3.1. Anaerobic biodegradability of TWAS, Lystek, and TWAS plus Lystek

The anaerobic biodegradability of TWAS, Lystek, and TWAS plus 4% by volume Lystek was evaluated using continuous stirred-tank reactors (CSTRs) at two SRTs of 10 and 15 days. For the Lystek feed, the raw Lystek was diluted, based on COD, prior to feeding in order to achieve the same OLR for the TWAS of about 3.3 kg COD/m^3 d. Fig. 2a shows the methane production rates of the TWAS, Lystek, and TWAS with 4% Lystek at an SRT of 10 days. Average steady-state methane production rates of 4.1, 7.0, and 4.9 L CH_4/d were observed for the TWAS, Lystek, and TWAS with 4% Lystek, respectively. When

4% Lystek by volume was added to the TWAS, the methane production rate increased by about 20%, from 4.1 to 4.9 L CH_4/d. Fig. 2b and c show the methane yields of the different feeds. As shown in Fig. 2b, a methane yield of 7 L/L_{feed} was observed for Lystek, 70% higher than 4.1 L/L_{feed} for TWAS. Moreover, the methane yield from TWAS with 4% Lystek at 4.9 L CH_4/L_{feed} was 20% higher than that the methane yield from TWAS only. This increase was not only due to the higher SCOD of the Lystek feed of 18,000 mg/L (after dilution to maintain the same OLR of 3.1–3.3 kg COD/m^3.d) compared to TWAS of 710 mg/L, but also due to the effect of the steam-aided alkaline hydrolysis pretreatment which reduces the particle size resulting in increased specific surface area, and hence enhanced digester performance (Sanders et al., 2000). As shown in Table 1, the SCOD to TCOD ratios in the Lystek and TWAS were 48% and 2%, respectively. On the other hand, 4% Lystek addition to the TWAS increased the methane yield by only 20%, from 4.1 L CH_4/L_{feed} to 4.9 1 L CH_4/L_{feed}. This increase in methane yield after adding 4% Lystek was expected due to the increase in the SCOD from 710 mg/L for TWAS only to 2900 mg/L for the TWAS with 4% Lystek. The increase in the SCOD due to 4% Lystek addition of 2200 mg/L is equivalent to about 0.8 L methane (identical to the observed), suggesting that the increase in the methane yield of the TWAS with Lystek addition was mainly due to the increase in the SCOD. On the other hand, as shown in Fig. 2c, methane yields of 0.22, 0.26, and 0.32 L CH_4/g VSS_{added} were observed for the TWAS, Lystek, and TWAS with 4% Lystek feed, respectively. The aforementioned increase in the methane yield per g VSS_{added} represents a 20% enhancement compared to the TWAS only. Furthermore, there were no differences in the methane yields based on the TCOD added, 0.122 and 0.127 L CH_4/g $TCOD_{added}$ for TWAS, and TWAS with 4% Lystek, respectively. Furthermore, as shown in Fig. 3a, the VSS destruction efficiency for Lystek of 52% was 27% higher than that of TWAS only (41%) and 11%

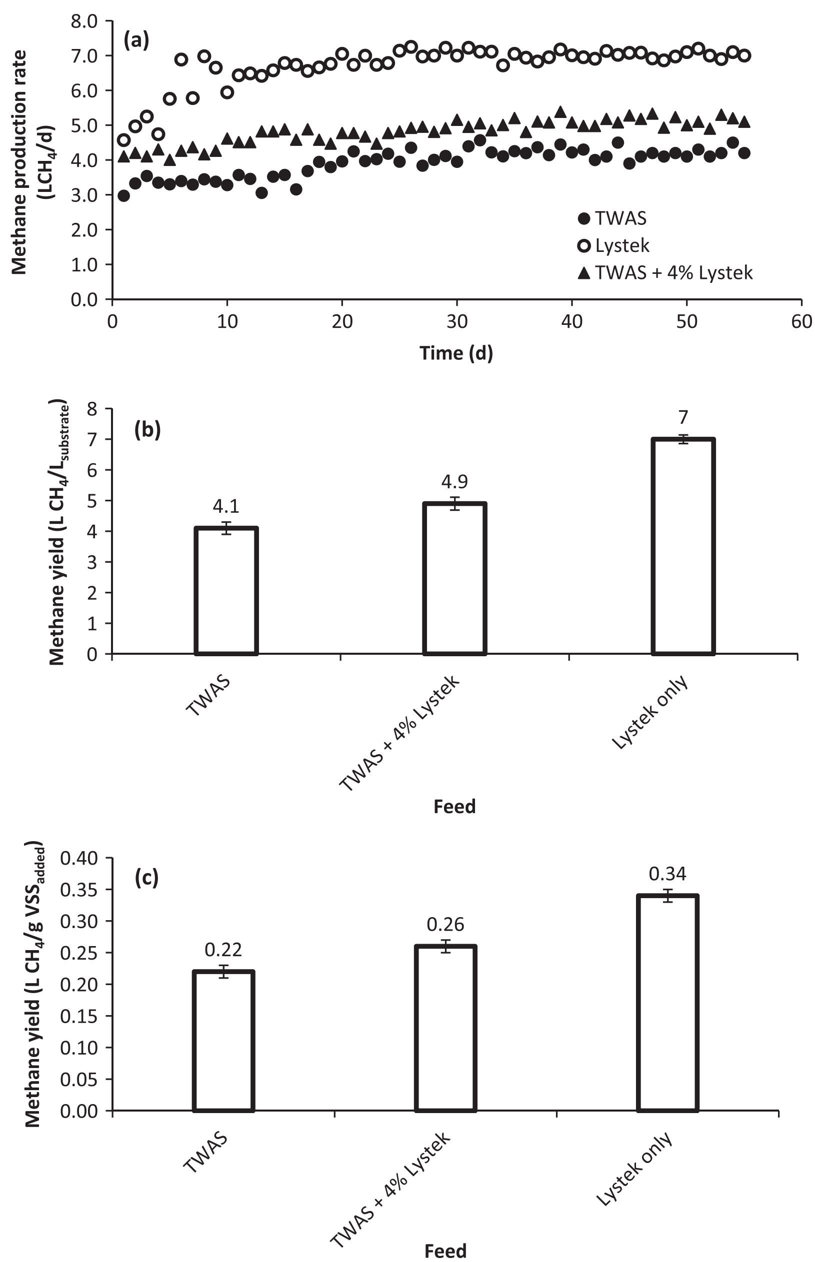

Fig. 2. Average methane production rate and yields of the different feeds at SRT of 10 days (a) methane production rate, (b) methane yield as $LCH_4/L_{substrate}$ and (c) methane yield as LCH_4/g VSS_{added}.

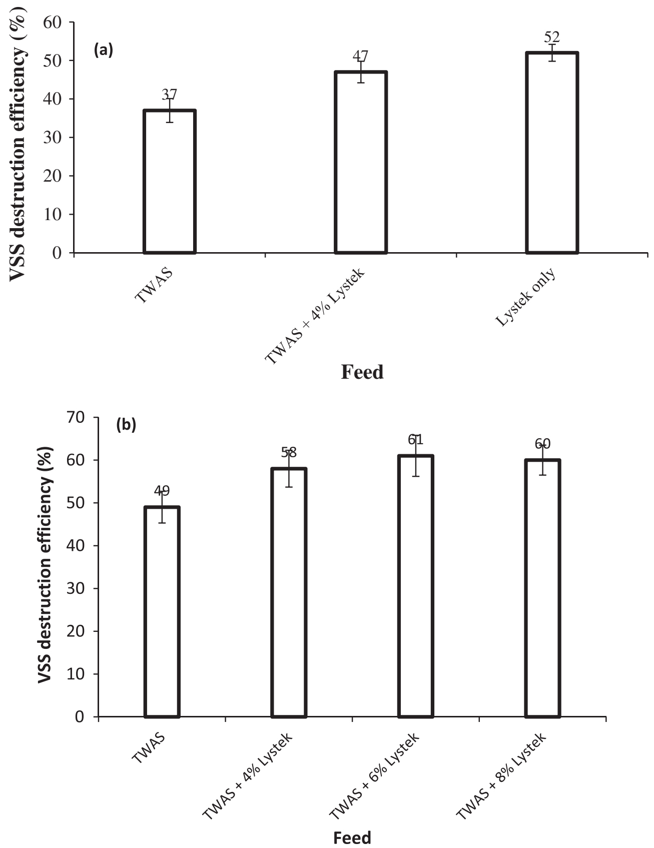

Fig. 3. Average volatile suspended solids (VSS) destruction efficiencies of the different feeds at (a) SRT of 10 days and (b) SRT of 15 days.

higher than that of TWAS plus 4% Lystek (47%). The increase in VSS destruction due to 4% Lystek addition to TWAS feed was 27% compared to TWAS only (47% vs. 37%, see Fig. 3a). Based on the aforementioned results, it was obvious that adding 4% Lystek by volume to the TWAS in a CSTR at SRT of 10 days resulted in 20% and 27% increase in methane yield and VSS destruction efficiency, respectively. The findings of this study are comparable with some thermal pretreatment processes. Bishnoi (2012) reported a 10% increase in the VS destruction efficiency and 18% increase in methane production compared to the control digester when the TWAS was pretreated at 170 °C for 3 h contact time prior to feed to CSTR at an SRT of 15 days. Furthermore, EXELYS by Kruger Inc., a subsidiary of Veolia Water developed a thermal pretreatment system which produced 20–40% more biogas compared to the control digester (Bishnoi, 2012). Furthermore, Tiehm et al. (1997) applied ultrasonication in a pilot plant using a high performance ultrasound reactor (3.6 kW, 31 kHz) for 64 s on a mixture of primary sludge and WAS (53% primary sludge and 47% WAS) with average VSS of 25 g/kg, and observed a 10% increase in VS removal efficiency of sonicated waste over the conventional AD process at an SRT of 22 days. It must be asserted, however, that the performance of the post-AD thermo-alkaline biosolids treatment is indeed superior to the two aforementioned thermal and ultrasonication technologies, despite treating a less biodegradable waste stream.

3.2. Impact of Lystek addition doses on the anaerobic biodegradability of TWAS

The effect of different doses of Lystek addition on the anaerobic biodegradability of TWAS from St. Marys WWTP was evaluated in a CSTR at an SRT of 15 days using three different doses of 4%, 6%, and 8% by volume. The OLR varied from 2.6 kg COD/m^3 d for the TWAS only and increased gradually with Lystek addition to 3.4 kg COD/m^3 d for the TWAS with 8% Lystek. Fig. 3b shows the VSS destruction efficiency of the TWAS only, and the TWAS with Lystek addition. A VSS destruction efficiency of 49% was observed for TWAS only compared to about 58–61% for TWAS with Lystek. The increase in VSS destruction efficiency was 18% when 4% of Lystek was added and about 24% when 6% or 8% of Lystek was added. Based on the abovementioned results, it was clear that increasing the Lystek dose from 4% to 6% or 8% did not have a significant effect on either methane production or solids destruction, as the difference between the absolute methane yields was less than 10%.

Fig. 4a shows the methane production rates of the TWAS, and TWAS with the different Lystek doses. As shown in the Figure, an average steady-state methane production rate of 4.3 L CH_4/d was achieved for TWAS only, increasing to 4.9 L CH_4/d at 4% Lystek, and to 5.1 and 5.4 L CH_4/d at 6% and 8% Lystek addition, respectively.

Fig. 4b and c show the methane yields of the TWAS and the TWAS with different Lystek doses. As shown in Fig. 4b, the methane yield increased from 5.8 L/L_{feed} for TWAS only to 6.3, 6.9, and 7.2 L/L_{feed} when Lystek was added at doses of 4%, 6%, and 8%, respectively. The volumetric methane yield at an SRT of 15 days increased by only 8% at 4% Lystek and to 19% and 24% at 6% and 8% Lystek addition, respectively. It should be noted that the incremental methane production with Lystek was about 90% of the theoretical methane production based on the increased SCOD only. For example, as shown in Table 1, the SCOD increased from 710 mg/L for TWAS only to 2900 mg/L for TWAS with 4% Lystek, while the increase in methane production rate was 0.54 L/d.

Interestingly, there were no significant differences between the yields of the TWAS only and the TWAS with Lystek at any dose when normalized per mass of VSS added, with methane yields of 0.27–0.29 L CH_4/g VSS_{added} observed for all feeds (see Fig. 4c). The paired *t*-test results confirmed that there were no statistically significant differences at the 95% confidence level.

3.3. Comparison between CSTRs's Performance at SRT of 10 days and 15 days

Based on the aforementioned results, the methane yield of TWAS only increased by 40% when the SRT increased from 10 days to 15 days, to 5.8 L CH_4/L_{feed}. Furthermore, the increase in methane yield due to the increase in the SRT from 10 to 15 days was less pronounced for the TWAS plus 4% Lystek, as the methane yield increased by 30%, (4.7 vs. 6.3 L CH_4/L_{feed}). The increase in volatile solids destruction efficiencies with the longer SRT were 32% and 23% for TWAS only, and TWAS plus 4% Lystek, respectively.

On the other hand, the influence of Lystek addition on methane yield and solids destruction efficiencies was more pronounced at the shorter SRT (20% at an SRT of 10 d vs. 9% at an SRT of 15 d for methane yield) and 27% at an SRT of 10 d) compared to 22% at an SRT of 15 d for VSS destruction efficiency.

The paired t-test was used to test the hypothesis of equality at the 95% confidence level. The null hypothesis was defined as no difference between the two groups tested vs. the alternative hypothesis that there is a statistical difference between the two groups. Based on the results of the *t*-test presented in Table 4, it was evident that for the SRT of 10 days, there were statistically significant differences between the methane produced from different substrates. Furthermore, for SRT of 15 days, there were statistically significant differences between the methane produced from TWAS and the other substrates i.e. TWAS plus Lystek at any dose. On the other hand, comparing the methane produced from the TWAS plus 4% Lystek with the TWAS plus 6% or 8% Lystek, there were no statistically significant differences at 95% confidence level as displayed in Table 4.

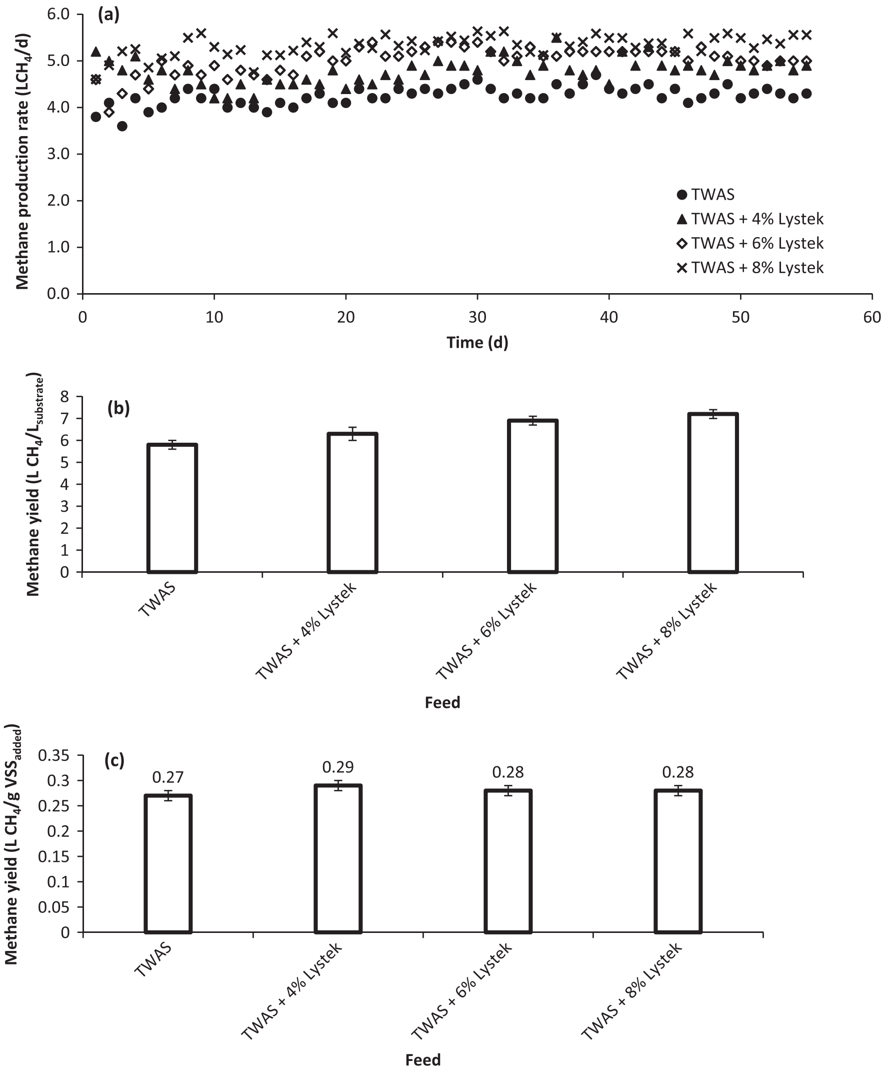

Fig. 4. Average methane production rate and yields of the different feeds at SRT of 15 days (a) methane production rate, (b) methane yield as $LCH_4/L_{substrate}$ and (c) methane yield as LCH_4/g VSS_{added}.

3.4. First order kinetic coefficients and predicted VSS destruction

The first order kinetic coefficients (k) were calculated for the different feeds based on the VSS destruction and the SRT using the following equation (Vavilin et al., 2008):

$$K = \frac{1}{t}\ln\frac{C}{C_0} \tag{1}$$

where t is the SRT (d), C is the effluent VSS concentration, and C_0 is the influent concentration or C/C_0 = (100 – VSS destruction efficiency)/100

Table 2 presenting the first order kinetic coefficients of the different feeds at different SRT, indicates that k values of 0.053 d^{-1} and 0.073 d^{-1} were observed for TWAS and Lystek at an SRT of 10 days. Thus, it is evident that Lystek degradation kinetics are 40% faster than the TWAS. For TWAS only, by increasing the SRT from 10 to 15 days, the VSS destruction efficiency increased by 20% (41% vs. 49%) and the k value decreased by 15% from 0.053 d^{-1} to 0.045 d^{-1}. The k value of the TWAS plus Lystek at an SRT of 15 days was mostly around 0.061 d^{-1}, exhibiting no sensitivity to the percentage of Lystek in the feed.

To predict the VSS destruction efficiencies for the TWAS with Lystek at the 15-days SRT, the k value of 0.045 d^{-1} (see Table 2) for TWAS only at an SRT of 15 days was used and the k value of the Lystek only at an SRT of 15 days was estimated based on the k value of Lystek only at SRT of 10 days (0.073 d^{-1}) and the 15% decrease in TWAS's k value at the longer SRT i.e. k (Lystek at SRT of 15 days) = 0.073 × (0.045/0.053) = 0.062 d^{-1}. The predicted VSS destruction efficiencies of the TWAS plus Lystek were calculated based on the k values of TWAS only and Lystek only and the SRT. As shown in Table 3, the observed (measured) VSS destruction efficiencies were higher than the predicted one by about 14–19% which emphasized that the observed VSS destruction efficiencies of the TWAS plus Lystek mixtures were not merely the cumulative VSS destruction of TWAS and Lystek solids, but that indeed there

Table 2
First order kinetic coefficients of the CSTRs.

Feed	SRT d	Measured VSS destruction eff. (%)	k d^{-1}
TWAS only	10	41	0.053
TWAS only	15	49	0.045
Lystek only	10	52	0.073
TWAS + 4% Lystek	10	47	0.063
TWAS + 4% Lystek	15	58	0.058
TWAS + 6% Lystek	15	61	0.063
TWAS + 8% Lystek	15	60	0.061

Table 3
Comparison between measured and calculated VSS destruction efficiencies for TWAS + Lystek at an SRT of 10 days.

Feed	SRT d	Lystek addition g TSS/d	TWAS addition g TSS/d	Predicted effluent VSS g VSS/d	Predicted VSS destruction efficiency (%)	Measured VSS destruction efficiency (%)
TWAS + 4% Lystek	10	2.0	21.1	9.7	42	47
TWAS + 4% Lystek	15	1.5	15.8	8.7	50	58
TWAS + 6% Lystek	15	2.3	15.5	9.0	51	61
TWAS + 4% Lystek	15	3.0	15.2	9.3	51	60

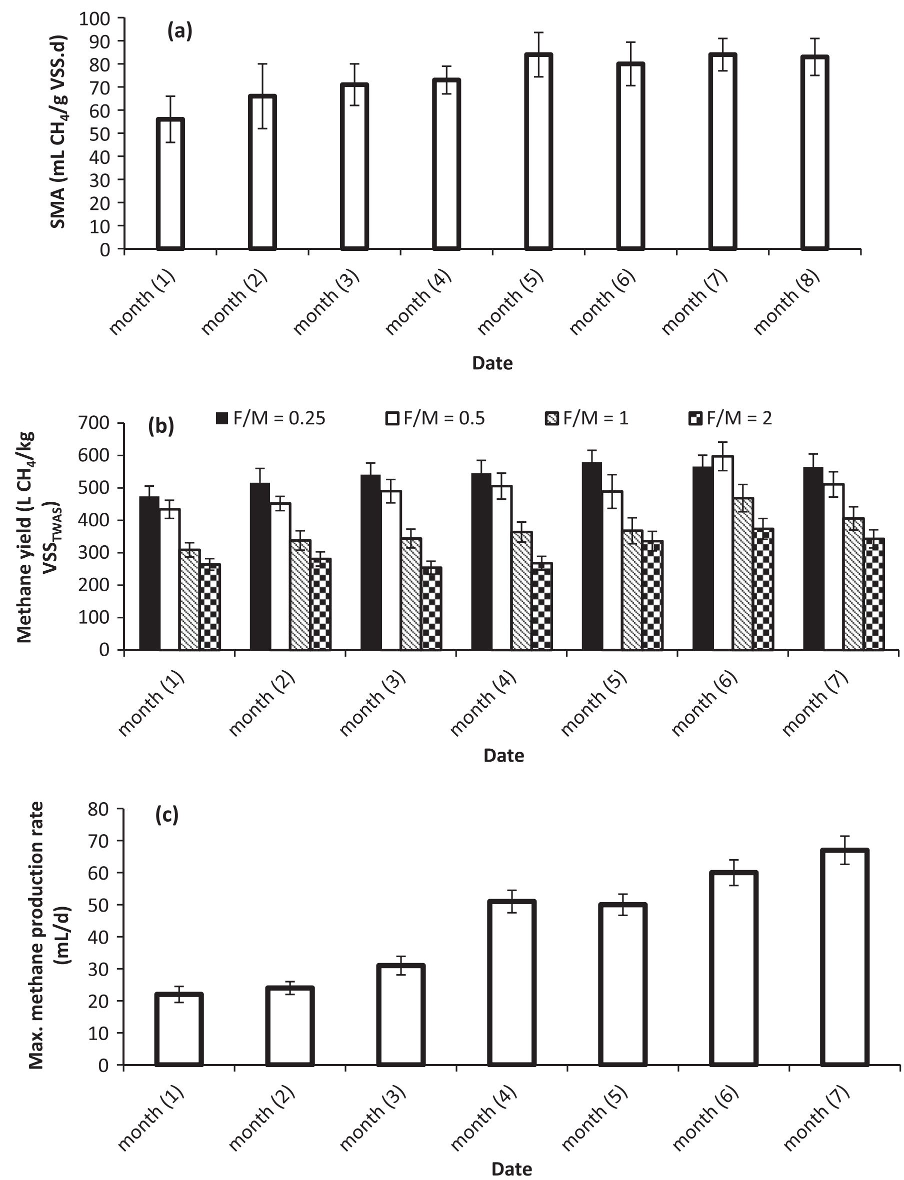

Fig. 5. Temporal variation of (a) average specific methanogenic activity of St. Marys digestate, (b) methane yields at different F/M ratio during the BMP tests and (c) Maximum methane production rate during the BMP tests.

was some synergy between Lystek and TWAS that enhanced overall VSS destruction efficiencies.

3.5. Long-term impact of recirculated Lystek on St. Marys full-scale anaerobic digester

The long-term impacts of recirculated Lystek sludges at 4% by volume to the full-scale primary anaerobic digester at St. Marys WWTP (AD1 in Fig. 1) were evaluated by monthly measurements of the activity of methanogenic bacteria as well as the BMP from the TWAS. Eight SMAs were conducted using different eight samples (seed) collected monthly from St. Marys full-scale anaerobic digester. Four different substrate to biomass' ratios (S/X) of 0.25, 0.5, 1.0, and 2.0 g COD/g VSS were used. Fig. 5a shows the average SMA of St. Marys digestate over time. It is noteworthy that the coefficient of variations (CV) of all SMA results were less than 10% except for the first two SMAs (CV was 17–20%). As depicted in Fig. 5a, the average SMA increased gradually during the first four months and then stabilized during the last four months. In the first four runs, the SMA gradually increased from 56 mL/gVSS-d for first

Table 4
Result of the paired *t*-test for the methane production.

		T-test (value)			
		TWAS	Lystek	TWAS + 4% Lystek	TWAS + 6% Lystek
CSTR 10 days	Lystek	64.12 (0.00)			
	TWAS + 4% Lystek	18.20 (0.00)	47.27 (0.00)		
CSTR 15 days	TWAS + 4% Lystek	9.82 (0.00)			
	TWAS + 6% Lystek	30.72 (0.00)		1.22 (0.12)	
	TWAS + 8% Lystek	32.57 (0.00)		0.62 (0.27)	0.26 (0.40)

month sample to 84 mL/gVSS-d for the fifth month sample, and then stabilized for the samples from months six to eight at about 83 mL/gVSS-d. Thus, it was evident that the St. Marys digestate required five months to achieve 50% enhancement in the methanogenic activity after the addition of Lystek to the digester at 4% of the feed by volume. The COD mass balance closures ranged between 88% and 103%, thus emphasizing data reliability. On the other hand, the final pH of all SMA was above 6.5, ranging from 6.5 to 7.4.

Fig. 5b shows the average net yields (after correcting for the seed sludge biogas) from the seven BMP tests as L CH_4/kg VSS_{feed} at the four different S/X ratios. As shown in Fig. 5b, the methane yield exhibited the same trend of gradual increase from the beginning to the fifth month and stabilization thereafter for the S/X ratios of 0.25, 0.5, and 1.0 g COD/g VSS. For all batches, the methane yields decreased with increasing the S/X ratio The highest methane yields were observed at S/X ratio of 0.25 g COD/g VSS with the methane yield increasing gradually from 474 L CH_4/kg VSS_{feed} for the first sample to 580 L CH_4/kg VSS_{feed} for the fifth month sample, after which, the methane yield decreased slightly to 566 L CH_4/kg VSS_{feed}. Furthermore, as shown in Fig. 5c, the maximum methane production rate (MMPR) followed the same trend of the methane yield. The MMPR increased from 22 mL/d in first month sample to a maximum of 67 mL/d in last sample. It must be emphasized that the BMP test were run for 65–88 days, The COD mass balance closures of the BMP tests ranged between 91% and 107%, thus emphasizing data reliability. On the other hand, the final pH of the BMP tests ranged from 7.3 to 7.8.

As observed from the SMA and BMP tests conducted to evaluate the long-term performance of the full scale digester, it was evident that the activity and/or number of various microbial groups i.e. acidogens, acetogens, and methanogens increased after Lystek addition. This could be due to the faster biodegradation kinetics as delineated in the side-by-side laboratory comparative testing, or microbial population dynamics, which required further testing beyond the scope of this study.

4. Conclusion

The outcome of this study emphatically revealed the positive effect of Lystek addition on the anaerobic digestability of TWAS on both lab and full-scale digesters. Based on the findings of this study, the following conclusions can be drawn:

- Adding 4% Lystek by volume to the TWAS feed in a CSTR at SRT of 10 days resulted in 20% and 27% increase in methane yield and VSS destruction efficiency, respectively.
- The volumetric methane yield at an SRT of 15 days increased by 8%, 19%, and 24% when 4%, 6%, and 8% of Lystek was added to the feed, respectively.
- The methane production rate increased from 4.3 L CH_4/d to 4.9, 5.1, and 5.4 L CH_4/d when 4%, 6%, and 8% Lystek were added to the TWAS, respectively.
- The increase in VSS destruction efficiency was 18% when 4% of Lystek was added and 24% when 6% or 8% of Lystek was added.
- At an SRT of 15 days, there were no significant differences between the yields of the TWAS only and the TWAS with Lystek at any dose when it normalized per mass of VSS added.
- The methane yield increased by 40% and 30% when the SRT increased from 10 days to 15 days for TWAS only, and TWAS with 4% Lystek, respectively.
- Lystek degradation kinetics were 40% faster than the TWAS.
- SMA results showed that Lystek addition at 4% by volume to the full-scale primary anaerobic digester at St. Marys WWTP enhanced the methanogenic activity by 50% after five months.
- BMP results showed that Lystek addition at 4% by volume to the full-scale primary anaerobic digester at St. Marys WWTP improved the methane yield by 22% after five months.

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APPENDIX B

Third Party Research Examining the fate of PFAS in Lystek THP Treated Biosolids

Water Environment Federation
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Per- and polyfluoroalkyl substances in commercially available biosolid-based products: The effect of treatment processes

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Additional Supporting Information may be found in the online version of this article.

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Abstract

Per- and polyfluoroalkyl substances (PFAS) have been used in a variety of consumer and industrial products and are known to accumulate in sewage sludge due to sorption and their recalcitrant nature. Treatment processes ensure safe and high-quality biosolids by reducing the potential for adverse environmental impacts such as pathogen levels; however, they have yet to be evaluated for their impact on the fate of PFAS. The objective of this study was to compare PFAS concentrations in four commercially available biosolid-based products that received different types of treatments: heat treatment, composting, blending, and thermal hydrolysis. Seventeen perfluoroalkyl acids (PFAAs) were quantified using liquid chromatography with tandem quadrupole time-of-flight mass spectrometry followed by screening for 30 PFAA precursors. Treatment processes did not reduce PFAA loads except for blending, which served only to dilute concentrations. Several PFAA precursors were identified with 6:2 and 8:2 fluorotelomer phosphate diesters in all samples pre- and post-treatment. © 2019 Water Environment Federation

Practitioner points

- Heat treatment and composting increased perfluoroalkyl acid (PFAA) concentrations.
- Only dilution from blending with non-PFAS material decreased PFAA concentrations.
- Thermal hydrolysis process had no apparent effect on PFAA concentrations.
- PFAS sources are a greater driver of PFAS loads in biosolid-based products than treatment processes.

Key words

blending; composting; heat treatment; perfluoroalkyl acids; PFAA precursors; thermal hydrolysis

Introduction

Biosolids are nutrient-rich materials from the treatment of domestic wastewater in a water resource recovery facility (WRRF) which are applied to agricultural land as a fertilizer to enhance agricultural production and maintain soil quality. Although biosolid-derived products have many benefits, they may contain per- and polyfluoroalkyl substances (PFAS) of varying levels depending on sources entering WRRFs. PFAS are a group of man-made chemicals with both water- and oil-repellant properties and thus widely used in industrial and commercial products, such as paper, textiles, fire retardants, food packaging, pesticides and others (Buck et al., 2011). PFAS contain variable carbon chain lengths with covalently bonded fluorine atoms, making them chemically and thermally stable. Hence, PFAS are difficult to degrade via chemical and biological processes (Kissa, 2001). PFAS include numerous subclasses such as fluorotelomer alcohols (FTOHs) and perfluoroalkyl sulfonamides, which are known to be precursors to perfluoroalkyl carboxylic acids (PFCAs) and perfluoroalkyl sulfonic acids (PFSAs) (Wang, DeWitt, Higgins, & Cousins, 2017). PFCAs and PFSAs together are referred to as perfluoroalkyl acids (PFAAs), and thus, their precursors will be herein referred to as PFAA precursors. Due to their ubiquitous usage and recalcitrant nature, PFAS are persistent in the environment and frequently detected in various environmental matrices such as water (Appleman et al., 2014; Guelfo & Adamson, 2018; Hu et al., 2016), biosolids (Alder & van der Voet, 2015; Armstrong, Lozano, Rice, Ramirez, & Torrents, 2016; Navarro et al., 2018; Venkatesan & Halden, 2013), soil (Munoz et al., 2018), plant (Scher et al., 2018) and wildlife (Sedlak, Benskin, Wong, Grace, & Greig, 2017). In addition, PFAS including some long-chain PFCAs and PFSAs can bioaccumulate in aquatic organisms (Babut et al., 2017; Gewurtz et al., 2014; Hong et al., 2015) and may transfer to the food chain. Several animal toxicity studies have shown that PFAS exposure might lead to hepatotoxicity, developmental toxicity, immunotoxicity, and hormonal disruption (Lau et al., 2007).

Conventional activated sludge processes are ineffective in removing PFAS in wastewater (Sinclair & Kannan, 2006). In some cases, PFAS concentrations in the effluent have been higher than those observed in the influent (Filipovic & Berger, 2015; Guerra et al., 2014; Sinclair & Kannan, 2006). This has been attributed to the biodegradation of PFAA precursors to PFAAs (Arvaniti, Ventouri, Stasinakis, & Thomaidis, 2012; Dauchy et al., 2017; Schultz et al., 2006), which are terminal degradation products of PFAS (Arvaniti et al., 2012; Z. Wang et al., 2017). PFAAs can be produced from the breakdown of PFAA precursors or can be directly used in commercial and industrial products (Benskin, Li, Ikonomou, Grace, & Li, 2012; Favreau et al., 2017). Furthermore, since PFAS degradation typically leads to other PFAS subclasses, any decrease in the total PFAS load in the wastewater will be primarily due to partitioning into the sludge during wastewater treatment processes (D'eon, 2012; Higgins, Field, Criddle, & Luthy, 2005; Sinclair & Kannan, 2006). Although some PFAS such as FTOHs are volatile (Ross et al., 2018), in the presence of high organic matter solids such as sludge, loss due to volatility will be low compared to degradation (Liu, Lee, Nies, Nakatsu, & Turco, 2007; Wang et al., 2011).

Treatment of sludge is necessary to meet the EPA Part 503 Biosolids regulations that require the reduction of pathogens, vector attraction (VAR), and heavy metals in order to use biosolids as nutrient sources and soil conditioners (USEPA, 1994). Depending on these levels, biosolids are categorized to Class A or Class B. Class A biosolids meet stringent pathogen and VAR standard (no restricted use), while Class B biosolids contain a higher level of pathogens than Class A biosolids (restricted use) (USEPA, 1994). Composting and heat treatment are the most common methods to improve the stability of organic matter and decrease pathogen levels (Fernández, Plaza, Hernández, & Polo, 2007; Marttinen, Hänninen, & Rintala, 2004). Currently, different types of commercially available biosolid-based products are available on the market. The most common types of fertilizers are biosolids co-composted with woody materials and heat-treated biosolids in a pelletized form. Other types may include a biosolid product blended with woody materials and a liquid fertilizer that has undergone thermal hydrolysis processes. Although treatment processes can improve the quality of commercially available biosolid-based products, the effects of these processes on the fate of PFAS have not been evaluated.

The objective of this study was to compare PFAA concentrations in four commercially available biosolid-based products that received different treatments: heat treatment, composting, blending, and thermal hydrolysis process. To evaluate PFAA loads before (pre) and after (post) various treatment processes, Class A or B biosolids (pretreatment) and its final product (post-treatment) were obtained from four different processing facilities in the United States and Canada. Seventeen PFAAs were quantified, and qualitative analyses of PFAA precursors were assessed using a total oxidizable precursor (TOP) assay as well as target screening of 30 PFAA precursors with time-of-flight mass spectrometry.

Materials and methods

Standards and reagents

All 17 PFAAs were purchased as mixtures (PFCA-MXB) from Wellington Laboratories (Guelph, Canada), containing 13 perfluorocarboxylic acids (PFCAs, C4-C18, perfluoro-n-butanoic acid (PFBA), perfluoro-n-pentanoic acid (PFPeA), perfluoro-n-hexanoic acid (PFHxA), perfluoro-n-heptanoic acid (PFHpA), perfluoro-n-octanoic acid (PFOA), perfluoro-n-nonanoic acid (PFNA), perfluoro-n-decanoic acid (PFDA), perfluoro-n-undecanoic acid (PFUdA), perfluoro-n-dodecanoic acid (PFDoA), perfluoro-n-tridecanoic acid (PFTrDA), perfluoro-n-tetradecanoic acid (PFTeDA), perfluoro-n-hexadecanoic acid (PFHxDA), and perfluoro-n-octadecanoic acid (PFODA)) and 4 perfluorosulfonic acids (PFSAs, potassium perfluoro-1-butanesulfonate (PFBS), sodium perfluoro-1-hexanesulfonate (PFHxS), sodium perfluoro-1-octanesulfonate (PFOS), and sodium perfluoro-1-decanesulfonate (PFDS)). Isotopically labeled compounds were also purchased in premixed ampules from Wellington Laboratories (MPFAC-MXA), containing 1,2,3,4-$^{13}C_4$-labeled perfluorobutanoic acid (MPFBA), 1,2-$^{13}C_2$-labeled perfluorohexanoic acid (MPFHxA), 1,2,3,4-$^{13}C_4$-labeled perfluorooctanoic acid (MPFOA), 1,2,3,4,5-$^{13}C_5$-labeled perfluorononanoic acid (MPFNA), 1,2-$^{13}C_2$-labeled perfluorodecanoic acid (MPFDA), 1,2-$^{13}C_2$-perfluoro undecanoic acid (MPFUdA), 1,2-$^{13}C_2$-labeled perfluorododecanoic acid (MPFDoA), $^{18}O_2$-labeled sodium perfluoro-1-hexanesulfonate (MPFHxS), and 1,2,3,4-$^{13}C_4$-labeled sodium perfluoro-1-octanesulfonate (MPFOS). The reagents used in the solvent extraction, TOP assay, and chromatographic analysis are described in the Supporting Information (SI).

Biosolid-based product collection

All biosolid-based products were obtained between August 2018 and September of 2018 from four WRRFs (nutrient analysis

Table 1. Description of the biosolid-based products used in the study

POST-TREATMENT PROCESS	SAMPLE	SAMPLE NAME	WRRF INFORMATION
Heat treatment (Rotary drying at 480–650°C for 45 min)	Class B biosolids Heat-treated biosolids	Heat treatment (pre) Heat treatment (post)	~1.1 million people served Average flow: ~95 million gallon per day (MGD) Activated sludge process Aerobic and anaerobic digestion
Blending with maple sawdust and aged bark (20% of Class A-EQ biosolids + 20% sawdust + 60% aged bark)	Class A-EQ biosolids Blended biosolids Sawdust Aged bark	Preblend Post-blend Sawdust (blending material) Bark (blending material	~90,000 people served Average flow: ~ 27MGD Activated sludge process Aerobic and anaerobic digestion
Thermal hydrolysis process (A high shear mixing between 800 to 1,000 rpm at 70–75°C, 15 psi and pH 9.5–10 for 1 hr)[a]	Class B biosolids Liquid biosolids (regular process) Liquid biosolids (stored in a lagoon for 2 to 8 months after process at pH 9.5–10) Liquid biosolids (high pH condition)	Prethermal hydrolysis Post-thermal hydrolysis (pH 9.5–10) Post-thermal hydrolysis (pH 9.5–10, lagoon) Post-thermal hydrolysis (> pH 12)	1.5 million people served Average flow: ~150 MGD Activated sludge process Anaerobic digestion
Composting with sawdust (Windrow technology, 55°C Active composting/curing for ~84 days, 20% biosolids and 80% sawdust)	Class B biosolids (2018)[b] Composted 2016 biosolids[c] Composted 2018 biosolids[c] Sawdust	Class B biosolids from 2018 Composted 2016 biosolids Composted 2018 biosolids Co-composting material (sawdust)	~800,000 people served Average flow: ~70 MGD Activated sludge process Anaerobic digestion

[a]This hydrolysis process used for this product was conducted at lower pressure (as well as lower pressure) than is typically used (typically >140°C) in thermal hydrolysis processes (McNamara et al., 2012; Strong, McDonald, & Gapes, 2011).

[b]Biosolids from a single municipal water resource recovery facility (WRRF).

[c]Class B biosolids from four different WRRFs.

and other parameters in Table S1, Supporting Information). The treatment processes include heat treatment, composting, blending, and thermal hydrolysis as detailed in Table 1. The Class A or B biosolids before treatment (pre), final biosolid-based products (post-treatment), and co-composting materials that were added during the treatment process (sawdust or aged bark) were obtained from the different WRRFs (Table 1). In addition, one facility supplied three additional samples where thermal hydrolysis processes were used to assess whether different pH values (pH 9.5–10 vs. >12) as well as lagoon storage had additional impacts on PFAS levels, which was assessed for the pH 9.5–10 treatment process. For composted Class B biosolids, the composted material included biosolids from four different WRRFs at two different times (2016 and 2018), whereas the 2018 Class B biosolids that were to be representative of PFAS loads prior to composting were from one WRRF in 2018. Therefore, data for the composting process will be discussed differently, given a direct comparison is limited. Additional information associated with each of four WRRFs is given in Table 1 (last column).

Upon receipt, samples were weighed and transferred to 50-ml polypropylene (PP) tubes and frozen (−20°C) until freeze-drying. Prior to extraction, all biosolid-based products were freeze-dried for 72 hr using a freeze dryer (Labconco). The freeze-dried samples were sieved (<2 mm) to obtain homogeneous samples (Table S1, Supporting Information). Fertilizer solution pH was measured (Accumet research AR20, Fisher Scientific) for a 0.5 g sample to 5 ml deionized water after a 24-hr equilibration (Table S1, Supporting Information).

Biosolid-based product extraction

For all samples, PFAA analysis was done on subsamples from the <2 mm fraction. In addition, the >2 mm fraction of the post-composted 2016 biosolids product and post-blend product, as well as the blending and co-composting materials, was evaluated for PFAA loads, which we hypothesized would not contribute significantly to the overall PFAA loads in the final product. Freeze-dried samples (five replicate subsamples from each sample) were extracted for 17 PFAAs using a method modified from (Sepulvado, Blaine, Hundal, & Higgins, 2011). Briefly, 0.5 g samples were added to a 15-ml PP tubes immediately followed by the addition of isotopically labeled surrogate mixtures (10 ng each). Samples were extracted with 7 ml 99/1 v/v methanol/200 mM ammonium hydroxide aqueous solution and vortexed for 1 min. The samples were then sonicated in a heated sonication bath at 30°C for one hour followed rotating end over end for 2 hr. The samples were centrifuged (1,613 RCF) for 30 min, and the supernatant transferred to a clean 50-ml PP tube. This process was repeated two more times. Prior to analysis, all solvent extracts were combined and concentrated under nitrogen using a RapidVap Vacuum Evaporation System (Labconco) and reconstituted with 1,000 µl of 99:1 (v/v) methanol and glacial acetic acid. A fraction of the extract (500 µl) was saved for PFAA precursor screening analysis. The remaining extract (500 µl) was cleaned with 20–30 mg of ENVI-Carb to reduce matrix effects that may affect quantitation. An aliquot of cleaned extract (400 µl) was transferred to a 1.5-ml injection vial containing 400 µl of 0.003% ammonium hydroxide in nanopure water (1:1, MeOH/H_2O, v/v). The samples were stored in a refrigerator at 4°C until analysis.

PFAA analysis

All samples were analyzed for 17 PFAAs by liquid chromatography with tandem mass spectrometry (LC-MS/MS) using a Shimadzu system coupled to a SCIEX TripleToF 5600+. PFAA analysis was performed based on the method described by Youn et al. (Choi, Kim Lazcano, Yousefi, Trim, & Lee, 2019). Briefly, Analyst TF1.7 software (SCIEX) was used to control the instrument. Target analytes (15 µl injection volume) were separated using a Kinetex® EVO C18 column (100 Å, 100 × 2.1 mm, 5 µm, Phenomenex) with a gradient at a flow rate of 0.75 ml/min. A delay column (Luna C18, 100 Å, 30 × 4.6 mm ID, 3 µm, Phenomenex) was installed between the mobile phase mixer and autosampler injection port to separate PFAS background contamination from the system. The gradient used 0.15% acetic acid in water (a) and 20 mM ammonium acetate in methanol (b) mobile phases with the following gradient profile (total 11 min): 0–0.5 min: 30%B; 0.5–3 min: 30%–70%B; 3–6.5 min: 70%–100%B; 6.5–8.5 min: 100%B; 8.5–9 min: 100%–30%B; and 9–11 min: 30%B. All data were processed with MultiQuant software 3.0.1 (SCIEX). Precursor to product ions is summarized in Table S2 (Supporting Information)

PFAA precursor screening analysis

The potential presence of PFAA precursors in the biosolid-based products that are subject to generate PFAAs in the future was explored by screening for 30 known PFAA precursors (see Table S3, Supporting Information) using LC-QToF/MS in SWATH™ acquisition mode. The PFAA precursor data were acquired on the SCIEX 5600 QToF as described by Choi et al. (2019), which used the same column and mobile phases as noted for the PFAA quantification except with a different gradient at 0.5 ml/min as follows (total 18.20 min): 0–0.1 min: 10%B; 0.1–10 min: 10%–100%B; 10–15 min 100%B; 15.00–15.20 min: 10%B; and 15.20–18.20 min: 10%B. Biosolid-based product extracts in methanol, the procedural blank, and a standard mixture of analytical PFAA precursors (EtFOSE, EtFOSAA, EtFOSA, MeFOSA, FOSA, FOSAA, 6:2 FTOH, 6:2 FTCA, and 5:3 FTCA) were processed with a 30-µl injection volume. PeakView 2.2 software with MasterView (SCIEX) was used to analyze SWATH™ data. Only [M-H] was considered. PFAA precursors were identified using a comparison of MS/MS spectra with the mixture of analytical standards or the Fluorochemical High-Resolution MS/MS Spectral Library (SCIEX) database.

Analytical QA/QC

A stable isotope dilution with nine mass-labeled standards was used to correct for the matrix effect and the extraction recovery. A six-to eight-point calibration curve (0.01–15 µg/L) to cover the entire range of the sample concentrations was prepared and performed at the beginning and the end of a sample batch. A continuing calibration verification standard was injected every 12 injections immediately after an instrument blank, which was used to monitor potential carryover between injections. The limit of detection (LOD) and quantification (LOQ), as well

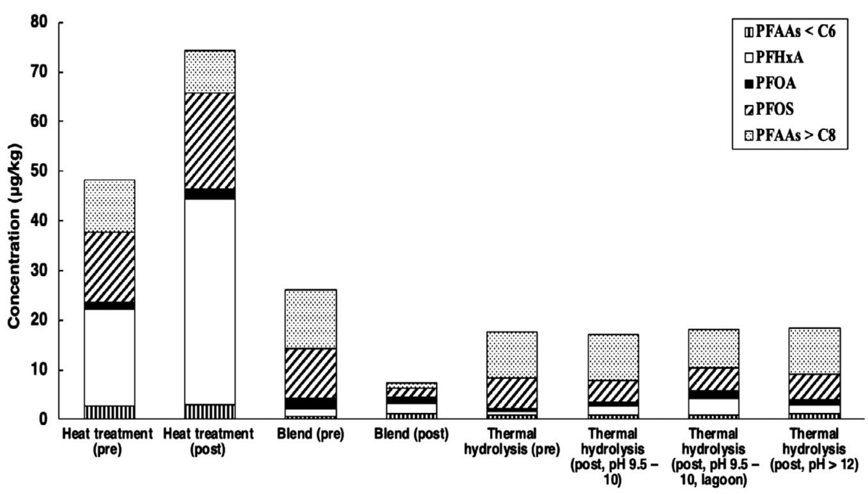

Figure 1. PFAA loads (µg/kg, dry wt.) for the <2 mm particle size fraction of the samples. Pre: before post-treatment process (the Class A or B biosolids) and post: after post-treatment process. PFAAs <C6 include PFBA and PFBS, and PFAAs >C8 include PFNA, PFDA, PFUdA, PFDoA, PFTrDA, and PFTeDA.

as recoveries and other analytical details, are included in Table S2 (Supporting Information).

Statistical analysis

Statistical analyses were performed using R software (version 3.4.3). Normality and homogeneity of the variances were tested with the Shapiro–Wilk test and Levene's test, respectively. One-way analysis of variance (ANOVA) followed by Tukey's post hoc tests ($p < 0.01$) was performed to determine the statistical differences.

Results

PFAA concentrations in pre- and post-samples

PFAA composition and loads (μg/kg dry weight) in the <2 mm particle size fraction before (pre) and after (post) heat treatment, blending, or thermal hydrolysis are summarized in Figure 1 (additional details in Tables S4 and S5, Supporting Information). PFAAs ranged from 18 to 49 μg total PFAAs/kg (PFHxA: 0.4–19 μg/kg, PFOA: 0.7–1.3 μg/kg, and PFOS: 6.1–14.3 μg/kg) prior to treatment process. The ranges are generally within the range of PFAS detected in wastewater solids (Armstrong et al., 2016; Gottschall et al., 2017; Navarro et al., 2017). After treatment, samples ranged from 8 to 123 μg total PFAAs/kg. Individual PFAA concentrations are summarized in Figures 2 and 3. Heat treatment (45 min at 480–650°C) led to an increase in the total PFAA concentrations by 53% (49–75 μg/kg), which was mainly due to increased PFHxA concentrations (19–42 μg/kg) (Figure 2). Increases in PFHxA indicate that some PFAA precursors with a C6 perfluorinated alkyl chain were degraded during the heat treatment. Although PFAS are known to be thermally stable, limited thermal degradation of PFAS data is currently available. However, a few studies have suggested that certain fluoropolymers such as polytetrafluoroethylene (PTFE) and FTOHs can thermally (~500°C) degrade to PFCAs (Ellis, Mabury, Martin, & Muir, 2001; Ellis et al., 2004). Based on the other degradation studies, fluorotelomer-based PFAA precursors, which contain a CH_2CH_2-linkage between the fluoroalkyl chain and polar functional group, break down to PFCAs via aerobic biotransformation (Liu & Liu, 2016; Wang et al., 2011) and heat-activated chemical oxidation (Park, Lee, Medina, Zull, & Waisner, 2016). The blending process reduced the total PFAA concentrations by 72% (27–8 μg/kg), which is a dilution effect from blending of biosolids (20%) with 80% woody products (20% sawdust and 60% aged bark) (Table 1).

For the thermal hydrolysis treatment process (70–75°C), there were no significant differences in total PFAAs before and after the pH 9.5–10 for 1-hr treatment even after lagoon storage or after the pH > 12 treatment (Figure 1). However, PFHxA and PFOA concentrations (μg/kg) did increase after 2–8 months of lagoon storage after the pH 9.5–10 thermal hydrolysis treatment (Figure 3). PFAS breakdown under anaerobic conditions such as anaerobic sludge digestion (Sun, Gerecke, Giger, & Alder, 2011) and landfills (Benskin et al., 2012) has been reported although degradation rates are slower than those observed in aerobic conditions (Sáez, de Voogt, & Parsons, 2008).

For composting, PFAA concentrations were higher in the composted 2018 biosolids compared with the untreated Class B biosolids from 2018 (Figure 4); however, the differences cannot be automatically assumed to be from the composting process. As noted earlier, the uncomposted biosolids came from one WRRF,

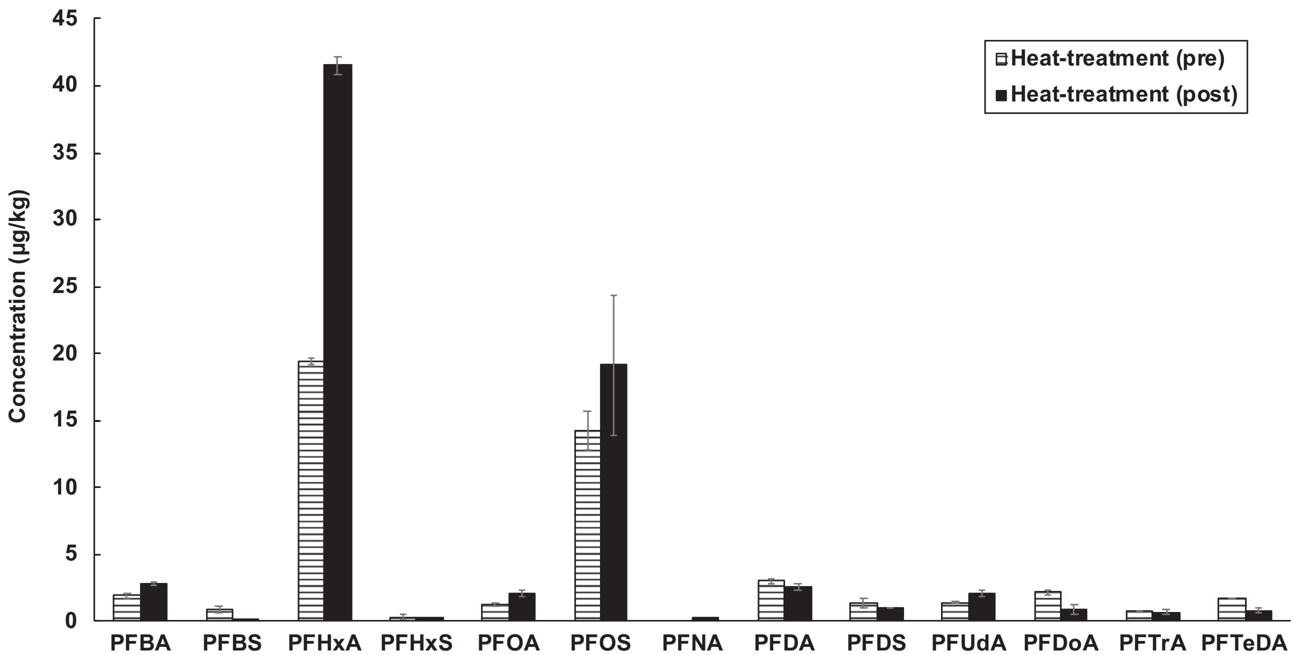

Figure 2. Individual PFAA concentrations (μg/kg, dry wt.) in biosolid-based products (<2 mm fraction) pre- and post-heat treatment. Error bars represent the standard error of the mean (n = 4–5).

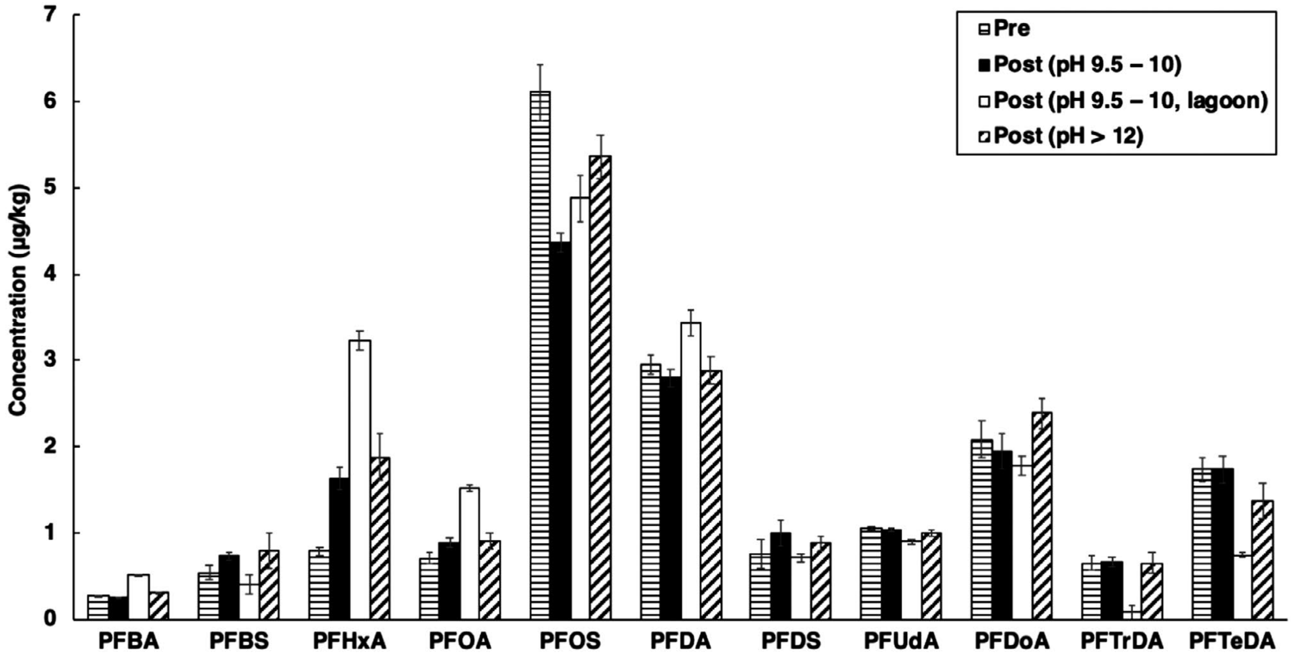

Figure 3. Individual PFAA concentrations (μg/kg, dry wt.) in the biosolid-based products (<2 mm particle size fraction) treated by thermal hydrolysis. Pre: Class B biosolids before thermal hydrolysis; post (pH 9.5–10): thermally hydrolyzed at pH 9.5–10; post (pH 9.5–10, lagoon): lagoon storage after thermal hydrolysis at pH 9.5–10; and post (pH > 12): thermally hydrolyzed at higher pH (> 12). Error bars represent the standard error of the mean (*n* = 4–5).

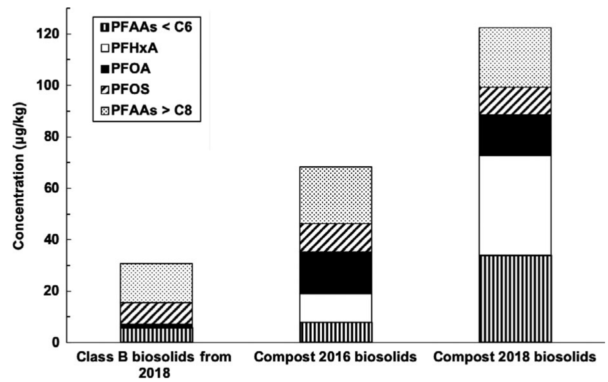

Figure 4. PFAA loads (μg/kg, dry wt.) for the <2 mm particle size fraction of the Class B biosolids from 2018 from one municipal water resource recovery facility (WRRF) and final composted 2016 and 2018 fertilizer products that contained Class B biosolids from four different WRRFs. Only one source of the Class B biosolids from 2018 was obtained and analyzed. PFAAs <C6 include PFBA and PFBS, and PFAAs > C8 include PFNA, PFDA, PFUdA, PFDoA, PFTrDA, and PFTeDA.

whereas the biosolids that had been composted were a mix of biosolids from three additional WRRFs, which constituted approximately 40% of the total biosolids that were composted in both 2016 and 2018. Without knowing the PFAAs level in the unanalyzed sources of the actual Class B biosolids that were used in the composting process prior to composting, it is difficult to evaluate the effect of composting on PFAS fate. The potential reasons for elevated PFAA concentrations in the composted samples can be attributed to higher PFAA levels in the other Class B biosolid sources or breakdown of PFAA precursors to PFAAs during composting process. Also, it was noticed that there are several nearby manufacturing facilities that may use PFAS in their processes which may be potential sources of contamination to the composting site, which could occur through air transport or possibly contaminated water. Some volatile PFAS such as FTOHs can be transported and oxidized in the atmosphere yielding PFCAs (Ellis et al., 2004). For example, the primary product of 8:2 FTOH degradation and atmospheric oxidation is PFHxA (Ellis et al., 2004; Liu et al., 2007). However, PFHxA concentrations are three times higher in the composted 2018 biosolids compared to the composted 2016 biosolids, whereas there are negligible differences in PFOA and PFOS. Therefore, increases in PFHxA are more likely to be a direct response to its use as a replacement of PFOS and PFOS precursors in 2002 and PFOA- and PFOA-related chemicals in 2015 (Alder & van der Voet, 2015; USEPA, 2006). Even with the phase-outs, PFOS is still used in the chrome plating industry and many previously purchased consumer products containing PFOA-based materials are still in use (Briels, Ciesielski, Herzke, & Jaspers, 2018; United Nations Environmental Program, 2009). Although dilution could occur in a composting process if co-composting materials such as plant materials are added as part of the process, others have shown that composting biosolids are ineffective in reducing contaminant levels in sludge or other types of biosolids products (Kinney et al., 2006).

Variation in PFAA levels between the <2 mm and >2 mm particle size fractions

In the larger particle size fractions (>2 mm), which were evaluated for the composted 2016 biosolids, >2 mm) and the blend (post >2 mm), the total PFAA concentration was 35 and

Table 2. A summary of ΣPFCAs, ΣPFSAs, ΣShort chains, ΣLong chains, and ΣPFAAs concentrations (μg/kg) of the >2 mm particle size fraction and blending and co-composting materials from the blend and compost products ($n = 5$). The value in parentheses is the standard error of the mean

SAMPLE	ΣPFCAS	ΣPFSAS	ΣSHORT[a]	ΣLONG[b]	ΣPFAAS
Blended (post)	11.0 (5.5)	6.0 (1.5)	8.5 (2.9)	9.5 (4.1)	16.9 (6.9)
Composted 2016 biosolids	25.3 (5.3)	9.6 (1.5)	16.8 (2.8)	19.9 (4.1)	34.9 (6.8)
Bark (blending material)	1.1 (0.5)	0.2 (0.1)	1.6 (0.4)	0.2 (0.1)	1.3 (0.4)
Sawdust (blending material)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0)
Co-composting material (sawdust)	0.1 (0)	0 (0)	0.2 (0)	0 (0)	0.2 (0)

[a]Short chains include PFCAs ≤C7 and PFSAs ≤C5.

[b]Long chains include PFCAs ≥C8 and PFSAs ≥C6.

Table 3. PFAA precursors identified in the screening of 30 targeted PFAS (see Table S5)

	HEAT TREATMENT	BLENDING	THERMAL HYDROLYSIS[a]	COMPOSTING[b]
Pre	5:3 FTCA 6:2 FTSA 8:2 FTSA 6:2/6:2 diPAPs 6:2/8:2 diPAPs 8:2/8:2 diPAPs	5:3 FTCA 6:2/6:2 diPAPs 6:2/8:2 diPAPs 8:2/8:2 diPAPs 8:2/10:2 diPAPs	5:3 FTCA 6:2/6:2 diPAPs 6:2/8:2 diPAPs 8:2/8:2 diPAPs 8:2/10:2 diPAPs	5:3 FTCA 6:2/6:2 diPAPs 6:2/8:2 diPAPs 8:2/8:2 diPAPs
Post	5:3 FTCA 6:2 FTSA 8:2 FTSA 6:2/6:2 diPAPs 6:2/8:2 diPAPs	6:2/6:2 diPAPs 8:2/8:2 diPAPs 8:2/10:2 diPAPs	5:3 FTCA 6:2/6:2 diPAPs 6:2/8:2 diPAPs 8:2/8:2 diPAPs	FOSA 5:3 FTCA 6:2 FTSA 8:2 FTSA 6:2/8:2 diPAPs 8:2/8:2 diPAPs 8:2/10:2 diPAPs

[a]For the materials processed with the standard thermolysis process at pH 9.5–10.

[b]Composting (pre) sample represents Class B biosolids from a single source in 2018, whereas the composting (post) sample represents the composted 2018 Class B biosolids from different municipal water resource recovery facilities (WRRFs).

17 μg/kg, respectively, but with high standard deviations (*SD*) among the 5 replicates (±15 μg/kg and ± 16 μg/kg, respectively). This high variation may be due to the clinging of the finer material (<2 mm) to the larger particles (>2 mm). It was difficult to separate the two fractions unless a washing process was used, which could have leached out some of the PFAAs. For the bark blend, sawdust blend, and sawdust compost materials, total PFAAs were <2 μg/kg (Table 2). Therefore, when PFAA concentrations determined for the <2 mm particle size fraction are normalized to the whole product, overall PFAS loads per mass of product decrease (a dilution effect) with 32% of the blended and 39%–47% of the composted 2016 and 2018 product consisting of the particle size >2 mm. Although these blending materials for these products were low in PFAAs, previously reported PFAS levels in wood building materials ranged from 1.39 to 18.3 μg/kg with a median concentration of 4.9 μg/kg (Bečanová, Melymuk, Vojta, Komprdová, & Klánová, 2016). For these wood-based materials with higher PFAA levels, residual sealants and other adhesive products may serve as the PFAS source (Bečanová et al., 2016).

Screening for PFAA precursors

A summary of the PFAA precursors found in the biosolid-based products is presented in Table 3. Of those found, 6:2 and 8:2 fluorotelomer phosphate diesters (diPAPs) were detected in all samples pre- and post-treatment. 6:2 and 8:2 fluorotelomer sulfonates (FTSAs) and 5:3 fluorotelomer carboxylic acid (FTCA) were detected in the heat treatment (pre and post), the 2018 Class B biosolids (from one WRRF) and the composted 2018 biosolids (represented Class B biosolids from several WRRFs). The 5:3 FTCA is a metabolite unique to degradation of fluorotelomers (Liu & Avendaño, 2013). Also detected in only the composted biosolids was perfluorooctane sulfonamide (FOSA), which is an intermediate metabolite prior to the formation of PFOS for *N*-ethyl perfluorooctane sulfonamidoethanol (EtFOSE) (Zhang, Lee, Niu, & Liu, 2017) and mono/diPAPs (Benskin et al., 2013). The half-lives reported for microbial degradation of FTSAs are >3 months and vary widely for PAPs (Liu & Avendaño, 2013). The detection of diPAPs, FTSAs, and FTCAs in biosolids was consistent with previous studies (Eriksson, Haglund, & Kärrman, 2017; Lee, Tevlin, Mabury, & Mabury, 2013).

Conclusions

This study examined the effect of the treatment processes on the level of PFAS in commercially available biosolid-based products. The post-treatment processes either increased the PFAA concentrations due to the breakdown of PFAA precursors or had no significant effect on the level of PFAAs with one exception. The blending process by dilution reduced the overall concentration of PFAAs. The QToF/MS screening revealed that some PFAA precursors remained after the treatment processes, which can degrade to PFAAs after application of biosolid-based products. Due to the ineffectiveness of common post-treatment processes on PFAS concentrations in biosolid-based products, it is important to control sources contributing to PFAS levels in biosolids. Implementation of control measures can rapidly reduce loads coming in our wastewater treatment plants. For example, Krogh, Lyons, and Lowe (2017) and Brose et al. (2019) (Brose et al., 2019; Krogh et al., 2017) found statistically significant decreases in triclosan and/or triclocarban concentrations in wastewater influent in 2014 compared to previous years, which could be attributed to a policy change by the U.S. FDA affecting the source of these compounds in consumer products. Likewise, Andrade et al. (2015) (Andrade et al., 2015) showed a decrease in brominated diphenyl ether (BDE)-47 and BDE-49 concentrations in wastewater influent that could be attributed to the phase-out of these compounds in manufacturing. Additional control measures are needed such as pretreatment of high PFAS level containing WRRF influent to reduce PFAS loads that may partition into materials used in producing biosolid-based products. These are critical points in the PFAS discussion as it relates to wastewater treatment given their persistence.

It is also important to inspect potential points of contamination in the biosolid treatment process such as equipment used in the treatment process that may contain PFAS. PFAS deposition from the area surrounding the composting facility can occur, especially when placed amidst other industry and manufacturing facilities that may use PFAS in their production line. Although biosolid-based products are beneficial to plant health and reduce wastes by recycling, thus diverting materials from incineration or landfilling, the presence of PFAS in biosolid-based products is a rapidly growing concern among the public and within regulatory agencies. Recently, the Maine Department of Environmental Protection (DEP) has established screening standards for three PFAS (1,900 μg/kg for PFBS, 2.5 μg/kg for PFOA, and 5.2 μg/kg for PFOS) that products from all biosolids/sludge program licenses and biosolids/sludge composting facilities must meet to be land-applied. In our study, only three samples meet all three screening levels among all pre- and post-samples (a total of 11). These types of regulations will put an enormous amount of pressure on composting facilities along with additional costs. This research is an important first look at understanding how different treatment processes affect PFAS concentrations in final biosolid-based products. In addition to controlling PFAS sources entering our WRRFs, research is needed to find ways to minimize the PFAS in biosolids and reduce PFAS leachability from biosolids-based products to reduce PFAS loads entering the environment and risks to human and ecosystem health.

Acknowledgments

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Data Availability

Most data have been presented in the manuscript or supplemental information. Additional details or data that support the findings of this study are available from the corresponding author upon reasonable request.

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Exhibit 4

NEFCO
Recycle, Renew, Restore

April 25, 2019

Ms. Jeanette Cotinola
South Orange County Wastewater Authority
34156 Del Obispo Street
Dana Point, California 92629

Re: South Orange County Wastewater Authority
Request for Proposals for
Innovative Solids/Biosolids Technology Solicitation

Dear Ms. Cotinola,

NEFCO is pleased to submit the attached Proposal in response to South Orange County Wastewater Authority's (SOCWA) Request for Proposal for Innovative Solids/Biosolids Technology.

NEFCO is widely recognized as an industry leader in designing, building and operating rotary dryer biosolids facilities, exactly like what is being proposed at the SOCWA facilities. As an example, our operating contract with the Massachusetts Water Resources Authority has been in place since 1991 and is a model for the benefits of a private sector partnership with a public entity. Further evidencing our expertise in biosolids drying, we designed, built, and have been operating and maintaining the largest drying facility in North America in Detroit, MI. Our selection for this project was based on our expertise, our reputation, and the confidence that the Great Lakes Water Authority had and currently has in NEFCO. Ninety combined years of designing, operating, maintaining, and beneficially distributing the resulting product has resulted in an expertise that NEFCO will bring directly to SOCWA:

- Investment in the South Orange County Community – NEFCO understands the importance of community, and will utilize local resources in the construction and operation of new facilities:
  - Maximize use of local Small Business Enterprises and Minority Business Enterprises.
  - South Orange County and California-based construction subcontractors will be used.
  - Team with local engineering partner, Civiltec, and key local specialty consultants.
  - Hiring for new OMR staff will be done locally.
  - Non-proprietary equipment/technology allows use of local fabricators and vendors for repairs, spare parts, and services.

NEFCO
500 Victory Road, 4th Floor, North Quincy, MA 02171
(t) 617.773.3131 (f) 617.773.3122

- Potential Ban on Biosolids Land Application – NEFCO ensures each of its plants are equipped to handle sudden regulation changes by creating diverse market opportunities and producing a high quality dried biosolids product:
  - Beyond the current SOCWA properties, we will develop a geographically diverse portfolio of product outlets.
  - Establish alternative high-quality outlets such as alternative fuel and soil amendment opportunities.
- Deferral of Capital Investments – Significant capital investments are expected at the JBLTP and the RTP within the next ten years to reconstruct the digestion and dewatering systems. NEFCO's drying technology provides flexibility for SOCWA to defer capital projects, including:
  - Ability to process undigested dewatered sludge. NEFCO's system can continue to dry undigested sludge during digester upgrades or can allow SOCWA to wait while other more critical investments are made.
  - NEFCO provides dewatering in three of its facilities. Our system handles a significant range of cake solids, from 13% to over 30%. The Infrastructure needed to incorporate dewatering into our system is very simple, reducing SOCWA's cost and providing significant flexibility.

- Neighborhood Impacts – Biosolids hauling from each facility has an impact on the surrounding community in terms of both odors and noise. NEFCO has experience managing these impacts in urban areas and will design new facilities to mitigate these issues:
  - Use best practices developed by NEFCO through decades of experience managing biosolids in large metropolitan urban environments.
  - Design odor control measures into the transportation of SOCWA biosolids and incorporate odor control technologies into the building to ensure any emitted air is treated for odors.
  - Utilize best management odor control practices in hauling and application of dried product.
  - Use public outreach and partner with SOCWA to proactively manage community and regulatory sensitivities.
  - Include design measures to mitigate any impact to the community from noise in the facility. NEFCO works with vendors to ensure equipment noise is minimized, and designs facilities to include sound-attenuating systems downstream of tonal noise sources.

- Facility Reliability – NEFCO will use its non-proprietary biosolids drying process for the County's new Biosolids Management Facility (BMF) to provide a higher level of reliability for each plant's operations:
  - Increase in on-site storage will give more flexibility with transportation scheduling.
  - Development of Asset Management Plan to drive the maintenance program for each facility, focusing on predictive and preventative maintenance to reduce downtime and lengthen equipment life.
  - Use of U.S. based vendors allows time for repairs to be greatly reduced versus procuring foreign parts and materials.
- Energy Management – Both the JBLTP and the RTP have existing cogeneration facilities, and the energy generation capacity for each is a key concern for SOCWA. NEFCO will seek to develop a biosolids management solution that will help maximize the amount of energy produced from their solids:
  - Ability to incorporate a variety of alternative, renewable energy sources into the system's operation. NEFCO has experience utilizing digester biogas and landfill gas as fuel for the drying process in multiple facilities.
  - In addition to a traditional drying facility, NEFCO will evaluate a range of technologies that could be used to optimize SOCWA's energy generation and overall utilization.

The point of contact for this project will be:

Larry Bishop, P.E.
General Manager
NEFCO
500 Victory Road
North Quincy, Massachusetts 02171
(617) 773.3131 (t); (617) 773.3122 (f)
lbishop@nefcobiosolids.com

NEFCO hereby acknowledges Addendum 1 and Addendum 2 (acknowledgements attached hereto).

Our goal for the SOCWA / NEFCO contract is to assume the operational and performance risk for SOCWA's assets, and to provide the best value for the rate payers. We appreciate the opportunity to submit this proposal.

Sincerely,

Larry W. Bishop, P.E.
General Manager

SOUTH ORANGE COUNTY WASTEWATER AUTHORITY

ADDENDUM No.1
TO REQUEST FOR PROPOSALS
FOR TECHNOLOGY SOLICITATION OF

INNOVATIVE SOLIDS/BIOSOLIDS TECHNOLOGY PROJECT

THE PROPOSER SHALL EXECUTE THE CERTIFICATION AT THE END OF THE ADDENDUM AND SHALL ATTACH THE ADDENDUM TO THE PROPOSAL (NOT TO BE INCLUDED AS PART OF THE PAGE COUNT).

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1. The proposal due date was originally March 21, 2019 at 2:00 pm. The due date has been changed to **April 18, 2019 at 2:00 pm**. All other dates for the project will remain unchanged.

DATED: March 6, 2019

Jason Manning
Jason Manning, Sr. Engineer

BIDDER'S CERTIFICATION

I acknowledge receipt of the foregoing Addendum No. 1 and accept all conditions contained herein.

DATED: April 23, 2019

BIDDER: *Larry W. Bishop*

BY: Larry W. Bishop, P.E.
General Manager
NEFCO

SOUTH ORANGE COUNTY WASTEWATER AUTHORITY

ADDENDUM No.2
TO REQUEST FOR PROPOSALS
FOR TECHNOLOGY SOLICITATION OF

INNOVATIVE SOLIDS/BIOSOLIDS TECHNOLOGY PROJECT

THE PROPOSER SHALL EXECUTE THE CERTIFICATION AT THE END OF THE ADDENDUM AND SHALL ATTACH THE ADDENDUM TO THE PROPOSAL (NOT TO BE INCLUDED AS PART OF THE PAGE COUNT).

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1. The proposal due date was revised to April 18, 2019 at 2:00 pm by Addendum No. 1. The due date has been changed to **April 25, 2019 at 2:00 pm**. All other dates for the project will remain unchanged.

DATED: __April 8, 2019__ *Jason Manning*

Jason Manning, Sr. Engineer

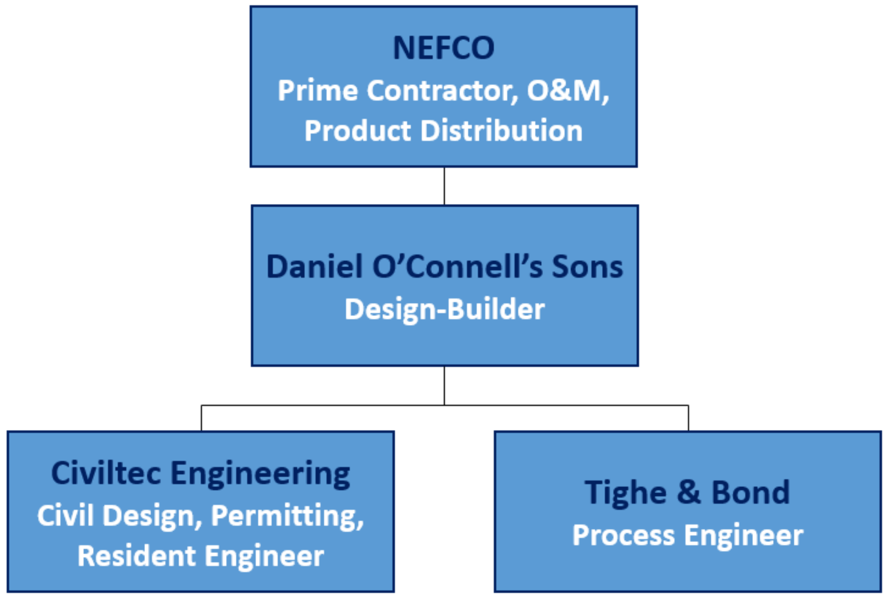
BIDDER'S CERTIFICATION

I acknowledge receipt of the foregoing Addendum No. 2 and accept all conditions contained herein.

DATED: April 23, 2019 BIDDER: Larry W. Bishop

BY: Larry W. Bishop, P.E.
General Manager
NEFCO

NEFCO is a prominent developer and operator of biosolids management facilities. NEFCO, a 30-year old company, is a subsidiary of The O'Connell Companies, Incorporated, a privately-held firm founded in 1879 which provides construction, biosolids management, commercial real estate development, commercial property and asset management, and energy services. The O'Connell Companies employs more than 350 people. This skilled work-force includes project managers, superintendents, civil, chemical, electrical, environmental, and mechanical engineers, estimators, operators, accountants, finance, legal, and office/administrative staff.



NEFCO TEAM STRUCTURE

NEFCO is uniquely qualified to provide biosolids management services to the South Orange County Wastewater Authority (SOCWA) as we have designed, constructed, and operated facilities throughout North America for over three decades. NEFCO has been in continuous, successful, and profitable operation since 1988, during which time we have constantly expanded our base of client contracts.

NEFCO is also supported by a team of proven partners including Daniel O'Connell's Sons (an affiliate company of NEFCO), Civiltec Engineering, and Tighe & Bond Engineers.

In 1988, NEFCO began the permitting, design, and construction of one of the world's premier dewatering, drying, and pelletizing facilities. ***Since 1991, NEFCO has operated this 240-dry ton per day (DTPD) facility in Quincy, Massachusetts. That is 28 years to date!*** This facility provides services to the City of Boston and 43 surrounding communities via a long-term operations contract with the Massachusetts Water Resources Authority (MWRA). NEFCO receives all of MWRA's liquid sludge (over 1,000,000 gallons per day) via a seven-mile-long, deep rock pipeline, then dewaters and dries the sludge into a pelletized product for beneficial use.

NEFCO's Cumberland facility is an excellent model for the new SOCWA facility.

Although NEFCO has designed and constructed some of the largest facilities in the world, we are modeling the SOCWA system after our smallest drying facility in Cumberland, Maryland (11 dry tons per day). This single train system was retrofit into an existing sludge bunker and the resulting facility has been successfully operating since 2010. We propose to do something similar by retrofitting a system into the existing biosolids dewatering building at each of the SOCWA facilities.

NEFCO Operated Biosolids Processing Facilities

West Palm Beach, Florida Facility — *Quincy, Massachusetts Facility* — *Cumberland, Maryland Facility*

Shakopee, Minnesota Facility — *North Andover, Massachusetts Facility* — *Detroit, Michigan Facility*

In addition to the facilities in Quincy, Massachusetts and Cumberland, Maryland, NEFCO has permitted, designed, constructed and operates a 52 DTPD biosolids drying facility in Shakopee, Minnesota for the Metropolitan Council Environmental Services (MCES), a 100 DTPD regional facility for the Solid Waste Authority (SWA) of Palm Beach County, Florida, and a 420 DTPD dewatering and drying facility for the City of Detroit, Michigan, the largest biosolids processing facility in North America.

NEFCO markets and distributes 100% of the biosolids product from their operating facilities. NEFCO takes pride in the fact that each year it distributes nearly 150,000 tons of product from six different facilities for beneficial use across the United States. NEFCO's product marketing results clearly demonstrate a unique expertise that has benefited its municipal partners over the term of the operating contracts. Table 1 lists the approximate quantities of biosolids processed and distributed by NEFCO from their operating facilities during 2018.

Table 1: Year 2018 - Dried Biosolids Product Distributed by NEFCO

Operating Facility	**Quantity Distributed (dry tons)**
Massachusetts Water Resources Authority (Boston, MA)	34,004
Metropolitan Council Environmental Services (Shakopee, MN)	7,827
Greater Lawrence Sanitation District (North Andover, MA)*	5,043
Solid Waste Authority (West Palm Beach, FL)	23,786
City of Cumberland, MD	1,071
Great Lakes Water Authority (Detroit, MI)	81,257
Total	**152,988**

*Contract completed Sept 2018; 2017 dry tons total

Detailed reference facility information is provided in Table 2. This table summarizes the location, scope of services, facility size, duration, and success of each project. References for each facility are also listed in this table. NEFCO was the prime developer and contractor on all six facilities.

Table 2: NEFCO Reference Facility Table

Location / Facility Square Footage / Design Capacity	Scope of Services	Duration; Success of Each Project	References
Biosolids Processing Facility Quincy, MA 114,000 square feet 280 dry tons per day capacity	This process utilizes direct-fired, rotary drum drying systems fueled by natural gas. Dryer exhaust is treated by scrubbing, condensing, recirculation, and thermal oxidation. The facility design capacity in excess of 960 wet tons per day (based on 25% solids). Each drying train can process in excess of approximately 160 wet tons per day (based on 25% solids). The facility has twelve centrifuges and six dryer process trains.	Initial contract was executed in 1988. Operations commenced December 1991. RFP issued June 2000 – new 15-year operations contract awarded to NEFCO. This facility processes approximately 36,000 dry tons per year.	David Duest Director – Deer Island Treatment Plant (617) 660-7870
SSO/Digestion Energy Center & Biosolids Drying Facility North Andover, MA 15,767 square feet 42 dry tons per day capacity	This process utilizes direct-fired, rotary drum drying systems fueled by digester gas with natural gas as standby fuel. Dryer exhaust is treated by scrubbing, con-densing, recirculation, and thermal oxidation. The facility design capacity is in excess of 152 wet tons per day (based on 25% solids). Each drying train can pro-cess in excess of 76 wet tons per day (based on 25% solids). This facility has two independent dryer process trains.	Design, construction and operations agreement was executed with GLSD in February 1999. Facility has been in operation for 15 years (designed and built by NEFCO). This facility processes approximately 5,500 dry tons per year.	Cheri Cousens General Manager (978) 685-1612
Biosolids Processing Facility West Palm Beach, FL 27,519 square feet 100 dry tons per day capacity	This process utilizes direct-fired, rotary drum drying systems fueled by landfill gas and natural gas. Dryer exhaust is treated by scrubbing, condensing, recircula-tion, and thermal oxidation. Each drying train can process in excess of 330 wet tons per day. This facility has two independent dryer process trains.	Operations commenced Summer 2009. NEFCO will operate the facility initially under a 10-year contract renewable for an additional 10 years. (Designed and built by NEFCO.) This facility processes approximately 23,000 dry tons per year.	Raymond Schauer Director, Engineering & Public Works (561) 640-4000
Heat Drying Facility Cumberland, MD 2,886 square feet 11 dry tons per day capacity	This process utilizes a direct-fired, rotary drum drying system fueled by natural gas. Facility is equipped with a new high solids centrifuge. The facility design capacity is approximately 11 dry tons per day (based on 27% solids). The Facility includes a biosolids dryer which is capable of evaporating in excess of 3,000 pounds per hour of water from the incoming sludge cake.	Contract awarded Spring 2009. Construction commenced Fall 2009. Design, build, operate and maintain facility initially under a 15-year contract. This facility processes approximately 1,100 dry tons per year.	John DiFonzo Director, Engineering Division (301) 759-6601
Biosolids Dryer Facility Detroit, MI 45,915 square feet 420 dry tons per day capacity	This facility processes 420 dry tons per day (peak capacity) and features tech-nologically advanced air pollution, noise, and odor control systems ensuring NEFCO is a good neighbor to the community. The process utilizes four direct-fired, rotary drum dryer trains fueled by natural gas. The process exhaust is treated by scrubbing, condensing, recirculation, and thermal oxidation. Dewatering is achieved using 8 centrifuges (two per train) prior to drying.	The initial contract was executed in May 2013. Construction was completed in 2015, with a twenty-year Operation & Maintenance Contract through 2037. This facility processes approximately 87,000 dry tons per year.	Philip Kora Head Engineer - Wastewater Construction (313) 297-5909

NEFCO's ninety years of combined experience in designing, operating, maintaining, and beneficially distributing biosolids products has resulted in an expertise that NEFCO will bring directly to SOCWA:

- Investment in the South Orange County Community - NEFCO understands the importance of community, and will utilize local resources in the construction and operation of new facilities:
  - Maximize use of local Small Business Enterprises (SBEs) and Minority Business Enterprises (MBEs).
  - South Orange County and California-based construction subcontractors will be used.
  - Team with local engineering partner, Civiltec, and key local specialty consultants.
  - Hiring for new OMR staff will be done locally.
  - Non-proprietary equipment/technology allows use of local fabricators and vendors for repairs, spare parts, and services.
- Potential Ban on Biosolids Land Application - NEFCO ensures each of its plants are equipped to handle sudden regulation changes by creating diverse market opportunities and producing a high quality dried biosolids product:
  - Beyond the current SOCWA properties, we will develop a geographically diverse portfolio of product outlets.
  - Establish alternative high-quality outlets such as alternative fuel and soil amendment opportunities.
- Deferral of Capital Investments - Significant capital investments are expected at the JBLTP and the RTP within the next ten years to reconstruct the digestion and dewatering systems. NEFCO's drying technology provides flexibility for SOCWA to defer capital projects, including:
  - Ability to process undigested dewatered sludge. NEFCO's system can continue to dry undigested sludge during digester upgrades or can allow SOCWA to wait while other more critical investments are made.
  - NEFCO provides dewatering in three of its facilities. Our system handles a significant range of cake solids, from 13% to over 30%. The Infrastructure needed to incorporate dewatering into our system is very simple, reducing SOCWA's cost and providing significant flexibility.
- Neighborhood Impacts - Biosolids hauling from each facility has an impact on the surrounding community in terms of both odors and noise. NEFCO has experience managing these impacts in urban areas and will design new facilities to mitigate these issues:
  - Use best practices developed by NEFCO through decades of experience managing biosolids in large metropolitan urban environments.
  - Design odor control measures into the transportation of SOCWA biosolids and incorporate odor control technologies into the building to ensure any emitted air is treated for odors.
  - Utilize best management odor control practices in hauling and application of dried product.
  - Use public outreach and partner with SOCWA to proactively manage community and regulatory sensitivities.
  - Include design measures to mitigate any impact to the community from noise in the facility. NEFCO works with vendors to ensure equipment noise is minimized, and designs facilities to include sound-attenuating systems downstream of tonal noise sources.

- Facility Reliability - NEFCO will use its non-proprietary biosolids drying process for the County's new Biosolids Management Facility (BMF) to provide a higher level of reliability for each plant's operations:
    - Increase in on-site storage will give more flexibility with transportation scheduling.
    - Development of Asset Management Plan to drive the maintenance program for each facility, focusing on predictive and preventative maintenance to reduce downtime and lengthen equipment life.
    - Use of U.S. based vendors allows time for repairs to be greatly reduced versus procuring foreign parts and materials.
- Energy Management - Both the JBLTP and the RTP have existing cogeneration facilities, and the energy generation capacity for each is a key concern for SOCWA. NEFCO will seek to develop a biosolids management solution that will help maximize the amount of energy produced from their solids:
    - Ability to incorporate a variety of alternative, renewable energy sources into the system's operation. NEFCO has experience utilizing digester biogas and landfill gas as fuel for the drying process in multiple facilities.
    - In addition to a traditional drying facility, NEFCO will evaluate a range of technologies that could be used to optimize SOCWA's energy generation and overall utilization.

Table 3: Technology Rating Summary

Goal	Proposed Technology Rating	Explanation
Address potential ban on biosolids land application	High	NEFCO creates a high-quality product with demand for shipments across the country, including industries outside of land application
Defer capital investments	Medium	Ability to treat an undigested sludge and a wide range of dewatered cake will allow deferment of digester and centrifuge upgrades
Minimize neighborhood impacts	High	Aside from a vastly reduced hauling volume, NEFCO facilities build in design features to mitigate odor, noise, and dust issues and use best management practices to avoid impacting local communities
Provide additional reliability	High	NEFCO's focus on asset management leads to reduced equipment downtime, and expanding on-site storage will provide flexibility for solids shipments
Maximize renewable energy production	Low	A dryer system can improve the utilization of heat from the cogenerations process, and the beneficial product has potential as a fuel source in various industries

Aside from understanding SOCWA's drivers for this project, NEFCO also has a clear understanding of each of the project tasks to be completed when moving forward with the development of a new BMF. These tasks will be completed as follows:

- Progress Meetings - NEFCO will conduct at least four (4) in-person monthly progress meetings including one kick-off meeting at one of SOCWA's locations.
- Document Review and Staff Interviews - NEFCO will review available planning and condition assessment documents and facility drawings. NEFCO will visit each plant to confirm the correctness of existing as-built drawings and utilization of facilities. NEFCO will review project needs and details, develop a list of questions to understand how to integrate the innovative solids/biosolids technology at the existing facility (or facilities), and meet with Operations and Maintenance staff to discuss those. The findings of the review and interviews will be summarized in a Technical Memorandum. Five copies of the draft memorandum shall be submitted to SOCWA for review and comment. NEFCO will respond to all review comments. Five copies and a pdf version of the finalized memorandum shall be submitted to SOCWA.
- Safety Assessment - NEFCO will evaluate conformance of space with NEC, OSHA and other pertinent requirements and work with SOCWA staff to identify an approach to the design of safety requirements for new equipment. The findings of the assessment will be summarized in a Technical Memorandum. Five copies of the draft memorandum shall be submitted to SOCWA for review and comment. NEFCO will respond to all review comments. Five copies and a pdf version of the finalized memorandum shall be submitted to SOCWA.
- 30% Submittal - This submittal shall include drawings, specifications, and cost estimate. The drawings should include basic site-civil drawings, plan/section of major equipment, single line electrical drawings, process and instrumentation drawings, equipment list and cut sheets for major process equipment, and other critical elements of the project, such as features needed for odor control, noise control and visual screening for adjacent neighborhoods.
- Implementation Plan - After completion of Tasks II, III, and IV, NEFCO will develop an implementation plan to show the schedule for completing 100% design and how construction can be completed while maintaining plant operations. This plan will also include a timeline for permitting and environmental compliance and pilot testing (if applicable). The findings of the implementation plan will be summarized in a Technical Memorandum. Five copies of the draft memorandum shall be submitted to SOCWA for review and comment. NEFCO will respond to all review comments. Five copies and a pdf version of the finalized memorandum shall be submitted to SOCWA.
- Proposal #2 - NEFCO will submit a second (more detailed) proposal defining the technology/facility components, capacity, site location, cost, and other details based on the results of the 30 percent design analysis and the Existing Operations, Safety, and Implementation Plan Technical Memoranda. Five copies and a pdf version of the finalized proposal shall be submitted to SOCWA.

Fundamentally, the success of a DBOO project is a result of the structures and processes of a well-organized team. NEFCO has been able to develop a significant library of lessons-learned and best practices from past and current projects, and this information provides the foundation for the organizational structure for the Project. This revolves around a clear structure implemented by a well-defined contractual structure and responsibility scheme, functional groupings such as NEFCO's DB team, and the provision of a primary point of contact that can draw upon the resources of the entire team to coordinate responses to issues that may arise during the Project.

NEFCO will lead the project given its track record of past experience in guiding the development of biosolids management facilities from design through construction, and into operations. NEFCO's development expertise has been refined over six alternative delivery projects in the last three decades. This provided the NEFCO team with a variety of perspectives on how to prepare for and approach both general and deal specific risks.

Civiltec, founded in 1986 in Pasadena, California focuses its services on water engineering, environmental engineering and general municipal engineering. Civiltec's expertise provides engineering projects in accordance with general plans, master plans, CEQA guidelines, and standards for public agencies throughout Southern California. Civiltec will provide civil, utilities, and structural engineering, all permitting (including coastal commission and air), and resident engineering during construction.

In business for more than a century, Tighe& Bond is one of the most experienced, continuously operating civil engineering and environmental consulting firms in the United States. Tighe & Bond has worked together with NEFCO's construction company, DOC, on construction projects for nearly a century and has worked directly with NEFCO on biosolids dryer facility projects since NEFCO's inception in the 1980's. Over the last 30 years, Tighe & Bond has become an industry leader in the design of biosolids thermal drying facilities, providing innovative engineering solutions to some of the largest thermal drying plants in the North America. Helping communities properly process and manage biosolids is a key strength of Tighe & Bond's wastewater engineering practice, in addition to our work designing state-of-the-art treatment facilities and collection systems.

The reference facility projects demonstrate the NEFCO Team's experience and capability with successfully developing and managing complex projects, highlighting the importance of a well-defined organizational structure and the benefits that an integrated team can bring in terms of innovation and value for money. On these projects NEFCO has led the bid, construction, and operation stages and understand key elements as highlighted below:

- **PROJECT MANAGEMENT:** on past opportunities NEFCO was involved in the negotiation of all agreements and managing the life cycle of the project. This includes all elements of the design, construction, equipment selection and procurement, O&M and product distribution.
- **PROJECT ADVISORY COMMITTEE:** NEFCO, DOC and Civiltec senior executives will participate on the committee, which meets regularly to monitor the design and construction progress, as well as review the findings of the project team on the project.
- **PROJECT FINANCING:** depending on the ultimate project financing approach NEFCO has a strong financial standing and is positioned to align with private financing partners if that is the path SOCWA desires. The lowest cost option is for SOCWA to use public financing, but that is not necessary.
- **O&M, DESIGN AND CONSTRUCTION INTEGRATION**: NEFCO's O&M team has considerable experience ensuring that operational issues are addressed during the design-build process and long-term reliability and efficiency is designed into the system.

Within the role of project development, more specifically, on past alternative delivery projects NEFCO has successfully implemented the following:

- Develop a design that achieved the clients' objectives;
- Negotiate detailed scopes prior to bid with the design and construction subcontractors; and
- Develop an appropriate sub, SBE, MBE and OMR staffing plan to ensure the project proceeds efficiently following NTP.

Table 4 highlights key individuals' planned roles, responsibilities, and accountabilities on the Project (resumes can be found at the end of this proposal):

Table 4: Key Individuals

Role	Member	Responsibility
Project Manager	Larry Bishop, PE	Primary contact for NEFCO with SOCWA throughout execution of the project. As a Professional Engineer in the United States Larry has the experience to lead the development of biosolids drying DBOM projects including the design, construction, financing, and operations of biosolids management facilities. Larry has a proven track record of leading large project teams and meeting schedule and budget requirements. He is very experienced managing projects for large municipalities, providing them with communicative, responsive service.
Civil/Structural Design Lead	Shem Hawes, PE	Shem Hawes serves as senior engineer and principal at Civiltec. His primary responsibilities include the daily supervision of a large design team, management of project budgets and schedules, effective utilization of Civiltec team resources in meeting project technical and schedule requirements, maintaining lines of communication between Civiltec and clients and assisting in Civiltec's quality assurance and technical review programs
Advisory Committee – DOC	Jeff Bardell	Jeff is the President of DOC and has over 40 years' experience managing project team execution of wastewater and biosolids projects delivered via design-bid-build, design-build and CM-at-Risk. Jeff will provide the highest level of commitment as the design-builder and will be available to the team to provide and decisions or commitments.
Advisory Committee – NEFCO	James Sullivan	Jim, as President of the O'Connell Companies and the former General Manager of NEFCO, oversees ownership's interest in NEFCO's performance. He also provides extensive contractual knowledge from our six other contracts.
Advisory Committee – Civiltec	David Byrum	David, as President of Civiltec and having ultimate responsibility for Civiltec's relationship with SOCWA, provides the highest level of comment to the success of the biosolids drying project for SOCWA and the NEFCO Team.
Design-Build Lead – DOC	Sarah Stine	As Design-Build Lead, Sarah will assume the helm of the design-build team. She will lead team integration during design development and drive the construction process. Her responsibilities will include overall project administration, budget control and forecasting, construction scheduling, safety and quality control. She will ultimately be responsible for the on time/on budget management of the project and will ensure that the right resources are available to service the NEFCO Team's commitment to the owners.
Process Equipment Selection and O&M Lead	Manuel Irujo	Responsible for coordination of OMR team and integration with the design team (e.g., evaluation of material and equipment selection options from a lifecycle perspective; evaluation of alternative renewal schedules); overall monitoring of OMR during the implementation phase, including monitoring performance with operating specifications. He will also be responsible for hiring the OMR staff.
Process Design Lead	Chris Bone, PE	Chris Bone serves as principal and project manager on a variety of water and wastewater treatment facility projects. He will utilize his on other biosolids drying facilities and lead the process design elements for the biosolids drying project.
Process Engineer	Sean Murnan	As NEFCO's Process Engineer Sean will develop the sizing criteria and perform the modeling as the basis of design for the drying system. This basis of design will be used to design the system and provide the rest of the team with the necessary information to select the right pieces of equipment.

Included on page 20 of the Proposal is a Confidential Table of Effort and proposed schedule for the project which shows the anticipated timeline moving forward and breaks down the expected hours each team member will work for various subcategories. NEFCO will invest labor hours as needed for the project and is not included in the Table of Effort. These figures have also been attached in full scale form at the end of the proposal for easier reading.

Technical Approach and Methodology

NEFCO's biosolids processing technology is a highly automated drying process that produces free-flowing dry granular solids from sludge cake that is beneficially used as fertilizer, and alternatively as a renewable fuel source. NEFCO utilizes a layout for solids handling that is superior to other drying systems because of its simplicity. The facility layouts developed by NEFCO provide excellent space utilization, safety, a high degree of reliability, and low maintenance.

Since our team's solution is not proprietary, SOCWA receives the benefit of lower capital costs, competitive bid opportunities, rapid procurement for maintenance, and lower overall operating costs. NEFCO develops specifications for each major piece of equipment or process system and individually sources them from vendors. We have developed relationships with equipment manufacturers that have proven they can provide robust equipment to process municipal sludge, and will incorporate the strengths of each vendor into an overall product that will guarantee performance needs are met.

In order to help SOCWA meet its energy related goals, NEFCO's proposed design innovatively utilizes exhaust heat from an engine generator fueled by renewable digester gas. Hot exhaust from engine-generator catalysts will be ducted directly into rotary dryers. Bypassing the existing boilers will transfer approximately 25% more exhaust energy to evaporate water from the sludge cake than would utilizing water or steam to transfer the energy. SOCWA may elect to utilize only exhaust heat in the dryers in order to dry just a portion of its sludge. These same dryer systems will be capable of drying all sludge from each of the JBLTP and RTP plants with supplemental fuel. The energy from the engine exhaust currently being used to preheat sludge going to the digesters could then be replaced by waste heat from the drying process, leading to an overall more energy efficient operation. This is discussed further of page 13 of this proposal, including Figure 3 that presents a simplified block diagram demonstrating solids, air, and heat flows through the system.

The drying process contains two sub-systems that operate simultaneously; the solids handling system and the air handling system. These two sub-systems ensure a sustainable beneficial use product and the highest level of control available for emissions from the process.

Solids Handling System

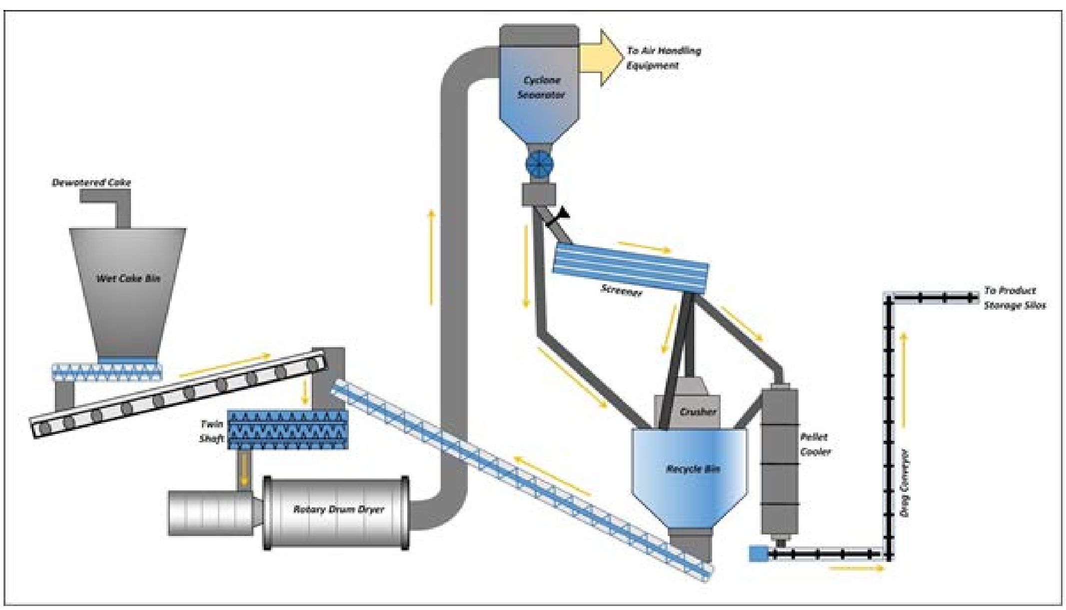


Figure 1: Biosolids Drying and Pelletizing Process

The solids handling process shown in Figure 1 starts with the dewatering of effluent sludge from the digesters. Currently this process is handled by SOCWA through individual centrifuge dewatering systems at each site. These systems separate the water and solids in the sludge, producing a concentrated wet cake with 20-30% solids content. The data provided by the County shows that both plants produce a cake with an average solids content of 23-24%, which is well within the range of NEFCO's feedstock standards. NEFCO has typically preferred to include dewatering under our scope of services for projects, and would be interested in either looking at including upgrades to centrifuge dewatering in the project or taking over operations of current dewatering operations. Such integration is economical with regards to labor and considerably reduces the cost of storing, feeding, and conveying cake. However, if SOCWA would prefer to maintain ownership over dewatering process then NEFCO is completely comfortable moving forward with that arrangement.

At the RTP the dewatered cake from the centrifuges is currently sent to cake storage bins that are used to load tractor trailers for land application or disposal. At the JBLTP, cake from the dewatering equipment is sent directly to tractor trailers using screw conveyors. For the drying process, both of these systems would be retrofitted with dual feeder screws that would feed a belt conveyor. The belt conveyor would weigh the cake for process control and material balance purposes, and then discharge into a pugmill mixer. The pugmill is also fed with previously dried solids that are stored in a recycle bin and conveyed back to the front of the process using a recycle screw conveyor. The wet and dry materials are intensively mixed together in the pugmill to create a free-flowing, granular mixture that is fed into the dryer throat (entrance). Inside the rotary drum dryer, most (~95%) of the initial moisture is driven off through intimate contact with hot air.

The dry solids discharge upwards from the drum within a high velocity duct to a cyclonic separator, which is typically located above the roof. The dried solids, which are now in the form of discrete granules, are Class A biosolids and pathogen-free. These granules are collected by the separator and discharged via an airlock to a screener. The granules are screened into four fractions: trash, oversized, finished product, and fines. Trash, consisting of coarse plastic and other undesirable solids is collected in a dumpster for disposal at a landfill. Oversized granules drop into a roll crusher, and subsequently fall into the recycle bin. Fines, which are undersized granules, also fall into the recycle bin. The recycle bin stores the dry material that is to be mixed with the wet biosolids as previously described. The remaining, properly sized granules, which are the finished product, are cooled and conveyed to a storage silo. The silos will be equipped with a continuous nitrogen blanketing system to provide an inert atmosphere inside to prevent hot spots from occurring. The combined processes of cooling after screening and continuous inert blanketing assure trouble-free product storage.

The proposed silos will be constructed with full skirts to provide a weather-protected loading area that facilitates loading of fertilizer during thunderstorms and other inclement weather. The product will be loaded from the silos into trucks using a mixing screw that adds a small amount of dust suppression agent to the finished product during loading of trucks. This will minimize dust release both on site and at the point of use.

As a function of our layouts' dependence on material movement by gravity, a minimum number of conveyors are used. Troublesome bucket elevators are not used. The layout provides excellent space utilization, high reliability, and low maintenance.

Air Handling System

The air handling system shown in Figure 2 is used to provide the heat necessary to evaporate moisture from the biosolids mix. The furnace burner can utilize a wide variety of fuels to create a very hot mix of combustion products, which is tempered or cooled by recycling dehumidified exhaust gas back through the system. The tempered, hot gas dries the sludge in the drum and provides the motive force to propel the solids through the dryer. The overall mix of gasses at the dryer inlet typically varies between 700-1000 °F (370 – 540°C) depending on processing rate, and the dryer outlet temperature is controlled between 180-200 °F.

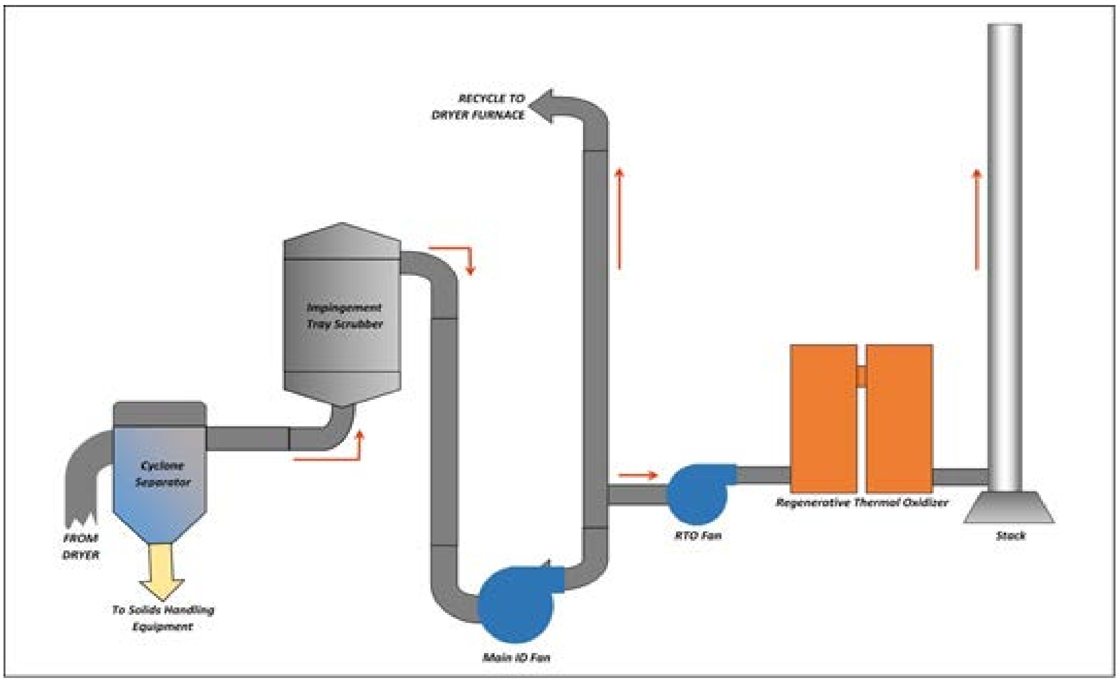


Figure 2: Air Handling System

The cooled gas, solids, and evaporated water exit the drum and are carried up through a duct to the cyclonic separator, where the solids are separated from the gas. The exhaust gas is then treated in a tray scrubber to remove the small amount of residual solids and to condense the water vapor from the drying process. The water discharged from the tray scrubber will then either be discharged back to the head of the facility, or pumped through a heat exchanger before being recirculated back through the scrubber. This will depend on the limits for wastewater effluent returned to the treatment plant.

The greater part of this cleaned and dehumidified gas is returned to the inlet of the dryer and is used as tempering air within the dryer as described above. After scrubbing, the fan pushes the remainder of the exhaust through to the facility's emissions control system. There are several options for emission control systems depending on the on air quality standards for the area. For simple emissions controls, a reagent scrubber is a low maintenance and economical option to remove criteria pollutants such as NO_x and H_2S. For more stringent emissions limits a Regenerative Thermal Oxidizer (RTO) would most likely be used. An RTO is the most advanced emissions control technology used in the industry, destroying odor causing compounds, carbon monoxide, and organic vapors by heating the exhaust gas to about 1500°F (815°C). The volatile organic compounds are oxidized to odorless carbon dioxide, and are discharged to the atmosphere. Thermal oxidizers destroy about 98% of organic vapors. Most of the heat required in these thermal oxidizers is recovered and reused.

The air handling and odor control system is a key feature of the dryer system. The combination of wet scrubbing, condensing, exhaust circulation, and thermal oxidation provides excellent control of odors, low emissions of regulated pollutants, and economical operation.

Alternative Technology Evaluation

In addition to a rotary drum dryer system NEFCO will be evaluating the feasibility of using additional technologies to reach SOCWA's stated goals. Due to the size of the JBLTP and RTP facilities and the energy resources available, belt dryers are one alternative being evaluated. The operation of a belt dryer system is quite different than a typical rotary drum dryer. First, heated water supplied by the heating system and internal heat exchangers transfer heat into the reticulating air. Sludge is placed on the upper belt by the extruder system and conveyed to the far end of the dryer. Then the sludge is placed onto the bottom belt and transferred back to the feed end of the dryer where it is discharged from the dryer. During the entire conveyance process the air is pulled through the belt in each module evaporating the water in the process. After each pass of the sludge layer on the belt, the air is reheated by a heat exchanger to maintain a constant process temperature. These systems are modular by design, and the capacity of the dryer system can be increased or decreased depending on size constraints. Furthermore, as the system uses hot water for heat transfer it can also use any heat source available, including waste heat from other processes. This is especially advantageous for belt dryers as the process temperature the dryer uses much lower, typically in the 190°F to 300°F range.

In order to help SOCWA meet their biogas generation needs, NEFCO will also evaluate technology that could improve the performance of SOCWA's digesters. Specifically, a thermo-chemical hydrolysis system used to condition sludge prior to digestion could be an excellent fit based on plant needs and spatial restraints. These systems combine caustic soda and heated water to break down the cell membranes of thickened waste-activated sludge using a compact and simple system design, leading to improved digester and dewatering performance. NEFCO will evaluate the potential benefit of this technology for SOCWA, including potential improved biogas production, polymer use reduction, and increased cake solids content.

Integration into SOCWA's JBLTP & RTP Facilities

NEFCO's long-term expertise allows us to prepare a layout that incorporates decades of best practices and design improvements. Our team has worked together on numerous facility designs, and strives to take lessons learned from each project and use them in an effort to continuously improve our designs. This approach has allowed us to produce facilities that efficiently utilize the available design space and streamline process flows with innovative equipment layouts. NEFCO's designs feature many advantages that will ensure a successful operation, such as:

- Reducing conveyance needs by laying out plant to reduce distance travelled, and utilizing gravity fed systems as much as possible.
- Streamlining material flow through the process by using innovative geometry for ductwork and piping.
- Using equipment that has been proven to be efficient and safe for operation, such as drag conveyors instead of traditional bucket elevators.
- Incorporation of state of the art safety systems, such as a nitrogen generator to prevent product self-heating and provide fire suppression if needed.

Facility Layout and Process Flow

The scope of SOCWA's project allows for a number of options for integrating a drying system as part of the overall biosolids management solution. NEFCO has prepared concepts for systems for both the JBLTP and

RTP that utilize the available space and resources at each plant's current biosolids processing building. As mentioned above, ideally NEFCO would be able to retrofit the trailer loading bays so that the current cake storage bins could be used to feed the drying process. Instead of having trailers in the bays to be loaded, an outdoor product silo similar to other NEFCO facilities could be used for loading pellets. The product silo designed by NEFCO will have a small footprint to fit in the available space and avoid being intrusive on current operations, but will significantly increase storage capacity of the facility due to the reduced product volume from the drying process. Even a small product silo would have a storage capacity of at least one week, which would give SOCWA much more flexibility for their trucking arrangements. By repurposing the trucking bay there would also be a significant amount of free space for equipment at both plants, and a dryer drum would be installed in one of these bays. Additionally, there is open space in certain areas of both facilities' solids handling and energy buildings that could be used to accommodate equipment for a drying system and are conveniently adjacent to the trucking bays.

NEFCO proposes to retrofit drying systems into SOCWA's existing dewatering buildings.

Another benefit of installing the drying system into the existing buildings is the proximity to the cogeneration systems at each facility. This opens up the opportunity to incorporate waste heat from the engines into the drying process, which can help the County reach its energy related goals. Ideally the exhaust would be sent directly to the furnace to provide a portion of the heat and air circulation required for the dryer. NEFCO recognizes that the engine exhaust is currently used to preheat the sludge feeding the anaerobic digester on site, but believe that the heat demand for the sludge can be replaced from other waste heat sources in the drying process. Specifically, the effluent from the IT scrubber/condenser and the exhaust from an RTO system are both potential sources of heat that can be utilized. Overall this would be a more effective and efficient use of the available energy resources.

The simplified block diagram in Figure 3 illustrates how NEFCO's system would fit in with current plant operations, including how the waste heat flows mentioned above could work. The Confidential process flow diagram and Confidential conceptual layout included at the end of this proposal also show NEFCO's primary design concepts for the JBLTP and RTP facilities. It should be noted that the layout is a generic design that is meant to estimate equipment spatial impacts. As mentioned above, NEFCO believes the equipment will fit into existing areas at each facility. These layouts are in the preliminary stages and NEFCO would work to address any thoughts or concerns the County has in future design iterations.

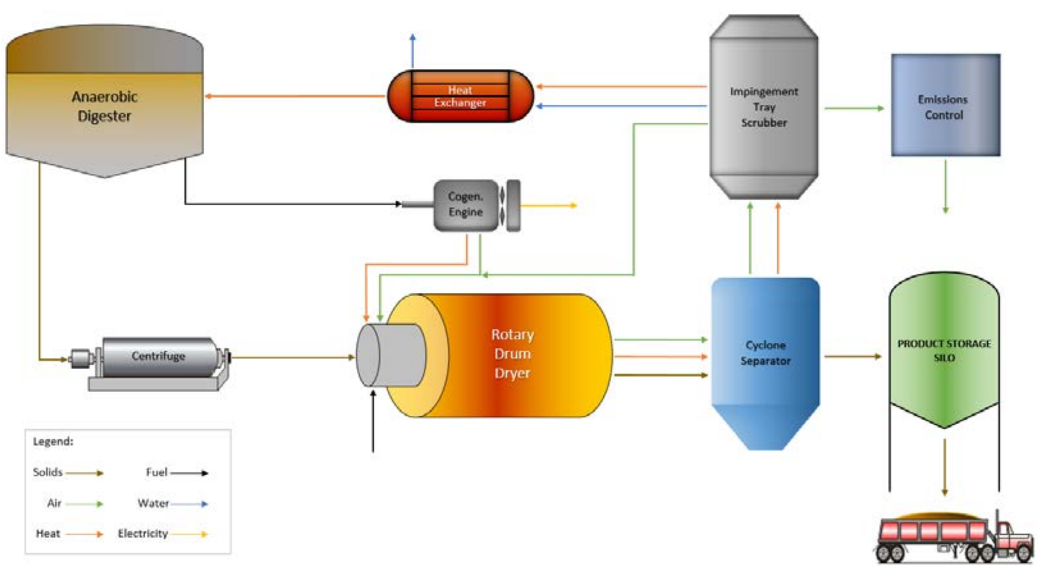


Figure 3: Block Diagram

Renewable Energy and Energy Efficiency

NEFCO also understands SOCWAs' energy related goals for the project and will work to help meet these goals however possible. NEFCO has a vested interest in maintaining an energy efficient operation not just for economic reasons, but as a company dedicated to providing sustainable biosolids management solutions. This includes the ability to incorporate a variety of alternative, renewable energy sources into the system's operation. NEFCO has experience utilizing digester biogas and landfill gas as fuel for the drying process in multiple facilities. Including this ability in a system design will allow SOCWA to maximize the usage of the gas from their digesters, as well as keep the options open for other fuel sources in future years. NEFCO is also invested in researching the use of biosolids as an energy source in multiple applications. Product from NEFCO facilities has been used as an alternative fuel source in industrial applications, replacing coal requirements for applications such as cement kilns. NEFCO is also leading the way in developing the use of biosolids in the pyrolysis process, which creates a synthetic gas ("syngas") that can be utilized as a renewable energy source.

NEFCO also takes a proactive approach in maintaining efficient operations, and has developed several tools for tracking the utilities consumption and plant efficiency for its current operations that will be implemented at any future projects for SOCWA. These tools will allow plant management and operators to identify opportunities to improve plant efficiency and quickly correct issues that could be impacting utilities consumption. The goal is to provide guidance on optimizing energy use within the process and insight into potential improvements to the plant that could be both economically and environmentally advantageous. The information from the utilities tracking tools can be paired with maintenance data from the CMMS and operational data collected by the operators, which will allow trends in consumption to be identified and analyzed to determine potential causes of variation.

Table 5 summarizes key areas where NEFCO has identified opportunities to develop an energy efficient facility and help SOCWA optimize the use of their energy resources:

Table 5: Energy Efficient Optimization

Operations Area	Energy Efficiency Opportunities	Design Considerations
Process Equipment	Process Equipment	Plant design and layout will Incorporate lessons from previous plant such as: ● Limit belt or gearbox driven motors that reduce energy efficiency ● Utilize gravity feeding systems for solids handling (screeners, crusher, pellet coolers) ● Reduce conveyance needs by optimizing plant layouts
	Domestic Energy Use	Administrative areas will be equipped with energy efficient fixtures such as: ● LED light bulbs and T-5 fluorescent lights ● Proximity sensors for automatic lighting control ● Air-to-air enthalpy wheels for heat recovery from ventilation air
	Management Systems	Implement robust management systems to assist with process evaluations such as: ● Tracking process metrics (solids received, utility consumption, pellet production) ● Generating reports for guidance of operations team and maintenance scheduling
Fuel Consumption	Waste Heat Integration	Waste heat can be integrated into the process in multiple areas: ● Waste heat from SOCWA's engines can provide energy for the drying process ● Waste heat from the drying process (scrubber effluent and RTO exhaust) can provide energy for preheating sludge to the ADs ● Waste heat from ventilating process areas can provide building heat for domestic areas
	Alternative Fuel Sources for Drying Process	NEFCO has experience utilizing various forms of alternative fuels for the drying process: ● Digester gas blending system for burners at GLSD plant ● Landfill gas blending system for burners at SWA facility
Product Use	Pellets as Alternative Fuel Source	NEFCO understands that the energy content of biosolids makes it a potential fuel sources in industry applications, and has sent product to cement kilns to be used as fuel since 2007
	Pyrolysis	NEFCO is at the forefront of developing the use of biosolids in the pyrolysis process, and currently working with industry experts to develop a pyrolysis application that could use pellets to create fuel (syngas) and a beneficial product (biochar)

Product Marketability

NEFCO will be 100% responsible for beneficially reusing the dried product through our Product Distribution and Marketing Program. Over the years, NEFCO has successfully marketed nearly one million tons of biosolids product throughout the country, and is well positioned to distribute the SOCWA product. In order to manage this responsibility, NEFCO develops a diverse product marketing plan and distribution portfolio for each facility to ensure that we never turn away a single pound of feedstock.

NEFCO also stays current with biosolids land application regulation changes across the United States. Regulation changes do occur and it's our Product Distribution Manager's (Distribution Manager) responsibility to watch these closely and alter distribution strategies as needed. The Distribution Manager also has diverse outlets that include other end uses that are not just land application such as alternative fuel and bagged fertilizer blenders.

NEFCO has worked through temporary changes in state regulations to long term changes. Our drying system offers a Class A EQ biosolids which allows for various types of end uses that other biosolids forms and qualities cannot utilize. For example, in the state of Florida there was a proposed bill that was going to ban land application of Class B Biosolids in certain watersheds. Class A material was never mentioned in the proposed bill potentially because end users purchase these Class A biosolids and nutrient over application is not a concern in comparison to Class B biosolids that are typically difficult to beneficially reuse and find application sites for.

If material did need to go to landfill because of regulatory issues beyond our control, the dried product can be used to create a topsoil to be used at the landfill. NEFCO insures each of its plants are equipped to handle sudden regulation changes by creating diverse market opportunities and having a dried biosolids product (the highest quality form of biosolids) that can be used in those markets.

Market Opportunities

NEFCO has been marketing various biosolids products from different sources for over 28 years. NEFCO's experience has been that a successful beneficial use program can be achieved through diversification. NEFCO also believes that each facility requires a unique product management approach due to regional regulations and regional market opportunities, and seasonal demand variations.

The proposed heat drying process maximizes volume reduction and produces a high-quality low odor Class A product with proven fertilizer value. In order to continually move product from the Facility, NEFCO's targeted beneficial use markets for the end product will be as follows:

- Bulk Distribution to agricultural users
- Bulk Distribution to fertilizer blenders / manufacturers
- Bulk Distribution for Use as an alternate fuel / energy source
- Bulk Distribution for manufactured topsoil / reclamations
- Bulk Distribution for Golf courses

Agricultural Markets – NEFCO understands that the preservation of natural resources and environmental sustainability are very important to the stakeholders of the Facility. The use of pelletized biosolids as a fertilizer safely conserves irreplaceable natural resources. Biosolids reduce the consumption of manufactured fertilizers that use natural resources for production.

By taking advantage of the nitrogen in dried biosolids, there is a reduction in the demand for manufactured synthetic nitrogen. Synthetic ammonia made from fossil fuel (natural gas) is the primary building block for most manufactured nitrogen fertilizers, including urea, ammonium sulfate, ammonium nitrate, and ammoniated phosphates. The use of biosolids is a much more sustainable replacement for nitrogen needs and contributes to a global reduction in fossil fuel consumption.

The phosphorus in biosolids also replaces phosphate rock and sulfur (used in refining phosphate rock) that must be otherwise mined and shipped to California.

NEFCO takes pride in the fact that they are currently moving 140,000 tons per year of dry product from five plants…100% of the dry product went to beneficial use.

Heat-dried granulated Class A biosolids pellets offer an excellent source of organic matter and slow release nutrients to improve both soil health and crop yield. The pellets provide nitrogen in an organic form, as well as phosphorus and other micronutrients. The pellets provide a slow release of nitrogen in the soil for the crop over the entire growing season.

The local agricultural community will see an annual increase in crop production yield. As the pellets build and revitalize the soil, these crops will benefit from:

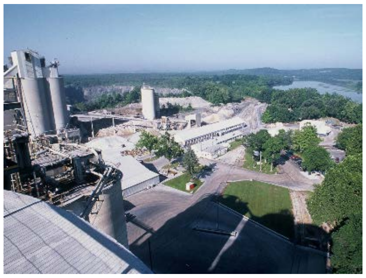
- Essential plant nutrients and micronutrients
- Residual nitrogen available in future years
- Slow release of nutrients
- High organic matter
- Stronger root development
- Increased water retention and reduced potential for leaching

NEFCO has found that many agricultural outlets know the cost advantages and improved crop yield of Class A biosolids, and demand for this fertilizer outstrips supply. With the heavy concentration of seed, corn, wheat, and hay crops, and their high consumption of expensive chemical fertilizers, the product movement of biosolids is ensured. At a typical application rate of three tons per acre, a single large farm might use all of the annual production. However, several farms in multiple geographical locations will be contracted to provide multiple outlets, competitive pricing, and redundancy.

Fertilizer Blenders/Manufacturers – Often times, fertilizer blenders incorporate biosolids as an ingredient in some of their blends to offset the costs of other more expensive ingredients. Fertilizer blenders have come to realize the plant food and soil enrichment attributes of the biosolids, in addition to their use as a filler or bulking agent. NEFCO has developed strategic relationships with local, regional, and international fertilizer companies in response to supplying them with product from the other biosolids drying facilities that NEFCO operates.

Energy/Alternative Fuel – NEFCO understands that energy and sustainability are interrelated and are very important issues to SOCWA. NEFCO has joined many experts in the biosolids management industry by acknowledging the fact that dried biosolids are a potential form of fuel energy, in addition to their fertilizer value.

NEFCO has become a leader in the development of the beneficial use of biosolids as a renewable alternative to fossil fuels in the energy intensive cement manufacturing process. Specifically, NEFCO sent a significant portion of the production from the MWRA biosolids drying facility to cement kilns.



Utilization of biosolids in cement kilns is a particularly advantageous energy use for biosolids. Other solid fuel users (such as boilers) produce ash that must be disposed at some cost. Use of biosolids in a cement kiln incorporates the ash into the cement, providing part of the kiln's silica and lime feed. Instead of ash disposal costs subtracting economic value from biosolids fuel, more cement is produced and sold. Cement kilns are a market whose technical and economic value has already been established, and this outlet may expand in response to reasonably foreseeable legislation requiring kilns to use renewable fuels.

Community and Environmental Impacts

Our team focuses on being an advocate for our client and a good neighbor to adjacent communities, nearby residents and businesses, and other client assets. NEFCO facilities are proven in urban environments. Our flagship facility has operated since 1991 on the harbor in Quincy, MA (Metropolitan Boston) in close proximity to a heavily residential area, but despite increased scrutiny due to its location no community concerns have been raised due to our practices and the characteristics of our dried product. NEFCO designed plants include many features to ensure no nuisances result from our operations, including: State-of-the-art emissions controls

- Significant reductions in hauling volumes and product odors from drying process
- Enclosed buildings to mitigate process odor and noise concerns
- Air collection and chemical odor control systems to treat all air that passes through the building
- In-process dust control systems, as well as dust suppression agents for final product
- Energy efficient operations, with renewable energy utilized when possible

State of the Art Emissions Control

The facility will be equipped with Best Available Emission Controls Technology (BACT), as needed. One of the great advantages of our drying technology is very low regulated emissions. The combination of low NOx burners, wet scrubbers, exhaust circulation, and RTO/reagent scrubber substantially reduces emissions of Particulate Matter, NOx, SOx, CO and volatile organic compounds (VOCs).

Odor Control and Air Treatment

The Beneficial Product created from the thermal drying process has many advantages related to odor control compared to the end product of the current system. The drying process will create a dry product that has a solid content of ~95%. The reduction in moisture content will help in eliminating the odors currently present in SOCWA'S final product.

By getting rid of the majority of the moisture in the product, the volume that needs to be shipped will also be reduced by ~80%. This means less public exposure to shipments of product due to a significant reduction in the number of truckloads being hauled, and increased product storage on-site. The product will be treated for pathogens to a "Class A" standard, and will not attract disease vectors such as flies or other insects along the route.

Additionally, the facility will be tightly sealed to prevent the escape of odorous air. Building exhaust from odorous process areas of the plant will be collected and treated prior to discharge. The ventilation fans will create a slight vacuum inside the building to ensure that no odorous air can escape unless treated.

Noise Control

Noise can be very impactful to the surrounding community. NEFCO has significant experience operating in highly urbanized environments and will take measures to control the noise from the facility. Our system includes fans, motors, and other equipment that do not emit more than 85 dB (A) at 3 feet. This low level of noise means that workers and visitors to the plant will not need hearing protection. In addition to providing inherently quiet equipment, the equipment will be located indoors where the building envelope will provide additional sound attenuation.

One often overlooked source of noise is any process fan. Process fans can generate a pure tone that can propagate through ducts or stacks. NEFCO's design for odor treatment and RTOs are forced draft, placing sound-attenuating equipment downstream of the fans. The RTO media and scrubber packing or adsorbent will absorb tonal noise, eliminating any problems that could impact the surrounding community.

Dust Control and Suppression

Dust from the drying process is not just a nuisance concern for the public, but also a health and safety concern for the plant. NEFCO takes dust control very seriously to ensure reliable and safe plant operations. Dust from the storage silos, recycle bin, screener, crusher, pellet cooler and pneumatic transporter is collected and separated from the air stream by a bag house type dust collector. The bag house discharges dust to the recycle bin for eventual re-incorporation into the finished fertilizer product.

Dust is also generated by handling of the product, as with any bulk material. Pelletized biosolids, as delivered from the screener, is essentially dust free. However, subsequent handling such as loading into the silo or into transport vehicles creates dust via abrasion. The silos will be equipped with a product oiling system that sprays oils or glycerin onto the surface of the pellet. This binds dust to the pellet, and minimizes dust creation during transport to the buyers and market and provides lasting dust control, both at the silos and at the point of beneficial reuse. Loading will occur beneath fully skirted silos to protect the product loading operation from weather and wind.

Financial Capability

NEFCO's financial statements or any other documents that provide proof of financial capability will be made available, if requested, to SOCWA for their review. NEFCO, as a privately held company, focuses on sound financial decisions that have resulted in a company with the highest rating achievable with strong financial resources. NEFCO, and it managing general partner, O'Connell's, maintains a very strong balance sheet, ample liquidity, and sound financial fundamentals. Neither NEFCO nor O'Connell is in violation of any debt or financial covenants or under a waiver from any debt or financial covenant violation(s).

Bonding Capacity

NEFCO has obtained both design-build bonds and operations bonds over the previous 30 years for its many biosolids projects. NEFCO obtained a performance and payment bond for the design-build project with MWRA in the amount of $60 million, with MCES in the amount of $14 million, with GLSD in the amount $13 million, with SWA in the amount of $27 million, and with the City of Cumberland in the amount of $10 million. In addition, NEFCO maintains annual renewable operations bonds with MWRA in the amount of $20 million, with MCES in the amount of $4.5 million, with GLSD in the amount of $3 million, with SWA in the amount of $1 million, and with the City of Cumberland, MD in the amount of $1 million. The total annual renewable security posted on NEFCO's behalf by our surety company exceeds $30 million. NEFCO will be able to post the required operations period performance bond as prescribed by DWSD; a face amount equal to essentially two times annual revenue.

From a construction perspective, we have posted performance and payment bonds totaling well in excess of a billion dollars over the last twenty years. We have enjoyed a long-term relationship with Travelers, spanning nearly 75 years, and are considered to be one of Travelers most respected clients in the country. NEFCO currently has bonding program limits of $250,000,000 per project and $400,000,000 in aggregate. Letters of support from both Travelers Casualty and Surety Company of America and Peoples Bank can be found in at the end of this proposal.

NEFCO verifies that we will maintain required insurance levels as stated in Exhibit A of the RFP.

Recent references can be found in Table 2 on Page 3 of this document.

Environmental Permit Obligations

NEFCO has maintained an outstanding environmental permit compliance record in all its facilities throughout its history, in particular having processed over one and a half million tons of biosolids. Permit compliance responsibilities are primarily the responsibility of each facility's Plant Manager. The Plant Manager has compliance support from in plant staff as well as corporate resources including the Vice President of Operations, the Environmental Compliance Manager, the Product Distribution Manager, and corporate Engineering support.

NEFCO's drying technology is specifically designed to minimize environmental impact and to maintain robust permit compliance. Air emissions control equipment is Best Available Control Technology and NEFCO has a vast database of stack emissions test data to help develop new air permits. Siting the drying facilities at the Wastewater Treatment Plant allows for closed loop recycle of solids with a guaranteed maximum return amount and robust NPDES permit compliance. Facility ventilation, odor control, dust mitigation, and housekeeping standards minimize external odors and nuisance complaints.

As a result of this robust compliance framework, NEFCO has only had only three permit obligation issues in the last five years which are summarized below.

- Solid Waste Authority (SWA), West Palm Beach, FL
    - Since facility startup, NEFCO has occasionally exceeded its wastewater BOD discharge limits to the City of West Palm Beach due to processing of undigested sludge. NEFCO negotiated a solution with the City and invested in a pump station and force main to utilize SWA's deep injection wells for wastewater. Small volume City discharges occur for short periods when the injection wells are undergoing maintenance.
- Great Lakes Water Authority (GLWA), Detroit, MI
    - In 2016, NEFCO received a Notice of Violation from the Michigan DEQ for exceeding sulfur dioxide air permit limits during initial stack testing at startup of the facility. NEFCO installed SO2 scrubbers and current emissions are now less than 10% of permit limits.
    - In 2017 NEFCO received three Notices of Violation from the MDEQ for land application issues associated with its land application broker's inattention to Best Management Practices. NEFCO subsequently terminated the land application broker contract and has since maintained 100% compliance.

NEFCO has no litigation issues in its history.

NEFCO has no issues with the example engineering contract in the RFP for conceptual engineering work. Further alternative delivery work such as, integrated design-build, with or without facility ownership and O&M services will require a different contract to address terms and conditions for those elements.

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Table of Effort

Conceptual Design - Table of Effort
Innovative Solids/Biosolids Technology Project
South Orange County Wastewater Authority

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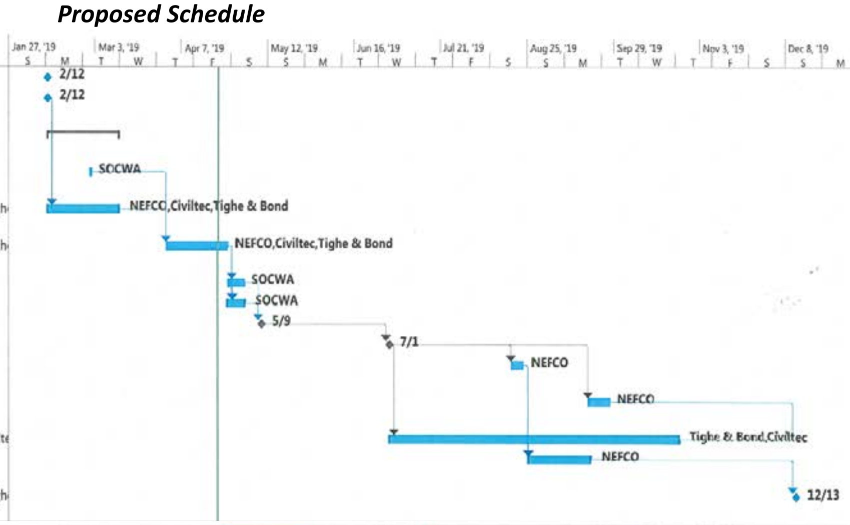
	Tighe & Bond Staff					Civiltec						
Description	Project Director	Project Manager	Project Engineer	Electrical Engineer	Senior Drafter	Senior Engineer	Project Manager	Staff Engineer	Designer	CAD Technition	V&A Env.	Total Hours Man-hours
Conceptual Design												
1. Progress Meetings (Assume 4 at SOCWA)	64	16	0	0	0	16	16	8				120
2. Document Review and Staff Interviews												0
a. Review Draft Biosolids Management Strategic Plan Update	1	1	0	0	0							2
b. Review Regional Treatment Plant Facility Plan	1	1	0	0	0							2
c. Review Facility Drawings	2	2	0	0	0	4	4	4				16
d. Site Visit to JBLTP and RTP plants - Confirm Drawings and Staff Interviews (Note 3)	16	16	0	0	0							32
e. Prepare Technical Memorandum of Existing Conditions and O&M Staff Concerns	2	8	0	0	0							10
f. Respond to SOCWA Comments and Finallize Technical Memorandum	2	4	0	0	0							6
3. Safety Assessment												0
a. Conduct Safety Workshop with NEFCO and SOCWA (Note 5)	0	0	0	0	0							0
b. Prepare Safety Technical Memorandum (Note 6)	2	2	0	2	0							6
c. Review SOCWA Comments and Finallize Memorandum	1	1	0	1	0							3
4. Conceptual Design Submittal												0
a. Prepare 30% Drawings												0
G-001 Cover Page and Index (Tighe & Bond)	1	2	0	0	2							5
G-101 JBLTP Process Flow Diagram (Tighe & Bond)	1	2	0	0	4							7
G-201 RTP Process Flow Diagram (Tighe & Bond)	1	2	0	0	4							7
C-101 JBLTP Site Plan (Civiltec)	0	0	0	0	0	2	4	8	8	2		24
C-101 JBLTP Yard Piping Plan (Civiltec)						2	4	8	8	2		24
C-201 RTP Site Plan (Civiltec)	0	0	0	0	0	2	4	8	8	2		24
C-202 RTP Yard Piping Plan (Civiltec)						2	4	8	8	2		24
A-101 JBLTP Architectural Plan (Civiltec)						2	4	8	12	2		28
A-102 JBLTP Architectural Elevations (Civiltec)						2	4	8	12	2		28
A-201 RTP Architectural Plan (Civiltec)						2	4	8	12	2		28
A-202 RTP Architectural Elevations (Civiltec)						2	4	8	12	2		28
M-101 JBLTP Mechanical Process Plan - Lower Level (Tighe & Bond)	2	8	2	0	10							22
M-102 JBLTP Mechanical Process Plan - Upper Level (Tighe & Bond)	2	8	2	0	10							22
M-103 JBLTP Mechanical Section (Tighe & Bond)	2	8	2	0	10							22
M-201 RTP Mechanical Process Plan - Lower Level (Tighe & Bond)	2	8	2	0	10							22
M-202 RTP Mechanical Process Plan - Upper Level (Tighe & Bond)	2	8	2	0	10							22
M-203 RTP Mechanical Section (Tighe & Bond)	2	8	2	0	10							22
PI-101 P&ID - Dewatering System (Tighe & Bond)	1	6	1	0	6							14
PI-102 P&ID - Drying Equipment - 1 (Tighe & Bond)	1	6	1	0	6							14
PI-103 P&ID - Drying Equipment - 2 (Tighe & Bond)	1	6	1	0	6							14
PI-104 P&ID - Drying Equipment - 3 (Tighe & Bond)	1	6	1	0	6							14
PI-105 P&ID - Exhaust Air Treatment (Tighe & Bond)	1	6	1	0	6							14
PI-106 P&ID - Odor Scrubber (Tighe & Bond)	1	6	1	0	6							14
PI-107 P&ID - Ancillary Support Systems (Tighe & Bond)	1	6	1	0	6							14
E-101 JBLTP One-Line Diagram (Tighe & Bond)	1	2	1	8	4							16
E-201 RTP One-Line Diagram (Tighe & Bond)	1	2	1	8	4							16
b. Prepare Preliminary Specifications for Major Process Equipment (See List Below)	4	16	16	0	0							36
c. Prepare Equipment List and Cut Sheets for Major Process Equipment	2	8	8	0	0							18
d. Preliminary Permitting Memo (Air Permitting, Coastal Commission Permitting, Visual Screening, Noise, Odor	0	0	0	0	0	16	24	32			40	112
e. Air Permitting Subcontactor Assistance (Coordinated by Civiltec)	0	0	0	0	0	4		2			20	26
f. Other Conceptual Design Tasks by Civiltec (See Note 8 and additional sheets added above)	0	0	0	0	0							0
g. Respond to SOCWA Comments	2	8	2	2	4	4	2	2			4	30
5. Implementation Plan - Assume Implementation Plan Memo Prepared by NEFCO / DOC	0	0	0	0	0							0
Total	123	183	47	21	124	60	78	112	80	16	64	908

Proposed Schedule

WBS	Task Name	Start	Finish	Resource Names
1	RFP Issued	Tue 2/12/19	Tue 2/12/19	
2	Pre-proposal Meeting	Tue 2/12/19	Tue 2/12/19	NEFCO
3	**Proposers Submit Questions**	**Tue 2/12/19**	**Tue 3/12/19**	**NEFCO**
3.1	SOCWA Responses to Proposers Questions	Fri 3/1/19	Fri 3/1/19	SOCWA
3.2	Review planning documents, including as-builts	Tue 2/12/19	Tue 3/12/19	NEFCO,Civiltec,Tigh & Bond
4	Final Date for Proposal Submittal	Mon 4/1/19	Thu 4/25/19	NEFCO,Civiltec,Tigh & Bond
5	Third Party Review	Fri 4/26/19	Thu 5/2/19	SOCWA
6	Engineering Committee Review	Fri 4/26/19	Thu 5/2/19	SOCWA
7	Approval of Award by Board	Thu 5/9/19	Thu 5/9/19	SOCWA
8	Notice to Proceed to FIRM	Mon 7/1/19	Mon 7/1/19	SOCWA
9	Summary of Existing Operations TM Completion	Mon 8/19/19	Fri 8/23/19	NEFCO
10	Safety Assessment TM Completion	Thu 9/19/19	Fri 9/27/19	NEFCO
11	30% Design Completion	Mon 7/1/19	Fri 10/25/19	Tighe & Bond,Civilte
12	Implementation Plan TM Completion	Mon 8/26/19	Thu 9/19/19	NEFCO
13	Deliver Proposal #2	Fri 12/13/19	Fri 12/13/19	Civiltec,NEFCO,Tigh & Bond



Project: Simple Project Plan
Date: Mon 4/22/19

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

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South Orange County Wastewater Authority

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3. Safety Assessment												0
a. Conduct Safety Workshop with NEFCO and SOCWA (Note 5)	0	0	0	0	0							0
b. Prepare Safety Technical Memorandum (Note 6)	2	2	0	2	0							6
c. Review SOCWA Comments and Finalize Memorandum	1	1	0	1	0							3
4. Conceptual Design Submittal												0
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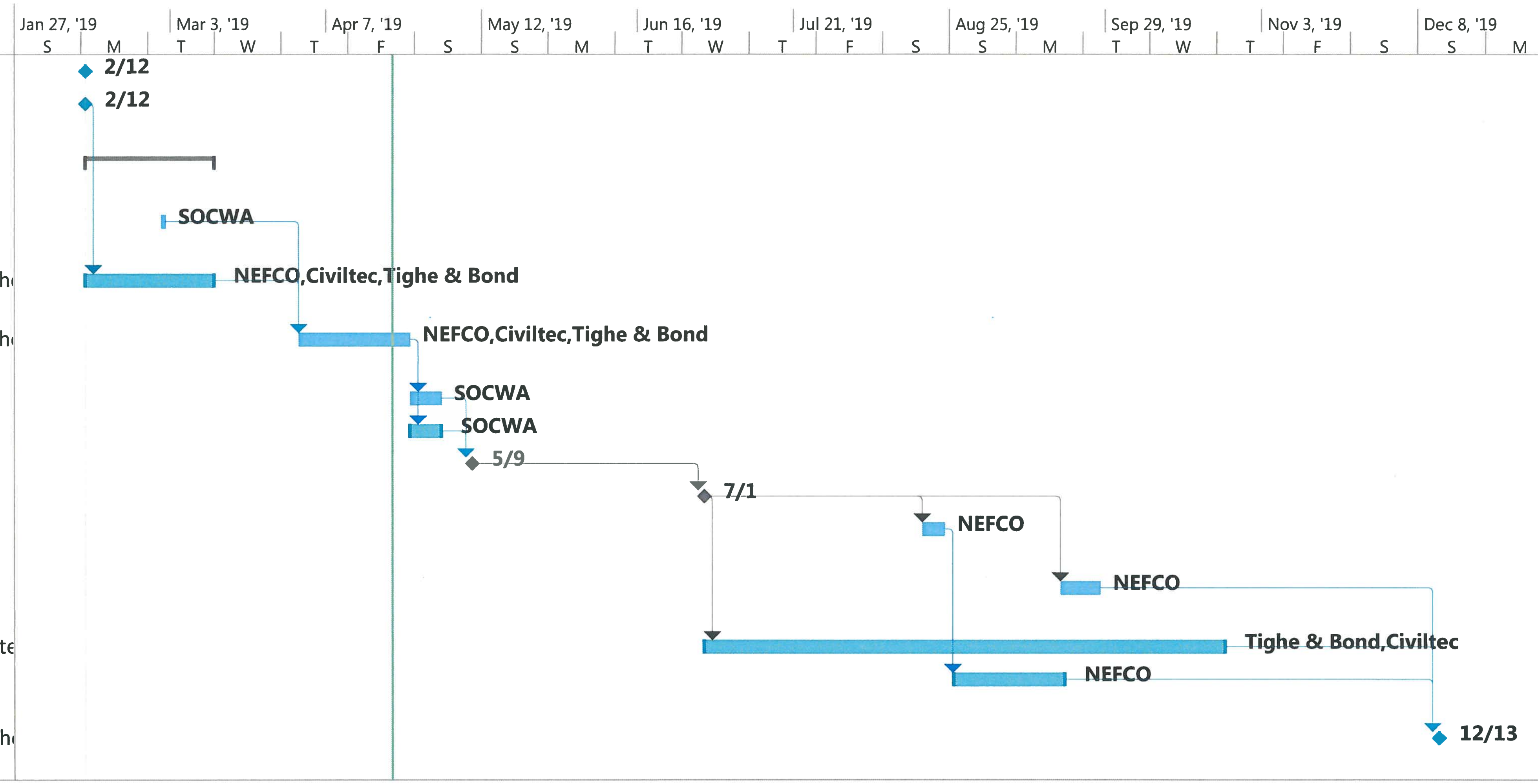
b. Prepare Preliminary Specifications for Major Process Equipment (See List Below)	4	16	16	0	0							36
c. Prepare Equipment List and Cut Sheets for Major Process Equipment	2	8	8	0	0							18
d. Preliminary Permitting Memo (Air Permitting, Coastal Commission Permitting, Visual Screening, Noise, Odor Control,	0	0	0	0	0	16	24	32			40	112
e. Air Permitting Subcontractor Assistance (Coordinated by Civiltec)	0	0	0	0	0	4		2			20	26
f. Other Conceptual Design Tasks by Civiltec (See Note 8 and additional sheets added above)	0	0	0	0	0							0
g. Respond to SOCWA Comments	2	8	2	2	4	4	2	2			4	30
5. Implementation Plan - Assume Implementation Plan Memo Prepared by NEFCO / DOC	0	0	0	0	0							0
Total	**123**	**183**	**47**	**21**	**124**	**60**	**78**	**112**	**80**	**16**	**64**	**908**

Notes:

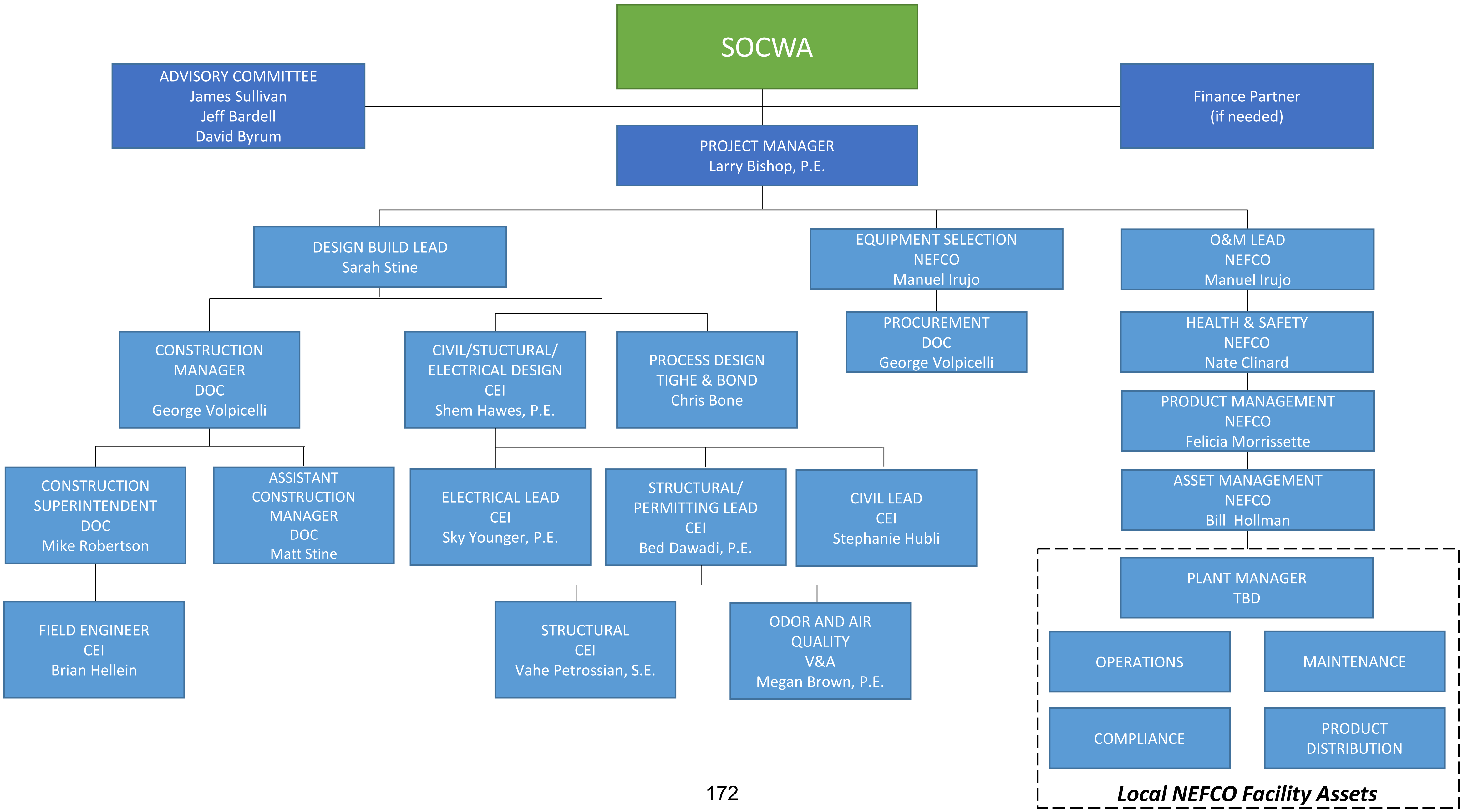
1. Preliminary specifications for major equipment developed during the conceptual design phase include: Centrifuges, Dryer System, and Odor Control Scrubbers.
2. At the conceptual design phase, one set of P&IDs will be developed, and any unique features at JBLTP and RTP will be identified.
3. Treatment plant site visits and staff interviews will be coordinated with Progress Meeting No. 1. Separate travel expenses are not assumed for this site visit.
4. We have assumed that the Safety Workshop will be conducted at a Progress Meeting, so no additional labor time or travel expenses have been assumed for this effort.
5. Conceptual design does not include structural design and/or structural analysis of existing buildings and structures.
6. Mechanical (HVAC) and Fire and Life Safety analysis and design for new and existing buildings is not included.

WBS	Task Name	Start	Finish	Resource Names
1	RFP Issued	Tue 2/12/19	Tue 2/12/19	
2	Pre-proposal Meeting	Tue 2/12/19	Tue 2/12/19	NEFCO
3	**Proposers Submit Questions**	**Tue 2/12/19**	**Tue 3/12/19**	**NEFCO**
3.1	SOCWA Responses to Proposers Questions	Fri 3/1/19	Fri 3/1/19	SOCWA
3.2	Review planning documents, including as-builts	Tue 2/12/19	Tue 3/12/19	NEFCO,Civiltec,Tigh & Bond
4	Final Date for Proposal Submittal	Mon 4/1/19	Thu 4/25/19	NEFCO,Civiltec,Tigh & Bond
5	Third Party Review	Fri 4/26/19	Thu 5/2/19	SOCWA
6	Engineering Committee Review	Fri 4/26/19	Thu 5/2/19	SOCWA
7	Approval of Award by Board	Thu 5/9/19	Thu 5/9/19	SOCWA
8	Notice to Proceed to FIRM	Mon 7/1/19	Mon 7/1/19	SOCWA
9	Summary of Existing Operations TM Completion	Mon 8/19/19	Fri 8/23/19	NEFCO
10	Safety Assessment TM Completion	Thu 9/19/19	Fri 9/27/19	NEFCO
11	30% Design Completion	Mon 7/1/19	Fri 10/25/19	Tighe & Bond,Civilte
12	Implementation Plan TM Completion	Mon 8/26/19	Thu 9/19/19	NEFCO
13	Deliver Proposal #2	Fri 12/13/19	Fri 12/13/19	Civiltec,NEFCO,Tigh & Bond



Project: Simple Project Plan
Date: Mon 4/22/19

Task, Split, Milestone, Summary, Project Summary, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, External Tasks, External Milestone, Deadline, Progress, Manual Progress


SOCWA
ADVISORY COMMITTEE
James Sullivan
Jeff Bardell
David Byrum
Finance Partner
(if needed)
PROJECT MANAGER
Larry Bishop, P.E.
DESIGN BUILD LEAD
Sarah Stine
EQUIPMENT SELECTION
NEFCO
Manuel Irujo
O&M LEAD
NEFCO
Manuel Irujo
CONSTRUCTION MANAGER
DOC
George Volpicelli
CIVIL/STUCTURAL/ ELECTRICAL DESIGN
CEI
Shem Hawes, P.E.
PROCESS DESIGN
TIGHE & BOND
Chris Bone
PROCUREMENT
DOC
George Volpicelli
HEALTH & SAFETY
NEFCO
Nate Clinard
PRODUCT MANAGEMENT
NEFCO
Felicia Morrissette
CONSTRUCTION SUPERINTENDENT
DOC
Mike Robertson
ASSISTANT CONSTRUCTION MANAGER
DOC
Matt Stine
ELECTRICAL LEAD
CEI
Sky Younger, P.E.
STRUCTURAL/ PERMITTING LEAD
CEI
Bed Dawadi, P.E.
CIVIL LEAD
CEI
Stephanie Hubli
ASSET MANAGEMENT
NEFCO
Bill Hollman
PLANT MANAGER
TBD
OPERATIONS
MAINTENANCE
COMPLIANCE
PRODUCT DISTRIBUTION
Local NEFCO Facility Assets
FIELD ENGINEER
CEI
Brian Hellein
STRUCTURAL
CEI
Vahe Petrossian, S.E.
ODOR AND AIR QUALITY
V&A
Megan Brown, P.E.

LARRY W. BISHOP, PE

Vice President
General Manager

REGISTRATION

- **Professional Engineer:**
  Florida, Louisiana, Mississippi, South Carolina, Pennsylvania, Massachusetts

EDUCATION

- B.S. & M.E. Civil Engineering, University of South Florida
- MBA Courses, Penn State University

WORK EXPERIENCE

New England Fertilizer Company *(2011 – Present).*

Vice President, General Manager
Responsible for the overall management of the company, which includes biosolids processing facilities located in Quincy, MA; North Andover, MA; Shakopee, MN; West Palm Beach, FL; Cumberland, MD; and Detroit MI. This includes strategic and financial plans and performance for the company. Ultimate responsibility for manufacturing operations, quality control, maintenance, environmental compliance, safety, budgeting, cost control, union negotiations and product marketing.

Areas of focus include:

- Advocate and implement Safety Management Program enhancements with a goal of zero personal and OSHA incidents.
- Implement asset reliability program to formalize maintenance program.
- Negotiate contract extensions and renewals.
- Develop risk identification program to proactively address performance or financial issues.

Vice President, Engineering & Business Development
Responsible for managing engineering project ranging from small retrofits to a $140 million greenfield facility.

Also led all business development activities including new leads, prepositioning, development of qualifications packages and proposals, technical papers and conferences, and client relations.

REPRESENTATIVE PROJECT EXPERIENCE

- **PC-792 GLWA Biosolids Drying Facility DBOM, Detroit.** The Great Lakes Water Authority design-build-operate-maintain contract for a new biosolids management and drying facility to replace an incineration facility that has reached the end of its useful life. Project Manager for overall execution and management responsibilities related to the design, engineering, construction, and startup of the biosolids drying facility.

- **Biosolids Processing Facility – industrial Wastewater Force Main Project, West Palm Beach**. In order to economically dispose of high strength wastewater that is discharged from the facility it was necessary to plan, design, and construct a one-mile force main from the BPF to existing deep injection wells. The project included the directional drilling of the pipe, a new pumping station and SCADA improvements to provide monitoring and control of the system to the BPF.

- **Biosolids Processing Facility – Hydrogen Sulfide Project, West Palm Beach**. The currently operating BPF receives undigested sludge from a portion of the six municipalities that utilize the facility. The undigested sludge has resulted in excessive hydrogen sulfide (H2S) concentrations near the receiving bins. Therefore, NEFCO undertook a design and construction project to collect the H2S and safely treat it in the facility's wet scrubber system.

- **Biosolids Processing Facility – City of West Palm Beach**. NEFCO undertook a program to increase the airflow in the existing dryer system. The project required modeling, engineering, permitting and installation of the improvements. The improvements included the replacement of the tray scrubber trays and a retrofit to the cyclone separator. The additional airflow allowed additional sludge to be processed through the facility.

- **Biosolids Processing Facility – Wastewater Treatment, West Palm Beach**. The City of West Palm Beach has a regional drying facility, which produces granular material for fertilizer use. The drying process produces high strength wastewater that significantly exceeds pretreatment standards. Project Manager for the review of the drying process and developed an aerobic, fixed film treatment process (moving bed bioreactor) to treat the high strength wastewater to meet permit requirements.

- **Biosolids Processing Facility – Conveyor Improvements, Cumberland**. This project included the evaluation, engineering and construction of new screw conveyors to transport dewatered sludge from existing centrifuges to the rotary dryer. The allowed the facility to process more sludge using the same major equipment.

- **Biosolids Processing Facility – Drum Replacement, Massachusetts Water Resources Authority, Quincy, Massachusetts**. After 23 years of operation a drum replacement project was executed to replace rotary dryer drums at one of the largest drying facilities in the world. The project included planning, rigging, and structural steel support of ingress/egress for a 32-foot long, 10-foot diameter drum replacement.

PROFESSIONAL AFFILIATIONS

- North American Clean Water Agencies
- Water Environment Federation
- American Water Works Association
- Miller Heiman Strategic Selling Workshop

James N. Sullivan

Managing Partner, NEFCO
President, The O'Connell Companies

EDUCATION

- Bachelor of Science in Finance, University of Massachusetts
- Master Degree in Finance, Western New England College

PREVIOUS SPECIALIZED WORK EXPERIENCE

- **New England Fertilizer Company, Quincy, MA** (2017 – Present)**.** *Managing Partner*. In his role as Managing Partner of New England Fertilizer Company, Mr. Sullivan has overall responsibility for the successful management and strategic direction of NEFCO. These responsibilities include, in part, oversight of all financial, operational, contractual, and business development matters.

- **New England Fertilizer Company, Quincy, MA** (1990 - 2016). *General Manager.* Mr. Sullivan has successfully implemented biosolids management public-private partnerships including all contractual, legal and pricing aspects for the following contracts:

    - Massachusetts Water Resources Authority – Biosolids Management Facility, Quincy, MA
    - Metropolitan Council Environmental Services – Biosolids Management Facility, Shakopee, MN
    - Greater Lawrence Sanitary District – Biosolids Drying and Pelletizing Facility, North Andover, MA
    - Solid Waste Authority of Palm Beach County – Biosolids Management Facility, West Palm Beach, FL
    - City of Cumberland – Heat Drying Facility, Cumberland, MD
    - Great Lakes Water Authority – Biosolids Dryer Facility, Detroit, MI

- **The O'Connell Companies, Holyoke, MA** (1982 – Present).
  President (2019-Present). Mr. Sullivan is responsible for oversight of the successful management and strategic direction of The O'Connell Companies and its subsidiaries, including two construction companies, real estate development and property management divisions, and NEFCO. These responsibilities include real estate development, commercial property acquisitions and divestitures, property and asset management services, and energy management services.
  Treasurer (1982-2018). Mr. Sullivan has been with The O'Connell Companies, Inc. since beginning his professional career in 1982. In his role as Treasurer, he offers an extensive background in financial, legal, and contractual issues associated with development/construction projects. Mr. Sullivan has financial oversight on each and every construction and development project pursued by O'Connell's.

- **O'Connell Development Group, Holyoke, MA** (2017 – Present). *President.* Mr. Sullivan is responsible for the successful management and strategic direction of O'Connell Development Group and its subsidiaries. These responsibilities include real estate development, commercial property acquisitions/divestitures, property/asset management services, energy management services and New England Fertilizer Company.

James N. Sullivan

Managing Partner, NEFCO
President, The O'Connell Companies
Page Two

PROFESSIONAL AFFILIATIONS

- Mr. Sullivan is a prior member of the Board of Directors for the Associated General Contractors of Massachusetts, and former chairperson, of its Risk Management and Bonding subcommittee.

- Mr. Sullivan is a former member (1990-1999) of the Board of Trustees for the Sister of Providence Health System, serving on its executive committee, finance committee, and fund development committee.

- Mr. Sullivan is the Chairman of the Boys and Girls Club of Holyoke, also serving on its Executive and Finance committees.

MANUEL J. IRUJO
Vice President, Operations

EDUCATION

- MBA, Worcester Polytechnic Institute
- BS, Chemical Engineering, Worcester Polytechnic Institute

PREVIOUS SPECIALIZED WORK EXPERIENCE

New England Fertilizer Company *(2007 – Present).*

Vice President, Operations

Responsible for the overall management of biosolids processing facilities located in Quincy, MA; North Andover, MA; Shakopee, MN; West Palm Beach, FL; Cumberland, MD; and Detroit MI. This includes day-to-day manufacturing operations, quality control, maintenance, environmental compliance, safety, budgeting, cost control, union negotiations and product marketing.

- Implemented enhancements to Safety Management Programs resulting in over 50% reduction in OSHA incidents.
- Led operational start-up of largest biosolids processing facility in North America.
- Managed $1.5 million capital project to install four sulfur dioxide scrubbers.
- Established an Asset Reliability Program to improve dryer system utilization, extend equipment life, and reduce maintenance costs.

Plant Manager, Quincy, MA. Responsible for entire plant operations and maintenance converting biosolids sludge into beneficial use fertilizer. Reported to the Vice President of Operations. Plant consists of about 30 people, with an annual operating expense budget of ~$14 million.

- Managed $1 million capital project for upgrade of centrifuge drive and control systems which received utility energy efficiency incentives.
- Developed an inventory tracking and forecasting process to maximize product sales revenue and deliver $300K annual cost savings.
- Implemented an expense forecasting system and linked to purchasing system to improve monthly forecasting by 75%.
- Led process changes to reduce utility usage for an annual savings of $250K.
- Facilitated fertilizer pellet consistency process improvements for a savings of $100K annually.
- Initiated cultural changes towards effective teamwork, employee involvement, and accountability.

Polaroid Corporation *(1988 – 2007).*

Manufacturing Plant Director, Norwood, MA (2003 – 2007). Responsible for all aspects of manufacturing polarized sheet for sunglasses, coating photographic positive sheet, and contract coating of external medical and display films. Reported to the Sr. Vice President of Manufacturing. The division consisted of 40-75 people, with an annual expense budget of ~$8-12 million, and shipments of ~$18 million.

- Instituted P&L management financial procedures leading to real-time yield data, >99% inventory accuracy, and 3X bottom line forecasting improvement.
- Completed in-source of polarized sheet manufacturing for annual savings of $3 million.
- Led yield improvement efforts to eliminate $2 million in unfavorable variances.
- Grew contract coating from a $300K to a $4 million business.
- Reorganized leadership team by recruiting key contributors from other areas.

Site Operations Manager, New Bedford, MA (2000 – 2003). Responsible for managing 230 people manufacturing photographic negative, positive sheet, contract coatings, and digital print media. Departments included coating, slitting, packaging, chemical mix, analytical lab, and trades. Annual expense budget was ~$21 million with shipments of ~$100 million.

- Spearheaded continuous improvement Kaizen lean manufacturing activities resulting in inventory reductions of $5 million and 70% cycle time reduction for rework.
- Led Operations Team in contract coating efforts for incremental annual revenue of $15 million.
- Delivered operations scale up of new professional peel-apart film sheet and negative, contributing to $30 million improvement in market share.
- Directed Operations Team in new pay plan implementation and administration.

Chemical Mix Manufacturing Manager, New Bedford, MA (1998 – 2000). Responsible for managing 45 people manufacturing dispersions, coating fluids, and photographic silver emulsions. In addition to the Senior Engineer responsibilities listed below, duties included Supervisor coaching, handling personnel issues, budget management, capital justifications, project coordination, and resource allocation. Annual expense budget was ~$4 million with WIP value of ~$30 million.

- Combined two departments to improve efficiencies, saving $500K in annual expenses.
- Standardized batch chemical adjustments, improving in-spec metrics from 88% to 98%.
- Oversaw SAP implementation within the Chemical Mix department.

Senior Engineer, New Bedford, MA (1992 – 1998). Supervised various shifts responsible for manufacturing complex chemical dispersions and coating fluids. Duties include Six Sigma variability reduction leader, new product introductions, quality assurance, contamination control, production planning, process troubleshooting, and writing operating procedures.

- Established SPC within the Chemical Mix department, improving average Cpk from 0.8 to 1.3.
- Executed a Six Sigma project for developer composition control, resulting in $250K rework reduction and a 20% improvement in film customer quality.
- Led scale up of coating fluids for new film platform using DFM methodology.

LEVEL OF EXPERTISE

- Biosolids processing and heat drying
- Class A biosolids / fertilizer marketing
- P & L Management
- Profitability Improvement

PROFESSIONAL CERTIFICATIONS AND AFFILIATIONS

- North East Biosolids and Residuals Association, former Board of Directors member
- Wastewater Treatment Plant Operator, Massachusetts Grade 4M
- Certified Reliability Leader, Association for Asset Management Professionals
- Six Sigma Certification

Nate Clinard

Health & Safety, NEFCO
Vice President, Corporate Safety, The O'Connell Companies

Mr. Clinard has more than 26 years of experience in Construction Safety and General Industry Safety including more than six years as the Corporate Safety Director at a multi-facility heavy manufacturing company and ten years at an electric utility company supporting their fleet of power generating stations and all construction activities. Nate has significant hands-on experience in the following areas: safety management and influence of large scale multi-trade construction sites; design and implementation of best practice safety programs based on sound predetermined goals and objectives; safety management system evaluations; hazard recognition, control and abatement programs; field audit development; compliance auditing with corrective action plan tracking, and, building and sustaining strong safety cultures. Mr. Clinard received his Bachelors of Science Degree in Safety Studies in 1992 and joined NEFCO/The O'Connell Companies in 2012.

EDUCATION AND MEMBERSHIPS

- Keene State College: B.S. Safety Studies
- National Safety Council
- American Society of Safety Engineers

RELEVANT EXPERTISE

- Experience supporting multiple locations
- Excellent communication skills and ability to work collaboratively as part of the project teams
- Construction safety management
- Behavior based safety and safety program evaluation
- Hazard recognition and control technique
- Building relationships with Local, State and Federal Regulators

RELEVANT PROJECT EXPERIENCE

- **NEFCO, Detroit Biosolids Drying Facility:** NEFCO Detroit Biosolids Drying Facility: This $125 million project consists of the construction of 47,500 SF operations building which including piles, various foundations, precast walls, office space, and process equipment. Major process equipment includes centrifuges, dryer system, RTO, silos, and odor control system.

- **Salem State University:** Mainstage Theater Modernization and Upgrade: This $20 million project was a renovation of the Mainstage Theater containing approximately 32,182 sf that included a renovated 490-seat audience chamber, stage improvements, scene shop improvements, additional space for rehearsals, a lobby/ student lounge, an art gallery space, and a 35-person conference room. This project was delivered via Chp. 149-A program.

- **Phillips Exeter Academy:** Center for Theater and Dance: This new $32 million project is comprised of five levels and approximately 20,449 sf. The lowest level houses mechanical, storage, dressing, costume, green room and drama program spaces. The first and second levels houses the End-Stage and Apron Theaters, theater rehearsal room, scene shop, classrooms, office and related support spaces. The third level houses the dance performance space, dance rehearsal spaces, changing rooms and related support spaces.

- **Fall River Disinfection Facility:** This $8.5 million project includes construction of a 35 million gallon per day combined sewer overflow (CSO) screening and disinfection facility and site improvements at Bicentennial Park.

- **West Warwick WWTP, West Warwick, RI:** This $12 million project consisted of upgrading the quality of the water discharged by the plant back into the watershed by constructing a new building that will house the phosphorous removal system equipment.

- **Kennebec Valley Expansion, Oakland, ME:** This $7.5 million project was a network consisting of over 80 miles of steel gas pipeline, which brings alternative heating fuel to 15,000 homes and businesses in central Maine. DOC was awarded this contract by Summit Natural Gas of Maine to install 8 miles of 8-inch steel gas main, a half mile of 10-inch low pressure gas main, as well as the management of over 1500 feet of Horizontal Directional Drilling designed to service one of the largest paper mills in North America.

SEAN MURNAN
Process Engineer

NEFCO
Recycle, Renew, Restore

EDUCATION

- Rochester Institute of Technology, Rochester, NY
  Masters of Engineering, Sustainable Engineering, December 2017
- University of Hartford, Hartford, CT
  Bachelor of Science, Mechanical Engineering, May 2012

WORK EXPERIENCE

New England Fertilizer Company *(2018 – Present). Process Engineer*
Oversees design of mechanical and thermal processes for biosolids management facilities including thermal dryers, emissions control equipment, biosolids conveyance and storage equipment, biogas collection and utilization systems, thermal pre-treatment, anaerobic digestion and combined heat and power (CHP) facilities. Additionally, responsible for leading the efforts in the following areas:

- Works with outside engineering consultants and equipment vendors, developing technical specifications, and interfacing with NEFCO's affiliate construction company.
- Performs economic, non-economic, and feasibility analysis for biosolids handling projects, including process calculations and models for system evaluation and sizing.
- Provides startup, commissioning, and operations assistance for biosolids processing facilities. Also leads development of process O&M specifications.
- Performs process optimization for energy savings projects at biosolids management facilities.
- Directs and participates in physical on-site trouble-shooting, repairs or maintenance activities.

ClearCove Systems *(2014 – 2018). Laboratory Manager & Operations Engineer*
Managed both in-house and independent environmental/analytical laboratory needs and supported engineering team working on wastewater treatment systems designs in both field and office settings for startup wastewater treatment and renewable energy company. Major responsibilities included:

- Prepared sampling plans for treatability studies, collected and performed a wide range of analyses on samples, analyzed data and generated performance reports for projects.
- Designed and implemented experimental plans for studying system performance characteristics.
- Wrote proposals for pilot technology demonstrations projects, and worked with operations staff in the field to run pilot and provide on-site laboratory analysis support.
- Acted as senior operator for full-scale wastewater treatment plant startups. Performed daily O&M on systems, collected and analyzed operational data, and trained new staff.
- Assisted sales team on initial customer interactions by providing logistics support for sample collection and testing, analysis of various client waste streams, and detailing potential treatment options.

SELECTED PROJECTS

Pilot Operation / System Installation / Plant Startup for Dairy Producer – Upstate NY
Spring 2016 – Spring 2018

- Designed pilot plan for demonstrating treatment technology to large dairy producer in New Wilmington, PA. Worked in the field for the duration of the two-month project supporting senior operator with system O&M. Managed sampling needs for client laboratory, performed all field analysis on samples, and wrote performance report for customer.
- Assisted senior operator in installation of full-scale system at dairy producer's location in York, NY. Designed and carried out experiments to test several system parameters prior to startup. Worked as operator for several months during plant startup, while also performing in-house laboratory analysis and training customer's staff on system O&M.

Pilot System Install & Operation for Municipal Wastewater Plant - Fort Worth, TX
Fall 2015

- Managed all environmental/analytical laboratory needs for six-week pilot project. Designed sampling plan, coordinated sampling logistics with several independent laboratories, and performed all field analysis on wastewater samples.
- Assisted senior operators with the transportation of equipment, as well as the setup, operation, and breakdown of multiple treatment systems.

SELECTED PUBLICATIONS

- Murnan, S. and Thorn, B.K. "Life-Cycle Comparison of Artificial Turf and Natural Grass Sports Fields" 2014, presented at Industrial and Systems Engineering Research Conference 2014

PROFESSIONAL CERTIFICATIONS AND AFFILIATIONS

- Water Environment Federation (WEF)
- New England Water Environment Associates (NEWEA)

FELICIA MORRISSETTE

Product Distribution Manager

NEFCO
Recycle, Renew, Restore

EDUCATION

- University of New Hampshire, B.S. Forestry

WORK EXPERIENCE

New England Fertilizer Company *(2018 – Present). Product Distribution Manager*

Responsible for ensuring a diverse biosolids distribution plan for NEFCO's five biosolids processing facilities and nearly 150,000 tons, annually of Class AA product. Additionally, responsible for leading the efforts in the following areas:

Product Distribution

- Enhancing existing agriculture and blender customers, plus Identify and seek beneficial relationships with potential agriculture and blender customers with a focus on increasing product revenue.
- Establishing multi-layered marketing and distribution plan for agriculture markets to enhance diversification and financial performance of plants with blender-quality product.
- Developing and implementing innovative product marketing opportunities to increase diversity through soil blending, land reclamation, and alternative fuel projects.
- Providing logistics and technical guidance for land application programs, including agronomy.
- Consolidating and managing product inventory database

Outreach Programs

- Working with regional wastewater and biosolids associations to plan and execute interactive activities promoting recycling of biosolids.
- Work directly with existing and new end user customers to ensure they understand agronomic, soil, and beneficial use considerations.
- Immediately respond to any biosolids land application complaints including site visits and meetings with town or city officials.
- Interacting with local politicians, farm bureaus, conservationists, etc. as needed for ongoing understanding of biosolids use in local plant areas.
- Developing biosolids agriculture and turf research projects in conjunction with associations or universities.

Regulatory

- Member of national committee formed with regulators and generators to evaluate the evolving PFAS regulations in groundwater and biosolids.
- Ensure product distribution activities maintain compliance with land application permits and all applicable state and federal laws.
- Monitor and understand regulatory trends such as phosphorus limitations, micro-contaminants, and personal care products and their potential impact on product marketing.

Felicia Morrissette
Product Distribution Manager
Page Two

Resource Management, Inc. *(2014 – 2018). Project Manager: Compliance & GIS*

Responsible for implementing the company's compliance program with the objective of maintaining local, state and federal regulatory compliance pertaining to beneficial reuse of regulated residuals.

- Manage compliance aspects of recycling 200,000 tons of organic residuals annually from waste water treatment plants, biomass electrical generators, paper mills and drinking water facilities for beneficial agricultural and industrial reuse across all New England states and New York.
- Ensure compliance with EPA 503s and maintain certification statements for generators for pathogen and vector attraction reduction requirements.
- Communicate with a diverse group of stakeholders including state and federal environmental agencies, commercial and organic agricultural representatives, conservation services, policy makers, municipalities, university extension, farmers, engineers, operators and concerned citizens of the community.
- Obtain and maintain permits for all products represented by RMI.
    - Produce annual reports for customers and states.
    - Class B site permits in New Hampshire.
- Collect product samples for testing.
    - Monitor and organize laboratory results of materials.
    - Nutrient management, certifying guarantee numbers for land application.
- Manage ArcGIS mapping database to monitor and maintain land application sites.
- Assisted in the design and implementation of a new marketing plan for firm.

SELECTED PROJECTS

- **Permit, renew and manage 42 Class B biosolids permits in NH.**
- **NH Sludge Management rulemaking** – 2016 rule updates to improve land application management

PROFESSIONAL CERTIFICATIONS AND AFFILIATIONS

- Water Environment Federation (WEF)
- New England Water Environment Associates (NEWEA)
- North East Biosolids & Residuals Association (NEBRA)

William J. Hollman, MBA, PMP, CRL

Corporate Operations and Safety Manager

EDUCATION

- MBA, University of Rhode Island
- BS, Physics, Marquette University
- Certificate in Dispute Resolution, University of Massachusetts-Boston

PREVIOUS SPECIALIZED WORK EXPERIENCE

New England Fertilizer Company *(20014 – Present).*

Corporate Operations Manager

Assistant to the Vice President of Operations and Vice President of Safety, working with and monitoring all NEFCO plants nationwide, ensuring safe and reliable operations. Duties include Plant Management, major project management, process reliability and optimization, vendor RFPs, staffing and plant commissioning. Particular focus has been on new plant commissioning of the Detroit facility, and implementation of the corporate wide computerized maintenance management system. Asset Reliability and Management expert as Certified Reliability Leader – Blue Belt.

A2B Tracking Solutions *(2012 – 2014)*

Project Manager

Spearheaded all planning, executing and analysis processes for A2B Marking and Data Capture teams in multiple DoD projects on worldwide deployments. Major projects included a $6 million, 18 month US Navy project and an $800,000 6 month US Air Force project. Responsibilities included directing all phases of MDC program projects from inception through completion, including planning and execution, risk management, technical and managerial communications.

SAIC Enterprise Solutions *(2007 – 2012)*

Engineering Department Manager

Division Sr. Staff. Lead the Naval Undersea Warfare Center (NUWC) underwater test range customer advocate support; Coordinated of new projects for NUWC operated underwater test ranges.

Lead efforts for multiple proposals including surface ship torpedo defense, submarine, and port security testing systems.

Coordinated test plans for UUV hull security inspection unit.

Headed the 40 man engineering department in support of the NUWC Propulsion Test facility, testing advances to torpedo propulsion units for both the heavyweight and lightweight torpedo, surface ship torpedo defense, submarine electronic imaging.

Sonalysts, Inc. *(2005 - 2007)*

Senior Analyst

Led support of NUWC Code 34 personnel and participating agencies in providing program-planning analysis in submarine imaging systems for the Virginia Class and SSGN submarines

Polaroid Corporation, New Bedford, MA, (1987 – 2005)

Site Maintenance Manager
Responsible for material condition and maintenance of $600MM of site-wide assets and the administration of the maintenance activities of the Media Manufacturing. Duties included the direct budgetary responsibility for a $10MM department budget and overall vision and leadership of 57 maintenance supervisors and technicians.

Coating Operations Department Manager
Led the operational and financial performance of the photographic coatings department. Duties included the overall operation of the prime converting line of Polaroid Corporation, the planning and execution of production runs in excess of $15MM, direct responsibility for the $2.5MM department budget and the administration of a cross-functional, multi-shift team of 40 supervisors and technicians.

Commercial / Technical and Industrial Product Manager
Led production run planning, and testing, as well as liaison internal to Negative Manufacturing and with worldwide release & assembly customers.
Responsible for the yield and budget performance of up to 12 multi-million dollar production runs annually, while continuing product improvements. Specific improvements included increased yield performance, $1.7MM favorable to budget.

Capital Engineer / Senior Engineer / Team Coordinator & Supervisor
Led the coordination, funding procurement, and management of large capital projects involving engineers and technicians across several departments and disciplines both inside and outside of Negative Manufacturing, as well as external vendors.
Responsible for the operational performance, administration, mentoring and training of a crew of approximately 28 members, including hourly and salary personnel, in the negative coating operations group.

U.S. Navy / Navy Reserve: Submarine Warfare (1982 - 2012)

Captain, specializing in submarine and operational level of warfare. Graduate of U.S. Navy Nuclear Power Engineering School and qualified submariner; served as a junior officer on an SSN. Excelled in six tours as the CO of diverse reserve units, directing up to 140 personnel. Final assignment was as Reserve Component Chief of Staff in Commander U.S. Third Fleet, lead over 500 reservists focused on international, joint and interagency operations.

LEVEL OF EXPERTISE
- Biosolids processing and heat drying
- P & L Management
- Profitability Improvement
- Asset Management and Reliability
- Military Operations

PROFESSIONAL CERTIFICATIONS AND AFFILIATIONS
- PMP
- CRL – Blue Belt

C. Shem Hawes, PE

Civiltec Engineering, Inc.

Mr. Hawes has 15+ years (11+ with Civiltec) of water and wastewater experience. Over his tenure at Civiltec, he has been integral in developing relationships with clientele and interacting at multiple levels with business partners and owners to develop solutions for water, wastewater and public works projects. He has been the responsible engineer for hundreds of unique planning, design and analytical projects while acting in the role of project manager and/or senior engineer.

Wastewater experience has included the planning, design and construction management of wastewater treatment facilities including performing analysis on sewer collection facilities and designing sewer pump stations. In addition, he has been involved in modeling and designing water distribution and sewage collection systems. He was intimately involved with development of mass balance models for wastewater treatment processes which integrated recycled and utility water return and solids handling into the overall loading of the plant. Unique wastewater treatment plant processes could be programmed into this model to simulate mass loading through the plant and determine the cause and effect to the facility. Mr. Hawes also developed hydraulic modeling systems to simulate hydraulic conditions through the plant's operations.

Mr. Hawes has prepared numerous studies and analysis for several projects requiring environmental review. Projects have included the Valley County Water District Arrow Reservoirs Mitigated Negative Declaration Document, City of Garden Grove Negative Declaration for the Supplemental Transmission Main, Three Valleys Water District Mitigated Negative Declaration for Well No. 2, La Puente Valley County Water District Zone 3 Pipeline Categorical Exemption and City of El Monte Well No. 3 Treatment Facility Categorical Exemption.

Similar Project Experience

Engineering Manager Services, Elsinore Valley Municipal Water District
Project Manager. Responsible for specialized engineering expertise to supplement staff and provide engineering management services since 2015. Supplemental staff were present in Elsinore Valley Municipal Water District's office on a routine basis to assist the Engineering Department with organization, management, work tasks and meetings with staff, outside agencies and developers. Engineering support was provided for large design projects and in a collaborative fashion to assist with organization, distribution, and management of design projects and development of request for proposals for consultant distribution. Projects included Lakeland Village construction management services and Lee Lake Recycled Pipeline Analysis.

Hollywood Casino Wastewater Treatment Plant, Confidential
Project Manager. Under a design-build delivery method, responsible for the design of a new wastewater treatment facility located in San Diego County, approximately 20 miles east of downtown San Diego. The plant houses a membrane bioreactor to treat high strength wastewater to remove biochemical oxygen demand, while ensuring the recycled use water meets Title 22 requirements for total nitrogen concentrations. The treatment plant consists of state of the art technologies to treat the wastewater and reused the recycle

Professional Registration
Professional Engineer, California No. 69578

Education
B.S. Civil and Environmental Engineering, University of Utah, 2002

Professional Affiliations
Orange County Water Association

Southern California Water Utilities Association water inside the Casino facility. Wastewater discharged from the casino, restaurant and community center is collected in a 12-foot diameter influent lift station. The sewer is pumped into the fine screen before it is treated biologically into the bioreactors. The bioreactors are of concrete structure and are designed in such a way that anoxic and aerobic kinetics takes place in the same reactor. The biologically treated wastewater is feed into the membrane bioreactors and pumped out the permeate for further treatment using reverse osmosis. A sodium hypochlorite system was also installed as redundant disinfection system. Hydrogen sulfide the source of foul odor is collected from influent lift station, screen and digester, and treated through granular activated carbon beds. The tertiary treatment system is equipped with automatic valves to bypass all or a single system.

Victoria No. 1 Lift Station Rehabilitation, City of Laguna Beach

Project Manager. The lift station is constructed in a concrete wet well and accessible through a steel frame access hatch. Raw sewage is pumped from the lift station to the manhole located just north of the stairway access in Victoria Drive. Sewage is then conveyed via gravity to the Victoria Lift Station No. 2. The lift station includes two identical pumps with one utilized for normal operations and one on standby and all necessary electrical and appurtenances. The lift station capacity was sized according to the maximum daily flow of 19 gallons per minute and the existing conditions in the field.

Donald C. Tillman In-Plant Storage Design-Build, City of Los Angeles

Project Manager. Responsible for the development of fast tracked construction drawings to expedite front-end execution of site improvements and excavation work. This $8.5 million design-build project included design and engineering of two 7.3 million gallon open storage tanks, interconnecting 48-inch and 36-inch diameter pipelines from existing facilities to and from the storage tanks, a live connection to an existing 96-inch sanitary sewer pipeline, a 48-inch hot-tap connection to the primary effluent channel, control valves, control logic for valve and system operation, cast-in-place valve vaults, 48-inch meters and associated structure, groundwater monitoring system, basin pressure relief system, landscaping improvements, basin wash down system, high-voltage power feed design, medium voltage and instrumentation design, and primary sludge conveyance mechanical improvements. Initial grading and drainage permits were secured within 4 months from the notice to proceed and final structural and mechanical permits were secured within 10 months from the notice to proceed.

Integrated Fixed Film and Activated Sludge Plant, City of Tooele

Project Engineer. Responsible for complete design of the 4.75 million gallons per day facility in Utah. This included the design of improved headworks screening and dewatering equipment, a 60-foot diameter clarifier, yard piping, return activated sludge/waste activated sludge pumping, Oxidation Ditch modification that integrated diffused air, the blower and electrical building, post oxidation splitter structure. Design included expansion the Integrated Fixed Film and Activated Sludge, additional clarifier capacity, cloth filtering, removal of the existing lime stabilization facility for solids handling and installation of a new solids handling facility. New solids handling improvements included study of conversion of the existing gravity thickener into a dissolved air flotation unit, enhancements to the existing belt filter press process and polymer dosing, installation of new solar active drying beds utilizing green house, solids heating, solids feeding, solids turning and solids removal. ***(Individual Experience)***

Integrated Fixed Film and Activated Sludge, City of Springville

Project Engineer. Responsible for the design of the 6.6 million gallons per day integrated fixed film and activated sludge plant in Utah. This system included design of the process supported in two 1 million gallon concrete basins, two 80 foot diameter secondary clarifiers, raising of existing clarifier walls to match the hydraulic gradient for a third 80 foot diameter secondary clarifier, the return and waste activated sludge pump station for the system (approximately 15,000 gallons per minute capacity), the snail and grit removal clarifier and classifier system for post trickling filter treatment, design of the trickling filter recycle pump station (10,000 gallons per minute capacity), design of the modified gravity thickener system utilizing an existing 50 foot diameter secondary clarifier, ultra violet disinfection, the solids handling facility belt filter press, polymer dosing for solids coagulation, and solids feed and conveyance structures. ***(Individual Experience)***

W. David Byrum, PE

Civiltec Engineering, Inc.

Mr. Byrum is Owner, President and Principal Engineer of Civiltec Engineering, Inc. He is responsible for the overall management of Civiltec's headquarters office. Mr. Byrum has 40+ years (25+ with Civiltec) of experience as a systems planner, design engineer, project manager, principal engineer and construction manager. He is an expert in the planning and design of water distribution and transmission pipelines, water treatment plants, booster pumping stations, steel and concrete reservoirs, groundwater wells, specialty valving stations, wastewater lift stations, flow equalization stations, wastewater treatment plants, storm drains and street improvement projects. He also prepares regulatory agency compliance reports and technical studies to ensure water purveyors remain in compliance with current regulations. Mr. Byrum serves as an expert witness and has been involved in several cases centered on water industry issues, including the Chromium 6 Pacific Gas and Electric (PG&E) case for 6 years.

Similar Project Experience

Donald C. Tillman In-Plant Storage Design-Build, City of Los Angeles
Principal. Responsible for the development of fast tracked construction drawings to expedite front-end execution of site improvements and excavation work. This $8.5 million design-build project included design and engineering of two 7.3 million gallon open storage tanks, interconnecting 48-inch and 36-inch diameter pipelines from existing facilities to and from the storage tanks, a live connection to an existing 96-inch sanitary sewer pipeline, a 48-inch hot-tap connection to the primary effluent channel, control valves, control logic for valve and system operation, cast-in-place valve vaults, 48-inch meters and associated structure, groundwater monitoring system, basin pressure relief system, landscaping improvements, basin wash down system, high-voltage power feed design, medium voltage and instrumentation design, and primary sludge conveyance mechanical improvements. Initial grading and drainage permits were secured within 4 months from the notice to proceed and final structural and mechanical permits were secured within 10 months from the notice to proceed.

Munz-Mendenall Probation Camp Wastewater Treatment Rehabilitation, Los Angeles County
Principal. Under a design-build delivery method, responsible for the installation of a new membrane bioreactor facility, new headworks screening unit, modified aeration basins to process the aerobic and anoxic phases of treatment, a new blower facility, a new control building and laboratory facility, return activated sludge/waste activated sludge pumping, flow equalization pumping and effluent pumping systems.

Acton Rehabilitation Center Treatment Facility, Los Angeles County
Principal. This is a residential short-term and long-term facility offering accommodations for persons with co-occurring mental and substance abuse disorders. Serving both women and men, the facility currently houses 165 rehabilitation patients and 30 full-time live-in employees and 30 daytime employees. The facility is to be expanded to 309 full-time patients and exceed a 600-person population during the daytime hours. Water supply is a blend of 40% surface water to 60% groundwater and is serviced by Los Angeles County Water Works District 37. Under a design-build delivery method, responsible for

Professional Registration
Professional Engineer, California No. 43296

Education
B.S., Mechanical Engineering, University of California, Los Angeles, 1977
A.S., Electro-Mechanical Engineering, Western Texas College, 1974

Professional Affiliations
American Council of Engineering Companies

American Water Works Association

Association of California Water Agencies

California Utility Executives Management Association, Board of Directors

Orange County Water Association

Southern California Water Utilities Association, Past President full design and engineering services to distribute and pump effluent from the wastewater treatment facility to the Center's ball fields and recreation areas. The Center also operates a groundwater well to supply water for irrigation purposes to the ball fields and landscape areas.

Monkhill Operable Unit, Pasadena Water and Power

Principal. This project included the design and construction management of a treatment system that included a water disinfection building, pipelines, electrical improvements, site improvements and building on concrete pad were the treatment tanks are located. The design to re-equip the four Pasadena-owned production wells ran concurrently with design and construction of the treatment plant at the Windsor Reservoir. Design included new equipment, mechanical piping, electrical and controls for four existing production wells with a total production capacity of 7,000 gallons per minute; new high-efficiency booster pumps with 8,400 gallons per minute capacity near Ventura Well and three vertical turbine pumps including mechanical, instrumentation, electrical and controls system; booster station wet well and building improvements that included conversion of an existing 38,000-gallon capacity concrete sump to a new wet well and structurally reinforcing the wet well to support the pumps and a new self-framed metal building; Monkhill site improvements that included new roadway access, stormwater retention and treatment, landscape and irrigation, grading and drainage; and water filtration system for perchlorate removal through ion exchange and volatile organic compounds removal through carbon adsorption. Start-up and performance testing of the wells and treatment plant was also administered.

Tertiary Wastewater Treatment Plant, Confidential

Principal. Under a design-build delivery method, responsible for the design of a new wastewater treatment facility located in San Diego County, approximately 20 miles east of downtown San Diego. The plant houses a membrane bioreactor to treat high strength wastewater to remove biochemical oxygen demand, while ensuring the recycled use water meets Title 22 requirements for total nitrogen concentrations. The treatment plant consists of state of the art technologies to treat the wastewater and reused the recycle water inside the Casino facility. Wastewater discharged from the casino, restaurant and community center is collected in a 12-foot diameter influent lift station. The sewer is pumped into the fine screen before it is treated biologically into the bioreactors. The bioreactors are of concrete structure and are designed in such a way that anoxic and aerobic kinetics takes place in the same reactor. The biologically treated wastewater is feed into the membrane bioreactors and pumped out the permeate for further treatment using reverse osmosis. A sodium hypochlorite system was also installed as redundant disinfection system. Hydrogen sulfide the source of foul odor is collected from influent lift station, screen and digester, and treated through granular activated carbon beds. The tertiary treatment system is equipped with automatic valves to bypass all or a single system.

Amherst Treatment Plant, City of La Verne

Principal. This plant included design and construction management of 2,500 gallons per minute perchlorate reduction treatment and nitrate reduction treatment trains. The project combined production from four wells into the perchlorate ion-exchange treatment system and then into a nitrate ion-exchange system. Three existing wells were utilized and a new fourth well was drilled and equipped. A sodium hypochlorite system and an acid pH adjustment system were design and constructed at the plant site. The treatment plant was permitted with the California Department of Public Health.

Conjunctive Use Project, Foothill Municipal Water District/Metropolitan Water District

Project Manager. Implemented a $2.2 million conjunctive use project involving the Foothill Municipal Water District and Metropolitan Water District. This project included updates to the preliminary design report for submittal to the Metropolitan Water District and design of a new 2000-gallons per minute aquifer storage and recovery well, new volatile organic compound treatment facility, new perchlorate removal system, miscellaneous pipelines, new chlorination facility and miscellaneous improvements at two Foothill Municipal Water District water pumping and storage facilities.

Stephanie Hubli, EIT

Civiltec Engineering, Inc.

Ms. Hubli has 2+ years (recently joined Civiltec) of experience in water and wastewater engineering. Her experience includes sanitary collection system modeling, pump station process and control design, contract administration, dam inspections and Emergency Action Plans, dam repair and removal design, hydraulic and hydrologic modeling, stormwater management design, residential septic system design and drainage system site design. She has been an active participant in the American Water Works Association's Young Professionals chapter and was invited to give a presentation on PFAS compounds at the national conference in June 2018. Wastewater experience encompasses planning, design and construction management of wastewater infrastructure such as collection systems, pump stations and treatment facilities. She has worked on a variety of projects involving sewer capacity analyses and collection system modeling, sanitary sewer evaluation studies (SSES), pump station design and construction management, solids handling, treatment plant upgrades and establishment of local limits. Ms. Hubli assisted in managing construction of a 4.0-MGD wastewater pump station with inlet headworks and coordinated roles and responsibilities among 5 subconsultants.

Similar Project Experience

Water Treatment System 1,4 Dioxane Removal,
San Gabriel Valley Water Company

Staff Engineer. Project included the design of basic civil site improvements, piping configurations, structural upgrades, mechanical improvements and electrical modifications to install new Trojan UVFlex treatment equipment. The installation was facilitated through two phases: Phase 1 incorporated the design of necessary improvements to deliver treatment of 3,900 gallons per minute of water for demonstration purposes while the existing low pressure ultraviolet (LPUV) system serves as a redundant and permitted treatment system to validate ultimate operation of UVFlex equipment. This phase also incorporated powering only one UVFlex reactor comprised of 144 lamps, the associated power distribution center (PDC), UV local control panel (LCP) and associated power requirements. Phase 2 of the work will incorporate powering all Phase I components plus an additional UVFlex reactor and its PDC, thus requiring a total 107 kVa power supply to reach the desired flow of 7,800 gallons per minute.

Wilson Reservoir 1,2,3-TCP, East Pasadena Water Company

Staff Engineer. Project included providing final design, testing, record drawings and construction support for the furnishing and installation of two 45,000-pound granular activated carbon (GAC) contactors. Also included two 18,000-gallon backwash tanks and all necessary interconnecting piping to operate the system. The project consisted of modifications to existing piping to tie the GAC contactors into the system and structural analysis.

FTP Pump Station Solids Handling, City of Middletown

Staff Engineer. Reviewed proposed design of grit removal system and screenings wash press at a 4.0 million gallons per day (MGD) wastewater pump station in the city of Middletown, CT. Estimated quantities of grit and screenings expected to be generated by these processes. Provided waste management solution alternatives for solids disposal comprising temporary on-site storage in conjunction with bi-weekly collection and transfer to an accepting landfill. ***(Individual Experience)***

Professional Registration
Engineer in Training
Connecticut No. 0011938

Education
B.S., Engineering, University of Connecticut, 2017

Certifications
OSHA 30 Hour Construction

Professional Affiliations
American Water Works Association (AWWA)

American Society of Civil Engineers (ASCE)

Stephanie Hubli, EIT

Civiltec Engineering, Inc.

FTP Pump Station Construction Services, City of Middletown

Staff Engineer. Provided contract administration engineering services during construction of a 4.0-MGD wastewater pump station. Coordinated review of process control, electrical, structural, architectural, HVAC and plumbing submittals and requests for information among five subconsultants. Prepared an engineer's opinion of probable cost for an associated request for proposal for change items across all project disciplines. ***(Individual Experience)***

Pump Station Rehabilitation Design, Town of Stratford

Staff Engineer. Assisted in the rehabilitation design of six pump stations for the Town of Stratford in Stratford, Connecticut. Design included conducting pump drawdown tests, evaluating expected future flow increases, performing hydraulic analyses for sizing pumps, investigating energy savings with VFDs, incorporating resiliency measures, and preparing equipment vendor requests and specifications. ***(Individual Experience)***

Sanitary Sewer Capacity Analysis, Town of Stratford

Staff Engineer. Developed an interactive model of the sanitary sewer collection system for the Town of Stratford in Stratford, Connecticut using Bentley SewerGEMS software. Imported existing pipe network from GIS shapefiles. Utilized and manipulated flow meter and pump station operating data to evaluate existing system capacity by creating multiple scenarios of varying infiltration and inflow. Matched base sanitary treatment plant inflow and field verified areas of surcharging to ensure model calibration. Identified areas of excessive infiltration and inflow and provided future development solutions and recommendations based on modeled results. Planned and managed the performance of a Sanitary Sewer Evaluation Study (SSES) consisting of overnight flow isolating testing, smoke testing, and closed-circuit television (CCTV) inspections to pinpoint locations of Sanitary Sewer Overflows (SSOs). ***(Individual Experience)***

Combined Sewer Capacity Analysis, Trinity College

Staff Engineer. Modeled and evaluated alternatives to reduce flooding from combined sewers at Trinity College in Hartford, Connecticut by simulating storm events using the Bentley SewerGEMS software. Aided in the development of a comprehensive report by detailing a capacity analysis of the existing system and a summary of recommended mitigation alternatives. ***(Individual Experience)***

Hemlocks Tracer Study, Aquarion Water Company of Connecticut

Staff Engineer. Calculated baffling factor for the 8 MG storage tank at the Hemlocks Water Treatment Plant (WTP) using existing data from a 2017 tracer study for the purpose of determining CT compliance. Summarized results of the analysis within a memo and recommended retesting. Developed procedure for retesting, which described preferred test conditions (flow, water level, sampling interval), outlined step-by-step instructions, and provided a schematic of flow of the tracer through the system. ***(Individual Experience)***

Simsbury Centralized Treatment, Aquarion Water Company of Connecticut

Staff Engineer. Aided in the design of two centralized drinking water treatment facilities for Aquarion Water Company for the purpose of reducing the system's six separate points of chemical injection to two. Design included chemical feed systems for orthophosphate, hypochlorite, and fluoride; a Lowry aeration system for pH control; and below-grade steel water storage tanks. ***(Individual Experience)***

Bed Dawadi, PE

Civiltec Engineering, Inc.

Mr. Dawadi has 11+ years (6+ with Civiltec) of water and wastewater engineering experience. His responsibilities have included the planning, design and construction management of public works projects. He has prepared/processed injury and illness prevention programs (IIPPs) and stormwater pollution prevention plans (SWPPPs), developed odor control and sewer renovation, bypass and commissioning plans for sewer pump stations, and designed collection/solid handling facilities for water and wastewater treatment plants. Mr. Dawadi is an expert in hydraulic modeling and the design of treatment systems, pipelines, wells and mechanical systems. He also has extensive experience preparing specifications, cost estimating, project coordination and budget management.

Mr. Dawadi also brings experience as a Wastewater Treatment Plant Operator. His responsibilities included maintaining and operating a 2.0 million gallon per day municipal conventional activated sludge wastewater treatment plant. This included sample collection, responding to process alarms and laboratory testing of wastewater samples for biological oxygen demand, total suspended solids, ammonia and coliforms.

Similar Project Experience

Hollywood Casino Wastewater Treatment Plant, Confidential Client

Project Engineer. This project designed a new wastewater treatment facility located in San Diego County, roughly 20 miles east of downtown San Diego. The plant houses a membrane bioreactor to treat high strength wastewater to remove biochemical oxygen demand, while ensuring the recycled use water meets Title 22 requirements for total nitrogen concentrations. The treatment plant consists of state of the art technologies to treat the wastewater and reused the recycle water inside the casino facility.Wastewater discharged from the casino, restaurant and community center is collected in a 12-foot diameter influent lift station. The sewer is pumped into the fine screen before it is treated biologically into the bioreactors. The bioreactors are of concrete structure and are designed in such a way that anoxic and aerobic kinetics takes place in the same reactor. The biologically treated wastewater is feed into the membrane bioreactors and pumped out the permeate for further treatment using reverse osmosis. A sodium hypochlorite system was also installed as a redundant disinfection system. Hydrogen sulfide the source of foul odor is collected from influent lift station, screen and digester, and treated through granular activated carbon beds. The tertiary treatment system is equipped with automatic valves to bypass all or a single system.

Donald C. Tillman In-Plant Storage Design-Build Project

Project Engineer. This project designed two 7.3 million gallon open storage tanks, interconnecting 48-inch and 36-inch diameter pipelines from existing facilities to and from the storage tanks, a live connection to an existing 96-inch sanitary sewer pipeline, a 48-inch hot-tap connection to the primary effluent channel, control valves, control logic for valve and system operation, cast-in-place valve vaults, 48-inch meters and associated structure, groundwater monitoring system, basin pressure relief system, landscaping improvements, basin wash down system, high-voltage power feed design, medium voltage and instrumentation design and primary sludge conveyance mechanical improvements.

Professional Registration

Professional Engineer, California No. 79112

Education

M.Sc., Civil and Environmental Engineering, South Dakota State University, 2007

B.Sc., Civil Engineering, 2002

Bed Dawadi, PE

Civiltec Engineering, Inc.

Regional Water Recycling Plant No. 1 Flare System Improvements, Inland Empire Utilities Agency
Project Engineer. Responsible for the design of a new automatic digester gas direct feed valve along with associated controls, evaluation of the existing digester gas collection system and paving in the existing flare system area at the RP-1 treatment plant under a design-build delivery method. These system improvements minimize release of digester gas to the atmosphere when gas production exceeds the capacity of the existing fuel cell and boiler systems.

Victoria No. 1 Lift Station Rehabilitation, City of Laguna Beach
Project Engineer. The lift station is constructed in a concrete wet well and accessible through a steel frame access hatch. Raw sewage is pumped from the lift station to the manhole located just north of the stairway access in Victoria Drive. Sewage is then conveyed via gravity to the Victoria Lift Station No. 2. The lift station includes two identical pumps with one utilized for normal operations and one on standby and all necessary electrical and appurtenances. The lift station capacity was sized according to the maximum daily flow of 19 gallons per minute and the existing conditions in the field.

Santa Clarita Water Division, Contract Principal Engineer
Project Engineer. Responsible for more than 10 projects under this contact. Projects included engineering reviews, geographic information system support, potable water pipeline, pump station, well (siting and design), tank (siting and design) and reservoir designs as well as water master planning and hydraulic modeling and analysis. Construction management and traffic control plans were also provided on projects as needed.

Technical Evaluation and Rate Study, County of Madera, Resource Management Agency
Project Engineer. Completed a technical evaluation and rate study for Madera Rancho. This included preparing an engineering report by evaluating the distribution system, well sites and components. The project also involved preparing capital improvement plans and proposing a new rate structure after system improvements were completed. Technical reports were prepared for the Safe Drinking Water State Revolving Fund and applications for five maintenance districts. These districts were invited to apply for the funding. Some of these districts had higher arsenic and uranium concentration than currently regulated. The water remediation technology treatment system was recommended as a feasible alternative for arsenic and uranium treatment.

College Avenue Pump Station Rehabilitation Project, Orange County Sanitation District
Project/Field Engineer. This project involved construction management services and a commissioning plan for an 8.0 million gallons per day sewer pump station. The lift station was rehabilitated to address the mechanical and operational deficiencies. Valuable solutions were developed to resolve the groundwater problem during construction of drywell.

Westside Pump Station Rehabilitation Project, Orange County Sanitation District
Project/Field Engineer. Provided construction management services, including preparing and processing submittals, writing and processing requests for information, ordering of materials, processing invoices, scheduling subcontractors, weekly construction meeting participation, and preparing a commissioning plan for rehabilitation of the facility with a pumping capacity of 12 million gallons per day. A sewer bypass and odor control plan was prepared and implemented to rehabilitate the existing pump station. The construction cost of the project was $6.1 million.

Stephen "Sky" Younger

Civiltec Engineering, Inc.

Mr. Younger has 40+ years (recently joined Civiltec) of electrical engineering experience. He specializes in solar, water/wastewater treatment systems and semiconductor fabrication plants. His knowledge includes electrical and control system design for hospitals, high tech laboratories, power plants, schools, museums, and theaters in addition to large scale semiconductor fabrications and solar power plants.

Mr. Younger also has extensive executive experience as a manager, vice president and president of electrical consulting services. Additionally, he possesses the understanding and knowledge of negotiating and executing large master service agreements with outside engineering firms and approving work orders up to one million dollars. Mr. Younger's widespread knowledge and ability to take on large projects makes him an excellent asset to the team.

Similar Project Experience

Water System SCADA, City of Lake Havasu City
Electrical Engineer. Designed a new wireless communication SCADA system for all pump stations. ***(Individual Experience)***

City of Phoenix
Electrical Engineer. Designed a large new submersible lift station and control system. ***(Individual Experience)***

City of Peoria
Electrical Engineer. Designed several lift stations. ***(Individual Experience)***

City of Mesa
Electrical Engineer. Designed several lift stations. ***(Individual Experience)***

Palo Verde Wastewater Treatment Plant
Electrical Engineer. Provided a new fiber optic communication system to existing sewage treatment plant for employees working at the plant site. ***(Individual Experience)***

91st Avenue Wastewater Treatment Plant, City of Phoenix
Electrical Engineer. Redesigned a motor control system for this plant. ***(Individual Experience)***

Richmond Wastewater Treatment Facility, State of California
Electrical Engineer of Record. Designed a complete rebuild of the electrical distribution system for the 16 million gallons per day facility. ***(Individual Experience)***

SolarCity, Inc. (various)
Electrical Engineer of Record. Reviewed and approved 187 commercial solar power plant designs totaling over 169MW of new solar power generation in California, Arizona, and New York. ***(Individual Experience)***

Professional Registration
Professional Engineer (Electrical),
Arizona No. 17036
California No. E16176
New York No.077580-1
Oregon No. 62972PE
Nevada No. 19744
NCEES Registered

Education
B.S., Electrical Engineering, University of Nebraska, Lincoln, 1978

Professional Affiliations
Developmental Enrichment Centers, Inc.;
Chairman of the Board

Solidarity LLC: Owner

Arizona State Board of Technical Registration, Technical Enforcement Committee

Young Life Capernaum, Club Leader

ACE Mentoring; Past Mentor

Stephen "Sky" Younger

Civiltec Engineering, Inc.

American Electric Power Total Energy Power Plant, Guyama, Puerto Rico
Electrical Construction Manager. Responsible to oversee all electrical construction on new 454 MW power plant on south side of island. This was the cleanest coal-burning power plant in the Western Hemisphere. ***(Individual Experience)***

Sky Harbor Photovoltaic Concentrator, Tempe, Arizona
Electrical Engineer of Record. Designed the largest utility-connected solar power plant in the USA in 1984. ***(Individual Experience)***

Solar Test and Research (STAR) Center, Tempe, Arizona
Electrical Engineer of Record. Designed the leading solar energy research facility in the USA in 1985. ***(Individual Experience)***

Newberry Springs Solar Farm, Barstow, California
Electrical Engineer of Record. Designed large scale 1.68MW concentrator solar project in Mohave Desert. ***(Individual Experience)***

Barrick Cortez Mine Booster Pump Station, Battle Mountain, Nevada
Electrical Engineer of Record. Designed a new water pumping system for large gold mining operation. ***(Individual Experience)***

Four Corners Water Treatment Plant, Arizona Public Service Company
Electrical Engineer. Designed the power distribution for a water treatment plant for the Four Corners Power Plant located near Farmington, New Mexico. ***(Individual Experience)***

Keyes Community Water Treatment Facility, State of California
Electrical Engineer. Electrical engineer on record for the arsenic mitigation at the water facility. ***(Individual Experience)***

Palo Verde Water Reclamation Facility, Arizona Public Service Company
Electrical Engineer. Provided technical support as well as small instrumentation projects for the 90 million gallons per day plant cleaning effluent water from the 91st Avenue Wastewater Treatment Plant for use in the nation's largest nuclear power plant. Was also called out on an emergency basis to troubleshoot the PLC control system associated with the emergency gas turbine generator. ***(Individual Experience)***

Arrowhead Ranch Water Reclamation Facility, City of Glendale
Electrical Engineer. Redesigned the complete electrical distribution system for the 3 million gallons per day facility. ***(Individual Experience)***

Rio Verde Water Reclamation Facility, Rio Verde Utilities
Electrical Engineer. Redistributed and documented electrical power system for this facility. ***(Individual Experience)***

Wild Horse Pass Water Reclamation Facility, City of Chandler
Electrical Engineer. Designed new influent grinder system. ***(Individual Experience)***

Bryan Hellein, Observer

Civiltec Engineering, Inc.

Mr. Hellein has 40+ years (6+ with Civiltec) of construction observation experience on a variety of different projects. His primary responsibilities include observation of pipeline, well and pump stations, and reservoirs. He recently inspected the construction of the $16 million Station Square village, which included a new Metro station and major improvements in the vicinity.

Similar Project Experience

Munz-Mendenall Probation Camp Wastewater Treatment Rehabilitation, Los Angeles County

Construction Observer. Under a design-build delivery method, responsible for the installation of a new membrane bioreactor facility, new headworks screening unit, modified aeration basins to process the aerobic and anoxic phases of treatment, a new blower facility, a new control building and laboratory facility, return activated sludge/waste activated sludge pumping, flow equalization pumping and effluent pumping systems.

San Antonio Spreading Grounds, Berm Repair and Reconstruction, Pomona Valley Protective Association

Construction Observer. Responsible for the design of repairs and reconstruction of the San Antonio Spreading Grounds berms and basins to comply with the Federal Emergency Management Agency (FEMA) grant application. This project consisted of reconstructing the damaged basin elements and providing additional armoring and hydraulic relief to the basin berms. The basin berms were reconstructed and recompacted with native material supplemented with crushed aggregate base material as needed. The upstream faces of the berms were armored with a shotcrete material surfacing that extended below the ground surface to prevent hydraulic piping and berm face surface erosion. The basins were designed for a flow rate of 40 cubic feet per second.

Well No. 3 and 2A VOC Treatment, City of El Monte

Construction Observer. Project constructed a granular activated carbon system and a nitrate blending system at production Well No. 2A and production Well No. 3.

Operable Unit Construction Support, City of El Monte

Construction Observer. Responsible for inspection and observation during construction for installation of granular activated carbon treatment, site improvements, chlorine disinfection, buildings, 30,000 linear feet of transmission pipelines, three production wells, electrical, controls, and integration.

Water System Supervisor, City of El Monte

Planned, organized, and supervised the construction, maintenance and repair of El Monte's water production and distribution system including 36 miles of distributions mains ranging from 4-inch to 12-inches, 4,500 domestic water services, 208 fire hydrants, 185 fire services, 712 inline gate valves, 6 productions wells, 3 treatment systems (GAC), a 1.0 MG reservoir, a 250,000-gallon elevated tank, and 3 emergency interconnects. Work included coordination with the State of California Department of Public Health (Hollywood District), Governor's Office of Emergency Services, State of California Resources Water Control Board, South Coast Air Quality Management District, and San Gabriel Basin Water Master.

CIVILTEC engineering inc.

Training/Certifications

Foundation for Cross-Connection Control and Hydraulic Research

Backflow Prevention Tester Foundation for Cross-Connection Control and Hydraulic Research Specialists in cross connection

40 hours First responder Hazwoper

8 hour "Hazwoper" Refresher Course

CTAC 40 hours Hazardous Waste Workers Operation Level-1

Confined Space Hazards and Respirators

Confined Space Entry and Rescue

Traffic Control and Flagging Safety

Lock Out/Tag Out" Refresher Trenching and Shoring Safety

Personal Protection Equipment and Hearing Safety

OSHA Compliance and Workplace Safety

Megan Brown, PE
V&A Consulting

Megan is licensed as a civil engineer with more than 15 years of experience working in water system planning, hydraulic modeling, condition assessment and design of water and wastewater facilities. She has completed projects throughout Southern California including planning, design, and construction management of pipelines, pump stations, storage reservoirs and water treatment plants.

Similar Project Experience

San Diego County Water Authority Carlsbad Conveyance System Design Review. Carlsbad, CA
Serving as the project manager/project engineer for the independent design review and construction inspection services for the Carlsbad Desalination Plant Conveyance System. Project consists of 52,000-feet of high-pressure welded steel pipe, including suspension from a major bridge, 72-inch tunnel section, multiple jack and bore crossings, flow control facilities, air release and blow-off appurtenances, and cathodic protection system. Project includes a review of pipeline structural design and drawings, compliance review with California Department of Public Health guidelines, operation and maintenance concerns, review of surge analysis, geotechnical studies, and design build documents to ensure compliance with the client's design standards and industry standard practice.

Rincon del Diablo Municipal Water District
R1 Reservoir Recycled Water Conversion Project. Escondido, CA
Served as the project manager/project engineer for the design of the R1 Reservoir Recycled Water Conversion Project. The project consisted of the preliminary and final design of infrastructure improvements including approximately 6,000 linear feet of 16-inch diameter DIP, flow control facility, cathodic protection, and reservoir modifications.

Coachella Valley Water District Highway 86 Transmission Main. Coachella, CA
Served as the project manager for the design and construction of a 10-mile, 30-inch diameter transmission main along Caltrans State Highway 86. Project success required coordination with Caltrans, Department of Fish and Game, State Water Quality Control Board, Bureau of Indian Affairs, Torres Martinez Desert Cahuilla Indians, County of Riverside, California Department of Public Health, Imperial Irrigation District, Coachella Valley Unified School District, and several local cities. Design elements included materials evaluation, corrosion protection measures, multiple jack and bore crossings, flow control facilities, air release and blow-off appurtenances.

City of Garden Grove Water Improvement Project No. FF024 and Sewer Improvement Project Nos. 96 & 99. Garden Grove, CA
Served as the project manager/project engineer for preparation of design drawings and construction documents to replace approximately 7,200 feet of 8-inch PVC pipe with 16-inch PVC pipe to improve fire flow within an area

Professional Registration
Civil Engineer, CA (C74708)

Education
B.S., Mechanical Engineering, University of California, San Diego, 2003

of the City. Project also includes the replacement of approximately 1,000 feet of 8-inch VCP with 10-inch and 12-inch VCP. Design services included utility coordination, preparation of plan and profile drawings, design of multiple connections into the City's existing system, replacement of service lines, and installation of fire hydrants in accordance with the City's water standards.

City of Garden Grove Water Improvement Project Nos. FF011 and FF084. Garden Grove, CA
Served as the project manager/project engineer for preparation of design drawings and construction documents to replace approximately 5,000 feet of 6-inch asbestos concrete pipe with 12-inch PVC pipe to improve fire flow within an area of the City. Design services included utility coordination, preparation of plan and profile drawings, design of multiple connections into the City's existing system, replacement of service lines, and installation of fire hydrants in accordance with the City's water standards.

City of Poway Berglund Water Treatment Plant Facilities Assessment. Poway, CA
Serving as the project manager, this project involved a condition assessment of all treatment plant facilities, documentation of plant structural, mechanical, and electrical deficiencies, development of prioritized improvement project list and summary report. The project also includes an evaluation of potential upcoming water quality regulations and impact analysis on existing treatment operations.

Coachella Valley Water District Highway 86 Pump Station. Coachella, CA
Served as the project manager. Project completed in a step-wise fashion in an effort to select the most cost-effective pump station site and pumping configuration. Key project elements included identification and evaluation of potential pump station sites, utility coordination, demand projections phased through 2035, hydraulic analysis, and pump/motor alternatives evaluation.

City of Oceanside Robert A. Weese Filtration Plant Major Improvements Project. Oceanside, CA
Serving as the project manager/project engineer, the project consisted of prioritized key facilities improvements for the plant including electrical equipment upgrades, chemical storage and pumping improvements, and new solids handling lagoons. The improvements will provide long-term flexibility in operations, as well as alleviate water quality concerns associated with recycling plant process water. Project includes the development of individual design reports for each phase of improvements and detailed design.

City of San Diego Storm Water Recovery Feasibility Study. San Diego, CA
Served as the project manager for this feasibility project as part of the Pure Water San Diego initiative. This project included evaluating the potential for capture and recovery of storm water as an additional source of water supply for the Pure Water San Diego Phase II project. Storm water would be diverted to the City's existing wastewater collection system where capacity is available, treated with sewer flows and then sent to a future advanced water purification facility. Alternatives analysis included the conceptual plans for storm water capture system including storage, pumping, pipelines, and interconnection facilities.

City of San Diego Advanced Water Purification Facility Design. San Diego, CA
Served as the project engineer for various tasks on the design of the advanced water purification facility for the Pure Water San Diego project. Lead author for cost savings and cost estimate technical memorandums submitted to the City for budget and funding allocations. Provided internal design review for 30-, 60-, and 90-percent design submittals.

Padre Dam Municipal Water District As-Needed Civil Engineering Services Contract. San Diego, CA
Served as project manager for the As-Needed Civil Engineering Services contract with various project tasks including planning studies, hydraulic modeling, and infrastructure improvement design.

Vahé Petrossian

ANB Consulting Engineers

Mr. Petrossian has over 26 years experience in structural engineering. His experience includes design and analysis of Concrete Reservoirs, elevated tanks, pump stations, storm drain structures, municipal buildings, highway and local pedestrian bridges, retaining structures, and other infrastructure facilities.

Mr. Petrossian has extensive experience in State-of-Art Structural analysis. He is active in several Code writing committees that oversee several subcommittees that develop Codes and guidelines for Earthquake Resistant Designs.

Mr. Petrossian has designed numerous reservoirs utilizing the latest computer aided design technology, coupled with the latest industry standards and AWWA design criteria. He is experienced in the design of post tensioned and wire wrapped concrete reservoirs, as well as steel tanks. His experience also includes design and restoration of water and Sewer lines and other facilities.

Similar Project Experience

Design of two 2.6 million gallon reservoirs; one for reclaimed and one for domestic water at Signal Peak for Irvine Ranch Water District. These two tanks were completely buried.

Design of 3.7 million gallon reservoir No. 2A for the City of Pomona. The design included two options of wire wrapped concrete reservoir and welded steel tank.

Structural design of a 5.2 million gallon Shopping Center II Tank constructed in the City of Thousand Oaks for California American Water Company. This concrete reservoir consists of post-tensioned floor, wire wound walls, and conventional concrete roof and is partially buried.

Concrete reservoir 6.0 MG for California American Water Company Potrero II. The 37-feet high walls in this reservoir are tensioned with grouted thread bars, vertically, and wire wound and shot created, horizontally.

Concrete reservoir 5.0 MG for Rowland Water District Reservoir No. 11. This reservoir is partially buried and, due to the unusual site, geology, and proximity of active faults, a special seismic design has been performed.

Concrete reservoir 5.2 million gallon Shopping Center II Tank constructed in the City of Thousand Oaks for California American Water Company. This concrete reservoir consists of post-tensioned floor, wire wound walls, and conventional concrete roof and is partially buried.

1.0 MG reservoir in San Simeon for the State of California located near Hearst Castle. This circular reservoir is completely buried. The walls have been tensioned with seven wire, conventional strands anchored at the pilasters. The roof consists of a two-way slab and is thoroughly waterproofed to carry three feet of overburden.

Professional Registration

Registered Civil Engineer, California/C42780

Registered Structural Engineer, California/S3421

Education

B.S. Civil Engineering, 1977

M.S. Structural Engineering, 1979

ANB

Vahé Petrossian
ANB Consulting Engineers

Rehabilitation of Lower Busch Tank, LA County Waterworks District 29; Seismic Retrofit of this partially buried concrete reservoir built in 1920's. The concrete reservoir was circular and reinforced with vertical and horizontal mild reinforcing steel and covered with conventional wood framed roof.

Burbank Reservoir No. 4 constructed in the 1950's. Involved in the testing, rebar detection, evaluation, and analysis of the two-way roof slab to carry the proposed playground over three feet of fill.

Pump Stations

City of Pasadena Pump Stations; Design of Monk Hill Chlorine and Ammonia Treatment Facility Building. The design included Span-crete Roof over many Chambers and Interior Cranes.

City of Pasadena Pump Stations; Design of Monk Hill Ventura Well Pump Building. The design included Concrete Slab Roof Supporting 3 heavy Suction Pumps.

City of Pasadena Steel Vessels; Design of Monk Hill Exterior Treatment Pad housing a multitude of Steel Vessels of various sizes.

City of Cerritos Pump Stations; Design of C-2 Well Pump Station Building. The design included Span-crete Roof and Interior Cranes.

City of La Palma Pump Stations; Design of Additions to Walker Well Pump Station and City Yard Chlorination Buildings. The Design Included Emergency Showers, Disabled Bathrooms, and Anti Terror Security Devices. The Exteriors were architecturally designed with Sheet Metal Mansards to hide the Rooftop equipment and blend in with the surrounding residential area.

Design of three different pump house buildings for the City of Beverly Hills. Special consideration was given to the aesthetics as well as enclosure of silencer units.

Design of four pump stations at different phases for Rowland Water District.

Design of two pump house and control buildings at Bristol Reservoir for the City of Santa Ana.

Spanish Hills Pump Station, City of Camarillo, California. Complete design and preparation of construction documents for a 4,000 gpm emergency pump station building, valve boxes, and monitoring vaults.

Metropolitan Water District; Riverside Reservoir; Provided Engineering Services for the relocation and upgrade of the the MWD Visitor Center in Hemet, California. The two story building was part of the properties acquired by MWD for the construction of the East Side Reservoir Project and was spared from demolition and selected to be relocated to the new site. The project included complete earthquake retrofit of the building, gravity load system, and new foundations supports as well as other upgrades for disabled access and bathrooms.

CHRISTOPHER C. BONE, P.E. | *Vice President*

Chris Bone serves as principal and project manager on a variety of water and wastewater projects as well as Technical Director of our Water Business Line. His experience at Tighe & Bond includes all aspects of project implementation, including planning, permitting, design, cost estimating, and construction phase services. While he has overseen a number of new treatment plants, Chris specializes in challenging upgrades to existing facilities, and finding innovative and cost effective solutions that meet our client's goals while maintaining facility operations. Chris serves as Tighe & Bond's biosolids technical specialist, and leads all of the our ongoing thermal drying projects.

YEARS OF EXPERIENCE

22

SPECIALTIES

Biosolids Drying

Wastewater

Water

Treatment Facility Upgrades

Nitrogen & Phosphorus Removal

Chemical Feed System Improvements

LICENSES/REGISTRATIONS

Professional Engineer - MA (#45674)

Professional Engineer - CT (#25850)

Professional Engineer – FL (#79925)

EDUCATION

Bachelor of Science
Mechanical Engineering
University of Notre Dame

Master of Science
Environmental Engineering
University of Wisconsin at Madison

PROFESSIONAL AFFILIATIONS

American Water Works Association

New England Water Works Association

Water Environment Federation

Professional Experience

- **Detroit, MI Sludge Dryer Facility:** Served as project manager on a design-build team for a $130M sludge dryer facility for the City of Detroit, MI, which will be the largest facility in North America of its kind. The project included centrifuge dewatering, a dry polymer feed system, four gas-fired dryer drums, screeners, crushers, pellet coolers, product storage silos, extensive conveying systems, tray scrubbers, regenerative thermal oxidizers, and chemical scrubbers for odor control. A 270-ft x 175-ft structural steel building with architectural precast concrete walls houses the process equipment, offices, chemical storage rooms, and maintenance and storage areas.

- **Massachusetts Water Resources Authority (MWRA) Biosolids Processing Facility Capital Projects:** Served as principal-in-charge for three capital upgrade projects at the MWRA Biosolids Processing Facility in Quincy, MA, which serves the Boston-metro region. This project was initiated by our client, New England Fertilizer Company (NEFCO), as part of a 5-year operating contract extension with MWRA. The capital upgrade contracts included painting of storage silos and sludge holding tanks, electrical improvements (including MCC replacement, VFD replacements, and various controls upgrades), and mechanical upgrades (including conveyor replacements, gas train improvements, dryer drum replacements, and new dust collectors).

- **West Palm Beach, FL Biosolids Processing Facility:** Served as project manager for two separate upgrade projects for NEFCO's biosolids processing facility in West Palm Beach, FL. The first project involved the design of new screw conveyors. The conveyors included in a metering section to recycle dried biosolids pellets to the drying process. The conveyors were also used to pre-mix dewatered sludge cake with the pellets, which is a sticky, abrasive and high energy process. To improve reliability by eliminating troublesome hanger bearings in the mixing stage, three shorter conveying sections were used to replace one longer conveyor in each drying train. The second project involved replacement of screeners and installation of a new dust collector for the product silos. This project also included minor enhancements to the recycle bins to improve product flow.

- **North Attleborough Wastewater Treatment Facility Upgrade:** Served as project manager for a $22M nitrogen and phosphorus removal upgrade to this WWTF in North Attleborough, MA. Project included construction of a new 5-stage Bardenpho aeration system consisting of baffled aeration tanks with fine bubble aeration, high-speed turbo blowers, and submersible mixers. Phosphorus removal to a 0.1 mg/L permit limit was accomplished with a new coagulation system, and a cloth media filtration system.

- **Southington, CT Phosphorus Upgrade Project:** Served as project manager on the design of a $57M upgrade of the Southington, CT's Water Pollution Control Plant. The project primarily involves design of a new Co-Mag ballasted flocculation system to remove phosphorus. Tighe & Bond assisted the Town in achieving favorable financing on the project, including partial grant funding, so the Town is taking advantage of this financing to perform extensive capital upgrades at the treatment plant. Designed a low level phosphorus removal system for this 1.3 mgd facility in Sturbridge, MA to achieve effluent total phosphorus of 0.05 mg/L.

- **Chicopee Wastewater Improvements:** Served as project manager on various projects for the Chicopee, MA wastewater treatment plant and pumping stations. These projects include a bypass disinfection project, sodium hypochlorite conversion project, a headworks improvements project, an odor control project, several projects upgrading sludge handling systems, and pumping station improvements. Each project has included evaluations, design of recommended improvements, and construction administration. The bypass disinfection project included design of a pumping station, chlorine contact chamber, and chemical feed systems. The headworks improvement project involved construction of a new headworks structure and installation of a mechanically cleaned screen. Sludge handling system projects have included installation of dewatering centrifuge and sludge cake pumping systems.

- **Jones Ferry CSO Treatment Facility:** Managed the evaluation, design, and construction of the award-winning 41 MGD Jones Ferry CSO Treatment Facility in Chicopee, MA. This facility treats overflows from the City's largest CSO up to 3-month storm events. The design consists of a new CSO diversion structure, automatically cleaned screens, submersible pump station, Parshall flume, chlorine contact chamber, and a GAC odor control system. Sodium hypochlorite and sodium bisulfite facilities are provided for chlorination and dechlorination, respectively.

- **Various Wastewater Treatment Facility Upgrades:** Served as project manager for upgrade projects at a number of other wastewater treatment facilities, including South Hadley, MA; Adams, MA; Hull, MA; and Winchendon, MA. The South Hadley project included improvements to primary treatment, secondary treatment, sludge handling, odor control, implementation of a SCADA system, and upgrades to two pumping stations. The Adams project included improvements to secondary treatment, disinfection, phosphorus removal, and solids handling. In Hull, mechanical improvements were performed on all unit processes from the headworks to the disinfection system. Design responsibilities on the Winchendon project included a fine bubble diffused aeration system, process modifications to existing aeration basins to achieve nitrification/denitrification, gravity thickening, chemical feed systems, and odor control.

- **Cumberland, MD Sludge Dryer Facility:** Served as project manager on a design-build team for this facility in Cumberland, MD. Project included centrifuge dewatering, gas-fired dryer drum, various screw and belt conveyors, regenerative thermal oxidizer, and a wet scrubber for odor control.

- **Ocean County, NJ Value Engineering:** Served on a value engineering team as the residuals handling specialist for a project expanding cake receiving facilities at the Ocean County, NJ drying facility. The project included extensive sludge cake pumping and conveying systems, and the value engineering team made a number of recommendations to simplify the process to improve reliability.

- **Sao Paulo, Brazil Sludge Management Study:** Served as process engineer on a long-range planning study evaluating sludge disposal options for multiple wastewater treatment facilities in Sao Paulo, Brazil. Options evaluated included dewatering, digestion, and thermal drying.

- **Sludge Conveying System Modifications:** Designed sludge conveying system modifications for the South Essex Sewerage District in Salem, MA. Included evaluating improvements to the sludge conveying system and designing the recommended modifications. The design included new and modified screw conveyors, sludge plows, weigh scales, and control system upgrades.

- **Westfield Wastewater Treatment Facility:** Managed nutrient removal studies at this Westfield, MA facility. The project included evaluation of phosphorous removal improvement alternatives, including bench-scale testing of aluminum sulfate, sodium aluminate, polyaluminum chloride, and ferric chloride to achieve phosphorus limits of 0.46 mg/l in the summer and 1.0 mg/L in the winter. Secondary process enhancements to improve biological phosphorous removal were also evaluated. The project also included a nitrogen optimization study and a nitrogen/phosphorus source study to determine collection system nutrient sources.

JEFFREY C. BARDELL
President / Principal-in-Charge

Mr. Bardell has over forty years experience directing large scale building and heavy / civil / utility construction work, and is the President of Daniel O'Connell's Sons.

Relevant Expertise

- Proven ability to ensure the delivery of successful project outcomes for public and private clients.
- Ability to provide personal insight and assess construction resource requirements during project design and planning phase.
- Extensive experience directing large scale building, civil and heavy construction work.
- Strong personal working relationships with trade contractors throughout New England.
- Ensures appropriate resources and management are provided for each project.

Relevant Project Experience

- **Charles River Wastewater Treatment Plant, Medway, MA:** This $17.4 million wastewater treatment plant upgrade involved a variety of challenging tasks including bypass pumping, deep excavations to tie in large diameter yard piping and control systems and mechanical processing equipment replacement without disturbing the daily operation of the plant.
- **Fall River Disinfection Facility, Fall River, MA:** This $8.5 million project includes construction of a 35 million gallon per day combined sewer overflow (CSO) screening an disinfection facility and site improvements at Bicentennial Park.
- **John Carroll Water Treatment, Marlborough, MA:** This $30 million project consisted of renovating the 25 MGD existing drinking water disinfection plant by installing new ultraviolet disinfection equipment, all new electrical equipment, instrumentation and controls equipment and HVAC equipment.
- **Bucklin Point WWTP, East Providence, RI:** This 46 MGD wastewater plant underwent a $35 million improvement that include the installation of a new plant wide power distribution system, six new final clarifiers, two new sludge thickeners, modifications to the exist aeration systems, two new high speed turbo blowers, new chemical feed systems, one new sludge pumping station, and construction of a new vehicle storage building. Major floo protection improvements were also installed around the site perimeter to improve drainage and protect the plant from the Seekonk River in the event of a flood
- **Deer Island Rehabilitation of the Primary and Secondary Clarifiers, Boston Harbor, MA:** This $59 million project included the rehabilitation of the 48 primary and 54 secondary rectangular tanks, respectively. Each clarifier consists of four bays (20'x 200')
- **Fields Point Wastewater Treatment Facility, Providence, RI:** This $56 million project consisted of new and upgrade work associated with biological nitrogen removals. Upgrades to this 77 MGD plant included the primary/secondary clarifiers; grit handling facilities gravity thickeners and aeration tanks. The renovated facility is the largest IFAS (Integrated Fixed-film Activated Sludge) biological waste water treatment facility in the world.
- **NEFCO Detroit Biosolids Drying Facility, Detroit, MI:** As Design/Builder, DOC assisted our sister company, NEFCO in the design, permitting, and construction of this $125 million facility consisting of a 47,500 sf building that included piles, various foundations, precast walls, office space, and process equipment. Major process equipment included centrifuges, dryer system, RTO, silos, and odor control system.
- **Cumberland Biosolids Heat Drying Facility, Cumberland, MD:** As Design/Builder, DOC assisted our sister company, NEFCO in the design, permitting, construction and operation of this new $10 million heat drying facility. With a design capacity of 11 dry tons per day, the facility received digested sludge from an adjacent complex and converted it into fertilizer.

JEFFREY C. BARDELL

President / Principal-in-Charge

- **MDC Aeration & Final Settling Tanks, Hartford, CT:** This $35 million project involved building and fitting out two new aeration tanks and two new final settling tanks for the secondary waste water treatment process at the plant.
- **Upper Blackstone Wastewater Treatment Facility, Millbury, MA:** This $24 million renovation and upgrade of the 45 Million Gallon/Day (MGD) Waste Water Treatment Facility. This Phase III project included upgrades of the dissolved air flotation units for waste activated sludge thickening; new belt filter press sludge dewatering units; new sludge pumping and storage improvements; new ash handling system for the multiple hearth furnaces, and odor control for sludge handling. This project was delivered via Chp. 149-A program.

Education and Memberships

- **University of Pittsburgh:** Bachelor of Science, Civil Engineering
- OSHA 30 Hour Training

References

- Stantec: BK Boley, AIA LEED AP, Principal, 617-234-3212
- Odeh Engineers: David Odeh, P.E., Principal, 401-724-1771
- Worcester Polytechnic Institute: Jeff Solomon, Executive Vice President of Finance and Operations, 508-831-5288

SARAH STINE

Assistant Project Manager

Sarah Stine joined Daniel O'Connell's Sons in 2012 and has worked as an office engineer, a field engineer, assistant project manager and project manager. In addition to having a wide array of field experience, she is well versed in using sophisticated electronic project management tools.

Relevant Expertise

- Adept at coordinating and leading the entire project team, and generating accurate project reports and exercising project controls.
- Proficient in the use of electronic project management methods, and in budgeting, cost accounting and scheduling.
- Ability to develop collaborative relationships with clients, architects, and trade contractors.
- Extensive experience developing bid packages, garnering interest in projects and facilitating effective buy-out processes.
- Experience working with a multitude of equipment vendors and materials suppliers from initial fabrication through final installation to ensure successful coordination of equipment delivery and construction progress.

Relevant Project Experience

- **Nefco Detroit Biosolids Drying Facility:** This $125 million facility consisted of the construction of the 47,500 SF building that included piles, various foundations, precast walls, office space, and process equipment. Major process equipment included centrifuges, dryer system, RTO, silos, and odor control system.
- **Mansfield WWTP Upgrades, Norton, MA:** This $29 million project consists of improvements to the existing 3.14 mgd wastewater treatment plant (WWTP) to expand to average day flow of 4.14 mgd including construction of a new primary clariflocculator, new primary sludge pump station, new anoxic tanks, new secondary clarifer and new chlorine contact tank. Also included are replacement of the existing influent pumps, modifications to the existing primary sludge pump station, existing aeration tanks, existing activated sludge pump, station, and existing effluent filters, replacement of the plant water system and all chemical feed systems, removal of the sludge, processing equipment, and other process building improvements including new laboratory and administrative facilities, drainage and site improvements, and all other work necessary to complete the work under this Contract including demolition, site work, yard piping, plumbing, fire protection, HVAC, electrical and instrumentation and controls.
- **Union Station Intermodal Transportation Center, Springfield, MA:** This $69 million will convert a vacant rail terminal into a modern transportation facility with a restored 120,250 sf main terminal area, a 24-bay bus terminal area with 480 structured parking spaces above, on what is now the baggage building site. Office space will be provided for public transit agencies with a daycare center to serve the downtown area. The ADA-accessible facility will also include space for the phased private development of transit-related space and future office uses. This project is being delivered via Chp. 149-A program.
- **Amherst College: Greenway Dorms:** This $56 million project consists of the construction of a new 112,000 GSF student residential complex consisting of four interconnected buildings providing 302 beds, 2 faculty apartments, seminar rooms, an event space and an interactive landscape.

Education and Memberships

- **Rensselaer Polytechnic Institute:** Bachelor of Science Civil Engineering
- Engineer in Training
- OSHA 40 Hour Training

References

- **Detroit Water and Sewerage Department:** Daniel Schechter, P.E., Superintendent of Engineering – Wastewater, 313-297-6408
- **Wade Trim Engineering Consultants:** Stephen D'Alecy, PE, Resident Engineer, 734-947-9700
- **Tighe & Bond**: Christopher Bone, P.E., Senior Project Manager, 413-572-3266

GEORGE VOLPICELLI
Chief Estimator, Heavy/Civil Division

Mr. Volpicelli has more than 20 years experience estimating large civil and heavy construction work, including water and wastewater treatment plants, bridges, utilities, and general site projects. He has prepared bids from take-off to closing for scores of heavy civil projects. His experience also includes post-bid project setup.

Relevant Expertise
- Project management on numerous projects.
- Much of Mr. Volpicelli's work has focused on estimates for municipalities and heavy/civil construction clients.
- Thoroughly versed in all factors which may affect construction costs in New England.
- Ability to obtain input from qualified trade contractors, and to help plan the most cost-effective bid packages and procurement strategies.

Relevant Project Experience
Mr. Volpicelli has served as project estimator and/or project manager for the following projects:
- **NEFCO - Detroit Biosolids Drying Facility, Detroit, MI**: $125 million facility consisting of the construction of a 47,500 SF building.
- **Upper Blackstone Wastewater Treatment Facility, Millbury, MA:** A $23 million renovation and upgrade of the 45 Million Gallon/Day (MGD) Waste Water Treatment Facility.
- **Fields Point Wastewater Treatment Facility, Providence, RI:** New and upgrade work associated with biological nitrogen removals.
- **Deer Island Primary & Secondary Clarifier Rehabilitation: Deer Island, Boston Harbor, MA:** Rehabilitation of the Primary & Secondary Clarifiers at the 1,200 mgd Deer Island Treatment Plant.
- **Cumberland Biosolids Heat Drying Facility, Cumberland, MD:** Plant to manufacture fertilizer from biosolids.
- **Lyman Street Bridge, Holyoke, MA**
- **Sludge Drying Facility, City of Cumberland, MD**
- **Upper Blackstone Phase III Upgrades, Worcester, MA**
- **Silver Lake Water Treatment Plant Upgrades, Halifax, MA**
- **East Boston Sewer Relief Project for the Massachusetts Water Resources Authority**
- **Sakconnet River Bridge Foundation Load Tests, Portsmouth, RI**
- **Sakconnet River Bridge Structural Repairs, Portsmouth, RI**
- **Dorchester CSO Tunnel, Boston, MA**
- **Copley Tunnel Ceiling Inspection, Boston, MA**
- **MBTA Traction Power Substation, Boston, MA**
- **Deer Island Waste Water Treatment Plant Primary Clarifiers A&B, Boston, MA**
- **Disinfection Basins/Sea Wall, Boston, MA**
- **CA/T Vent Building #3, Boston, MA:** $107 million project.
- **CA/T Vent Building #6, South Boston, MA:** $23 million project.

Education and Memberships
- **University of Massachusetts, Amherst:** Bachelor of Science, Civil Engineering

References
- **Upper Blackstone Waste Water Treatment Plant:** Karla Sangrey, 508-755-1286 Ext. 19
- **Rhode Island Department of Transportation:** Larry Bailey, Resident Engineer, 401-265-5294
- **The Maher Corporation:** Fred Kibble, President, 781-421-2600

MATTHEW C. STINE

Assistant Superintendent

ESTABLISHED 1879

Matthew Stine joined Daniel O'Connell's Sons as an intern and upon graduating from Rensselaer Polytechnic Institute in 2011 he joined our DOC full time. He has extensive experience coordinating all field phases of work and is exceptionally skilled at controlling, coordinating, and scheduling a productive work force.

Relevant Expertise

- Experience in estimating, procurement, quality control and compliance inspection.
- Adept at calculating material and labor takeoff quantities, analyzing subcontractor bids, maintaining field document controls and performing field inspections.
- Possesses effective institutional communication skills.
- Experience working with the following software:
  AutoCAD, NX-5, Rhino 3D, RISA and Primavera
- Ability to communicate and work collaboratively with the project team.

Relevant Project Experience

- **Nefco Detroit Biosolids Drying Facility:** This $125 million facility consisted of the construction of the 47,500 SF building that included piles, various foundations, precast walls, office space, and process equipment. Major process equipment included centrifuges, dryer system, RTO, silos, and odor control system.
- **Upper Blackstone Wastewater Treatment Facility, Millbury, MA:** This $23 million renovation and upgrade of the 45 Million Gallon/Day (MGD) Waste Water Treatment Facility. This Phase III project included upgrades of the dissolved air flotation units for waste activated sludge thickening; new belt filter press sludge dewatering units; new sludge pumping and storage improvements; new ash handling system for the multiple hearth furnaces, and odor control for sludge handling. This project was delivered via Chp. 149-A program.
- **Worcester Polytechnic Institute, Gateway Park Undergraduate Residence, Worcester, MA:** This design/build $35m LEED registered residence hall will have 250 beds arranged in suites consisting of 4 beds per suite. Each suite contains a full kitchen to allow meal preparation.
- **Indian Orchard Pump Station, Springfield, MA:** A $16.6 million upgrade of Springfield's central waste water pumping station. Maintaining operating capacity of this 35 million gallon per day (MGD) plant during construction presented significant technical and logistical challenges.
- **Palmer Dam / Dean's Mill Water Treatment Plant, Stonington, CT:** The work on this $10 million project included demolition of an existing dam, distribution building, chemical building and portions of the tailrace and spillway. New work involved dam reconstruction, spill containment area, water mains and crest gates and sedimentation basin modifications. A temporary water intake system to re-route water supplied to the existing and new chemical building. Steel sheet cofferdams were constructed, including an Engineering Action Plan to control storm water runoff volume.
- **Lyman Street Bridge Over Second Level Canal, Holyoke, MA:** This $5 million project consisted of phased demolition and removal of an existing bridge and phased construction of a new bridge.

Education and Memberships

- **Rensselaer Polytechnic Institute:** Bachelors Degree in Civil Engineering
- Engineer in Training (EIT) Certification
- OSHA 30 & 10 Hour Training

References

- **CDM-Smith:** John Regan, Field Engineer, 617-201-5259
- **Upper Blackstone Water Pollution Abatement District:** Randy Komssi, Engineer, 508-857-9535
- **State Electric Company:** Bob Foster, Foreman, 781-760-1326

MICHAEL D. ROBERTSON
Superintendent

Mike Robertson joined our company in 2004 and currently serves as Superintendent. He is a very knowledgeable construction professional and is experienced in coordinating and supervising all phases of field work.

Relevant Expertise

- Proven performance in successfully carrying out renovation and new construction.
- Ability to develop effective rapport with clients and other members of the project communities
- Ability to communicate and work collaboratively with the project team.
- Effective leadership in coordinating construction activities

Relevant Project Experience

- **Massport: Logan International Airport Taxiway C, East Boston, MA**: The project is the rehabilitation of major sections of taxiway C along with construction of a new stub taxiway between runway 15R-33L and the existing taxiway C. Work was completed during short term closures of the active runways and taxiways adjacent to the project.
- **Massport: L.G. Hanscom Field Runway 11-29 Rehabilitation Project, Bedford, MA**: This $10 million rehabilitation project provided improvements to the runway, which is 7,000 feet long x 200 feet wide with additional 2,000 feet long x 200 feet wide end areas. Work included milling of existing asphalt pavement, rubblizing the concrete base under the asphalt pavement and placing new asphalt pavement for the entire length of the runway.
- **NEFCO Detroit Biosolids Drying Facility, Detroit, MI**: This $125 million facility consisted of the construction of the 47,500 sf building that included piles, various foundations, precast walls, office space, and process equipment. Major process equipment included centrifuges, dry system, RTO, silos, and odor control system.
- **MDC Aeration & Final Settling Tanks, Hartford, CT**: This $35 million project involved building and fitting out two new aeration tanks and two new final settling tanks for t secondary waste water treatment process at the plant. The tank construction involved heavy sitework, earth retention, under pinning, de-watering, pile driving and months of concrete construction. New process piping was installed to serve the new tanks and tie into the existing processes and involved new large diameter ductile iron pipe, pumps, valves, flow meters, an pipe supports, as well as more than half a dozen shutdowns for tie-ins to existing systems.
- **Lyman Street Bridge Over Second Level Canal, Holyoke, MA**: This $5 million project consisted of phased demolition and removal of an existing bridge and phased construction of a new bridge.
- **Palmer Dam / Dean's Mill Water Treatment Plant, Stonington, CT**: The work on this $10 million project included demolition of an existing dam, distribution building, chemical building and portions of the tailrace and spillway. New work involved dam reconstruction, spill containment area, water mains and crest gates and sedimentation basin modifications A temporary water intake system to re-route water supplied to the existing and new chemical building was built. Steel sheet cofferdams were constructed, including an Engineering Action Plan to control storm water runoff volume

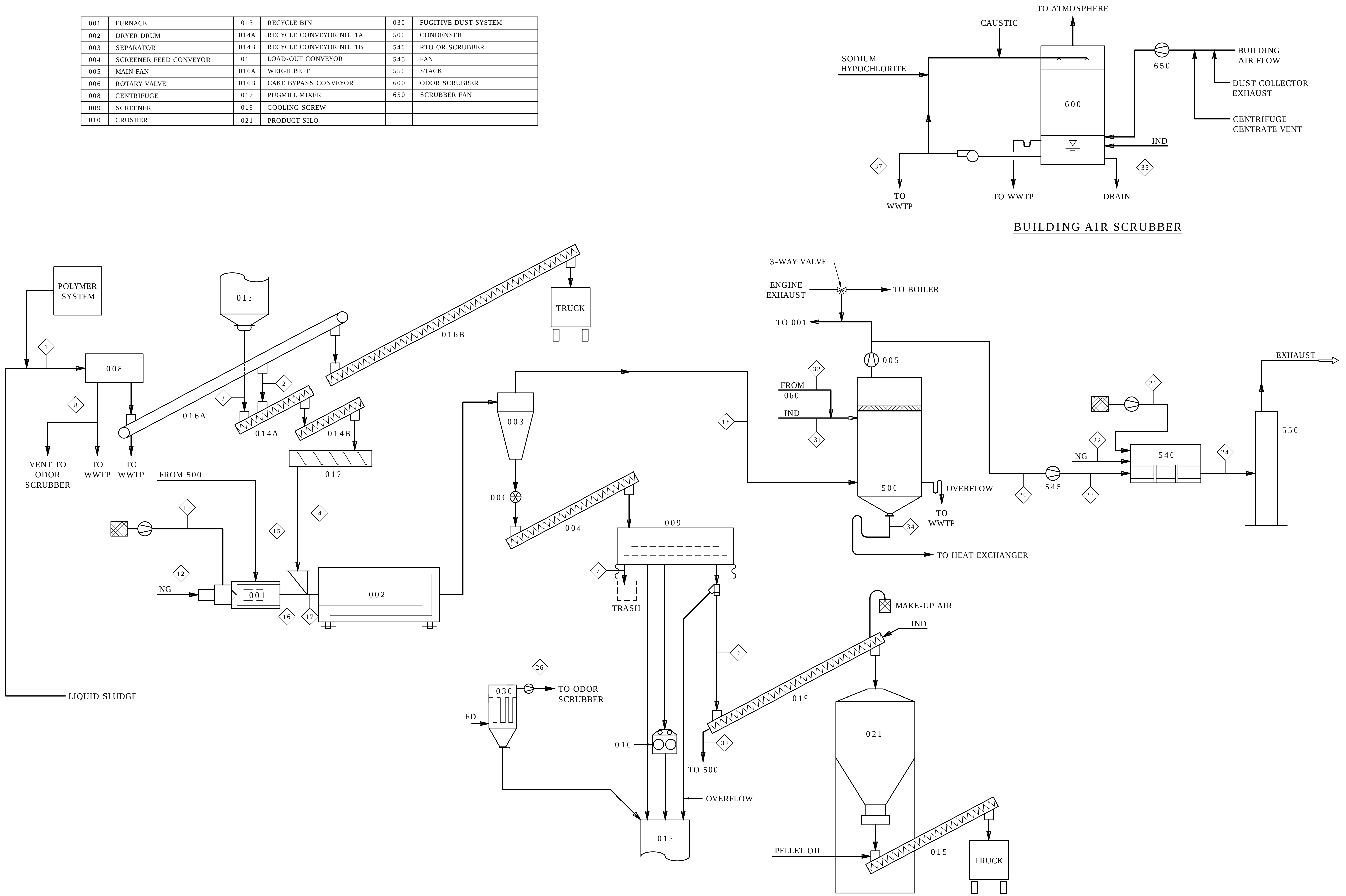
Education and Memberships

- **University of Massachusetts**: Bachelors Degree in Civil and Environmental Engineering
- Grade 1 ACI Certified Concrete Field Testing Technician
- OSHA 30 Hour Training

References

- Massachusetts Highway Department: James White, Resident Engineer, 413-582-0599
- Wade Trim: Jason Yoscovitis, Construction Inspector, 734-771-3926
- Tighe & Bond: Chris Bone, Vice President, 413-572-3266

001	FURNACE	013	RECYCLE BIN	030	FUGITIVE DUST SYSTEM
002	DRYER DRUM	014A	RECYCLE CONVEYOR NO. 1A	500	CONDENSER
003	SEPARATOR	014B	RECYCLE CONVEYOR NO. 1B	540	RTO OR SCRUBBER
004	SCREENER FEED CONVEYOR	015	LOAD-OUT CONVEYOR	545	FAN
005	MAIN FAN	016A	WEIGH BELT	550	STACK
006	ROTARY VALVE	016B	CAKE BYPASS CONVEYOR	600	ODOR SCRUBBER
008	CENTRIFUGE	017	PUGMILL MIXER	650	SCRUBBER FAN
009	SCREENER	019	COOLING SCREW		
010	CRUSHER	021	PRODUCT SILO		



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Engineers | Environmental Specialists

CIVILTEC engineering inc.
Civil, Water, Wastewater, Drainage, and Transportation Engineering
Construction Management • Surveying
California • Arizona

CONCEPTUAL
NOT FOR
CONSTRUCTION

South Orange County Wastewater Authority

Innovative Solids/Biosolids Technology Project

Dana Point, California

MARK	DATE	DESCRIPTION

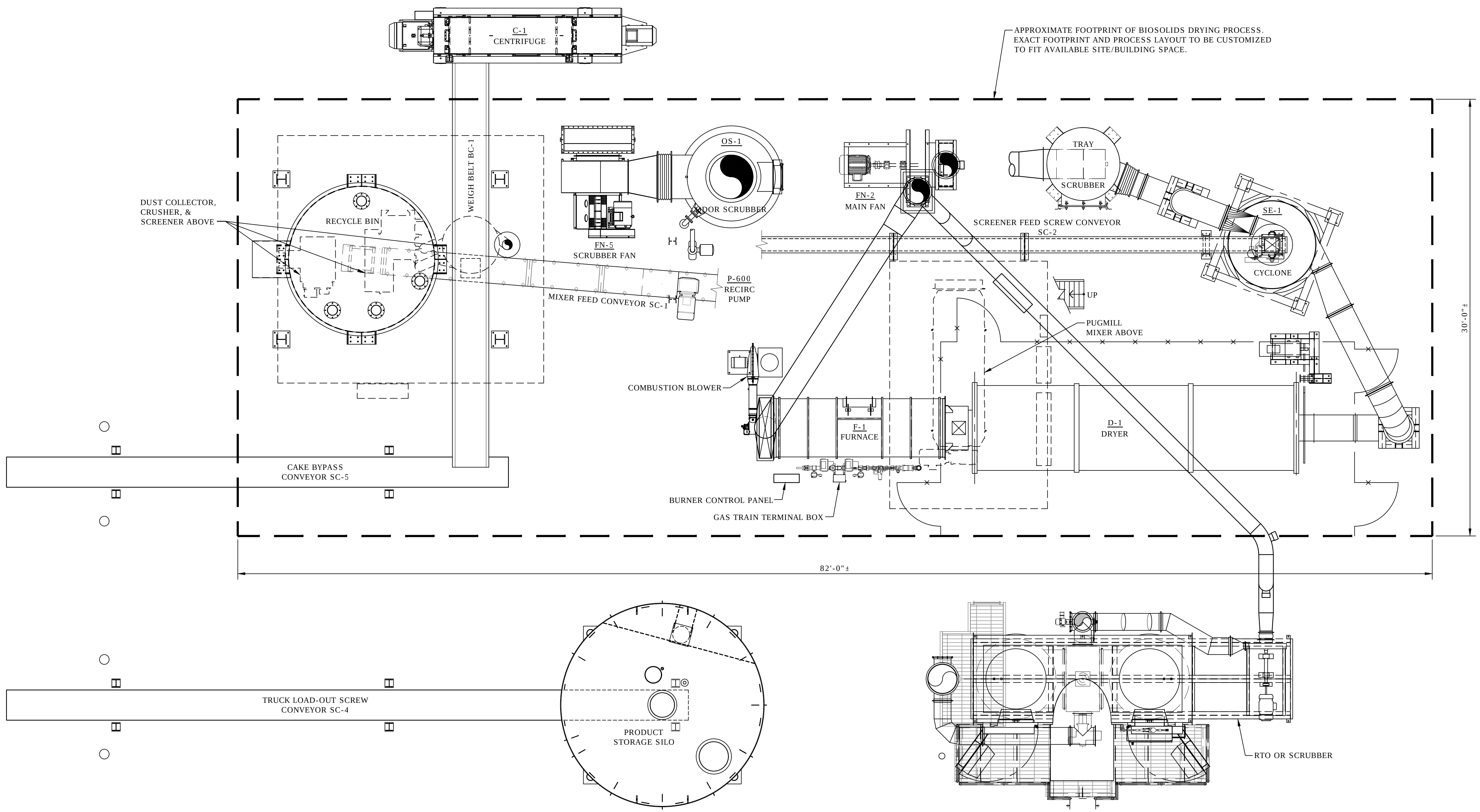
PROJECT NO: N5034
DATE: FEBRUARY 2019
FILE: G-001.dwg
DRAWN BY: RWK
CHECKED: RLS
APPROVED: CCB

DRYING SYSTEM
PROCESS FLOW DIAGRAM

SCALE: NO SCALE

G-001
SHEET X OF X

Last Saved: 4/16/2019
Plotted On:Apr 17, 2019-6:15am By: rwk
Tighe & Bond C:\Users\RWK\Documents\G-001.dwg



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CIVILTEC engineering inc.
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Construction Management • Surveying
California • Arizona

CONCEPTUAL
NOT FOR
CONSTRUCTION

South Orange
County
Wastewater
Authority

Innovative
Solids/Biosolids
Technology
Project

Dana Point, California

MARK	DATE	DESCRIPTION

PROJECT NO:	N5034
DATE:	FEBRUARY 2019
FILE:	M-101.dwg
DRAWN BY:	RWK
CHECKED:	RLS
APPROVED:	CCB

DRYING SYSTEM
EQUIPMENT LAYOUT PLAN

SCALE: 1/4" = 1'-0"

M-101
SHEET X OF X

TRAVELERS

April 1, 2019

South Orange County Wastewater Authority
Administration Building
34156 Del Obispo Street
Dana Point, CA 92629

Contractor: New England Fertilizer Company
800 Kelly Way, Holyoke, MA 01040

Project: Innovative Solids/Biosolids Technology Solicitation

To Whom It May Concern:

Travelers Casualty and Surety Company of America is the surety for New England Fertilizer Company and considers them among our finest clients. They have achieved an impeccable record of construction performance and have a vast expertise in all facets of the construction business.

This is to advise that Travelers Casualty and Surety Company of America, as surety for New England Fertilizer Company has supported single projects in the range of $250,000,000 as part of a total work program of $600,000,000. Travelers Casualty and Surety Company of America is an A++ (Superior) Rated company by A.M. Best and have a Treasury Listing for single size jobs in excess of $201,664,000. Travelers Casualty and Surety Company of America is licensed to do business in the State of Texas and its name appears on the United States Treasury Department Circular 570. Should New England Fertilizer Company be awarded the captioned project, subject to our normal underwriting requirements, Travelers Casualty and Surety Company of America is prepared to issue in an amount equal to or greater (100%) Performance and (100%) Payment Bonds of the estimated contract amount.

New England Fertilizer Company has enjoyed an excellent relationship with Travelers Casualty and Surety Company of America for over twenty years and we would be pleased to provide any additional information you may require. If you should have any questions, please do not hesitate to contact me at (860) 231-7250. Thank you.

Travelers Casualty and Surety Company of America

Michael E. Watts

Michael E. Watts
Attorney-In-Fact

TRAVELERS

Travelers Casualty and Surety Company of America
Travelers Casualty and Surety Company
St. Paul Fire and Marine Insurance Company

POWER OF ATTORNEY

KNOW ALL MEN BY THESE PRESENTS: That Travelers Casualty and Surety Company of America, Travelers Casualty and Surety Company, and St. Paul Fire and Marine Insurance Company are corporations duly organized under the laws of the State of Connecticut (herein collectively called the "Companies"), and that the Companies do hereby make, constitute and appoint **Michael E Watts** of **West Hartford Connecticut**, their true and lawful Attorney-in-Fact to sign, execute, seal and acknowledge any and all bonds, recognizances, conditional undertakings and other writings obligatory in the nature thereof on behalf of the Companies in their business of guaranteeing the fidelity of persons, guaranteeing the performance of contracts and executing or guaranteeing bonds and undertakings required or permitted in any actions or proceedings allowed by law.

IN WITNESS WHEREOF, the Companies have caused this instrument to be signed, and their corporate seals to be hereto affixed, this **3rd** day of **February**, **2017.**

State of Connecticut

City of Hartford ss.

By: Robert L. Raney, Senior Vice President

On this the **3rd** day of **February, 2017**, before me personally appeared **Robert L. Raney**, who acknowledged himself to be the Senior Vice President of Travelers Casualty and Surety Company of America, Travelers Casualty and Surety Company, and St. Paul Fire and Marine Insurance Company, and that he, as such, being authorized so to do, executed the foregoing instrument for the purposes therein contained by signing on behalf of the corporations by himself as a duly authorized officer.

In Witness Whereof, I hereunto set my hand and official seal.

My Commission expires the **30th** day of **June, 2021**

Marie C. Tetreault, Notary Public

This Power of Attorney is granted under and by the authority of the following resolutions adopted by the Boards of Directors of Travelers Casualty and Surety Company of America, Travelers Casualty and Surety Company, and St. Paul Fire and Marine Insurance Company, which resolutions are now in full force and effect, reading as follows:

RESOLVED, that the Chairman, the President, any Vice Chairman, any Executive Vice President, any Senior Vice President, any Vice President, any Second Vice President, the Treasurer, any Assistant Treasurer, the Corporate Secretary or any Assistant Secretary may appoint Attorneys-in-Fact and Agents to act for and on behalf of the Company and may give such appointee such authority as his or her certificate of authority may prescribe to sign with the Company's name and seal with the Company's seal bonds, recognizances, contracts of indemnity, and other writings obligatory in the nature of a bond, recognizance, or conditional undertaking, and any of said officers or the Board of Directors at any time may remove any such appointee and revoke the power given him or her; and it is

FURTHER RESOLVED, that the Chairman, the President, any Vice Chairman, any Executive Vice President, any Senior Vice President or any Vice President may delegate all or any part of the foregoing authority to one or more officers or employees of this Company, provided that each such delegation is in writing and a copy thereof is filed in the office of the Secretary; and it is

FURTHER RESOLVED, that any bond, recognizance, contract of indemnity, or writing obligatory in the nature of a bond, recognizance, or conditional undertaking shall be valid and binding upon the Company when (a) signed by the President, any Vice Chairman, any Executive Vice President, any Senior Vice President or any Vice President, any Second Vice President, the Treasurer, any Assistant Treasurer, the Corporate Secretary or any Assistant Secretary and duly attested and sealed with the Company's seal by a Secretary or Assistant Secretary; or (b) duly executed (under seal, if required) by one or more Attorneys-in-Fact and Agents pursuant to the power prescribed in his or her certificate or their certificates of authority or by one or more Company officers pursuant to a written delegation of authority; and it is

FURTHER RESOLVED, that the signature of each of the following officers: President, any Executive Vice President, any Senior Vice President, any Vice President, any Assistant Vice President, any Secretary, any Assistant Secretary, and the seal of the Company may be affixed by facsimile to any Power of Attorney or to any certificate relating thereto appointing Resident Vice Presidents, Resident Assistant Secretaries or Attorneys-in-Fact for purposes only of executing and attesting bonds and undertakings and other writings obligatory in the nature thereof, and any such Power of Attorney or certificate bearing such facsimile signature or facsimile seal shall be valid and binding upon the Company and any such power so executed and certified by such facsimile signature and facsimile seal shall be valid and binding on the Company in the future with respect to any bond or understanding to which it is attached.

I, **Kevin E. Hughes**, the undersigned, Assistant Secretary of Travelers Casualty and Surety Company of America, Travelers Casualty and Surety Company, and St. Paul Fire and Marine Insurance Company, do hereby certify that the above and foregoing is a true and correct copy of the Power of Attorney executed by said Companies, which remains in full force and effect.

Dated this **1st** day of **April**, **2019**

Kevin E. Hughes, Assistant Secretary

To verify the authenticity of this Power of Attorney, please call us at 1-800-421-3880.
Please refer to the above-named Attorney-in-Fact and the details of the bond to which the power is attached.

PeoplesBank

February 28, 2019

City of Fort Worth Purchasing Division
Fort Worth Municipal Building (Lower Level)
200 Texas Street
Fort Worth, TX 76102

Contractor: New England Fertilizer Company
800 Kelly Way, Holyoke, MA 01040

Project: Request for Qualifications to Design, Build, Operate and Maintain Village Creek WaterReclamation Facility Biosolids Management and Beneficial Reuse, City of Fort Worth – Water Department. City Project No.: 101961

To Whom It May Concern:

Please allow this letter to serve as our credit reference for the company referenced above. New England Fertilizer Company has been an excellent customer of the Bank for over 5 years.

We currently provide New England Fertilizer Company with two unsecured credit facilities, both of which are in the low seven figure range. Payments have always been made as agreed.

New England Fertilizer Company also maintains a deposit relationship with PeoplesBank. Should you have any questions, please do not hesitate to contact me.

Sincerely,

Marian E Poe-Heineman

Marian E. Poe-Heineman
First Vice President
Commercial Lending
Email: mpoe-heineman@bankatpeoples.com
Phone: 413-493-7507

January 31, 2020

Mr. Jason Manning, P.E.
Director of Engineering
South Orange County Wastewater Authority
34156 Del Obispo Street
Dana Point, CA 92629

Re: South Orange County Wastewater Authority (SOCWA)
Request for Proposals for
Innovative Solids/Biosolids Technology Solicitation

Dear Jason,

NEFCO is pleased to submit the attached following in response to the questions received in an email from Sarah Deslauriers dated January 16, 2020.

1. ***Would NEFCO develop a market for the dried solids in this region?***

NEFCO always strives to develop a multifaceted market for the Class A biosolids produced in its facilities. As we have done at our six other facilities, markets would be developed in multiple states for land application and use as an alternative fuel source. This would allow for continuous beneficial use of the product even if regulatory changes in the future restrict or impact land application of biosolids.

In California, Class A biosolids are widely accepted. All markets developed for this project would be strategically located to prevent any nuisances and follow all local, state, and federal regulations. The drying technology selected (rotary drum vs belt) will impact the quality of product being created, and will have different market opportunities that will be approached. Low cost markets closest to the drying facility will be the first priority to minimize transportation costs and to keep nutrients local. In order to provide regulatory resiliency, markets outside of California will be developed in conjunction to the local region.

Class A biosolids end uses will depend on the final product quality. A belt dryer will produce a Class A biosolids that is irregular in shape that can be used in the following markets:

- Agriculture - Bulk
- Alternative Fuel
- Soil Blenders
- Mine Reclamation
- Compost Additive

NEFCO
500 Victory Road, 4th Floor, North Quincy, MA 02171
(t) 617.773.3131 (f) 617.773.3122

Pictured:
Pellets from a rotary drum dryer (left) and dried biosolids from a belt dryer (right)

As shown above, a rotary drum dryer will produce a higher quality granular Class A biosolids pellet. On top of the markets above, the Class A pellet will provide more lucrative opportunities such as:

- Fertilizer Blenders (Bagged Product)
- Golf Courses
- Garden Centers

Both Class A products provide different markets and are perceived differently due to the physical and visible differences in the product. Different costs would be associated with distribution depending on the dryer unit selected. NEFCO would develop a plan that would fit the biosolids quality that is produced, including:

- Bulk agricultural outlets in areas of El Centro, CA and Yuma, AZ.
- Farmers and other distribution outlets will typically pay for transportation costs for a pelletized product and outlets are easier to find locally. Belt dryer product can be distributed in bulk but may have the risk of higher transportation costs due to customers being unwilling to spend as much.
- Use as a composting additive at a nearby chicken manure compost operation in California.
- If pelletized, fertilizer blenders can be developed or developing and marketing bagged product on behalf of SOCWA.

This is not the exhaustive list of potential outlets. End uses can be tailored once a drying technique is selected to continue building interest in the market.

If there is a disruption in service or off spec material for any reason, NEFCO will have space reserved on an emergency basis at a landfill in Nevada or Arizona. Landfilling is the last option to be considered. If product meets all local, state and federal requirements, beneficial use sites will be sought in surrounding states prior to landfilling.

2. ***What is the intended energy source (e.g., biogas, natural gas, etc.) for operation of the dryer and how would opportunities to supply power to the dryer differ at RTP or JBL?***

There are several options for energy sources in the thermal drying process that could be utilized at both the RTP and JBLTP. NEFCO proposed the possibility of using either a rotary drum dryer or belt dryer to meet SOCWA's needs, and both systems have flexibility in the source of energy they can use. NEFCO's rotary drum drying facilities utilize a wide range of fuels for their furnaces including natural gas, anaerobic digester biogas, and landfill gas. Belt dryers typically use hot water and heat exchangers to heat the air used in their process which opens up even more energy options, including systems that run on electricity alone. Both systems would also be capable of utilizing waste heat from the cogeneration systems at each facility into the drying process, and waste heat from the drying process could be used for the digesters or facility energy demands. If SOCWA has a specific energy source they find preferable to use, NEFCO will work to develop a system that falls in line with the energy goals for each plant. Since each plant would likely have its own drying system, the fuel source, and even style of dryer, can be tailored to meet the needs of each plant specifically. See below for an estimate on energy usage for each system:

Process/Data	JBLTP	RTP
Biosolids Generation		
Amount Generated (WTPY)	8,400	14,400
Average Percent TS (%)	23.9%	22.8%
Amount Generated (DTPY)	2,008	3,283
Average Amount Generated (WTPD)	23.0	39.5
Average Amount Generated (DTPD)	5.5	9.0
Rotary Drum Dryer Energy		
Heating Requirements (MMBTU/hr)	3.0-4.0	5.5-6.5
Heating Requirements (Therm/DT)	130-175	145-175
Electricity Requirements (kWh/DT)	300-450	300-450
Belt Dryer Energy		
Heating Requirements (MMBTU/hr)	2.5-3.5	5.0-6.0
Heating Requirements (Therm/DT)	110-150	130-160
Electricity Requirements (kWh/DT)	200-250	200-250
Cogeneration Waste Heat		
Exhaust Temperature (°F)	985	975
Exhaust Flow (lb/hr)	7,900	10,500
Heat Recovery in Drum (MMBTU/hr)	1.1-1.5	1.5-2.0
Heat Recovery in Boiler (MMBTU/hr)	0.9-1.2	1.2-1.6

3. Do you have any data on PFAS/PFOS/PFOA destruction in the process? If not, do you plan to collect data or do you expect destruction? If you don't expect destruction, how do you expect it to partition?

To date, data does not suggest there is destruction of PFAS/PFOS/PFOA from processes used for thermal drying of biosolids. There is a large amount of research on the topic and the current thinking is that destruction of these compounds occurs somewhere around 1000 °C or greater, whereas conventional drying processes operate at 1000 °F (~550 °C) or lower. It is unclear how California will be approaching this issue with respect to biosolids, but the ban on landfill disposal of biosolids and notification levels set by the State Water Resources Control Board shows that they have begun to take a stricter regulatory approach to the industry which will certainly impact the beneficial reuse market.

NEFCO has been investigating technologies for further thermal processing of dried biosolids, such as furnaces or pyrolysis, to address the issue of residual PFAS compounds in biosolids. Further studies are needed to better understand the fate of the compounds in these emerging technologies, but the results are promising so far. Though not part of our initial proposal for the project, NEFCO would be happy to discuss potential options for these technologies in the system design for SOCWA. The most recent update from the California Association of Sanitation Agencies (CASA) on the upcoming DC Policy Forum in February includes a discussion a variety of these systems, which will be a great indication of their future in the industry. These technologies have additional benefits on the energy generation side which could help SOCWA towards meeting their goals for energy at the facilities as well.

4. What is the maximum height of proposed structures/stacks installed with this system?

System height would depend on individual equipment height and the style of dryer that ends up being utilized for the systems at the JBLTP and RTP. NEFCO was not able to get copies of drawings with information on building elevations and interior details for each plant, so this would need to be verified before we could be sure of equipment location and fit.

A rotary drum drying process will include a Regenerative Thermal Oxidizer (RTO) for emissions control that would have a 24-inch diameter stack approximately 70-feet tall which would be located outdoors. NEFCO's process designs also strive to utilize gravity for material flow as much as possible, and would likely include placing equipment on the roof of the building housing the dryer system. The design would also include a combination of solids handling equipment (screener, crusher, pellet cooler, etc.) stacked on top of each other inside the building in order to utilize gravity feed as well. Structural steel platforms could be utilized with existing levels to locate equipment and conveyance.

List of rotary drying equipment with approximate heights:

Equipment	Estimated Height[1]	Location
RTO (w/ Stack)	70 ft	Outdoors
Tray Scrubber	22 ft	Indoors
Cyclone Separator (w/ Ductwork)	24 ft	Indoors/Outdoors
Odor Control (w/ Stack)	30 ft	Indoors/Outdoors
Solids Handling Combination[2]	26 ft	Indoors
Screener	*6 ft*	*Indoors*
Pellet Cooler	*8 ft*	*Indoors*
Crusher	*4 ft*	*Indoors*
Recycle Bin (w/ Baghouse)	*22 ft*	*Indoors*

[1] *These heights are based on NEFCO's Cumberland, MD facility, which is comparable in solids loading to the RTP. Actual dimensions could be tailored to fit in each SOCWA facility as needed.*

[2] *The "Solids Handling Combination" is the arrangement of equipment listed in the table in italics. As mentioned above this equipment is typically arranged in a tiered platform, but individual heights are listed for the consideration of alternative arrangements.*

The belt dryer system would be much simpler with respect to ancillary equipment. There would likely be no need for an RTO meaning no stack to worry about, and the solids handling equipment would be simplified with no need for the tiered equipment platforms used in the rotary drum design. Likely the tallest equipment in the belt dryer design would be the odor control scrubber system, which can be tailored to stay within any space restrictions at the plant. The following is a list of belt drying equipment with approximate heights:

Equipment	Estimated Height	Location
Belt Dryer (w/ Ductwork)	15-20 ft[3]	Outdoors
Odor Control (w/ Stack)	30 ft	Indoors

[3] *Dryer height dependent on model and manufacturer.*

Both systems would need silo(s) for product storage. A comparable sized drying facility NEFCO operates in Cumberland, MD produces about 10-15 DTPD and has a silo that is approximately 35-feet tall. The silos will be flexible in what dimensions are used though, and if there is a height restriction then the design will certainly be able to stay within those limits.

5. ***If there is a disruption in operations or in the supply chain, what is the plan for managing the biosolids?***

NEFCO develops rigorous Asset Management Plans at each of its plants to ensure the proper maintenance of equipment and eliminate or reduce down time for processing. In the unlikely event of a disruption in operations or supply chain, NEFCO would like to develop a contingency Class B land application program. NEFCO would need to receive documentation that shows Class B requirements are being met in the anaerobic digester including temperature, retention time, and certification statement. This would allow for a Class B land application program to be activated seamlessly. NEFCO would locate end users and permit fields that could take Class B at a moment's notice.

In the event there is a change in regulation which creates a disruption in the local region's beneficial use program within the state of California, NEFCO will have already developed markets outside of California in the surrounding states of Arizona and Nevada. Regulatory resiliency is necessary for projects such as these, and NEFCO will be prepared by creating a diverse program with multiple options for beneficial reuse.

NEFCO has experience with regulatory disruption from the pelletizing facility in Quincy, MA owned by Massachusetts Water Resource Authority (MWRA), which has been managed by NEFCO for almost 30 years. The moratorium on biosolids land application by the State of Maine effected not just NEFCO, but the entire biosolids industry in the Northeast. Over the years NEFCO has been able to develop a large market for the product from Quincy, which is permitted for use in 19 states that range from Florida to Indiana and up to Canada with customers ranging from cement kilns to agricultural users to fertilizer blenders. This diverse market allowed NEFCO to continue moving product despite this disruption, and also provides the seasonal needs for continued product distribution during periods of inclement weather.

The highly experienced NEFCO team looks forward to working with SOCWA to develop a solution to your biosolids management needs. NEFCO feels confident that we will be able to accomplish this by providing you with a project that is technically and environmentally sound, and by utilizing a proven technology and reliable equipment.

Sincerely,

Larry W. Bishop

Larry W. Bishop, P.E.
General Manager

LWB/lrh