Brown AND Caldwell

PRELIMINARY DESIGN REPORT

st.petersburg

Biosolids to Energy Project

June 19, 2015 | Contract No. 13057-111

Biosolids to Energy
Preliminary Design Report

Prepared for
Florida Department of Environmental Protection
Temple Terrace, FL
June 19, 2015

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AADF	annual average daily flow
ACH	air change per hour
ADF	average daily flow
AWWRF	Albert Whitted Water Reclamation Facility
BC	Brown and Caldwell
BEBR	Bureau of Economic and Business Research
BFP	belt filter presses
BOD	biochemical oxygen demand
BTF	biotrickling filter
BTU	British thermal unit
BUS	biogas upgrading system
C	Celsius
$CBOD_5$	five-day carbonaceous biochemical oxygen demand
CCT	chlorine contact time
CENSUS	US Census Bureau
CFD	computational fluid-dynamic
CFM	cubic foot per minute
City	City of St. Petersburg
CMAR	Construction Management at Risk
CNG	compressed natural gas
COD	chemical oxygen demand
CO_2	carbon dioxide
CS	carbon steel
cu	cubic
D	dimension
DB	design build
dBA	decibels
DEMON	deammonification
DG	digested gas
DIP	ductile iron pipe
DO	dissolved oxygen
DS	digested sludge
D1	Digester 1
D2	Digester 2
d	day
EPA	Environmental Protection Agency
ERP	Environmental Resource Permit
F	Fahrenheit
FA	foul air
F.A.C.	Florida Administrative Code
FBC	Florida Building Code
Fe	ferric
$FeCl_3$	ferric chloride
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
FL	Florida
FOG	fats, oil, and grease
FPC	Florida Fire Preventative Code
FRP	fiber reinforced plastic
ft	feet
gal	gallon
GBT	gravity-belt thickening
GMP	Guaranteed Maximum Price
gpd	gallon per day
gpm	gallons per minute
H_2S	hydrogen sulfide
HID	high density discharge
HMI	human machine interface
HP	horsepower
HPF	high power factor
hr	hour
HVAC	heating, ventilation and air conditioning
ISO	International Organization for Standardization
I/O	input/output

kg	kilogram
KV	kilovolt
L	length
lb	pound
LCP	local control panel
LED	light emitting diode
LS	lift station
LOTO	Lockout/Tagout
mg	milligram(s)
MG	million gallons
mg/L	milligrams per liter
m	meter
MCC	motor control center
MGD	million gallons per day
MBtu	million btu
MinF	minimum hourly flow
MMF	maximum month flow
mph	mile per hour
N	nitrogen
NA	not applicable
NEWRF	Northeast Water Reclamation Facility
NFPA	National Fire Protection Association
NH_3-N	ammonia nitrogen
NOI	notice of intent
NO_3-N	Nitrate
NTU	nephelometric turbidity unit
NWWRF	Northwest Water Reclamation Facility
O&M	operation and maintenance
O2	oxygen
OSHA	Occupational Safety and Health Administration
P	phosphorus
PD	gravity process drain
PDF	peak day flow
PDR	Preliminary Design Report
PE	primary clarifier effluent
P.E.	Professional Engineer
pH	potential of Hydrogen
PHF	peak hour flow
PID	process and instrumentation diagram
PLC	programmable logic controllers
PLW	chloridated plant water
PO_4-P	phosphate as phosphorus
ppbv	parts per billion - volume
ppd	pounds per day
ppm	parts per million (by weight)
ppmv	parts per million (by volume)
PSA	pressure swing absorption
psi	pounds per square inch
psig	pounds per square inch, gauge
PVC	polyvinyl chloride
PW	potable water
PWF	peak week flow
RAS	return activated sludge
SBR	sequencing batch reactor
SCADA	supervisory control and data acquisition
scf	standard cubic foot
scfd	standard cubic feet/day
scfm	standard cubic feet per minute
sf	square foot
SFC	submerged fixed cover
SND	simultaneous nitrification-denitrification
SOx	sulfur dioxides
SRS	screened raw sewage
SRT	solids retention time
SS	stainless steel
SSC	secondary scum
STD	storm drain
STP	System Turn Over Package
SU	standard units
SVI	sludge volume index
SWA	Safe Work Authorization
SWD	side water depth

SWWRF	Southwest Water Reclamation Facility
TAZ	Traffic Analysis Zones
THC	The Haskell Company
THS	thickened sludge
TM	Technical Memorandum
TM4	Technical Memorandum 4
TM6	Technical Memorandum 6
TKN	total kjeldahl nitrogen
TP	total phosphorus
TPAD	Temperature Phased Anaerobic Digestion
TSS	total suspended solids
TWAS	thickened waste activated sludge
UBC	Uniform Building Code
UPS	uninterruptible power supply
U.S.	United States
V	volt
VAC	volt alternating current
VFD	variable frequency drive
VOCs	volatile organic compounds
VOL	volume
VS	volatile solids
VSS	volatile suspended solids
W	width
w/	with
WAS	waste activated sludge
WEF	Water Environment Federation
WGA	waste gas
WRF	water reclamation facility
WWTP	wastewater treatment plant
yr	year
%	percent

Section 1

Introduction and Background

1.1 Background and Objectives

The objective of this Preliminary Design Report (PDR) is to provide technical information in support of the Florida Department of Environmental Protection (FDEP) Application for a Minor Revision to the Wastewater Facility Permit at the City of St. Petersburg (City) Southwest Water Reclamation Facility (SWWRF).

The work at the SWWRF which is part of this application is referred to as the Biosolids to Energy Program and consists of several discrete projects as identified below:

1. Biosolids to Energy Project – Led by the consulting firm Brown and Caldwell (BC) (Reference Appendix A for key project drawings).
    a. New splitter structure to divert influent flow to new Primary Clarifiers and to provide liquid stream process flexibility to utilize a new step feed and biological stabilization feature for the aeration basins,
    b. Two new Primary Clarifiers and support facilities to capture additional sludge from the Northwest Water Reclamation Facility (NWWRF) and Northeast Water Reclamation Facility (NEWRF) for new anaerobic digestion processes,
    c. Two new anaerobic digesters, a digested sludge Batch Tank, and support facilities to achieve Class-AA biosolids,
    d. New supplemental feedstock receiving facility for the digesters, envisioned to initially consist of limited amounts of fats, oils and grease (FOG) but with the capability of receiving other feedstock for potential inclusion (such as pulped food waste),
    e. New digester gas storage and handling facilities to provide momentary gas production storage and flare excess digester gas,
    f. New digester gas upgrade systems to upgrade the quality of the digester gas to pipeline quality recycled natural gas, and
    g. New odor control facilities for the new splitter box, Primary Clarifiers, and the Sludge Storage Tank and thickening facilities which are part of the Thickening Project.
2. Thickening Project – Led by the consulting firm Carollo (Appendix B).
    a. Upgrades to the thickening facilities.
3. Dewatering Project – Led by the consulting firm AECOM (Appendix C).
    a. New dewatering facilities to replace existing aged dewatering facilities.
4. Engine Project – Led by the consulting firm Black & Veatch.
    a. Demolition of abandoned old plant and abandoned digestion tanks to make room for Biosolids to Energy Project,
    b. New engine facility to provide duty use of natural gas or upgraded digester gas to provide partial power needs for the plant,
    c. New hot water boiler supply system for the Biosolids to Energy Project, and

d. New structure for electrical equipment to support new engine facility and some parts of the Biosolids Improvements Program efforts.

Other work associated with the Biosolids to Energy Program but is not part of this permit application include the following:

5. Waste Activated Sludge (WAS) Transfer from NEWRF to SWWRF Project.
    a. Modification of the NEWRF biosolids facilities for use as temporary sludge storage, and
    b. New transfer pipeline for transfer of WAS from the NEWRF to the SWWRF collection system for processing at the SWWRF.
6. WAS Transfer from NWWRF to SWWRF Project.
    a. Modification of the NWWRF biosolids facilities for use as temporary sludge storage, and
    b. New transfer pipeline for transfer of WAS from the NWWRF to the SWWRF collection system for processing at the SWWRF.

It is important to note that the SWWRF has recently undergone a previously permitted liquid stream change and is now receiving the ferelows from the service area of the Albert Whitted Wastewater Reclamation Facility (AWWRF).

This Biosolids Improvements Program is based primarily on a study project *Technical Memorandum 4 – Biosolids and Yard Waste to Energy Feasibility Study – Brown and Caldwell - July of 2011*. This study recommended the following concept plan.

- Consolidating wastewater solids handling by conveying WAS produced at the NEWRF and NWWRF to the SWWRF using a combination of new forcemains and the existing collection system,
- Adding primary clarification to the SWWRF to collect the conveyed WAS,
- Upgrading the solids treatment facilities at the SWWRF to Class-A, temperature-phased anaerobic digestion (TPAD; thermophilic followed by mesophilic) and certification of the produced Class-AA biosolids as a fertilizer,
- Expanding the SWWRF gravity-belt thickening (GBT), digestion, and dewatering capacity to accommodate the new facilities,
- Adding new odor control systems to account for the new facilities,
- Providing a supplemental feedstock tipping station at the SWWRF, and
- Continuing to process yard waste using the City's current practices but re-evaluating thermal processing of these materials at a later date.

The improvements identified were recommended for implementation primarily in order to produce Class-AA biosolids and avoid the increasingly stringent and cost-prohibitive requirements for Class-B land application under Florida Administrative Code (F.A.C) Chapter 62-640. Side benefits included the creation of additional digester gas which can be converted to energy for use by the City.

In order to bridge the time between the F.A.C. mandate commencement date and the finalization of the Biosolids Improvements Program, the City instituted lime stabilization of the generated biosolids at the SWWRF.

The City has selected The Haskell Company to perform the Construction Management at Risk (CMAR) services for the Biosolids to Energy Project, the Thickening Project and the Dewatering Project.

1.2 Biosolids to Energy Project Scope of Work

The following presents the major design elements included in BC's scope of work for the Biosolids to Energy Project and which are the primary focus of the main body of this PDR.

1. Construction of a new splitter box and raw sewage conveyance piping to divide flow to the new Primary Clarifiers. The new splitter box will be connected to piping tees in the yard that are being installed under a separate project. The splitter box will also provide for flow splitting to step feed and contact stabilization feed points in the aeration basins for process flexibility.
2. Construction of two new Primary Clarifiers in the area currently occupied by the smaller 4 million gallons per day (MGD) plant. The design will include odor control covers, construction of a new primary sludge pumping station, piping of the primary sludge to the existing thickening system, new odor control system and liquid stream piping back to the aeration system.
3. Construction of a new temperature phased anaerobic digestion system which will include a digester control enclosure, thermophilic digestion and Batch Tank holding followed by mesophilic digestion, to facilitate Class-AA sludge production.
4. Incorporation of the new digestion facilities with the Thickening Project, the Dewatering Project and the Engine Project.
5. Digester gas storage and handling systems and a gas upgrade to pipeline quality system.
6. New supplemental feedstock receiving and handling facility.
7. General, civil, architectural, structural, process-mechanical, electrical, instrumentation and control, heating, ventilation, and air conditioning (HVAC), and plumbing design efforts required for design of the project.

Section 2

Flows, Loads and Hydraulic Profile

2.1 Design Flows

This Section provides a summary of the design flows for the Biosolids to Energy Program.

2.1.1 St. Petersburg City Service Area

The City of St. Petersburg covers over 85,000 acres in southern Pinellas County. The City's wastewater system service area encompasses all of the City's areas and the City of Treasure Island, St. Pete Beach, Gulf Port, South Pasadena and part of Pinellas Park. The City's wastewater service area is divided into four sub-service areas – Northwest (served by the Northwest WRF), Northeast (served by the Northeast WRF), Southwest (served by the Southwest WRF) and Southeast (formerly served by the Albert Whitted WRF; however, now this flow is transferred to the SWWRF).

Figure 2-1 provides a division of the service areas relative to the City.

The Northwest wastewater service area serves the City's northwest area along with the wastewater from the City of Treasure Island, St Pete Beach, and South Pasadena. The Northeast wastewater service area serves the City's northeast area along with the wastewater from part of the City of Pinellas Park. The Southwest and Albert Whitted wastewater service area handles wastewater from those regions of the City's service areas with the Southwest WRF also servicing Gulf Port.

According to the US Census Bureau (Census), the City's population in 2010 was estimated to be 247,516 and the population of the City's wastewater service area was estimated at 282,482 people.

The City of St. Petersburg Planning Commission and the City Council are the primary departments regulating the future development of land within the City. According to the City's 2007 Evaluation and Appraisal Report, the predominant land use within the City is currently residential (approximately 43%) while 36% of the land is non-buildable. No other land use category (industrial, institutional, commercial, etc.) exceeds 5%. Because the City is nearly fully developed (less than 6% vacant), the land use within the City is not anticipated to change significantly within the planning period for this project which is through the year 2035. The wastewater system service area land use is primarily urban residential areas along with some small industries and commercial properties, and some undeveloped areas, mainly in the northeastern part of the City.

2.1.2 Design Average Daily Influent Flow Selection

The Biosolids Improvement's Program will be designed for the higher of either the current permitted capacity i.e. 20.0 MGD or the projected planning period (2035) average daily flow (inclusive of the flow from the Albert Whitted service area).

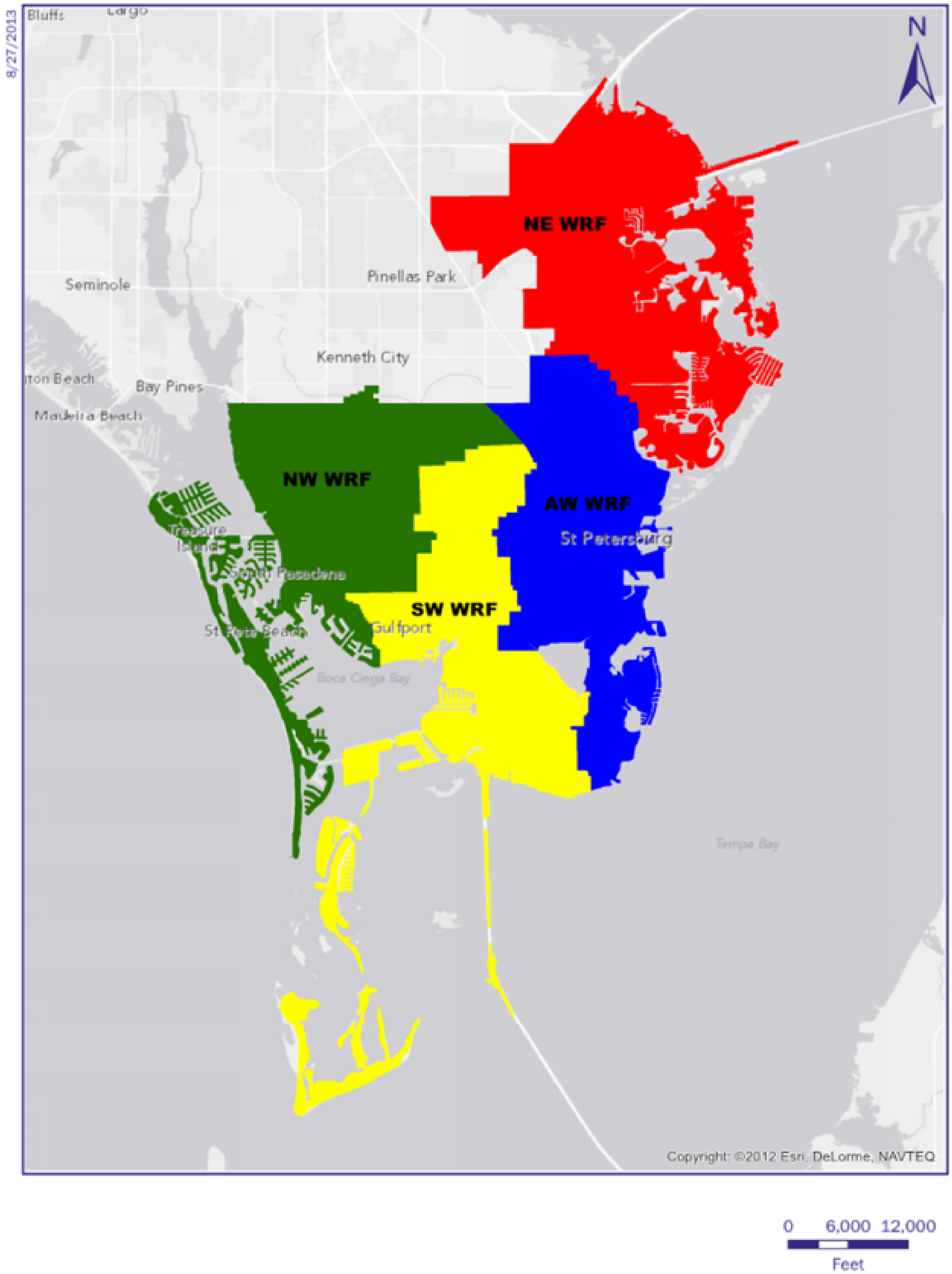


Figure 2-1. Water Reclamation Facilities Service Areas

The City recommended that the following average yearly wastewater flow percentage increase be used for the design year (2035) average daily flow wastewater estimation:

- NWWRF Service Area: 0.026%
- NEWRF Service Area: 0.026%
- SWWRF Service Area: 0.400%
- AWWRF Service Area: 0.400%

Table 2-1 presents the summary of the potential average daily wastewater flow from the four service areas. Note that NWWRF and NEWRF are included as WAS will be transferred from those plants to the SWWRF.

The recommended design average daily flow for the Biosolids Improvement's Program is the SWWRF permitted capacity, 20 MGD.

Table 2-1. Average Daily Flow WRF Wastewater Flow Projections

WRF	Wastewater Flows			
	NWWRF	NEWRF	SWWRF	Albert Whitted Service Area[a]
2012 (actual)	9.51	8.10	10.30	6.04
2020 (projected)	9.71	11.12	10.63	6.24
2025 (projected)	9.87	11.26	10.85	6.36
2030 (projected)	9.97	11.41	11.07	6.49
2035 (projected)[b]	10.11	11.57	11.29	6.62
Recommended Design Flow for Biosolids Program[b]	10.11	11.57	20.00	

a. *Albert Whitted Service Area was formerly served by the AWWRF; however, is now part of the SWWRF.*

b. *2035 total projected average daily flow to SWWRF = 11.29 MGD + 6.62 MGD = 17.91 MGD. Permitted average daily flow is 20.0 MGD. Biosolids Program average daily design flow will be for the SWWRF permitted average daily design flow.*

2.1.3 Peak Influent Flow Selections

Table 2-2 presents the results of the 2014 Process Capacity Study (*SWWRF – Wet Weather and Liquid Process Capacity Assessment, Brown and Caldwell, July 31, 2014*).

Table 2-2. Flow Peaking Factors (Combined Flow from SWWRF and AWWRF)

Year	2007	2008	2009	2010	2011	2012	2013
Maximum Month/Annual Average	1.28	1.22	1.39	1.33	1.39	1.44	1.57
Maximum Week/Annual Average	1.52	1.33	1.54	1.60	1.63	2.00	2.09
Maximum Day/Annual Average	1.92	1.47	1.87	1.92	1.99	2.91	2.63
Peak Hour/Annual Average	--[a]	--[a]	--[a]	--[a]	--[a]	3.30	3.41

a. *Data not available.*

Historical hourly flow measurements for the AWWRF and the SWWRF were reported for 2012 and 2013 as presented in Figure 2-2.

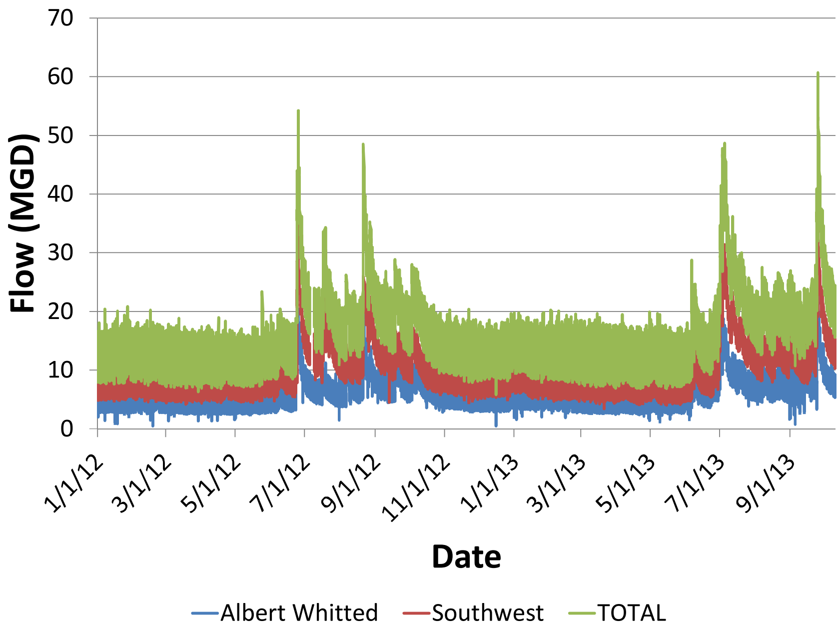


Figure 2-2. Historical Hourly Flow Measurements from January 2012 through November 2013

For the purposes of the Biosolids to Energy Program a peak hour flow for the new facilities of 70 MGD was selected.

The historical flow data from the 2012-2013 period showed a maximum wet weather flow contribution in excess of the dry weather flow of approximately 43.2 MGD. Assuming that the maximum dry weather flow and the storm flow occur at the same time, the total projected flow to the SWWRF was estimated to be 68.7 MGD (25.5 MGD + 43.2 MGD). A rounded up value of 70.0 MGD will be used for the Biosolids to Energy Program.

Table 2-3 presents other peaking flow parameters which were used for the work associated with the Biosolids to Energy Program.

Table 2-3. SWWRF Design Flows

Description	Flow (MGD)	
Average Daily Flow (ADF)	20.0	Plant Permitted ADF.
Maximum Month Flow (MMF)	31.4	Highest recorded monthly peaking factor of 1.57 (2013).
Peak Week Flow (PWF)	41.8	Highest recorded weekly peaking factor of 2.09 (2013).
Peak Daily Flow (PDF)	58.2	Highest recorded daily peaking factor of 2.91 (2012).
Peak Hourly Flow (PHF)	70.0	Highest wet weather flow portion during study period plus diurnal peak applied to plant permitted ADF (and rounded up from 68.7 MGD to 70.0 MGD).
Minimum Hourly Flow (MinF)	14.2	Lowest diurnal low through study period.

It is important to note that this data was additive on an hourly basis for the two plants and may not necessarily reflect what would have flowed to the SWWRF at that hour given the delay between the two plants. The highest combined annual average daily flow (AADF) observed was in 2013 with a PHF of 60.72 MGD which occurred on September 25, 2013. Analysis of historical data in that study indicated that the hourly flows higher than 40 MGD occurred less than 1% of the times and the maximum 24-hour rolling average flow was recorded as 50.5 MGD. Only 1% of the daily average flow was above 39 MGD. The analysis of historical data showed that the flows higher than 60 MGD occurred for only two hours in the 22-months of hourly data evaluated, which corresponds to a 0.01% probability. Daily dry weather diurnal factors ranged from approximately 0.71 to 1.27; hence, under normal circumstances, the projected dry weather flow to the SWWRF at 20 MGD design flow conditions would range from 14 MGD to 25.5 MGD.

2.2 Load Projections, Sludge Production and Plant Mass Balance

It is important to note that wastewater flows and sludge production do not track together. Peak wastewater flows do not result in peak loading or peak sludge production. As this project is a biosolids focused project, an evaluation of the projected loadings and sludge production was performed.

2.2.1 Load Evaluation and Projections

Historical influent concentration and loadings for the SWWRF and AWWRF were evaluated from January 2007 through December 2011. A summary of the combined plant data flows and pollutant loadings for annual average, maximum month and maximum day conditions are summarized in Table 2-4.

Table 2-4. Summary of Historical Flow and Pollutant Loads for the Combined Influent of AWWRF and the SWWRF – January 2007 through December 2011

Parameter	Condition	2007	2008	2009	2010	2011
Flow	Annual Average	14.25	15.22	15.54	16.10	16.52
	Maximum Month	18.22	18.63	21.67	21.35	22.96
	Maximum Day	27.37	22.42	29.12	30.98	32.93
$CBOD_5$	Annual Average	23,327	23,112	24,833	22,239	22,894
	Maximum Month	30,851	29,025	30,627	24,628	27,146
	Maximum Day	38,110	40,453	51,305	35,113	45,066
TSS	Annual Average	23,281	26,581	28,697	29,127	32,710
	Maximum Month	44,341	46,609	37,415	35,704	43,852
	Maximum Day	49,462	64,221	61,027	59,895	82,649

Table 2-5 presents a summary of the loading peaking factors adopted for this project.

Table 2-5. SWWRF Design Loading Ratios

Description	Ratio
Maximum Month Load / Annual Average Daily Load	1.30
Peak Week Load / Annual Average Daily Load	1.56
Peak Day Load / Annual Average Daily Load	1.85
Peak Hour Load / Annual Average Daily Load	2.35

Table 2-6 shows a summary of influent wastewater fractions collected during a wastewater characterization study conducted by BC. These fractions were adopted as part of this project. Additional wastewater fractions can be found in a report submitted by BC to the City on March 18, 2013 entitled *City of St. Petersburg's Southwest Water Reclamation Facility Treatment Process and Hydraulic Evaluation* and followed these ratio values.

Table 2-6. SWWRF Design Loading Ratios

Wastewater Fraction	Ratio
COD-to-$CBOD_5$	2.34
$CBOD_5$-to-TSS	0.95
VSS-to-TSS	0.84
COD-to-TKN	12.4
NH_3-N-to-TKN	0.69
COD-to-TP	85
PO_4-P-to-TP	0.45

Table 2-7 summarizes the influent criteria adopted for this analysis based on selected historical peaking factors for flow and loading conditions. It was assumed that the influent pollutant concentrations would not change in the future due to infiltration and inflow rehabilitation in the collection system or reduced water consumption. The design criteria provided assumes that there will be no new significant industrial loads and the influent wastewater will continue to be primarily domestic.

Table 2-7. Summary of Pollutant Loadings

Parameter	Influent
Temperature (°C)	
Average / Maximum Day / Maximum Month	25 (77 °F) / 31 (87.8 °F) / 28 (82.4 °F)
Minimum Month / Minimum Day	26 (78.8 °F) / 23.2 (73.8 °F)
$CBOD_5$ Load (lb/d)	
Annual Average	35,862
Maximum Month	46,621
Maximum Day	71,003
Peak Hour	89,954
TSS Load (lb/d)	
Annual Average	40,032
Maximum Month	52,042
Maximum Day	79,259
Peak Hour	100,413
TKN Load (lb/d)	
Annual Average	6,750
Maximum Month	8,775
Maximum Day	13,364
Peak Hour	16,931

Table 2-7. Summary of Pollutant Loadings	
Parameter	Influent
TP Load (lb/d)	
Annual Average	998
Maximum Month	1,298
Maximum Day	1,976
Peak Hour	2,504

2.2.2 Sludge Production Evaluation and Projections

Operational data for all the WRFs were assessed to determine the WAS production rates for each facility. Historical operational WAS for each WRF is presented in Figures 2-3 through 2-6 and summarized in Table 2-8. This table includes historical mass rates for annual average, maximum month, maximum week, and maximum day.

Table 2-9 depicts historical average sludge yield coefficients for all the facilities and compares these with theoretical values expected at the plants. The observed sludge yield values for the SWWRF and AWWRF are approximately 60 to 80% lower than the theoretical sludge yield values. Process model calibration, using the BioWin® simulator, conducted by BC during the project entitled *City of St. Petersburg's Southwest Water Reclamation Facility Treatment Process and Hydraulic Evaluation* showed that the reported WAS measurements at the SWWRF were underestimated by approximately 40%; hence, the historical values should be corrected to obtain a reliable sludge production measurement. In the case of AWWRF, no analysis was conducted to determine the reliability of the historical values since the facility would be taken out of service and the influent flow would be pumped to the SWWRF for treatment. The observed sludge yield values for the NEWRF and NWWRF are within range of the theoretical values; hence, they are assumed to be accurate.

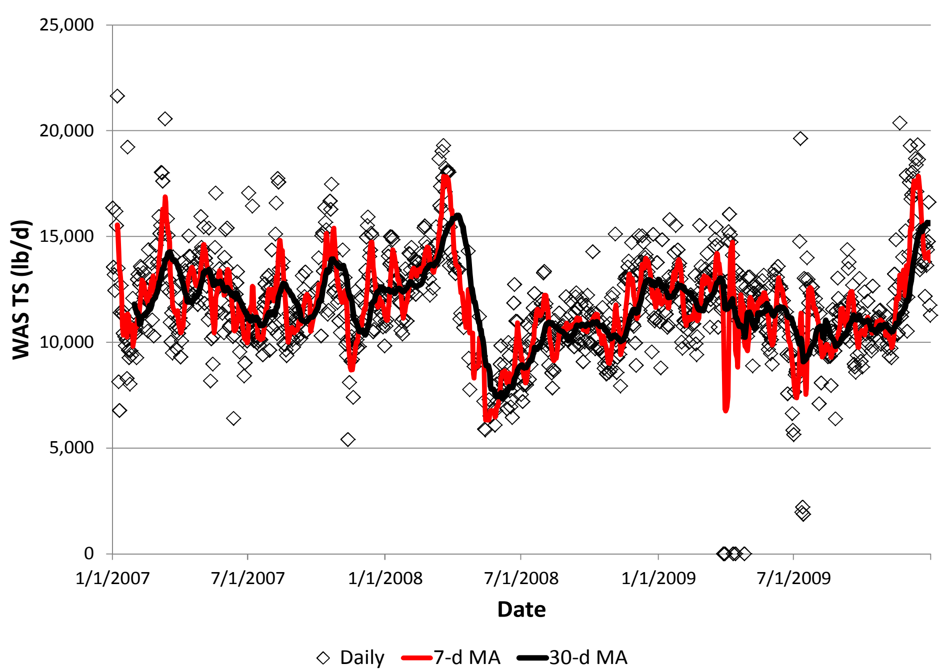


Figure 2-3. Historical WAS Production at the SWWRF

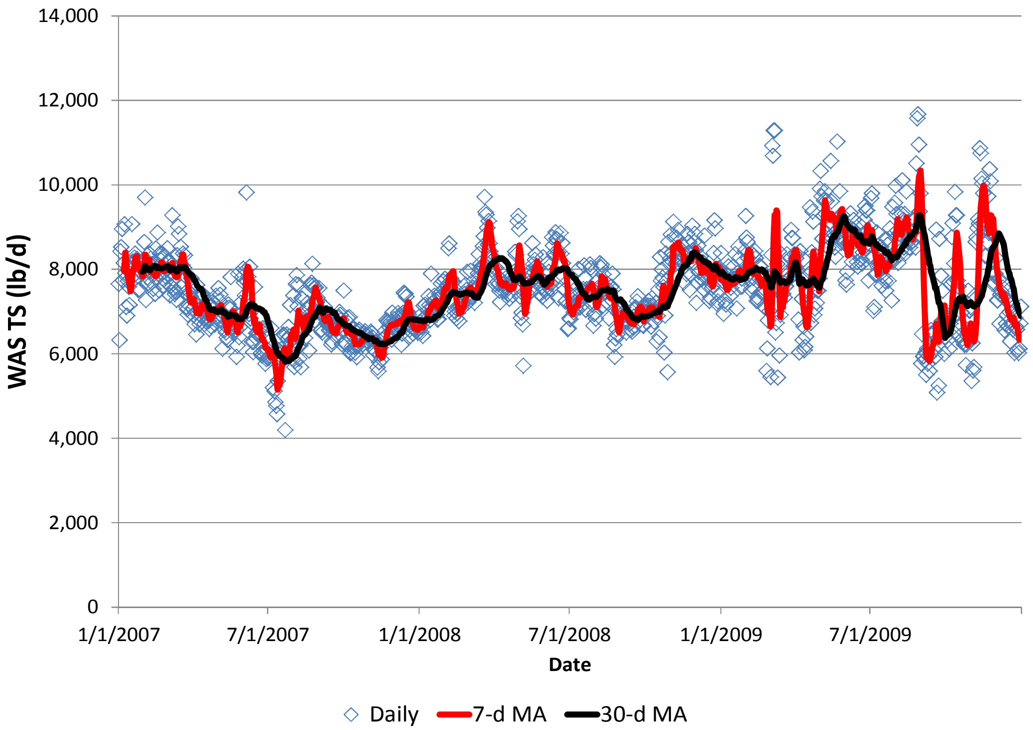


Figure 2-4. Historical WAS Production at the AWWRF

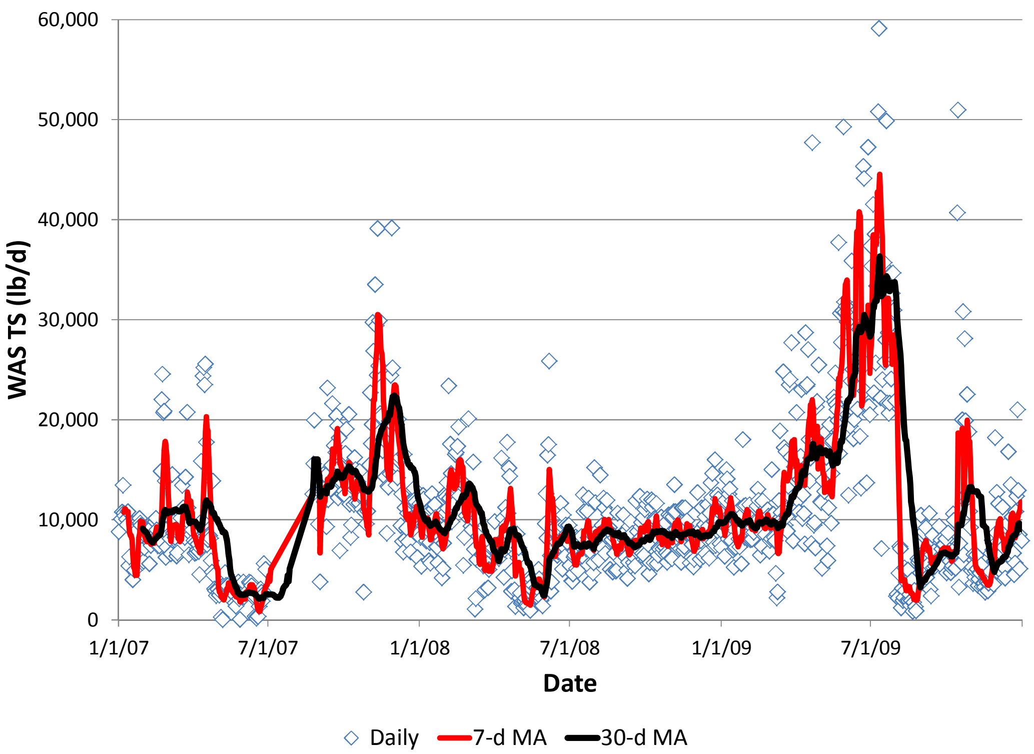


Figure 2-5. Historical WAS Production at the NEWRF

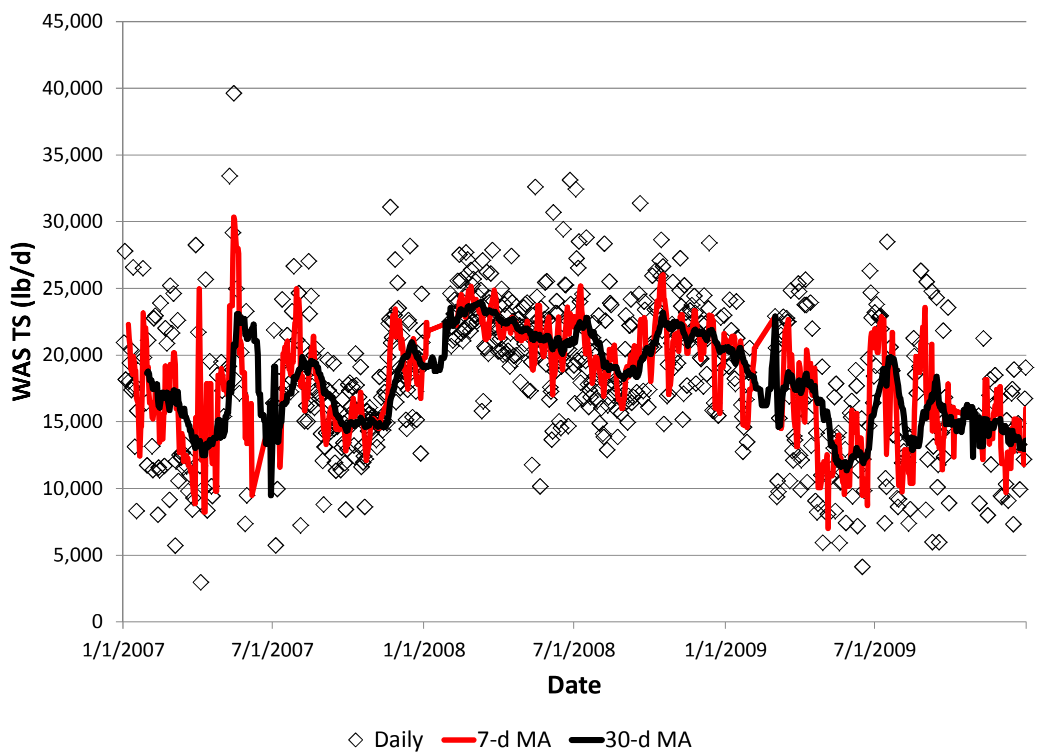


Figure 2-6. Historical WAS Production at the NWWRF

Table 2-8. Historical WAS Production Mass Rates				
Condition	WAS Production (lb/d)			
	Southwest	Albert Whitted	Northeast	Northwest
Annual Average	11,840	7,515	11,273	18,505
Maximum Month	16,003	9,283	22,433	23,977
Maximum Week	17,853	10,341	30,514	30,341
Maximum Day	21,636	11,673	39,165	39,615

Table 2-9. Historical Observed Sludge Yield Values		
WRF	Observed Yield (lb VS per lb BOD5)	Theoretical Yield (lb VS per lb BOD5)[a]
Southwest	0.53	0.8-0.9
Albert Whitted	0.65	
Northeast	1.09	
Northwest	0.9	

a. *Theoretical sludge yield coefficients for a system with a total SRT of 6 days and a wastewater temperature of 25°C.*

In order to estimate the projected sludge production rates at the SWWRF, BioWin modeling and the operational sludge production data were utilized. For the purpose of this project and as mentioned earlier in this Section, a decision was made to design the new sludge processing facilities to handle the sludge produced at the SWWRF at its rated capacity of 20 MGD. In addition, the new sludge process units would have adequate capacity to handle the WAS generated from the NEWRF and NWWRF. Table 2-10 presents the current flows to the City's WRFs and compares these values to the annual average design flows recommended during this project.

Table 2-10. Current and Design Annual Average Daily Flows

WRF	Current Flow[a] (MGD)	Design Flow (MGD)
Southwest	16.3[b]	20[c]
Northeast	8.1	11.57[d]
Northwest	9.5	10.11[d]

a. *2012 annual average daily flows.*
b. *Combined influent from SWWRF and AWWRF.*
c. *Rated capacity for the SWWRF.*
d. *2035 Projected flows for NEWRF and NWWRF.*

The calibrated BioWin model developed by BC was used to estimate the sludge production at different loading conditions to the SWWRF. These values were used as the basis of design for sizing the sludge processing units. Figure 2-7 shows the BioWin flow diagram for the SWWRF. This shows that the influent from the southwest and Albert Whitted's service areas were combined as described in the report entitled *City of St. Petersburg's Southwest Water Reclamation Facility Treatment Process and Hydraulic Evaluation - Brown and Caldwell-2013.* In addition, the BioWin model included separate WAS sources from the NEWRF and NWWRF to simulate the conveyance of WAS from these facilities to the SWWRF. For the purpose of this analysis, it was assumed that the observed sludge yield values from the NEWRF and NWWRF will remain the same as those presented. In the case of the WAS produced at the SWWRF, the calibrated BioWin model was used to estimate the biological sludge production rates at the target operational conditions. Bench-scale testing and computational fluid-dynamic (CFD) modeling was used to estimate the performance of the primary settling tanks. These results indicated that approximately 80% of the total influent suspended solids (raw and WAS) would be removed by primary clarification (provided no additional flocculation enhancement measures were incorporated).

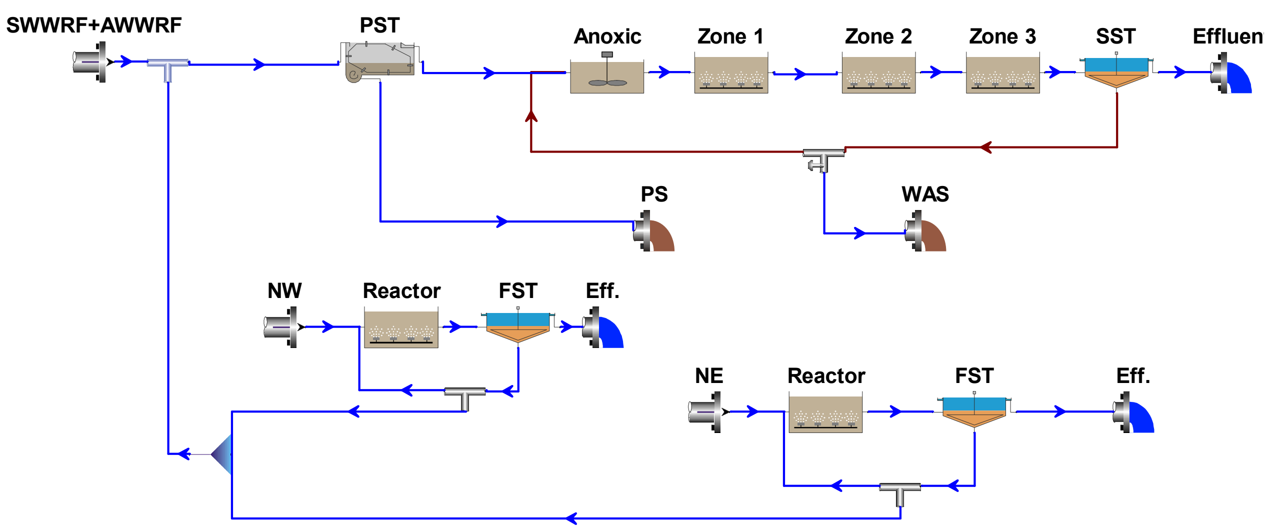


Figure 2-7. BioWin Configuration for the Liquid Treatment at the SWWRF

Brown AND Caldwell

Table 2-11 presents the primary sludge and secondary sludge production rates at varying conditions. For this, different primary settling tank efficiencies were selected ranging from 65% to 80% to account for variable performance and for possible changes in the characteristics of the WAS from NEWRF and NWWRF during the conveyance process that were not observed during the bench-scale trials. As is discussed later, ultimately, the CFD modeling results with the use of ferric addition indicated the ability for the primary treatment to reliably achieve an average removal efficiency of 80%, which was used for the purpose of this evaluation. Figures 2-8 and 2-9 show the BioWin prediction values for primary sludge and WAS for a 365-day dynamic simulation assuming a primary settling tank efficiency of approximately 80%. The BioWin prediction utilizes ideal settling characteristics without the analysis of velocity currents and other actual reactor design inefficiencies. The CFD modeling takes into account these less than ideal characteristics of a true Primary Clarifier and more accurately predicts efficiencies. As such, the efficiency in the BioWin modeling is the same as the efficiency in the CFD modeling with the addition of ferric chloride.

Table 2-11. Sludge Production Rate at Varying Clarifier Performance

PST Performance	Primary Sludge (lb/d)				WAS (lb/d)			
	Average	Max Month	Max Week	Max Day	Average	Max Month	Max Week	Max Day
65%	48,800	56,500	61,850	69,350	26,400	32,900	36,050	38,100
70%	56,150	65,200	71,350	80,050	20,900	25,800	28,400	30,300
80%	63,800	73,900	80,900	90,700	15,500	19,500	21,600	23,150

Notes: 1) Primary Sludge values do not include Ferric Addition quantities.

2) Primary Sludge and WAS production do not include Primary and Secondary Scum loads.

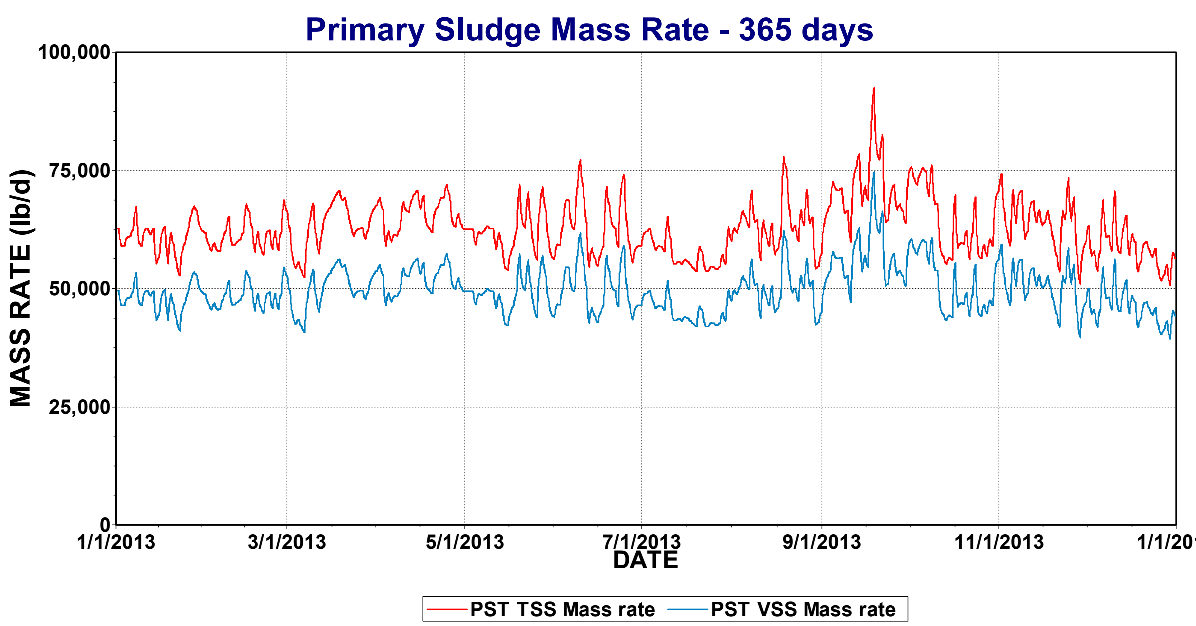


Figure 2-8. BioWin Predictions for Primary Sludge Production

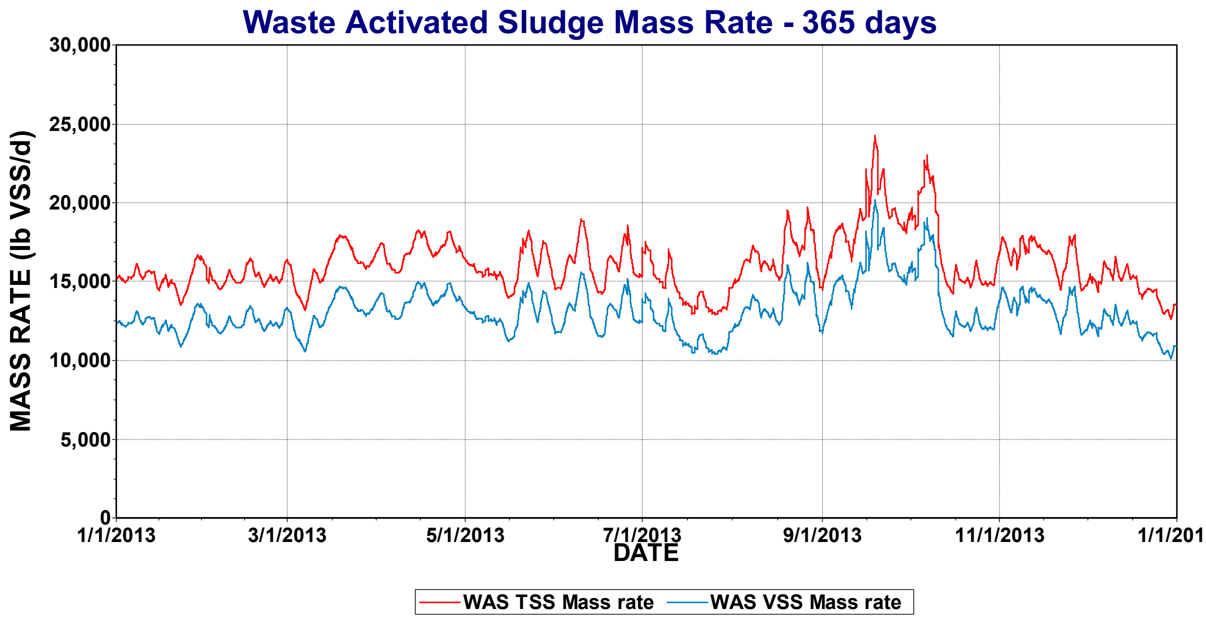


Figure 2-9. BioWin Predictions for WAS Production

2.2.3 Mass Balance Summary

Drawing G-00-45 provides a summary of the Mass Balance. Key summary values of sludge flows are provided in Table 2-12.

Table 2-12. Mass Balance of Sludge

Source	Average Day		Max Month		Peak Day		Peak Hour	
	lbs/day	gpm	lbs/day	gpm	lbs/day	gpm	lbs/day	gpm
Primary Sludge[1,3]	64,600	269	74,700	311	91,500	381	94,050	392
Primary Scum[2,3]	1,668	4.6	2,252	6.2	2,794	7.8	3,336	9.3
Secondary Sludge (WAS)[3]	15,500	129	19,500	162	23,150	193	25,050	209
Secondary Scum[2,3]	2,002	3.7	2,702	5.0	3,353	6.2	4,003	7.4
Combined Sludge[3]	83,770	406	99,154	485	120,797	588	126,439	617
Thickened Sludge[3]	79,581	110	94,196	131	114,757	159	120,117	167
GBT Underflow[3]	4,188	296	4,958	354	6,040	428	6,322	450
FOG[3]	4,500	7.5	4,500	7.5	4,500	7.5	4,500	7.5
Total to Digester[3]	84,081	118	98,696	138	119,257	167	119,257	174
Digested Sludge[3]	50,120	118	58,811	138	71,032	167	74,207	174
Press Cake[3]	47,614	--	55,870	--	67,480	--	70,497	--
Press Centrate[3]	2,506	114	2,941	133	3,552	161	3,710	168

Notes: *1) Primary Sludge values = Primary Sludge + Ferric. Primary sludge value uses 80% capture in the Primary Clarifiers.*

2) Flow for Scum is pumped several times in an hour depending on rotational speed of clarifier.

3)PS: 2.0%, PSC: 3.0%, WAS: 1.0%, SSC: 4.5%, Combined Sludge: 1.7%, THS: 6.0%, GBT Underflow: 0.12%, FOG: 50%, DS: 3.5%, Cake: 15.0%, Press Centrate: 0.18%

2.3 Hydraulic Profile

The hydraulic elements at the SWWRF were evaluated and modeled using the hydraulic modeling program PROFILE™.

A summary of the Hydraulic Profile is provided in Drawing G-00-41.

2.3.1 Hydraulic Profile Setup

The hydraulic model for the SWWRF was constructed to take a conservative hydraulic path through the facility. Specifically, the flow path used was taken through Secondary Clarifier 3 which operates at a higher hydraulic level than Secondary Clarifier 1 and Secondary Clarifier 2 due to its higher v-notch weir setting. Secondary Clarifier 3 is also located the furthest from the filters, which is the next downstream process area. The modeled flow path continues through the northern-most filter, which is also the longest path through the filter process.

The following assumptions were used in the creation of that model:

- A process unit was determined to be able to hydraulically pass the modeled flows if the unit maintained an adequate amount of freeboard during peak flows (> 1 foot) and did not submerge any flow controlling or flow splitting devices. These flow controlling or flow splitting devices include the weirs in the Aeration Basin and Secondary Clarifier Splitter Boxes and the weirs on the Secondary Clarifiers.
- All process units and trains are in service.
- The return activated sludge (RAS) flow rate was set to 20 MGD at the peak flow condition.
- In order to account for the worst case scenario of blinded filters, the hydraulic elevation in the filters was conservatively maintained at the filter overflow elevation of 115.3-feet.
- Typical yet conservative friction and minor head loss coefficients for the pipe material, pipe size, pipe age and fitting types were utilized.
- New Primary Clarifiers 1 and 2 were designed hydraulically to be capable of passing a peak hydraulic flow of 40 MGD.
- Other elements being added or modified as part of this project (piping, splitter box, step feed) were sized for a peak flow of 70 MGD.

2.3.2 Hydraulic Profile Results

For the purposes of the Biosolids to Energy Program a peak hour influent flow for the new facilities of 70 MGD was selected. While this is higher than current peak flows experienced at the plant, this will help facilitate future expansion at the plant if needed.

The results of the modeling effort showed that there are hydraulic bottlenecks both upstream and downstream of the proposed Biosolids to Energy Program facilities at the 70 MGD flow.

Upstream of the proposed facilities, a hydraulic bottleneck exists between the Headworks and the Aeration Basins where there is currently a flowmeter that is installed immediately upstream of the Aeration Basin Splitter Box. This flow meter, and its associated upstream and downstream piping and valves, are 30-inch diameter, while the remainder of the conveyance piping is 48-inch diameter. This flow meter and piping will no longer be in the primary flow path once the proposed Primary Clarifiers and its splitter box are constructed. A diagram of this part of the project is provided in Section 3.4 of this PDR. As described in Section 3.4, the reported influent flow for the SWWRF is calculated from the sum of the influent flow meters located at the Headworks and the flow meter in this 30-inch line is not utilized.

Downstream of the proposed facilities multiple hydraulic bottlenecks were identified under the 70 MGD peak hour flow condition:

- Effluent Weir Channel at Chlorine Contact Basin.
- 54-inch pipe between Filters and Chlorine Contact Basin.
- 24-inch pipe from Filter #4 to Filter #3.
- 48-inch pipe between Secondary Clarifiers and Filters.
- 48-inch pipe between Aeration Basin to Secondary Clarifiers.

Upstream of the proposed facilities the 48-inch pipe which connects the Headworks with the new pipe going to the Primary Clarifier Splitter Box is a bottleneck which at 70 MGD appears to cause flow to back up on the upstream side of the screens. However, several operational measures including opening the direct connection between the Headworks and the Aeration Basins could alleviate this without changing the pipe.

Future hydraulic improvements will be needed to allow the entire SWWRF to hydraulically pass a peak flow of 70 MGD. Since these are not yet designed, to effectively model the proposed improvements at 70 MGD, the hydraulic grade in the downstream end of the aeration basin was fixed at 122.92. That fixed elevation is the calculated hydraulic elevation in the aeration basin when passing 70 MGD of flow over its discharge weirs with the removal of downstream hydraulic bottlenecks.

2.3.3 Biosolids to Energy Program Facilities Hydraulics

The hydraulic modifications as part of this project between the Headworks and the Aeration Basin Splitter Box include the following:

- Two Primary Clarifiers.
- Primary Clarifier Splitter Box including flow splitting for:
  - Primary Clarifiers.
  - Step-feed to Aeration Basins.

The Primary Clarifier Splitter Box will first serve to evenly distribute the flow between the Primary Clarifiers. This will generally be up to 40 MGD of the influent. The primary flow path for the primary effluent is over a weir and into the head of the Aeration Basin Splitter Box. Beyond 40 MGD, influent flow will overflow a bypass weir for return along with the effluent from the Primary Clarifiers to the aeration basins, thereby bypassing the Primary Clarifiers.

When flows exceed 40 MGD, the primary effluent and influent flow bypassing the Primary Clarifiers can be directed to three potential locations. The primary flow path is to the head of the Aeration Basin Splitter Box, as discussed previously. As flows increase, up to 25 MGD of flow can be step-fed into the second zone of the aeration basin using a modulating weir gate that adjusts according to the metered flow coming into the Primary Clarifier Splitter Box and the measured flow being sent to the Aeration Basin Splitter Box. A third flow path will be for the highest flow periods and up to 25 MGD of flow can be sent to the third aeration zone for contact stabilization. An overflow weir gate will control the amount of flow sent to contact stabilization.

At 70 MGD, approximately 30 MGD would be sent through the primary flow path to the front of the aeration basins with the other 40 MGD being split between the step feed and contact stabilization flow paths. The proposed and potential flow splits to the three feed points are discussed in greater detail in Section 3.

Section 3

Processes

A review of each of the plant processes is provided in this section. Not all the processes are affected by the Biosolids to Energy Program. When a process is not affected a brief overview of the process is provided for reference purposes. When a process is affected, a review of the existing processes is provided followed by a review of the proposed modifications or new processes.

Note that some of the improvements indicated are part of the Biosolids Improvements Program but not part of the Biosolids to Energy Project. The improvements which are part of other projects (the Engine Project, the Thickening Project, and the Dewatering Project, or the WAS Transfer Projects) are only briefly mentioned here and are more thoroughly described in their respective Preliminary Design Reports.

Included in Appendix A of this PDR are key project design drawings for the Biosolids to Energy Project. These drawings form an integral part of the PDR and are referenced throughout this document.

Provided first in this section is a general overview of the existing facilities followed by a general overview of the new facilities. Following these overviews a brief summary of reliability strategies for the new processes is presented. Finally, summaries of the processes including the proposed improvements are provided. The process areas are grouped into the following categories:

- Preliminary Treatment (Influent Pumping and Headworks),
- Primary Treatment (not part of the existing treatment processes),
- Secondary Treatment, Tertiary Treatment, Disinfection and Effluent Pumping,
- Thickening,
- Anaerobic Digestion and Batch Tanks,
- Digester Gas Handling,
- Digester Gas Upgrading and Final Compression,
- Dewatering and Dewatered Sludge Handling,
- Side stream Handling,
- Supplemental Feedstock Facility,
- Odor Control Systems, and
- Supporting Processes.

3.1 General Overview of Existing Facilities

The SWWRF is located at 3800 54th Avenue South. Originally constructed in the 1950s as a primary treatment plant, the facility has undergone major expansions and upgrades over the last 60 years. Today, the SWWRF provides preliminary treatment, secondary treatment, effluent filtration, and disinfection. Final effluent is distributed as reclaimed water to a public access urban reuse irrigation system and is provided to Eckerd College for use as cooling water. Deep-well injection is used as the backup effluent disposal method.

In general, the existing liquid treatment facilities at the SWWRF include influent screening; grit removal; activated sludge process and secondary clarification; deep bed filtration; and disinfection with sodium hypochlorite. The plant is permitted for an annual daily flow of 20 MGD. The plant recently underwent a re-permitting process where aeration basin modifications were performed which allowed the plant to decommission the “old plant” while maintaining its 20 MGD average daily flow permitted capacity.

Residuals treatment previously included gravity belt thickening (GBT), anaerobic digestion, and dewatering by belt filter presses. Residuals had historically been treated to Class-B standards and land applied by a contract hauler. However, in July, 2012 the plant switched to a lime stabilization process to produce a Class-A biosolids and the low heavy metal levels of the sludge allow for a Class-AA rating. The process is based on a system developed by Schwing Bioset. The plant leases equipment from Schwing Bioset and has temporarily modified the residuals handling processes such that the GBT system is not used. WAS is pumped from the WAS holding tank to the belt filter presses (BFP) and then conveyed to the Schwing Bioset lime stabilization process. From that process, contract haulers final dispose of the stabilized Class-AA sludge by land application.

Figure 3-1 provides an aerial view of the existing SWWRF with the major process units identified. Figure 3-2 provides a simplified process flow schematic for the existing treatment facility. Table 3-1 provides a summary of the design data for the major existing unit processes at the treatment facility.

The following key drawings provide additional detail regarding the existing and the proposed facilities.

- G-00-11: Existing and Demolition Process Flow Diagram 1 – Liquid Stream
- G-00-12: Existing and Demolition Process Flow Diagram 2 – Solids Stream
- G-00-21: New Process Flow Diagram 1 – Liquid Stream
- G-00-22: New Process Flow Diagram 2 – Solids Stream
- G-00-32: Gas Process Schematic
- G-00-33: Foul Air Process Schematic
- G-00-41: New Hydraulic Profile
- C-01-00: Civil/Paving and Grading Key Plan

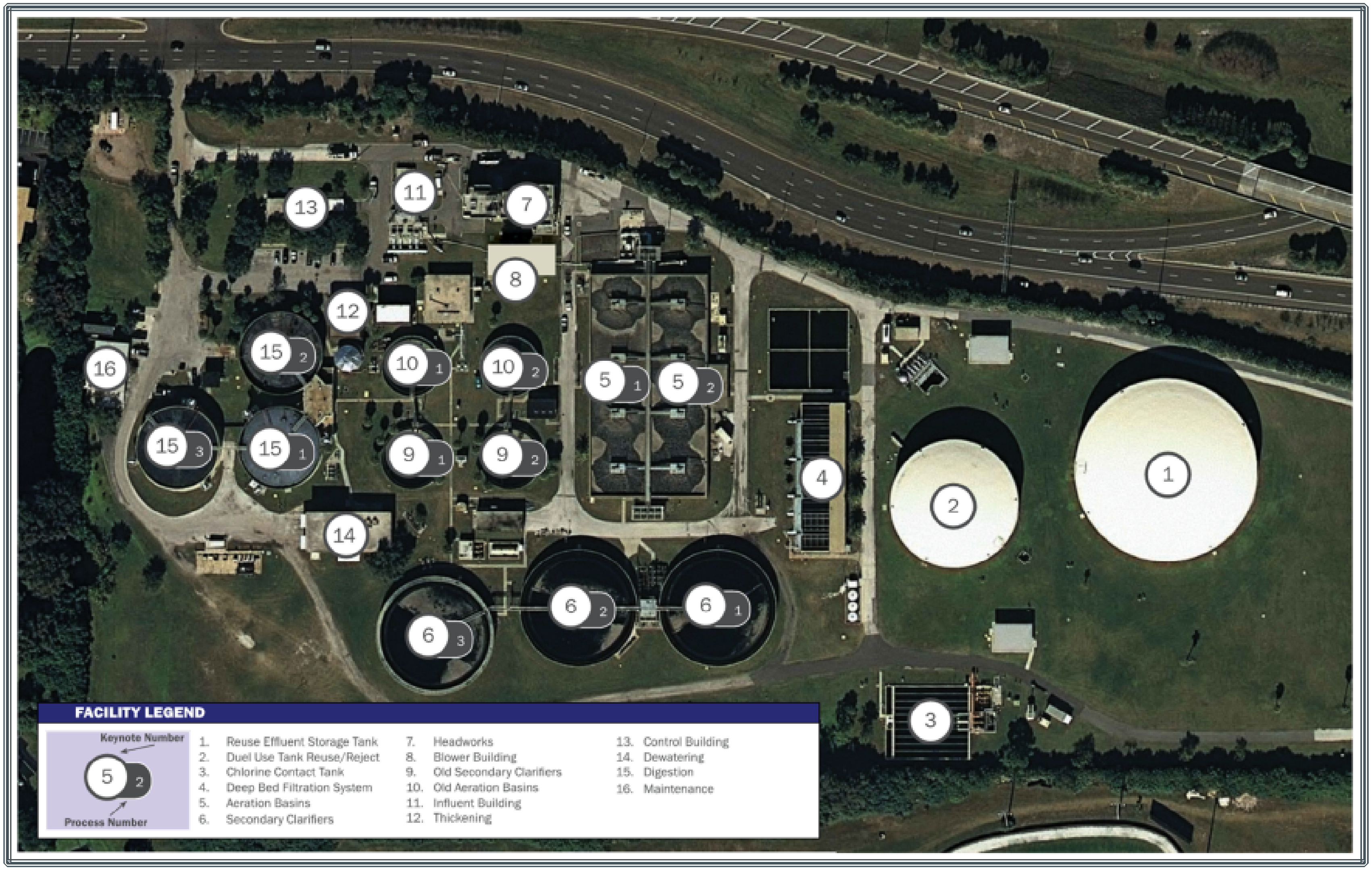


Figure 3-1. Aerial View of the Existing Facilities at the SWWRF

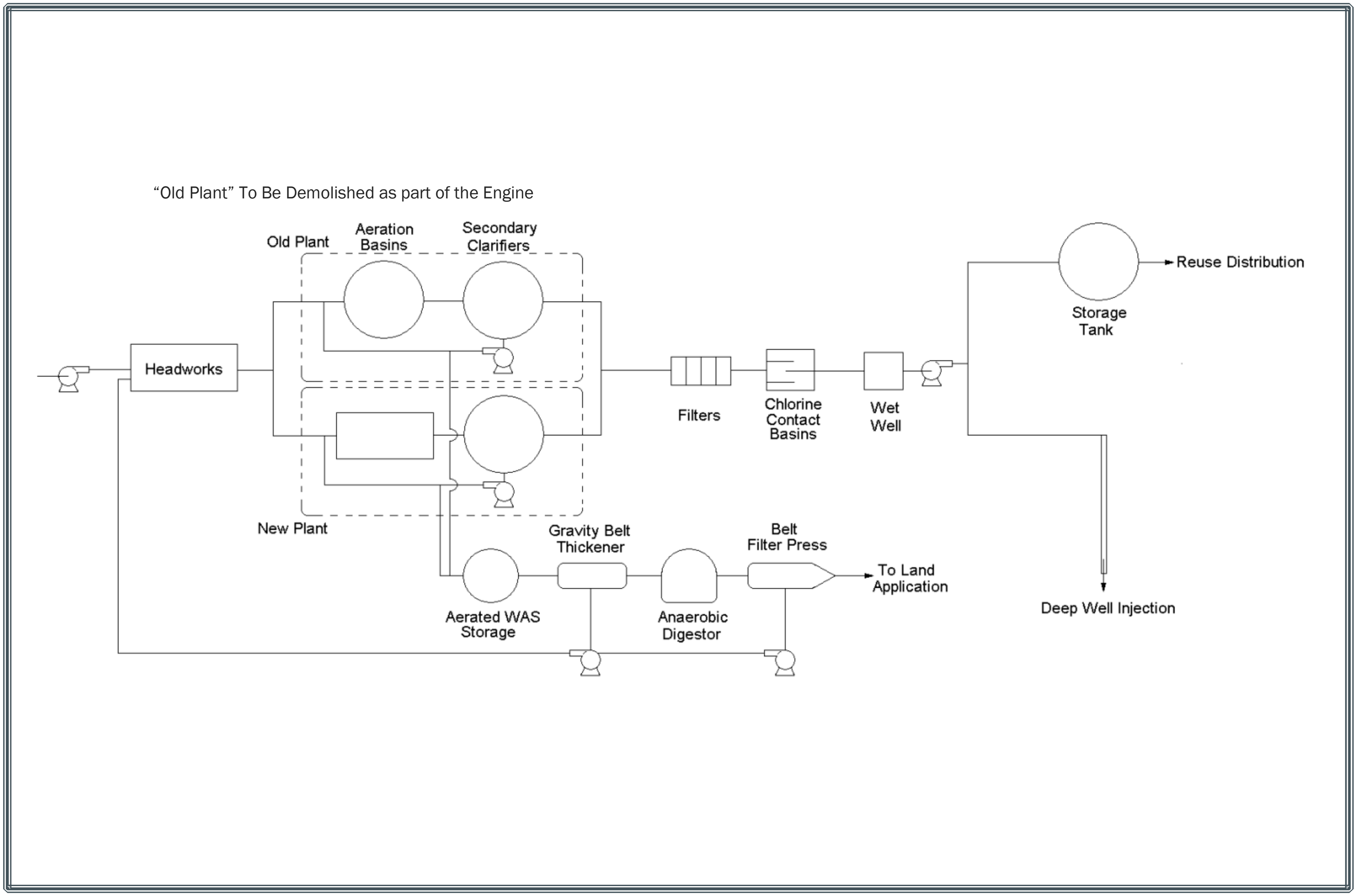


Figure 3-2. Simplified Existing Process Flow Diagram for the SWWRF

Table 3-1. Summary of Existing Unit Processes at the SWWRF

	Parameter	Unit	Value	Notes
Preliminary Treatment				
Mechanical Screens	Coarse Screens	Number	2	Located in the influent wet well
	Fine Screens	Number	2	Located in the headworks structure
Influent Pumping	Submersible Pumps	Number	4	
	Horsepower	HP	150	
Grit Removal	Low Energy Centrifugal	Number	2	
Secondary Treatment				
Aeration Basins	Number of Basins	--	2	Rectangular
	Dimensions (L x W x D)	ft	268 x 67 x 15	
	Total Reactor Volume	MG	4.03	
Secondary Clarifiers	Number	--	3	Circular
	Diameter	ft	135	
	Side Water Depth (SWD)	ft	12 (#1 &#2) – 15 (#3)	Old clarifiers and the new clarifier has different SWD
	Total Clarifier Volume	MG	3.85	
	RAS Pump Capacity	GPM	3 pumps at 4200	
Secondary Effluent				
Deep Bed Filtration	Number of Filters	--	4	
	Dimensions (L x W x D)	ft	38 x 37 x 9	
	Total Filter Area	ft^2	5,624	
Disinfection	Number of CCT's		2	Uses liquid sodium hypochlorite
	Dimensions (L x W x D)	ft	88 x 103 x 7	
	Total Volume	ft^3	126,896	
Reclaimed Water Storage	Number of Tanks	--	2	
	Volume	MG	5, 10	
Effluent Pumping	Pumps	Number	5	
	Capacity	MGD	39.6	
Deep Wells	Capacity	MGD	27	
Solids Handling Processes				
Sludge Holding Tank	Number of Tanks	--	1	
	Volume	Gal	110,000	
Gravity Belt Thickener	Number of Units	--	1	
	Size	meter	2	Currently not operating
Anaerobic Digestion	Number of Tanks	--	3	Currently not operating
	Diameter	ft	100	
	Side Water Depth	ft	22.5	At high level
	Volume	MG/each	1.3	
Belt Filter Press	Number of Units	--	2	
	Size	meters	2	Belt width

Notes: 1. Temporary Class-A Schwing Bioset system not included.

Operation of the SWWRF treatment and disposal facilities is subject to state and federal regulations stated in FDEP Operating permit FLA 128848-016-DWI/MR.

Table 3-2 summarizes the effluent quality standards for reuse and land application system as stated in the existing operating permit.

Table 3-2. SWWRF Effluent Quality Standards for Reuse and Land Application

Parameter	Unit	Limit
Flow	MGD	20 – Annual Average
Carbonaceous Biochemical Oxygen Demand – 5 days ($CBOD_5$)	mg/L	20 – Annual Average
		30 – Monthly Average
		45 – Weekly Average
		60 – Any One Sample
Total Suspended Solids (TSS)	mg/L	5 – Any One Sample
Fecal Coliform	#/100 mL	25 (Maximum)
pH	SU	6.0 – 8.5
Nitrate (NO_3-N)	mg/L	Report Only
Total Residual Chlorine	mg/L	1 – State Minimum
		1.5 – Operating Protocol Minimum
Turbidity	NTU	2.5 – Operating Protocol Maximum

Reclaimed water which exceeds the reuse demand is disposed of through three existing Class-I high-level disinfection injection wells located at the SWWRF site. The wells have a combined permitted disposal capacity of 27 MGD. Table 3-3 summarizes the effluent quality standards for deep well injection.

Table 3-3. SWWRF Effluent Quality Standards for Deep Well Injection

Parameter	Unit	Limit
Flow	MGD	27
Carbonaceous Biochemical Oxygen Demand – 5 days ($CBOD_5$)	mg/L	20 – Annual Average
		30 – Monthly Average
		45 – Weekly Average
		60 – Any One Sample
Total Suspended Solids (TSS)	mg/L	20 – Annual Average
		30 – Monthly Average
		45 – Weekly Average
		60 – Any One Sample
pH	SU	6.0-8.5

3.2 General Overview of New Facilities

A generalized aerial of the proposed demolition associated with the Biosolids Improvement's Program is provided in Figure 3-3. This figure presents the demolition scope color coded to the two major portions of the Program. A similar color coded aerial of the proposed new facilities associated with the Program is provided in Figure 3-4.

3.3 General Reliability Strategies for Modified or New Processes

General reliability and redundancy strategies for the modified or new process units are presented in Table 3-4. Specific reliability and redundancy strategies are discussed in the individual process sections in this report.

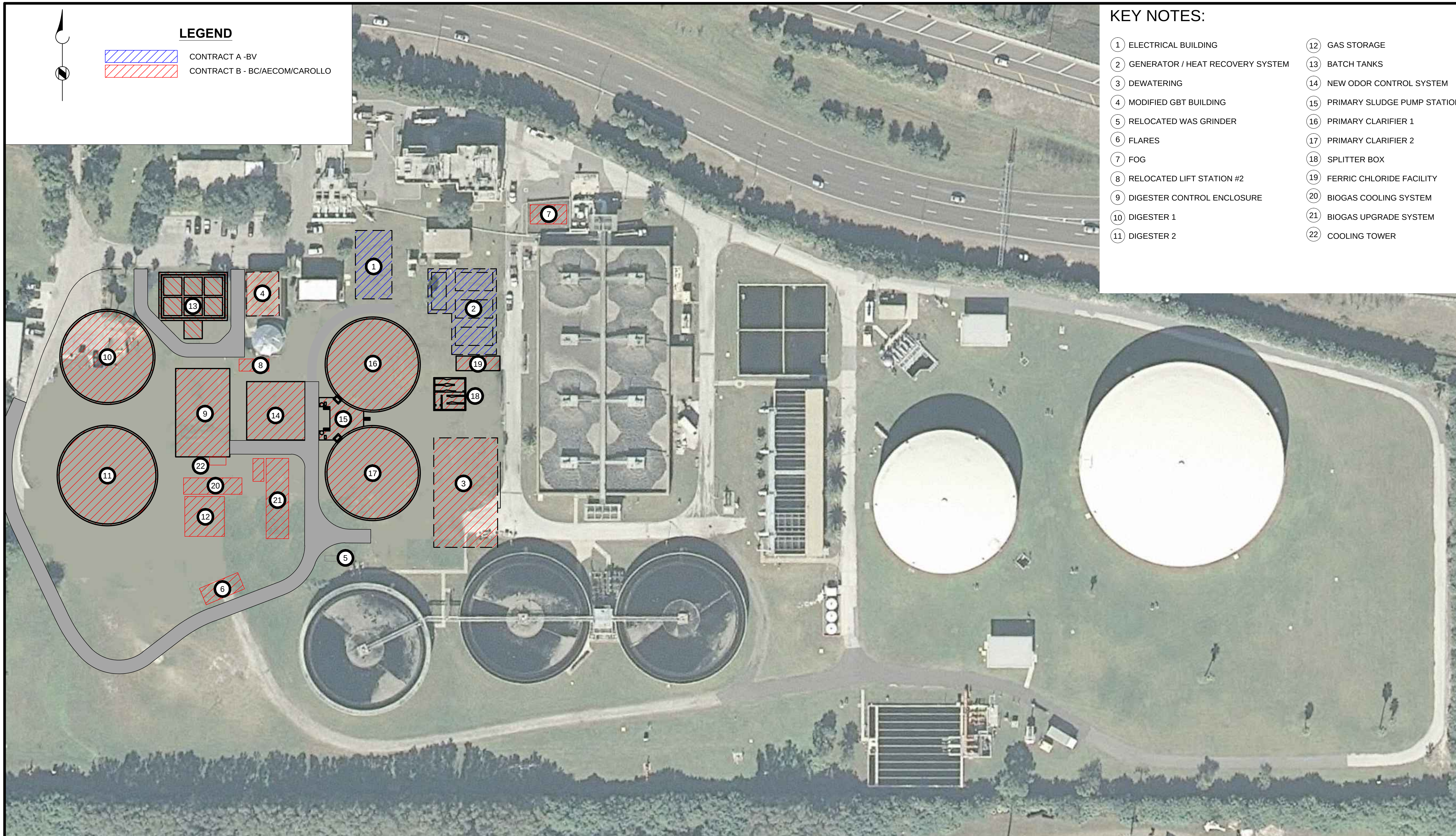
The Biosolids to Energy Project is being designed to meet or exceed Class-I reliability standards in accordance with the United States (U.S.) Environmental Protection Agency (EPA) Technical Bulletin: Design Criteria for Mechanical, Electric, and Fluid System Component Reliability as interpreted by and in accordance with guidance provided by the FDEP. Additional information regarding reliability guidelines is provided in Section 5.

Table 3-4. Reliability Summary

Unit Process or Plant Component	Reliability/Redundancy Provided
Structures	Finished first floor slabs for critical new structures are set at 1-foot above 100-year flood. Structures are designed to withstand 100-year flood in accordance to the Federal Emergency Management Agency (FEMA) guidelines.
Electrical and Mechanical Equipment	Critical new electrical and mechanical equipment are set at 1-foot above 100-year flood. Requirement is for this equipment to be located above the 100-year flood plain.
Pumping	All critical process pumping systems are designed such that each set has an on-line redundant pump providing n+1 redundancy.
Chemical Feed Systems	Tankage is designed for one month storage for peak month conditions and pumping is provided in accordance with the pumping reliability standard and peak day demand conditions.
Influent Pumping	Not affected by this project.
Headworks	Not affected by this project.
Primary Clarification	Primary Clarifiers are designed to operate at target capture rates for up to 40 MGD which is the plant peak hour flow with both in service. With one Primary Clarifier in service, target capture rates will be maintained for 20 MGD which is the SWWRF permitted AADF. Primary Clarifier sludge pumping is provided in accordance with pumping reliability standards and peak hour requirements.
Odor Control	New odor control system will provide odor control for Primary Clarifier Splitter Box, Primary Clarifiers (2), WAS Storage Tank and Thickening Building. System is provided with a redundant fan and a redundant carbon polishing unit. Carbon polishing units back up the primary system which is a biotrickling filter. It should be noted that under a separate project (and PDR) the odor control system for the Solids Dewatering is addressed.
Aeration Basins	Process flexibility is being added to allow for Step Feed of a portion of the forward flow to the central aeration zones and Contact Stabilization (for extreme high flow periods) of a portion of the forward flow to the final portions of the aeration zones.
Secondary Clarification	Not affected by this project.
Tertiary Filters	Not affected by this project.
Disinfection	Not affected by this project.
Effluent Handling (Reuse and Disposal)	Not affected by this project.
Solids Thickening	Under the Solids and Dewatering Project, this system is being modified to add a 2^{nd} gravity belt thickener and associated support equipment.

Table 3-4. Reliability Summary	
Unit Process or Plant Component	**Reliability/Redundancy Provided**
Solids Digestion and Batch Tanks	Digester 1 (new) is a thermophilic digester only and Digester 2 (Mesophilic and new) can be operated as the first digester in the digester train and in Thermophilic mode if Digester 1 is out of service. Digester 1 is a fixed volume digester but can be operated in variable mode if required. Digester 2 is a variable volume digester. A redundant thermophilic HEX is provided in the event that a thermophilic HEX is out of service. A redundant Batch Tank is provided to the Batch Tank system which provides batch time and temperature requirements. Temperature buffer is added to the Batch Tanks such that design is calculating losing 2°F in the Batch Tanks (at peak winter condition); however, the system will be able to lose up to 4°F in the Batch Tanks before falling out of time and temperature compliance (131°F for 24 hours). (Note this is at peak day sludge production) All critical transfer pump stations and recirculation pump stations are provided with a duty and standby pump and are sized to pump the peak hour flow. Digesters are provided with a redundant draft tube mixer.
Solids Dewatering	Under the Dewatering Project this system is being modified to discontinue the use of the belt filter presses and install four new screw presses (3 duty and one redundant) designed to operate on a continuous basis. The dewatering system also includes solids storage of approximately 24 hours at average daily sludge production in Digester 2.
Gas Handling and Flares	One enclosed flare will be provided. The flare is designed for the16-inch pressure zone (nominal pressure) for the new Digesters 1 and 2. The flare will serve in duty operation with a low amount of flared gas when most gas flow is being sent to the gas upgrade system. The flare will also serve for high gas flow for cases when the gas upgrade system is not operating. System includes gas storage in a Gas Storage Tank on the 16-inch pressure zone to account for instantaneous gas production drops and spikes. A storage volume of approximately 30 minutes at startup year average gas production will be provided.
Supplemental Feedstock Receiving Facility	System is designed to receive not only FOG but other pre-processed (screened/pulped) alternative feed-stocks. This system is not process critical and will be provided with minimal redundancies.
Gas Upgrade System	This system is not process critical and will be provided with minimal redundancies. System includes processed gas storage and buffering to provide for continuous operation when the system is operating.
Plant Lift Station 1	Not affected by this project.
Plant Lift Station 2	Station will be moved but will not be functionally modified. Existing station is provided with a duty and redundant pump. New station will add a third pump to enhance reliability.


LEGEND
CONTRACT A -BV
CONTRACT B - BC/AECOM/CAROLLO
KEY NOTES:
1 OLD RAS/WAS PUMP STATION
2 OLD AERATION BASIN 2
3 OLD CLARIFIER 2
4 OLD AERATION BASIN 1
5 OLD CLARIFIER 1
6 OLD WET WELL PUMP BUILDING
7 OLD CHLORINATOR AND CYLINDER STORAGE BUILDING
8 TRANSFER PUMP STATION
9 ALUM BUILDING (DEMO BY CITY)
10 ODOR CONTROL SYSTEM
11 SLUDGE DEWATERING BUILDING
12 DIGESTER HEADHOUSE
13 ANAEROBIC DIGESTER #2
14 ANAEROBIC DIGESTER #1
15 AERATION BASINS
16 SECONDARY CLARIFIERS
17 FILTERS
18 WASHWATER RECOVERY BASIN
19 CHLORINE CONTACT BASINS
20 5.0MG GROUND STORAGE TANK
21 10.0MG GROUND STORAGE TANK
22 DIGESTER #3



LEGEND
CONTRACT A -BV
CONTRACT B - BC/AECOM/CAROLLO
KEY NOTES:
1 ELECTRICAL BUILDING
2 GENERATOR / HEAT RECOVERY SYSTEM
3 DEWATERING
4 MODIFIED GBT BUILDING
5 RELOCATED WAS GRINDER
6 FLARES
7 FOG
8 RELOCATED LIFT STATION #2
9 DIGESTER CONTROL ENCLOSURE
10 DIGESTER 1
11 DIGESTER 2
12 GAS STORAGE
13 BATCH TANKS
14 NEW ODOR CONTROL SYSTEM
15 PRIMARY SLUDGE PUMP STATION
16 PRIMARY CLARIFIER 1
17 PRIMARY CLARIFIER 2
18 SPLITTER BOX
19 FERRIC CHLORIDE FACILITY
20 BIOGAS COOLING SYSTEM
21 BIOGAS UPGRADE SYSTEM
22 COOLING TOWER

3.4 Preliminary Treatment

The following presents a review of the existing preliminary treatment facilities and any new or modified facilities which are a part of the Biosolids to Energy Project.

3.4.1 Description of Existing Facilities

The preliminary treatment facility at the SWWRF consists of mechanical bar screening, and grit removal units located in the headworks structure. The influent comes to the headworks structure directly from multiple operational forcemains as listed below (listed from North to South as they enter the Headworks structure):

- Lift Station 1. Plant pump station for process drains for the eastern half of the plant.
- Lift Station 28. Collection system pump station located off the facility.
- Lift Station 2. Plant pump station for process drains and stormwater for selected areas for the western half of the plant.
- Influent Pump Station. Plant influent pump station which receives flow from the primary incoming gravity interceptor.
- Albert Whitted Pump Station.

The SWWRF reports the influent flow by adding the flow for the Influent Pump Station, Lift 28 and the Albert Whitted Force Main (FM). For additional details on general process flows in the plant, refer to the process flow schematic in Drawing G-00-11.

3.4.2 Proposed Facilities

The modifications to the preliminary treatment system involve connecting the proposed Primary Clarifier System with the pipe which transfers flow from the Headworks to the Aeration Basin Splitter Box. Figure 3-5 illustrates this connection and bypassing capability. Effluent from the Primary Clarifiers will be connected an existing tee at the Aeration Basin Splitter Box.

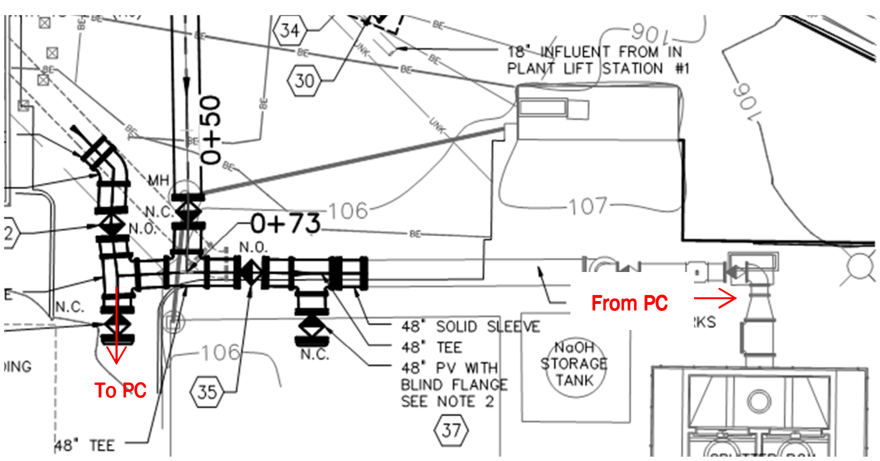


Figure 3-5. Tie in to Pipeline from Headworks to Aeration Basin Splitter Box

Reference also the following key drawings:

- G-00-21: New Process Flow Diagram
- I-19-10: Primary Clarifier Splitter Box (PID)

3.5 Primary Treatment

The following presents a review of the existing primary treatment facilities and any new or modified facilities which are a part of the Biosolids to Energy Project.

3.5.1 Description of Existing Facilities

The facility currently does not have primary treatment.

3.5.2 Proposed Facilities

The proposed new facilities consist of the Ferric Chloride Addition, Primary Clarifier Splitter Box, Primary Clarifiers, and the Primary Sludge and Scum Pump Stations.

3.5.2.1 Ferric Chloride Addition System

The following describes the key development information, features, design data and operations and control narrative for the Ferric Chloride Addition System. Reference also the following key drawings:

- G-00-21: New Process Flow Diagram

3.5.2.1.1 Key Development Information, Features and Design Data

The Ferric Chloride Addition System includes the following features and Table 3-5 summarizes the critical process data.

- Ferric chloride will be added to aid coagulation and settling in the Primary Clarifiers. The design dose is 5 mg/L as ferric chloride ($FeCl_3$). The chemical addition point will be prior to the Primary Clarifier Splitter Box. Mixing will be accomplished within the Primary Clarifier Splitter Box. The use of this portion of the ferric chloride addition system will be dependent on Primary Clarifier effectiveness and a balance between ferric chloride addition costs and the benefits of capturing additional sludge and thereby creating additional digester gas. A likely scenario with this system is that during lower flow periods of the day, no ferric addition will be added and during the diurnal peaks ferric will be added to aid with Primary Clarifier capture. Operational experience will eventually dictate the actual dose and timing for this ferric addition dosing point.
- Ferric chloride will also be added to the thickened sludge feed piping to Digester No. 1, downstream of the heat exchangers. The purpose of this addition is twofold. The primary purpose is for reduction of hydrogen sulfide (H_2S) in order to prevent corrosion in the downstream components. The secondary purpose is for the prevention of struvite formation. In order to reduce H_2S concentration of 3,300 mg/L (by volume) (Reference 3.9.3), a dose of 586 mg/L of ferric chloride (as $FeCl_3$) would be added. This dose includes 7:1 ratio over the stoichiometric dose needed to oxidize H_2S. This excess would also be available for struvite control. Similar to the Primary Clarifier application point, the use of this ferric addition point will be subject to operational experience once installed. The control of H_2S gas in the digester gas is desired in order to add longevity to the digester gas handling and upgrading equipment; however, the exact quantity of H_2S in the digester gas is difficult to predict. Reference Section 3-9 for additional information regarding predicted H_2S in the digester gas. The minimum required dose to control struvite is estimated to 586 mg/L (where mg is ferric chloride and liters is thickened sludge feed to the digester) and is dependent on the Thickened Sludge Flow and Total Phosphorus content in the sludge. Since the only the stoichiometric portion of the hydrogen

sulfide dose (i.e. 1/7th of the calculated 586 mg/L dose) is actually consumed in the sulfide oxidation reaction, the remainder would be available for struvite control. With that in mind, the total dose for both hydrogen sulfide and struvite control would be 622 mg/L ferric chloride applied to the TWAS.

- The capacity of the metering pumps are based upon the aforementioned dosages applied to a flow rate of 70 MGD in order to establish the maximum pump capacity. Using a hydraulic diaphragm metering pump will allow for a 100:1 turndown, which is more than adequate for the anticipated minimum flow rates.
- Fiber reinforced plastic (FRP) bulk storage tanks are sized based upon providing a minimum of 30 days storage at average flow. Double wall construction is specified in order to provide secondary containment without the need for a large concrete containment structure. However, a 6-inch concrete containment curb is provided around the perimeter of ferric chloride storage and slab level in order to contain minor spills and leaks.

Table 3-5. Ferric Chloride Addition System - Key Design Data

Element	Design
Ferric Chloride Bulk Storage Tanks	
Type	Double-Wall FRP
Capacity, Each	7,400 Gallons (14800 Gallons Total)
Storage Criteria	30 Days, Maximum Month
Primary Clarifier Metering Pumps	
Number	1 (With One on-the-Shelf Spare)
Type	Hydraulic Diaphragm Metering Pump- Skid-Mounted
Capacity	0.36-36 Gallons/Hour
Demand	7-37 Gallons/Hour
Digester Metering Pumps	
Number	1
Type	Hydraulic Diaphragm Metering Pump- Skid-Mounted
Capacity, Each	0.19-19 Gallons/Hour
Demand	4-19 Gallons/Hour

3.5.2.1.2 Operation and Control Narrative

Ferric chloride bulk solution will be delivered in 30-40% (by weight of $FeCl_3$) via tanker truck. Ferric chloride will be unloaded into the tanks via a polyvinyl chloride (PVC) fill line that will have a bag filter to capture impurities prior to it entering the tanks.

A system local control panel will provide tank level monitoring and high level alarms visible and audible to the delivery personnel as well as to the plant supervisory control and data acquisition (SCADA) system. The local control panel will also provide power and control information to the metering pump skids. The control panel will have local/remote control, start/stop, and common trouble alarms for both sets of pumps.

The pumps skids will be prefabricated/assembled simplex units containing the valves, calibration columns, pump manifold piping and other appurtenances. Each skid will be dedicated to their respective applications, one skid for the Primary Clarifier feed, and the other for the Digester feed.

Ferric chloride solution will be conveyed to the application points via Schedule 80 PVC piping. The pumps will be flow-paced from the influent flow meter for the Primary Clarifier feed, and the thickened sludge feed for the digester feed. Normal operation will be automatic based upon these flow-pacing signals, although local and/or manual control will be provided as a back-up. Additional cross-connect piping and isolation valves will allow either metering pump skid to feed either dosing location.

3.5.2.2 Primary Clarifier Splitter Box

The Primary Clarifier Splitter Box consists of two sides. The north side receives flow from the Headworks and divides that flow equally to the two new Primary Clarifiers using two identical cutthroat flumes. The north side also has an overflow controlled by a manual weir gate that allows some or all of the flow from the Headworks to bypass the Primary Clarifiers and pass to the south side of the splitter box. The south side of the splitter box receives Primary Clarifier effluent is directed to up to three flow paths. The primary flow path is to the Aeration Basin Splitter Box. This primary flow stream has been designed for up the 40 MGD peak flow. Beyond 40 MGD, the splitter box would divert flow downstream zones in the aeration basins. The second flow path is to the Step Feed discharge in the beginning of the second aeration zone of the aeration basins. The third flow path is to the Contact Stabilization discharge points located in the beginning of the third aeration basin zone.

The flow paths discussed for the Primary Clarifier Splitter Box are shown schematically on drawings G-00-21, New Process Flow Diagram, and I-19-10, Primary Clarifier Splitter Box PID.

3.5.2.2.1 Key Development Information, Features and Design Data

The Primary Clarifier Splitter Box includes the following features and Table 3-6 summarizes the critical process data.

- Two cutthroat flumes for flow split to the Primary Clarifiers, (6-ft Entrance, 4-ft Throat) with isolation gates at flume mouth.
- Overflow 8-foot weir gate to bypass Primary Clarifiers.
- Overflow 24-foot weir to Aeration Basin Splitter Box.
- 6-foot weir gate controlling flow to Step Feed.
- 6-foot weir gate controlling flow to Contact Stabilization.

Table 3-6. Primary Clarifier Splitter Box - Key Design Data

Element	Design
Overall Dimensions (Length x Width x Height)	35.25-ft by 36.00-ft by 25.00-ft
Flow Split to Primary Clarifiers	50/50 Flow Splitting using Cut-Throat Flumes
Flume Dimensions to Primary Clarifiers	6-ft Entrance, 4-ft Throat
Maximum Flow to Primary Clarifiers	20 MGD (each), 40 MGD (combined). Above this flow, Screened Raw Sewage (SRS) entering the Primary Clarifier Splitter Box will overflow into the Primary Effluent side of the Splitter Box for transfer to the Aeration Basins.
Primary Clarifier Inlet Flume Isolation Gate Dimensions	6-ft wide by 4-ft tall
Weir Length to Aeration Basin Splitter Box	24-ft
Weir Gate to Step Feed / Contact Stabilization	6-ft wide by 2.5-ft tall / 6-ft wide by 2.5-ft tall
Maximum Flow to Aeration Basins [a]	40 MGD
Maximum Flow to Step Feed [a]	25 MGD
Maximum Flow to Contact Stabilization [a]	25 MGD

a. *The sum of the individual flow capacities exceeds the peak hourly flow of 70 MGD. At 70 MGD flow, it is proposed that 30 MGD be sent to the head of the aeration basin with 20 MGD to step feed and 20 MGD to contact stabilization.*

3.5.2.2.2 Operation and Control Narrative

The north side of the Primary Clarifier Splitter Box splits flow automatically using two identical cutthroat flumes. The cutthroat flumes will equally divide flow to each clarifier.

The south side of the Primary Clarifier Splitter Box diverts flow to the Step Feed using the water elevation upstream of the cutthroat flume to the Aeration Basin to calculate the amount of flow going to that flow path. The weir gate controlling the flow to the Step Feed will be automatically adjusted to send a set ratio of total flow, as measured by the influent flow meter, to the Step Feed. Operators will be able to set the ratio of Step Feed flow to total flow through the control system. The weir to the contact stabilization will be manually set to allow overflow to the Contact Stabilization discharge point during high flows.

3.5.2.3 Primary Clarifiers

The following describes the key development information, features, design data and operations and control narrative. Reference also the following key drawings:

- G-00-21: New Process Flow Diagram
- I-21-10: Primary Clarifier 1 PID
- I-22-10: Primary Clarifier 2 PID

3.5.2.3.1 Key Development Information, Features and Design Data

The Primary Clarifiers include the following features and Table 3-7 summarizes their key design data.

- Bench-scale testing of Primary Clarifier performance was conducted to simulate the proposed transfer of WAS from the NEWRF and the NWWRF to the SWWRF. Settleability tests conducted at the SWWRF indicated that the combined raw sewage from the SWWRF and the AWWRF and the WAS constituent from the NEWRF and the NWWRF that approximately 80% TSS removal efficiency and 50% COD removal efficiency could be achieved under ideal conditions.
- Primary Clarifiers were modeled using a CFD model to test varying diameters, depths and internal configurations to determine removal efficiencies versus ideal conditions.
- The optimum diameter determined was 100-feet with only minor TSS removal efficiencies gained by increasing the diameter to 120-feet. The optimum sidewater depth was 14-feet with degrading efficiencies with a sidewater depth less than 14-feet and greater than 14-feet. The center-well configuration was also modeled and the optimum diameter and depth were determined to be 25-feet and 5-feet, respectively. The use of perimeter baffling was modeled and was found to provide only minimal benefit and was thus not contemplated further.
- Utilizing the optimum design conditions mentioned earlier, the CFD model was then used to predict 75% TSS removal efficiencies at average daily flow conditions. The addition of 5 mg/L of Ferric Chloride was modeled and enhanced the TSS removal to 85% under ideal conditions.
- A ferric addition system will be incorporated into the design and located near the Primary Clarifiers. The ferric addition system was discussed earlier in this PDR. The ferric system also serves to aid with odor control, H_2S removal in the digester gas and struvite control in the digestion systems.
- Primary Clarifiers will be covered with a pre-engineered flat aluminum cover system and the Primary Clarifiers will be odor controlled. Reference Drawing G-00-33 and the Odor Control section of this PDR.

Table 3-7. Primary Clarifiers - Key Design Data	
Element	**Design**
Number of Units	2
Diameter	100 ft
Sidewater Depth	14 ft
Total Surface Area	15,708 ft2
Center Well Diameter and Depth	25 ft / 5 ft
Launder Type	Outboard
Average/Peak Surface Overflow Rate	1,295 gpd/ft2 and 2,585 gpd/ft2
Influent Pipe	48-inches
Withdrawal/Scraper Type	Pumped Center Withdrawal/Straight Scraper
Cover Type	Flat Aluminum Cover
Target TSS Removal %	85% at AADF
Maximum Fe Addition	5 mg/L

3.5.2.3.2 Operation and Control Narrative

Each Primary Clarifier includes a local control panel provided by the collector manufacturer. The collectors are started and stopped manually at the local control panel.

If the clarifier sludge collector torque exceeds a preset point, a high torque switch opens, the drive motor stops, and an indicator light on the local panel is illuminated. The alarm is also reported to SCADA and is displayed on a graphic screen for this area. Manual reset is required.

If the clarifier sludge collector drive shear pin breaks, a switch opens and the drive motor stops. The alarm is also reported to SCADA and is displayed on a graphic screen for this area.

3.5.2.4 Primary Clarifier Sludge and Scum Pump Stations

The following describes the key development information, features, design data and operations and control narrative. Reference also the following key drawings:

- G-00-21: New Process Flow Diagram
- I-21/22-10: Primary Clarifier 1 and 2 PIDs (showing Scum Pump Station)

3.5.2.4.1 Key Features and Design Data

The Primary Sludge Pump Station and Primary Scum Pump Station include the following features and Table 3-8 summarizes their key design data.

- There is a dedicated sludge pump per Primary Clarifier with a standby which serves both Primary Clarifiers. The station is located between the two Primary Clarifiers. A grinder serves the flow from each Primary Clarifier. Two flow meters are provided to be able to measure the primary sludge being withdrawn from the two Primary Clarifiers. The primary sludge pumps include variable frequency drives (VFDs) for modulating their flow and are positive displacement rotary lobe pumps.
- The static head differential between the water surface level in the Primary Clarifiers and the range of operating levels in the WAS storage tank is very minimal. At high level in the WAS storage tank, the water surface differential is approximately 1-foot and at low level in the WAS storage tank, the water surface differential is approximately negative 5-feet. The desire to make sludge piping 6-inch minimum per good practice leads to very minimal system losses under all

cases. While low system head conditions are anticipated, the pumps will be provided with up to 75 psi pressure capabilities in order to deal with unanticipated blockages.

- There is a scum receiving pit and pump which is shared between the two Primary Clarifiers. The pump has a dedicated grinder upstream of the pump. The pump is a positive displacement rotary lobe type pump. There are not flow meters on the primary scum pump. The primary scum pump does not have VFDs.

Table 3-8. Primary Sludge and Scum Pump Stations – Key Design Data	
Element	**Design**
Primary Sludge Grinders	
Number	2 (one per PC)
Size, Max Flow, HP	6-inch, 550 gpm, 2 HP
Primary Sludge Pumps	
Number, Type	3 (one per PC and one spare), Rotary Lobe
Nozzle Size, HP, Drive	6-inch, 20 hp, VFD
Flow Range and Maximum Pressure	0-200 gpm, 75 psi
Startup Year Average Flow and Pressure Condition	100 gpm, 5 psi
Primary Scum Grinders	
Number	1
Size, Max Flow, HP	6-inch, 550 gpm, 2 hp
Primary Scum Pumps	
Number, Type	1 Rotary Lobe
Nozzle Size, HP, Drive	6-inch, 15 HP, Constant
Design Flow and Maximum Pressure	100 gpm, 100 psi
Startup Year Flow and Pressure Condition	100 gpm, 5 psi

3.5.2.4.2 Operation and Control Narrative

The Primary Sludge Pumps and Primary Clarifier Scum Pump have a combined local control panel.

The Primary Sludge Pumps may be started and stopped manually at the local control station or via SCADA. The speed of the pump may be manually set at the control panel or via SCADA. Flow meters located at the primary sludge station (one for each Primary Clarifier) report flow to SCADA. The sludge grinders are interlocked to the sludge pumps and turn on when its corresponding sludge pump is on. Initially the pumps will be set at 100 gpm upon; however, operator review of the sludge blanket accumulation tendencies will eventually set the final sludge withdrawal value. It is anticipated that over time and with seasons, the operators will adjust the set points to meet plant requirements, however, diurnal adjustments will not be made and the pumps will pump thinner sludge to the WAS storage tank on diurnal lows and thicker sludge on diurnal highs. Operators will attempt to minimize sludge blanket accumulation by taking periodic (once per shift) sludge judge measurements. This will minimize deleterious process effects which can be a result of building a blanket in the Primary Clarifiers.

Automatic valves on the suction side of the Primary Sludge Pumps close when the pump is off to mitigate swamping the WAS Storage Tank with sludge passing through the pump while not operating.

The primary scum pump may be started and stopped manually at the local control station or via SCADA. In automatic mode, the pump turns on and off based on the well level in the scum pit. The scum grinder is interlocked to the scum pump and turns on when the scum pump is on. A water flush line will feed the scum pit with a solenoid valve control set on level set points. The water flush will serve to dilute the scum initially and then serve as a momentary washing effect for the pit as the pit is drawn down.

3.6 Secondary Treatment, Tertiary Treatment, Disinfection and Effluent Pumping

The following presents a review of the existing secondary treatment, tertiary treatment, disinfection and effluent pumping facilities and any new proposed facilities which are a part of the proposed improvements.

3.6.1 Description of Existing Facilities

An abandoned secondary treatment process at the SWWRF comprises the “old plant” which had a rated and permitted average daily flow capacity of 4 MGD. The “old plant” was generally comprised of two circular aeration basins and two secondary settling tanks with associated supporting systems.

The secondary treatment at the “new plant” consists of a conventional activated sludge process. The treatment includes two rectangular aeration basins with anaerobic selectors and fine bubble aeration and three secondary settling tanks. The secondary treatment of the “new plant” was recently re-rated and permitted for an average daily flow of 20 MGD and the “old plant” has been effectively discontinued from service.

The screened raw sewage is mixed, at the inlet of the aeration basins, with RAS from the secondary settling tanks. The mixed liquor from the aeration basins then flows into the secondary settling tank distribution structure by gravity.

The flow is then diverted to the secondary clarifiers for liquid-solids separation. The treatment train includes three circular clarifiers. All three clarifiers have a diameter of 135-feet. All three clarifiers are equipped with scum skimming equipment and pumping, RAS pumping and WAS pumping. The WAS is pumped through a set of grinders prior to being piped to the WAS Storage Tank.

From the clarifiers, the effluent water flows by gravity to the deep bed multimedia filters. The filtration facilities include four multi-media filters, and a backwash system that includes a sweep system and a backwash water holding basin. The water settles through the filter bed and then flows into the Chlorine Contact Basin.

Disinfection facilities at the plant include sodium hypochlorite storage, chlorine feed equipment, and a chlorine contact basin. The chlorination system is capable of discharging upstream of the filters and/or into the mixing boxes of the chlorine contact chamber.

Filtered effluent is conveyed to the chlorine contact tanks for final disinfection with liquid sodium hypochlorite before being stored in the reuse tanks located at the SWWRF.

The SWWRF's effluent storage is comprised of two reclaimed water storage tanks. The final effluent is stored in the two above ground storage tanks for use in the City’s public access urban reuse program. A portion of this effluent is also used by neighboring Eckerd College for cooling water. If the effluent water intended for reclaimed water use does not meet the required water quality standards for this use it is sent to the 5 million gallons (MG) reject water storage tank and then back to the front of the plant. Deep injection wells take the excess plant high level disinfected effluent in times of decreased reclaimed water demand.

3.6.2 Proposed Facilities

There are only minor modifications proposed for the secondary treatment system and these are highlighted below:

- The aeration basins will be modified to accept step feed in the middle of the aeration basins and a contact stabilization flow toward the end. This process flexibility as described earlier is intended to enhance the facility's treatment capabilities during high flow events. Reference also the following key drawings:
  - G-00-21: New Process Flow Diagram
  - I-31-10: Aeration Basins for Step Feed and Contact Stabilization

  Reference Section 3.5.2.2 for additional information regarding operation and control of this system. The step feed and contact stabilization is fed from the Primary Clarifier Splitter Box.
- The existing WAS pumping grinder system will require re-locating as part of the Thickening Project portion of Biosolids to Energy Program.
- The existing WAS and secondary scum piping will be relocated as part of the Thickening Project portion of the Biosolids to Energy Program. The destination point, the WAS Storage Tank, will remain the same.

3.7 Thickening

The following presents a review of the existing thickening facilities and the new proposed facilities which are a part of the proposed improvements. For additional details, see Appendix B.

3.7.1 Description of Existing Facilities

WAS is pumped to a holding tank before feeding them regularly to a GBT with polymer addition. The sludge holding tank is equipped with an aeration system to ensure good mixing of the sludge. The GBT facility is currently an awning type structure that contains one GBT and has space for a future unit. A polymer feed system is used to enhance the thickening process.

3.7.2 Proposed Facilities

The proposed facilities will be modified under the Thickening Project portion of the Biosolids to Energy Program. The modifications to the thickening system generally consist of the following:

- Installation of a second 2-meter GBT in the Thickening Building.
- Enclosure of the Thickening Building.
- Temporary relocation of the Odor Control facilities to clear room for other portions of the Biosolids to Energy Project. The Biosolids to Energy Project will then connect the modified GBT Building (and WAS Tank) to the new Odor Control system (Reference Section 3.14) once constructed and will remove the temporarily moved system.
- Facilities will be designed to provide 6% thickened sludge to the digestion process within a reasonable tolerance level.

3.8 Anaerobic Digestion and Batch Tanks

The following presents a review of the existing anaerobic digestion facilities and the new proposed facilities which are a part of the proposed improvements.

3.8.1 Description of Existing Facilities

The plant currently has three digesters and a digester control building. All three digesters are offline. All three digesters will be demolished and replaced with two new larger digesters and the digester control building will be replaced with a new Digester Control Enclosure which will be an awning type structure with an attached electrical room.

3.8.2 Proposed Facilities

The following describes the key development information, features, design data and operations and control narrative for the new digestion facilities. Reference also the following key drawings:

- G-00-22: New Process Flow Diagram – Solid Stream
- I-81-10 through I-85-10: Digester Area PIDs

3.8.2.1 Key Development Information, Features and Design Data

The new digestion facilities include the following features:

- One new concrete covered thermophilic digester (Digester 1) and one new concrete covered mesophilic digester (Digester 2). Digester 2 will also be able to operate as a thermophilic digester when Digester 1 is out of service for cleaning and maintenance. The digesters will be draft-tube mixed.
- Six Batch Tanks in a two-by-three configuration with common wall construction. The batch-tank installation is also equipped with discharge pumps to convey "thermophilically-batched" solids to the cooling heat exchangers which in-turn feeds D2.
- A new Digester Control Enclosure will house sludge transfer pumps, recirculation pumps for operation with heating and cooling heat exchangers, foam suppression pumps, a mesophilic recycle pump, heating and cooling heat exchangers, and heat exchanger water recirculation pumps. The Digester Control Enclosure will also include an electrical/mechanical room. There will be no gas handling equipment located inside the Digester Control Enclosure.

Table 3-9 provides key design related information regarding Digester 1, Digester 2 and the Batch Tanks.

Table 3-9. Digester 1, Digester 2 and Batch Tanks Key Design Information[e]

Element	Digester 1 Design	Digester 2 Design	Batch Tanks
Digester Type/Tank Type	Fixed Volume Cast-in-Place Concrete	Variable Volume Cast-in-Place Concrete	Variable volume – Cast in Place Concrete
Diameter/ Length-Width	100-ft	105-ft	21' x 21' (each cell – there are 6 cells)
Sidewall Invert	106.00	106.00	102.00
Top of Side-Wall	136.00	148.00	130.00
Normal Liquid Level	138.39[f]	141.50	127.00
Normal High Level for Storage	--[c]	145.50	--
High Level Overflow Level	141.82[f]	146.00	127.50
Cover Type/Withdrawal Location	Concrete Cover (Submerged Fixed Cover) – Surface withdrawal from Gas Dome	Concrete Cover (Fixed Cover) – Surface Withdrawal from internal overflow box.	Concrete Cover
Design Operating Pressure/Pressure Relief Valve Set Point	20-inches w.c. /24-inches w.c.	20-inches w.c. /24-inches w.c.	20-inches w.c. /24-inches w.c.

Table 3-9. Digester 1, Digester 2 and Batch Tanks Key Design Information[e]			
Element	Digester 1 Design	Digester 2 Design	Batch Tanks
Operating Volume (not including bottom cone)	1,760,000 gallons[a]	2,300,000 gallons[b]	82,500 gallons (each) – 247,000 gallons combined for 3 tanks.
Storage Volume	--[c]	260,000 gallons[d]	--
Hydraulic Retention Times[h]			
At Average Daily Sludge Production	10.4 days	13.5 days	34.9 hours
At Maximum Month Sludge Production	8.9 days	11.5 days	29.8 hours
At Peak Day Sludge Production	7.4 days	9.5 days	24.6 hours
Mixing	Internal draft tubes (4) – 3 duty, 1 standby (15 hp)	Internal draft tubes (4) – 3 duty, 1 standby (15 hp)	--

a. Operating Volume for D1 is volume of digester cylinder only and does not include the volume available in the cone nor in the gas/sludge dome.

b. Operating Volume for D2 is volume of digester cylinder to the normal overflow level and does include the volume available in the storage portion, the cone portion nor in the gas/sludge dome.

c. Digester 1 normally will operate in a fixed volume mode. It can be operated in a variable volume mode when D2 is out of service and the available storage at that point would be determined by the operator.

d. Digester 2 storage volume is the volume from normal overflow point to high liquid level in tank. Normally D2 will operate in a variable volume mode with gravity surface overflow. D2 could be operated in bottom withdrawal mode which would increase storage volume in Digester 2 to its operating volume.

e. All elevations in table are shown using the St. Pete vertical datum.

f. Liquid Level in D1 is normally within the gas/sludge dome and so is slightly above the top of the side wall as is the high level overflow.

h. All retention times are calculated using the Operating Volume value presented in this table and all thickened inflows including Primary Sludge, Ferric, Primary Scum, Secondary Sludge (WAS), Secondary Scum, and FOG.

A number of criteria were used in developing the digester sizing. Specifically:

- Either Digester 1 or Digester 2 could function as the first-stage thermophilic digester.
- Digester 1 is not envisioned to operate in mesophilic mode.
- The functional first-stage thermophilic digester volume is limited by the following sizing criteria:
  - Peek week organic loading rate of less than 0.350 lb-VS/ft 3-day.
  - Hydraulic retention time of greater than 7 days at average loading condition.
- Each first-stage mesophilic digester is limited by the following criteria:
  - Hydraulic retention time of greater than 10 days at average loading condition.
  - Organic loading on this stage is not considered limiting as the upstream thermophilic digester will greatly reduce the volatile solids in the feed.
- Batch Tanks:
  - Provide time and temperature hold requirements described later in this PDR. At 24 hours of retention time, a temperature of 131ºF or higher must be maintained.
  - Are not considered as part of the thermophilic volume to comply with the above thermophilic criteria.

3.8.2.2 Reliability and Redundancy

There are several potential operational modes that will allow either digester to be removed from service. These flow regimes are shown in Figure 3-6. Each digester is represented as a configuration icon with a number denoting that digester's official designation and a color denoting functional operation (either as thermophilic-red, mesophilic-green, or out of service-white/empty). Each schematic is discussed below:

- **Normal Operation.** Both digesters are in service and the system operates in normal mode.
- **Digester 1 Out of Service.** With Digester 1 out of service, Digester 2 serves as the thermophilic digester and the system will operated in thermophilic mode only.
- **Digester 2 Out of Service.** When Digester 2 is out of service, the system will operate in thermophilic mode only and Digester 1 will serve in variable volume mode providing storage upstream of dewatering.

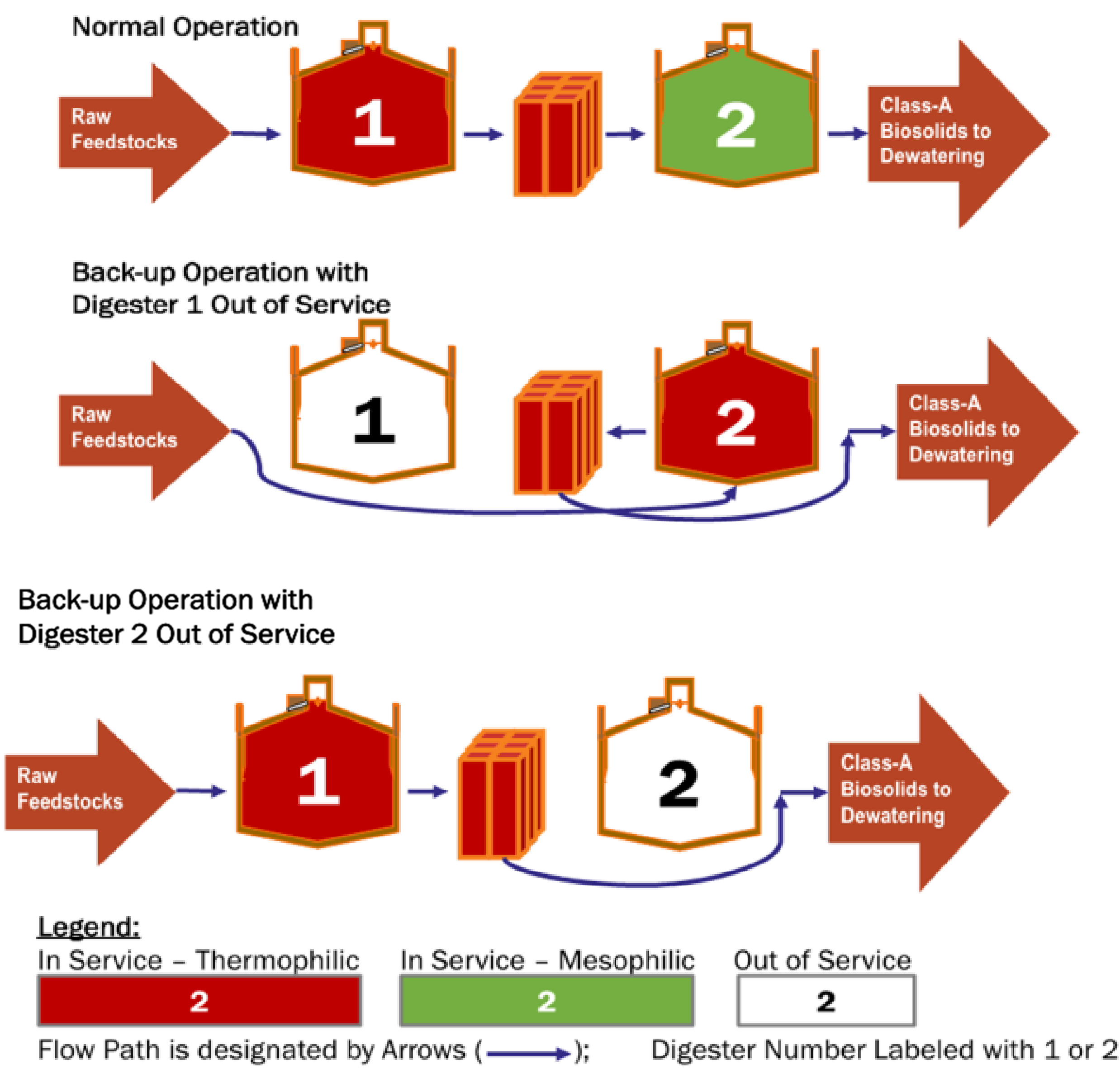


Figure 3-6. Operational Flow Mode Schematics

3.8.2.3 Operation and Control Narrative

Each digester has control features for digester temperature, discharge pumping control, level detection, overflow detection and control, and foam suppression (for Digesters 1 and 2, only). The control systems are defined as follows:

Digester Temperature. Each digester has a dedicated temperature control system. The modeled temperatures and flows at key locations within the process are shown on Drawing G-00-31.

1. Thermophilic Digester *(either Digester 1 or Digester 2 can fulfill this service)*. The thermophilic digester will be held at a temperature of 135ºF. The majority of the heating will be provided by three heating heat exchangers operated in series (2-duty and 1-standby). The feed to these heat exchangers will consist of the thickened sludge feed from the GBTs plus a larger flow of sludge recirculated from the operational thermophilic digester. The recirculation pump will be variable-speed driven with the speed adjusted to maintain an operator-set sludge flow rate through the heat exchanger. The amount of heat applied on the hot-water side of the heat exchanger will be controlled by actuated three-way mixing valves that modulate to maintain an operator-set temperature in the sludge leaving the heat exchangers.
2. Batch Tanks. The Batch Tanks will maintain sludge temperature by providing insulation for the tanks. Insulation will be provided allow for a maximum temperature loss of less than 4ºF over 24 hours under the worst case conditions (high winds, low temperatures, high sludge flows). The temperature of the thermophilic solids leaving the Batch Tanks will be continuously monitored for compliance purposes; alarms will be initiated when the time and temperature calculation is not met. The Batch Tank discharge would then be re-routed back to the WAS storage tank for re-processing or to Lift Station for re-pumping to the Headworks.
3. Mesophilic Digester *(normally Digester 2)*. The target temperature for the mesophilic digester is 99ºF; however, the temperature of this digester is less critical than the thermophilic digester. The bulk of the cooling will be provided by a pair of cooling heat exchangers operated in series. The feed to these heat exchangers will consist of the discharge from the thermophilic Batch Tanks plus a larger flow of sludge recirculated from the operational mesophilic digester. The recirculation pump will be variable-speed driven with the speed adjusted to maintain an operator-set sludge flow rate through the heat exchanger. The amount of cooling water applied on the cold side of the heat exchangers will be controlled by actuated three-way mixing valves that modulate to maintain an operator-set temperature in the sludge leaving the heat exchangers.

Level Detection, Overflow Detection and Control, and Foam Suppression.

- Normally, contents of the digester will surface overflow through internal overflow structures and piping within the digesters. The discharged solids will be conveyed to a dedicated (one per new digester) standpipe that serves as the control point and suction for the respective digester discharge pumps. The discharge pump speed modulates to maintain an operator-set level in the standpipe. This pump is also plumbed to the bottom cone of the digester to facilitate periodic bottom withdrawal for grit removal.
- In case of high level within the digester, there will be a second high-level passive overflow located above the normal overflow/operating surface. These overflows will be equipped with water traps/seals to prevent fugitive gas emissions; sight glasses so that overflow events can be physically observed; and instrumentation to indicate that an overflow is occurring. Overflows will drain by gravity to Lift Station 2 which in turn will return these overflows to the Headworks.
- In case of extreme high level, a high-high-level passive relief-hatch-type will be provided as a last resort protection to the tank structure. Operation of this hatch will also trigger an alarm. This will relieve the digester and spill digester contents on the roof of the digester where it will be

directed by curbing off the roof, down the side and into an at grade retaining area that will also be piped to Lift Station 2.

- A foam suppression system consisting of a dedicated, constant speed foam pump withdraws digesting solids from the digester and feeds a series of nozzles located in the headspace of the digester gas dome for Digester 1. The discharge from these nozzles serves to beat foam down and back into solution while also directing surface material to the normal surface wasting pipe. Digester 2 does not have this feature as the surface area of the top level is the full circumference of the Digester where-as in Digester 1 this surface area is only within the gas dome.

Each Batch Tank will include a high level alarm and automatic shut-off valve on the inflow piping, each cell has an overflow pipe which routes to a common U-Tube assembly which is routed to Lift Station 2 (similar to the Digesters) and each the cell will be further protected with a passive relief-hatch.

Discharge Pumping Control. The paragraphs below summarize how solids conveyance from each digestion process element is controlled:

1. **Digesters 1 and 2.** Normally, contents of the digester will surface overflow through internal overflow structures and piping within the digesters. The discharged solids will be conveyed to a dedicated (one per new digester) standpipe that serves as the control point and suction for the respective digester discharge pumps. The discharge pump speed modulates to maintain an operator-set level in the standpipe.
2. As an alternative, the discharge pumps can be fed directly from the bottom of the digester using a cone-withdrawal suction pipe. Under this operation, various control programs are possible using the level measurements in the standpipes and digesters.
3. **Batch Tank Filling.** Under normal operation, the Batch Tanks do not control the amount of solids discharged from the thermophilic digester; instead they accommodate the flow and direct it to the appropriate Batch Tank using actuated, isolation plug valves. Each Batch Tank is equipped with an actuated isolation feed valve, an actuated isolation discharge valve, and a surface-detecting radar level element. Operators can set any 5-tank or 6-tank order that they desire (i.e., 2-6-3-4-5-1 is one possible 6-tank order). 5-tank batch-tank orders will use 8-hour cycling intervals while 6-tank batch-tank orders will use 6-hour intervals. An operator-set high level condition limits the volume of digesting solids that can be fed to each Batch Tank; at a high-level alarm the operator will be notified that the Batch Tank level is within 4-feet of the maximum allowable level. A high-high-level alarm will sound if the volume limit is reached before the end of the 6- or 8-hour cycle; this high-high-level alarm will call for the operator to stop the thermophilic digester discharge pumps and the GBT-feed pumps or redirect the batch tank discharge back to the WAS Storage Tank. Under normal operation, the level in each Batch Tank will not approach these high-level limits. The Batch Tanks have been sized for peak day planning year of 2035.
4. **Batch Tank Discharge.** When a new Batch Tank is placed in draw mode, the level in that tank will be measured and the flow rate needed to empty that tank (to the target, end-of-cycle low level) within the cycle time is calculated. The pump then operates at that flowrate (as controlled by a variable speed drive and a discharge flow meter) until otherwise adjusted. This same flow-rate-calculating algorithm is rerun and the pump flow rate reset at 1/2 through, 3/4 through, 90% through, 95% through, and 98% through based on measured cycle time. The pump will stop on low-low tank level but should not stop under normal circumstances as the low-low level is expected to be approximately one foot below the target, end-of-cycle low level.
5. At the end of the cycle, the valve positions change and the function of two Batch Tanks are modified: the “fill tank” becomes a “hold tank” and longest held “hold tank” becomes the draw tank. Valve cycling occurs in this order:

- Quickly open the new fill tank valve;
- Quickly close the old fill tank valve;
- Quickly open the new draw tank valve; and then
- Quickly close the old draw tank valve.

3.8.3 Digester Heating and Sludge Cooling Systems

The target temperature for the thermophilic digester is 135°F. The target minimum temperature for the Batch Tanks is 131°F, which will allow for a 24-hour batch to be considered as Class-A sludge. The target temperature for the mesophilic digesters is 99°F. Along with the incoming thickened sludge heating, heating is also required for maintaining set temperature at each of the digesters.

Based on the historical weather and incoming wastewater flow data, conditions as presented in Table 3-10 were used as the design basis for the calculation of heat requirements. Extreme temporary conditions i.e. during hurricane or a few hours of freezing temperatures are not included in the heat requirement calculations.

Table 3-10. Heat Requirements

Description	Sludge Flow (gpd)	Sludge Temperature (°F)	Air Temperature (°F)	Wind Velocity (mph)
Peak Day (Design Year – 2035)	240,000	68 (Winter)	45 (Winter)	12
Average Day (Design Year – 2035)	169,000	75 (Yearly Avg)	80 (Yearly Avg)	8
Min Day (Current Year – 2013)	70,000	85 (Summer)	95 (Summer)	8

Based on the above scenarios, the heating and cooling requirements for each of the processes were calculated and are presented in the Table 3-11.

To reduce the heating requirements and the operational costs associated with it, the Batch Tanks will be insulated and provided with a CMU block finished. The concrete walls and insulation will combine to provide for an estimated maximum 1°F temperature drop during the 24 hour sludge detention time in the Batch Tanks. Digested sludge from the Batch Tanks will be approximately 134°F upon discharge which is approximately 3°F above the target temperature for a 24 hour batch hold time which is 131°F. At 134°F, only 14 hours of Batch Tank retention time is required; however, buffer is allotted in the system such that the tanks will generally hold for 24 hours at near 134°F.

The sludge will have to be cooled to the target mesophilic temperature range which is 99°F using chilled water.

The sludge flows and temperature requirements for the TPAD processes are presented in Drawing G-00-31.

The majority of the heating for the themophilic digesters will be provided by tube-in-tube sludge to water heat exchangers. Three equally sized heat exchangers will be provided such there are two duty sized to deliver 100% of the heat demand and one on-line redundant. Hot water will be derived from a primary hot water loop provided by the Engine Project which will derive hot water from the engines and supplemented by boilers during engine downtime.

Table 3-11. Sludge Heating Requirements			
Heat Requirement Location	Peak Day (MBTU/HR)	Average Day (MBTU/HR)	Min Day (MBTU/HR)
Sludge Heating	5.59	3.31	1.22
Digester 1 (Thermophilic) Heat Loss – Maintenance Heating	0.65	0.39	0.28
Digester 2 (Mesophilic) Sludge Cooling	(2.92)	(2.05)	(0.85)
TOTAL HEATING REQUIRED	~6.2	~3.7	~1.5
TOTAL COOLING REQUIRED	~2.9	~2.1	~0.9

The cooling for the mesophilic digesters will be provided by tube-in-tube sludge to water heat exchangers. Two equally sized heat exchangers will be provided such that each are sized to provide 50% of the cooling needs. The cooling to mesophilic temperatures is less critical than the heating to thermophilic temperatures and as such the redundancy on the cooling system is less. Cool water will be derived from cool water loop which will pass through a cooling tower with potable water make-up and blow-off to the plant drain system.

3.8.4 Foam Control and Grit Accumulation

A brief review of foam control and grit accumulation issues is presented here. These items are particularly important to digester operation. Both digesters will normally surface overflow (internal to the digesters). The bottom of the tank includes a multi-coned configuration with the mixers centered over each low-point.

Foam Control

The following highlights the key points related to foam control.

- Thermophilic digesters will have a tendency to foam more than mesophilic digesters and as such the submerged fixed cover design is being employed for Digester 1.
- Both digesters will have foam continuously wasted from the top dome part of the digesters; however, the smaller gas dome in Digester 1 (the thermophilic digester) centralizes the foam for withdrawal at that location for more effective foam removal.
- Foam suppression pumps withdraw sludge from the digester and recirculate it to the top of the Digester 1 and then through a ring of nozzles located along the interior of the dome.

Grit Accumulation

The following highlights the key points related to grit accumulation.

- The Primary Clarifiers will capture much of the residual grit not captured by the headworks and pass it to Digester 1 and then on to Digester 2.
- Both digesters have a multi-coned floor (waffle bottom) with relatively steep cones to encourage deposition of grit with these areas. The draft tube mixers are centered over these cones to facilitate dispersion of the grit.
- Sludge withdrawal from the invert of each cone is provided and periodic discharge from that location instead of duty overflow will help keep these cones as free as possible of grit deposition.
- Large and multiple access manways at grade and in the roof will allow for quick and efficient cleaning when performed.

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3.9 Digester Gas Handling and Flares

The following presents a review of the existing digester gas handling facilities and the proposed new facilities which are a part of the Biosolids to Energy Project. Note that the gas upgrading facilities are discussed in Section 3.10.

3.9.1 Description of Existing Facilities

The existing gas system consists of a candlestick type flare. As the digesters are not in use, the candlestick flare and its associated natural gas pilot have been turned off.

3.9.2 Proposed Facilities

The following describes the key development information for the Digester Gas Handling systems. Reference Section 3.10 for a discussion of the Biogas Upgrade System which will draw digester gas from the gas handling system. Reference also the following key drawings:

- G-00-32: Gas Process Schematic

The Digester Gas Handling and Flare systems include the following key features.

- There will be one gas handling pressure zone at the main digestion facilities with a nominal pressure of 16-inches of w.c. This pressure zone is for Digesters 1 and 2, the Batch Tanks and the Gas Storage Tank.
- The 16-inch w.c. pressure zone will have a virtually zero headloss piping manifold between the digesters, Batch Tanks, and Gas Storage Tank. Gas will flow interchangeably in different directions depending on production within the digesters and the demands of the Biogas Upgrade System.
- The manifold will lower in size and drop to grade to a biogas heat exchanger prior to being routed to the Biogas Upgrade System. The heat exchanger system will cool the gas prior to transmission to the biogas upgrading system (BUS) in order to remove moisture. This transmission system will be designed with system headlosses such that the gas arriving at the Biogas Upgrade System will have not less than 4-inches w.c. of residual pressure.
- There will be one enclosed flare. The enclosed flare is a variable and high capacity flare which can flare all system gas from the 16-inch w.c. pressure zone should the Biogas Upgrade System not be receiving gas.
- The Gas Storage Tank will provide for the system to buffer instantaneous drops and peaks in gas production.
- Gas transfer piping will be above grade stainless steel and will be located along centralized transfer corridors. No gas piping or gas handling equipment will be inside the Digester Building.
- The preliminary estimated maximum design output for the flare is 750 standard cubic feet per minute (scfm). An average startup daily gas production is estimated to be approximately 300 scfm.
- Both digesters and the Batch Tank will be provided with local dual flame arrestors, sediment and condensate traps and drain configurations.

3.10 Digester Gas Upgrading

The proposed digester gas upgrading system is described in this section.

3.10.1 Description of Existing Facilities

There is currently no existing digester gas upgrading performed at the facility.

3.10.2 Overview

The digester gas upgrading facility will continuously upgrade raw digester gas at slight positive pressures to pipeline quality biomethane. Product gas from the digester gas upgrading system can also be used on site for the cogeneration engines and boilers.

The digester gas upgrading system consists of two main subsystems and their ancillary support systems:

- Pre-cooling, moisture removal and transport.
- The digester gas or BUS.

These sub-systems are described in the following subsections.

3.10.2.1 Pre-cooling, Moisture Removal and Transport

Moisture will be removed prior to the gas being transported through the piping to the BUS.

The gas cooling will be accomplished in two stages: one heat exchanger that uses cooling water from the cooling tower at 85°F and a second that uses chilled water at 32°F from a dedicated chiller. The two heat exchangers will be single pass, stainless steel shell and tube type. The liquid condensate will be removed in a separator vessel and drained to the condensate accumulator where it will be pumped back to the front of the plant. Figure 3-7 shows a schematic of the pre-cooling and moisture separation system.

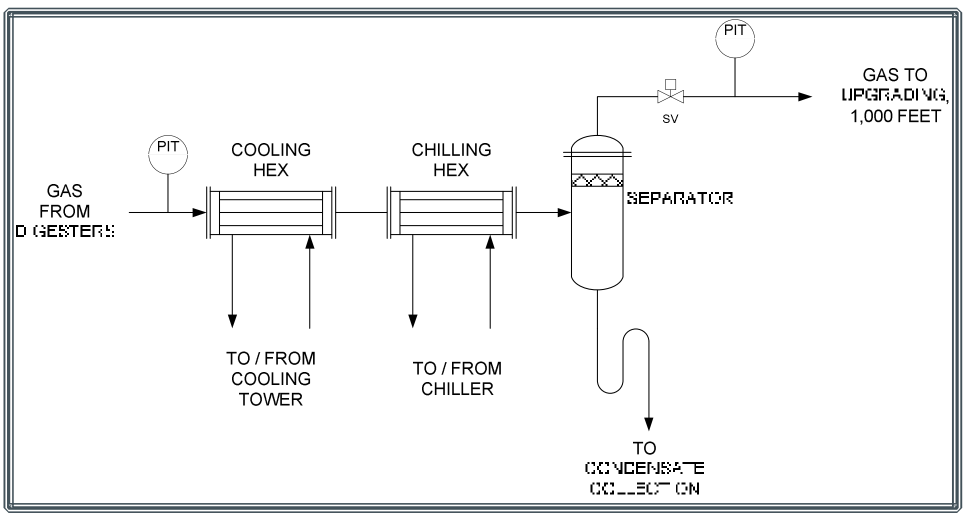

Figure 3-7. Pre-cooling and Moisture Separation Diagram

Even though most water is removed, some condensation will occur on very cold days and when the system is not in operation and condensation collection and transport will be provided.

3.10.2.2 Biogas Upgrading System

The BUS will be a pressure swing adsorption (PSA) type and designed to process raw digester gas to pipeline or CNG quality. The digester gas will enter the BUS at slight positive pressures and leave at about 90 pounds per square inch, gauge (psig) and at a gas quality at or above requirements recommended by the Society of Automotive Engineers standard for compressed natural gas vehicle fuel, SAE J1616 and TECO fuel quality requirements. The product gas will either be sent to the onsite engine-generators or sent to the CNG fueling system for further compression and end-use.

The BUS consists of five basic unit operations: feed gas compression, PSA, vacuum pumping, tail gas combustion in a thermal oxidizer, and buffer vessels.

- **Feed gas compression skid:** The feed gas compression skid will include an inlet separator, compressor, oil separator, post-compression cooler, condensate separator and gas re-heat heat exchanger. The gas will leave the skid at 100 psig and heated above the gas dew point to approximately 120 to 150°F. The feed gas compressor will be an oil-flooded screw type with a variable frequency drive.
- **PSA skid:** The PSA skid will have an inlet separator, three PSA vessels and pneumatically actuated valves for PSA vessel process cycling. Product gas will leave the skid fully cleaned and at 90 psig. The waste gas will be sent through the vacuum pump mounted on the PSA skid.
- **Vacuum pump:** The vacuum pump will draw a vacuum on the process vessels during the regeneration cycle and pressurize the gas to about 5 psig or sufficiently for the thermal oxidizer to combust the tail (or waste) gas. The vacuum pump will be the oil ring type with a soft start. The tail gas will contain carbon dioxide, methane, water, hydrogen sulfide, siloxanes, ammonia, nitrogen and other VOCs present in the digester gas. The methane content will be approximately 15% to support combustion in the thermal oxidizer.
- **Thermal oxidizer:** The thermal oxidizer will be an assisted combustion device specifically designed for burning low-BTU (i.e. low methane content) tail gas. The thermal oxidizer will have a pilot fueled by utility natural gas and a blower for combustion air.
- **Buffer vessels:** As part of the PSA system, buffer vessels will be installed with pneumatically actuated valves to smooth out pressures and flows during the cyclical process. The buffer vessels tend to generate the most noise during depressurization.

The equipment skids will have a Class-I, Div. 1 electrical hazardous classification 5-feet from equipment, valves and appurtenances and Class-I, Div. 2 at 10-feet beyond this.

Figure 3-8. Feed Compressor Skid from Guild

Figure 3-9. PSA and Vacuum Pump Skid and Buffer Vessels

Ancillary Devices / Systems

Ancillary device and systems required by the BUS include the following:

- **Gas chromatograph:** The gas chromatograph will measure methane, carbon dioxide, nitrogen and oxygen in the product gas.
- **Odorizer:** The odorizer will inject methyl mercaptan into the product gas to provide an odor similar to pipeline natural gas.
- **Instrument air:** Dual instrument air compressors will provide instrument air for pneumatic valve actuation.
- **Nitrogen purge:** A nitrogen purge station will automatically purge the feed compressor and oil separator on shut down, and provide for manual purging of the remainder of the skids.
- **Condensate collection:** Condensate will be collected from multiple points in the BUS and pumped back to the plant collection system.
- **Control**: A climate controlled pre-fabricated Control Room will provide a small control kiosk and electrical room for the BUS.

Noise Attenuation

Noise attenuation will be included. The noise attenuation system will include a 14 foot sound attenuation barrier walls surrounding the BUS.

3.10.3 BUS Sizing

A mass balance run was generated for a complete year (8,760 hours) in order to provide volatile solids loading to the digester in the design year of 2035. This was then de-rated to the startup year. Designing the BUS for the planning year (2035) was deemed excessive. The average digester gas production in the first year was calculated based on the solids loading and was determined to be approximately 436,000 scfd (300 scfm). This modeling of the BUS system sizes demonstrated that sizing the BUS for much above the average flow does not provide much additional gas capture.

The sizing criteria of the BUS were selected to be 1.1 times the average production in the year of startup, 2016. This equates to a BUS system capacity of 480,000 scfd (333 scfm). It is estimated that this will provide a gas capture rate of 99.5% in 2016 and a gas capture of 93% in 2035 (not including losses associated with BUS non-availability). Figure 3-10 shows the gas capture rate for a range of BUS system capacities normalized to the average yearly flow. Figure 3-11 shows the selected BUS capacity overlaid on projected digester gas production in 2035.

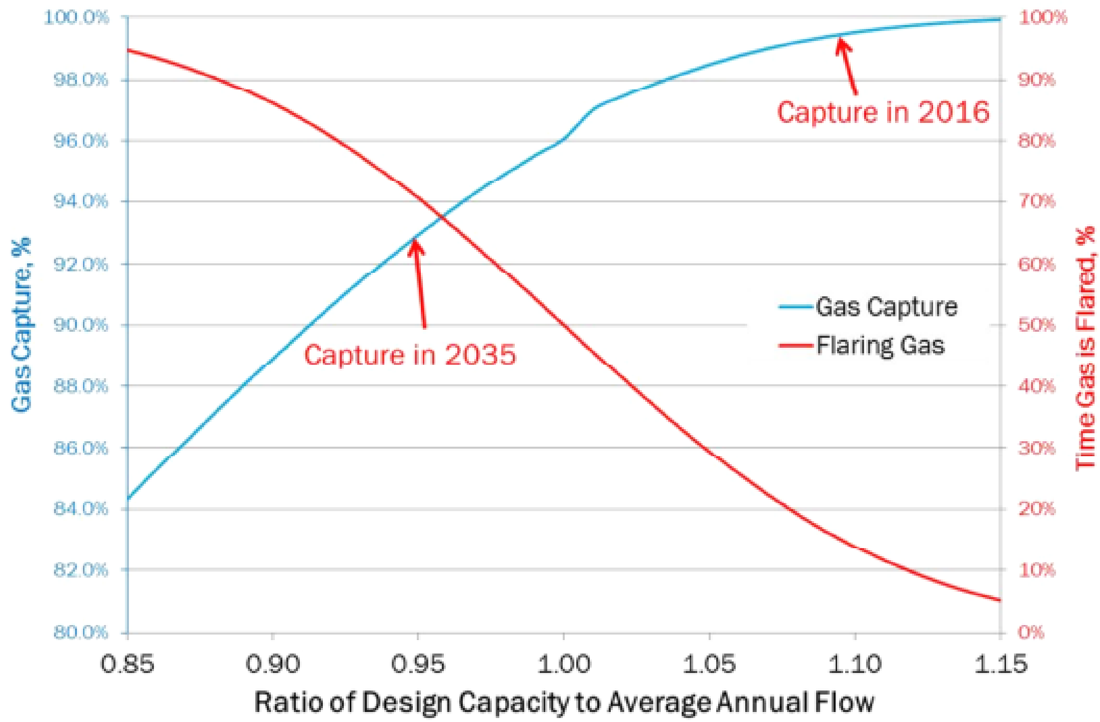

Figure 3-10. Biogas Upgrading System Capacity, Gas Capture and Time Gas is Flared

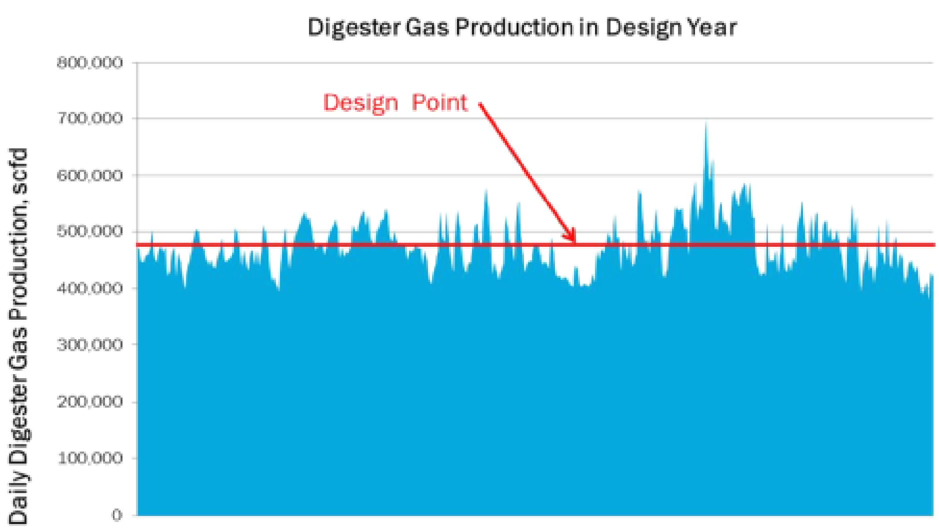

Figure 3-11. Selected Biogas Upgrading System Capacity Compared to Gas Production in 2035

The BUS system capacity model was augmented to include a low pressure digester gas holder. The low pressure gas holder was not found to provide much additional gas capture.

However, a low pressure gas holder provides system pressure stability which is critical to system operation. The low pressure gas holder will provide time for the BUS to change capacity throughput based on variations in digester gas production and provide other system gas system buffer benefits.

3.10.4 Design Criteria

Preliminary design criteria are provided in this section for each of the unit operations which identifies capacities, pressures and temperatures. Preliminary design criteria for the pre-cooling, moisture removal and transport system are defined in Table 3-12.

Table 3-12. Pre-Cooling Key Preliminary Design Information

Element	Design
Inlet Operating Pressure, inches water column	12 - 14
Cooling Heat Exchanger Capacity, BTU/hr	80,000
Chilling Heat Exchanger Capacity, BTU/hr	82,000
Cooling Tower Load, cooling tons [(a)]	8
Chiller Load, cooling tons	8

(a) Cooling tower load for digester gas only. Additional load for sludge cooling.

Preliminary design criteria for the BUS are shown in Table 3-13. Performance requirements for the BUS are shown in Table 3-14.

Table 3-13. BUS Key Preliminary Design Information

Element	Design
Inlet Operating Pressure, inches water column	2 - 10
Digester Gas Flow, scfm	333
Minimum Methane Recovery, %	87
Compressor Motor, hp	125
Vacuum Pump, hp	150
Ancillary Device, hp (estimate)	25

Table 3-14. BUS Process Preliminary Design Information

Element	Inlet Conditions	Product Conditions
Volumetric flow requirements, scfm:		
minimum (required turndown)	120	60 to 65 [(a)]
maximum	333	170 to 190 [(b)]
Inlet gas pressure	2 to 10 inches w.c.	80 to 90 psig
Gas temperature, degrees F	40 to 100	< 120
Methane, percent by volume (dry)	60 to 65	> 98
Carbon dioxide, percent by volume (dry)	35 to 40	< 2
Nitrogen, percent by volume (dry)	0 to 0.5	< 2 (including CO_2 and O_2)

Table 3-14. BUS Process Preliminary Design Information		
Element	**Inlet Conditions**	**Product Conditions**
Oxygen	0 to 50 ppmv	< 0.1 %
Water	40 to 50 degrees F dew point	< 1 lb/ million scf
Hydrogen sulfide, ppmv	100 to 10,000 (c)	< 1
Total siloxanes, ppmv	0 to 5	Non-detectable
Ammonia, ppmv	0 to TBD	Non-detectable
Other volatile organic compounds, ppmv	0 to 100	Non-detectable
Higher Heating Value, BTU/scf	530 to 580	> 985

(a) Flow is equivalent to 565 to 610 diesel gallon equivalent per day.

(b) Flow is equivalent to 1,575 to 1,770 diesel gallon equivalent per day. Product gas flow depends on methane concentration in digester gas.

(c) Hydrogen sulfide levels are expected to be reduced well below this amount by ferric chloride dosing.

3.10.5 Reliability and Redundancy

The BUS is expected to have good reliability without redundancy and the non-critical nature of the equipment for wastewater treatment make redundancy largely a question of economics.

Redundancy of major equipment as part of the BUS are not included in the design. A key spare parts inventory will be provided with the project.

Redundancy and reliability will be provided in the following manners:

- **Instrument air compressor:** The BUS requires instrument air to start and operate. Two instrument air compressors will provide redundancy at a relatively inexpensive capital cost.
- **Pad elevation:** The BUS will be installed above flood levels.
- **Standby power:** System control and safety devices will be on standby power.
- **Thermal oxidizer pilot**: The thermal oxidizer pilot will be fueled by natural gas rather than digester gas or biomethane to allow for continuous operation with or without digester gas availability. This will allow for system depressurization or purging when the BUS is isolated from the digester gas piping.
- **High pressure storage**: High pressure storage will provide about two hours for one tube-trailer to be disconnected and another to be connected.
- **Offsite monitoring**: Offsite monitoring of the BUS by the system manufacturer will be provided.

3.10.6 Operation and Control Narrative

An automated and fully integrated control system that integrates all components of the BUS will be provided.

Pre-Cooling and Moisture Removal Operation

The pre-cooling system will always be running when the BUS is running. The chiller will modulate load to maintain the discharge temperature from the chilling heat exchanger at about 40°F. The cooling tower will normally be running for digester cooling requirements. The chiller and cooling water pumps will automatically be started when the BUS receives a signal to start. The BUS will not be allowed to start until the chiller has reached operating temperature.

BUS Operation

The BUS will be provided the digester gas header pressure signal from the plant. When operating, the BUS will use this signal to automatically vary digester gas flow through the BUS to maintain a constant pressure in the digester gas header. In this way, the BUS will match digester gas utilization to gas production.

The BUS will be started and stopped at the BUS control system. If not ready, the thermal oxidizer will start with the signal for the BUS to start. The thermal oxidizer can be operated without the BUS to provide a location to depressurize the BUS.

When starting, the BUS will have the capability to operate in a recycle mode or to send product gas to the thermal oxidizer until product gas quality is proven.

The BUS will be interlocked to shut down for the following conditions:

1. Pressure signal at the inlet to the BUS reaches low set point.
2. Digester gas header pressure signal reaches low set point (hard-wired from the plant).
3. E-stop is pressed at BUS location or through plant control system (hard-wired from the plant).
4. Combustible or H_2S gas detection.

3.11 Dewatering and Dewatered Sludge Handling

The following presents a review of the existing dewatering facilities and the new proposed facilities which are a part of the proposed improvements. For additional details, see Appendix C.

3.11.1 Description of Existing Facilities

The current dewatering system approach varies quite a bit from the system originally designed. Currently, undigested sludge (and unthickened sludge) is sent directly to the existing belt filter presses where it is dewatered. From the dewatering, the sludge is conveyed to a temporary lime stabilization system to obtain Class-A sludge. From this system, the dewatered/stabilized sludge is hauled to land application by a contract hauler.

3.11.2 Proposed Facilities

The modifications to the dewatering system generally consist of the following:

- Construction of a new Dewatering Building which will contain enclosed truck loading, three duty and one standby screw press (with space provided for a fourth) and the bulk of the equipment for the supplemental feedstock receiving system.
- Relocation of the secondary clarifier emergency polymer system.
- Demolition of the existing dewatering building.

3.12 Side Stream Handling

The side streams associated with anaerobic digesters such as the centrate/filtrate return stream from digested sludge dewatering processes, are known to generate significant nutrient loads. In most instances, the ammonia-nitrogen and phosphorus loads are of most concern. These side streams will be returned to the Headworks.

With this project, the City intends to combine the WAS generated at the NEWRF and NWWRF at the SWWRF for handling and stabilization of the biosolids. Although, the combination of solids from the NEWRF and NWWRF at the SWWRF will provide an integrated biosolids management solution for the

City, it will also generate return flows from solid streams with higher nutrient loads back to the plant for removal in the secondary treatment system.

A BioWin model was developed to simulate the performance of the SWWRF operating with the solids received from other facilities. The BioWin model estimates the nutrient loads originated from recycle streams which are returned to the liquid stream processes at the facility based on the influent wastewater and biosolids characteristics.

The modeling results indicated that approximately 1,900 lb/day (840 kg/ day) as N and 660 lb/day (300 kg/day) as P are expected to be generated during the anaerobic digestion-sludge dewatering process.

Table 3-15 summarizes the BioWin predicted characteristics for the centrate at the SWWRF. Based on this information, the side stream returns will increase the existing WRF influent loads by approximately 30% for N and for P increasing the energy requirements at the WRF.

Table 3-15. Estimated Side Stream Characteristics

Parameter	Concentration, mg/L	Loads, lbs/d
Max Month Flow, MGD	0.144	
NH_3-N	1550	1,861
TP	550	661
TSS	450	540
COD	650	781

Since the facility currently does not have nutrient limitations and they are achieving well below permit requirements for CBOD, TSS and nitrate, it was calculated that introducing side streams into the facility will likely not impair their ability to satisfy the conditions of the permit.

Based on recent operational data, the SWWRF is partially nitrifying and experiencing simultaneous nitrification-denitrification (SND) process. The aeration basins are operated at very low dissolved oxygen (DO) levels. If the facility can continue to operate in a similar way at low DO concentration, the facility will have sufficient aeration capacity to handle the additional loads originating from the side streams. However, with increasing loads, sludge volume index (SVI) values may rise which would lead to settling issues (bulking sludge) at the facility. In that case, the operating DO levels would need to be increased in the aeration basins. Hence, there is a possibility that the existing aeration capacity may become a limiting factor at the SWWRF.

Equalization of side streams would provide benefits at the SWWRF by balancing the nutrient loads being sent back to the facility and would be the first approach should aeration demands and bulking become problematic. This would be modeled and bench scale tested if warranted following the construction of the Biosolids to Energy Project and if aeration demands rise dramatically due to the need to mitigate bulking issues.

In the case that further modeling and bench scale testing of an equalization approach does not prove to be adequate and the aeration system still becomes a limiting factor at the SWWRF and/or possible more stringent nitrogen levels are imposed at the facility, side stream treatment would be recommended.

Several biological processes can remove nitrogen from the side streams generated from biosolids processing. These processes can supply suspended or attached growth environment for specific type of organisms that can utilize nitrite and shortcut conventional nitrification/denitrification process. The phosphorus levels in the side stream treatment are of less concern since phosphorus can be removed at the WWTP by chemical precipitation with addition of metal salts.

3.13 Supplemental Feedstock Facility

The following presents a review of the supplemental feedstock facility. The acceptance of the supplemental feedstock is intended to increase the volume of digester gas generated and to further enhance the economics of the biogas upgrade system.

3.13.1 Description of Existing Facilities

There is currently no supplemental feedstock receiving systems at the facility.

3.13.2 Proposed Facilities

The following describes the key development information, features design data and operations and control narrative for the Supplemental Feedstock Facility. Reference also the following key drawings:

- G-00-22: New Process Flow Diagram – Solid Stream
- I-78-10: Supplemental Feedstock Facility – PID

3.13.2.1 Key Features and Design Data

The Supplemental Feedstock Facility includes the following features and Table 3-16 summarizes its key design data.

- The SWWRF will have a facility installed to accept and manage the loading of liquefied supplemental feedstock for the anaerobic digestion system. Supplemental feedstock may include FOG, pulped food waste or other high strength liquid organic wastes and is intended to supply no more than 4,050 lbs VS/day to the digesters. Tank sizing was derived from this and pump sizing was derived to meter the flow to the digesters over a 24 hour period.
- Wastes will be delivered via tanker truck(s) of varying size typically ranging from 1,500 to 6,000 gallons, depending on the supplier.
- Supplemental feedstocks will generally be accepted when pre-processed at offsite facilities to meet predetermined quality criteria to be set by the City. Supplemental feedstocks may include: FOG, food waste and high strength liquid organic wastes. Some feedstock may be accepted in its raw form if it is determined by the City staff that the raw material meets City quality standards.
- Supplemental feedstock materials will be directly introduced to the thermophilic anaerobic digesters, from the holding tank at the receiving facility. The storage tank is intended to reduce load peaking to the digesters and the subsequent gas production. Feedstock will be metered to the digestion process to increase biogas production, while maintaining process stability and maximizing beneficial use of the added gas production.
- At most facilities private haulers collect the materials and discharge at the wastewater plant for a set tipping fee, which is to be set by the City. Because the organics program is currently undefined only a rudimentary tracking system for loadings and access is included at this time. Comprehensive and integrated load tracking, billing and access systems are available, and may be required depending on the nature of the hauled waste acceptance program implemented by the City. These are modifications that can be made in the future.
- Digester feed pumps from the receiving facility are designed with 1 duty pump. The pump's rated capacity is greater than the average flow required for daily feed to allow for addition process control and flexibility.
- An immersion heat exchanger ("bayonet style") will provide process heating. The heat exchanger will be directly immersed in the process fluid through flange fitting on the side of the storage

tank. The heater will be used to maintain the contents of the tank at 95 degrees Fahrenheit (F). Hot water will be supplied to the heat exchanger from the plant hot water loop.

- System piping will all be glass lined.

Table 3-16. Supplemental Feedstock Facility – Key Design Data		
Element	Design Value	Notes
Total Solids Load	4,500 lb-TS/day	
Volatile Solids Load	4,050 lb-VS/day	
Volatile Fraction	0.90 lb-VS/lb-TS	
Total Solids Concentration	0.05 lb-TS/lb-FOG	
Flow	10,791 gpd	
FOG Circulation/Off Load Pump	350 gpm	Rated capacity, VFD driven, 1 duty
FOG Feed Pumps	20 gpm	Rated capacity, VFD driven, 1 duty, 1 standby
FOG Tank	20 tall x 12 diameter, 15,000 gallons nominal capacity	Fiber reinforced plastic
FOG HEX	3,200,000 BTU/hr	Tube in tube
HWS Pump	163 gpm	1 duty
FOG Grinder		1 duty

The organics/FOG receiving facility is not a core service so fully redundant units were not required or provided. Truck of loading and tank circulation were designed without redundancy as trucks can be diverted from the facility. FOG feed pumps were installed with one duty and one stand-by to allow for continuous operation during equipment maintenance. Space was allocated for additional redundant/future equipment if a more conservative system operation is required in the future.

3.13.2.2 Operation and Control Narrative

The FOG station will operate as follows:

- Hauler arrives and connects truck to loading pump connection.
- Hauler enters its hauler ID number volume to be offloaded.
- Logic controller calculates and ensures that volume to accept the load is available.
- Panel instructs the hauler to open valve on truck and press the start button on the panel to start the off load procedure.
- Automated valves will open and close to connect the suction of the circulation pump to the haulers truck.
- The hauler will press stop when the indicator on his truck indicates the contents are empty, or the process will automatically stop when the level indicator in the tank calculates that the volume entered has been discharged to the tank or at a high level alarm.
- After discharge the automated valves will return to the circulation operating position and FOG heating and circulation will resume. Hot water sprays will turn on and rinse down the rock trap of any residual grease.
- Periodically the rock trap will be opened and the debris removed. The frequency and responsibility of this service will be operationally defined by the City.

- The logic controller will create a record of the hauler and discharge quantity for billing and tracking purposes, this information will be stored in the plants data management system.
- FOG heating and circulation will be used to mix the storage tank and to heat the FOG to an operating temperature of 95˚F.
- FOG feed pump will continuously discharge to the active thermophilic anaerobic digester (Digester 1 or Digester 2) from the FOG storage tank.
- Odor control will operate continuously on the storage tank and associated facilities.
- Hot wash water will be provided for cleaning the truck connection point to the FOG system.

3.14 Odor Control Systems

This section discusses the odor control systems proposed for the Biosolids to Energy Program.

It includes a summary of the existing odor control facilities as well as the proposed new facilities which are a part of the proposed improvements. Reference also the following key drawings:

- G-00-33: Foul Air Process Schematic
- I-28-10: Odor Control Systems 1
- I-28-11: Odor Control Systems 2

The objective of the odor control strategy is that the new processes will not present odor impacts to the surrounding community.

3.14.1 Existing Odor Control Facilities

The current processes served by odor control systems include the following:

- Headworks and Influent Pump Station – served by a small chemical scrubber system.
- GBT Building and WAS Tank - served by a small chemical scrubber system.

3.14.2 Proposed Facilities

The proposed new process facilities include a splitter structure to divert influent flow to the Primary Clarifiers, Primary Clarifiers, anaerobic digesters, a digested solids Batch Tank, a supplemental feedstock receiving facility, and digester gas handling and upgrade systems.

Odor control as part of the Biosolids to Energy Project in the form of foul air capture and treatment will be provided for the new Primary Clarifier Splitter Box, the two new Primary Clarifiers, the WAS Storage Tank, modified Gravity Belt Thickening Building, Lift Station 2 and the Supplemental Feedstock Facility.

Under the Thickening Project there will be upgrades to the thickening facilities and under the Dewatering Project there will be a new dewatering building. The odor treatment for the Thickening Project will be included in the Biosolids to Energy Project due the proximity of its odor control facilities. The odor treatment for the Dewatering Project will include separate odor control systems.

The anticipated key odor characteristics of the largest process facilities which are scheduled for odor control under the Biosolids to Energy Project are shown in Table 3-17.

Table 3-17. Odor Characteristics of the Process Facilities to be Controlled

Process Area	Hydrogen Sulfide Concentration	Organic Sulfide Concentration
Splitter Box	High (>50 ppm)	Moderate (1 – 2 ppmv)
Primary Clarifiers	High (>50 ppm)	Moderate (1 – 2 ppmv)

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Table 3-17. Odor Characteristics of the Process Facilities to be Controlled		
Process Area	Hydrogen Sulfide Concentration	Organic Sulfide Concentration
WAS Storage Tank	Moderate (10 – 50 ppmv)	Low (< 1 ppmv)
Gravity Belt Thickener Hoods	High (>50 ppm)	Moderate (1 – 2 ppmv)
Thickening Building	Low (<10 ppmv)	Low (< 1 ppmv)

The SWWRF raw influent will comprise raw wastewater from the existing SWWRF collection system and also WAS from the NWWRF and the NEWRF and thus the splitter box and Primary Clarifiers will have especially high hydrogen sulfide gas concentrations.

Processes that will not require odor control include the digesters and Batch Tanks which will be sealed and connected to the gas handling system that is either sent to gas upgrade system or to flares.

The air flow rates for the processes that will receive odor control were calculated according to several different criteria. Required ventilation rates were estimated by two methods commonly used. These include the air change per hour (ACH) and infiltration methods. Minimum fresh air ventilation rates must be applied in all areas to provide a safe working environment and meet the requirements of standards and codes such as National Fire Protection Association Standard 820, Standard for Fire Protection in Wastewater Treatment and Collection Facilities (NFPA 820) and the Uniform Building Code (UBC). This criterion applies to the Thickening Building. The Infiltration criterion applies to covered, ventilated vessels and channels.

Table 3-18 below summarizes the calculated ventilation rates based on the two different approaches, and recommends a ventilation rate for each area. The recommended ventilation rates are summarized below.

Table 3-18. Design Ventilation Rates								
Room/Area	Area	Height	Volume	Air Change Criterion		Infiltration Criterion		Nominal Recommended
	Ft.2	Ft.	Ft.3	ACH	CFM	CFM/SF	CFM	CFM
Primary Clarifier 1	7,850	-	-	Not Used		0.50 CFM/SF	3,925	4,000
Primary Clarifier 2	7,850	-	-	Not Used		0.50 CFM/SF	3,925	4,000
Splitter Box	1090	-	-	Not Used		0.75 CFM/SF	817	800
WAS Holding Tank	860	-	-	Not Used		0.75 CFM/SF and 525 CFM Aeration Air	1,170	1,200
Gravity Thickener Building Hoods				Not Used		By Carollo Engineers	4,000	4,000
Total Concentrated Air Stream								14,000
GBT Room	3,200	15	48,000	12	9,600 (Less Hood Air Flow)	Not Used		6,000
Total Combined Air Flow								20,000

3.14.3 Recommended Covers

The recommended cover types are as follows:

- Flat aluminum covers with above cover truss system for the Primary Clarifiers.
- Flat aluminum covers for the Splitter Box.
- Existing Aluminum Dome cover for the WAS Holding Tank.
- GBT Integral Hoods and Dispersed Suction Ductwork in the GBT Room.

3.14.4 Odor Control Technologies

To determine which foul air treatment system is most appropriate for the odorous air stream, a first-level screening analysis was performed comparing H_2S concentration versus flow as shown in Table 3-19.

H_2S concentration is used because it is the best indicator of the treatment systems' ability to control odors for most wastewater processes.

Table 3-19. First Level Screening Matrix Based on Hydrogen Sulfide for Selecting Technology

Condition	Low Concentration <10 ppm	Medium Concentration 10-50 ppm	High Concentration >50 ppm
Low Flow <5,000 cfm	Adsorber	Adsorber Biofilter	Biofilter
Medium Flow 5,000 – 20,000 cfm	Adsorber	Biofilter Biotrickling Filter Chemical Scrubber	Biotrickling Filter Chemical Scrubber
High Flow > 20,000 cfm	Adsorber Biofilter Chemical Scrubber	Biofilter Biotrickling Filter Chemical Scrubber	Biotrickling Filter

Based on the guidelines presented and the anticipated odor characteristics and air flows presented in earlier, either a biotrickling filter (BTF) or possibly a chemical scrubber could serve as an appropriate technology. A BTF is recommended and will be installed for the following reasons:

- Avoids hazardous chemicals.
- Lower operational and maintenance demands.
- Longer media life.
- Biological System familiar to process operators.

A polishing second stage using activated carbon will be installed to account for organic sulfides and other trace organics in the foul air which may be present as well as to capture any residual H_2S which may pass the BTF, though the BTF will be specified and capable of obtaining 99% H_2S removal.

3.14.5 Summary of Proposed Foul Air Capture and Transport

The following defines key points regarding the proposed foul air capture and transport systems. Drawing G-00-33 provides a schematic of these concepts and provides air flows and sizes of the ductwork.

- Flat Covers and hoods designed to contain and capture the odorous air.
- Above grade FRP ductwork to transport the air to treatment.

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- All processes targeted for odor control will have negative pressures within them to minimize fugitive foul air.

3.14.6 Summary of Proposed Odor Control Treatment Facilities

The following defines key points regarding the proposed foul air treatment system.

3.14.6.1 Key Development Information, Features and Design Data

The odor control system will include the following features. Table 3-20 and Table 3-21 summarize the critical process data.

- Two first-stage BTFs in parallel handling equal air flow.
- Two second-stage activated carbon units in parallel handling equal air flow.
- Fans located between BTFs and carbon to reduce air humidity.
- Nutrient tanks and pumps to serve BTFs.
- A ferric addition system will be incorporated into the design and located near the Primary Clarifiers. This system was further discussed in Section 3.5. It serves to aid with overall odor control, H_2S removal in the digester gas and struvite control in the digestion systems.

Table 3-20. Biotrickling Filter Design Criteria

Parameter	Value
Number or Units	2
Detention Time	12 seconds
Bed Depth	16 ft
Vessel Diameter	12 ft
Media Volume	1800 cu ft
Media Life	>10 years
Gas Velocity	80 fpm
H_2S Removal, Typical	99%

Table 3-21. Activated Carbon System Design Criteria

Parameter	Guidelines
Detention Time	3.39 secs
Bed Depth	3 ft
Gas Velocity	53 fpm
H_2S Treatment Efficiency	99.9%
Influent H_2S Concentration	Up to 5 ppm
Odors Treated	H_2S, Organic Sulfides
Pressure Drop Across Carbon Bed	2 inches per ft of Media
Air Flow Direction	Upflow
Types of Carbon	Coconut Shell
Inlet Foul Air Relative Humidity (RH)	≤ 70% for Virgin Carbon ≤ 90% for Catalytic Carbon
Carbon Vessel Material	FRP

3.14.7.2 Operation and Control Narrative

The odor control system will consists of two BTFs, two operating fans, and two activated dual bed activated carbon units.

Normal Operation

Normal odor control operation is as follows:

- Two BTF (each rated at 10,000 cfm), followed by two duty activated carbon units (each rated at 10,000 cfm). Both odor control systems will operate continuously 24 hours a day.
- The odor control system will include air flow measuring devices and variable speed drive fan motors; speed will be changed manually. The goal is to maintain desired air flow through each system. Fan speed will be modulated to maintain a flow rate of approximately 10,000 cfm for each system while maintaining a negative pressure in tanks.
- Pressure under the covers of the Primary Clarifier tank, WAS holding tank and splitter box will be manually monitored to ensure that tanks are kept under negative pressure. Ductwork dampers and fan speed may be adjusted to maintain that pressure.
- The hydrogen sulfide levels downstream of BTF will be monitored to monitor that the BTF is performing satisfactorily.

Standby Operations

There are several standby operating scenarios using the spare fan rated at 10,000 cfm.

- If a fan is out of service, cross-connect piping allows using the other fan for both sides of the system.
- If a BTF is out of service foul air can bypass the BTF and go straight to the carbon system.
- If one or both carbon units are out of service the exhaust from the BTF passes straight to the atmosphere.
- If an entire odor control train is down, the system can be run with one train on line only; though with less effective capture at the process unit.

3.15 Supporting Processes

The following presents a review of the existing supporting process facilities and new proposed facilities which are a part of the proposed improvements.

3.15.1 Drain Pumping - Lift Station 1 (LS-1) and Lift Station 2 (LS-2)

The SWWRF's existing process drain facilities are comprised of two separate interplant, gravity collection systems. These two gravity systems drain to respective lift stations (LS-1 and LS-2) which collect tank drains, washdown drainage, centrates and a limited amount of stormwater and pump their respective flows back the Headworks for treatment.

This project will only impact LS-2. As a result of the improvements, a large portion of the existing process drain pipes it currently receives will be demolished. A new LS-2 wetwell will be constructed, its pumps relocated and additional pumps will be added.

3.15.2 Plant Reuse Water

The SWWRF is a permitted water reclamation facility that distributes treated effluent through the City's public access reclaimed water system. Onsite, the facility takes advantage of this water source for different process applications, which helps to offset their potable water demand.

The existing reuse water system runs throughout the site and services various process areas in lieu of potable water. There is an existing network of 4-inch and smaller pipelines that run through the facility. The impact to the existing pipelines will be selective demolition within the limits of the project area. However, these pipelines will be reestablished to maintain existing uses and to meet the additional demand of the project.

3.15.3 Potable Water

Potable water is used at the plant for bathrooms, water fountains, eye washes/showers, and miscellaneous wash down areas where reuse water is either unavailable or not desired.

The facility has a single 6-inch potable water feed that enters the site along the northern property line. The 6-inch pipeline branches east and west to services feeds around the site. The existing pipe network appears to be 6-inch along the northern portion of the site, but quickly reduces to smaller pipe sizes to facilitate the water needs around the site.

The project will improve upon the existing internal potable water system by creating a 6-inch loop that extends around to wrap the perimeter of the project area. This new loop will provide for potable water needs within the project area. Most notable will be the ability to service new fire hydrants on the south side of the project area.

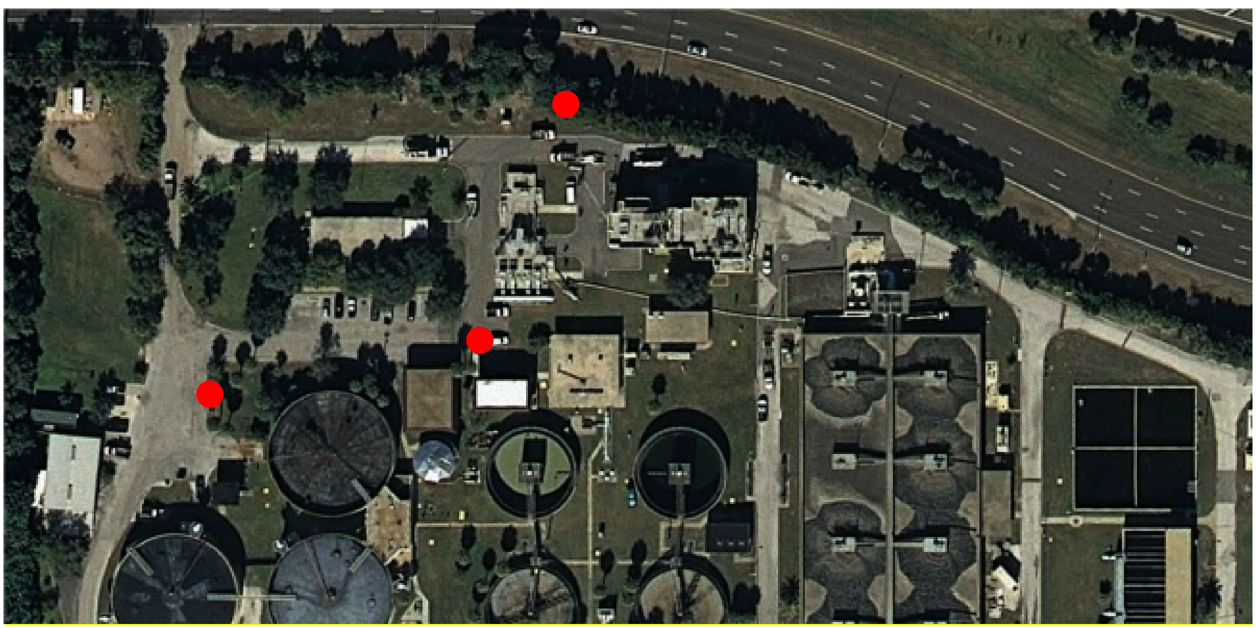


Figure 3-12. Location of Existing Fire Hydrants

3.15.4 Fire Suppression and Fire Hydrants

The SWWRF utilizes the potable water system for on-site fire hydrants. Existing hydrants are shown in Figure 3-12. The new 6-inch potable water loop as described earlier in this PDR will be used to supply new hydrants within the project area.

Along with the fire hydrants, all of the buildings have fire extinguishers placed at accessible locations. The Electrical, GBT and Chlorine MCC rooms all have fire alarms installed in the buildings. New MCC Rooms as part of this project will include fire alarms.

Section 4

Discipline Design Criteria

The following provides a review of the major design criteria for the primary disciplines involved in the project.

4.1 Site – Civil Design Review

4.1.1 Existing Site Conditions

The existing site conditions at the SWWRF have been altered over the course of the past 60-years that the plant has been in operation. The plant has undergone numerous expansions and improvements and the general layout of the site is split into two separate treatment plants. The "old plant" and the active operational facility which process all of the plant's wastewater flow. The "old plant" located in the middle of the facility is currently not in operation (circular aeration basin, secondary clarifiers, splitter box, etc.) and this area is relatively unused with the exception of miscellaneous pump stations used for sludge transfer or process/storm drain water. The "old plant" is to be demolished as part of the Biosolids to Energy Program.

In the last 15-years the most notable change to the site is the foundations for new mechanical/electrical equipment have been raised to be above the FEMA 100-year flood plain. These raised finished floor elevations are approximately 4 to 5-feet above the existing grade and accessed by stairs.

4.1.2 Overall Site Development and Coordination with Future Expansions

The overall development of the site has been coordinated with the other ongoing activities on site. In addition, future consideration for a fourth secondary clarifier and third digester has been planned and appropriate space has been identified.

4.1.3 Site Improvements

The site improvements proposed for this project are mostly confined within the center of the site. The following section describes the proposed improvements.

4.1.3.1 Internal Roads

The existing roads for the facility are sufficient for general access around the facility. The main roads are asphalt and are functionally in average condition. All new internal roads will be asphalt and a minimum of 15-foot wide. The new roadways will have a typical cross section, which includes 2.5-inch of asphalt, an 8-inch base, and a 12-inch sub base.

4.1.3.2 Internal Sidewalks

As a result of the demolition of the "old plant" and the existing abandoned digesters there is very little existing sidewalk within the central portion of the facility that will remain. New sidewalks will be constructed allowing a solid surface walkway interconnecting adjacent process areas and their associated stairways/doorways/pump pads/work areas. The sidewalks will be a standard 5-foot wide to accommodate not only pedestrians but also equipment dollies and hand trucks. It should be noted that due to the 100-year flood plain and the elevated finished floors for all mechanical equipment the sidewalks will in some situations, not match the finished slab elevations and will terminate at stairs or ramps which will lead up to the mechanical and electrical equipment.

4.1.3.3 Site Grading and Landscaping

The general topography of the site is flat with only minor variation in grade. The site is generally 5 to 7-feet above sea level. It is important to note the City of St. Petersburg has a historical vertical datum that is used within the City Limits. This vertical datum is approximately 99-feet greater than sea level. All elevations used for the purposes of this project are based upon this vertical datum.

The proposed topography will be raised in the center project area to improve access. Other areas will generally be maintained with minor grade adjustments made to provide positive drainage. Between tanks and various structures more fill may be used to level areas adjacent to raised foundations improving access.

Landscaping on site is sparse and is most notable along the property lines, outside of the existing fence. Interior to the site there are random trees, mostly palm trees with oak trees located near the operation building. The area associated with the Project will not receive any new landscaping beyond grass and occasional gravel features near structures.

4.1.3.4 Storm Water Drainage

The existing site is comprised of two drainage basins, as shown in Figure 4-1.

Basin 1 has an existing FDEP Environmental Resource Permits (ERP).

Basin 2, within which is included the majority of the proposed improvements in the Biosolids to Energy Program, does not have an existing ERP. This basin collects all surface water drainage within its basin in yard drains and inlets and then pumps it via Lift Station 1 or Lift Station 2 to the Headworks. Considering this method of stormwater collection and treatment no ERP has been required for Basin 2.

The proposed improvements will include re-grading a portion of the site which will allow for a portion of Basin 2 to be redirected to the existing stormwater pond which serves Basin 1. Figure 4-2 shows the approximate area to be redirected to the existing stormwater pond and is denoted as Proposed Basin 3. This modification will reduce the amount of stormwater that is currently collected and pumped to the Headworks.

This modification will require an expansion of the stormwater pond and an FDEP ERP permit modification. For areas within Basin 2 that cannot be modified, the project includes a new combined process drain and storm drain gravity system which will drain back to a relocated Lift Station 2. This system will be sized to accommodate a 25yr/ 24hr design storm. Yard drains and inlets will be strategically placed to capture runoff and promote positive drainage away from foundations.

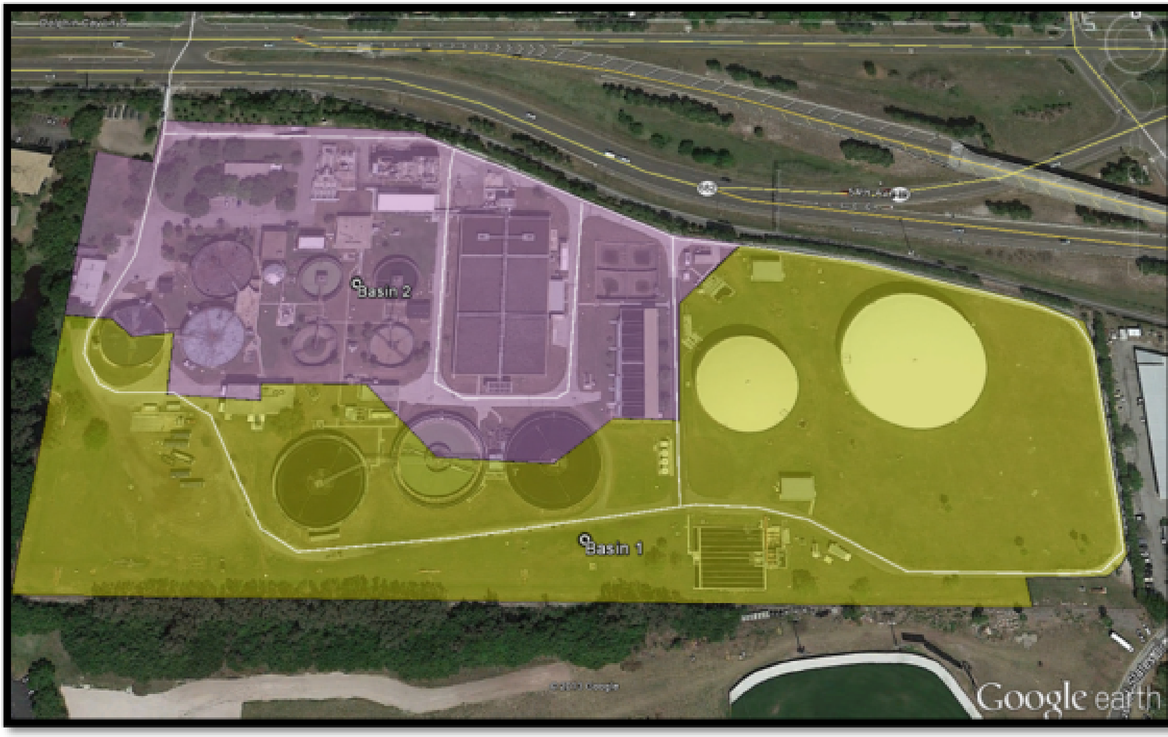


Figure 4-1. Drainage Basins

Figure 4-2. Modified Drainage Basins

4.1.3.5 Soil Erosion and Sediment Control

Given the existing topography and drainage basins, sediment and erosion control will be limited to protecting the existing drainage inlets associated with Basin 2. The contractor's laydown, spoil and fill stockpiles will require sediment control measures to prevent the migration of sediments. Additionally, any work adjacent to the property lines and existing onsite drainage facilities will be protected with either silt fence or hay bales as defined in the Stormwater Pollution Prevention Plan to be prepared by the Contractor.

4.1.3.6 Site Access and Security

The site currently has an existing 6-foot high chain link perimeter fence with primary access for all staff, visitors and delivery trucks through the main gate located on the south side of State Road 682/54th Avenue/Pinellas Bayway. All visitors are required to sign-in at the main office. No improvements are proposed to site access or security.

4.1.4 Yard Piping

The major piping systems along with their proposed designation, pipe diameter and pipe materials are summarized in Table 4-1 below.

Valves in the yard piping will include primarily plug valves on all process water and gate valves for potable water and reuse applications.

Utility separations/crossings will be in accordance with the FDEP, Rule 62-555.314.

Table 4-1. SWWRF Major Piping List

Process	Flow Designation[a]	Nominal Pipe Diameter (in)	Pipe Material
Preliminary Treatment	SRS	60-inch	DIP
Primary Treatment	PS and PSC PE CS SF	6-inch 48-inch 36-inch 36-inch	DIP
Secondary Treatment	WAS and SSC	6-inch	DIP
Thickening	THS	6-inch	DIP
Anaerobic Digestion and Batch Tanks	DS	6-inch	DIP
Digester Gas Handling	DG	8-inch to 24-inch	SS
Digester Gas Upgrading and Final Compression	DG and WGA	2 ½-inch to 10-inch	SSHDPE CS
Dewatering and Dewatering Sludge Handling	DS	6-inch	DIP
Supplemental Feedstock	FOG	6-inch	DIP
Odor Control	FA	12-inch to 42-inch	FRP/Restrained/Fiber Glass Weld
Drain Pumping	PPD	20-inch	DIP
Potable Water	PW	1-inch to 6-inch	DIP
Plant Reuse Water	PLW	1-inch to 6-inch	DIP

Table 4-1. SWWRF Major Piping List			
Process	Flow Designation[a]	Nominal Pipe Diameter (in)	Pipe Material
Process Drain	PD	6-inch to 24-inch	DIP
Storm Drain	STD	12-inch to 24-inch	DIP

[a] *Flow Designations: SRS – Screen Raw Sewage, PS-Primary Sludge, PSC – Primary Scum, PE – Primary Effluent, CS – Contact Stabilization, SF – Step Feed, WAS – Waste Activated Sludge, SSC – Secondary Scum, THS – Thickened Sludge, DS – Digested Sludge, DF – Digester Gas, WGA – Waste Gas, FOG – Fats Oil Grease, FA – Foul Air, PPD – Pumped Process Drainage, PW – Potable Water, PLW – Chloridated Plant Water, PD – Gravity Process Drain, STD – Storm Drain*

Pipe wrappings will be used and corrosion test stations installed in areas where soil corrosivity is expected. Additionally, import soil will be specified to be non-corrosive in nature.

4.2 Structural

4.2.1 Applicable Codes and Standards

The following standard codes have application at this site:

2014 FBC, *Florida Building Code* (2014)

ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures* (2010)

ACI-318-11, *Building Code Requirements for Structural Concrete* (2011)

ACI-350-06, *Code Requirements for Environmental Engineering Concrete Structures and Commentary* (2006)

ACI-530-11, *Building Code Requirements for Masonry Structures* (2011)

4.2.2 Structural Basis of Design

All buildings and other structures will be designed for the following loads on the gross floor or roof area. Equipment loads do not have to be independently accounted for if they do not exceed the uniform design load less an appropriate allowance for piping, conduits, or equipment suspended from the underside of the floor.

Dead Loads

Dead loads used in the calculations shall be the minimum expected and shall consist of only the structure dead load plus the minimum operating weight of major equipment. Allowances for concrete floor screening to achieve sloped floors shall be made by adding half of the screed thickness to the nominal floor thickness when calculating the slab dead load.

Typical dead load allowance for lighting and sprinkler piping unless noted otherwise: 5 psf

Live Loads

Note: "Collateral live load," where noted below in the table, will be further defined in the specific structures/building area drawings during subsequent project submittals.

Roofs (except electrical and control rooms):	20 psf roof live load + 10 psf collateral live load allowance
Electrical and control room roofs:	20 psf roof live load + 20 psf collateral live load allowance

Roof HVAC Mechanical equipment areas:	150 psf
Process area slab on grade:	400 psf (unless noted otherwise)
Non-process area slab on grade:	100 psf (unless noted otherwise)
Office and lobby area:	100 psf
Office file/records area:	125 psf
Laboratory:	125 psf
Electrical and control room floor:	300 psf
HVAC mechanical room floor:	150 psf (unless noted otherwise)
Material storage area slab on grade:	500 psf and forklift load as appropriate
Elevated grating floors:	100 psf posted LL + 20 psf collateral LL
Columns:	No column live load reduction allowed
Stairs, landings and exit ways:	100 psf
Equipment platforms, walkways/catwalks:	100 psf + 10 psf collateral LL
Truck access areas:	AASHTO HS20 loading

Concentrated Loads

The following structural elements shall be designed for the indicated concentrated live loads. The uniform live loads stated above need not be considered at the same time as the concentrated loads.

Concrete roof:	6 kips on 30"x30" area
Grating floors and walkways:	1 kip on 30"x30" area
Stairs:	1 kip point load

In addition, excess equipment loads must be considered. These loads could arise when equipment that is normally operated only partially full of fluid floods. Depending upon the frequency of the excess loading and activities occurring during such an event, it may be reasonable to consider reducing the floor live load as much as 50% during the event. Any excess equipment load that cannot be offset against live load shall be considered as live load in addition to the uniform live load. It is not necessary to consider excess loading in conjunction with wind loads.

Fall restraint ultimate strength loads of 5,000 pounds are to be provided for at every main frame line as a steel erection load or at locations where a permanent fall restraint anchor is provided. Live loads (not present at the same time as fall restraint loads), or wind loads do not need to be combined with this load.

Wind Loads

Code: Florida Building Code 2014

Ultimate Design Wind Speed -
(Risk Category III): 160 mph

Topographic Factor (K_{zt}): C

Facility is in a wind-borne debris region.

Seismic Loads

Seismic loads are not applicable for this facility as per the Florida Building Code 2014.

Foundation Loads, Buoyancy Loads and Flooding

A geotechnical investigation has been conducted due to uncertainty related to the exact positions of the structures. Results from the geotechnical report for the project and the foundation designs of existing structures were reviewed for the foundation designs.

Flooding and buoyancy loads are applicable.

Impact Loads

Impact loads shall be considered in the design of all floor and framing systems.

The following impact load factors shall be used unless recommendations of the equipment manufacturer will cause a more severe load case.

Rotating machinery:	20% (Fdn. Wt. = Min. 10 times rotating wt. or 3 times gross equipment wt., whichever is greater)
Reciprocating machinery:	50% (Fdn. Wt. = Min. 10 times reciprocating wt. or 3 times gross equipment wt., whichever is greater)

It may not be feasible to provide the above minimum foundation weights at elevated slabs or beam/slab systems. In this case a dynamic analysis may be required to ensure an acceptable design (no resonance at operating speed) for vibration.

Monorail hoists:	
Vertical:	25% of lifted load
Longitudinal:	10% of lifted load
Hangers supporting floors and platforms:	33% of live and dead load

Load Combinations

All buildings and structures shall be designed to withstand the load combinations as specified in the governing building code. Where the exclusion of live load, soil load, or impact would cause a more severe load condition for the member under investigation, then the load shall be ignored when evaluating that member.

4.2.3 Structural Materials

This section summarizes material properties and assumptions that will be used for the structural design.

Aluminum

Structural shapes:	6061-T6 per ASTM B308
Bolts:	Stainless steel ASTM A193, Grade B8M Class 1, AISI 316 for aluminum framing connections
Guardrails and handrails:	6061-T6 per ASTM B241
Floor and cover plates:	6061-T6 per ASTM B209
Grating:	6061-T6 per ASTM B221

Concrete

Concrete work shall conform to:	ACI 318-11 “Building Code Requirements for Reinforced Concrete” and ACI 301-10 “Specifications for Structural Concrete for

	Buildings." ACI 350-06 shall apply to liquid containing concrete design, such as basins and tanks.
Foundations:	4,500 psi @ 28 days
Elevated slabs/walls:	4,500 psi @ 28 days
Liquid containing structures:	4,500 psi @ 28 days
Cement:	Type I or II Cement per ASTM C150 (to be verified by geotechnical investigation)
Aggregate:	¾" max typ., except 1" max for foundations and concrete greater than 12" thick
Slump:	3" to 5" before adding high range water reducers. Maximum slump after adding water reducing admixture shall be 8"
Air entrainment:	4% to 6% except at interior slabs in heated buildings
Reinforcement:	ASTM A615, Grade 60 Deformed [ASTM A706, Grade 60, where welding is required]

Masonry

Concrete Block:	8" or 12" ASTM C90, f'm=1,500 psi (unless higher strengths are required by design), medium weight, Grade N block. Mortar, ASTM C270, type S
Grout:	ASTM C476, course grout with 2,000 psi, 28-day compressive strength
Reinforcing:	ASTM A615, Grade 60, Deformed

4.3 Piping and Pumping Systems

This section summarizes process-mechanical systems that will be used for the mechanical design.

4.3.1 Pipes

The major process mechanical piping requirements were previously discussed in this PDR. Key sludge piping considerations include the following.

- Two forty-five degree bends will be used in place of 90 degree bends where possible and especially on the suction side of pumps.
- Multiple cleanouts and hose connections will be provided through each piping system.
- Most sludge and scum piping will be glass lined ductile iron pipe.
- All sludge and scum lines will be 6-inches or larger regardless of pipe velocity.

4.3.2 Pumps

Rotary lobe type pumps were selected for sludge and scum pumping for the project. An attempt was made to unify the pumping systems as best as possible to simplify and standardize maintenance and operation.

End suction centrifugal pumps are the preferred type of pumps for pumping hot water that is required for sludge heating and cooling purposes.

4.4 Electrical Systems

4.4.1 Summary of Electrical Design

The plant power distribution system is currently under modification and when completed will consist of a looped 12 KV system. 12 KV will be run in a ring configuration around the plant feeding area power distribution transformers that step the 12 KV down to 480 VAC, 3 phase power for a given process area. Review and coordination with that project identified the need for additional transformers near the new digesters and the biogas upgrade system.

4.4.2 Electrical Design Standards

The EPA Class-I Reliability Criteria set forth in Design Criteria for Mechanical, Electrical, and Fluid Systems and Component Reliability (EPA 430-99-74-001) requires that two separate and independent sources of electric power be provided from either two separate utility substations or from a single substation and a plant-based standby power generation system.

The FBC references the 2005 edition of the National Fire Protection Association (NFPA) 70 National Electric Code. The National Fire Protection Association (NFPA) 820 is the guidance document for wastewater treatment plants and provides additional regulatory guidelines concerning fire protection and the electrical design which are particular to wastewater treatment facilities.

The FBC and Florida Fire Prevention Code (FPC) 2007 edition, will govern the design requirements for this project. The FPC references the 2006 edition of the NFPA 1 Uniform Fire Code and NFPA 1010 Life Safety Code.

The design of electrical power, distribution and control system will follow the requirements of NFPA 70 (National Electrical Code). The proposed systems described by this report will be integrated into the existing power distribution system at the SWWRF. This equipment will include motor control centers, switchboards, transformers and lighting panels. This Biosolids to Energy Project, Thickening Project and Dewatering Project do not include new sources of normal or standby power but rely on the Engine Project which will upgrade the standby power generation system.

4.4.2.1 Process Motor Control Centers

Each MCC will be fed from a respective area 12KV-480 VAC area transformer. The MCCs will be indoors and will provide 480V starters and feeders to the process equipment and other process mechanical loads.

The proposed MCC will be specified as:

- Enclosure Type: NEMA 1 gasketed.
- Main and Ground Bus: Tin-plated copper.
- Motor Starter Units: Combination type with contactor, thermal magnetic circuit breaker or motor circuit protector and solid-state overload unit.
- Circuit Breakers: Molded case thermal magnetic type.
- With power quality meters on each MCC main to include ethernet communications to SCADA.

4.4.2.2 Underground Duct Bank

Concrete duct banks with PVC conduits will be used to route feeders from the secondary side of transformers to MCCs and panelboards. The duct banks will be steel reinforced under roadways.

4.4.2.3 Uninterruptible Power Supply Requirements

Because two independent power sources are provided at the facility, uninterruptible power supplies (UPS) will not be required for the plant equipment and processes. UPS's will be provided, however, for key control equipment and plant SCADA system additions.

4.4.2.4 Lighting and Receptacles

LED or fluorescent light fixtures will be provided in the new electrical rooms. HID or LED wall packs will be installed on exterior walls as needed for egress lighting. Fluorescent light fixtures, if selected, will be equipped with energy efficient T8 lamps and high power factor (HPF) ballasts. HID fixtures will have energy efficient pulse start ballasts. Wall switches will control interior lighting. Emergency battery units with dual lamps and exit lighting will be provided for egress. Duplex and special purpose receptacles will be located on the exterior and interior, as required.

New site lighting will be provided for the areas affected by the Biosolids to Energy Project and coordinated with the other Biosolids Improvement Projects. Site lighting will consist of pole mounted LED fixtures with internal photocell. The fixture type, conventional or LED type lighting will be determined during subsequent design phases.

4.4.2.5 Conductors

The proposed conductors are specified as:

- Secondary Service Feeder: XHHW, 600 V, bare annealed copper with 90 oC dry, 75 oC wet, cross-linked polyethylene insulation.
- Indoor Branch Circuit Conductors: THWN, 600 V, bare annealed copper with 90 oC dry, 75 oC wet, polyvinylchloride (PVC) insulation.

Instrument and Signal Cable: Single twisted, shielded pair or triad, 18 or 16 AWG, 600 V, bare annealed copper, stranded per ASTM B8, with 90 oC temperature rated PVC insulation.

4.4.2.6 Lightning and Surge Protection

Lightning and surge protection systems will be provided on buildings, power distribution and controls systems. Integral surge protection will be provided in MCC's, switchboards, panel boards and control panels. Instruments will also be provided with "in line" surge protection systems to protect the instrument and controls systems. Control enclosures, for example, the Digester Control Enclosure, will include a lightning protection system designed and installed by a Master Installer Certified to provide a UL Master Label for the building.

4.5 Fire Alarm Systems

At this time we do not anticipate any new permanently occupied buildings. The Digester Control Enclosure will be classified as an unoccupied space; however, the New MCC Room as part of the Biosolids to Energy Project will include fire alarms. Fire alarm systems, smoke detectors, heat detectors, pull stations, horns and strobes will be provided as required by the National Fire Protection Agency (NFPA-820).

4.6 SCADA, Communications and Instrumentation

The plant SCADA system will consist of programmable logic controllers (PLCs) and will communicate over a fiber-optic Ethernet to existing SCADA servers. There are existing human-machine interface (HMI) computers located in the control room of the administration building. Additional facility-wide control terminals will not be installed as part of the Biosolids to Energy Project.

The fiber-optic Ethernet connection will provide electromagnetic noise, power surges and lightning protection for the PLC communication network and, if the existing system is configured in a fault tolerant configuration, will protect against communication loss due to cutting a communication conduit or degradation of a fiber communication port or connector.

The PLCs will be based on Allen Bradley Control Logix platform; the model will be selected for sufficient memory and I/O capabilities to accommodate current and future plant upgrades. PLCs will include the capability for communication with network-capable equipment including variable frequency drives, area MCCs, etc.

Each PLC will be powered through a UPS, which will provide both ride-through on power outages and additional filtering for power line transients. The PLCs will detect power loss and upon the return of power will sequentially restart equipment controlled by the PLCs. The sequence of equipment restart will be determined during detailed design and, when implemented, will also be adjustable by authorized personnel through password-protected HMI graphic screens.

Each area PLC will include a color touch screen operator interface to allow operations and maintenance staff to view the plant operation from the respective areas within the plant.

When located outside or on the plant floor, the PLC enclosure will have a type 316 Stainless Steel NEMA 4X enclosure. When located inside, in climate-controlled environments, the local control panel (LCP) enclosure will be rated NEMA 12.

Equipment driven by VFDs will have the VFDs networked to the PLCs in lieu of having hardwired PLC I/O. For the case where control panels for process equipment are equipped with PLCs for control, the PLC will generally communicate with the equipment’s control panel over an ethernet connection.

4.7 HVAC

This section summarizes the design criteria for the HVAC systems.

There is only one structure in the Biosolids to Energy Project which will require HVAC consideration, the Digester Control Enclosure and includes an MCC Room which will require air conditioning.

- Electrical Room containing Motor Control Center (MCC) and control station. The Digester Control Enclosure MCC Room will be air conditioned and will include an air purifying unit. Air conditioner units will include heresite coated copper coils. The electrical room will be included with two equally sized air conditioners to provide limited redundancy if one air conditioner fails.

The MCC Room will be designed with the following major design criteria.

Outside Design Conditions:

- Summer:
  - Design dry bulb temperature, °F: 91.3 (ASHARAE fundamentals, 1% design)
  - Design wet bulb temperature, °F: 77.3 (ASHARAE fundamentals, 1% design)
- Winter: (For information only, No heating will be provided)
  - Design dry bulb temperature, °F: 42.5 (ASHARAE fundamentals, 99% design)

Table 4-2 summarizes the indoor design criteria which will be reviewed during the detail design.

Table 4-2. Indoor Design Criteria

Parameter	Digester Control Enclosure Electrical Room[1]
Winter Condition, deg. F	60
Summer Condition, deg. F	75
Humidity Control	50% (Plus or Minus 5%) by Cooling Only
Air Conditioning	Yes
Heating	TBD
Ventilation	Yes (Small Amount to Pressurize the Room)

1. Electrical room has two AC units designed for 50% each. When one AC unit is off-line, the maximum temperature in the room will be 100 deg. F (summer time conditions, all equipment in full operation).

Section 5

Regulatory Requirements

This section presents a summary of the permits and the major regulatory guidelines applicable to this project.

5.1 Permits

The following are the primary regulatory agencies involved with granting permits for this project.

- FDEP
- City of St. Petersburg Building Department

Table 5-1 provides a summary of the potential and required permits. The following subsections provide additional details and are organized by regulatory agency.

Table 5-1. SWWRF Biosolids to Energy Permit List

Phase of Project/ (Review Time Required)	Regulatory Agency	Permit/ Permitting Action	Activity/Document Description	Permit Obtained By
60% Design	FDEP	Environmental Resource Permit (ERP) modification.	An ERP modification will be required for Basin 1 as a portion of Basin 2 will be re-graded to go to an expanded stormwater pond in Basin 1. Basin 2 does not have an ERP and thus will not require a modification.	Design Firm
60% Design	FDEP	Facility Construction Permit - Minor Modification to Operating Permit	Based on the pre-application meeting with FDEP on 01/30/2015, the submittal of a Wastewater Facility or Activity Permit Application Form 1 and an Application for a Minor Revision to a Wastewater Facility or Activity Permit and required supporting documentation will be required.	Design Firm
60% Design	City of St. Petersburg Building Department	Preliminary Meeting with St. Pete Building Department	An introductory meeting is held to review the project with the Bldg. Dept. and to receive guidance on document preparation/standards for this particular project.	Design Firm
100% Design	Pinellas County Health Dept.	Submittal for Approval by Health Dept.	A health department review will not be required as all water line modifications are being performed downstream of the facility meter and back-flow preventer.	Design Firm
100% - For Permitting Set	City of St. Petersburg Building Department --Structural Dept. --Electrical Dept. --Plumbing Dept. --Mechanical Dept. --Fire Dept.	Submittal to Building Dept. for discipline review, comment and approval.	A 100% For Permitting Set is submitted to the Building Department to receive a review, comments and approval. (Once reviewed, commented and approved, this set will be used for bidding).	Design Firm

Table 5-1. SWWRF Biosolids to Energy Permit List				
Phase of Project/ (Review Time Required)	Regulatory Agency	Permit/ Permitting Action	Activity/Document Description	Permit Obtained By
100% - For Construction	City of St. Petersburg Building Department. --Structural Dept. --Electrical Dept. --Plumbing Dept. --Mechanical Dept. --Fire Dept.	General Permit to Construct and Discipline Permits to Construct – to Contractor	Contractor resubmits drawings following the Bidding Phase. Building Department reviews sets to verify no substantive changes have occurred, verifies the Contractor's Insurance and License and then issues a General Permit to Construct to the Contractor.	Contractor
100% Design – For Construction	FDEP	NPDES Permit and Stormwater Pollution Prevention Plan	Contractor submits for an application for a NPDES permit and uses the construction design drawings and supplemental information for this permit application.	Contractor
Post Construction	FDEP	Operating Permit – Constructed as Designed	An application is made to FDEP to indicate that the plant has been constructed in accordance with the initial FDEP Facility Construction Permit.	Design Firm
Post Construction	FDEP	Operating Permit – Record Drawings and O&M Manuals	An application is made to FDEP to indicate that supplemental materials such as Record Drawings and O&M Manuals are located at the site.	Design Firm

5.1.1 FDEP

The EPA has granted permission to the FDEP to grant permits under the National Pollution Discharge Elimination System. The following summarizes the permits required by the FDEP.

- Minor Modification to Facility Permit.
- Environmental Resource Permit Modification.
- Stormwater Pollution Prevention Permit.

The strategy for the Biosolids Improvements Program is that a single application will cover the Biosolids to Energy Project, Thickening Project, Dewatering Project and Engine Project. Based on the pre-application meeting with FDEP on 01/30/2015, the submittal of a Wastewater Facility or Activity Permit Application Form 1 and an Application for a Minor Revision to a Wastewater Facility or Activity Permit and required supporting documentation will be required.

An ERP modification will be required for Basin 1 as a portion of Basin 2 will be regarded to go to an expanded stormwater pond in Basin 1. Basin 2 does not have an ERP and thus will not require a modification.

The FDEP will require a stormwater pollution prevention permit for the project during operation and construction. This will be obtained by the Contractor with by submitting a Notice of Intent (NOI) with the appropriate stormwater pollution prevention plan documentation.

5.1.2 Pinellas County

It is not believed that any permits or reviews will be required by Pinellas County. As all of the construction work is inside the WRF property, Department of Health permit is not required.

5.1.3 City of St. Petersburg

The following discusses the permitting efforts and permits required for the City of St Petersburg.

5.1.3.1 Planning and Economic Development – Development Review Committee (DRC)

The City of St. Petersburg requires a Special Exception, Site Plan Review for the improvements proposed as part of the project. The improvements will be presented to the DRC to demonstrate consistency with the existing use of the site and present adjacent impacts to neighboring properties.

5.1.3.2 Building Department

The building department requires that all buildings and structures be permitted regardless of occupancy. Signed and sealed drawings will be issued to the building department for review and approval (without specifications). Once all comments and questions issued by the Building Department are addressed, the Contractor will then be allowed to obtain the building permits.

5.2 Regulatory and Guideline Review

The following defines primary regulatory requirements and best practices regarding design, capacity and redundancy for this project.

5.2.1 Regulatory Capacity and Redundancy Requirements

The State of Florida regulations state that wastewater treatment plants shall be designed in general accordance with the best practices indicated in common texts and federal government guidance documents and cites, among many, two of the most common:

- EPA Technical Bulletin for the Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability – Supplement to Federal Guidelines for Design, Operation, and Maintenance of Waste Water Treatment Facilities.
- Water Environment Federation (WEF), Manual of Practice No. 8. Wastewater Treatment Plant Design.

The review of the EPA Technical Bulletin regarding equipment reliability is provided here and the review of the WEF Manual of Practice is provided in the following subsection concerning best practices.

5.2.1.1 EPA Redundancy and Reliability Guidelines

The following summarizes the key points of this reference which are relevant for this project. Note that portions which are redundant of the building code are not noted. All of the guidelines indicated here are being followed for this project.

110. – Works Location

"..structures and electrical and mechanical equipment shall be protected from physical damage by the maximum expected one hundred (100) year flood. The treatment work shall remain fully operational during the twenty-five (25) year floods"

"Works on coastal areas … shall be similarly protected from the maximum expected twenty five (25) and one hundred (100) year wave actions."

This is interpreted to mean that all critical plant processes and equipment which if not functioning would prevent the plant from meeting permitted effluent requirements shall be designed to these standards.

130. – Piping Requirements

"The works shall have provisions for flushing with water all scum, sludge lines…."

"All piping subject to accumulation of solids over a long period … shall be arranged in a manner to facilitate mechanical cleaning."

"Where practical, piping shall be sloped and/or have drain lines at low points to permit complete draining..."

140. – Component Maintenance and Repair

"Every vital mechanical component ... in the works shall be designed to enable repair or replacement without violating the effluent limitations or causing a controlled diversion."

211.5 – Unit Bypassing

"The design of the wastewater treatment system shall include provisions for bypassing around each unit operation, except as follows. Unit operations...such as open basins, sedimentation tanks .. shall not be required to have provisions for bypassing if the peak wastewater flow can be handled hydraulically with the largest flow capacity unit out of service."

212.1.2 – Pumps

"A backup pump shall be provided for each set of pumps which performs the same function. It is permissible for one pump to serve as backup for more than one set of pumps."

212.1.4 – Primary Sedimentation Basins

"..sufficient number of units of a size, such that with the largest unit out of service, the remaining units shall have a design flow capacity of at least 50 % of the total design flow."

While the Primary Clarifiers proposed for this project are not required to meet permitted conditions and are being installed rather to enhance solids capture and digester gas production, this guideline is still being followed.

221.1 – Alternate Methods of Sludge Disposal

"Alternate methods of sludge disposal and/or treatment shall be provided for each sludge treatment unit operation without installed back-up capability."

222.3.1 – Anaerobic Digestion Tanks

"At least two digestion tanks shall be provided. At least two of the tanks provided shall be designed to permit processing all types of sludges normally digested."

".....mixing shall have sufficient equipment or flexibility in system design to ensure that the total capability for mixing is not lost when any one piece of mechanical equipment is take out of service."

223.5 – Anaerobic Sludge Digester

"At least three access manholes shall be provided in the top of the tank. One opening shall be large enough to permit the use of mechanical equipment to remove grit and sand. A separate side wall mounted manhole shall also be provided."

234.2 – Division of Loads at Motor Control Centers

"Vital components serving the same function shall be divided as equally as possible between at least two motor control centers".

236.1 – Switchgear Location

"The electric switchgear and motor control center shall be located above ground and above the one hundred (100) year flood (or wave action) elevation."

236.3 – Motor Protection from Moisture

"...motors associated with vital equipment....shall be located at an elevation to preclude flooding from the one hundred (100) year flood or from clogged floor drains."

5.2.1.2 Water Environment Federation, Manual of Practice, No. 8

The primary elements regarding this project are included in the WEF Manual of Practice, No. 8 in Volume 1, Chapter 7 – Odor Control, Volume 2, Chapter 12 – Primary Treatment and Volume 3, Chapter 25 - Stabilization. The project conforms to the general best practices and guidelines provided in this manual of practice.

5.2.2 Florida Building Code

All buildings must comply with the 2010 edition of the Florida Building Code (FBC) Building, Plumbing, Mechanical and Test Protocol sections. This edition was officially adopted on December 31, 2010. An electronic version of the code can be found at the following website:

http://www2.iccsafe.org/states/florida_codes/

The primary standards can be found in Chapter 35 of the FBC: Building.

5.2.2.1 Usage Classification

There is only one building included in the Biosolids to Energy Project, the Digester Building (others are included in other parts of the Biosolids Improvements Program). The electrical room in the Digester Building will be classified as Factory Industrial F-2 Low-Hazard Occupancy while the main process room which includes equipment or piping will be classified as Special Purpose F-3.

5.2.2.2 Electrical Design and Fire Protection

The FBC references the 2005 edition of the National Fire Protection Association (NFPA) 70 National Electric Code. The National Fire Protection Association (NFPA) 820 is the guidance document for wastewater treatment plants and provides additional regulatory guidelines concerning fire protection and the electrical design which are particular to wastewater treatment facilities.

The FBC and Florida Fire Prevention Code (FPC) 2007 edition, will govern the design requirements for this project. The FPC references the 2006 edition of the NFPA 1 Uniform Fire Code and NFPA 1010 Life Safety Code.

5.2.2.3 Noise Requirements

The FBC only provides noise transmission guidelines for residential construction. Noise guidelines thus are governed by the 29 CFR 1910.95 and are enforced by the Occupational Safety and Health Administration. An electronic copy of these guidelines can be found at the following website:

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735

5.2.3 Local Regulations and Guidelines

Local regulatory agencies consist of the following:

- Pinellas County
- City of St. Petersburg

5.2.3.1 Pinellas County

It is not believed that any permits or reviews will be required by Pinellas County for the project.

5.2.3.2 St. Petersburg

The project will require a building permit from the City of St. Petersburg. The City of St. Petersburg's Construction Services and Permitting website indicates that any building permit application submitted shall be reviewed using the following:

- Florida Building Code 2010
- Florida Accessibility Code 2012
- Florida Fire Prevention Code 2010

The link to the permit application form is located on the website. The electronic permit application form is fillable and can be submitted via email, fax or in person. The application will be reviewed by both the City's Building Department and Zoning Department.

5.2.4 Environmental Protection Agency (EPA)

All of the solids produced at the SWWRF will be digested to Class-A levels based on the requirements of CFR 40 - Part 503 federal regulations.

The 40 CFR 503.32(a)(3) regulations establish the requirements for producing Class-A biosolids using thermal treatment. If a digestion process has influent concentrations below 7% total solids, the equation below determines what combinations of time and temperature will produce Class-A biosolids.

$$D = \frac{50,070,000}{10^{0.1400T}}$$

In this equation, D is equal to the number of days of batch detention time required to produce Class-A biosolids at T in degrees Celsius. Figure 5-1 provides a graph of the above equation with D multiplied by 24 to convert the detention time from days to hours. The Class-A process at the SWWRF will have a 24-hour, greater-than-55°C batch operation to obtain compliance with this regulation.

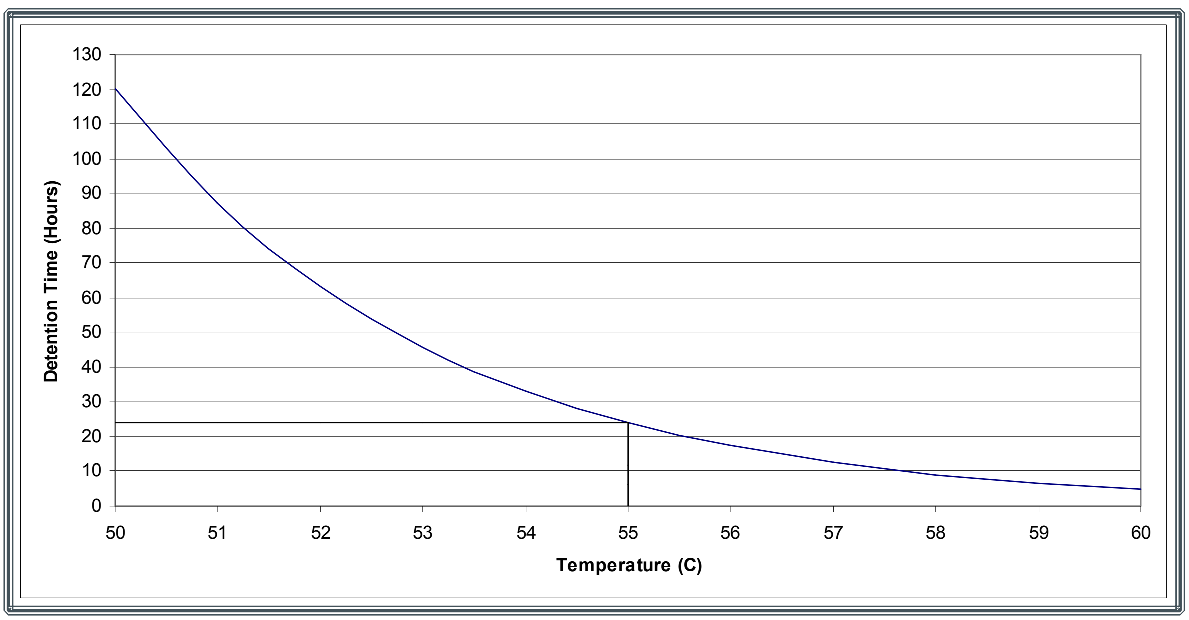


Figure 5-1. 40 CFR 503.32 Time and Temperature Requirements for Class-A Biosolids

Table 5-2 provides a summary of the required hold times versus degrees Fahrenheit and Celsius.

Table 5-2. 40 CFR 503.32 Time and Temperature Requirements for Class-A Biosolids		
Degrees Fahrenheit	Degrees Celsius	Required Hold Time (Hours)
122	50.0	120.2
123	50.6	100.5
124	51.1	84.0
125	51.7	70.2
126	52.2	58.7
127	52.8	49.1
128	53.3	41.0
129	53.9	34.3
130	54.4	28.7
131	55.0	24.0
132	55.6	20.0
133	56.1	16.8
134	56.7	14.0
135	57.2	11.7
136	57.8	9.8
137	58.3	8.2
138	58.9	6.8
139	59.4	5.7

Section 6

Construction Scheduling

The Biosolids to Energy Program is divided into multiple projects. The following portions of this Program will occur at the SWWRF.

- Engine Project. The lead design firm for the Engine Project is Black & Veatch and generally consists of demolition of the SWWRF's "old plant" infrastructure and two of the existing digesters to clear the way for the much of the follow-on work, installation and relocation of duty and standby engines and construction of a new electrical structure. This project will initiate first.
- Biosolids to Energy Project, Thickening Project and Dewatering Project. The lead design firm for the Biosolids to Energy Project is BC. The lead design firm for the Thickening Project is Carollo. The lead design firm for the Dewatering Project is AECOM. These three projects will occur concurrently and will follow the demolition portion of the Engine Project.

The following portions of the Program will occur outside of the SWWRF.

- WAS Transfer Pump Stations at the NEWRF and the NWWRF. The lead design firm for these projects is AECOM and generally consists of modifications to the NEWRF and NWWRF to provide WAS pumping to a transfer forcemain.
- WAS Transfer Forcemain for the NEWRF and the NWWRF. The City will perform the design services for this project which generally consists of forcemains from the facilities to points in the collection system which will then be used to transfer the WAS along with raw wastewater to the SWWRF.

The key proposed dates for the Biosolids to Energy Project, the Thickening Project and the Dewatering Project are as follows:

- Submit 100% Design Set to City — September, 2015
- Issue NTP to Contractor — December, 2015
- Production of Class-A Biosolids — January, 2019
- Final Completion — May, 2019

Section 7

Limitations

This document was prepared solely for City of St. Petersburg in accordance with professional standards at the time the services were performed and in accordance with the contract between City of St. Petersburg and BC dated April 19, 2013. This document is governed by the specific scope of work authorized by City of St. Petersburg; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by City of St. Petersburg and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

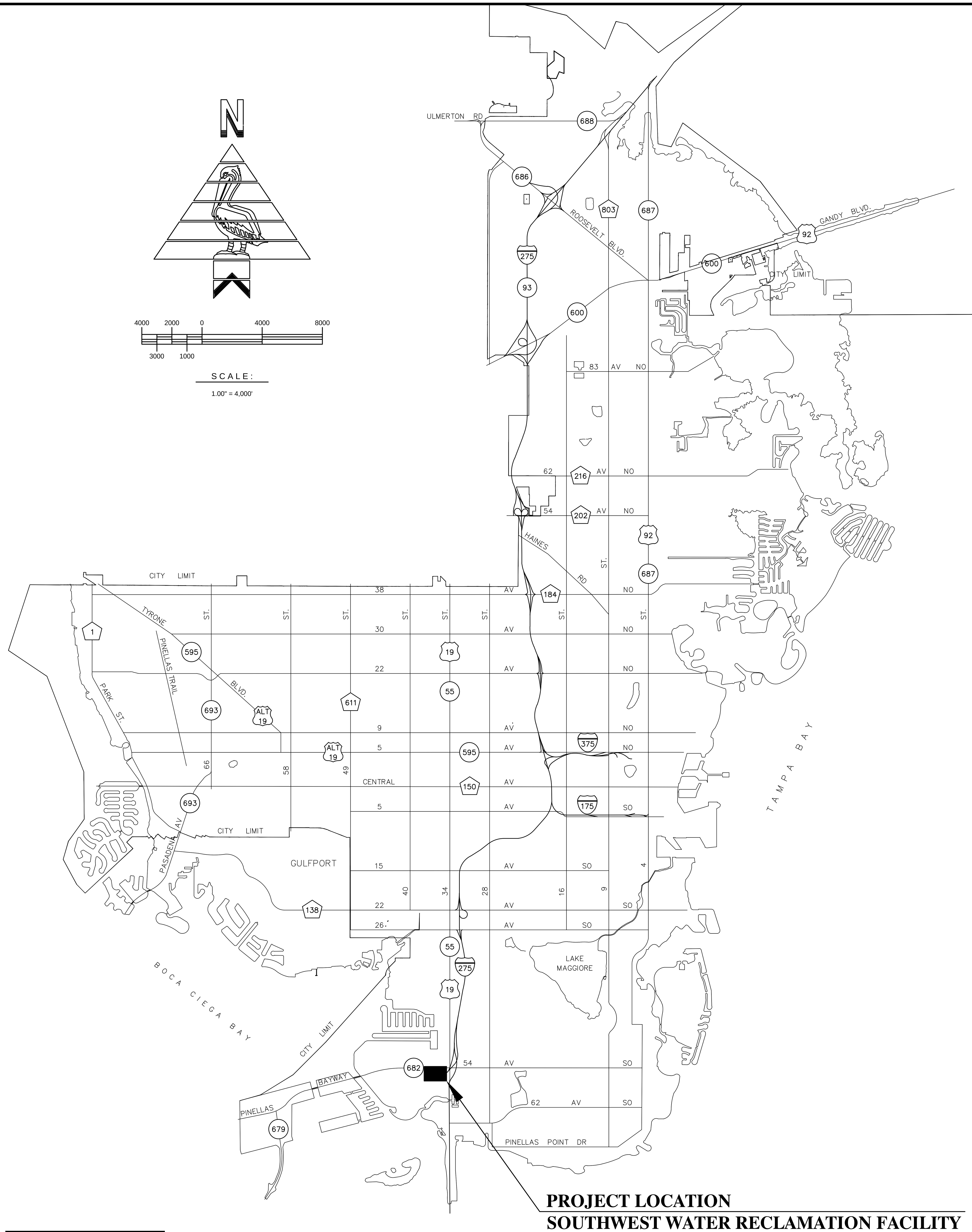
Further, BC makes no warranties, express or implied, with respect to this document, except for those, if any, contained in the agreement pursuant to which the document was prepared.

All data, drawings, documents, or information contained this report have been prepared exclusively for the person or entity to whom it was addressed and may not be relied upon by any other person or entity without the prior written consent of BC unless otherwise provided by the Agreement pursuant to which these services were provided.

Appendix A: Biosolids to Energy Project Key Design Drawings

CITY OF ST. PETERSBURG
BIOSOLIDS TO ENERGY

PRELIMINARY DESIGN REPORT SUBMITTAL



ENGINEERING AND CAPITAL
IMPROVEMENTS DEPARTMENT
CITY OF ST. PETERSBURG, FL.

Brown AND Caldwell

BROWN AND CALDWELL

DATE

WILLIAM ELEAZER, P.E.

ENGINEER OF RECORD

APPROVED FOR BID

DATE

THOMAS B. GIBSON, P.E.

DIRECTOR ENGINEERING DEPARTMENT

COPY No. ______

DATE: DECEMBER, 2013

DRAWING No. ---

GENERAL NOTES

1. ABBREVIATIONS FOR THE ENTIRE PROJECT EXCEPT ELECTRICAL ARE PROVIDED IN THESE GENERAL SHEETS.
2. ALL MECHANICAL SYMBOLS ARE IDENTIFIED IN THESE GENERAL SHEETS. GENERAL SHEETS DO NOT PROVIDE SYMBOLS NOR DETAILS FOR FOR ANY DISCIPLINE OTHER THAN MECHANICAL SYMBOLS. REFERENCE THE INDIVIDUAL DISCIPLINE SHEETS FOR ADDITIONAL DISCIPLINE-SPECIFIC SYMBOLS.

PIPING SYSTEM ABBREVIATIONS

FLOW STREAM ABBREVIATIONS

A	AERATION AIR
ABE	AERATION BASIN EFFLUENT
ABI	AERATION BASIN INFLUENT
BFPF	BELT FILTER PRESS FILTRATE
CD	CHEMICAL DRAIN
CHEM	CHEMICAL
CEN	CENTRATE
CNG	COMPRESSED NATURAL GAS
CS	CONTACT STABILIZATION
CW	COLD WATER
CWR	COLD WATER RETURN
CWS	COLD WATER SUPPLY
DG	DIGESTER GAS
DS	DIGESTED SLUDGE
DSF	DIESEL FUEL
FA	FOUL AIR
FBW	FILTER BACKWASH
FECL	FERRIC CHLORIDE
FOG	FATS OIL GREASE
GBTF	GRAVITY BELT THICKENER FILTRATE
HPA	HIGH PRESSURE AIR
HW	HOT WATER
HWR	HOT WATER RETURN
HWS	HOT WATER SUPPLY
IA	INSTRUMENT AIR
NGA	NATURAL GAS
NIT	NITROGEN
OA	OUTSIDE AIR
ODO	ODORANT
OF	OVERFLOW
PD	GRAVITY PROCESS DRAIN
PE	PRIMARY EFFLUENT
PE-CS	PRIMARY EFFLUENT - CONTACT STABILIZATION
PE-SF	PRIMARY EFFLUENT - STEP FEED
PLW	CHLORINATED PLANT WATER
POL	POLYMER
PS	PRIMARY SLUDGE
PSC	PRIMARY SCUM
PPD	PUMPED PROCESS DRAINAGE
PW	POTABLE WATER
RAS	RETURN ACTIVATED SLUDGE
RD	ROOF DRAIN
RNG	RENEWABLE NATURAL GAS
RS	RAW SEWAGE
SD	SANITARY DRAIN
SE	SECONDARY EFFLUENT
SF	STEP FEED
SLW	SEAL WATER
SPW	SPRAY WATER
SRS	SCREENED RAW SEWAGE
SSC	SECONDARY SCUM
STD	STORM DRAIN
THS	THICKENED SLUDGE
TD	TANK DRAIN (PROCESS UNIT TANK DRAIN)
V	VENT
VC	CHEMICAL VENT
WAS	WASTE ACTIVATED SLUDGE
WGA	WASTE GAS

PIPING TYPE ABBREVIATIONS

304SS	304 STAINLESS STEEL
316SS	316 STAINLESS STEEL
CI	CAST IRON
CIS	CAST IRON SOIL PIPE
CMLS	CEMENT LINED STEEL
CMP	CORRUGATED METAL PIPE
CPVC	CHLORINATED POLYVINYL CHLORIDE
CU	COPPER PIPE
CUK	COPPER PIPE - TYPE K
CUL	COPPER PIPE - TYPE L
DI	DUCTILE IRON
DIGL	GLASS LINED DUCTILE IRON
ELS	EPOXY LINED STEEL
FRP	FIBER REINFORCED POLYETHYLENE
HDPE	HIGH DENSITY POLYETHELYENE
PCCP	PRESTRESSED CONCRETE PIPE
PVC	POLYVINYL CHLORIDE
RCP	REINFORCED CONCRETE PIPE
ST	STEEL

EQUIPMENT ABBREVIATIONS

A	AERATOR
AB	AERATION BASIN
ACC	AIR CONDITION COIL
ACU	AIR CONDITIONING UNIT
AD	AIR DRYER
AF	AIR FILTER
AHC	AIR HANDLING UNIT W/COIL
AHU	AIR HANDLING UNIT
APU	AIR PURIFICATION UNIT
ASC	ADJUSTABLE SPEED CONTROL
ASD	ADJUSTABLE SPEED DRIVE
B	BLOWER
BFP	BELT FILTER PRESS
BLR	BOILER
BNR	BURNER
C	COIL
CCT	CHLORINE CONTACT TANK
CDR	CONDENSER
CFR	CHEMICAL FEEDER
CHR	CHILLER
COL	COLLECTOR
COM	COMMINUTOR
CON	CONVEYOR
CP	COMPRESSOR
CPUL	CARBON POLISHER
CRN	CRANE
CT	COOLING TOWER
CTF	CENTRIFUGE
CV	CONTROL VALVE
CVR	FLOATING COVER
CYL	CYLINDER
DIS	DISTRIBUTOR
DPR	DAMPER
DS	DISCONNECT SWITCH
DU	DRIVE UNIT
E	ENGINE
EB	ENGINE BLOWER MODULE
EF	EXHAUST FAN
EPR	EVAPORATOR
F	FAN
FCT	FERRIC CHLORIDE TANK
FLT	FILTER
FPU	FLUID POWER UNIT
FT	FOG TANK
FTP	FLAME TRAP
FUR	FURNACE
GBT	GRAVITY BELT THICKENER
GDR	GRINDER
GEN	GENERATOR
GT	GATE
H	HOIST
H	HEAT EXCHANGER
HOP	HYDRAULIC OPERATOR
HP	HEAT PUMP
HPU	HYDRAULIC POWER UNIT
HTR	HEATER
HTT	HEAT TRACE TAPE
HV	HAND OPERATED VALVE
INJ	INJECTOR
IW	INJECTION WELL
LCP	LOCAL CONTROL PANEL
LVR	LOUVER
M	MOTOR
MME	MISC. MECHANICAL EQUIPMENT
MOP	MOTOR OPERATOR
MSP	MOTOR STARTER PANEL
MUX	MULTIPLEXER
MX	MIXER
MZ	MULTIZONE UNIT
ORT	ODOR REMOVAL TOWER
P	PUMP
PC	PROCESS OR PERSONAL COMPUTER OR PRIMARY CLARIFIER
PLC	PROGRAMMABLE LOGIC CONTROLLER
POP	PNEUMATIC OPERATOR
PRV	PRESSURE RELIEF VALVE
PVL	PRESSURE VESSEL
RAD	RADIATOR
REC	RECEIVER
SC	SECONDARY CLARIFIER
SCR	SCRUBBER
SEP	SEPARATOR
SF	SUPPLY FAN
SLG	SLIDE GATE
SLR	SILENCER
SMP	SAMPLER
ST	STEAM TRAP
STDP	STANDPIPE
STN	STRAINER
STP	SEDIMENT TRAP
SUB	SUBSTATION
SWBD	SWITCHBOARD
T	TANK
TBN	TURBINE
TCV VALVE	TEMPERATURE CONTROL
TFR	TRANSFORMER
TM	TIMER
TRS	TRANSFER SWITCH
UH	UNIT HEATER
VE	VESSEL
VEN	VENTILATOR
VP	VACUUM PUMP
WCC	WATER CONTROL CABINET
WGB	WASTE GAS BURNER
WH	WATER HEATER
WHR	WASHER
WSR	WATER SOFTENER UNIT

GENERAL ABBREVIATIONS

A	AMPERE OR AERATOR
AB	AERATION BASIN
ACC	AIR CONDITION COIL
ACU	AIR CONDITIONING UNIT
AD	AIR DRYER
ADJ	ADJUSTABLE
AF	AIR FILTER
AFD	ADJUSTABLE FREQUENCY DRIVE
AFF	ABOVE FINISHED FLOOR
AFG	ABOVE FINISHED GRADE
AHC	AIR HANDLING UNIT W/COIL
AHU	AIR HANDLING UNIT
AL	ALUMINUM
ASC	ADJUSTABLE SPEED CONTROL
ASD	ADJUSTABLE SPEED DRIVE
ASPH	ASPHALT
ASR	AQUIFER SURFACE RECHARGE
ASSOC	ASSOCIATION
ASTM	AMERICAN SOCIETY OF TESTING MATERIALS
ATS	AUTOMATIC TRANSFER SWITCH
AUTO	AUTOMATIC
AUX	AUXILIARY
AVG	AVERAGE
AWG	AMERICAN WIRE GAGE
B	BLOWER
BEL	BELOW
BF	BLIND FLANGE
BFP	BACKFLOW PREVENTER
BFPF	BELT FILTER PRESS FILTRATE
BFV	BUTTERFLY VALVE
BHP	BRAKE HORSEPOWER
BLDG	BUILDING
BLR	BOILER
BM	BENCH MARK
BNR	BURNER
BOT	BOTTOM
BT	BACKWASH TANK OR BATCH TANK
BTDPS	BATCH TANK DISCHARGE PUMP STATION
BV	BALL VALVE
C	CELSIUS OR COIL
CAB	CABINET
CATV	CABLE TELEVISION
CB	CATCH BASIN
CCT	CHLORINE CONTACT TANK
CDR	CONDENSER
CF	CUBIC FOOT
CFR	CHEMICAL FEEDER
CHAN	CHANNEL
CHR	CHILLER
CI	CAST IRON
CIR	CIRCLE
CJ	CONSTRUCTION JOINT
CL	CENTERLINE
CLG	CEILING
CLR	CLEAR
CMU	CONCRETE MASONRY UNITS
CO	CLEANOUT
COL	COLUMN OR COLLECTOR
COM	COMMINUTOR
CON	CONVEYOR
CONC	CONCRETE / CONCENTRIC
CP	COMPRESSOR
CPLG	COUPLING
CR	CRANE
CT	CURRENT TRANSFORMER
CTF	CENTRIFUGE
CTG	COATING
CYL	CYLINDER
D1	DIGESTER 1
D1PS	DIGESTER 1 DISCHARGE PUMP STATION
D1RPS	DIGESTER 1 RECYCLE PUMP STATION
D2	DIGESTER 2
D2PS	DIGESTER 2 DISCHARGE PUMP STATION
D3	DIGESTER 3
D3PS	DIGESTER 3 DISCHARGE PUMP STATION
DB	DUCT BANK
DC	DIRECT CURRENT
DEMO	DEMOLITION / DEMOLISH
DEPT	DEPARTMENT
DIA	DIAMETER
DIM	DIMENSION
DIS	DISTRIBUTOR
DPR	DAMPER
DS	DISCONNECT SWITCH
DU	DRIVE UNIT
DWG	DRAWING
DWL	DOWEL
E	EAST OR ENGINE
EA	EACH
EB	ENGINE BLOWER MODULE
ECC	ECCENTRIC
ECF	EQUIPMENT CONNECTION FITTING
EF	EACH FACE
EL	ELEVATION
ELEC	ELECTRICAL / ELECTRIC
EMH	ELECTRICAL MANHOLE
ENGR	ENGINEER
EOP	EDGE OF PAVEMENT
EPR	EVAPORATOR
EPS	EFFLUENT PUMP STATION
EQ	EQUAL
EQUIP	EQUIPMENT
ES	ELECTRICAL SERVICE
ESMT	EASEMENT
EW	EACH WAY
EST	ESTIMATE / ESTIMATED
EXIST	EXISTING
EXP	EXPANSION
EXT	EXTERIOR
F	FAHRENHEIT OR FAN
FBW	FILTER BACKWASH
FC	FAIL CLOSED
FCPS	FERRIC CHLORIDE PUMP STATION
FCT	FERRIC CHLORIDE TANK
FH	FIRE HYDRANT
FLEX	FLEXIBLE
FLR	FLOOR
FLT	FILTER
FM	FORCEMAIN
FO	FAIL OPEN
FP&L	FLORIDA POWER & LIGHT
FPM	FEET PER MINUTE
FPS	FOG DISCHARGE PUMP STATION
FPU	FLUID POWER UNIT
FR/FPS	FOG RECYCLE FEED PUMP STATION
FSPS	FOAM SUPPRESSION PUMP STATION
FT	FEET / FOOT OR FOG TANK
FTP	FLAME TRAP
FUR	FURNACE
FURN	FURNISHED
GBFT	GRAVITY BELT THICKENER FILTRATE
GBV	GLOBE VALVE
GDR	GRINDER
GEN	GENERATOR
GFI	GROUND FAULT INTERRUPTER
GPD	GALLONS PER DAY
GPM	GALLONS PER MINUTE
GR	GRADE
GRT	GROUT
GSKT	GASKET
GT	GATE
GV	GATE VALVE
H	HIGH OR HOIST
HGL	HYDRAULIC GRADE LINE
HGR	HANGER
HOA	HAND-OFF-AUTO
HOP	HYDRAULIC OPERATOR
HOR	HORIZONTAL
HP	HEAT PUMP
HPU	HYDRAULIC POWER UNIT
HTR	HEATER
HTT	HEAT TRACE TAPE
HV	HAND OPERATED VALVE
HZ	HERTZ
ID	INSIDE DIAMETER
IE	INVERT ELEVATION
IN	INCH
INSUL	INSULATION
INV	INVERT
IPS	INFLUENT PUMP STATION
IW	INJECTION WELL
JB	JUNCTION BOX
JT FLR	JOINT FILLER
KW	KILOWATT
L	LENGTH
LB	POUND
LCP	LOCAL CONTROL PANEL
LF	LINEAR FEET
LP	LIGHT POLE / LIGHTING PANEL
LPNG	OPENING
LS	LIMIT SWITCH OR LIFT STATION
M	MOTOR
MAS	MASONRY
MATL	MATERIAL
MAX	MAXIMUM
MCC	MOTOR CONTROL CENTER
MECH	MECHANICAL
MFR	MANUFACTURER
MGD	MILLION GALLONS PER DAY
MH	MANHOLE
MIN	MINIMUM / MINUTE
MOP	MOTOR OPERATOR
MPH	MILES PER HOUR
MSP	MOTOR STARTER PANEL
MUX	MULTIPLEXER
MZ	MULTIZONE UNIT
N	NORTH
NAVD	NATIONAL AMERICAN VERTICAL DATUM
N.C.	NORMALY CLOSED
NE	NORTHEAST
NEC	NATIONAL ELECTRICAL CODE
NEG	NEGATIVE
NEUT	NEUTRAL
NGVD	NATIONAL GEODETIC VERTICAL DATUM
N.O.	NORMALLY OPEN
NOM	NOMINAL
NTS	NOT TO SCALE
NW	NORTHWEST
OA	OUTSIDE AIR
OD	OUTSIDE DIAMETER
OH	OVERHEAD
OHP	OVERHEAD POWER
OPER	OPERATOR
OPNG	OPENING
P	POWER
PAR	PARALLEL
PC	PROCESS OR PERSONAL COMPUTER OR PRIMARY CLARIFIER
PE-CS	PRIMARY EFFLUENT - CONTACT STABILIZATION
PE-SF	PRIMARY EFFLUENT - STEP FEED
PH	PHASE
PLC	PROGRAMMABLE LOGIC CONTROLLER
PLT	PLANT
PLYWD	PLYWOOD
PNL	PANEL
POI	POINT OF INTERSECTION
POL	POLYMER
POP	PNEUMATIC OPERATOR
POT	POINT OF TANGENCY
PP	POWER POLE
PRPS	PUBLIC REUSE PUMP STATION
PS	PUMP STATION
PSA	PRESSURE SWING ABSORPTION
PSF	POUNDS PER SQUARE FOOT
PSI	POUNDS PER SQUARE INCH
PT	POINT
PTS	PRELIMINARY TREATMENT STRUCTURE
PV	PLUG VALVE
PVL	PRESSURE VESSEL
Q	FLOW
QTY	QUANTITY
R	RADIUS
R/W	RIGHT OF WAY
RE	RIM ELEVATION
REC	RECEIVER
REF	REFERENCE
REINF	REINFORCE / REINFORCED / REINFORCING
REQD	REQUIRED
REV	REVISION
RPM	REVOLUTIONS PER MINUTE
S	SOUTH
SAN	SANITARY
SB	SOIL BORING
SC	SECONDARY CLARIFIER
SCH	SCHEDULE
SCPS	SCUM PUMP STATION
SCR	SCREEN OR SCRUBBER
SE	SOUTHEAST OR SECONDARY EFFLUENT
SEP	SEPARATOR
SHT	SHEET
SLR	SILENCER
SMP	SAMPLER
SPEC	SPECIFICATION
SSC	SECONDARY SCUM
ST	STEAM TRAP
STA	STATION
STD	STANDARD
STRUC	STRUCTURE / STRUCTURAL
STRW	STORAGE REJECT WATER
SUB	SUBSTATION
SV	SOLENOID VALVE
SW	SOUTHWEST
SWBD	SWITCHBOARD
SWGR	SWITCHGEAR
SWK	SIDEWALK
SYM	SYMMETRICAL
TBN	TURBINE
TCV	TEMPERATURE CONTROL VALVE
TEL	TELEPHONE
TEMP	TEMPORARY / TEMPERATURE
TFR	TRANSFORMER
TM	TIMER
T.O.	TOP OF
TPS	TRANSFER PUMP STATION
TRS	TRANSFER SWITCH
TS	TEMPERATURE SWITCH
TYP	TYPICAL
UH	UNIT HEATER
US	UTILITY STATION
V	VOLTS
VAC	VACUUM OR VOLT ALTERNATING CURRENT
VAR	VARIABLE / VARIES
VCP	VENDOR CONTROL PANEL
VE	VESSEL
VEL	VELOCITY
VEN	VENTILATOR
VERT	VERTICAL
VOL	VOLUME
VP	VACUUM PUMP
W	WEST
W	WIDTH
w.c.	WATER COLUMN
W/	WITH
W/O	WITHOUT
WB	WET BULB
WH	WATER HEATER
WHR	WASHER
WL	WATER LEVEL
WSR	WATER SOFTENER UNIT
XFMR	TRANSFORMER
XP	EXPLOSION PROOF
YR	YEAR
ZS	POSITION SWITCH

Brown AND Caldwell
TAMPA, FLORIDA

SUBMITTED: PROJECT MANAGER DATE
APPROVED: BROWN AND CALDWELL DATE

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)

DESIGNED:	B ELEAZER
DRAWN:	T DIMICELI
CHECKED:	B ELEAZER
CHECKED:	T BOSSO
APPROVED:	T BOSSO

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BIOSOLIDS TO ENERGY

GENERAL
ABBREVIATIONS

FILENAME 144490-G-00-04.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-04
SHEET NUMBER ---- OF

Jun 12, 2015 - 11:06am
\\BCTPAFP01\projects\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\G-General\144490-G-00-04.dwg
JUNE 2015

GENERAL NOTES

1. ABBREVIATIONS FOR THE ENTIRE PROJECT EXCEPT ELECTRICAL ARE PROVIDED IN THESE GENERAL SHEETS.
2. ALL MECHANICAL SYMBOLS ARE IDENTIFIED IN THESE GENERAL SHEETS. GENERAL SHEETS DO NOT PROVIDE SYMBOLS NOR DETAILS FOR FOR ANY DISCIPLINE OTHER THAN MECHANICAL SYMBOLS. REFERENCE THE INDIVIDUAL DISCIPLINE SHEETS FOR ADDITIONAL DISCIPLINE-SPECIFIC SYMBOLS.
3. REFERENCE SHEET G-00-04 FOR FLOW STREAM ABBREVIATIONS, PIPE TYPE ABBREVIATIONS, EQUIPMENT ABBREVIATIONS AND PROJECT WIDE GENERAL ABBREVIATIONS.

SHEET NUMBERING STRATEGY

X - XX - XX
- SHEET NUMBER DESIGNATION
- AREA DESIGNATION
- DISCIPLINE DESIGNATION

DISCIPLINE DESIGNATION (SINGLE CHARACTER)
- G - GENERAL
- C - CIVIL
- CD - CIVIL DEMOLITION
- A - ARCHITECTURAL
- S STRUCTURAL
- SD - STRUCTURAL DEMOLITION
- I - INSTRUMENTATION
- M - PROCESS/MECHANICAL
- MD - PROCESS/MECHANICAL DEMOLITION
- H - HVAC
- P - PLUMBING
- E - ELECTRICAL
- ED - ELECTRICAL DEMOLITION

AREA DESIGNATION
- 12 - LIFT STATION 2
- 18 - FERRIC CHLORIDE SYSTEM
- 19 - PRIMARY CLARIFIER SPLITTER BOX
- 21 - PRIMARY CLARIFIER 1
- 22 - PRIMARY CLARIFIER 2
- 23 - PRIMARY CLARIFIER SLUDGE PS
- 28 - ODOR CONTROL SYSTEM
- 31 - AERATION BASIN 1
- 32 - AERATION BASIN 2
- 78 - FOG FACILITY
- 80 - DIGESTER BUILDING
- 81 - DIGESTER 1
- 82 - DIGESTER 2
- 83 - DIGESTER 3
- 85 - BATCH TANKS
- 86 - GAS STORAGE
- 87 - GAS FLARE
- 88 - BIOGAS UPGRADE SYSTEM

CIVIL DESIGNATIONS
- 00 - GENERAL INFORMATION, NOTES, ABBREVIATIONS, SYMBOLS, LEGENDS AND STANDARD DETAILS
- 01 - SITE
- 05 - YARD PIPING
- 08 - PAVING AND GRADING
- 09 - EROSION AND CONTROL

G, C, M, A, S, H, P SHEET NUMBER DESIGNATORS
- 0X - GENERAL NOTES, ABBREVIATIONS, SYMBOLS
- 0X - PLANS - EXISTING AND DEMOLITION
- 1X - PLANS - NEW
- 2X - PARTIAL AND ENLARGED PLANS
- 3X - SECTIONS, ELEVATIONS AND PROFILES
- 4X - SCHEMATICS, ISOMETRICS AND SCHEDULES
- 5X - DETAILS

PLAN SHEET DESIGNATORS

EXISTING	NEW	
00	10	SUBSURFACE AND FOUNDATION PLANS
01	11	LOWER, 1ST FLOOR AND FLOOR PLANS
02	12	UPPER, TOP AND 2ND FLOOR PLANS
03	13	ROOF PLAN

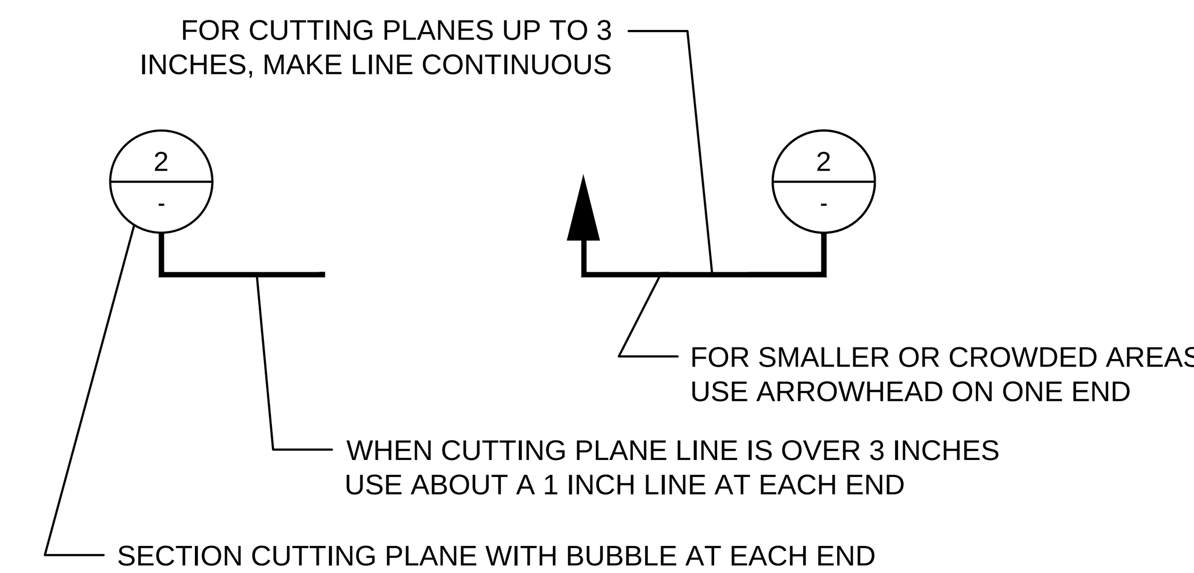
ELECTRICAL DESIGNATORS
- 00 - GENERAL INFORMATION, NOTES, ABBREVIATIONS, SYMBOLS, LEGENDS AND STANDARD DETAILS
- 01 - SITE
- 02 - SCHEMATICS AND SCHEDULES

PIPE CALL OUT SYSTEM

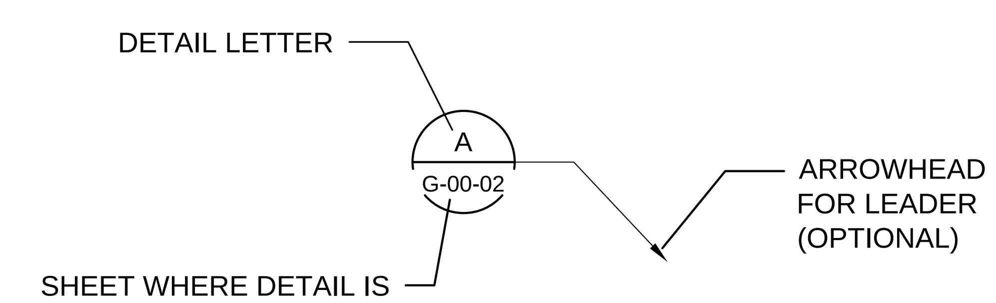
X" - XXX - XXX
- PIPE TYPE
- FLOW STREAM
- PIPE SIZE

REFERENCE SHEET G-00-04 FOR FLOW STREAM AND PIPE TYPE ABBREVIATIONS

SECTION CUT SYMBOLS



DETAIL CALL OUT SYMBOLS



LINETYPE LEGEND

- NEW
- DEMOLITION
- EXISTING
- ROAD RECONSTRUCTION
- RELOCATE OR REMOVE AND KEEP

EQUIPMENT CALL OUT SYSTEM

XXX-XXXX
- SEQUENTIAL NUMBER
- AREA RELATED NUMBER (ALSO DIRECTLY RELATED TO EXACT I SHEET)
- EQUIPMENT ABBREVIATION

HEX-8201
- SEQUENTIAL NUMBER
- AREA 82
- ABBREVIATION FOR HEAT EXCHANGER

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TAMPA, FLORIDA

SUBMITTED: ____ PROJECT MANAGER DATE
APPROVED: ____ BROWN AND CALDWELL DATE

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DESIGNED:	B ELEAZER
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BIOSOLIDS TO ENERGY

GENERAL

SYMBOLS AND LEGENDS 1

FILENAME 144490-G-00-05.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
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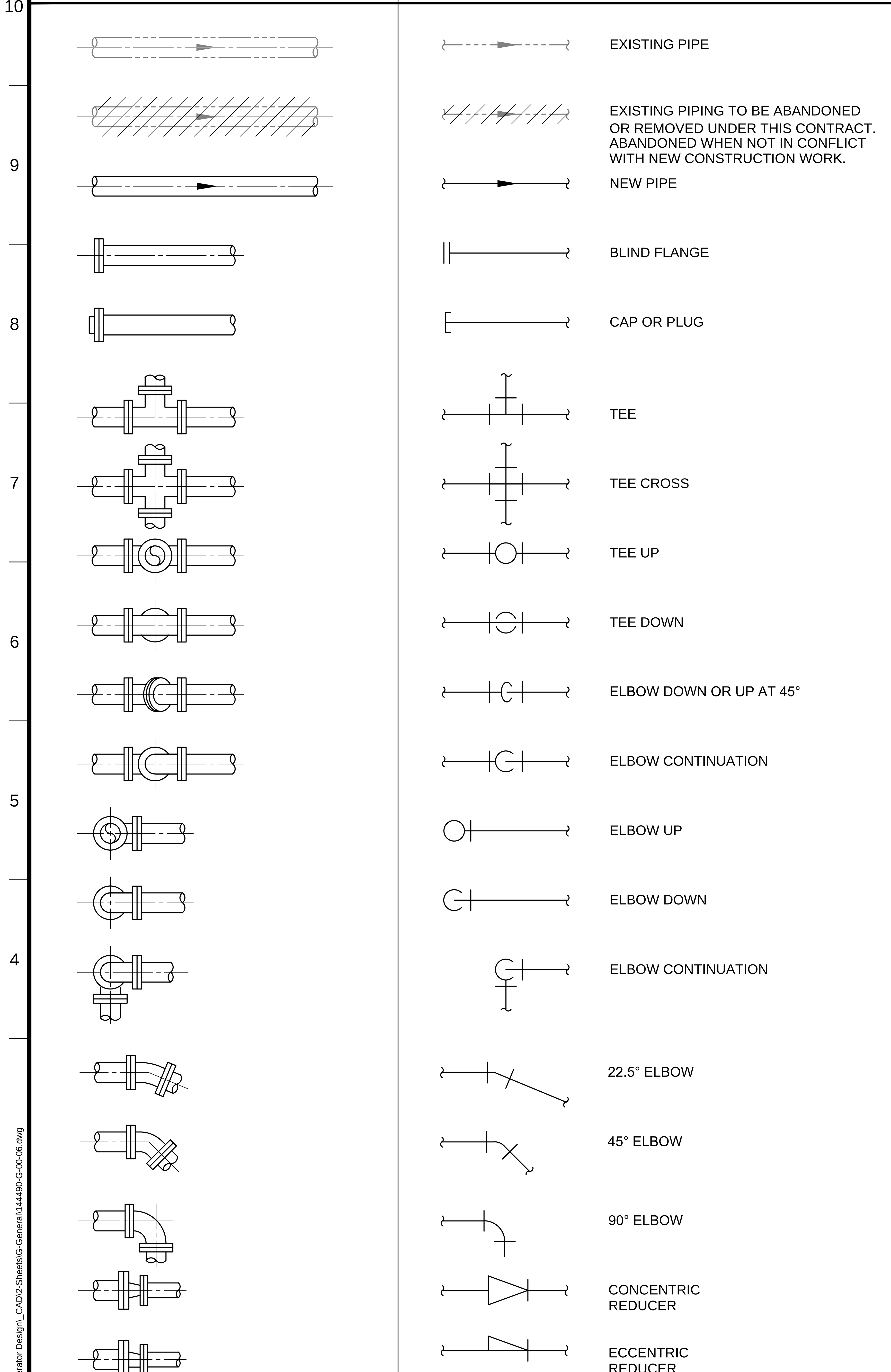
DECEMBER 2013

Dec 04, 2013 - 11:02pm P:\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\G-General\144490-G-00-05.dwg

PIPE FITTING SYMBOLS

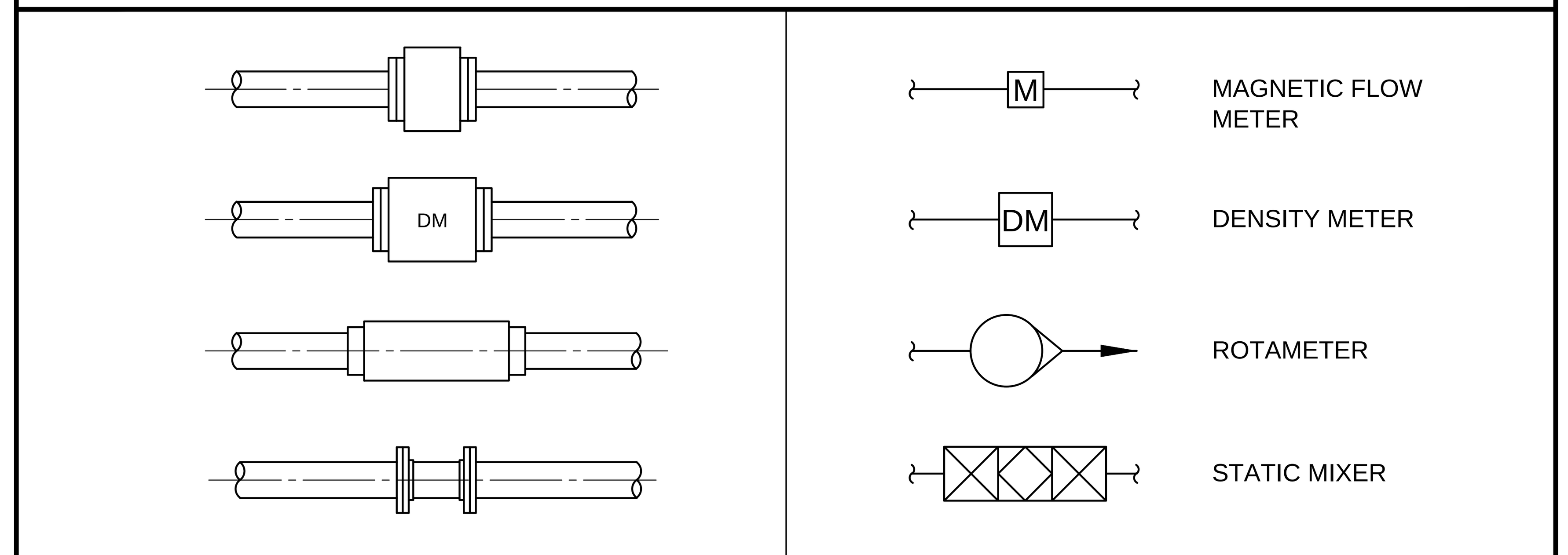
DOUBLE LINE | SINGLE LINE



- EXISTING PIPE
- EXISTING PIPING TO BE ABANDONED OR REMOVED UNDER THIS CONTRACT. ABANDONED WHEN NOT IN CONFLICT WITH NEW CONSTRUCTION WORK.
- NEW PIPE
- BLIND FLANGE
- CAP OR PLUG
- TEE
- TEE CROSS
- TEE UP
- TEE DOWN
- ELBOW DOWN OR UP AT 45°
- ELBOW CONTINUATION
- ELBOW UP
- ELBOW DOWN
- ELBOW CONTINUATION
- 22.5° ELBOW
- 45° ELBOW
- 90° ELBOW
- CONCENTRIC REDUCER
- ECCENTRIC REDUCER

- LATERAL
- LATERAL UP
- LATERAL DOWN

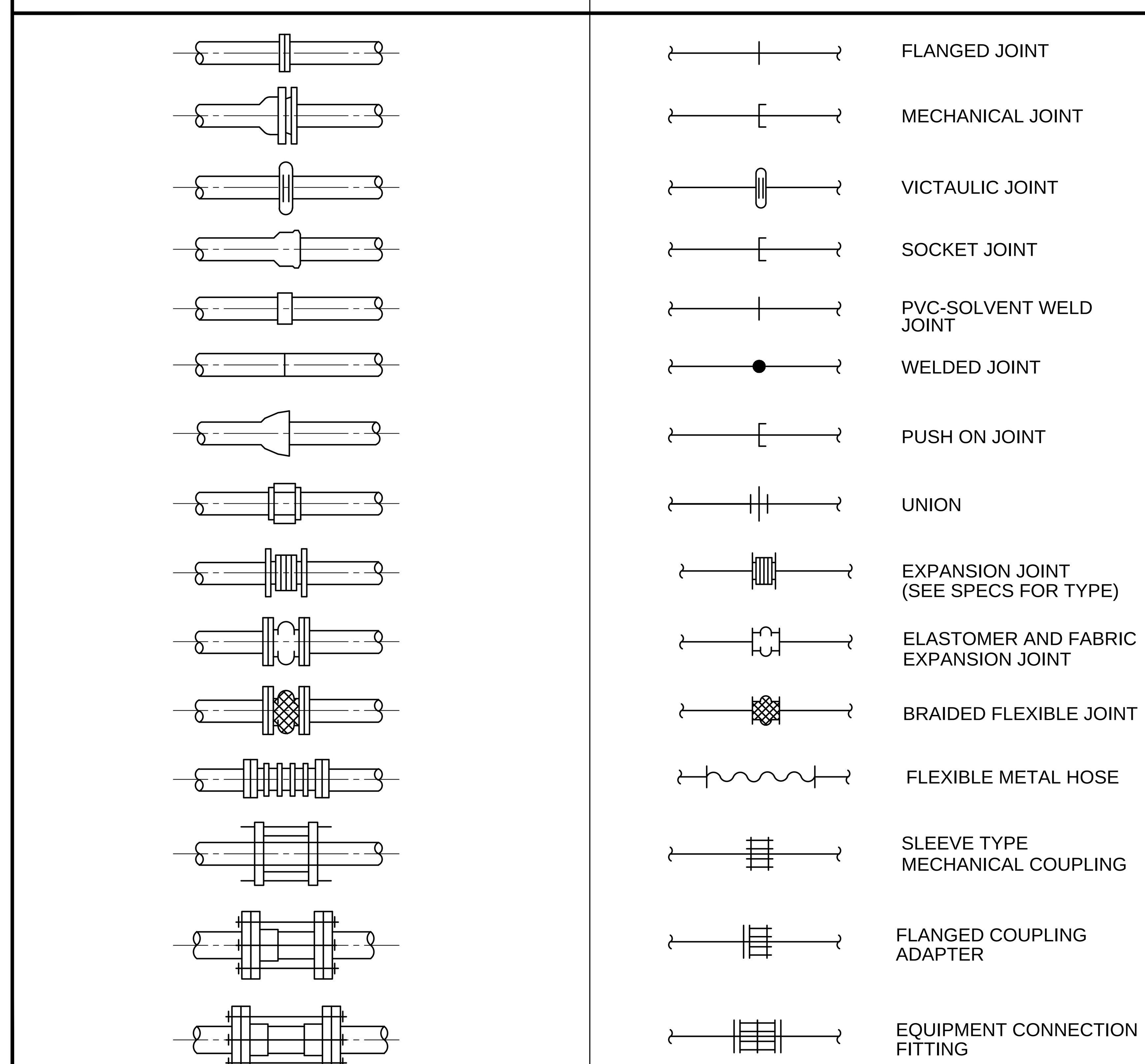
MAJOR PIPE DEVICES



- MAGNETIC FLOW METER
- DENSITY METER
- ROTAMETER
- STATIC MIXER

PIPE JOINTS AND COUPLINGS

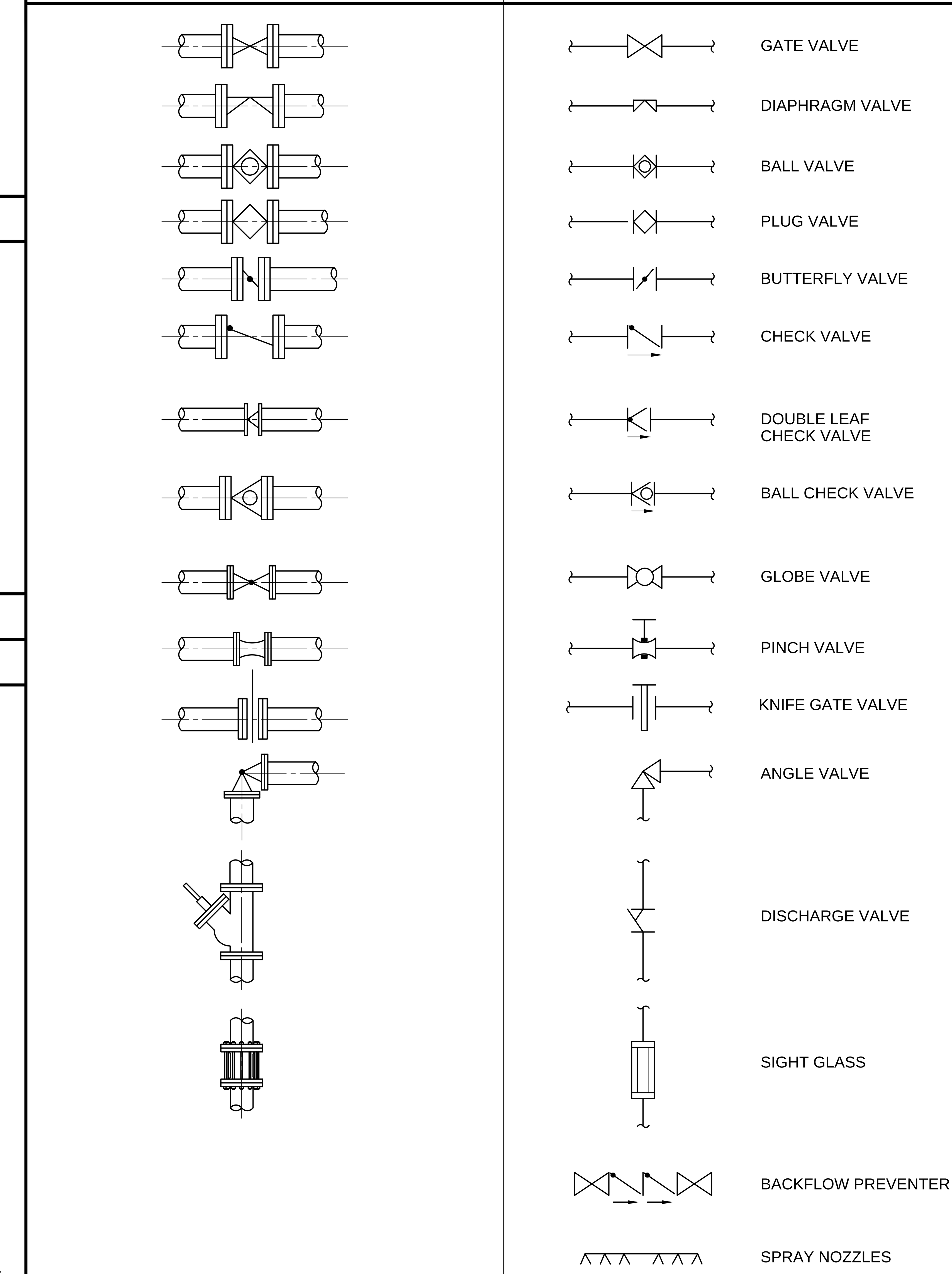
DOUBLE LINE | SINGLE LINE



- FLANGED JOINT
- MECHANICAL JOINT
- VICTAULIC JOINT
- SOCKET JOINT
- PVC-SOLVENT WELD JOINT
- WELDED JOINT
- PUSH ON JOINT
- UNION
- EXPANSION JOINT (SEE SPECS FOR TYPE)
- ELASTOMER AND FABRIC EXPANSION JOINT
- BRAIDED FLEXIBLE JOINT
- FLEXIBLE METAL HOSE
- SLEEVE TYPE MECHANICAL COUPLING
- FLANGED COUPLING ADAPTER
- EQUIPMENT CONNECTION FITTING

PIPE VALVE SYMBOLS

DOUBLE LINE | SINGLE LINE



- GATE VALVE
- DIAPHRAGM VALVE
- BALL VALVE
- PLUG VALVE
- BUTTERFLY VALVE
- CHECK VALVE
- DOUBLE LEAF CHECK VALVE
- BALL CHECK VALVE
- GLOBE VALVE
- PINCH VALVE
- KNIFE GATE VALVE
- ANGLE VALVE
- DISCHARGE VALVE
- SIGHT GLASS
- BACKFLOW PREVENTER
- SPRAY NOZZLES

NOTE:

1. SOLID FILLED VALVES INDICATE NORMALLY CLOSED (NC) POSITION.

2. SINGLE LINE PIPE SHOWN DOES NOT DEPICT FITTING TYPES. SEE SPECIFICATIONS FOR MATERIALS AND FITTINGS TO BE USED.

3. ALL PIPING LESS THAN 4 INCHES IS DEPICTED WITH A SINGLE LINE ON DRAWINGS HAVING A SCALE OF 1/4"=1'-0". FOR PIPING DRAWN AT OTHER SCALES WITH A SINGLE LINE, REFER TO THE TABLE:

SCALE	PIPE SIZE
1/8" = 1'-0"	LESS THAN 8"
3/16" = 1'-0"	" " 6"
1/4" = 1'-0"	" " 4"
3/8" = 1'-0"	" " 3"
1/2" = 1'-0"	" " 2"
3/4" = 1'-0"	" " 1 1/2"
1" = 1'-0"	" " 1"

Brown AND Caldwell
TAMPA, FLORIDA

SUBMITTED: ______ PROJECT MANAGER ______ DATE
APPROVED: ______ BROWN AND CALDWELL ______ DATE

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DESIGNED:	B ELEAZER
DRAWN:	T DIMICELI
CHECKED:	B ELEAZER
CHECKED:	T BOSSO
APPROVED:	T BOSSO

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BIOSOLIDS TO ENERGY

GENERAL

SYMBOLS AND LEGENDS 2

FILENAME 144490-G-00-06.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-06
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DECEMBER 2013

Dec 04, 2013 - 11:03pm
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ADDITIONAL PIPING SYMBOLS

- THREE WAY VALVE
- FOUR WAY VALVE
- VALVE WITH SOLENOID OPERATOR
- VALVE WITH MOTOR OPERATOR
- VALVE WITH PNEUMATIC OPERATOR
- VALVE WITH MANUAL OPERATOR
- VALVE WITH PRESSURE BALANCE OPERATOR
- VALVE WITH PISTON OPERATOR
- FLOAT VALVE
- IN-LINE, SPRING LOADED RELIEF VALVE
- FLAP GATE
- VALVE ON RISER
- VACUUM/PRESSURE RELIEF VALVE
- VACUUM RELIEF VALVE
- PRESSURE RELIEF VALVE
- MANUAL AIR VENT
- AUTOMATIC AIR VENT
- STRAINER
- PIPELINE FLUSHING/SAMPLING CONNECTION (THREADED)
- QUICK CONNECTION FITTING
- PRESSURE REGULATING VALVE
- BACK PRESSURE VALVE
- NEEDLE VALVE
- TELESCOPING VALVE
- THERMOSTATICALLY CONTROLLED VALVE
- GUAGE OR ROOT VALVE
- MUD VALVE
- PIPE ANCHOR
- COCK CONNECTION
- FLEXIBLE BRAIDED RUBBER HOSE (SINGLE OR DOUBLE LINE PIPE)
- PIPE WITH INSULATION (SINGLE OR DOUBLE LINE PIPE)
- HEAT TRACED PIPE WITH INSULATION (SINGLE OR DOUBLE LINE PIPE)
- (PLAN) (SECTION) HOSE RACK
- EQUIPMENT FLOOR DRAIN
- FLOOR DRAIN
- A UTILITY STATION (LETTER, IF ANY, DESIGNATES TYPE
- BALANCING DAMPER
- FLAME ARRESTER
- D DRAIN
- SEPARATOR
- FILTER
- DIFFUSER

EQUIPMENT SYMBOLS

- FLAT BOTTOM TANK
- CLARIFIER
- BOILER
- AERATION BASIN
- CONE BOTTOM TANK
- DIGESTER
- GRAVITY BELT THICKENER
- DRY SEAL GAS STORAGE TANK (LOW PRESSURE)
- GAS FLARE
- HEAT DUMP RADIATOR
- DUMPSTER
- CONVEYOR
- INTAKE HOOD
- SILENCER
- MIXER
- GRINDER
- HEAT EXCHANGER
- CENTRIFUGE
- GRINDER PUMP
- CENTRIFUGAL PUMP
- SUBMERSIBLE PUMP
- IN-LINE PUMP
- METERING PUMP
- PROGRESSING CAVITY PUMP
- ROTARY LOBE PUMP
- ROTARY LOBE BLOWER
- CENTRIFUGAL BLOWER
- STATIC MIXER
- COMPRESSOR
- INLET AIR FILTER-SILENCER
- SILENCER
- FINE BUBBLE DIFFUSER
- COARSE BUBBLE DIFFUSER
- SEDIMENT TRAP

SLIDE AND SLUICE GATES

NORMALLY OPEN	NORMALLY CLOSED
FLAP GATE	FLAP GATE
NO BUTTERFLY GATE	NC BUTTERFLY GATE
STOP GATE	STOP GATE
SLIDE GATE	SLIDE GATE
SLUICE GATE	SLUICE GATE

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TAMPA, FLORIDA

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CHECKED:	B ELEAZER
CHECKED:	T BOSSO
APPROVED:	T BOSSO

EXTERNAL REFERENCE FILES

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BIOSOLIDS TO ENERGY

GENERAL

SYMBOLS AND LEGENDS 3

FILENAME	144490-G-00-07.dwg
BC PROJECT NUMBER	144490
CLIENT PROJECT NUMBER	----
DRAWING NUMBER	G-00-07
SHEET NUMBER	---- OF

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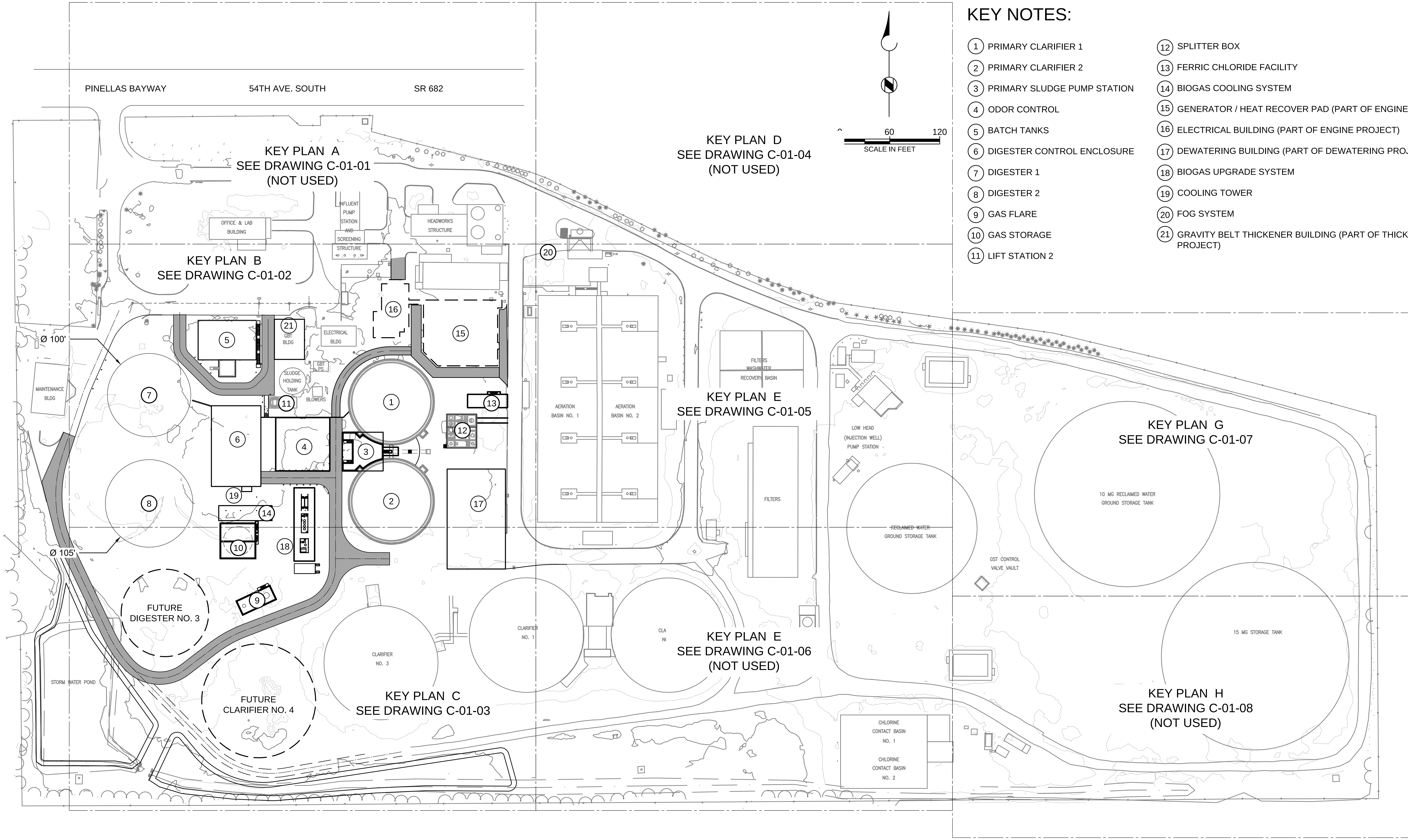

KEY NOTES:

1. PRIMARY CLARIFIER 1
2. PRIMARY CLARIFIER 2
3. PRIMARY SLUDGE PUMP STATION
4. ODOR CONTROL
5. BATCH TANKS
6. DIGESTER CONTROL ENCLOSURE
7. DIGESTER 1
8. DIGESTER 2
9. GAS FLARE
10. GAS STORAGE
11. LIFT STATION 2
12. SPLITTER BOX
13. FERRIC CHLORIDE FACILITY
14. BIOGAS COOLING SYSTEM
15. GENERATOR / HEAT RECOVER PAD (PART OF ENGINE PROJECT)
16. ELECTRICAL BUILDING (PART OF ENGINE PROJECT)
17. DEWATERING BUILDING (PART OF DEWATERING PROJECT)
18. BIOGAS UPGRADE SYSTEM
19. COOLING TOWER
20. FOG SYSTEM
21. GRAVITY BELT THICKENER BUILDING (PART OF THICKENING PROJECT)

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TAMPA, FLORIDA

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X-C-EXISTING.dwg
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X-85S01-ZP-STRC.dwg
X-C-TOPO-NEW.dwg
X-80-M.dwg
X-88S01-ZP-STRC-BC.dwg

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BIOSOLIDS TO ENERGY

CIVIL

CIVIL / PAVING AND GRADING KEY PLAN

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BC PROJECT NUMBER
144490
CLIENT PROJECT NUMBER

DRAWING NUMBER
C-01-00
SHEET NUMBER
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LEGEND:

(hatched) TO BE DEMOLISHED

GENERAL NOTES:

1. ONLY MAJOR OPERATING FORWARD FLOW AND MAJOR BYPASSES ARE SHOWN. DETAILED PROCESS SCHEMATICS ARE PROVIDED IN THE I-DRAWINGS.
2. SEE DRAWING G-00-12 FOR THE SOLIDS TREATMENT SYSTEM.

KEY NOTES:

(1) NOT USED.
(2) TO BE RECONSTRUCTED. SEE SHEET G-0021 DETAILS IN VOLUMES 4 AND 5 OF THIS CONTRACT.
(A) PART OF GENERATOR ELECTRICAL IMPROVEMENTS PROJECT.
(B) WORK DETAILED IN VOLUMES 6 AND 7 OF THIS CONTRACT.
(C) WORK DETAILED IN VOLUMES 4 AND 5 OF THIS CONTRACT.

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	CHECKED: B ELEAZER			
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GENERAL

EXISTING AND DEMOLITION PROCESS FLOW DIAGRAM

FILENAME 144490-G-00-11.dwg

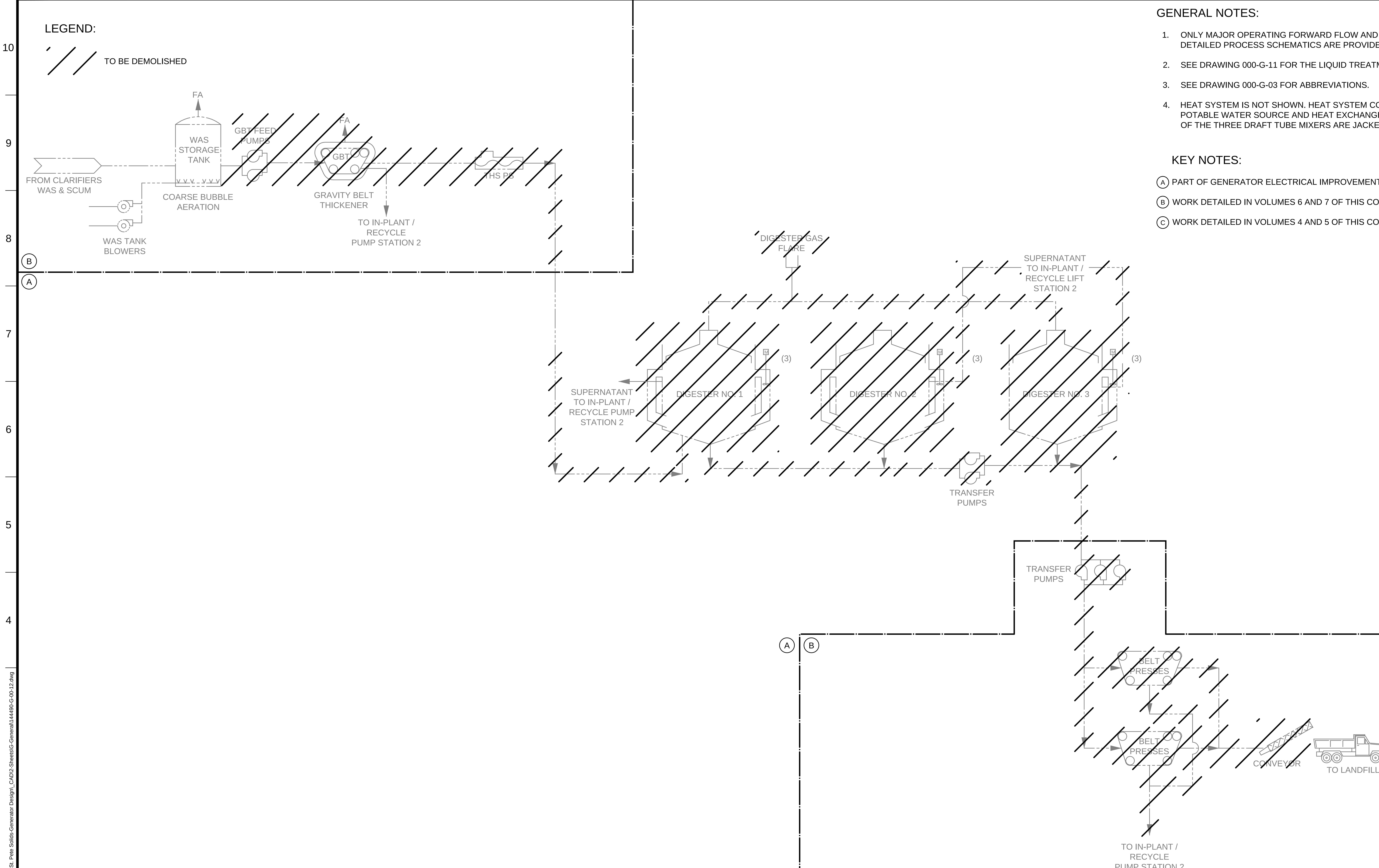
BC PROJECT NUMBER 144490

CLIENT PROJECT NUMBER ----

DRAWING NUMBER G-00-11

SHEET NUMBER ---- OF

JUNE 2015



GENERAL NOTES:

1. ONLY MAJOR OPERATING FORWARD FLOW AND MAJOR BYPASSES ARE SHOWN. DETAILED PROCESS SCHEMATICS ARE PROVIDED IN THE I-DRAWINGS.
2. SEE DRAWING 000-G-11 FOR THE LIQUID TREATMENT SYSTEM.
3. SEE DRAWING 000-G-03 FOR ABBREVIATIONS.
4. HEAT SYSTEM IS NOT SHOWN. HEAT SYSTEM CONSISTS OF A WATER BOILER, A POTABLE WATER SOURCE AND HEAT EXCHANGERS. FOR EACH DIGESTER, TWO OF THE THREE DRAFT TUBE MIXERS ARE JACKETED WITH HOT WATER.

KEY NOTES:

(A) PART OF GENERATOR ELECTRICAL IMPROVEMENTS PROJECT.

(B) WORK DETAILED IN VOLUMES 6 AND 7 OF THIS CONTRACT.

(C) WORK DETAILED IN VOLUMES 4 AND 5 OF THIS CONTRACT.

Jun 12, 2015 - 11:08am \\BCTPAFP01\projects\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\G-General\144490-G-00-12.dwg

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BIOSOLIDS TO ENERGY

GENERAL

EXISTING AND DEMOLITION SOLIDS TREATMENT SYSTEM

FILENAME 144490-G-00-12.dwg

BC PROJECT NUMBER 144490

CLIENT PROJECT NUMBER ----

DRAWING NUMBER G-00-12

SHEET NUMBER ---- OF

GENERAL NOTES:

1. ONLY MAJOR OPERATING FORWARD FLOW AND MAJOR BYPASSES ARE SHOWN. DETAILED PROCESS SCHEMATICS ARE PROVIDED IN THE I-DRAWINGS.
2. DRAWING G-00-31 FOR HEAT RESERVOIR SYSTEM AND SEE DRAWING G-00-32 FOR A SCHEMATIC OF THE DIGESTER GAS TREATMENT SYSTEM.

KEY NOTES:

- (A) PART OF GENERATOR ELECTRICAL IMPROVEMENTS PROJECT.
- (B) WORK DETAILED IN VOLUMES 6 AND 7 OF THIS CONTRACT.
- (C) WORK DETAILED IN VOLUMES 4 AND 5 OF THIS CONTRACT.

KEY NOTES:

1. TO FOUL AIR COLLECTION SYSTEM.
2. FUTURE POLYMER FEED SYSTEM FOR PRIMARY AND SECONDARY CLARIFERS.
3. NOT USED.
4. RELOCATED LS-2. WORK DETAILED IN VOLUMES 4 AND 5 OF THIS CONTRACT.

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BIOSOLIDS TO ENERGY

GENERAL

NEW PROCESS FLOW DIAGRAM 1

FILENAME 144490-G-00-21.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-21
SHEET NUMBER ---- OF

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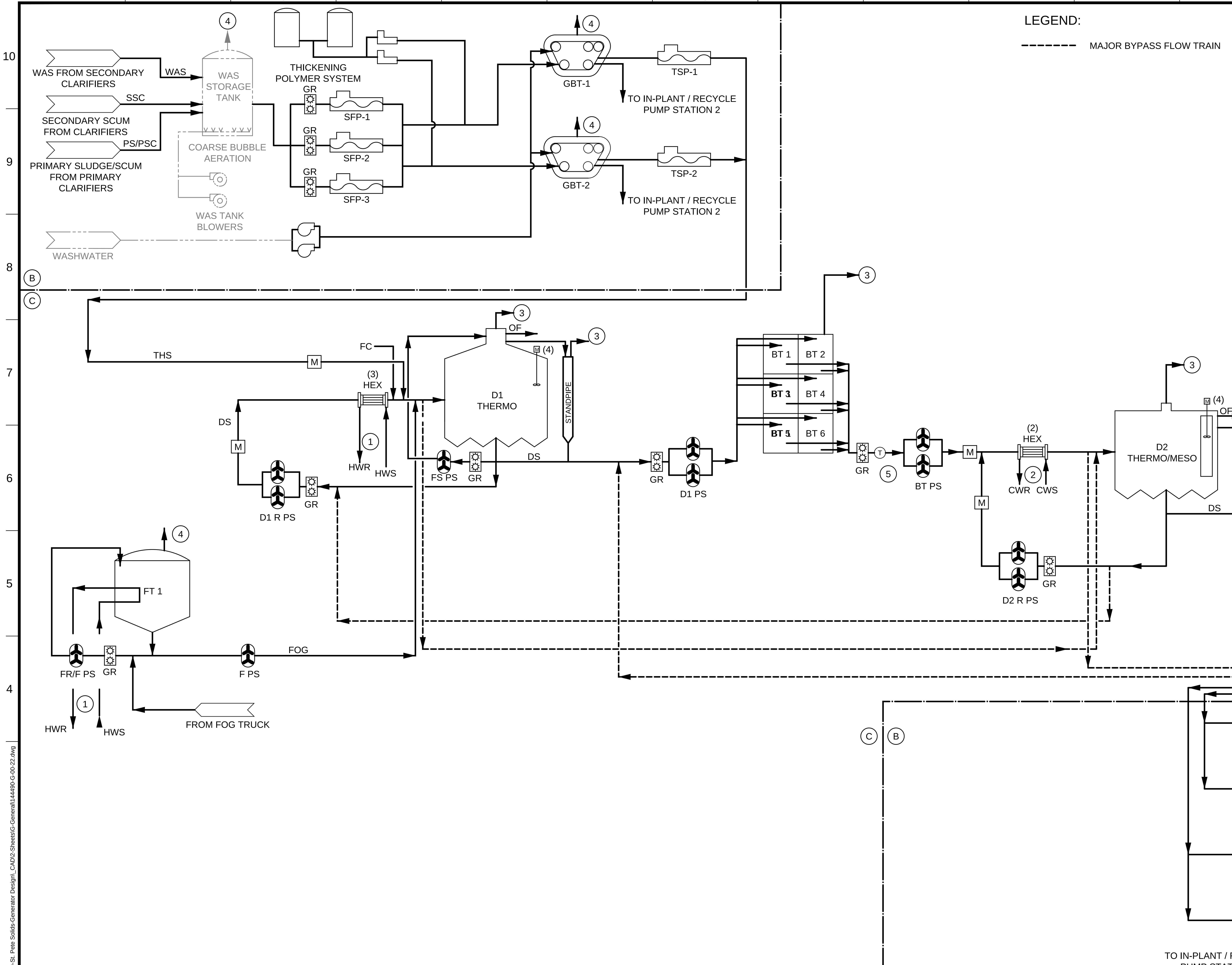

LEGEND:

- - - - - MAJOR BYPASS FLOW TRAIN

GENERAL NOTES:

1. ONLY MAJOR OPERATING FORWARD FLOW AND MAJOR BYPASSES ARE SHOWN. DETAILED PROCESS SCHEMATICS ARE PROVIDED IN THE I-DRAWINGS.
2. SEE DRAWING G-00-31 FOR HEAT RESERVOIR SYSTEM AND G-00-32 FOR A SCHEMATIC OF THE DIGESTER GAS TREATMENT SYSTEM.

KEY NOTES:

- (A) PART OF GENERATOR ELECTRICAL IMPROVEMENTS PROJECT.
- (B) WORK DETAILED IN VOLUMES 6 AND 7 OF THIS CONTRACT.
- (C) WORK DETAILED IN VOLUMES 4 AND 5 OF THIS CONTRACT.
- (1) TO/FROM SECONDARY HOT WATER LOOP
- (2) FROM PRIMARY COLD WATER LOOP
- (3) TO GAS COLLECTION SYSTEM
- (4) TO FOUL AIR COLLECTION SYSTEM
- (5) TEMPERATURE COMPLIANCE POINT

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BIOSOLIDS TO ENERGY

GENERAL

NEW PROCESS FLOW DIAGRAM
SOLID STREAM

FILENAME 144490-G-00-22.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-22
SHEET NUMBER ---- OF

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Jun 16, 2015 - 9:58am \\BCTPAFP01\projects\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\G-General\144490-G-00-22.dwg

KEY NOTES:

- (A) PART OF GENERATOR ELECTRICAL IMPROVEMENTS PROJECT.
- (B) WORK DETAILED IN VOLUMES 6-9 OF THIS CONTRACT.
- (C) WORK DETAILED IN VOLUMES 2-5 OF THIS CONTRACT.
- (1) TO GAS COLLECTION SYSTEM
- (2) TO FOG HEATING SYSTEM
- (3) FROM COOLING WATER SYSTEM
- (4) HEX-8101, HEX-8102 AND HEX-8103 ARE EACH SIZED TO PROVIDE 50% OF THE HEATING REQUIRED AND ARE INSTALLED IN SERIES.
- (5) HEX-8201 AND HEX-8202 ARE EACH SIZED TO PROVIDE 75% OF THE COOLING REQUIRED AND ARE INSTALLED IN SERIES.
- (6) BATCH TANKS ARE REQUIRED TO HOLD CONTENTS AT 131°F (OR HIGHER) FOR 24 HOURS. ANTICIPATED BATCH TANK HEAT LOSS - 0.7°F/24 HOURS UNDER PEAK DAY DESIGN CONDITION. ANTICIPATED BATCH TANK HEAT LOSS - 3.3°F/24 HOURS UNDER MIN CURRENT CONDITION.
- (7) HEAT EXCHANGER IS PART OF BUS SYSTEM.

GENERAL NOTES:

1. THICKENED SLUDGE (THS) AND DIGESTED SLUDGE (DS) FORWARD FLOW PROCESS SHOWN FOR ILLUSTRATIVE PURPOSES ONLY.
2. SEE DRAWING G-00-22 FOR SCHEMATIC OF SOLIDS HANDLING SYSTEM AND G-00-32 FOR SCHEMATIC OF GAS HANDLING SYSTEM FEEDING THE ENGINES AND BOILERS.
3. SEE DRAWING I-81-10 FOR DIGESTER 1 HEAT EXCHANGERS, I-82-10 FOR DIGESTER 2 HEAT EXCHANGERS, I-82-12 FOR COOLING TOWERS AND I-87-10 FOR GAS PRE-COOLING HEAT EXCHANGERS P&ID DETAILS.

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BIOSOLIDS TO ENERGY

GENERAL

HEAT RESERVIOR LOOP SCHEMATIC

FILENAME 144490-G-00-31.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-31
SHEET NUMBER ---- OF

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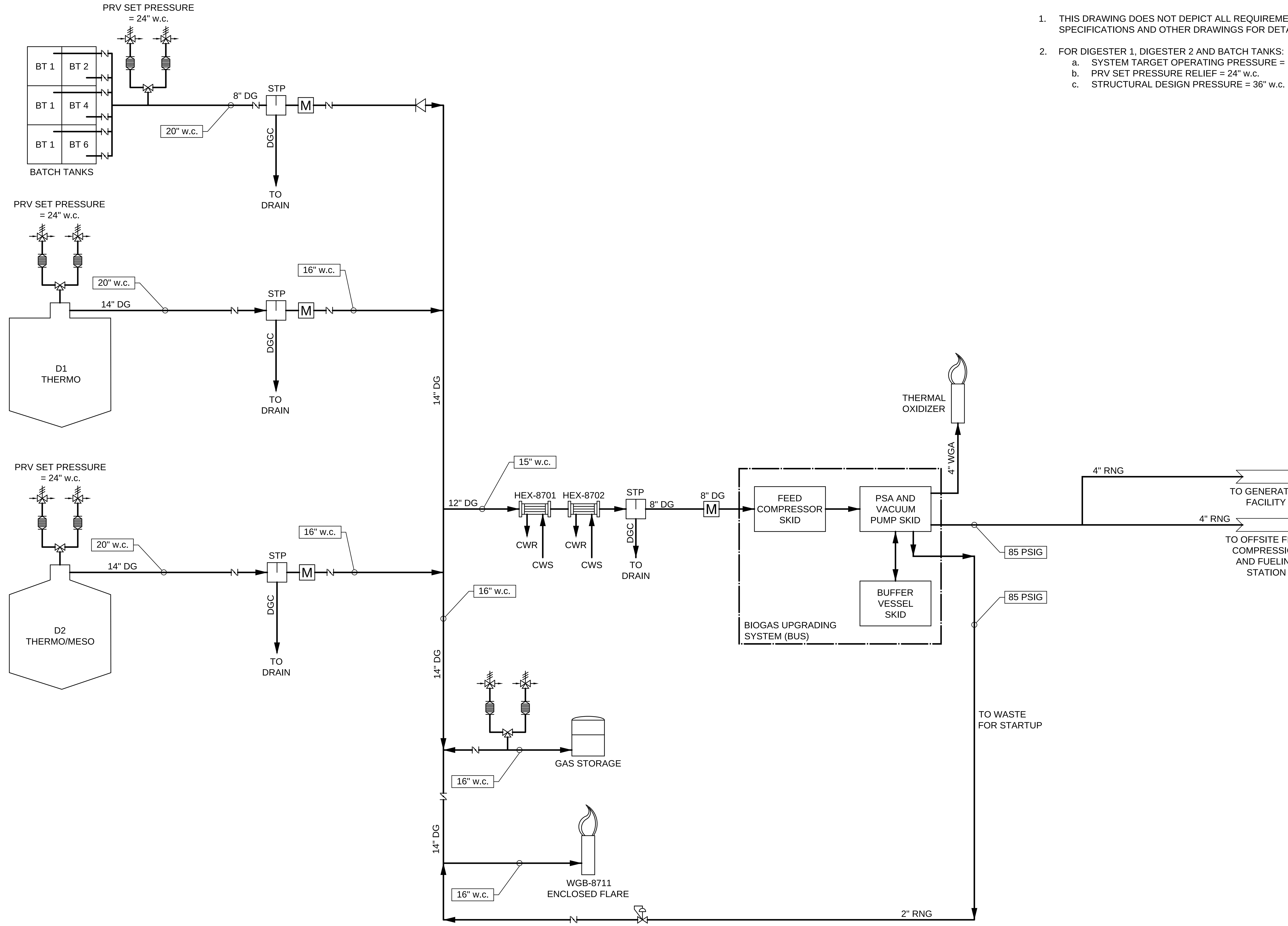
GENERAL NOTES:

1. THIS DRAWING DOES NOT DEPICT ALL REQUIREMENTS. REFER TO THE SPECIFICATIONS AND OTHER DRAWINGS FOR DETAILED REQUIREMENTS.
2. FOR DIGESTER 1, DIGESTER 2 AND BATCH TANKS:
   a. SYSTEM TARGET OPERATING PRESSURE = 16" w.c.
   b. PRV SET PRESSURE RELIEF = 24" w.c.
   c. STRUCTURAL DESIGN PRESSURE = 36" w.c.



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BIOSOLIDS TO ENERGY

GENERAL

GAS PROCESS SCHEMATIC

FILENAME 144490-G-00-32.dwg

BC PROJECT NUMBER 144490

CLIENT PROJECT NUMBER ----

DRAWING NUMBER G-00-32

SHEET NUMBER ---- OF

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GENERAL

FOUL AIR PROCESS SCHEMATIC

FILENAME
144490-G-00-33.dwg
BC PROJECT NUMBER
144490
CLIENT PROJECT NUMBER

DRAWING NUMBER
G-00-33
SHEET NUMBER
---- OF

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HYDRAULIC PROFILE NOTES:

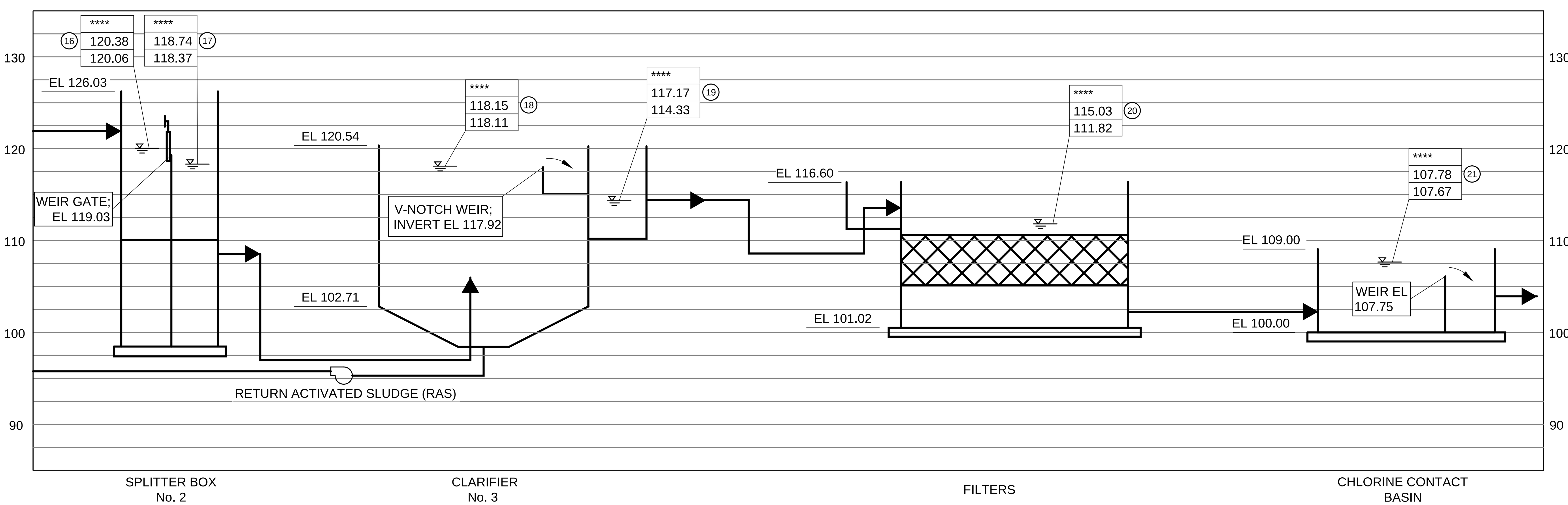
1. ELEVATIONS OF EXISTING STRUCTURES BASED UPON SURVEY PERFORMED BY McKIM & CREED, OCTOBER 2013.
2. PROFILE WAS MODELED USING A RAS FLOWRATE OF 20 MGD.
3. PRIMARY CLARIFIERS HAVE A PEAK CAPACITY OF 40 MGD. INFLUENT FLOWS BEYOND THIS AMOUNT WILL BE BYPASSED AROUND THE PRIMARY CLARIFIERS.
4. AT FLOWS GREATER THAN 40 MGD, 30 MGD WILL BE SENT TO THE FRONT OF THE AERATION BASINS, WITH THE REMAINDER BEING SENT TO A COMBINATION OF THE STEP FEED AND CONTACT STABILIZATION FEED POINTS.
5. THE 70 MGD PROFILE IS BASED UPON A FIXED HYDRAULIC GRADE OF 122.92 IN THE AERATION BASINS AND IS MODELED UPSTREAM TO THE PROPOSED TIE-IN POINT OF THIS PROJECT. ADDITIONAL MODIFICATIONS ARE NEEDED TO PASS THESE FLOWS UPSTREAM AND DOWNSTREAM OF THE MODELED PORTION OF THE FACILITY.

LEGEND

70 MGD
40 MGD
20 MGD

SEE NOTES 3-5

LOCATION		MODELED CONDITION AND FLOW		
NUMBER	DESCRIPTION	20 MGD	40 MGD	70 MGD, SEE NOTE 5
1	HEADWORKS UPSTREAM OF SCREEN	132.11	132.84	****
2	HEADWORKS DOWNSTREAM OF SCREEN	132.03	132.67	****
3	HEADWORKS EFFLUENT BOX	129.28	131.05	****
4	DOWNSTREAM HEADWORKS TIE-IN	128.96	129.78	130.20
5	PRIMARY CLARIFIER SPLITTER BOX - UPSTREAM	128.91	129.56	129.57
6	PRIMARY CLARIFIER SPLITTER BOX - DOWNSTREAM	128.19	128.48	128.48
7	PRIMARY CLARIFIER NO. 1	128.12	128.18	128.18
8	PRIMARY CLARIFIER NO. 1 EFFLUENT BOX	126.80	127.62	127.52
9	AB/STEP FEED SPLITTER BOX - UPSTREAM	126.64	127.24	127.16
10	AB/STEP FEED SPLITTER BOX - DOWNSTREAM	125.04	126.86	125.85
11	CONTACT STABILIZATION DOWNSTREAM BOX	N/A	N/A	124.98
12	AERATION BASIN SPLITTER BOX - UPSTREAM	124.47	124.84	124.66
13	AERATION BASIN SPLITTER BOX - DOWNSTREAM	122.99	123.32	123.21
14	AERATION BASIN	122.81	122.92	122.92
15	AERATION BASIN EFFLUENT CHANNEL	120.92	122.02	****
16	CLARIFIER SPLITTER BOX - UPSTREAM	120.06	120.38	****
17	CLARIFIER SPLITTER BOX - DOWNSTREAM	118.37	118.74	****
18	CLARIFIER NO. 3	118.11	118.15	****
19	CLARIFIER NO. 3 EFFLUENT BOX	114.33	117.17	****
19	FILTERS	111.82	115.03	****
20	CCB	107.67	107.78	****



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SUBMITTED: ____ PROJECT MANAGER DATE
APPROVED: ____ BROWN AND CALDWELL DATE

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)

DESIGNED: V PATEL
DRAWN: T DIMICELI
CHECKED: B ELEAZER
CHECKED: T BOSSO
APPROVED: T BOSSO

EXTERNAL REFERENCE FILES
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BIOSOLIDS TO ENERGY

GENERAL

NEW HYDRAULIC PROFILE

FILENAME 144490-G-00-41.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-41
SHEET NUMBER ---- OF

JUNE 2015

Jun 19, 2015 - 11:27am
\\BCTPAFP01\projects\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\G-General\144490-G-00-41.dwg

GENERAL NOTES

1. ONLY MAJOR FORWARD FLOW OF SOLIDS STREAM SHOWN.

PART OF THICKENING PROJECT (streams 5–7); PART OF DEWATERING PROJECT (streams 9–10)

PARAMETER		ANNUAL AVERAGE CONDITIONS												
		1	2	3	4	5	6	7	6A	6B	8	9	10	
STREAM	UNITS	PRIMARY SLUDGE	PRIMARY SCUM	SECONDARY SLUDGE	SECONDARY SCUM	COMBINED SLUDGE	THICKENED SLUDGE	GBT UNDERFLOW	FOG	TO DIGESTER	DIGESTED SLUDGE	PRESS CAKE	PRESS CENTRATE	TOTAL RETURN
SOLIDS	ppd	64,600	1,668	15,500	2,002	83,770	79,581	4,188	4,500	84,081	50,120	47,614	2,506	6,694
	% solids	2.0%	3.0%	1.0%	4.5%	1.7%	6.0%	0.12%	50.0%		3.5%	15.0%	0.18%	0.14%
	wtppd	3,230,000	55,600	1,550,000	44,480	4,880,079	1,326,352	3,553,727	9,000		1,416,349	317,426	1,365,425	4,919,152
FLOW	gpm	269	4.6	129	3.7	406	110	296	7.5	118	118	N/A	114	410

PARAMETER		MAXIMUM MONTH CONDITIONS												
		1	2	3	4	5	6	7	6A	6B	8	9	10	
STREAM	UNITS	PRIMARY SLUDGE	PRIMARY SCUM	SECONDARY SLUDGE	SECONDARY SCUM	COMBINED SLUDGE	THICKENED SLUDGE	GBT UNDERFLOW	FOG	TO DIGESTER	DIGESTED SLUDGE	PRESS CAKE	PRESS CENTRATE	TOTAL RETURN
SOLIDS	ppd	74,700	2,252	19,500	2,702	99,154	94,196	4,958	4,500	98,696	58,811	55,870	2,941	7,898
	% solids	2.0%	3.0%	1.0%	4.5%	1.7%	6.0%	0.1%	50.0%		3.5%	15.0%	0.2%	0.14%
	wtppd	3,735,000	75,060	1,950,000	60,048	5,820,107	1,569,938	4,250,169	9,000		1,659,935	372,467	1,600,181	5,850,350
FLOW	gpm	311	6.2	162	5.0	485	131	354	7.5	138	138	N/A	133	487

NOTES:
1) PRIMARY SLUDGE = PRIMARY SLUDGE PRODUCTION + FERRIC ADDITION.
2) FLOW FOR SCUM IS PUMPED SEVERAL TIMES IN AN HOUR DEPENDING ON THE ROTATION SPEED OF THE CLARIFIER - IT IS NOT EQUALIZED FOR THE ENTIRE PERIOD.
3) PRIMARY SLUDGE PRODUCTION BASED ON AN 80% TSS CAPTURE RATE IN THE PRIMARY CLARIFIERS.

PART OF THICKENING PROJECT (streams 5–7); PART OF DEWATERING PROJECT (streams 9–10)

PARAMETER		MAXIMUM DAY CONDITIONS												
		1	2	3	4	5	6	7	6A	6B	8	9	10	
STREAM	UNITS	PRIMARY SLUDGE	PRIMARY SCUM*	SECONDARY SLUDGE	SECONDARY SCUM*	COMBINED SLUDGE	THICKENED SLUDGE	GBT UNDERFLOW	FOG	TO DIGESTER	DIGESTED SLUDGE	PRESS CAKE	PRESS CENTRATE	TOTAL RETURN
SOLIDS	ppd	91.500	2,794	23,150	3,353	120,797	114,757	6,040	4,500	119,257	71,032	67,480	3,552	9591
	% solids	2.0%	3.0%	1.0%	4.5%	1.7%	6.0%	0.1%	50.0%		3.5%	15.0%	0.2%	0.14%
	wtppd	4,575,00	93,130	2,315,000	74,504	7,057,633	1,912,613	5,145,020	9,000		2,002,609	449,866	1,930,438	7,075,459
FLOW	gpm	381	7.8	193	6.2	588	159	428	7.5	167	167	N/A	161	589

* FLOW FOR SCUM IS PUMPED SEVERAL TIMES IN AN HOUR DEPENDING ON THE ROTATION SPEED OF THE CLARIFIER - IT IS NOT EQUALIZED FOR THE ENTIRE PERIOD.

PARAMETER		PEAK HOUR CONDITIONS												
		1	2	3	4	5	6	7	6A	6B	8	9	10	
STREAM	UNITS	PRIMARY SLUDGE	PRIMARY SCUM*	SECONDARY SLUDGE	SECONDARY SCUM*	COMBINED SLUDGE	THICKENED SLUDGE	GBT UNDERFLOW	FOG	TO DIGESTER	DIGESTED SLUDGE	PRESS CAKE	PRESS CENTRATE	TOTAL RETURN
SOLIDS	ppd	94,050	3,336	25,050	4,003	126,439	120,117	6,322	4,500	119,257	74,207	70,497	3,710	10,032
	% solids	2.0%	3.0%	1.0%	4.5%	1.7%	6.0%	0.1%	50.0%		3.5%	15.0%	0.2%	0.14%
	wtppd	4,702,500	111,200	2,505,000	88,960	7,407,658	2,001,954	5,405,704	9,000		2,091,951	469,978	2,016,553	7,422,258
FLOW	gpm	392	9.3	209	7.4	617	167	450	7.5	174	174	N/A	168	618

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TAMPA, FLORIDA

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APPROVED: ______ BROWN AND CALDWELL DATE

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DESIGNED: D DURSUN
DRAWN: J CONAWAY
CHECKED: B ELEAZER
CHECKED: T BOSSO
APPROVED: T BOSSO

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BIOSOLIDS TO ENERGY

GENERAL

MASS BALANCE

FILENAME 144490-G-00-45.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER G-00-45
SHEET NUMBER ---- OF

JUNE 2015

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INSTRUMENTATION SYMBOLS

PRIMARY ELEMENT SYMBOLS

- ORIFICE PLATE
- VENTURI OR FLOW TUBE
- FLUME
- RUPTURE DISC
- CHEMICAL SEAL (NOT SHOWN) ISOLATION VALVE PER SPECIFICATION
- CONCENTRIC CHEMICAL SEAL PER SPECIFICATION
- PROPELLER OR TURBINE FLOW METER
- MAGNETIC FLOW ELEMENT
- SONIC FLOW METER (DOPPLER OR TRANSIT TIME)
- THERMAL MASS FLOWMETER (FE)
- SONIC LEVEL SENSOR (LE)
- BUBBLE LEVEL TUBE
- AVERAGING PILOT TUBE
- VARIABLE AREA FLOW INDICATOR (ROTOMETER) (FI)
- WEIR
- FLOW STRAIGHTENING VANES
- THERMOWELL (TW)
- LEVEL PROBE (LE, GND)
- MAGNETIC FLOW PROBE
- LEVEL FLOAT SWITCH (LS)
- PRESSURE INDICATOR (PI)
- SUBMERGED HYDROSTATIC LEVEL ELEMENT
- AUTOMATIC VENT
- SONIC LEVEL SENSOR

SPECIAL OR INSTRUMENT FUNCTION DESIGNATIONS

Σ	ALGEBRAIC ADDITION
±, + -	BIAS
AVG	AVERAGE
X	MULTIPLY
÷	DIVIDE
√	EXTRACT SQUARE ROOT
x^n OR $x^{1/n}$	RAISE TO POWER
f (X)	CHARACTERIZE
1:1	BOOST AND ISOLATE
>	HIGHEST VALUE SELECTION
<	LOWEST VALUE SELECTION
REV	REVERSE
GAF	GAP ACTION FLOATING
S & H	SAMPLE AND HOLD
SRG	SPLIT-RANGING
E/P,I/P (TYPICAL)	INPUT/OUTPUT CONVERTERS USING FOLLOWING SIGNALS: E - VOLTS; H - HYDRAULIC; I - CURRENT; O - ELECTROMAGNETIC OR SONIC; P - PNEUMATIC; R - RESISTANCE; A - ANALOG; D - DIGITAL
% OR P	PROPORTIONAL CONTROL ACTION
∫ OR I	INTEGRAL CONTROL ACTION
d/dt OR D	DERIVATIVE CONTROL ACTION
1 - 0	ON - OFF CONTROL ACTION
△1 - 0	DIFFERENTIAL GAP CONTROL ACTION
1:3, 2:1 (TYPICAL)	GAIN OR ATTENUATE
CL2	CHLORINE
DO	DISSOLVED OXYGEN
V*	VENDOR PACKAGE
RDY	READY
RUN	RUNNING
O	OPEN
C	CLOSED
PLC	PROGRAMMABLE LOGIC CONTROLLER
OIS	OPERATOR INTERFACE WORKSTATION
RB	PLC INPUT/OUTPUT REMOTE BASE
MA	MANUAL-AUTO
UV	ULTRA VIOLET
OL	OVERLOAD
TURB	TURBIDITY

FUNCTION IDENTIFICATION

FIRST LETTER(S): MEASURED OR INITIATING VARIABLE	FIRST LETTER(S): MODIFIER	SUCCEEDING LETTERS: READOUT OR PASSIVE FUNCTION	SUCCEEDING LETTERS: OUTPUT FUNCTION	SUCCEEDING LETTERS: MODIFIER
A ANALYSIS		ALARM		
B BURNER (FLAME)				
C CONDUCTIVITY			CONTROL	
D DENSITY	DIFFERENTIAL			
E POTENTIAL (ELEC)		PRIMARY ELEMENT		
F FLOW RATE	RATIO			
G FIRE, SMOKE		GLASS		
H HAND				HIGH
I CURRENT (ELEC)		INDICATE		
J POWER	SCAN			
K TIME	TIME RATE CHANGE		CONTROL STATION	
L LEVEL		PILOT LIGHT		LOW
M MOISTURE	MOMENTARY			MIDDLE
N EQUIPMENT STATUS				
O TORQUE		ORIFICE		
P PRESSURE		TEST CONNECTION		
Q QUANTITY	INTEGRATE			
R RADIATION		RECORD		
S SPEED, FREQUENCY	SAFETY		SWITCH	
T TEMPERATURE			TRANSMIT	
U MULTI VARIABLE		MULTI FUNCTION	MULTI FUNCTION	MULTI FUNCTION
V VIBRATION			VALVE, DAMPER	
W WEIGHT		WELL		
X UNCLASSIFIED		UNCLASSIFIED	UNCLASSIFIED	
Y EVENT, STATUS			RELAY, COMPUTE	
Z POSITION			MISC. ACTUATOR	

INSTRUMENT AND FUNCTION SYMBOLS

- SHARED DISPLAY (GRAPHICAL OPERATOR INTERFACE)
- PROGRAMMED CONTROL, OPERATOR INACCESSIBLE
- DISPLAY NOT NORMALLY OPERATOR ACCESSIBLE (GRAPHICAL OPERATOR INTERFACE)
- HARDWIRED INTERLOCKING OR SEQUENTIAL CONTROL FUNCTION, SEE INTERLOCK NOTES.
- FACE MOUNTED ON MAIN PANEL OPERATOR ACCESSIBLE
- PLC INTERLOCKING OR SEQUENTIAL CONTROL FUNCTION, SEE PLC NOTES
- MOUNTED IN PANEL OPERATOR INACCESSIBLE
- FACE MOUNTED ON FIELD PANEL OPERATOR ACCESSIBLE WITH TYPICAL PANEL NUMBER
- MOUNTED IN FIELD PANEL OPERATOR INACCESSIBLE
- SHARED DISPLAY MOUNTED IN FIELD PANEL OPERATOR INACCESSIBLE
- FIELD MOUNTED DEVICE

MISCELLANEOUS

- (P) PURGE OR FLUSHING CONTROL UNIT. REFER TO MECHANICAL DETAILS AND SCHEMATICS.
- (C) SEAL WATER CONTROL UNIT. REFER TO MECHANICAL DETAILS AND SCHEMATICS.
- (R) RESET FOR LATCH-TYPE OPERATOR

HAND SWITCH (HS) FUNCTION DESIGNATIONS

FR	FORWARD-REVERSE
HLS	HIGH-LOW-STOP
HOA	HAND-OFF-AUTO
HOR	HAND-OFF-REMOTE
LL	LEAD-LAG
LOR	LOCAL-OFF-REMOTE
LOS	LOCKOUT-STOP
LR	LOCAL-REMOTE
OAC	OPEN-AUTO-CLOSE
OSC	OPEN-STOP-CLOSE
OC	OPEN-CLOSE
OO	ON-OFF
SLOS	START-LOCKOUT-STOP
SS	START-STOP
RST	RESET
MA	MANUAL-AUTO
MOA	MANUAL-OFF-REMOTE
LF	LEAD-FOLLOW

INSTRUMENT LOCATION DESIGNATIONS

MCC	MOTOR CONTROL CENTER
IMC	INDIVIDUAL MOTOR STARTER
MCR	MAIN CONTROL ROOM
PNL	FEILD CONTROL PANEL
UCP or ECP	EQUIPMENT CONTROL PANEL
CPNL	CHEMICAL FEED PANEL
LCP	LOCAL CONTROL PANEL

GENERAL NOTES:

DRAWING CROSS-REFERENCE

1. PROCESS AND INSTRUMENTATION DIAGRAMS (P&IDs) ARE PROCESS FLOW AND CONTROL GUIDES. THEY DO NOT NECESSARILY REFLECT THE ACTUAL SPACE RELATIONSHIP OR ORIENTATION OF SOME ITEMS. P&IDs ARE NOT TO BE INTERPRETED AS PIPING SCHEMATICS OR WIRING DIAGRAMS.
2. PLANT AREA OR PROCESS UNIT PREFIX MAY BE OMITTED FROM DRAWINGS AND COVERED BY NOTE WHEN ALL INSTRUMENTS ON DRAWINGS HAVE SAME PREFIX.
3. DRAWINGS I-00-01 AND I-00-02 ARE GENERAL IN NATURE. SOME SYMBOLS AND IDENTIFICATIONS SHOWN HEREON MAY NOT BE USED ON THE CONTRACT DRAWINGS. OTHER SYMBOLS AS DEFINED BY ISA S5.1 MAY BE USED IN ADDITION TO THE SYMBOLS SHOWN.
4. SEE DRAWING G-00-05, G-00-06, AND G-00-07 FOR PIPING AND EQUIPMENT DESIGNATION SYSTEMS.
5. SEE DRAWING G-00-04 FOR GENERAL ABBREVIATIONS.
6. THE EQUIPMENT PREFIX IS APART OF THE CONTROL FUNCTION TAG NUMBER FOR CLARIFICATION.

PLC INPUT/OUTPUT SIGNALS

- ANALOG INPUT
- ANALOG MODULATION OUTPUT
- PULSE INPUT
- PULSE OUTPUT: X BLANK — TIME DURATION (PULSE WIDTH); F — PULSE TRAIN; T — TRIAC
- DISCRETE INPUT
- DISCRETE OUTPUT: X BLANK — MAINTAINED (ELECTRICALLY HELD); L — LATCHED (MAGNETICALLY OR MECHANICALLY HELD)

INSTRUMENT SYMBOL DESIGNATION

ZZZ / XXX / NNNN / YYY

- LOCATION DESIGNATION FURTHER DEFINES INSTRUMENT/FUNCTION LOCATION WHEN NOT READILY APPARENT BY SYMBOL MAKE-UP (ZZZ)
- LOOP NUMBER PLUS OPTIONAL SUFFIX (NNNN)
- SPECIAL FUNCTION DESIGNATION (YYY)
- FUNCTION DESIGNATION (SEE FUNCTION IDENTIFICATION TABLE) (XXX)

NOTE: REFER TO SPECIFICATION DIVISION 17 FOR PROCESS CONTROL DESCRIPTIONS.

INSTRUMENT LOOP IDENTIFICATION

XX NNNN

- LOOP NUMBER
- MEASURED OR INITIATING VARIABLE LETTER WITH OPTIONAL MODIFIER (SEE FUNCTION IDENTIFICATION TABLE)

INSTRUMENT TAG NUMBERS

XX YYY NNNN Z

- OPTIONAL SUFFIX
- LOOP NUMBER
- PASSIVE AND/OR OUTPUT FUNCTION LETTERS WITH OPTIONAL MODIFIER (SEE FUNCTION IDENTIFICATION TABLE)
- MEASURED OR INITIATING VARIABLE LETTER WITH OPTIONAL MODIFIER (SEE FUNCTION IDENTIFICATION TABLE)

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TAMPA, FLORIDA

SUBMITTED: PROJECT MANAGER DATE
APPROVED: BROWN AND CALDWELL DATE

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DESIGNED:	B ELEAZER
DRAWN:	T DIMICELI
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CHECKED:	T BOSSO
APPROVED:	T BOSSO

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

PROCESS AND MECHANICAL SYMBOLS

FILENAME 144490-I-00-01.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-00-01
SHEET NUMBER ---- OF

Dec 04, 2013 - 11:05pm
P:\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\I-Instrumentation\144490-I-00-01.dwg
DECEMBER 2013

PROCESS AND SIGNAL CROSS REFERENCE SYSTEM

I-18-10 (FROM) → I-19-10 (TO)

DEFINES A LINE CONTINUING FROM DRAWING "I-18-10" TO DRAWING "I-19-10".

PROCESS LINES

- NEW PRIMARY PROCESS FLOW
- NEW SECONDARY PROCESS FLOW
- NEW UTILITY PROCESS FLOW
- FUTURE
- EXISTING PROCESS FLOW, EQUIPMENT, OR SIGNAL PATH (SCREENED)
- NEW/EXISTING CONNECTIONS
- TEMPORARY PIPING
- PROCESS AREA
- VENDOR PACKAGE BOUNDARY

GENERAL NOTES:

1. THIS DRAWING IS GENERAL IN NATURE. SOME SYMBOLS SHOWN HEREON MAY NOT BE USED ON THE CONTRACT DRAWINGS.
2. SEE DRAWING G-00-04 FOR EQUIPMENT ABBREVIATIONS AND PIPING SERVICE AND TYPE ABBREVIATIONS.
3. SEE DRAWING G-00-05 FOR EQUIPMENT IDENTIFICATION AND OTHER DESIGNATION SYSTEMS.
4. SEE DRAWING G-00-06, G-00-07, AND I-00-02 FOR ADDITIONAL SYMBOLS.
5. SYMBOLS ARE ARRANGED ON SPECIFIC DRAWINGS AND IN CATEGORIES FOR CONVENIENCE ONLY; SYMBOLS MAY BE USED ON ANY OF THE CONTRACT DRAWINGS.

PROCESS AND SIGNAL LINE SYMBOLS

- MAIN PROCESS FLOW (WITH TYPICAL DIRECTION OF FLOW SHOWN)
- SECONDARY PROCESS FLOW (WITH TYPICAL DIRECTION OF FLOW SHOWN)
- INSTRUMENT SUPPLY, PROCESS TAPS
- EQUIPMENT BOUNDARY
- EXISTING
- FUTURE
- PNEUMATIC SIGNAL
- ELECTRIC SIGNAL
- MISC, ELECTRICAL
- CAPILLARY TUBE
- FLEX TUBING
- ELECTROMAGNETIC OR SONIC SIGNAL (GUIDED)
- ELECTROMAGNETIC OR SONIC SIGNAL (UNGUIDED)
- SOFTWARE OR DATA LINK
- MECHANICAL LINK
- HYDRAULIC SIGNAL
- ELECTRIC POWER, VARIABLE VOLTAGE
- PLW — PROCESS OR INSTRUMENTATION PIPING CONNECTION. PLANT WATER SHOWN.
- ES — ELECTRICAL POWER SUPPLY 120VAC 60 HZ U.O.N.
- AS — AIR SUPPLY U.O.N. 20 PSIG FOR INSTRUMENTS

Brown AND Caldwell
TAMPA, FLORIDA

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DESIGNED:	B ELEAZER
DRAWN:	T DIMICELI
CHECKED:	B ELEAZER
CHECKED:	T BOSSO
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BIOSOLIDS TO ENERGY

INSTRUMENTATION

ABBREVIATIONS AND IDENTIFICATION SYSTEMS

FILENAME 144490-I-00-02.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-00-02
SHEET NUMBER ---- OF

DECEMBER 2013

Dec 04, 2013 - 11:05pm
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GENERAL NOTES:

1. PUMPS 1 & 2 ARE EXISTING AND ARE TO BE RELOCATED FROM EXISTING WET WELL TO NEW WET WELL.

INTERLOCK NOTES:

1. FLOAT STATUS IS MONITORED BY PLC AND CONTROLS PUMP START/STOP WHEN LIT IS OUT OF SERVICE. SHOULD PLC FAIL, BACK UP FLOAT RELAY LOGIC RESUMES CONTROL.

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DESIGNED:	B DICKERSON
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CHECKED:	B ELEAZER
CHECKED:	B DICKERSON
APPROVED:	J DIEDRICH

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

LIFT STATION 2

FILENAME 144490-I-12-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-12-10
SHEET NUMBER ---- OF

JUNE 2015

Jun 22, 2015 - 3:17pm
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BIOSOLIDS TO ENERGY

INSTRUMENTATION

FERRIC CHLORIDE ADDITION

FILENAME 144490-I-18-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-18-10
SHEET NUMBER ---- OF

JUNE 2015

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Brown AND Caldwell
TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

HEADWORKS TO SPLITTER BOX

FILENAME 144490-I-19-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-19-10
SHEET NUMBER ---- OF

JUNE 2015

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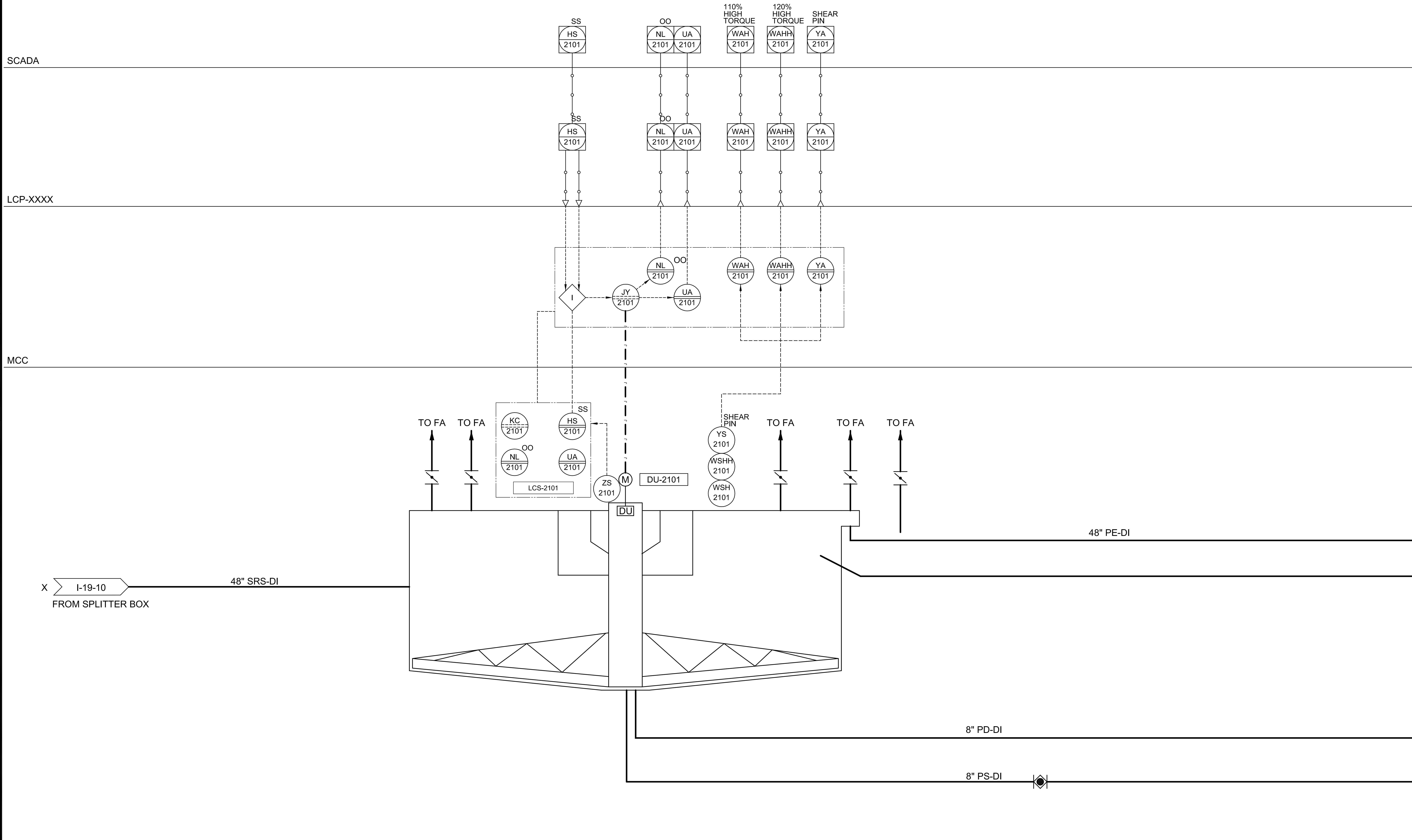

PRIMARY CLARIFIER 1
DRIVE UNIT
DU-2101

SPEC: 11161

GENERAL NOTES:

1. REFERENCE G-00-03 FOR FOUL AIR SCHEMATIC AND M-SHEETS FOR FOUL AIR LAYOUT.

KEY NOTES

(1) REFERENCE CIVIL SHEETS FOR CONTINUATION TO WAS STORAGE TANK. PART OF THICKENING DEWATERING DRAWINGS.

Brown AND Caldwell
TAMPA, FLORIDA

SUBMITTED: PROJECT MANAGER DATE
APPROVED: BROWN AND CALDWELL DATE

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)

DESIGNED:	B DICKERSON
DRAWN:	L DOFFLEMYER
CHECKED:	B ELEAZER
CHECKED:	B DICKERSON
APPROVED:	J DIEDRICH

EXTERNAL REFERENCE FILES
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BIOSOLIDS TO ENERGY

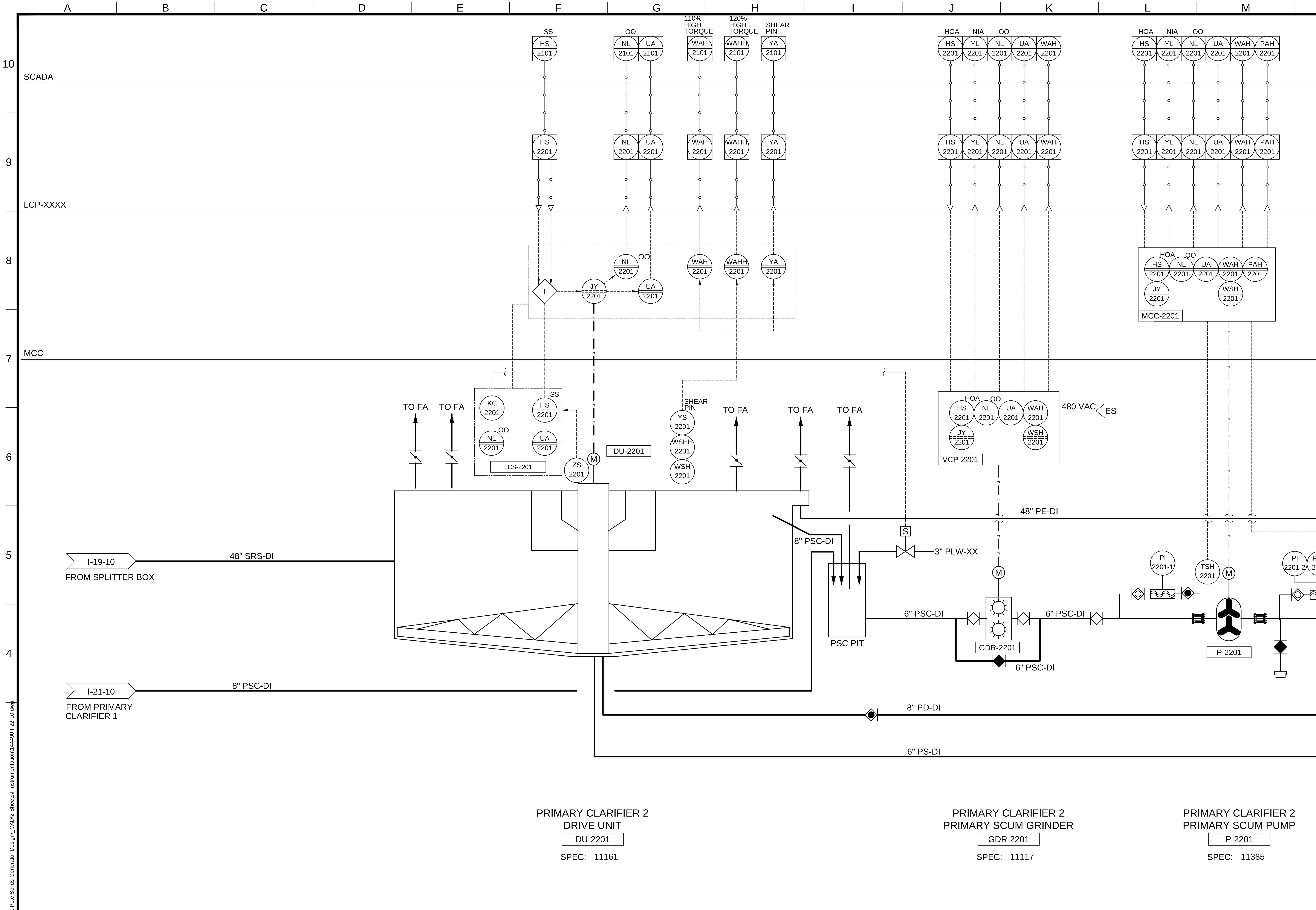
INSTRUMENTATION

PRIMARY CLARIFIER 1

FILENAME 144490-I-21-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-21-10
SHEET NUMBER ---- OF

JUNE 2015

Jun 18, 2015 - 8:27am
\\bcdpafs01\projects\St. Petersburg\144490-St. Pete Solids-Generator Design_CAD\2-Sheets\I-Instrumentation\144490-I-21-10.dwg



GENERAL NOTES:

1. REFERENCE G-00-03 FOR FOUL AIR SCHEMATIC AND M-SHEETS FOR FOUL AIR LAYOUT.

KEY NOTES

(1) REFERENCE CIVIL SHEETS FOR CONTINUATION TO WAS STORAGE TANK. PART OF THICKENING DEWATERING DRAWINGS.

Brown AND Caldwell
TAMPA, FLORIDA

SUBMITTED: ____ PROJECT MANAGER DATE
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BIOSOLIDS TO ENERGY

INSTRUMENTATION

PRIMARY CLARIFIER 2

FILENAME 144490-I-22-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-22-10
SHEET NUMBER ---- OF

JUNE 2015

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GENERAL NOTES:

1.

KEY NOTES

(1) REFERENCE CIVIL SHEETS FOR CONTINUATION TO WAS STORAGE TANK. PART OF THICKENING DEWATERING DRAWINGS.

Brown AND Caldwell
TAMPA, FLORIDA

SUBMITTED: PROJECT MANAGER DATE
APPROVED: BROWN AND CALDWELL DATE

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

PRIMARY SLUDGE PUMPING

FILENAME 144490-I-23-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-23-10
SHEET NUMBER ---- OF

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

ODOR CONTROL SYSTEMS 1

FILENAME 144490-I-28-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-28-10
SHEET NUMBER ---- OF

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GENERAL NOTES:

1. REFERENCE G-00-33 ALSO FOR THE FOUL AIR PROCESS SCHEMATIC

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TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

ODOR CONTROL SYSTEMS 2

FILENAME 144490-I-28-11.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-28-11
SHEET NUMBER ---- OF

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Jun 18, 2015 - 8:41am
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STEP FEED ISOLATION GATES	CONTACT STABILIZATION ISOLATION GATES
SLG-3111	SLG-3113
SLG-3112	SLG-3114
SPEC: 11109	SPEC: 11109

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TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

AERATION BASINS FOR CONTACT STABILIZATION

FILENAME 144490-I-31-11.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-31-11
SHEET NUMBER ---- OF

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

FOG FACILITY

FILENAME 144490-I-78-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-78-10
SHEET NUMBER ---- OF

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

HVAC SYSTEM 2
ELECTRICAL ROOM

FILENAME 144490-I-80-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-80-10
SHEET NUMBER ---- OF

JUNE 2015

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THERMOPHILIC HEX GRINDER

GDR-8101

SPEC: 11117

HOT WATER CONTROL VALVE

CV-8101

SPEC: 15172

DIGESTER 1 RECIRCULATION PUMPS 1 AND 2

P-8101
P-8102

SPEC:11385

THERMO HEX HOT WATER PUMPS 1 AND 2

P-8104
P-8105

SPEC: 11359

THERMO HEAT EXCHANGERS 1, 2, AND 3

HEX-8101
HEX-8102
HEX-8103

SPEC: 15754

KEY NOTES

1. FROM GRAVITY BELT THICKENER BUILDING. REFERENCE CAROLLO DRAWINGS AND DRAWING G-00-22.
2. FROM/TO PRIMARY HOT WATER LOOP. REFERENCE BLACK & VEATCH DRAWINGS, CIVIL DRAWINGS AND DRAWING G-00-31.

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TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

HEAT EXCHANGERS
DIGESTER 1

FILENAME 144490-I-81-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-81-10
SHEET NUMBER ---- OF

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GENERAL NOTES:

1.

KEY NOTES

(1) 4" MALE CAMLOCK CONNECTION FOR PORTABLE PUMP CONNECTION.

(2) EMERGENCY RELIEF MANWAY.

D1 FOAM SUPPRESSION PUMP	D1 FOAM SUPPRESSION GRINDER	THERMOPHILIC DIGESTER	DIGESTER 1 PRESSURE/VACUUM RELIEF ASSEMBLIES	DIGESTER 1 DRAFT TUBE MIXERS 1, 2, 3, AND 4	BOTTOM DISCHARGE CONTROL VALVE	STANDPIPE DISCHARGE CONTROL VALVE	DIGESTER 1 DISCHARGE PUMP GRINDER	DIGESTER 1 DISCHARGE PUMPS 1 AND 2
P-8111	GDR-8111	T-8111	PRV-8111 PRV-8112	MX-8111, MX-8113 MX-8112, MX-8114	CV-8111	CV-8112	GDR-8113	P-8116 P-8117
SPEC: 11385	SPEC: 11117	SPEC: N/A	SPEC: 15556	SPEC: 11581	SPEC: 15185	SPEC: 15185	SPEC: 11117	SPEC: 11385

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CHECKED:	B ELEAZER
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APPROVED:	J DIEDRICH

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

DIGESTER 1

FILENAME 144490-I-81-11.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-81-11
SHEET NUMBER ---- OF

JUNE 2015

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

HEAT EXCHANGERS
DIGESTER 2

FILENAME 144490-I-82-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-82-10
SHEET NUMBER ---- OF

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D2 FOAM SUPPRESSION PUMP	D2 FOAM SUPPRESSION GRINDER	MESOPHILIC DIGESTER	DIGESTER 2 PRESSURE RELIEF FALVES AND FLARE TRAPS	DIGESTER 2 DRAFT TUBE MIXERS 1, 2, 3, AND 4	BOTTOM DISCHARGE CONTROL VALVE	STANDPIPE DISCHARGE CONTROL VALVE	DIGESTER 2 DISCHARGE GRINDER
P-8211	GDR-8211	T-8211	PRV-8211, PRV-8212	MX-8211, MX-8213, MX-8212, MX-8214	CV-8211	CV-8212	GDR-8213
SPEC: 11385	SPEC: 11117	SPEC: N/A	SPEC: 15556	SPEC: 11581	SPEC: 15185	SPEC: 15185	SPEC: 11117

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TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

DIGESTER 2

FILENAME 144490-I-82-11.dwg
BC PROJECT NUMBER 144490
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BIOSOLIDS TO ENERGY

INSTRUMENTATION

CLOSED LOOP COOLING TOWER

FILENAME 144490-I-82-12.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-82-12
SHEET NUMBER ---- OF

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KEY NOTES

1. REFERENCE CIVIL SHEETS FOR CONTINUATION TO WAS STORAGE TANK. PART OF THICKENING DEWATERING DRAWINGS.
2. EMERGENCY RELIEF MANWAY.

BATCH TANK FEED CONTROL VALVES 1-6

CV-8501-1	CV-8504-1
CV-8502-1	CV-8505-1
CV-8503-1	CV-8506-1

SPEC: 15180

BATCH TANK DISCHARGE CONTROL VALVES 1-6

CV-8501-2	CV-8504-2
CV-8502-2	CV-8505-2
CV-8503-2	CV-8506-2

SPEC: 15180

RELIEF VALVES AND FLARE TRAPS

PRV-8501	FTP-8501
PRV-8502	FTP-8502

SPEC: 15180

BATCH TANK GRINDER

GDR-8501

SPEC: 11117

BATCH TANK DISCHARGE PUMPS 1 AND 2

P-8501
P-8502

SPEC: 11385

BATCH TANK REJECT CONTROL VALVE

CV-8501
CV-8502

SPEC: 15180

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TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

BATCH TANKS

FILENAME 144490-I-85-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-85-10
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DIGESTER 1 AND 2
SEDIMENT TRAPS

STP-8601
STP-8602

SPEC: XXXXXX

BATCH TANK
SEDIMENT TRAP

STP-8604

SPEC: XXXXXX

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TAMPA, FLORIDA

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INSTRUMENTATION

GAS COLLECTION SYSTEM

FILENAME 144490-I-86-10.dwg
BC PROJECT NUMBER 144490
CLIENT PROJECT NUMBER ----
DRAWING NUMBER I-86-10
SHEET NUMBER ---- OF

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INSTRUMENTATION

DIGESTER GAS STORAGE

FILENAME 144490-I-86-11.dwg

BC PROJECT NUMBER 144490

CLIENT PROJECT NUMBER ----

DRAWING NUMBER I-86-11

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APPROVED: BROWN AND CALDWELL DATE	DRAWN: L DOFFLEMYER	
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BIOSOLIDS TO ENERGY

INSTRUMENTATION

DIGESTER GAS PRE-COOLING

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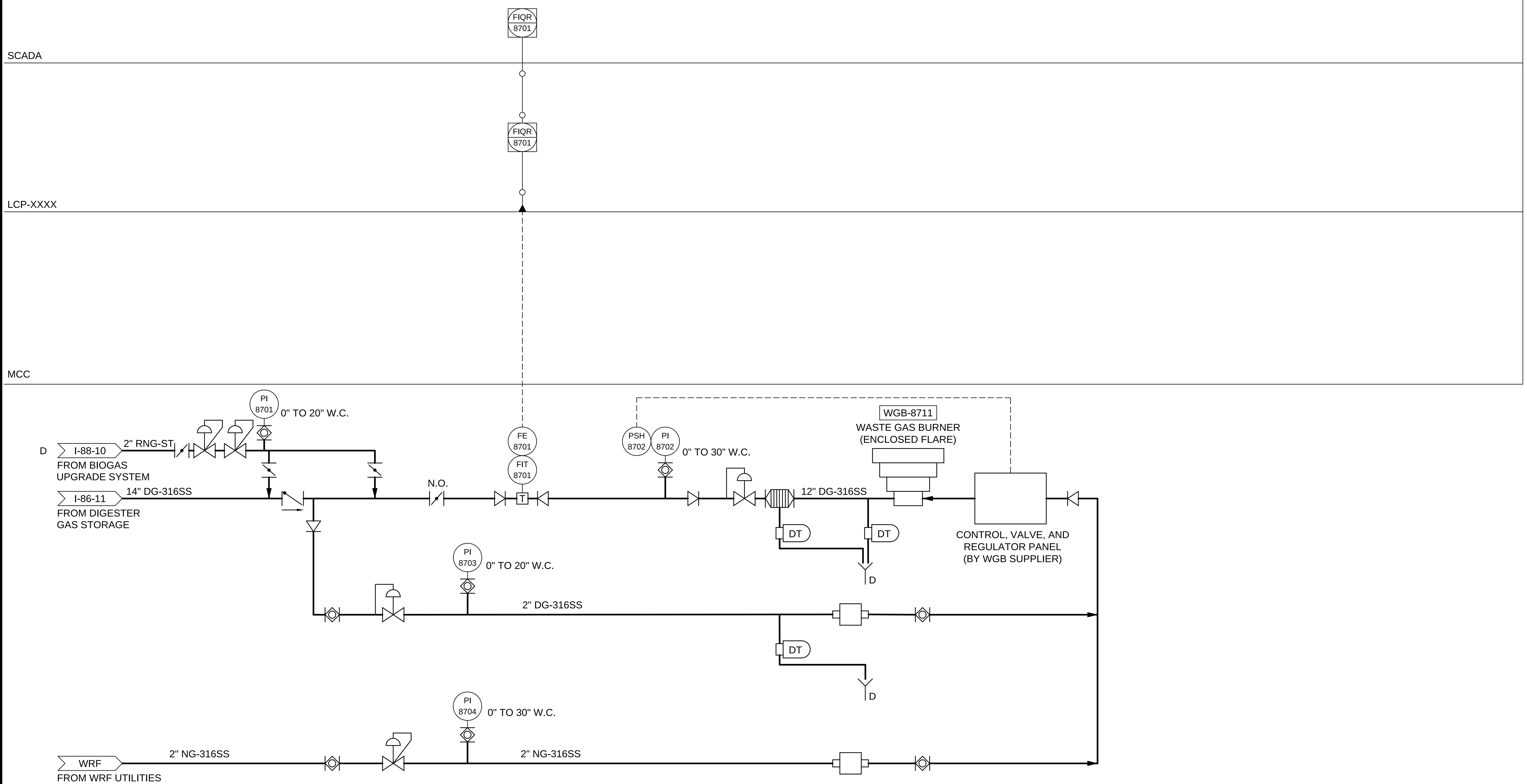

DIGESTER
WASTE GAS BURNER
WGB-8711

SPEC: XXXX

Brown AND Caldwell
TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

DIGESTER WASTE GAS BURNER

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INSTRUMENTATION

PID BIOGAS UPGRADE SYSTEM

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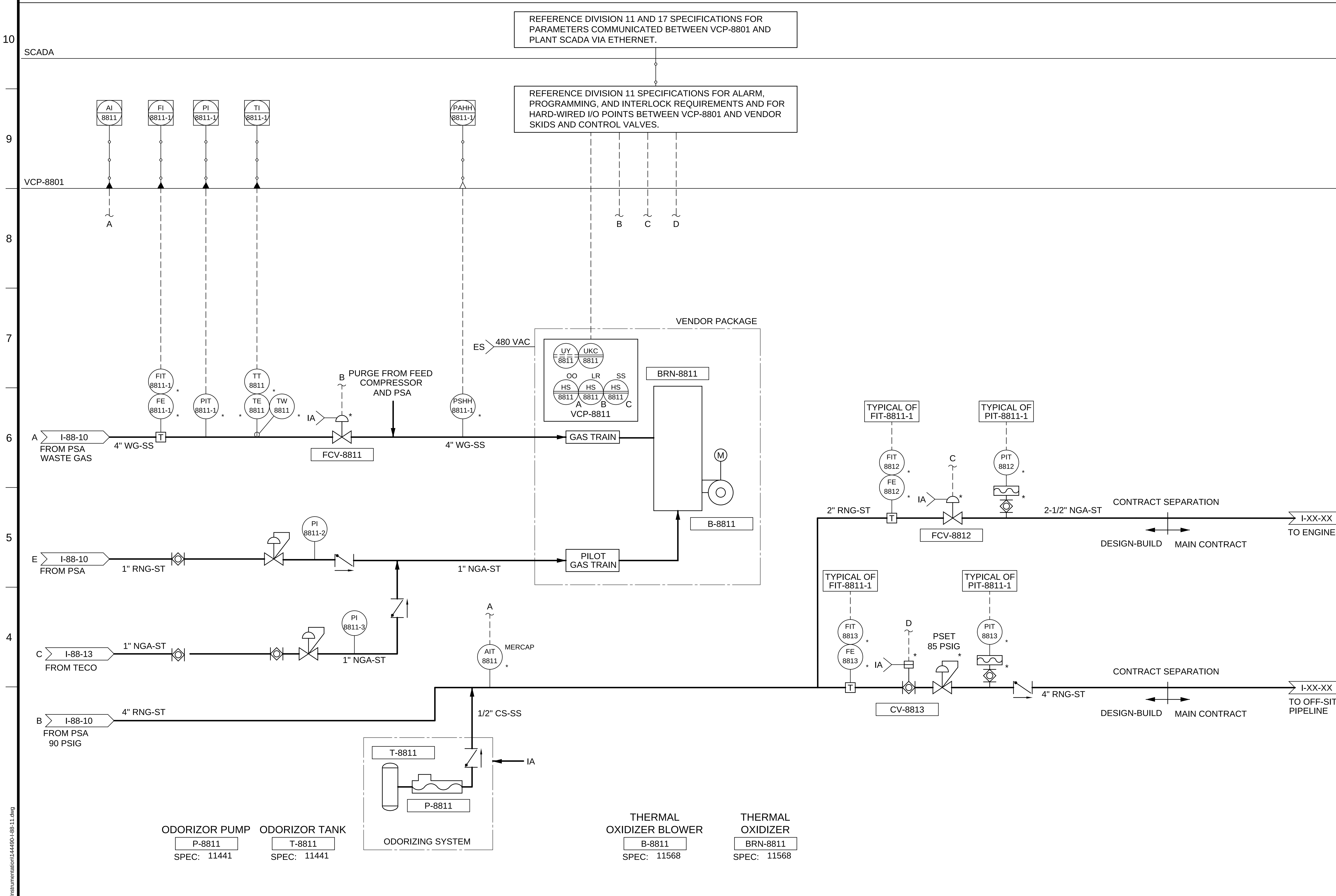

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

PID THERMAL OXIDIZER AND BIOGAS UPGRADE SUPPORT SYSTEMS

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TAMPA, FLORIDA

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BIOSOLIDS TO ENERGY

INSTRUMENTATION

PID BIOGAS UPGRADE
SUPPORT SYSTEMS

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Appendix B: Thickening Project Preliminary Design Report

CITY OF ST. PETERSBURG

SOUTHWEST WATER RECLAMATION FACILITY – SLUDGE THICKENING SYSTEM IMPROVEMENTS

BASIS OF DESIGN MEMORANDUM

FINAL

September 2013

401 NORTH CATTLEMEN ROAD, SUITE 306 • SARASOTA, FLORIDA 34232 • P. 941.371.9832 • F. 941.371.9873

CITY OF ST. PETERSBURG

SOUTHWEST WATER RECLAMATION FACILITY –
SLUDGE THICKENING SYSTEM IMPROVEMENTS

BASIS OF DESIGN MEMORANDUM

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SLUDGE THICKENING SYSTEM IMPROVEMENTS

1.0 INTRODUCTION

The City of St. Petersburg (City) has embarked on a program to decommission its Albert Whitted Water Reclamation Facility (AWWRF), currently treating a wastewater flow of around 6 – 8 mgd, and construct a new master lift station at the site to divert the wastewater flows from its service area to the Southwest Water Reclamation Facility (SWWRF). Further, the City has planned several process modifications at the SWWRF including addition of new primary clarifiers, upgrades to existing solids thickening process, upgrades to anaerobic digestion system, necessary upgrades to other treatment processes and a new solids dewatering system in an effort to make it a reasonable, feasible, economical and energy efficient wastewater treatment service while consolidating the City's wastewater treatment facilities.

As part of the proposed improvements to SWWRF, the City has retained Carollo Engineers Inc. (Carollo) to prepare a basis of design report (BODR) for the proposed modifications to its solids thickening process. The other elements such as addition of new primary clarifiers, upgrades to the anaerobic digestion system, other necessary upgrades to the facility and a new dewatering facility are being completed by other Consultants selected by the City.

This memorandum presents the basis of design for the proposed improvements to the sludge thickening system as a result of the proposed process changes to the SWWRF.

2.0 DESCRIPTION OF EXISTING FACILITIES

The SWWRF has a permitted capacity to treat 20 mgd of wastewater flow on an average day flow basis. Treatment at SWWRF comprises of influent raw wastewater coarse screens followed by fine screens and forced-vortex grit removal system. The screened and degritted wastewater is treated in two aeration basins with fine bubble diffusers. Mixed liquor suspended solids (MLSS) from the aeration basin are separated using three secondary clarifiers. A large portion of the MLSS is retuned to the aeration basin using return activated sludge (RAS) pumps, while the remaining portion of the MLSS is wasted to a sludge-holding tank using separate waste activated sludge (WAS) pumps. The secondary effluent is filtered, disinfected, stored, and pumped to a reclaimed water distribution system.

The WAS is thickened using one 2-meter gravity belt thickener (GBT). The thickened WAS is treated in anaerobic digesters and the digested solids are dewatered using belt filter presses (BFPs) and the dewatered cake is hauled offsite for disposal.

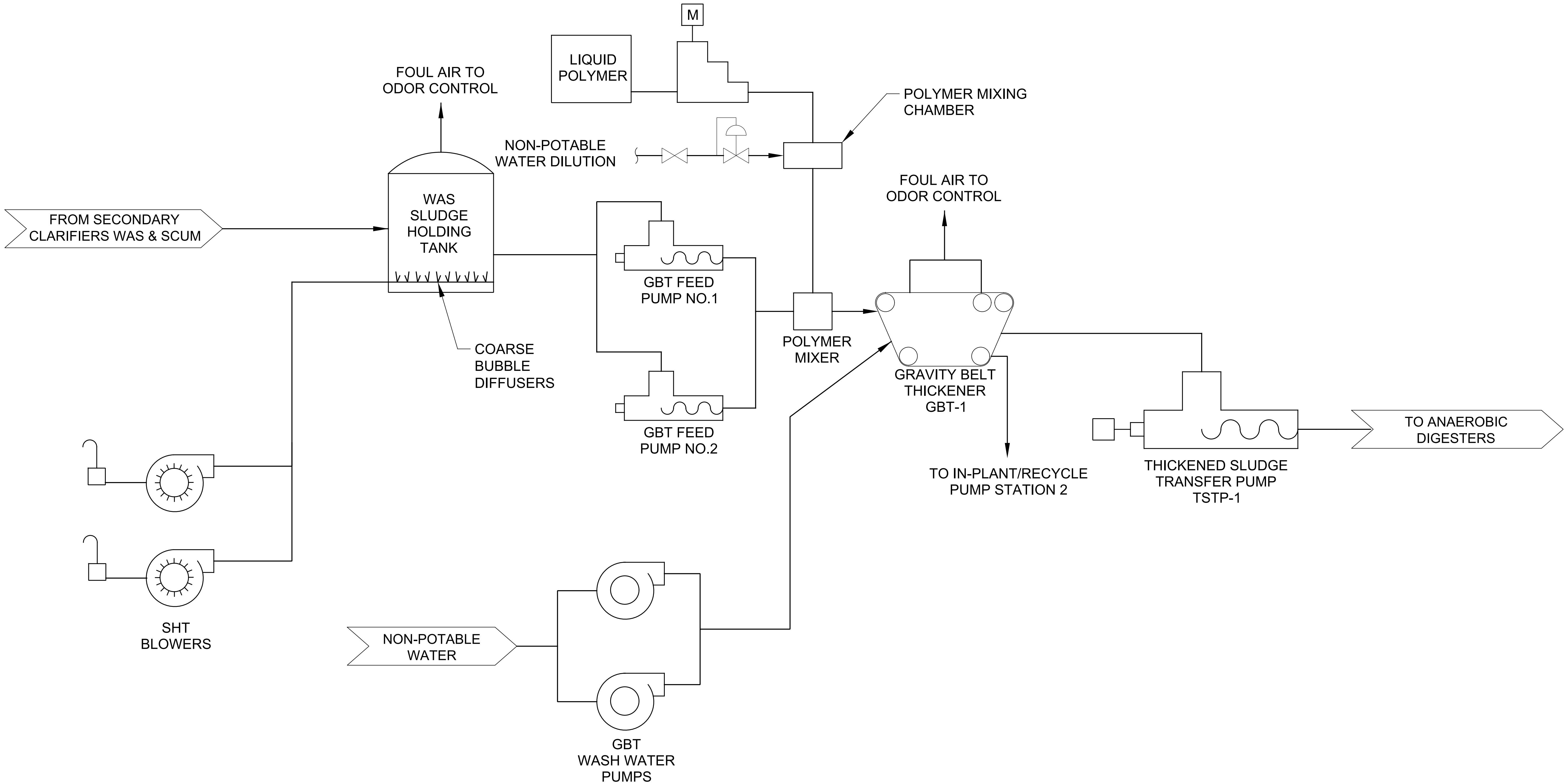
Currently, the WAS is directly pumped to the dewatering process where the dewatered cake is stabilized with addition of quicklime using the SCHWING Bioset process. The stabilized cake is classified as a Class A biosolids product and is hauled off site for disposal. Both the thickening and digestion processes are off-line.

With the proposed improvements to SWWRF, the City has planned to enhance their conventional mesophilic anaerobic digestion system to a temperature phased anaerobic digestion process (TPAD) with a thermophilic digester followed by a mesophilic digester to produce Class A biosolids while enhancing biogas production. The sizing of the new digestion process is based on feeding the digesters with a sludge mixture of PS and WAS at a concentration of 6% solids. With addition of WAS from the City's other two facilities, the existing thickening system at SWWRF will need to be upgraded and expanded.

2.1 Description of Sludge Holding and Thickening Facilities

The 2-meter GBT is housed inside a single-story partially open concrete block building with a metal roof. The GBT is model Aquabelt Type 85 as manufactured by Alfa Laval (formerly Ashbrook Simon Hartley). The building has approximate dimensions of 48-feet long, 36-feet wide, and approximately 16-feet tall. The building has space for addition of a second GBT. Figures 2.1, 2.2, and 2.3 provide the process flow diagram for the existing solids thickening process and mechanical plan and section views of the existing solids thickening building. Exhibits 1, 2, and 3 shows the photos of the existing thickening building and WAS holding tank. Two progressive cavity pumps feed WAS from the holding tank to the GBT. A progressive cavity thickened sludge pump transfers the thickened WAS to the anaerobic digester(s). The existing GBT was installed in the early to mid-1990. The City recently (2011) completed upgrades to the sludge thickening process including addition of a new liquid emulsion polymer dilution and feed system, addition of an odor control hood (316 stainless steel construction) and FRP ductwork over the existing GBT, adding new odor control ductwork to the WAS holding tank and adding a new 2-stage chemical odor control scrubbing system. At present time, the GBT is not operated. In the past, the GBT was operated 24 hours per day with the WAS thickened to a concentration of 4 – 8% solids. The GBT belt is continuously washed using two 5 HP wash water pumps (one duty/ one standby) that supplies approximately 40 gpm of wash water (reclaimed water from the effluent of the plant that is supplied for in-plant non-potable needs) at 85 pounds per square inch (psi) pressure to a spray pipe fitted with nozzles mounted on the GBT. The filtrate from the GBT is collected in a sump underneath the GBT unit and is routed to the in-plant lift station no. 2, which pumps the combined filtrate from the GBT and BFPs upstream of the fine screen at the headworks.

The WAS holding tank is an above grade poured-in-place concrete tank 30 feet in diameter with a 20-ft side water depth, providing a storage volume of approximately 105,000 gallons. The contents of the tank are mixed and solids are kept in suspension using a coarse bubble aeration system with belt driven positive displacement blowers installed on a pad outside on the east side of the holding tank. The holding tank has an aluminum geodesic dome covering the tank. The tank is also ventilated (scrubbed) to the new chemical odor control system installed in 2011.



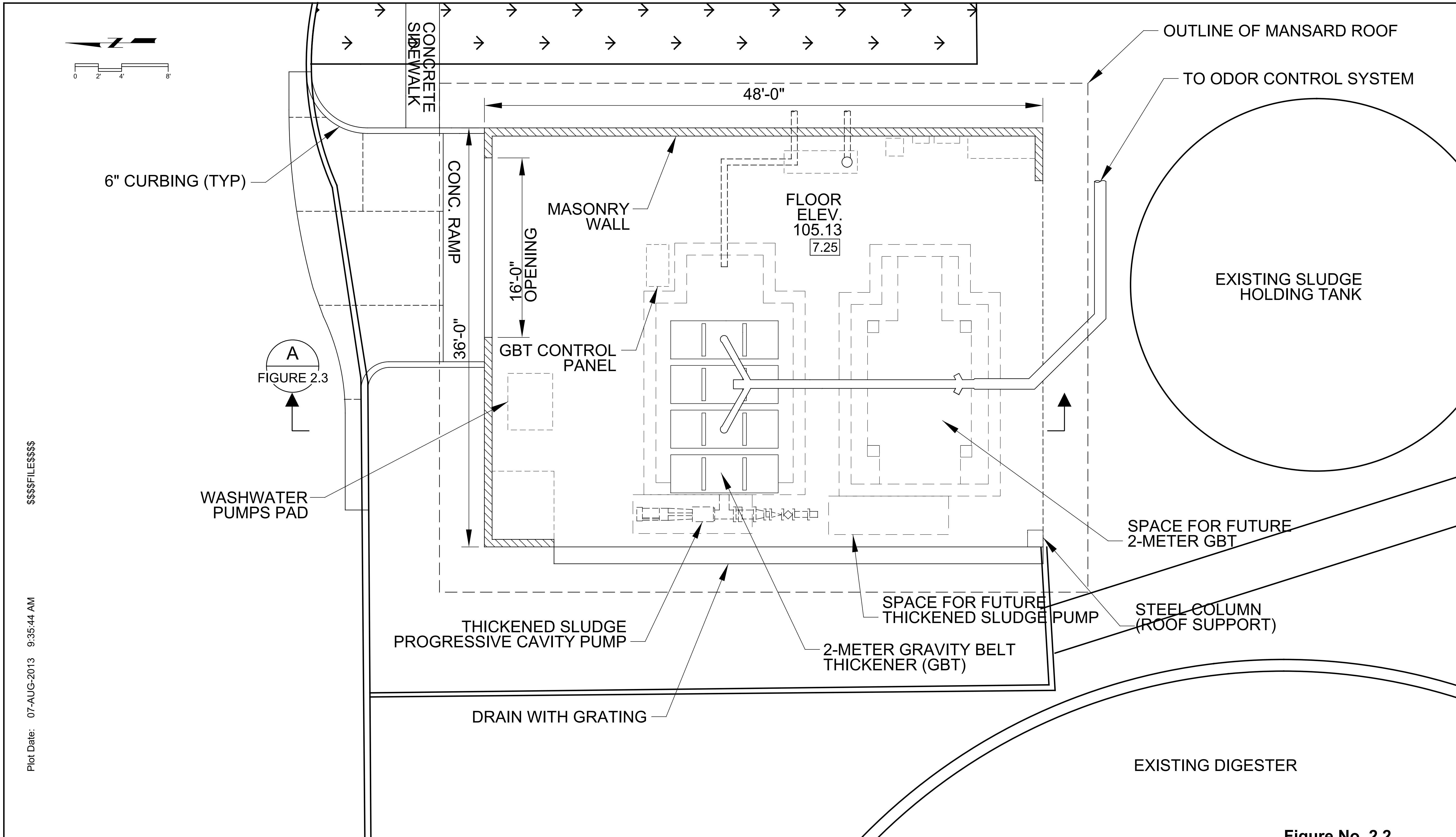
EXISTING SLUDGE THICKENING SYSTEM PROCESS FLOW DIAGRAM

Figure No. 2.1

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo



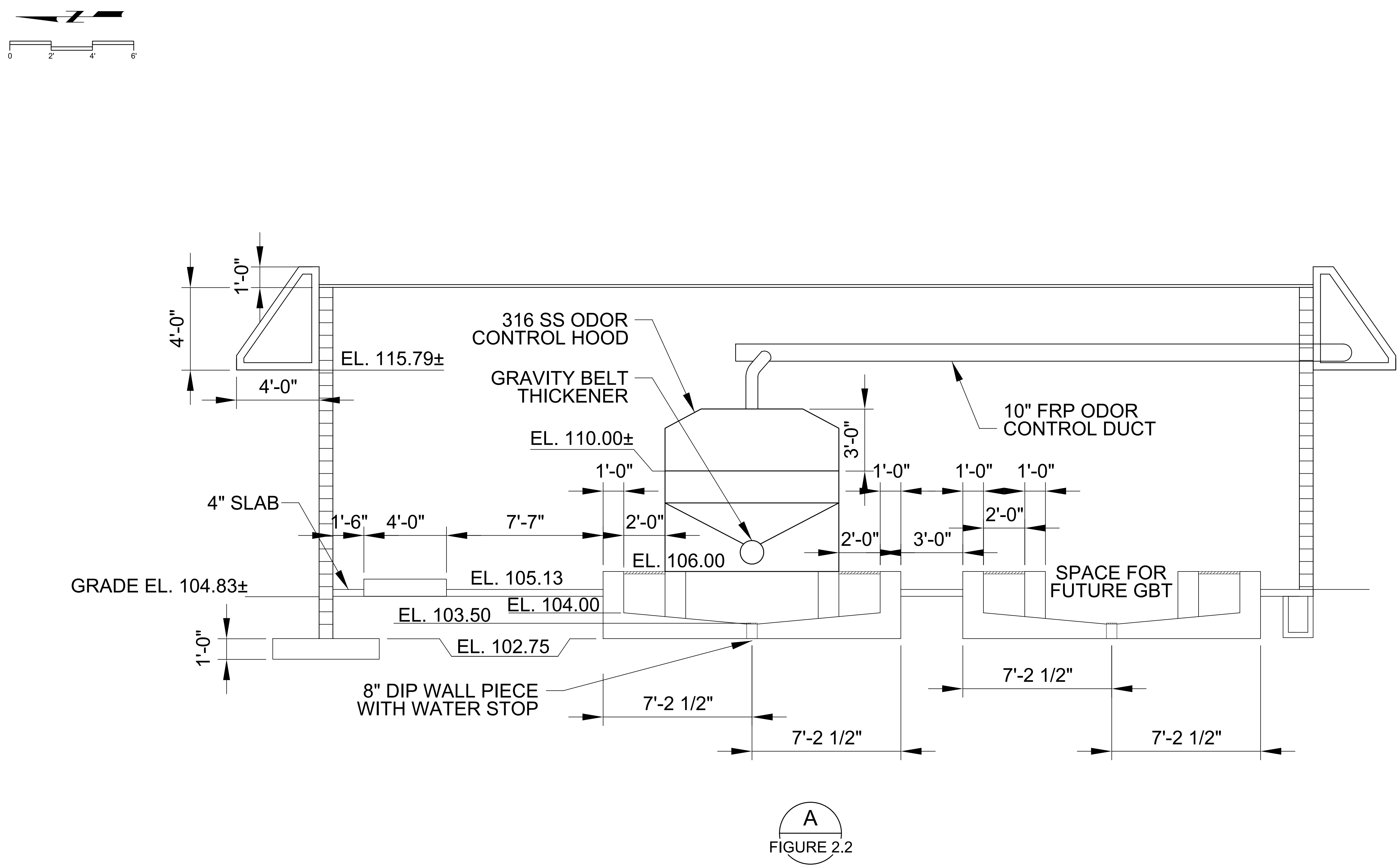
EXISTING GBT BUILDING FLOOR PLAN

Figure No. 2.2

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo



EXISTING GBT BUILDING SECTION

Figure No. 2.3

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo

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Exhibit No. 1 - North Elevation View of Existing Sludge Thickening Building

Exhibit No. 2 – North and West Elevations of the Existing Sludge Thickening Building

Exhibit No. 3 – Elevation View of the Sludge Holding Tank

3.0 SLUDGE QUANTITIES – BASIS OF DESIGN

In addition to diverting wastewater flows from the AWWRF, the City also plans to pump waste activated sludge from its Northwest and Northeast Water Reclamation Facilities (NEWRF and NWWRF) to the SWWRF. With addition of primary clarifiers at SWWRF, the City plans to capture a majority (~ 85%) of the suspended solids from the raw wastewater including solids from the other two facilities (NEWRF and NWWRF) in the primary sludge. The City plans to mix the primary and the WAS in the holding tank and co-thicken the sludge mixture using gravity belt thickeners.

Table 3.1 presents the estimates of raw sludge production. These estimates are for the design year 2035 and are based on process calculations prepared by the City's other consultant (Brown and Caldwell) who is responsible for design of the other components at the SWWRF as described above. The estimates of raw sludge production will form the basis of design for the expansion and upgrades to the sludge thickening process elements.

Table 3.1 Raw Sludge Production Estimates – Basis of Design SWWRF – Sludge Thickening System Improvements - BODR City of St. Petersburg			
Parameter	**Primary Sludge (PS)**	**Waste Activated Sludge (WAS)**	**Total Sludge (PS+WAS+Scum)**
% Solids	2.0%	1.0%	1.7%
Annual Average			
Flow, mgd	0.387	0.186	0.585
Mass Rate (lb/d)	64,600	15,500	83,770
Maximum Month			
Flow, mgd	0.448	0.234	0.698
Mass Rate (lb/d)	74,700	19,500	99,154
Maximum Week			
Flow, mgd	0.490	0.259	0.766
Mass Rate (lb/d)	81,700	21,600	108,694
Maximum Day			
Flow, mgd	0.549	0.278	0.846
Mass Rate (lb/d)	91,500	23,150	120,797
Peak Hour			
Flow, mgd	0.564	0.300	0.888
Mass Rate (lb/d)	94,050	25,050	126,939

Notes:
(1) Based on values provided by Brown & Caldwell, September 03, 2013 for the design year 2035.

3.1 Gravity Belt Thickener Loading Rates

Table 3.2 presents the loading rates for 2-meter GBTs. It is anticipated that the GBT(s) will be operated 24 hours per day, seven days per week. The expected loading rates are based on 23 hours of actual operation per day, assuming 1 hour of downtime for adjustment, cleaning, etc.

GBTs are typically sized on loading rates of 175 gpm to 250 gpm per meter, though GBT manufacturers claim a maximum loading rate of 300 gpm/meter at 0.5% feed solids. Based on consultations with Alfa Laval (formerly Ashbrook Simon Hartley), a safe maximum loading rate of 200 gpm/meter (1,775 lbs/hour/meter @ 1.7% solids concentration) is assumed for the design. Based on this rate, processing the maximum day sludge will require two (2), 2-meter duty GBTs. A third 2-meter GBT will be required to provide 100% redundancy. During average day conditions, only one 2-meter GBT will be required.

The City's other treatment facilities also use GBTs and each facility has two 2-meter GBTs. One 2-meter GBT at NEWRF is fairly new (installed in 2005-2006), whereas the 2-meter GBTs at the NWWRF were installed in late 1990's. Therefore, the overall plan will be to relocate one 2-meter GBT from each of the other two facilities (NWWRF and NEWRF) to the SWWRF. The primary and WAS will be stored and mixed in the existing sludge holding tank and the mixture will be co-thickened using two (2), 2-meter GBTs while the third GBT will serve as standby unit.

3.2 Design Criteria for the Sludge Thickening Improvements

The GBTs will be used to thicken the sludge mixture of primary and WAS to a solids concentration of 6% ±. Table 3.3 presents the design criteria for the sludge thickening improvements. The design solids capture ratio assumed is 95% of the total incoming solids. A liquid emulsion polymer will be used for conditioning the sludge mixture prior to thickening.

Table 3.2 Expected GBT Loading Rates (Year 2035)
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Parameter	Total Sludge Flow (PS+WAS), mgd	Total Solids (PS+WAS), lbs/d	Loading Rate per meter			
			One 2-meter GBT (gpm/meter)	Two 2-meter GBTs (gpm/meter)	One 2-meter GBT (lbs/hour/meter)	Two 2-meter GBTs (lbs/hour/meter)
Annual Average	0.585	83,770	212	106	1,821	910
Maximum Month	0.698	99,154	253	126	2,155	1,078
Maximum Week	0.766	108,694	278	139	2,363	1,181
Maximum Day	0.846	120,797	306	153	2,626	1,313

Notes:
(1) Total Sludge Flow is based on estimates provided by Brown & Caldwell, September 03, 2013.
(2) GBT operation assumes 23 hour operation with 1 hour downtime for adjustment, cleaning, etc.

Table 3.3 Sludge Thickening – Basis of Design
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Parameter	Feed Sludge					Thickened Sludge			Filtrate (GBT Underflow)		Polymer Dose
	Flow (mgd)	Total Solids (lb/d)	Volatile Solids (lb/d)	Total Solids (%)	Volatile Solid (%)	Flow (1) (mgd)	Total Solids (lb/d)	Total Solids (%)	Flow (1) (mgd)	Total Solids (lb/d)	(active lb/d)
Annual Average	0.585	83,770	67,016	1.7%	80%	0.157	79,582	6.0%	0.4281	4,188	200
Maximum Month	0.698	99,154	79,323	1.7%	80%	0.188	94,196	6.0%	0.510	4,958	235
Maximum Week	0.766	108,694	86,955	1.7%	80%	0.206	103,259	6.0%	0.560	5,435	260
Maximum Day	0.846	120,797	96,638	1.7%	80%	0.228	114,757	6.0%	0.618	6,040	290
Peak Hour	0.888	126,939	101,551	1.7%	80%	0.239	120,592	6.0%	0.649	6,347	300

Notes:
(1) GBT operation assumes 95% capture of Solids.
(2) Polymer dose is estimated based on 5 active lb/DT (as recommended by Polydyne Inc. for an emulsion polymer).

4.0 PROPOSED MODIFICATIONS TO EXISTING FACILITIES

4.1 Proposed Modifications to Sludge Holding Tank

The WAS holding tank has a total storage volume of 105,000 gallons. Two (2) 50 HP each, positive-displacement blowers supply air to a coarse bubble diffuser system that is used to mix the contents of the tank. No structural evaluation of the tank was conducted as part of this work effort. It is assumed that the tank is in good structural condition and no structural modifications are assumed to at this time. The same is assumed for the aluminum geodesic dome cover that covers the tank.

Under the proposed modifications to the thickening system, both the primary sludge pumps and the WAS pumps will pump the respective sludge to this tank. Under average day conditions, the total (PS+WAS) sludge flow into the tank is estimated to be 0.573 mgd (~ 400 gpm). The mixed sludge will be pumped to the GBT unit(s) for thickening. The detention time in the tank will be kept at a minimum (< 1 hour) during normal operations. At the incoming sludge flow rate of 400 gpm, the liquid level in the tank is estimated be 4.5 feet for a detention time of < 1 hour. The level will be kept constant by adjusting the flow rate of the GBT feed pumps. The existing tank has a level probe and based on consultations with SWWRF operating staff, the instrument is in good operating condition and will be used to control the GBT feed pumps.

The existing coarse bubble diffused aeration system is assumed to be in good operating condition. The blowers are operated continuously to ensure the WAS is well mixed and is kept aerobic at all times. Typically, coarse bubble mixing systems generate a spiral-roll pattern in the tank for effective mixing and therefore require a minimum liquid depth in the tank. Based on consultations with Sanitaire/Xylem, the existing coarse bubble aeration system will require a minimum liquid depth of 7-ft in the tank for effective mixing.

Table 4.1 presents the 20-year net present worth cost (NPW) for the existing coarse bubble mixing system. The estimates of the probable cost of construction used in the NPW costs are considered Class 3 “Budget Level” estimates per the Recommended Practice 18R-97 Cost Estimate Classification System for the Process Industries, published in 1998 by the Association for the Advancement of Cost Engineering (AACE). Engineering is typically 10 to 40 percent complete and the expected accuracy range is within +30 percent to -10 percent. This means that construction bids can be expected to fall within a range of 30 percent over the estimate to 10 percent under the estimate.

Table 4.1 Estimated Planning Level 20-Year Net Present Worth Costs for the Existing Coarse Bubble Mixing System SWWRF – Sludge Thickening System Improvements - BODR City of St. Petersburg					
Item	**No.**	**Unit(s)**	**Unit Cost ($)**	**Installation Cost ($)**	**Total Cost ($)**
				Total Project Capital Cost	**None**
Annual Power Cost (15 BHP @ 24 hour operation and $0.08/kWH)					$10,510
Annual Maintenance Cost (2.5% of total equipment cost - Subtotal 1)					$2,000
Annual Labor Cost (4 hours per month for 1 person @ $30 per hour)					$1,440
				Total Annual Operating Cost	**$13,950**
20-year NPW (using a discount rate of 3.9% and a uniform series compound factor of 13.7)					**$191,140**

Alternatively, the tank can be mixed using the following mixing systems:

a. Turbine type Mechanical Mixers

b. Pumped Mixing System

c. "Large Bubble" Mixing System

The following paragraphs describe each of the alternative mixing systems with advantages and disadvantages for each.

4.1.1 Turbine-Type Mechanical Mixers

Turbine-type mechanical mixers have hydrofoil impellers mounted on a vertical shaft and are a traditional method of mixing tanks. The motor and the gearbox are supported on a platform on top of the tank or basin. Installing turbine type mechanical mixers in the existing tank will require construction of a mixer support platform on the top of the tank. The tank is currently covered using an aluminum geodesic dome for odor control. Providing access to the mixer will be challenging and all components of the mixer will need to be corrosion resistant with electrical components such as motors explosion proof. This alternative mixing system will not be considered or evaluated further.

4.1.2 Pumped Mixed System

The second alternative would use centrifugal chopper pumps together with nozzle assemblies. The pumps will be mounted outside the tank, while the nozzle assemblies will be mounted on the tank floor. The tank contents will be recirculated through the pumps and the nozzle assembly creating a flow pattern within the tank that keeps the contents well mixed while minimizing any settlement of solids. The number, height, and orientation of the nozzles will maintain a minimum of 0.2 meter/second velocity within the tank while creating a spiral flow pattern.

A proposal was requested from Vaughan Co. Inc., for their RotaMix® system to mix the WAS holding tank. The RotaMix® system for this application will comprise of two (1 duty/ 1 standby) centrifugal chopper pumps with 15 HP motors. Each pump will have a pumping capacity of 800 gpm. There will be a total of three nozzles – one (1) single and one (1) double nozzle assembly installed inside the tank. The nozzle assemblies will be mounted such that the nozzles will be required to be submerged at all operating conditions. During normal operations, the tank level will need to be maintained no less than 6 feet (± 1.0 feet). Should the tank be required to be drained, the pump mixing system will need to be turned off.

Table 4.2 presents the NPW costs for the pumped mix system option.

Table 4.2 Estimated Planning Level 20-Year Net Present Worth Costs for Pumped Mix System
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Item	No.	Unit(s)	Unit Cost ($)	Installation Cost ($)	Total Cost ($)
Rotamix System	1	Each	$64,900	$13,000	$77,900
Rotamix System Piping 6" DIP	50	L.F.	$60	$15	$3,750
Valves and Misc.					$10,000
				Subtotal 1	$91,650
Site Civil, Electrical, Instrumentation & Controls (25% of Subtotal 1)					$22,900
				Subtotal 2	$114,550
Project Contingency (15% of Subtotal 2)					$17,200
				Subtotal 3	$131,750
Contractor Overhead & Profit, and General Conditions (15% of Subtotal 3)					$19,800
				Total Project Capital Cost	**$151,550**
Annual Power Cost (13.2 BHP @ 24 hour operation and $0.08/kWH)					$9,250
Annual Maintenance Cost (2.5% of total equipment cost - Subtotal 1)					$2,290
Annual Labor Cost (4 hours per month for 1 person @ $30 per hour)					$1,440
				Total Annual Operating Cost	**$12,980**
20-year NPW (using a discount rate of 3.9% and a uniform series compound factor of 13.7)					**$329,320**

4.1.3 "Large Bubble" Compressed-air Mixing System

The third alternative would be to use a "Large Bubble" Compressed-air mixing system. This is a fairly new and innovative method where mixing liquids is accomplished by firing short bursts of compressed air through engineered nozzles affixed to the floor of a tank. The compressed air is intermittently fired in fractional second durations to mix the tank. The relatively small surface area of the large gas volumes and their rapid upward velocity transfer an insignificant amount of oxygen to the liquid, providing efficient anaerobic/anoxic mixing.

A proposal was requested from EnviroMix for their BioMix™ system. The BioMix™ system for this application will comprise of three concentric rings of BioMix™ nozzle headers: one 4.4-ft long circular ring with three nozzles, one 13.2-ft long circular ring with six nozzles, and one 22-ft long circular ring with eight nozzles. A Valve Panel (VP) with 304SS enclosure mounted at the tank wall will control the compressed air through stainless steel press-technology tank piping and the 304 SS BioMix™ nozzles. An operator interface in the VP allows the user to input the firing pressure, sequence, frequency, and duration. Electrical power requirements are limited to the power to operate the compressed air source and the low voltage VP. A 5 HP, 175 psi duplex piston-type air compressor with an 80-gallon horizontal receiver will supply the air to the BioMix™ nozzles.

The BioMix™ system is not impacted by the level of the liquid in the tank and the system can be designed such that the VP would take a level signal input and utilize a proportional pressure regulator to automate the air-firing parameters to further optimize mixing power consumption.

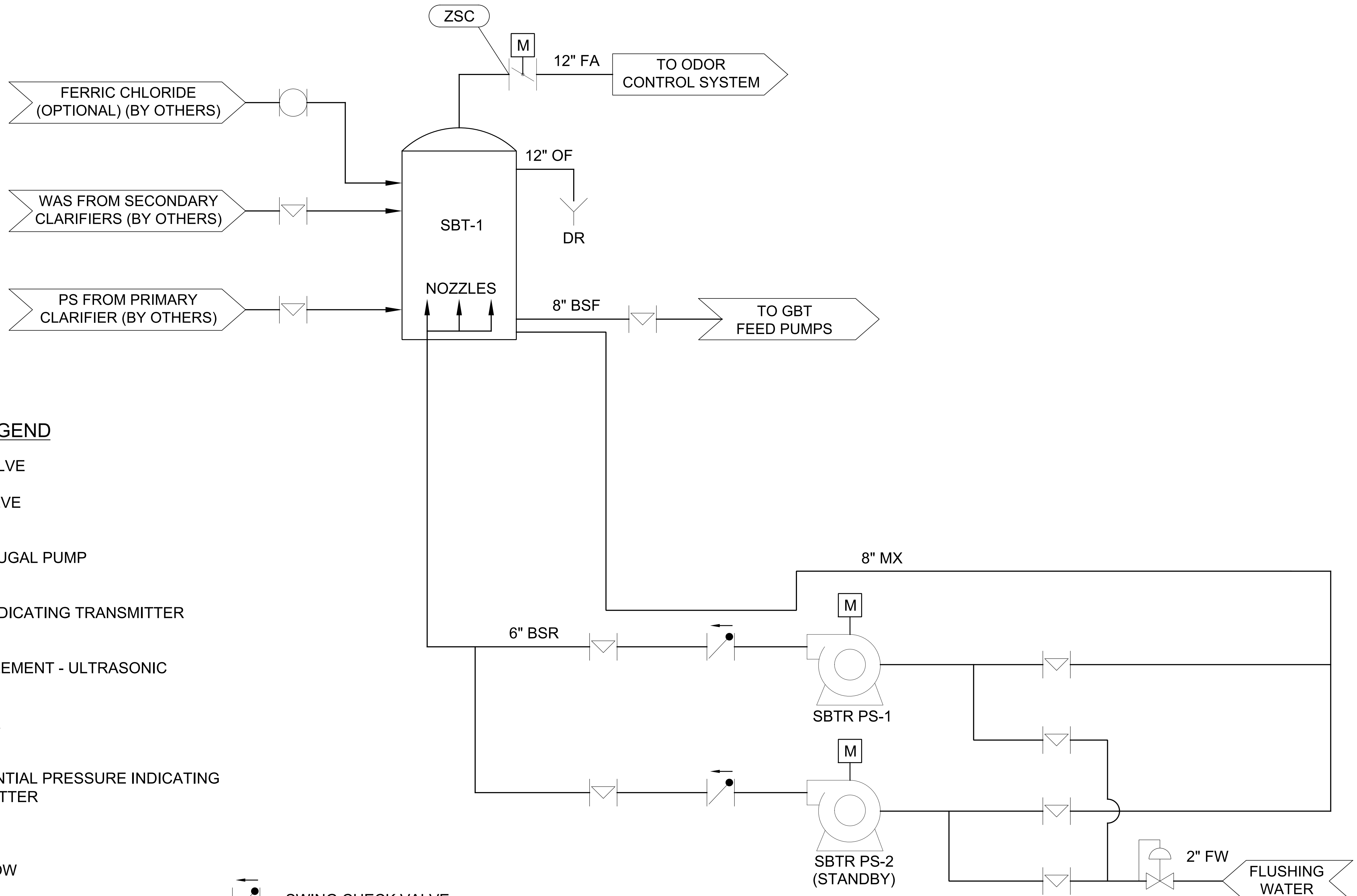
Table 4.3 presents the 20-year NPW cost for this alternative.

Table 4.3 Estimated Planning Level 20-Year Net Present Worth Costs for the "Large-Bubble" Mix System
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Item	No.	Unit(s)	Unit Cost ($)	Installation Cost ($)	Total Cost ($)
BioMix™ System	1	Each	$49,500	$9,900	$59,400
Subtotal 1					$59,400
Site Civil, Electrical, Instrumentation & Controls (25% of Subtotal 1)					$14,850
Subtotal 2					$74,250
Project Contingency (15% of Subtotal 2)					$11,140
Subtotal 3					$85,390
Contractor Overhead & Profit, and General Conditions (15% of Subtotal 3)					$12,800
Total Project Capital Cost					**$98,190**
Annual Power Cost (2.9 BHP @ 24 hour operation and $0.08/kWH)					$2,030
Annual Maintenance Cost (2.5% of total equipment cost - Subtotal 1)					$1,485
Annual Labor Cost (4 hours per month for 1 person @ $30 per hour)					$1,440
Total Annual Operating Cost					**$4,955**
20-year NPW (using a discount rate of 3.9% and a uniform series compound factor of 13.7)					**$166,110**

Figure 4.1 presents the process flow and instrumentation diagrams for the pumped mix and “large-bubble” mixing systems. Figure 4.2 presents a schematic for the pumped mixed system. Figure 4.3 provides a schematic photo of the “large-bubble” mixing system.

Based on comparing the 20-year NPW costs, the City may elect either to leave the existing coarse bubble aeration system in place or elect to retrofit the tank with the BioMix™ system to mix the sludge holding tank.



SYMBOLS/LEGEND

- PLUG VALVE
- BALL VALVE
- CENTRIFUGAL PUMP
LIT - LEVEL INDICATING TRANSMITTER
LE - LEVEL ELEMENT - ULTRASONIC
- GRINDER
DPIT - DIFFERENTIAL PRESSURE INDICATING TRANSMITTER
DR - DRAIN
OF - OVERFLOW
ZSC - LIMIT SWITCH CLOSED
- BUTTERFLY VALVE/DAMPER
M - ELECTRIC MOTOR

- SWING CHECK VALVE
SBT - SLUDGE BLENDING TANK
BSF - BLENDED SLUDGE FEED
BSR - BLENDED SLUDGE RECIRCULATION

SBTR PS-1, SBTR PS-2 } CENTRIFUGAL CHOPPER PUMPS

Figure No. 4.1

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

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SLUDGE BLENDING TANK PUMP MIX SYSTEM PROCESS & INSTRUMENTATION DIAGRAM

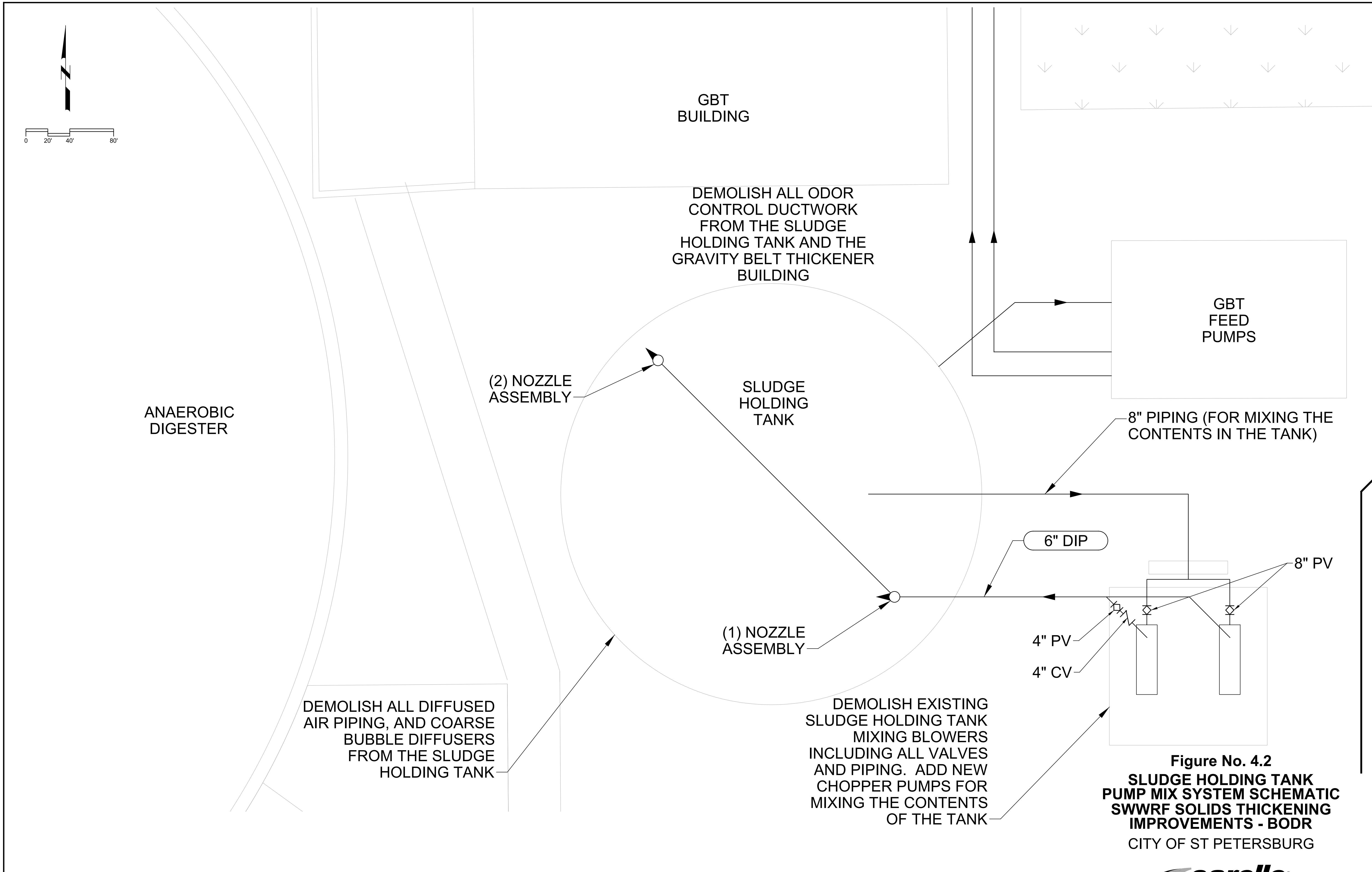


Figure No. 4.2
SLUDGE HOLDING TANK PUMP MIX SYSTEM SCHEMATIC
SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR
CITY OF ST PETERSBURG

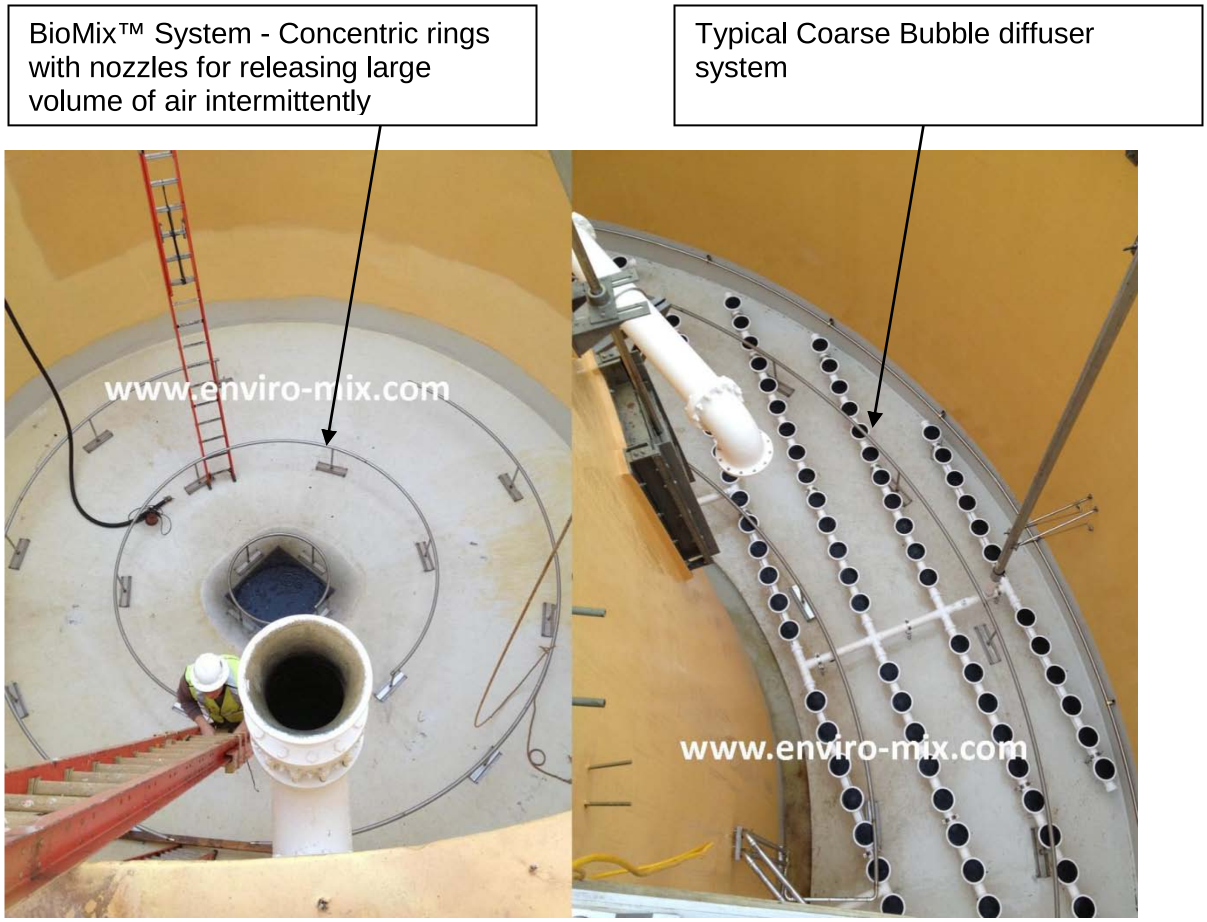


Figure 4.3 Photo Schematic of “Large-Bubble” Mixing Systems for Sludge Holding Tank

4.2 Proposed Modifications to Existing GBT Feed Pump Station

There are two (1 duty/1 standby) progressive cavity variable speed GBT feed pumps. The pumps are model 1G065G1 CDQ3 ARA, 2000 Series, single stage (8" suction/ 8" discharge), with a constant speed 7.5 HP electric motor, manufactured by Moyno Inc. Based on the cut-sheet obtained from Moyno, the capacity of the existing pump is 175 gpm at 25 psi of total dynamic head. Currently only one pump is operational. The second pump is off-line. Exhibit No. 4 shows the photo of the existing GBT feed pumps and the local control panels.

Exhibit No. 4 – Existing GBT Feed Progressive Cavity Pumps at SWWRF

Based on the equipment data sheet obtained from Moyno and consultations with SWWRF operations staff, this work effort will include replacing the two existing GBT feed pumps with new variable speed pumps and adding a third pump for 100% redundancy. The piping would be such that either of the pumps will be able to pump to any of the three GBTs to provide maximum flexibility.

Table 4.4 presents the design criteria for the GBT feed pump station. Each feed pump will be a progressive cavity pump capable of pumping 1.5 - 3% solids and will be operated with a variable speed drive. Addition of a grinder (Muffin Monster® by JWC Environmental or equal) will be evaluated during design. The grinder will grind any rags, plastic, and other undesirable solids that could clog the system and protect the GBT feed pumps. However, addition of the grinders will increase the head-loss on the suction side of the GBT feed pumps and will need to be evaluated during design.

Table 4.4 GBT Feed Pumps – Basis of Design
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Parameter	Value	Unit
Average Day Sludge (PS+WAS) Flow	0.573	mgd
	415	gpm
Average Day Sludge (PS+WAS) Solids	81,240	lb/d
	3,532	lb/hr
Peak Hour Sludge (PS+WAS) Flow	0.864	mgd
	600	gpm
Peak Hour Sludge (PS+WAS) Solids	122,500	lb/d
	5,100	lb/hr
No. of Duty GBT Feed Pumps	2	
No. of Standby GBT Feed Pumps	1	
Average Flow Capacity per Pump	210	gpm
Maximum Flow Capacity per Pump	300	gpm
Average Flow Total Dynamic Head	5	psi
Maximum Flow Total Dynamic Head	10	psi
GBT Feed Pump Maximum Horsepower	10	HP
GBT Feed Pump Make and Model	Moyno Model 1WB115 CDQ3PA AAD	

Notes:
(1) GBT operation assumes 23 hours per day with 1 hour downtime for cleaning, adjustment etc.
(2) GBT feed pumps will be designed to pump solids in the 1.5 – 3% concentration range.
(3) GBT feed pumps will be operated using a variable speed drive.

4.3 Proposed Modifications to Thickening and Associated Equipment

As discussed above, the average day design sludge quantities will require one 2-meter GBT, whereas the maximum day design sludge quantities will require one additional duty 2-meter GBT to process the solids operating 24 hours per day. A third 2-meter GBT will serve as a standby unit. The City plans to relocate one (1) 2-meter GBT from each of the NWWRF and the NEWRF. The existing building has space for adding one additional 2-meter GBT. The addition of the third 2-meter GBT will require expanding the building to the North side. The 2-meter GBTs from the SWWRF and NWWRF are 15+ years old, whereas the 2-meter GBT from the NEWRF is only 8 years old. A preliminary condition assessment of the GBTs, thickened sludge pumps, and associated electrical and instrumentation controls was performed on July 22, 2013, with representatives from Alfa Laval. Exhibits 5 - 7 show the photos of the existing 2-meter GBT, odor control hood, thickened sludge transfer pump, GBT hydraulic pack and the GBT wash water pumps at the SWWRF.

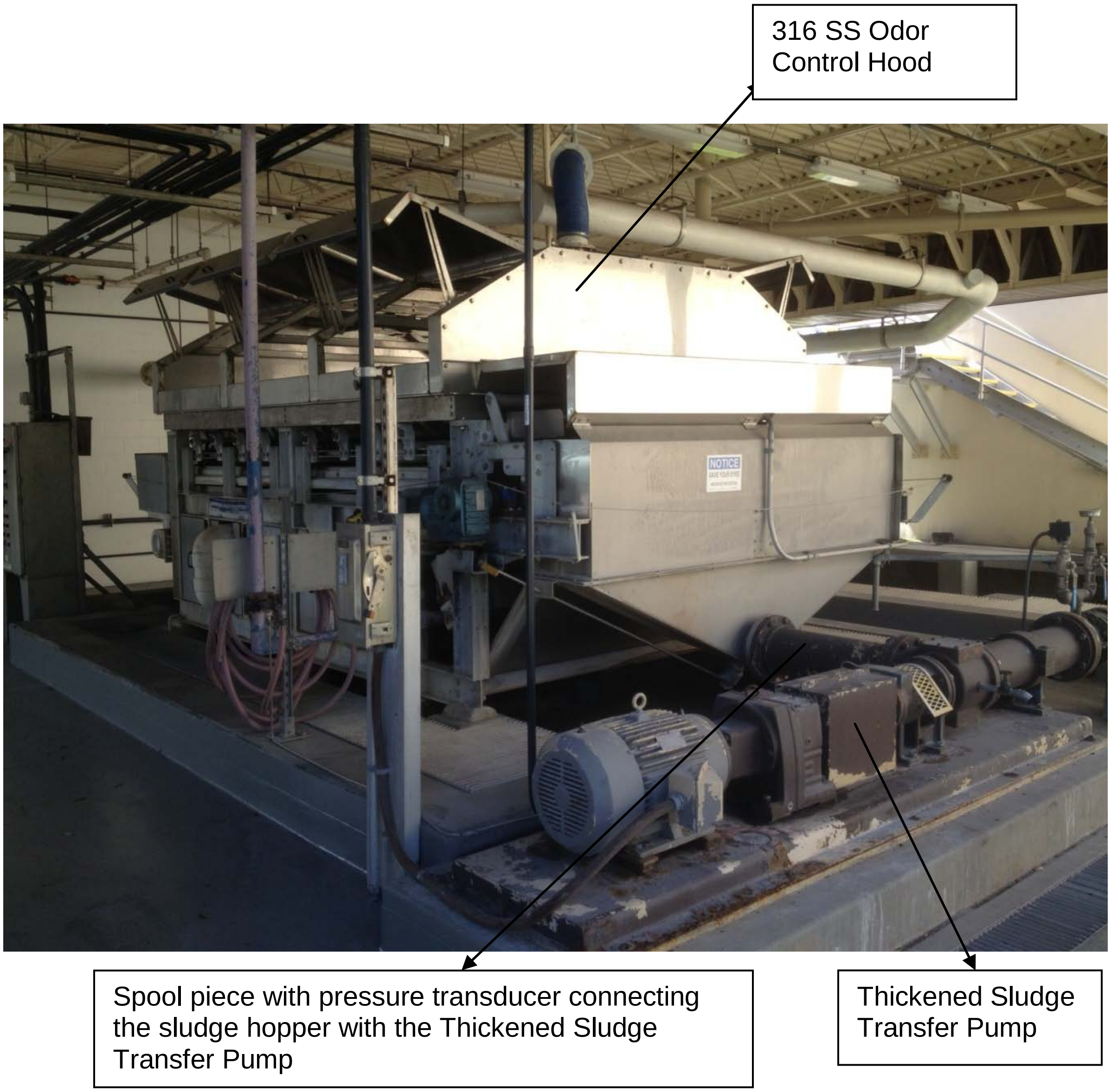


Exhibit No. 5 – Existing GBT with Thickened Sludge Transfer Pump and Odor Control Hood at SWWRF

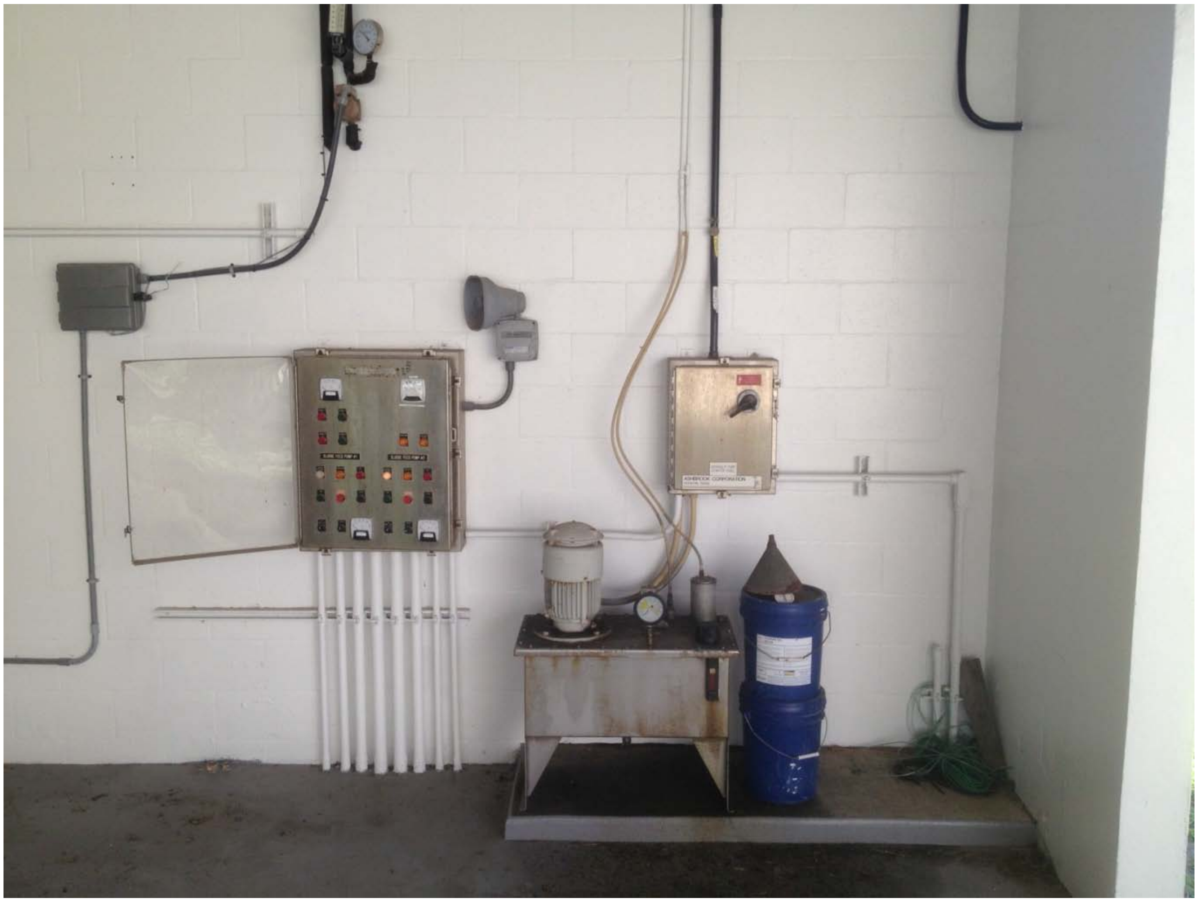


Exhibit No. 6 – Hydraulic Pack for the Existing GBT and GBT Feed Pump Control Panel at SWWRF

Exhibit No. 7 – Existing GBT Wash Water Pumps at SWWRF

Exhibits 8 - 12 show the photos of the existing 2-meter GBT, thickened sludge transfer pump, GBT hydraulic pack at the NWWRF and the existing 2-meter GBT, thickened sludge transfer pump, local PLC panel and the GBT wash water pumps at the NEWRF respectively. The equipment shown in these photos will be relocated to the SWWRF. Based on consultations with Alfa Laval, the City has an option to rebuild all three GBTs to upgrade this equipment to the state-of-art and increase the equipment life by another 25 years minimum. Typical rebuilds will include new roller and bearing assembly parts, new hydraulic system parts (mounted on the GBT unit), new variable drive system parts, new belt wash system parts, new poly wear items, new rubber seals, new odor control hoods, and galvanizing the support frame. The unit will also have the latest instrumentation such as auto-sensing belt alignment system, auto-sensing belt tensioning system, adjustable ramp, and a new in-line variable orifice polymer mixer. Additionally, all controls will be upgraded to match those of the GBT that will be relocated from NEWRF as described in the section 4.5 below.

The thickening operation and controlling the thickened sludge solids concentration is vital to proper functioning and operation of the downstream anaerobic digestion process (temperature phased anaerobic digestion). Upgrading and rebuilding the existing GBTs will provide the City with a more reliable system. Additionally, a bypass line will be designed to pump a small portion of the primary and WAS mixture from the sludge holding tank to the anaerobic digesters during events when the % solids from the GBT exceed the desired 6% ±1.0% concentration. The flow will be manually determined by the operator using the spare GBT feed pump. Each GBT feed pump will have a flowmeter on the discharge side.

Exhibit No. 8 – Existing GBT with Thickened Sludge Transfer Pump at the NWWRF

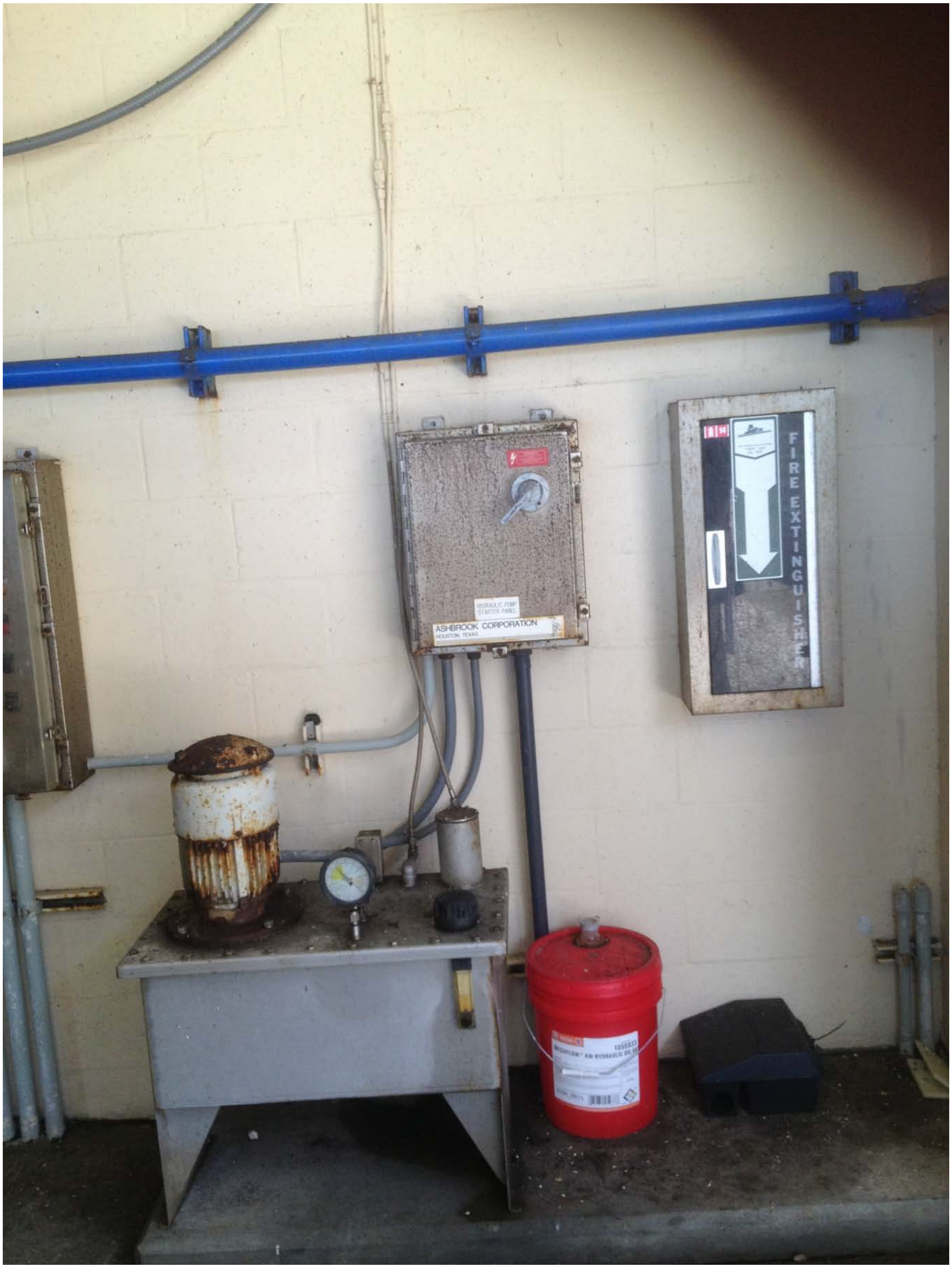


Exhibit No. 9 – Hydraulic Pack for the Existing GBT at the NWWRF

Exhibit No. 10 – Existing GBT with Thickened Sludge Transfer Pump at the NEWRF

Exhibit No. 11 – Existing GBT Local PLC Panel at the NEWRF

Exhibit No. 12 – Existing GBT Wash Water Pumps at the NEWRF

Table 4.4 presents the design criteria for the thickened sludge transfer pumps. The existing thickened sludge transfer pumps are model 2G065G1 CDQ3 AAA, 2000 Series, two stage (8" suction/ 8" discharge), with a variable speed 25 HP motor, manufactured by Moyno Inc. Based on the cut-sheet obtained from Moyno, the capacity of the existing pump is 200 gpm at 43 psi of total dynamic head. The existing pumps appear to be in good condition. However, the City has an option to replace the existing pumps with new "open-throat" style progressive cavity pumps that would be installed underneath the thickened sludge hopper of the GBT. This would eliminate the spool piece that currently connects the hopper with the close-coupled pump and would eliminate any pump suction hydraulic issues and offer a more efficient pump control.

Table 4.4 GBT Thickened Sludge Transfer Pumps – Basis of Design
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Parameter	Value	Unit
Average Day Thickened Sludge Flow	0.152	mgd
	~ 100	gpm
Average Day Thickened Sludge Solids	76,095	lb/d
	~ 3,300	lb/hr
Peak Hour Thickened Sludge Flow	0.226	mgd
	~156	gpm
Peak Hour Thickened Sludge Solids	113,145	lb/d
	~ 4,713	lb/hr
No. of Thickened Sludge Transfer Pumps	1	Per GBT
Thickened Sludge Transfer Pump Average Day Flow Capacity	50	gpm
Thickened Sludge Transfer Pump Average Day Flow Capacity	100	gpm
Thickened Sludge Transfer Pump Peak Flow Capacity	200	gpm
Thickened Sludge Concentration Range	5 to 7	%
Average Flow Total Dynamic Head	20	psi
Peak Flow Total Dynamic Head	30	psi
Thickened Sludge Transfer Pump Maximum Horsepower	15	HP
Thickened Sludge Transfer Feed Pump Make and Model	Moyno Model 2J115G2M10 CDQ 5AAA	

Notes:
(1) GBT operation assumes 23 hours per day with 1 hour downtime for cleaning, adjustment, etc.
(2) Thickened Sludge Transfer pumps will be operated using a variable speed drive.

Each GBT will be equipped with a dedicated wash water pump. The wash water requirements for a 2-meter GBT are approximately 40 gpm at a minimum pressure of 85 psi. A 5 HP end-suction centrifugal wash water pump will be provided. The pump will be connected to the existing in-plant reclaimed water pipe. The pump will be equipped with a Y-strainer to filter any suspended solids.

4.4 Proposed Modifications to Polymer Storage and Feed System

The SWWRF has recently converted from a dry polymer system to an emulsion polymer system for the thickening operation. The polymer dilution and mixing system includes a wall mounted skid system comprising of a polymer feed pump, a motorized mixing chamber, and rotameters for dilution water. The polymer dilution and feed system is Model Polyblend® M Series as manufactured by Wallace & Tiernan® ChemFeed. The polymer is injected into the inlet pipe to the GBT using a polymer injection ring. Exhibits 13 and 14 show the photos of the existing polymer feed and the polymer injection systems.

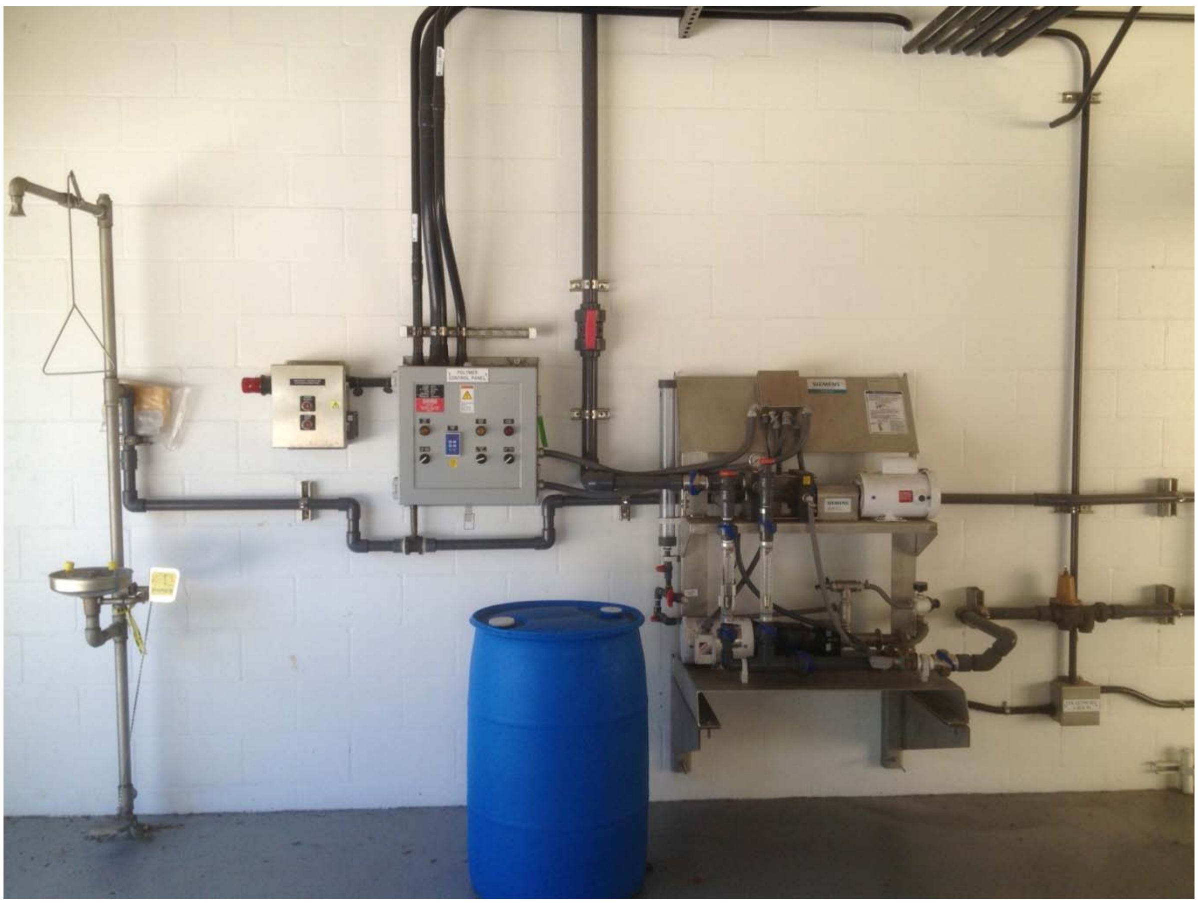


Exhibit No. 13 – Existing Emulsion Polymer Dilution and Feed System at the SWWRF

Exhibit No. 14 – Existing Polymer Injection System at the SWWRF

4.5 Proposed Modifications to Electrical and I&C Systems

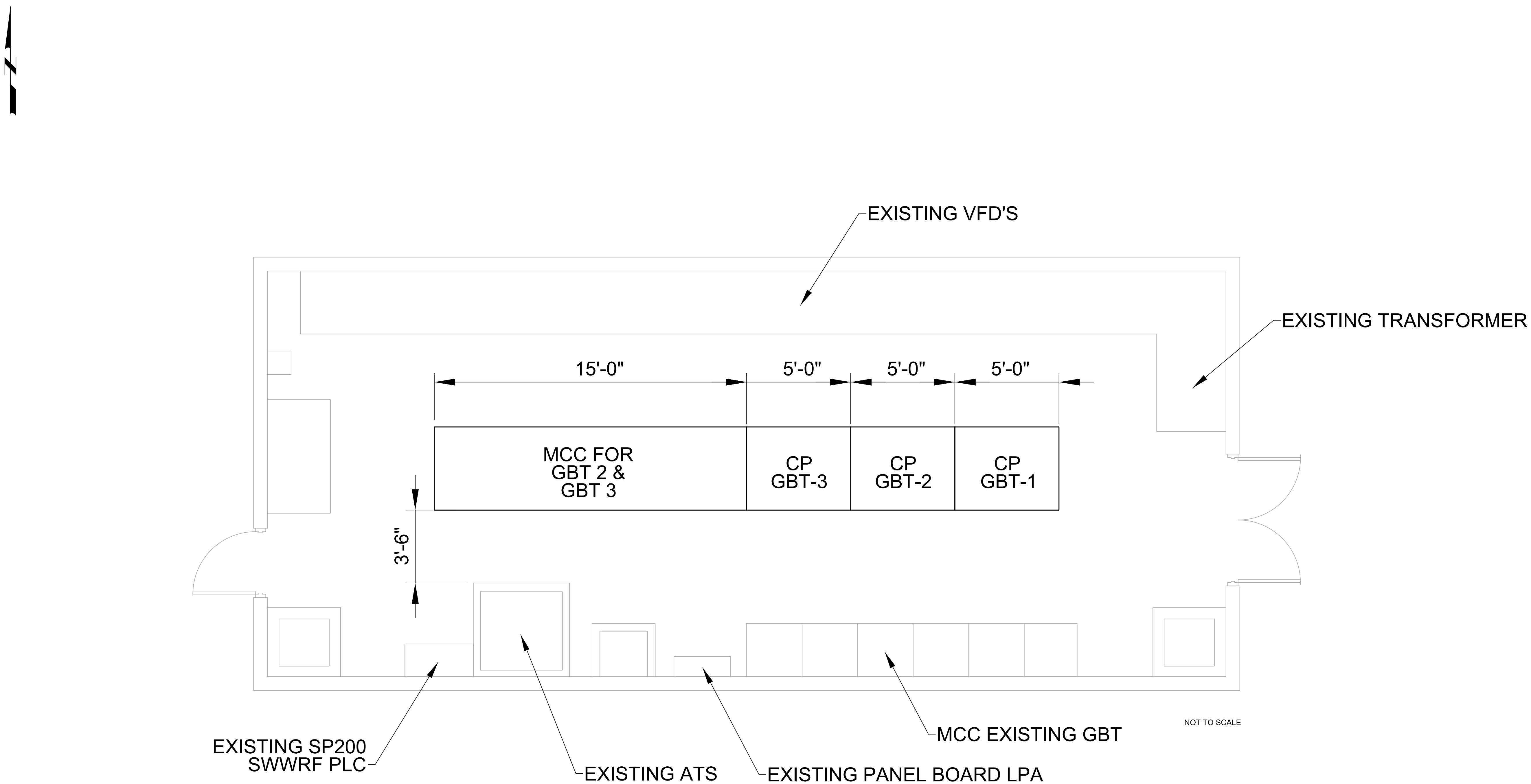
The electrical components for the existing GBT are located in a climate controlled building east of the existing GBT building. This building was upgraded in 2011 to include a new motor control center (MCC) for the existing GBT equipment. The building also has other electrical components for the influent pump station control panel, four existing variable speed drives for the influent pump station, a transformer, and an automatic transfer switch (ATS). Exhibit 15 shows the photo of the electrical building and the MCC. All components of the existing thickening system including the GBT feed pumps, GBT hydraulic pack, GBT control panel, GBT thickened sludge pump, GBT wash water pumps, polymer feed system, and WAS holding tank blowers are fed from this MCC.

The existing GBT at the SWWRF has one local control panel. Exhibit 16 shows the photo of this panel. This panel will be replaced to match controls from the GBT at the NEWRF, which will be relocated to the SWWRF. The GBT at the NEWRF has a local PLC panel (see Exhibit 17) and a main control panel mounted remotely in a climate controlled building. It is proposed that as part of the relocations of the GBTs, the controls of the existing GBT at the SWWRF and that of the GBT from the NWWRF will be upgraded to match the control philosophy of that the NEWRF with local PLC panels and remote main control panels. Exhibit 17 shows a photo of the main control panel for the GBT at the NEWRF. The existing GBT feed pumps will be replaced with new larger pumps with VFDs. The VFDs will also be located in the electrical building. Figure 4.4 shows the proposed modifications to the electrical building. The capacity of the existing air handling unit (AHU) will be evaluated to support the additional heat load from the new electrical gear.

Exhibit No. 15 – Existing Electrical Building at the SWWRF

Exhibit No. 16 – Existing GBT Control Panel at the SWWRF

Exhibit No. 17 – Existing GBT Main Control Panel at the NEWRF



CP - CONTROL PANEL

EXISTING ELECTRICAL BUILDING PROPOSED NEW EQUIPMENT LAYOUT

Figure No. 4.4

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

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4.6 Proposed Modifications to the Existing GBT Building

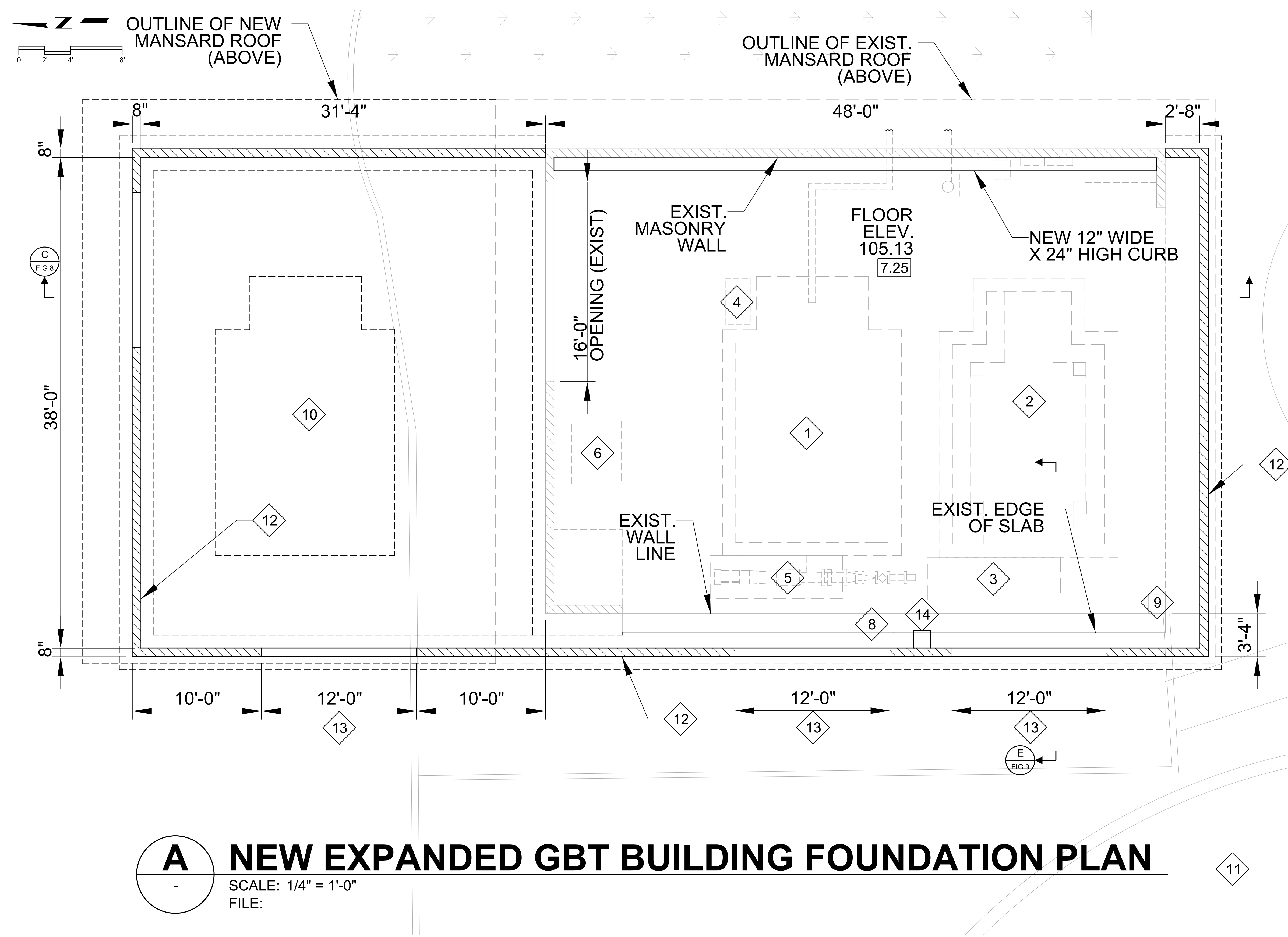
The existing building has a space for a second 2-meter GBT and the building will be expanded to the North to install the third 2-meter GBT. Figures 4.5, 4.6, and 4.7 show modifications to the existing GBT building to strengthen the existing structure and expand the building to meet current design codes. The existing building will be enclosed with CMU masonry wall on the South and West sides. These new walls will be constructed under the roof mansard by extending the existing slab to allow better equipment access on all sides. The building roof will be strengthened with addition of new joist bridging as shown in the figures. A 12”x24” concrete curb will be added to the base of the existing East wall to strengthen it to withstand current wind load requirements. The overall dimension of the new structure will be approximately 80-ft long, 38-ft wide, and 16-ft high. Three (3) 12-ft wide roll-up doors will be mounted on the west side centered on each GBT to allow for removal. A fourth 12-ft wide roll-up door will be mounted on the North wall to allow transport of emulsion polymer drums in and out of the building. The entire building will be ventilated and foul air will be treated in a new odor control system as described in the section below.

4.7 Proposed Modifications to the Odor Control System

The new GBT building will be enclosed on all sides and will be ventilated to provide a minimum of 12 air changes per hour. Based on the volume of the existing building, the ventilation rate is estimated to be around 10,000 cubic feet per minute (cfm). The building will be designed with appropriate louver system to allow the 12 air changes per hour and create a slight negative pressure to scrub the foul air from the building. Each of the three GBTs will have an odor control hood. Figure 4.8 provides conceptual details of the proposed odor control hood. The hood will be constructed of fiberglass reinforced plastic (FRP). Air from the hoods will be concentrated with hydrogen sulfide (H_2S) and is estimated to be 4,000 cfm. The air from the hoods will be routed to the new 2-stage biological odor control system with a polishing carbon unit located to the east of the building. The remaining 6,000 cfm air will be routed directly to the polishing carbon unit.

The sludge holding tank will also be provided odor control. The air requirements are estimated to be 1,000 cfm. The odor duct from the GBT hoods will be combined with the duct from the sludge holding tank and treated through the 2-stage biological odor control system.

The 2-stage biological odor control unit will also treat foul air from the primary clarifiers and will be designed by the City’s other consultant (Brown & Caldwell).



A NEW EXPANDED GBT BUILDING FOUNDATION PLAN

SCALE: 1/4" = 1'-0"
FILE:

11

KEY NOTES:

1. EXISTING 2-METER GRAVITY BELT THICKENER (GBT)
2. FUTURE 2-METER GBT
3. FUTURE THICKENED SLUDGE PUMP
4. EXISTING GBT CONTROL PANEL
5. EXISTING THICKENED SLUDGE PROGRESSIVE CAVITY PUMP
6. EXISTING WASH WATER PUMPS PAD
7. EXISTING SLUDGE HOLDING TANK
8. EXISTING DRAIN WITH GRATING
9. EXISTING STEEL COLUMN (ROOF SUPPORT)
10. FUTURE (THIRD) 2-METER GBT
11. EXISTING DIGESTER
12. NEW 8" CMU WALL
13. NEW 10' ALUMINUM COILING DOOR
14. NEW 16"X16" CMU PILASTER

Figure No. 4.5

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

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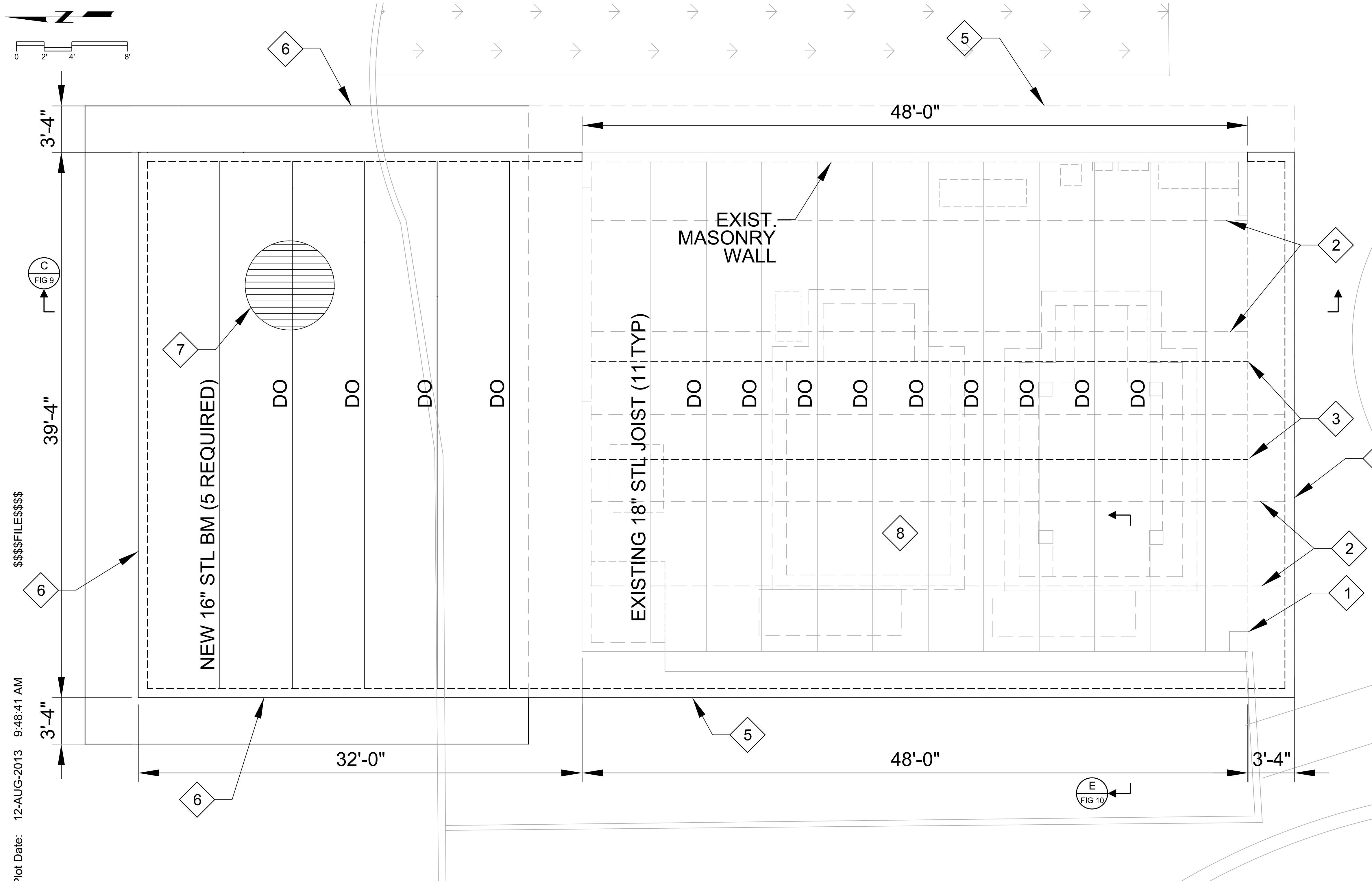

KEY NOTES:

1. EXISTING STEEL COLUMN (ROOF SUPPORT)
2. EXISTING JOIST BRIDGING
3. NEW JOIST BRIDGING
4. EXISTING DIGESTER
5. OUTLINE OF EXISTING MANSARD ROOF
6. OUTLINE OF NEW MANSARD ROOF
7. NEW BUILT-UP ROOF
8. EXISTING BUILT UP ROOF

B - NEW EXPANDED GBT BUILDING ROOF FRAMING PLAN

SCALE: 1/4" = 1'-0"
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Figure No. 4.6

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

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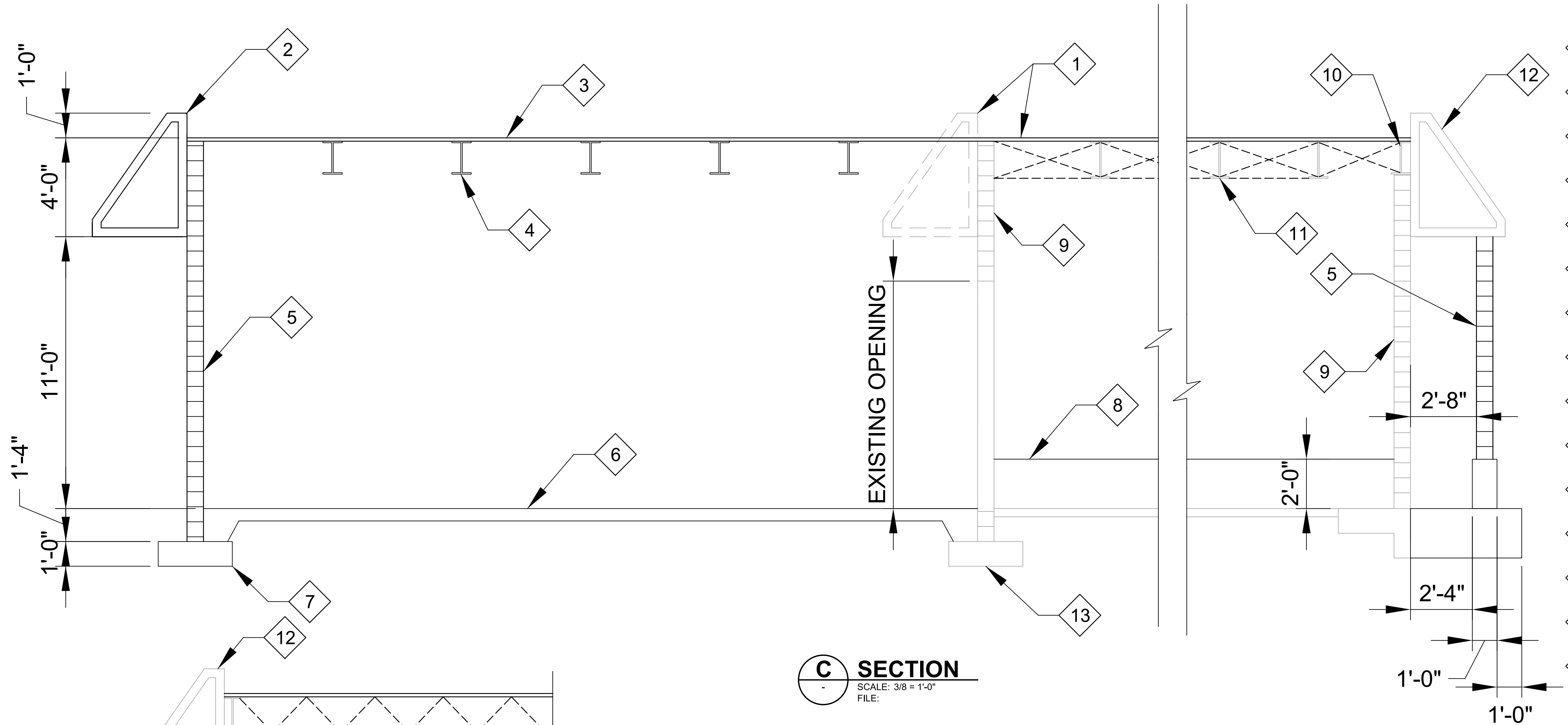

C SECTION
SCALE: 3/8 = 1'-0"
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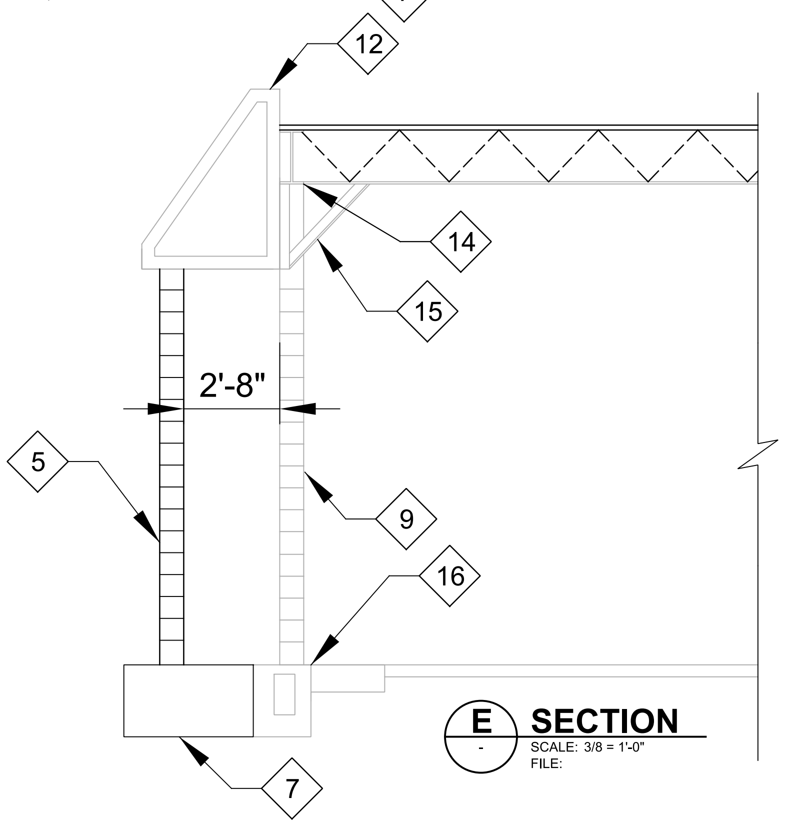

E SECTION
SCALE: 3/8 = 1'-0"
FILE:

KEY NOTES:

1. REMOVE EXISTING MANSARD. HOT MOP NEW ROOFING TO EXISTING.
2. NEW MANSARD
3. NEW ROOF DECK
4. NEW 16" STL BEAM
5. NEW 8" CMU
6. NEW 6" CONCRETE SLAB
7. NEW CONCRETE FOOTING
8. NEW 12"x24" CONCRETE CURB
9. EXISTING 8" CMU
10. EXISTING 16" STL BEAM
11. EXISTING 18" STL JOIST
12. EXISTING MANSARD
13. EXISTING CONCRETE FOOTING
14. EXISTING JOIST/BM CONNECTION
15. EXISTING MANSARD ANGLE BRACING
16. EXISTING SLAB AND TRENCH DRAIN

Figure No. 4.7

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

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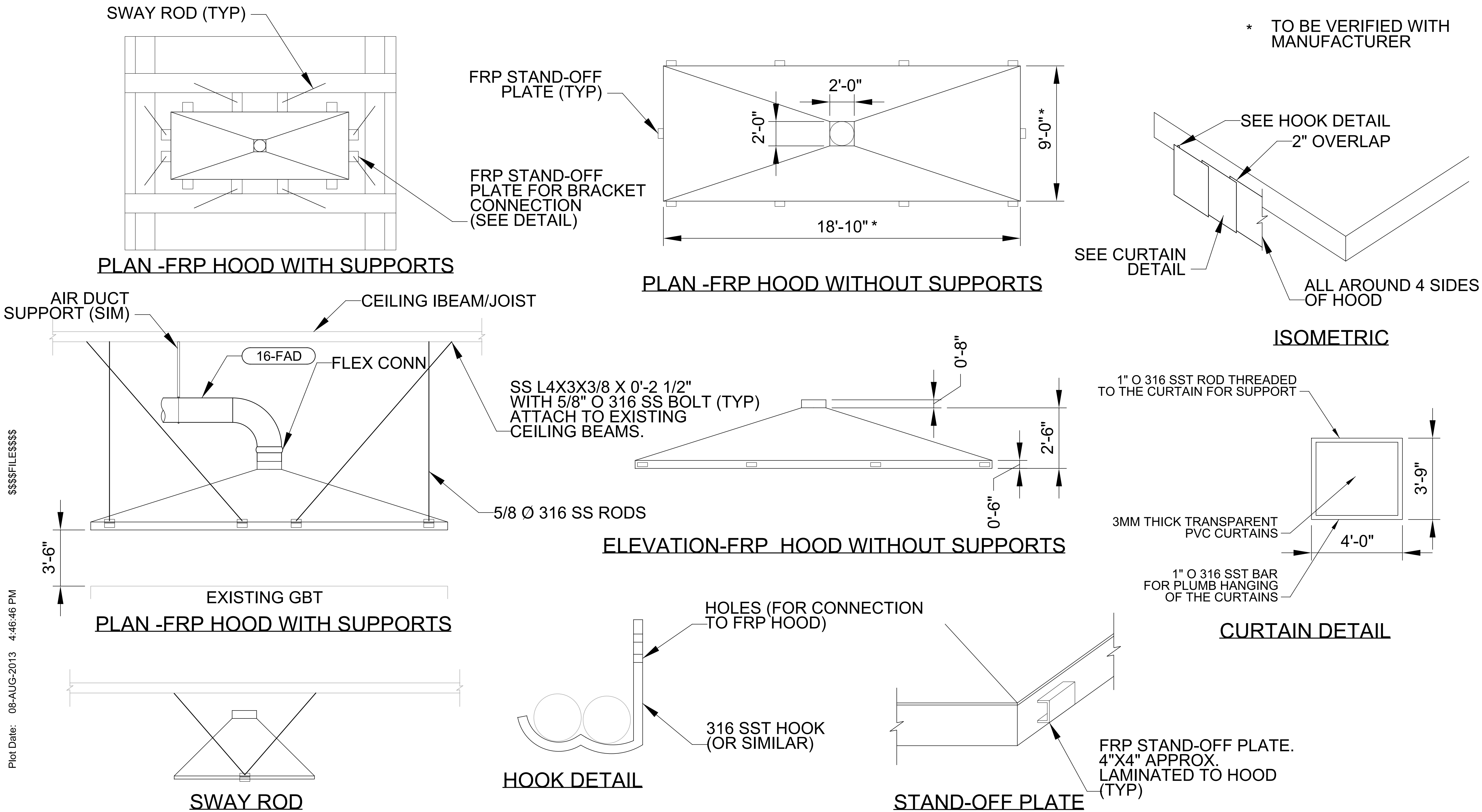

GBT ODOR CONTROL HOOD DETAIL

Figure No. 4.8

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

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5.0 SUMMARY OF PROPOSED THICKENING FACILITY IMPROVEMENTS AT THE SWWRF

This section summarizes the proposed thickening facility improvements to be constructed at SWWRF to enhance the thickening operation. Primary and WAS will be pumped from the primary clarifiers and secondary clarifiers respectively to the existing sludge holding tank. The sludge mixture will continue to be mixed with the coarse bubble aeration system at the sludge holding tank. The minimum liquid level in the tank will be maintained at 10-ft to provide efficient mixing.

The sludge mixture (~1.7% solids) will be pumped using three variable speed 10 HP progressive cavity pumps to thetwo GBTs. The third GBT will be added in the future. Two sludge grinders (1 duty/1 standby) will be installed on the suction side of the GBT feed pumps.

One 2-meter GBT from the NEWRF will be relocated to SWWRF. A third GBT from the NWWRF will be relocated in the future. The NEWRF GBT will be shipped to the manufacturer’s factory to be rebuilt and upgraded with state-of-art mechanical, electrical and instrumentation components. The manufacturer will be responsible for all labor, material, and incidentals for dismantling and shipping of the existing GBT, rebuilding, and installation of all GBT components. The electrical control panels will be shipped loose, and installed, tested, and put into operation by the Contractor. The GBT will have a local PLC panel (White painted 316 SS panel) and a remote main control panel mounted in the existing electrical building.

Each GBT will have a variable speed 15 HP, open throat progressive cavity pump to pump the thickened sludge (6.0%, ±1.0%) to the anaerobic digesters. Similarly, each GBT will have a dedicated wash water pump (40 gpm @ 85 psi, 5HP motor, end-suction centrifugal). Each GBT will also have a dedicated polymer dilution and feed system similar to the existing system (Wallace & Tiernan® M Series).

The existing GBT building will be enclosed using CMU masonry block. The entire building will be ventilated and the foul air will be treated at the central 2-stage biological odor control unit. Each GBT will have an odor control hood mounted on top that will also collect air to the odor control unit. Air from the sludge holding tank will also be scrubbed to the same odor control unit. Table 5.1 provides the summary of the design criteria for the various thickening components.

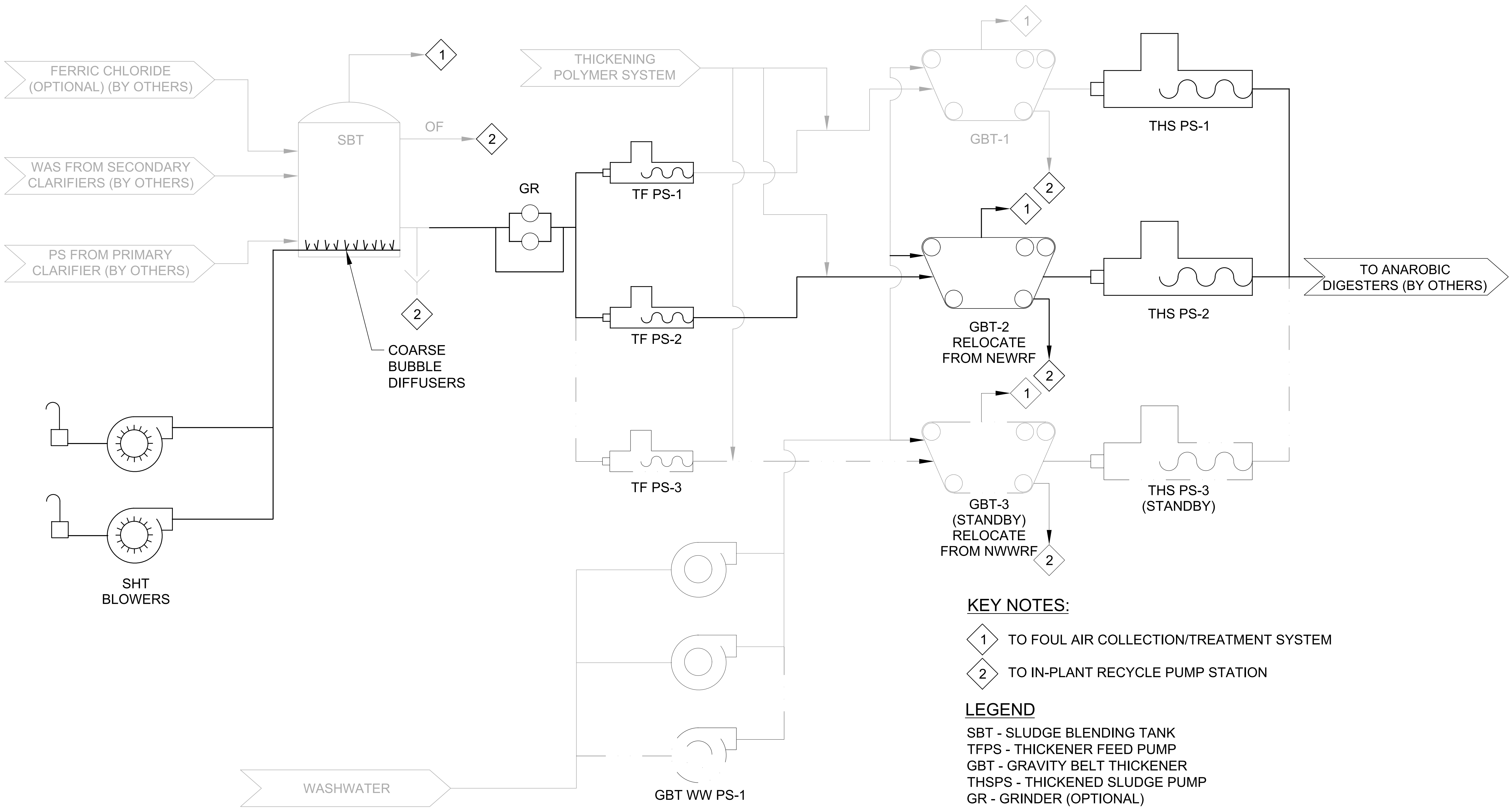
The existing floor of the GBT building is at elevation 105.13 while the 100-year flood elevation is 109.88. Based on consultations with City staff, all thickening process equipment including all GBT feed pumps, GBTs, thickened sludge transfer pumps, and wash water pumps will be located below the 100-year flood elevation. The thickening process, though crucial for the successful operation of the proposed TPAD anaerobic digestion process, is not critical to the operation of the plant under extreme conditions. During conditions such as a 100-year flood event, the primary and WAS will be trucked as liquid sludge to an off-site location for disposal under an emergency services contract with a third party vendor.

Figures 5.1 - 5.6 show the process flow and instrumentation diagrams for the proposed thickening system improvements. Figure 5.7 shows the overall site plan for the proposed improvements.

Table 5.1 Solids Thickening Components – Basis of Design
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Component	No.	Size/Description	Electrical	Manufacturer
Sludge Holding Tank	1	105,000 gallon poured in place concrete tank (existing)	-	-
Sludge Holding Tank Mixing System (Existing)	1	Coarse bubble diffusers with two PD blowers (existing) delivering 525 scfm of air	50 HP (1 duty/1 standby) blowers	Sanitaire® Diffusers. Sutorbilt-GD Blowers
Sludge Grinders	2	600 gpm	5 HP (1 duty 1 standby)	JWC Environmental Inc. Model - Muffin Monster 30004T-1208
GBT Feed Pumps	3	Progressive cavity pumps with pumping capacity of 100 – 300 gpm @ 25 psi	10 HP (2 duty/ 1 standby) with VFD	Moyno Inc. Model - 1WB115 CDQ3PA AAD
GBTs	2	Relocate one GBT from the NEWRF. Rebuild each of the two GBTs.	1.5 HP Hydraulic pack per GBT	Alfa Laval (formerly Ashbrook Simon Hartley) Model - Aquabelt Type 85
Thickened Sludge Pumps	2	Progressive cavity pumps (open throat) with pumping capacity of 50 – 200 gpm @ 50 psi	15 HP (1 per GBT) with VFD	Moyno Inc. Model - 2J115G2M10 CDQ 5AAA
Wash Water Pumps	2	End-suction centrifugal pumps 40 gpm @ 85 psi	5 HP per pump	Grundfos–Model CR-10-5
Polymer System	2	Emulsion Polymer dilution and feed system (one per GBT)	1.5 HP	Wallace & Tiernan® Model - M Series

User: DPerry   Plot Date: 18-SEP-2013 8:22:19 AM $$$$FILE$$$$



KEY NOTES:

1 TO FOUL AIR COLLECTION/TREATMENT SYSTEM

2 TO IN-PLANT RECYCLE PUMP STATION

LEGEND

SBT - SLUDGE BLENDING TANK
TFPS - THICKENER FEED PUMP
GBT - GRAVITY BELT THICKENER
THSPS - THICKENED SLUDGE PUMP
GR - GRINDER (OPTIONAL)
OF - OVERFLOW
DR - DRAIN
SBTR PS - SLUDGE BLENDING TANK RECIRCULATION PUMP

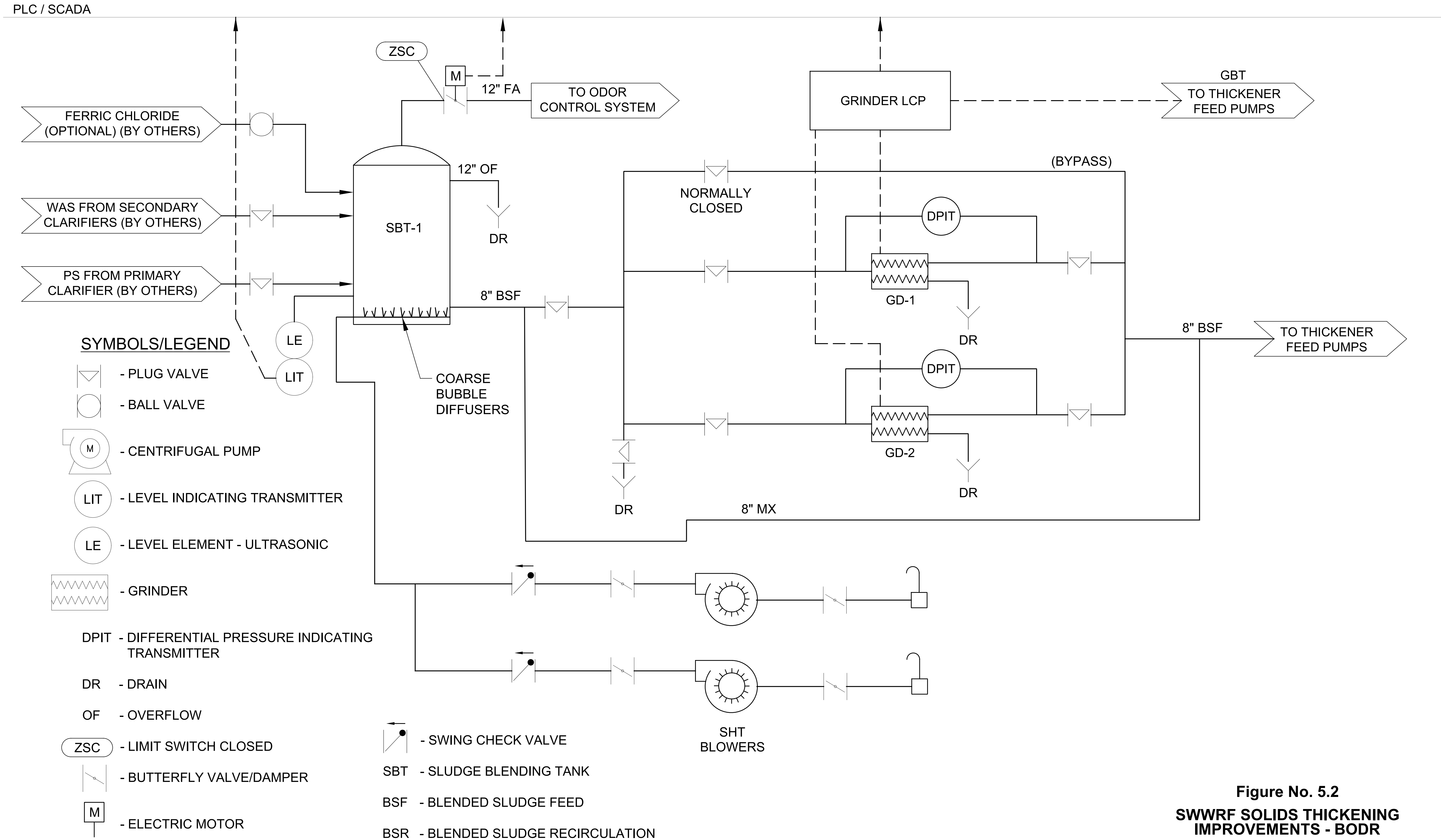
SLUDGE THICKENING SYSTEM IMPROVEMENTS PROCESS FLOW DIAGRAM

Figure No. 5.1

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo



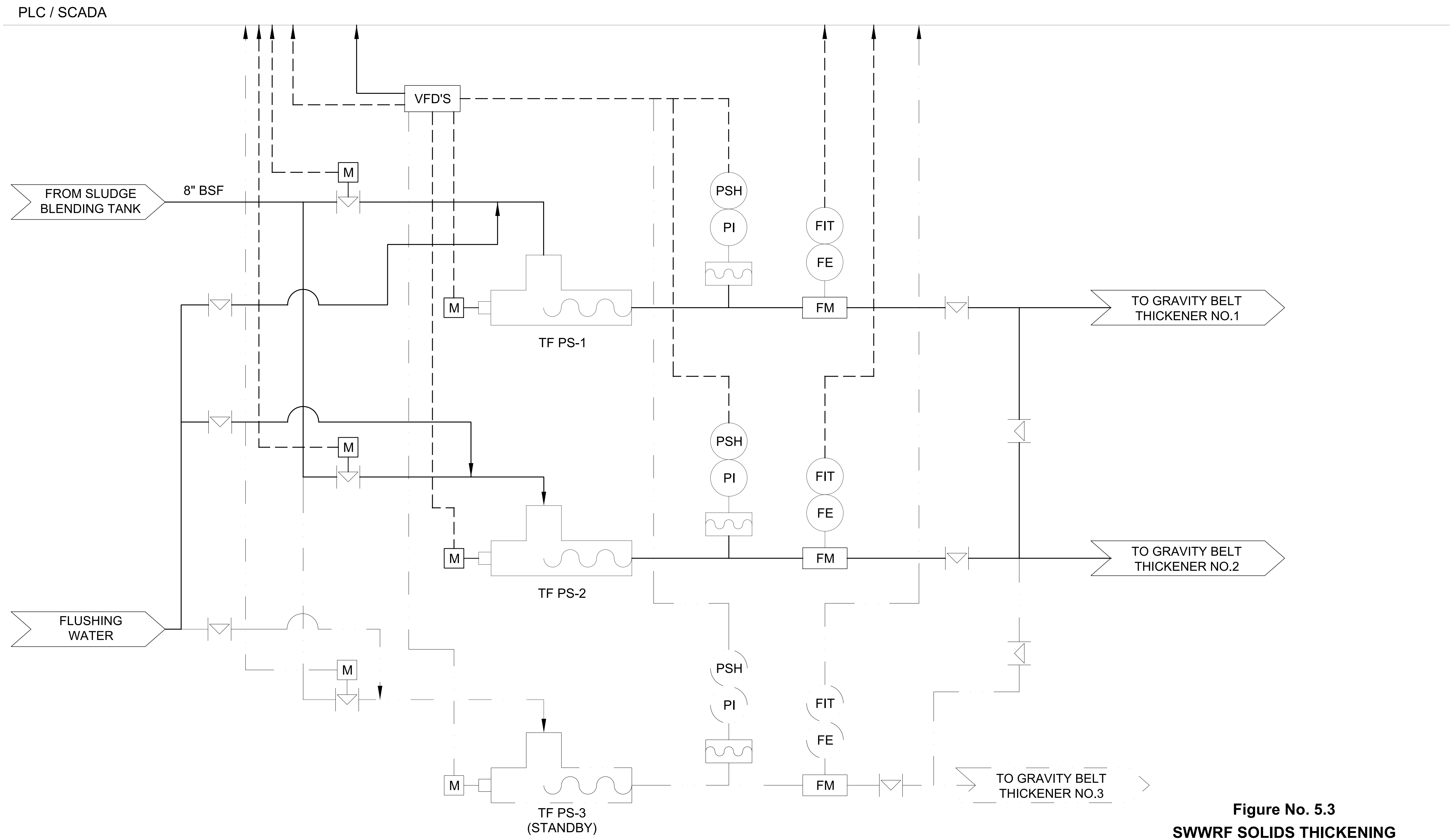
SLUDGE HOLDING TANK PROCESS & INSTRUMENTATION DIAGRAM

Figure No. 5.2

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo



GBT FEED PUMPS PROCESS & INSTRUMENTATION DIAGRAM

Figure No. 5.3

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo

User: DPerry Plot Date: 17-SEP-2013 2:18:33 PM $$$$FILE$$$$

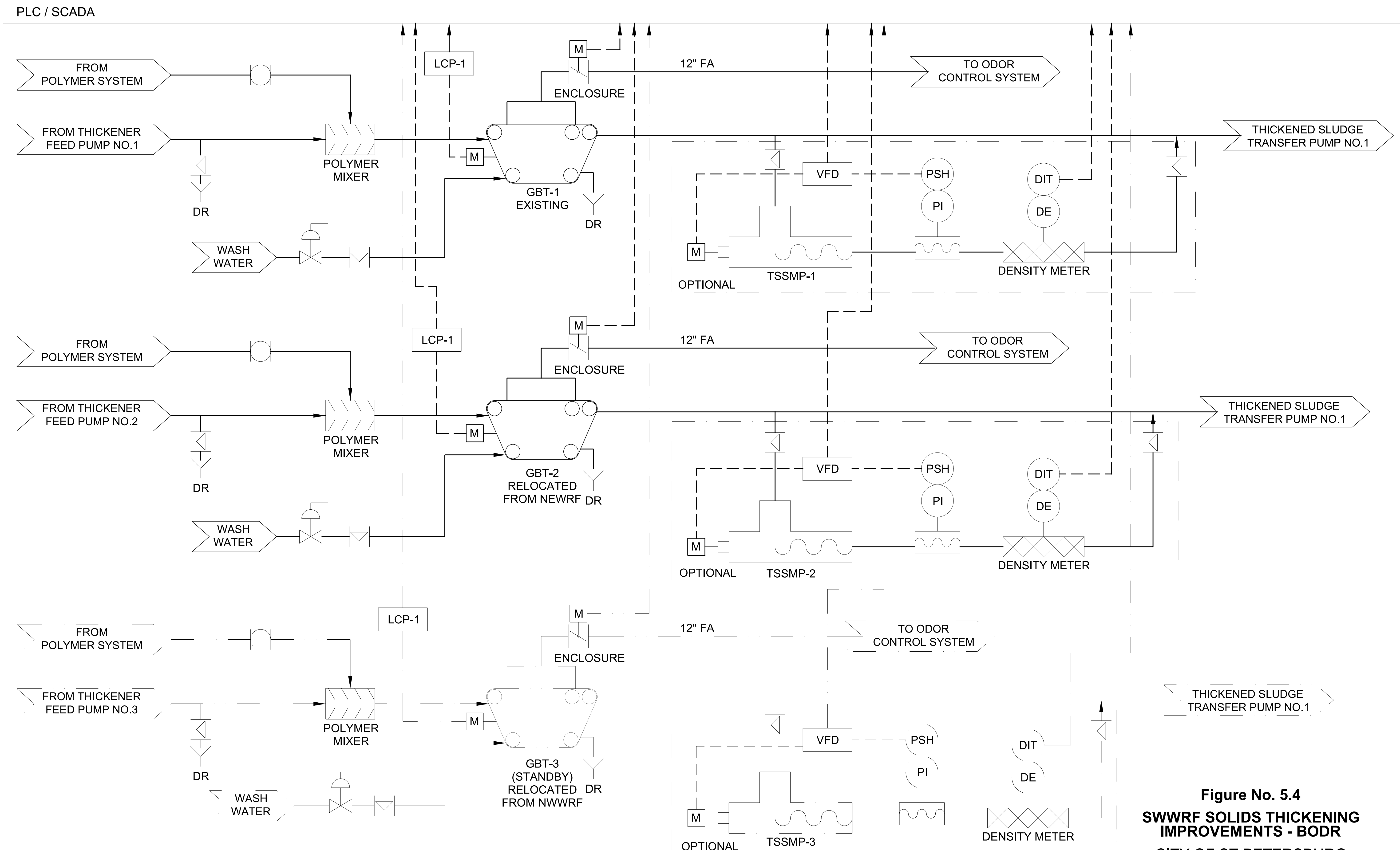


Figure No. 5.4

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo

GRAVITY BELT THICKENER PROCESS & INSTRUMENTATION DIAGRAM

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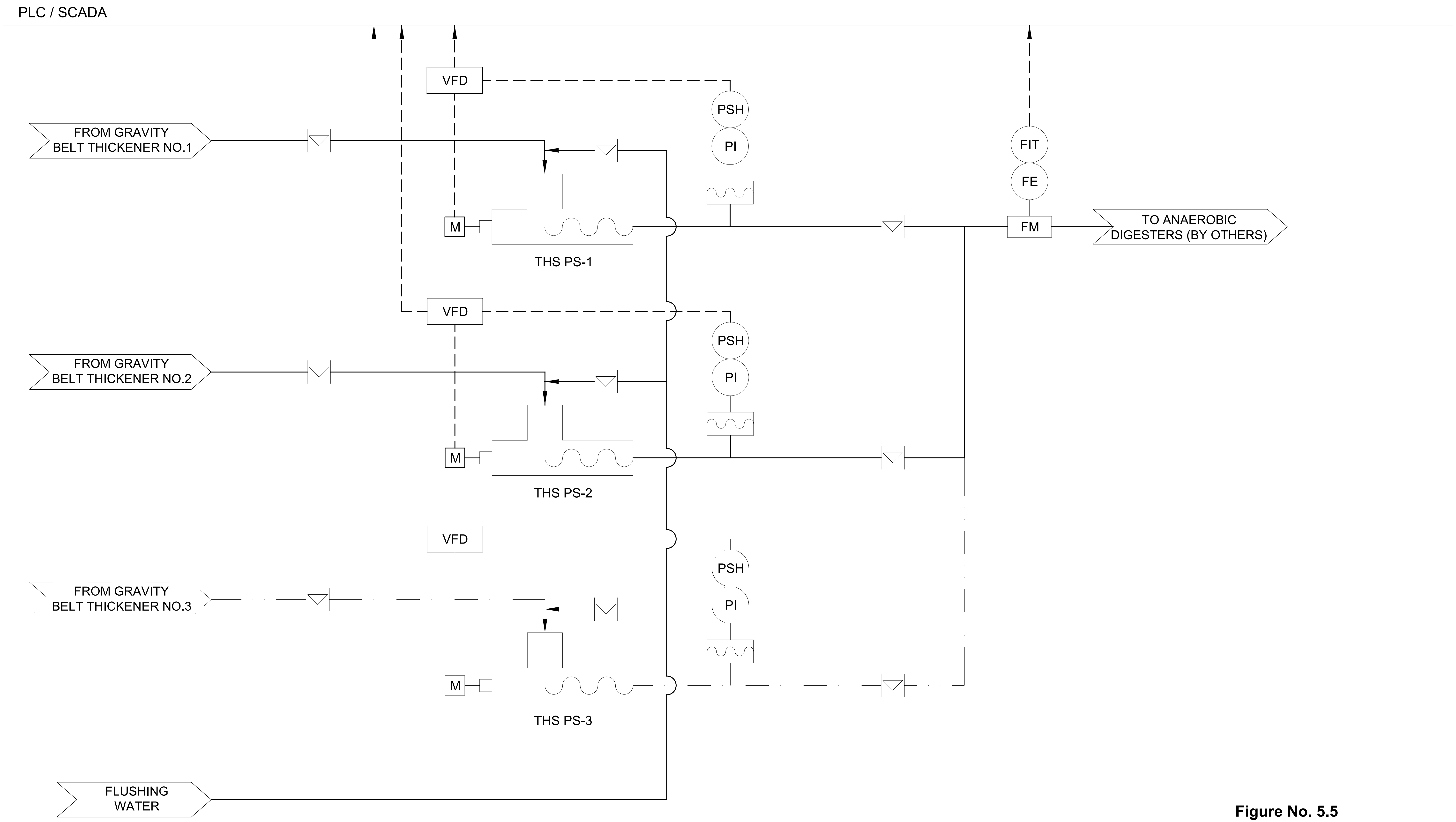


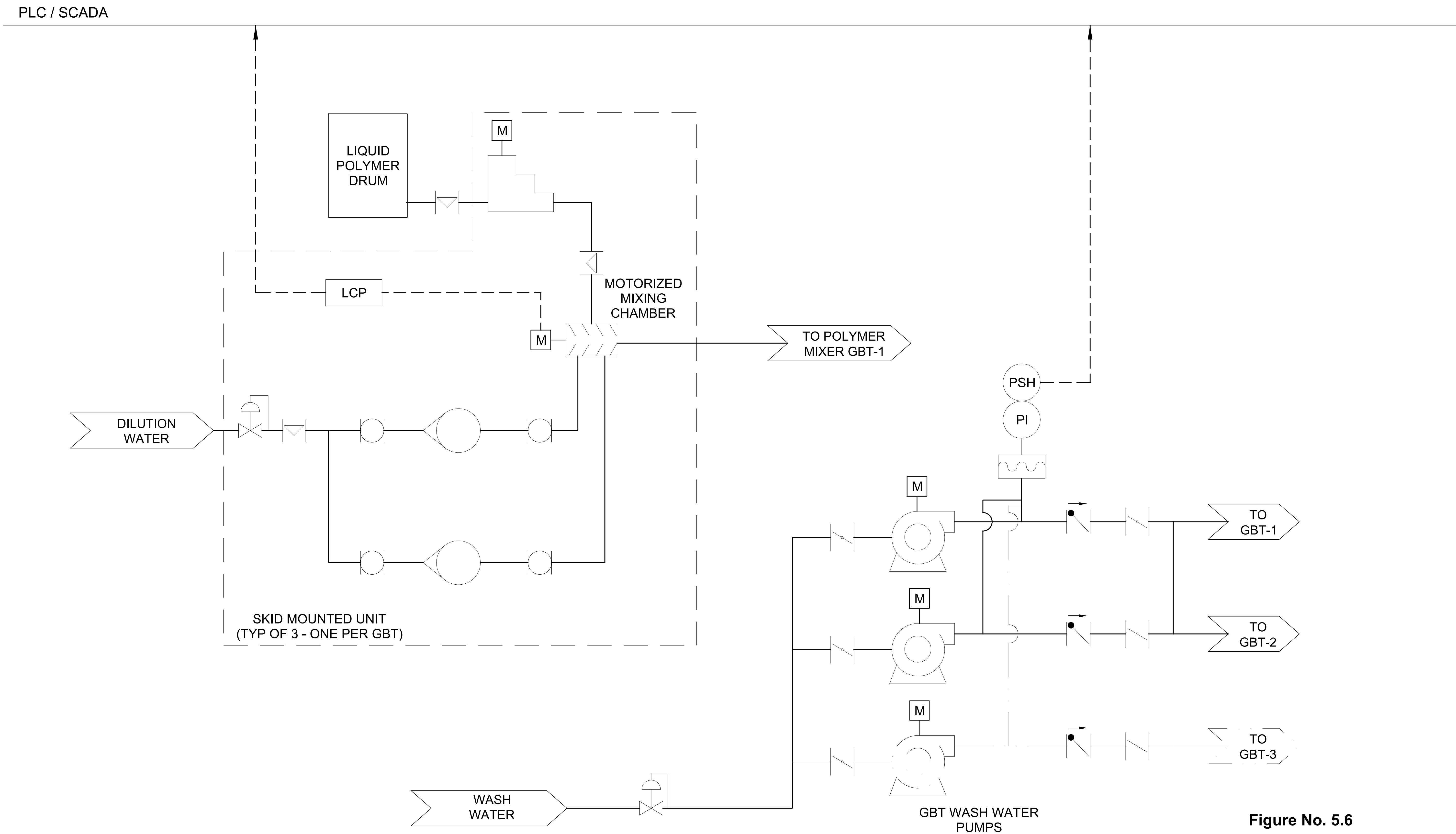
THICKENED SLUDGE TRANSFER PUMP PROCESS & INSTRUMENTATION DIAGRAM

Figure No. 5.5

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo



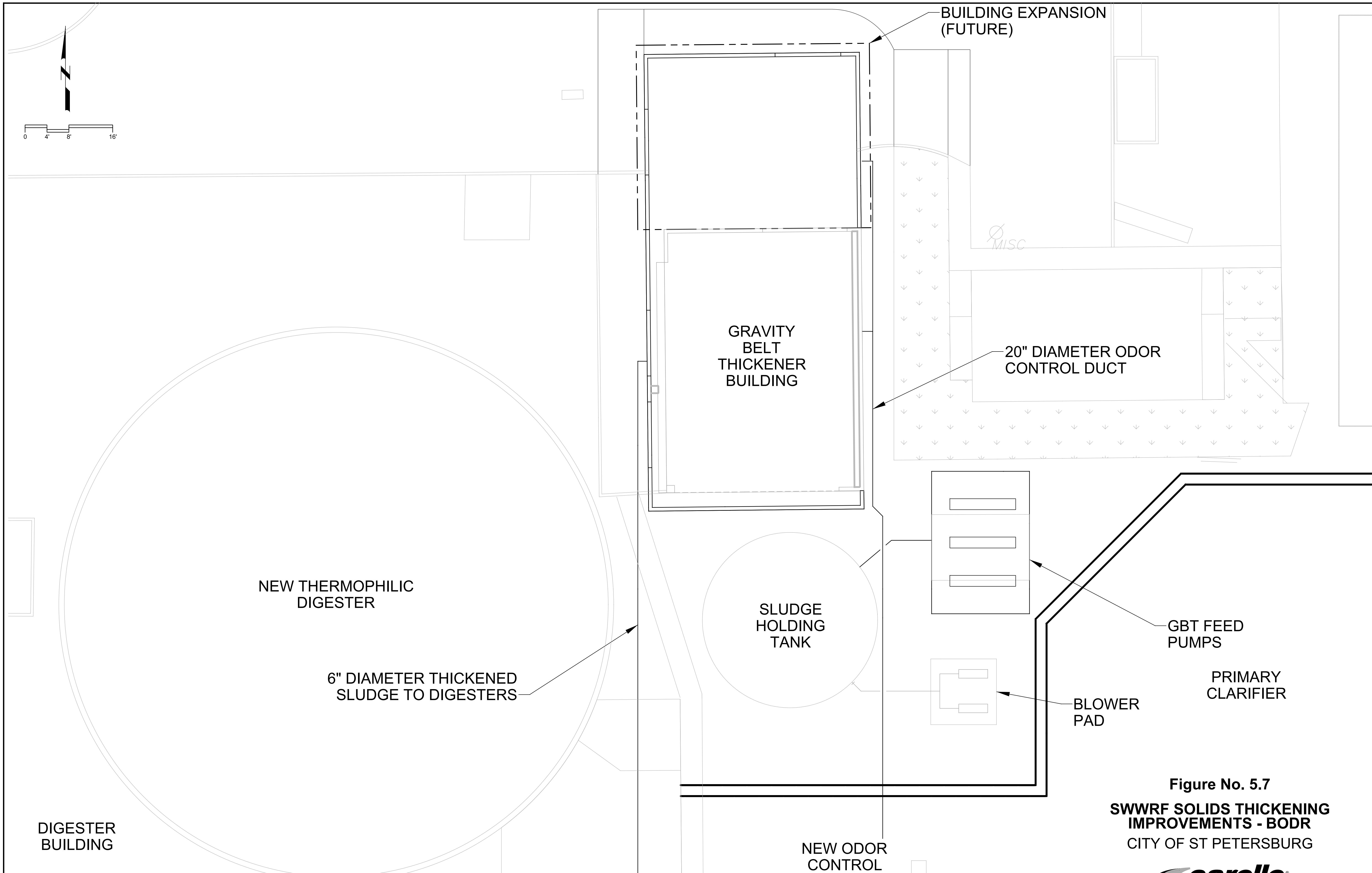
GBT POLYMER & WASHWATER PROCESS & INSTRUMENTATION DIAGRAM

Figure No. 5.6

SWWRF SOLIDS THICKENING IMPROVEMENTS - BODR

CITY OF ST PETERSBURG

carollo



OVERALL THICKENING SYSTEM IMPROVEMENTS SITE PLAN

6.0 PRELIMINARY COST ESTIMATE FOR THE PROPOSED THICKENING SYSTEM IMPROVEMENTS

Table 6.1 provides the preliminary cost estimate for the proposed thickening system improvements. The estimates of the probable cost of construction are considered Class 3 “Budget Level” estimates per the Recommended Practice 18R-97 Cost Estimate Classification System for the Process Industries, published in 1998 by the Association for the Advancement of Cost Engineering (AACE). Engineering is typically 10 to 40 percent complete and the expected accuracy range is within +30 percent to -10 percent. This means that construction bids can be expected to fall within a range of 30 percent over the estimate to 10 percent under the estimate.

Table 6.1 Estimated Planning Level Capital Costs for Solids Thickening System Improvements
SWWRF – Sludge Thickening System Improvements - BODR
City of St. Petersburg

Item	No.	Unit(s)	Unit Cost ($)	Installation Cost ($)	Total Cost ($)
GBT Feed Pumps (Moyno Model 1WB115 CDQ3PA AAD)	3	Each	$21,915	$4,385	$78,900
Sludge Grinders (Muffin Monster Model 30004T-1208)	2	Each	$21,500	$4,300	$51,600
Rebuild and Relocate GBTs (Alfa Laval Proposal)	Price Proposal from Alfa Laval for all three GBTs				$435,000
Polymer System (Wallace & Tiernan® M Series)	1	Each	$19,500	$3,900	$23,400
Washwater Pumps (Grundfos Model CR-10-5	2	Each	$10,000	$1,500	$23,000
Thickened Sludge Transfer Pumps (Moyno Model 2J115G2M10 CDQ 5AAA)	2	Each	$47,090	$9,420	$113,000
Structural Improvements and Expansion of the GBT building	Lump sum				$93,000
Odor Control Improvements (Louver, Ductwork etc)	Lump sum				$50,000
				Subtotal 1	$867,900
Site Civil and Yard Piping (10% of Subtotal 1)					$86,800
Electrical, Instrumental & Controls (25% of Subtotal 1)					$217,000
				Subtotal 2	$1,171,700
Project Contingency (20% of Subtotal 2)					$234,300
				Subtotal 3	$1,406,000
Engineering, Legal, and Administrative (15% of Subtotal 3)					$210,910
Contractor Overhead and Profit (15% of Subtotal 3)					$210,910
				Total Project Cost	**$1,828,000**

APPENDIX A – VENDOR PRICE PROPOSALS

CARL ERIC JOHNSON, INC.
1725Q MacLeod Drive
Lawrenceville, Georgia 30043
Phone: 678/377-3100
Fax: 678/377-2021
August 7, 2013

Mr. Sudhan Paranjape
Corollo Engineers
1089 W. Morse Blvd.
Suite A
Winter Park, Florida 32789

Subject : SWWRF Improvements St. Petersburg, FL

Dear Sudhan:

We are pleased to offer our **BUDGETARY** proposal for a Moyno Pumps as follows:

Following are conditions of service.

- ***Municipal thickened Sludge***
- ***Max 9% solids***
- ***Maximum 200 gpm***
- ***Normal discharge line pressure to 50 PSI.***
- ***Diameter Discharge Pipe, Length TBD***
- ***Ambient temperature normal sludge temperature.***
- ***Duty Cycle Continuous***

<u>Quantity Three Complete Thickened Sludge Pumps</u>

Each unit to include one (1) Moyno progressing cavity pump model 2J115G2M10 CDQ 5AAA. Pump to be driven by a 15 HP AC, 3PH/60HZ/230-460V, 1750 RPM, TEFC, frame 254TC, Service factor 1.15, inverter duty (inverter range 10:1) Baldor/Reliance C-face motor, Nord Class II C-face reducer with 7.73:1 ratio having 226 RPM output speed all components mounted on carbon steel break bent in line base with anchor holes and lifting lugs.

<u>Budget</u> Price (Qty Three) Thickened Sludge Pump assembly…..$116,765.00

Budget adder for (Qty Three) VFD's in NEMA 12 enclosure……..$ 24,502.00

Start-Up:
One normal eight hour day labor and expenses for start-up assistance. One day should be sufficient as long as unit is properly prepared. Additional days are at rate of $1000.00 per day.

Continued. . .

Mr. Sudhan Paranjape
Corollo Engineers
August 7, 2013
Page 2

Following are conditions of service.

- ***Municipal Sludge***
- ***Max 3% solids***
- ***Maximum 300 gpm***
- ***Normal discharge line pressure to 50 PSI.***
- ***Diameter Discharge Pipe, Length TBD***
- ***Ambient temperature normal sludge temperature.***
- ***Duty Cycle Continuous***

Quantity Three Complete GBT Feed Pumps

Each unit to include one (1) Moyno progressing cavity pump model 1WB115 CDQ3PA AAD Pump to be driven by a 10 HP AC, 3PH/60HZ/230-460V, 1750 RPM, TEFC, frame 215TC, Service factor 1.15, inverter duty (inverter range 10:1) Baldor/Reliance C-face motor, Nord Class II C-face reducer with 5.5:1 ratio having 318 RPM output speed, all components mounted on carbon steel break bent in line base with anchor holes and lifting lugs.

Budget Price (Qty Three) GBT Sludge Pump assembly………….$ 47,840.00

Budget adder for (Qty Three) VFD's in NEMA 12 enclosure……..$ 17,906.00

Enclosed are dimensional drawings for both pumps.

Please advise if additional data is required.

Thank you for your interest Moyno pumps and the opportunity to work with you on this project. Should you have any questions, please contact either Del Story in our Lake Mary, Florida office at 407/618-4386 or me in our Lawrenceville, Georgia office at 678/377-3100.

Regards,

Beverly Garner

Beverly Garner
Manager Municipal Markets
CARL ERI CJOHNSON, INC.

Cc: Roy Leffew, Del Story, File

Heyward
INCORPORATED

415 Country Club Drive, Winter Park, Florida, 32789, Ph 407.628.1880, Fax 407.628.9860

August 8, 2013

To: Sudhan Paranjape - Carollo Engineers

Subject: St. Petersburg, FL
SW WRF WAS Grinding
Muffin Monster Grinders

Dear Sudhan:

Heyward Florida Incorporated is pleased to offer the following budget price for grinding waste activated sludge (WAS) for your consideration:

Two (2) JWCE Model 30004T-1208-DI Muffin Monster sewage grinder with cast ductile iron housing, 12-inch tall cutting chamber, maximum capacity 1000-gpm, 7-tooth cam cutters, two (2) 2-inch hex shafts, four (4) sealed Conrad-Type ball bearings with mechanical seals and labyrinth pre-seals, tungsten carbide rotating and static races and Buna-N elastomers, 3-HP 240/480v/3ph/60Hz TEFC drive motor, 29:1 Sumitomo planetary gear reducer, and factory sand blast prime and prime and finish Tnemec epoxy paint system.

Two (2) JWCE Model PC 2220 motor controller in a NEMA 4X 316 stainless steel enclosure accepting a 240/480v/3ph/60Hz input power, includes IEC motor starter with over-current protection, jam-sensing current sensor, transformer, and Micro-PLC. This panel is capable of being interlocked with the WAS pumps through a run relay rated for 10 amps. Relay contacts are not powered (dry).

Four (4) Operation and Maintenance manuals

TOTAL FOR TWO UNITS…………………………………………$43,000.00

The prices offered above are based upon JWCE standard conditions of sale, which are attached and made part of this proposal. Price includes truck freight to the job site, and one trip, one day of start-up services.

The price excludes anchor bolts, conduit or conduit supports, pull wire, panel stanchions, J-boxes, hoists, mechanical or electrical installation, spare parts, or any state or local sales or use taxes.

Submittal drawings require 4-5weeks after receipt of an approved purchase order. Current manufacturing lead time is 6-8 weeks after receipt of approved submittal drawings.

Should you have any questions concerning our offering, or if we may be of any service, please do not hesitate to contact us.

Kindest regards,

HEYWARD INCORPORATED

Gregory J. Chomic

Gregory J. Chomic
Winter Park Office

August 7, 2013

Carollo Engineers, Inc.
1089 W. Morse Blvd., Suite A
Winter Park, FL 32789

Attention: Sudhan Parajape, P.E.

WATER AND WASTEWATER TREATMENT SOLUTIONS

Reference: Northeast W.W.T.P.
St Petersburg, FL
Budget Proposal
(1) Aquabelt 2.0 meter Type 96
Quote# **35470 Rev 1**

Dear Parajape,

Alfa Laval Ashbrook Simon-Hartley, Inc. ("Ashbrook") is pleased to offer its budget proposal on factory rebuilding of your existing (1) Aquabelt 2.0 meter Type 96 the above referenced location. Ashbrook's experience in designing and building new gravity belt thickeners and repairing/rebuilding gravity belt thickeners, can only enhance our position in offering the services and parts needed to provide additional years of service to your existing unit(s).

Ashbrook started its "Rebuild Program" to provide customers with "today's technology" on earlier model belt filter presses as an alternative to purchasing new replacement equipment. Over the past eighteen years Ashbrook has completed rebuild projects consisting of partial site repairs, complete site machine reconditioning, complete factory machine reconditioning, partial factory machine reconditioning and site machine upgrades.

Equipment on these projects includes Bellmer Winklepresses (German), English Belt Filter Presses, Ashbrook's MKII, Type 85, and Type 94 Klampresses, Aquabelt gravity belt thickeners and other Belt Filter Presses.

All parts supplied by Ashbrook for reconditioning your machine(s), shall meet Ashbrook's latest O.E.M. design standards. All parts will be made to Ashbrook's standard level of quality under ISO9001 certified procedures. All labor shall be performed by qualified Ashbrook trained service technicians who are experienced in the disassembly/reassembly of the Aquabelt.

Ashbrook's scope for rebuilding (1) Aquabelt Type 96 includes using only new O.E.M. (Original Equipment Manufacturer) parts, reconditioned parts, site labor for disassembly/reassembly, and inbound/outbound freight charges.

Typical rebuilds will include roller and bearing assembly parts, hydraulic system parts, drive system parts, belt wash system parts, poly wear items, rubber seals, and possibly retrofit or upgrade items. The particular scope of supply depends on the actual condition of the customer's machine at the time of the rebuild. A firm proposal will be issued at that time to tie down a firm scope of supply and allow our customers to issue a contract or purchase order so that work may proceed on their equipment.

Budget costing is important to allow our customer's to plan for the future needs of their facility. As such we have constructed budgetary pricing that will provide guidance on the financial resources that will need to be in place for the reconditioning of our customer's machines. For this specific project we would like to propose a budget cost of (see pages 3 & 4 for pricing) per machine. **This pricing is for budgetary purposes only and a firm proposal will be provided at the customer's request when their budget is in place**. The scope of supply on your project is as detailed on page 3.

We appreciate the opportunity to be of assistance in the planning for the future of your facility's equipment. We hope that we have addressed your needs in a suitable manner. If you have any questions please feel free to contact your Ashbrook representative, Mark Schlitzkus at 713-906-0505.

Best Regards,

Mark Schlitzkus

Mark Schlitzkus
PPS Environmental Regional Manager

Scope of supply:

Complete set of new 75mm stub shaft/forged end rollers consisting of the following:

(2) 8" Plain rollers (steering/tensioning)
(1) 10" Drive roller

Drive roller shall be coated with ¼" Buna-N rubber. All other rollers shall be coated with 30 mils of thermoplastic nylon. **The new Ashbrook rollers shall be warranted for a period of three (3) years against failure from defects in material and workmanship under normal use and service when used and maintained per Ashbrook's published operation and maintenance procedures.**

(6) New Ashbrook/Dodge 75mm bearing housing assemblies. New Ashbrook/Dodge bearing assemblies consist of housing, triple labyrinth seal, bearing with steel bronze machined cage, 316 stainless steel hardware and taper lock nut assembly. Housings will be nylon coated for maximum protection against corrosion. Housing shall have a triple labyrinth seal for superior sealing against contaminants. Greasing intervals every 6 months. **Bearing assemblies are warranted for 5 years as long as assemblies are maintained per Ashbrook's published operation and maintenance procedures.**

(2) New pivot plate assemblies. Parts fabricated form A-36 carbon steel then hot dipped galvanized.

(1) New shaft mount AC gearmotor (Eurodrive).

(1) New machine mount hydraulic system consisting of 316 stainless steel hydraulic fittings, 316 stainless steel hoses, 316 stainless steel steering valve/paddle assembly, 316 stainless steel tensioning valve and fiberglass steering/tensioning cylinders.

(1) New press mount hydraulic unit.

(1) New 316 stainless steel gravity section sludge restrainer

.

(1) Lot Replace worn electrical switches (no cake, belt misalignment, high sludge level and belt breakage). Install new 316ss NEMA 4x press mounted junction box.

(1) New emergency trip cord assembly consisting of trip cord switch, galvanized guide cable brackets, pull cable, switch support bracket and 316 stainless steel mounting hardware.

(1) New polymer manifold block assembly and 6" polymer injection ring assembly.

(1) Replace worn scraper blade at discharge end of machine and ramp blade. Scraper blade fabricated from UHMWPE.

(1)	Replace worn ramp blade. Ramp blade fabricated from UHMWPE.
(68)	New chicane blades in gravity section. New chicane blades fabricated from (UHMWPE).
(1) Lot	Install new poly grid wear bars and belt slide plate (UHMWPE) on the gravity section grid weldments.
(1) Lot	Install new rubber seals on washboxes and gravity section sludge restrainers.
(1)	Feed chute neoprene flap.
(1) Lot	Re-galvanizing of carbon steel main frame, cross-members, tension yoke weldment and all other carbon steel components on the machine.
(1) Lot	Sandblast and clean all stainless steel machine components.
(2) Lot	Site labor and expenses to totally disassemble and reassemble machine at site.
(1) Lot	Inbound and outbound freight charges between jobsite and Ashbrook's factory.

Budget Sell Price: **$ 108,000.00**

Odor Hood

- New odor hood assembly consisting of clear poly sheets (curtain) surrounding the machine. All supports fabricated from 316 stainless steel. Connection(s) shall be provided for connecting to customer air extraction system. (Note: Hood will be designed similar to the photos provided by Sudhan on Aug 1st).

Budget Sell Price: **$ 60,000.00**

August 7, 2013

Carollo Engineers, Inc.
1089 W. Morse Blvd., Suite A
Winter Park, FL 32789

Attention: Sudhan Parajape, P.E.

Reference: Northwest W.W.T.P.
St Petersburg, FL
Budget Proposal
(1) Aquabelt 2.0 meter Type 96
Quote# **35470 Rev 1**

Dear Parajape,

Alfa Laval Ashbrook Simon-Hartley, Inc. ("Ashbrook") is pleased to offer its budget proposal on factory rebuilding of your existing (1) Aquabelt 2.0 meter Type 96 the above referenced location. Ashbrook's experience in designing and building new gravity belt thickeners and repairing/rebuilding gravity belt thickeners, can only enhance our position in offering the services and parts needed to provide additional years of service to your existing unit(s).

Ashbrook started its "Rebuild Program" to provide customers with "today's technology" on earlier model belt filter presses as an alternative to purchasing new replacement equipment. Over the past eighteen years Ashbrook has completed rebuild projects consisting of partial site repairs, complete site machine reconditioning, complete factory machine reconditioning, partial factory machine reconditioning and site machine upgrades.

Equipment on these projects includes Bellmer Winklepresses (German), English Belt Filter Presses, Ashbrook's MKII, Type 85, and Type 94 Klampresses, Aquabelt gravity belt thickeners and other Belt Filter Presses.

All parts supplied by Ashbrook for reconditioning your machine(s), shall meet Ashbrook's latest O.E.M. design standards. All parts will be made to Ashbrook's standard level of quality under ISO9001 certified procedures. All labor shall be performed by qualified Ashbrook trained service technicians who are experienced in the disassembly/reassembly of the Aquabelt.

Ashbrook's scope for rebuilding (1) Aquabelt Type 96 includes using only new O.E.M. (Original Equipment Manufacturer) parts, reconditioned parts, site labor for disassembly/reassembly, and inbound/outbound freight charges.

Typical rebuilds will include roller and bearing assembly parts, hydraulic system parts, drive system parts, belt wash system parts, poly wear items, rubber seals, and possibly retrofit or upgrade items. The particular scope of supply depends on the actual condition of the customer's machine at the time of the rebuild. A firm proposal will be issued at that time to tie down a firm scope of supply and allow our customers to issue a contract or purchase order so that work may proceed on their equipment.

Budget costing is important to allow our customer's to plan for the future needs of their facility. As such we have constructed budgetary pricing that will provide guidance on the financial resources that will need to be in place for the reconditioning of our customer's machines. For this specific project we would like to propose a budget cost of (see pages 3 & 4 for pricing) per machine. **This pricing is for budgetary purposes only and a firm proposal will be provided at the customer's request when their budget is in place**. The scope of supply on your project is as detailed on page 3.

We appreciate the opportunity to be of assistance in the planning for the future of your facility's equipment. We hope that we have addressed your needs in a suitable manner. If you have any questions please feel free to contact your Ashbrook representative, Mark Schlitzkus at 713-906-0505.

Best Regards,

Mark Schlitzkus
Mark Schlitzkus
PPS Environmental Regional Manager

11600 East Hardy • Houston, Texas 77093 • 281-449-0322 • Fax 281-449-1324 • www.ashbrookcorp.com

Scope of supply:

Complete set of new 75mm stub shaft/forged end rollers consisting of the following:

(2) 8" Plain rollers (steering/tensioning)
(1) 10" Drive roller

Drive roller shall be coated with ¼" Buna-N rubber. All other rollers shall be coated with 30 mils of thermoplastic nylon. **The new Ashbrook rollers shall be warranted for a period of three (3) years against failure from defects in material and workmanship under normal use and service when used and maintained per Ashbrook's published operation and maintenance procedures.**

(6) New Ashbrook/Dodge 75mm bearing housing assemblies. New Ashbrook/Dodge bearing assemblies consist of housing, triple labyrinth seal, bearing with steel bronze machined cage, 316 stainless steel hardware and taper lock nut assembly. Housings will be nylon coated for maximum protection against corrosion. Housing shall have a triple labyrinth seal for superior sealing against contaminants. Greasing intervals every 6 months. **Bearing assemblies are warranted for 5 years as long as assemblies are maintained per Ashbrook's published operation and maintenance procedures.**

(2) New pivot plate assemblies. Parts fabricated form A-36 carbon steel then hot dipped galvanized.

(1) New shaft mount AC gearmotor (Eurodrive).

(1) New machine mount hydraulic system consisting of 316 stainless steel hydraulic fittings, 316 stainless steel hoses, 316 stainless steel steering valve/paddle assembly, 316 stainless steel tensioning valve and fiberglass steering/tensioning cylinders.

(1) New press mount hydraulic unit.

(1) New 316 stainless steel gravity section sludge restrainer
.
(1) Lot Replace worn electrical switches (no cake, belt misalignment, high sludge level and belt breakage). Install new 316ss NEMA 4x press mounted junction box.

(1) New emergency trip cord assembly consisting of trip cord switch, galvanized guide cable brackets, pull cable, switch support bracket and 316 stainless steel mounting hardware.

(1) New polymer manifold block assembly and 6" polymer injection ring assembly.

(1) Replace worn scraper blade at discharge end of machine and ramp blade. Scraper blade fabricated from UHMWPE.

(1) Replace worn ramp blade. Ramp blade fabricated from UHMWPE.

(68) New chicane blades in gravity section. New chicane blades fabricated from (UHMWPE).

(1) Lot Install new poly grid wear bars and belt slide plate (UHMWPE) on the gravity section grid weldments.

(1) Lot Install new rubber seals on washboxes and gravity section sludge restrainers.

(1) Feed chute neoprene flap.

(1) Lot Re-galvanizing of carbon steel main frame, cross-members, tension yoke weldment and all other carbon steel components on the machine.

(1) Lot Sandblast and clean all stainless steel machine components.

(2) Lot Site labor and expenses to totally disassemble and reassemble machine at site.

(1) Lot Inbound and outbound freight charges between jobsite and Ashbrook's factory.

Budget Sell Price: **$ 108,000.00**

Panels (Panels are similar to match panels at the Northeast WRF)

- New Main GBT Panel with touchscreen and PLC logic. Budget Price: **$ 65,000.00**
- New Local GBT Panel with touchscreen. Budget Price: **$ 12,500.00**

Odor Hood

- New odor hood assembly consisting of clear poly sheets (curtain) surrounding the machine. All supports fabricated from 316 stainless steel. Connection(s) shall be provided for connecting to customer air extraction system. (Note: Hood will be designed similar to the photos provided by Sudhan on Aug 1st).

Budget Sell Price: **$ 60,000.00**

August 7, 2013

Carollo Engineers, Inc.
1089 W. Morse Blvd., Suite A
Winter Park, FL 32789

Attention: Sudhan Parajape, P.E.

Reference: Southwest W.W.T.P.
St Petersburg, FL
Budget Proposal
(1) Aquabelt 2.0 meter Type 85
Quote# **35468 Rev 1**

Dear Parajape,

Alfa Laval Ashbrook Simon-Hartley, Inc. ("Ashbrook") is pleased to offer its budget proposal on factory rebuilding of your existing (1) Aquabelt 2.0 meter Type 85 the above referenced location. Ashbrook's experience in designing and building new gravity belt thickeners and repairing/rebuilding gravity belt thickeners, can only enhance our position in offering the services and parts needed to provide additional years of service to your existing unit(s).

Ashbrook started its "Rebuild Program" to provide customers with "today's technology" on earlier model belt filter presses as an alternative to purchasing new replacement equipment. Over the past eighteen years Ashbrook has completed rebuild projects consisting of partial site repairs, complete site machine reconditioning, complete factory machine reconditioning, partial factory machine reconditioning and site machine upgrades.

Equipment on these projects includes Bellmer Winklepresses (German), English Belt Filter Presses, Ashbrook's MKII, Type 85, and Type 94 Klampresses, Aquabelt gravity belt thickeners and other Belt Filter Presses.

All parts supplied by Ashbrook for reconditioning your machine(s), shall meet Ashbrook's latest O.E.M. design standards. All parts will be made to Ashbrook's standard level of quality under ISO9001 certified procedures. All labor shall be performed by qualified Ashbrook trained service technicians who are experienced in the disassembly/reassembly of the Aquabelt.

Ashbrook's scope for rebuilding (1) Aquabelt Type 85 includes using only new O.E.M. (Original Equipment Manufacturer) parts, reconditioned parts, site labor for disassembly/reassembly, and inbound/outbound freight charges.

Typical rebuilds will include roller and bearing assembly parts, hydraulic system parts, drive system parts, belt wash system parts, poly wear items, rubber seals, and possibly retrofit or upgrade items. The particular scope of supply depends on the actual condition of the customer's machine at the time of the rebuild. A firm proposal will be issued at that time to tie down a firm scope of supply and allow our customers to issue a contract or purchase order so that work may proceed on their equipment.

Budget costing is important to allow our customer's to plan for the future needs of their facility. As such we have constructed budgetary pricing that will provide guidance on the financial resources that will need to be in place for the reconditioning of our customer's machines. For this specific project we would like to propose a budget cost of (see pages 3 & 4) per machine. **This pricing is for budgetary purposes only and a firm proposal will be provided at the customer's request when their budget is in place**. The scope of supply on your project is as detailed on page 3.

We appreciate the opportunity to be of assistance in the planning for the future of your facility's equipment. We hope that we have addressed your needs in a suitable manner. If you have any questions please feel free to contact your Ashbrook representative, Mark Schlitzkus at 713-906-0505.

Best Regards,

Mark Schlitzkus

Mark Schlitzkus
PPS SE Environmental Regional Manager

<u>Scope of supply:</u>

Complete set of new 2 9/16" stub shaft/forged end rollers consisting of the following:

(1) 4" Guide roller
(2) 8" Plain rollers (steering/tensioning)
(1) 10" Drive roller

Drive roller shall be coated with ¼" Buna-N rubber. All other rollers shall be coated with 30 mils of thermoplastic nylon. **The new Ashbrook rollers shall be warranted for a period of three (3) years against failure from defects in material and workmanship under normal use and service when used and maintained per Ashbrook's published operation and maintenance procedures.**

(8) New Ashbrook/Dodge 2 9/16" bearing housing assemblies. New Ashbrook/Dodge bearing assemblies consist of housing, triple labyrinth seal, bearing with steel bronze machined cage, 316 stainless steel hardware and taper lock nut assembly. Housings will be nylon coated for maximum protection against corrosion. Housing shall have a triple labyrinth seal for superior sealing against contaminants. Greasing intervals every 6 months. **Bearing assemblies are warranted for 5 years as long as assemblies are maintained per Ashbrook's published operation and maintenance procedures.**

(2) New pivot plate assemblies. Parts fabricated form A-36 carbon steel then hot dipped galvanized.

(1) New washbox assemblies with adjustable panels, assembly shall consist of new washbox fabricated from 316 stainless steel, carbon steel galvanized mounting brackets, poly support blocks and 316 stainless steel hardware.

(1) New shaft mount AC gearmotor (Eurodrive).

(1) New machine mount hydraulic system consisting of 316 stainless steel hydraulic fittings, 316 stainless steel hoses, 316 stainless steel steering valve/paddle assembly, 316 stainless steel tensioning valve and fiberglass steering/tensioning cylinders.

(1) New press mount hydraulic unit.

(1) New 316 stainless steel gravity section sludge restrainer
.

(1) Lot Replace worn electrical switches (no cake, belt misalignment, high sludge level and belt breakage). Install new 316ss NEMA 4x press mounted junction box.

(1) New emergency trip cord assembly consisting of trip cord switch, galvanized guide cable brackets, pull cable, switch support bracket and 316 stainless steel mounting hardware.

(1) Lot New 316 stainless steel drain pans and SCH40 PVC drainage piping.

11600 East Hardy • Houston, Texas 77093 • 281-449-0322 • Fax 281-449-1324 • www.ashbrookcorp.com

(1)	New polymer manifold block assembly and 6” polymer injection ring assembly.
(1)	Replace worn scraper blade at discharge end of machine and ramp blade. Scraper blade fabricated from UHMWPE.
(1)	Replace worn ramp blade. Ramp blade fabricated from UHMWPE.
(68)	New chicane blades in gravity section. New chicane blades fabricated from (UHMWPE).
(1) Lot	Install new poly grid wear bars and belt slide plate (UHMWPE) on the gravity section grid weldments.
(1) Lot	Install new rubber seals on washboxes and gravity section sludge restrainers.
(1)	Feed chute neoprene flap.
(1) Lot	Re-galvanizing of carbon steel main frame, cross-members, tension yoke weldment and all other carbon steel components on the machine.
(1) Lot	Sandblast and clean all stainless steel machine components. Feed tank shall be clean in place.
(1) Lot	Site labor and expenses to totally disassemble and reassemble machine at site.
(1) Lot	Inbound and outbound freight charges between jobsite and Ashbrook’s factory.

Budget Sell Price: **$ 115,000.00**

Panels (Panels are similar to match panels at the Northeast WRF)

- New Main GBT Panel with touchscreen and PLC logic. Budget Price: **$ 65,000.00**
- New Local GBT Panel with touchscreen. Budget Price: **$ 12,500.00**

Odor Hood

- New odor hood assembly consisting of clear poly sheets (curtain) surrounding the machine. All supports fabricated from 316 stainless steel. Connection(s) shall be provided for connecting to customer air extraction system. (Note: Hood will be designed similar to the photos provided by Sudhan on Aug 1st).

Budget Sell Price: **$ 60,000.00**

Sudhan Paranjape

From:	Brian Schuette [bks@mosskelley.com]
Sent:	Monday, August 05, 2013 2:14 PM
To:	Sudhan Paranjape
Subject:	RE: St. Pete - Polymer System for Thickening
Attachments:	L13-0195 Carollo St. Pete SW Scope of Supply.pdf; M2400-P13AA CSI UGSI.DOC

Sudhan,
UGSI Chem Feed was quite responsive in getting back to us with the Polyblend Polymer Feed system to match in kind the unit St. Pete already has at the SW WRF. Attached please find a budget proposal and specification.

Budget price for the two (2) Polyblend systems as proposed is $39,000.

Let us know if you require anything additional.

Regards,
Brian Schuette
MOSS KELLEY, INC.
407-805-0063 Office
407-808-4264 Mobile
725 Primera Blvd. #155
Lake Mary, FL 32746
www.mosskelley.com

From: Sudhan Paranjape [mailto:SParanjape@carollo.com]
Sent: Friday, July 26, 2013 11:11 AM
To: Brian Schuette
Subject: St. Pete - Polymer System for Thickening

Brian

See attached photos of the existing Polyblend Series M system (liquid emulsion polymer system) that they are using at the Southwest WRF. This unit serves one 2-meter GBT.

I am requesting a budget proposal for two exactly similar systems for two additional 2-METER GBTs that they will be relocating from their other plants. For now I am assuming that each GBT can handle 500 gpm of a mixture of Primary and WAS.

Let me know if this information will suffice for you to put together a proposal. I will also like to request CAD drawings for the unit.

Thanks

Sudhan Paranjape, P.E.
Carollo Engineers, Inc.
1089 W. Morse Blvd., Suite A
Winter Park, FL. 32789
P: 407-478-4642
F: 407-478-4643
C:407-212-8840
www.carollo.com

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Please consider the environment before printing this email.

UGSI ChemFeed Inc.
1901 West Garden Rd
Vineland, New Jersey 08360

BUDGET PROPOSAL
POLYMER FEED SYSTEM

Customer:	Bidding Contractors
Project Name:	St. Pete SW WWTP
Project Location:	,
Engineer:	
Proposal No.:	L13-0195
Proposal Date:	5-Aug-2013
Applications Engineer:	Michael Snuffin
Sales Manager:	Carlos Assuncao
Manufacturer's Rep:	Moss Kelley - Lake Mary, FL
Contact:	Brian Schuette
Phone:	407.805.0063

BID INFORMATION

Bid Date:
Bid Time:
Spec Section:
Addendum:
Addendum Date:

SCOPE OF SUPPLY

Qty	Description
2	UGSI ChemFeed PolyBlend M2400-P13AA Polymer Activation/Feed
	System which includes:
	* Motor-Driven high energy mixer with 1 HP washdown motor and brass impeller
	and discharge pressure gauge
	* Progressive cavity type polymer pump, 13GPH, 100psi, 316ss construction, viton
	stator, mechanical seal, integral inverter duty gearmotor
	* Dilution water solenoid valve for dilution water on/off control
	* Dilution water flow sensor
	* 304 stainless steel frame / wall mounted.
	* Schedule 80 PVC plumbing and valves
	* Nema 4x stainless steel junction box
2	Wall Mount Control Panel in Nema 4x fiberglass enclosure
	includes three selector switches, three pilot light indicators and polymer pump
	speed controls thru the door.
	Inverter drive speed controls for polymer feed pump
	Water: 240 - 2400 GPH
	Polymer: 1.3 - 13 GPH
	Voltage: 120/60/1
2	Water Pressure Reducing Valve (shipped loose)
	1" brass body, 0 - 100 psi,
	Note: Similar to Serial # H000801 and pictures supplied.

SCOPE OF ENGINEERING

The following documentation shall be provided by Seller:

- Shop Drawing Submittal
  - Detailed Scope of Supply
  - Comments & Clarifications
  - Project Schedule
  - Technical Information / Equipment / Drawings
    Catalog Cut sheets
    Dimensional Drawings / General Assembly Drawings
    Functional Schematics / Piping and Instrumentation Diagrams (when applicable)
    Electrical Schematics (when applicable)
    Control Panel Layouts, Ladder Logic Diagrams (when applicable)
  - Receiving, Handling and Storage
  - Warranty Statement
- Operation and Maintenance Manuals
  - Ordering Information
  - Warranty Statement
  - Introduction
  - Safety Precautions
  - Preventive Maintenance General Information
  - Maintenance Record Card
  - Regional Offices
  - Technical Data
  - Installation
  - Operation
  - Service
  - Illustrations
  - Preventive Maintenance Kits and Spare Parts List
  - Additional Literature

NOTE - In an effort to be environmentally responsible, one (1) hard copy of the submittal and O+M will be supplied and up to eight (8) copies will be supplied on CD-ROM. Additional hardcopies of the submittal and O+M can be supplied at a cost of $50.00 each.

CLARIFICATIONS & EXCEPTIONS

Section	Part	Description

ITEMS NOT INCLUDED IN SCOPE

- Mechanical and electrical installation labor
- Civil work including supply of anchor bolts
- Interconnecting piping
- Interconnecting wiring (unless detailed above)
- Valves, fittings, appurtenances not specifically listed above
- Installation supervision
- All taxes, fees, lien waivers, bonds and licenses
- Room ventilation, air conditioning, or lighting
- Videotaping (unless a videotape agreement is signed)

COMMERCIAL OFFERING

Payment Terms:	100% Due on Shipment of Equipment All payments are due 30 days from date of invoice and are not subject to retention.
FOB:	Factory
Freight to Job Site:	Included
Submittal:	6-8 weeks after receipt and approval of purchase order
Shipment:	8 weeks after receipt of full information and approved drawings (when required)
Startup:	1 day included (to be performed by Moss Kelly)
Training:	Not Included
Extended Warranty:	Not Included
Price:	To Follow

Other Conditions:

1) UGSI Chemfeed, Inc. (Seller) proposes to furnish materials, and/or equipment for the product identified at the beginning of this proposal. Any items not shown above as detailed under (i) 'SCOPE OF SUPPLY', (ii) 'SCOPE OF ENGINEERING', or (iii) other attachments to this proposal, are EXCLUDED. In addition:
   a. Seller's price will be held valid for a period of 90 days from the date of this proposal ("Proposal Date"). Seller shall have the right to reprice this proposal if the Buyer's order is received more than 90 days beyond the Proposal Date.
   b. Prices are in US Dollars.
   c. Local or state taxes are not included in this proposal.
2) This proposal by Seller is contingent upon: (i) Seller's written acceptance of the signed proposal, a purchase order, or other document issued by the Buyer in response to this proposal; and (ii) Buyer's assent to the terms and conditions contained in this proposal, such terms to take precedence in the event of conflict with any other terms or documents incorporated into the contract arising out of this proposal unless otherwise agreed in a writing, signed by "Seller" (iii) satisfactory completion of an anti-corruption due diligence review, if applicable.
3) All of the information supplied by Seller in connection with this proposal (including drawings, designs and specifications) (the "Information") is confidential and/or proprietary and has been prepared for Buyer's use solely in evaluating the purchase of the equipment and/or services described herein. Transmission of all or any part of the Information to others, or use by Buyer for any purpose other than such evaluation, is expressly prohibited without Seller's prior written consent.
4) Please return a signed copy of this proposal or address and send your purchase order to:
   UGSI Chemfeed, Inc.
   1901 W Garden Rd
   Vineland, NJ 08360
   Attn: Bruce Figueroa
   Phone: 856.896.2160
   Fax: 856.457.5920
   E-mail: bfigueroa@wtchemfeed.com

Thank you for your interest in UGSI Chemfeed, Inc. We are committed to meeting your expectations.

PROPOSAL ACCEPTANCE

An authorized signature indicates Buyer's acceptance of this proposal, including without limitation Seller's Standard Terms and Conditions of Sale below.

____
Company Name

____
Buyer's Name (printed)

____
Buyer's Authorized Signature

____
Date

UGSI ChemFeed Inc.
1901 West Garden Rd
Vineland, New Jersey 08360

Standard Terms & Conditions of Sale

August 1, 2012 (Rev.1)

1. Applicable Terms. These terms govern Seller's sale, and Buyer's purchase, of the products and/or services contemplated by Seller's proposal or order acknowledgment (collectively, the "Products"). Whether these terms are included in an offer or an acceptance by Seller, such offer or acceptance is conditioned on Buyer's assent to these terms. Any additional, different or conflicting terms contained in Buyer's request for proposal, specifications, purchase order or any other written or oral communication from Buyer shall not be binding in any way on Seller. Seller's failure to object to any such additional, different or conflicting terms shall not operate as a waiver of these terms.

2. Pricing & Payment. The prices shall be: (a.) as stated in Seller's proposal or order acknowledgement, or if none are stated, (b.) Seller's standard prices in effect at the time of release for shipment. Discounts, if any, are as specified on the latest discount sheets issued from time to time by Seller. Cash discounts are not applicable to notes or trade acceptances, to prepaid transportation charges when added to Seller's invoice or to discountable items if there are undisputed past due items on the account. Cash discounts shall only be allowed on that portion of the invoice paid within the normal discount period. Buyer grants Seller a security interest in the Products to secure Buyer's payment obligations hereunder.

(a) Payment - Unless otherwise stated, all payments shall be net 30 days from invoice date payable in United States Dollars.

(b) Credit Approval - All orders are subject to credit approval by Seller. If Seller, in its discretion, is or becomes dissatisfied with Buyer's financial status, Seller may, without advance notice, terminate this order without liability; or condition such order on such modification to the terms of payment as Seller, in its discretion, deems appropriate. In such case, Seller may also, in its discretion, withhold further manufacture or shipment; require immediate cash payments for past and future shipments; or require other security satisfactory to Seller before further manufacture or shipment is made; and may, if shipment has been made, recover the Products from the carrier, pending receipt of such cash or other security.

(c) Installment Shipment - If these terms require or authorize delivery of Products in separate lots to be separately accepted by Buyer, Buyer may only refuse such portion of a lot that fails to comply with the requirements of the Agreement. Buyer may not refuse to receive any lot or portion thereof for failure of any other lot or portion thereof to be delivered or to comply with the Agreement, unless such right of refusal is expressly provided for on the face hereof. Buyer shall pay for each lot in accordance with the terms hereof. Payment shall be made for the Products without regard to whether Buyer has made or may make any inspection of the Products. Products held for Buyer are at Buyer's sole risk and expense.

(d) Taxes, Shipping, Packing, Handling - Except to the extent expressly stated in these terms, prices do not include any freight, storage, insurance, taxes, excises, fees, duties or other government charges related to the Product or the transaction contemplated hereby, and Buyer shall pay such amounts or reimburse Seller for any such amounts Seller pays. If Buyer claims a tax or other exemption or direct payment permit, it shall provide Seller with a valid exemption certificate or permit and indemnify, defend and hold Seller harmless from any taxes, costs and penalties arising out of same. Prices include the costs of Seller's standard domestic packing only. Any deviation from this standard packing (domestic or export), including without limitation U.S. Government sealed packing, shall result in extra charges. Any and all increases, changes, adjustments or surcharges (including, without limitation, fuel surcharges) which may be in connection with the freight charges, rates or classification included as part of these terms, shall be for the Buyer's account. Orders of less than $400 are subject to a $25 handling fee.

(e) Finance Charge - Buyer agrees to pay FINANCE CHARGES on the unpaid balance of all overdue invoices from the date each invoice is due until paid in full at an ANNUAL PERCENTAGE RATE of EIGHTEEN PERCENT (18%), or the highest lawful rate, if lower.

(f) Disputed Invoice - In the event Buyer disputes all or any portion of an invoice, it shall notify Seller in writing of the amount in dispute and the reason for its disagreement within 21 days of receipt of the invoice. The undisputed portion shall be paid when due, and FINANCE CHARGE shall accrue on the unpaid portion, from the date due until the date of payment, to the extent that such amounts are finally determined to be payable to Seller.

(g) Collection – Upon Seller's notice to Buyer of Buyer's default of these terms, Seller may, in addition to any other rights or remedies at contract or law, declare the entire balance of Buyer's account immediately due and payable or foreclose any security interest in Products delivered. If any unpaid balance is referred for collection, Buyer agrees to pay Seller, to the extent permitted by law, all collection costs incurred by Seller, including without limitation attorney fees, and court costs and expenses, in addition to all damages otherwise available, whether or not litigation is commenced or prosecuted to final judgment and any FINANCE CHARGES accrued on any unpaid balance owed by Buyer.

3. Delivery; Title; Risk of Loss. Product shall be delivered F.O.B. Seller's point of shipment. Seller may make partial shipments. Shipping dates are approximate only and Seller shall not be liable for any loss or expense (consequential or otherwise) incurred by Buyer or Buyer's customers if Seller fails to meet the specified delivery schedule.

4. Deferment and Cancellation. Buyer shall have no deferment rights and Buyer shall be liable for cancellation charges, which shall include without limitation a) payment of the full product price for any finished Product or works in progress; b) payment for raw materials ordered pursuant to a firm purchase order; and c) such other direct costs incurred by Seller as a result of such cancellation.

5. Force Majeure. If Seller suffers delay in performance due to any cause beyond its reasonable control, including without limitation acts of God, strikes, labor shortage or disturbance, fire, accident, war or civil disturbance, delays of carriers, failure of normal sources of supply, or acts of government, the time of performance shall be extended a period of time equal to the period of the delay and its consequences.

6. Buyer's Requirements. Timely performance by Seller is contingent upon Buyer's supplying to Seller all required technical information and data, including without limitation drawing approvals, if applicable, and all required commercial documentation.

7. Limited Warranty. (a.) Limited Product Warranty Statements. For each Product purchased from Seller or an authorized reSeller, Seller makes the following limited warranties: (i) the Product is free from defects in material and workmanship, (ii) the Product materially conforms to Seller's specifications that are attached to, or expressly incorporated by reference into, these terms, and (iii) at the time of delivery, Seller has title to the Product free and clear of liens and encumbrances (collectively, the "Limited Warranties"). Warranties with respect to software which may be furnished by Seller as part of the Product, if any, are expressly set forth elsewhere in these terms. The Limited Warranties set forth herein do not apply to any software furnished by Seller.

(b.) Conditions to the Limited Warranties. The Limited Warranties are conditioned on (i) the Product being stored, installed, operated and maintained in accordance with Seller's instructions, (ii) no repairs, modifications or alterations being made to the Product other than by Seller or its authorized representatives, (iii) the Product being used in compliance with any conditions or parameters set forth in specifications that are attached to, or expressly incorporated by reference into, these terms, (iv) use of the Product being discontinued after the Buyer or user has, or should have had, knowledge of any defect in the Product, (v) Buyer providing prompt written notice of any warranty claims within the warranty period described below, (vi) at Seller's discretion, Buyer either removing and shipping the Product or non-conforming part thereof to Seller, at Buyer's expense, or Buyer granting Seller access to the Products at all reasonable times and locations to assess the warranty claims, and (vii) Buyer not being in default of any payment obligation to Seller.

(c.) Exclusions from Limited Warranty Coverage. The Limited Warranties specifically exclude any equipment comprising part of the Product that is not manufactured by Seller or not bearing its nameplate. To the extent permitted, Seller herby assigns any warranties made to Seller for such equipment. Seller shall have no liability to Buyer under any legal theory for such equipment or any related assignment of warranties. Additionally, any Product that is described as being experimental, developmental, prototype, or pilot is specifically excluded from the Limited Warranties and is provided to Buyer "as is" with no warranties of any kind. Also excluded from the Limited Warranties are normal wear and tear items including any expendable items that comprise part of the Product, such as fuses, light bulbs and lamps.

(d.) Limited Warranty Period. Buyer shall have 12 months from initial operation of the Product or 18 months from shipment, whichever occurs first, to provide Seller with prompt, written notice of any claims of breach of the Limited Warranties. Continued use or possession of the Product after expiration of the warranty period shall be conclusive evidence that the Limited Warranties have been fulfilled to the full satisfaction of Buyer and user, unless Buyer has previously provided Seller with notice of a breach of the Limited Warranties.

(e.) Remedies for Breach of Limited Warranty. Buyer's sole and exclusive remedies for any breach of the Limited Warranties are limited to Seller's choice of repair or replacement of the Product, or non-conforming parts thereof, or refund of all or part of the purchase price for the subject Product or part. The warranty on repaired or replaced Product or parts is limited to the remainder of the original warranty period. Buyer shall be responsible for any labor required to gain access to the Product so that Seller can assess the available remedies and (ii) Buyer shall be responsible for all costs of installation of repaired or replaced Products or parts. All Products or parts replaced under this Limited Warranty will become the property of Seller.

(f.) Transferability. The Limited Warranties shall be transferable during the warranty period to the initial end-user of the Product.

THE LIMITED WARRANTIES SET FORTH IN THIS SECTION ARE Seller's SOLE AND EXCLUSIVE WARRANTIES AND ARE SUBJECT TO THE LIMITS OF LIABILITY SET FORTH IN SECTION 8 BELOW. Seller MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, OR ANY WARRANTIES THAT MIGHT ARISE FROM COURSE OF DEALING

8. LIMITATION OF LIABILITY. NEITHER SELLER, NOR ITS SUPPLIERS, SHALL BE LIABLE, WHETHER IN CONTRACT, WARRANTY, FAILURE OF A REMEDY TO ACHIEVE ITS INTENDED OR ESSENTIAL PURPOSES, TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY, INDEMNITY OR ANY OTHER LEGAL THEORY, FOR LOSS OF USE, REVENUE, SAVINGS OR PROFIT, OR FOR COSTS OF CAPITAL OR OF SUBSTITUTE USE OR PERFORMANCE, OR FOR INDIRECT, SPECIAL, LIQUIDATED, PUNITIVE, EXEMPLARY, COLLATERAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR FOR ANY OTHER LOSS OR COST OF A SIMILAR TYPE, OR FOR CLAIMS BY BUYER FOR DAMAGES OF BUYER'S CUSTOMERS. SELLER'S MAXIMUM LIABILITY UNDER ANY LEGAL THEORY SHALL BE THE ACTUAL PURCHASE PRICE RECEIVED BY SELLER FOR THE PRODUCT AT ISSUE OR ONE MILLION DOLLARS, WHICHEVER IS LESS. BUYER AGREES THAT THE EXCLUSIONS AND LIMITATIONS SET FORTH IN THIS ARTICLE ARE SEPARATE AND INDEPENDENT FROM ANY REMEDIES WHICH BUYER MAY HAVE HEREUNDER AND SHALL BE GIVEN FULL FORCE AND EFFECT WHETHER OR NOT ANY OR ALL SUCH REMEDIES SHALL BE DEEMED TO HAVE FAILED OF THEIR ESSENTIAL PURPOSE. THESE LIMITATIONS OF LIABILITY ARE EFFECTIVE EVEN IF BUYER AHS ADVISED SELLER OF THE POSSIBILITY OF SUCH DAMAGES.

9. Patent and Copyright Infringement. Seller will, at its own expense, defend or at its option settle any suit or proceeding brought against Buyer in so far as it is based on an allegation that any Product (including parts thereof), or use thereof for its intended purpose, constitutes an infringement of any United States patent or copyright, if Seller is promptly provided notice and given authority, information, and assistance in a timely manner for the defense of said suit or proceeding. Seller will pay the damages and costs awarded in any suit or proceeding so defended. Seller will not be responsible for any settlement of such suit or proceeding made without its prior written consent. In case the Product, or any part thereof, as a result of any suit or proceeding so defended is held to constitute infringement or its use by Buyer is enjoined, Seller will, at its option and its own expense, either: (a) procure for Buyer the right to continue using said Product; (b) replace it with substantially equivalent non-infringing Product; or (c) modify the Product so it becomes non-infringing.

Seller will have no duty or obligation to Buyer under this Section 9 to the extent that the Product is (a) supplied according to Buyer's design or instructions wherein compliance therewith has caused Seller to deviate from its normal course of performance, (b) modified by Buyer or its contractors after delivery, (c) combined with devices, methods, systems or processes not furnished hereunder and by reason of said design, instruction, modification, or combination a suit is brought against Buyer. In addition, if by reason of such design, instruction, modification or combination, a suit or proceeding is brought against Seller, Buyer shall protect Seller in the same manner and to the same extent that Seller has agreed to protect Buyer under the provisions of the Section above.

10. Compliance with Laws. Buyer agrees to comply with all applicable laws and regulations relating to the purchase, resale, exportation, transfer, assignment, disposal or use of the Products.

11. Changes in Work. Seller shall not implement any changes in the scope of work unless Buyer and Seller agree in writing to the details of the change and any resulting price, schedule or other contractual modifications. Any change to any law, rule, regulation, order, code, standard or requirement which requires any change hereunder shall entitle Seller to an equitable adjustment in the prices and any time of performance.

12. Non-waiver of Default. Each shipment made hereunder shall be considered a separate transaction. In the event of any default by Buyer, Seller may decline to make further shipments. If Seller elects to continue to make shipments, Seller' actions shall not constitute a waiver of any default by Buyer or in any way affect Seller' legal remedies for any such default. Any waiver by Seller of the right to require strict compliance with the provisions of the Agreement shall be in writing and any failure of Seller to require such strict compliance shall not be deemed a waiver of Seller' right to insist upon strict compliance thereafter.

13. Final Written Agreement; Modification of Terms. These terms in Seller's proposal, together with any quotation, purchase order or acknowledgement issued or signed by Seller, comprise the complete and exclusive agreement between the parties (the "Agreement") and supersede any terms contained in Buyer's documents, unless separately signed by Seller. The Agreement may only be modified by a written instrument signed by authorized representatives of both parties.

14. Assignment. Neither party may assign the Agreement, in whole or in part, nor any rights or obligations thereunder without the prior written consent of the other; provided however that Seller may assign its rights and obligations under the Agreement to its affiliates and Seller may grant a security interest in the Agreement and/or assign proceeds of the Agreement without Buyer's consent.

15. Applicable Law and Jurisdiction. These terms are governed and construed in accordance with the laws of the State of Delaware, without regard to its conflict of laws principles. The application of the United Nations Convention on Contracts for the International Sale of Goods is excluded. BUYER WAIVES ALL RIGHTS TO A JURY TRIAL IN ANY ACTION OR PROCEEDING RELATED IN ANY WAY TO THESE TERMS.

16. Severability. If any provision of these terms is held to be invalid, illegal or unenforceable, the validity, legality and enforceability of the remaining provisions will not in any way be affected or impaired, and such provision will be deemed to be restated to reflect the original intentions of the parties as nearly as possible in accordance with applicable law.

17. Export Compliance. Buyer acknowledges that Seller is required to comply with applicable export laws and regulations relating to the sale, exportation, transfer, assignment, disposal, and usage of the Products provided under the Agreement, including without limitation any export license requirements. Buyer agrees that such Products shall not at any time directly or indirectly be used, exported, sold, transferred, assigned or otherwise disposed of in a manner which will result in non-compliance with such applicable export laws and regulations. It shall be a condition of the continuing performance by Seller of its obligations hereunder that compliance with such export laws and regulations be maintained at all times. BUYER AGREES TO INDEMNIFY AND HOLD SELLER HARMLESS FROM ANY AND ALL COSTS, LIABILITIES, PENALTIES, SANCTIONS AND FINES RELATED TO NON-COMPLIANCE WITH APPLICABLE EXPORT LAWS AND REGULATIONS.

Appendix C: Dewatering Project Preliminary Engineering Report

SWWRF Biosolids Dewatering Engineering Evaluation
(Project No. 14055-11)

CONCEPTUAL DEWATERING FACILITY LAYOUT AND PRELIMINARY OPINION OF CONSTRUCTION COST
JUNE 30, 2014

Background

Through the overall Biosolids to Energy Project, the City plans to consolidate its citywide sludge processing at the Southwest Water Reclamation Facility (SWWRF). The Biosolids to Energy Project includes several interrelated components, one of which is the new dewatering facility.

A document entitled “Southwest Water Reclamation Facility Biosolids Dewatering Facility Technology Assessment” was prepared by Hazen and Sawyer (August 2013). It is part of the documentation used by the City as the basis for initiating the design of the new dewatering facility using centrifuges. Work by Brown and Caldwell (B&C) on other components of the Biosolids to Energy Project to be located at the SWWRF has progressed to about 60% design completion.

As part of an effort to verify the overall cost effectiveness of the Biosolids to Energy Project, the City wanted to confirm the decision to proceed with centrifuge dewatering technology and consider approaches for reducing the construction cost of the dewatering system.

Technology Review

The “Technology Review / Update” dated March 20, 2014, and included in the Attachments to this document, was presented to City staff along with several follow up group conference calls and internal City meetings. This effort concluded to not use centrifuge dewatering for this project due to the potential risk of pathogen reactivation and regrowth when centrifuge dewatering follows temperature phased anaerobic digestion (TPAD) processes. Furthermore, after review of previous technology comparisons for this project and contacts with several existing screw press facilities, proceeding with the use of screw presses was recommended and accepted by the City.

Research reports and other papers identified in the March 20, 2014 document are also included in the Attachments to this document.

Basic Design Criteria

Based upon previous project documentation by B&C, the dewatering facility will be designed to process TPAD digested sludge under the following conditions.

- Total feed sludge (maximum day conditions)
  - 159 gpm
  - 2,821 lbs/hr
  - 3.6 % solids
- Facility operation - 24 / 7 / 365

The following criteria were used for the purpose of selecting screw presses, related equipment and generally laying out the facility.

- Overall design objective is to select equipment and prepare a conceptual layout that provides the smallest footprint, lowest building height, and lowest equipment cost; without compromising functionality and durability
- Equipment sizing/selection is different for the two suppliers currently being considered

- FKC - 3 duty presses at 53 gpm each
- Huber - 4 duty presses at 40 gpm each

- An on-site back up drive motor will be provided in lieu of a dedicated back up press
- Each press will have its own dedicated positive displacement feed pump (designed by B&C; located at the digester complex)
- Each press will have its own dedicated polymer feed system
  - anticipated to be a liquid emulsion storage tote with solution blending pump panel
  - sized for 13 gph each; anticipating a dosage of up to 35 lbs per dry ton
- Each press will have its own dedicated cake pump
  - progressive cavity style mounted beneath the screw press
  - capacity up to 16 gpm
  - overhead piping (glass-lined ductile iron) to convey cake to the truck loading area
- Odor scrubber
  - provided only for the air ventilated from the truck loading area
  - assumed for the purposes of this conceptual layout and cost estimate to be a carbon scrubber system
  - sized at 13,000 scfm (12 air changes)
  - located east of the new dewatering structure; on the east side of the existing road; next to the aeration basins

Facility Layout/Features

Based upon using screw presses, equipment was selected and conceptually laid out to establish footprint, arrangement, and facility size/materials of construction.

- Equipment area has open sides with a roof over the equipment
  - floor elevation is set at EL = 110.25
  - screw presses, polymer feed systems, flocculation systems, and cake pumps
  - overhead bridge crane for convenient press servicing and other lifting purposes
  - loading dock area for equipment maintenance and polymer delivery
- Truck loading area is totally enclosed
  - floor elevation is set at grade – approximately EL = 106.00
  - 2 truck bays with overhead doors on east side only
  - arranged for trucks to back in and pull out; no drive-through
  - enclosed air space ventilated at 12 air changes/hr and sent to odor scrubber
  - equipped with truck scales
  - includes an observation platform located between the trucks with control panel to manually control cake discharge outlets
- Electrical room
  - floor elevation is set at EL = 110.25
  - contains all motor control and process control equipment
  - air conditioned space
- No provisions for FOG receiving/storage area
- Construction
  - concrete slab
  - single metal building over both the truck loading area and the open equipment area
  - truck area enclosed by metal siding
  - electrical room CMU block all 4 sides with hollow core slab for roof
- See attached preliminary layouts in Figures 1 and 2.

Construction Cost Opinion

Based upon the attached drawings, the equipment, and the characteristics described herein, the preliminary opinion of probable construction cost for the SWWRF dewatering facility is $8 million; which includes approximately 20% for contractor's overhead and profit and a contingency of approximately 30%.

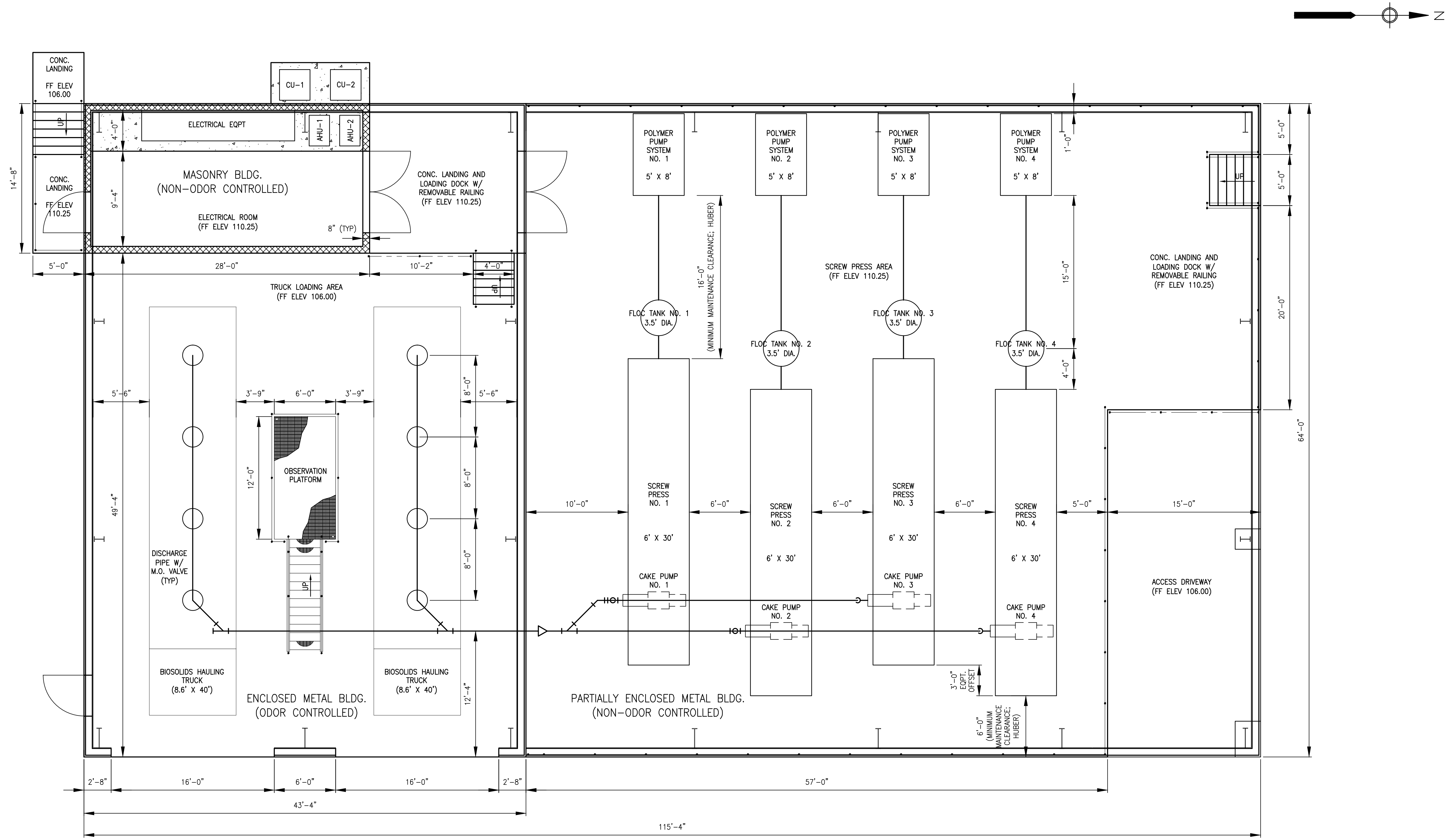
A breakdown of this estimate is provided below.

Description		Amount
Site/Civil	Site work, yard piping, appurtenances	$600,000
Mechanical	Process equipment, odor control, truck scales, HVAC	$3,400,000
Structural	Foundation, slab, metal building, handrail, bridge crane	$750,000
Electrical	Wire, conduit, lighting, lightening protection	$260,000
Instrumentation	Controls, SCADA	$325,000
Subtotal		**$5,335,000**
Overhead, Profit, General Conditions (approx. 20%)		$1,065,000
Contingency (approx. 30%)		$1,600,000
TOTAL		**$8,000,000**

Plan/Vision Going Forward

Following describes some of the thoughts, issues, and concepts that might influence the final design and ultimate construction estimate.

- Limitations of this report
  - This report recommended a complete change in dewatering technology from centrifuges to screw presses. Up until now, the thought processes of the entire team has been focused on the use of centrifuges. Although many aspects of the design approach are and will be similar, the unique considerations of screw press design have not yet been fully revealed.
  - Although actual equipment selections were made and there is a basis for the conceptual layout presented herein, the facility has not yet been designed and there are still design/coordination issues to be worked out.
- Considerations related to press manufacturers
  - During final design, it is possible that other screw press manufacturers will be identified that are worth considering – such as Schwing Bioset.
  - Likewise, it is possible that a manufacturer may be eliminated from consideration – such as Huber - because Huber requires more units, a separate flocculation tank, and the most floor space for disassembly and repair.
- Construction Manager at Risk (CMAR)
  - The insertion of the CMAR early into the design might influence certain aspects of the facility, such as equipment selection/configuration and materials of construction.
  - The CMAR may also be able to do some initial pricing to determine exactly which screw press the design should be based on. This has the advantage of avoiding an overly flexible/adaptable design that accommodates multiple manufacturers not knowing which one will be selected until the project is bid/awarded.
- Odor control
  - Further investigation into odor control might change the selected process.



PLAN

SCALE: 1"=10'-0"

AECOM AECOM Technical Services, Inc. 4010 Boy Scout Boulevard, Suite 300 Tampa, Florida 33607 T 813.630.2500 F 813.621.2300 FL Engineering Business No. EB-8115 www.aecom.com TIM CURRAN, PE ENGINEER 34809 FL LICENSE NO.	DESIGNED BY: LSB DATE: X-XX DRAWN BY: LSB DATE: X-XX CHECKED BY: TMC DATE: X-XX FIELD BOOK No. XXX PAGE XX THRU XX BM No. EL. 000.00 LOCATION: XXX XXX	REVISIONS / BY / DATE	**DEWATERING BLDG. PRELIMINARY LAYOUT** PLAN	ENGINEERING DEPARTMENT CITY of ST. PETERSBURG APPROVED BY:	**SWWRF BIOSOLIDS DEWATERING ENGINEERING EVALUATION** Project No. 14055-111

DATE:	MAY 2014
SCALE:	AS NOTED
SHEET No.	X-XXX
DRAWING No.	FIGURE 1

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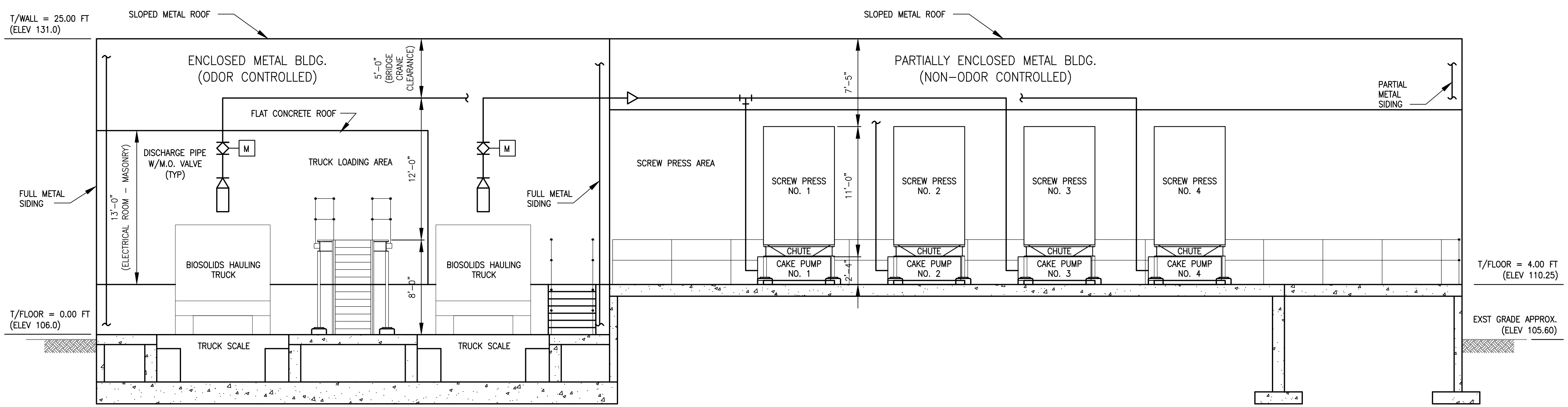

SECTION

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DEWATERING BLDG. PRELIMINARY LAYOUT

SECTION

ENGINEERING DEPARTMENT
CITY of ST. PETERSBURG

APPROVED BY:

SWWRF BIOSOLIDS DEWATERING ENGINEERING EVALUATION

Project No. 14055-111

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ATTACHMENTS

SWWRF Biosolids Dewatering Engineering Evaluation (Project No. 14055-11)
<u>Technology Review/Update</u>
March 20, 2014

Based upon the following, AECOM recommends that the Centrifuge be dropped from consideration as a dewatering option

1. Several research projects published by the Water Environment Research Federation WERF in 2011 indicate that sudden increase and regrowth of pathogens are prevalent with TPAD followed by centrifuge dewatering.
    a. Water Environment Research (Volume 83, Number 9)
        i. ***Sudden increase*** *appears to be more prevalent in* ***thermophilic*** *processes that are followed by* ***centrifuge*** *dewatering ...*
        ii. ***Sudden increase*** *does not appear to be a significant concern for mesophilic processes with centrifuges ...*
        iii. ***Regrowth*** *has been observed for both* ***thermophilic and mesophilic*** *digestion processes and is prevalent when these processes are coupled with high-solids* ***centrifuge*** *dewatering.*
    b. WERF ROSI Project (WEFTEC 2011):
        i. ***Regrowth, odors and sudden increase (ROSI)*** *are issues for some utilities that employ anaerobic digestion and different dewatering technologies. These issues are more prevalent with* ***centrifuge*** *dewatering.*
    c. WERF Anaerobic Digested biosolids odor generation and pathogen indicator regrowth after dewatering (ELSVIER 2011):
        i. *The occurrence of induction is likely the microbial response to substrate release and environmental changes, such as oxygen, resulting from* ***centrifuge shearing****.*
        ii. *The observed* ***regrowth*** *seems to be associated with* ***centrifuge*** *dewatering. High solids (2200 rpm) and low solids (1100 rpm) centrifuge dewatering present the same regrowth profiles in this study.*

2. Information presented in the H&S Technical Memorandum (August 2013) actually corroborates these concerns as follows:
    a. Section 2.2 – Potential for Pathogen Reactivation and Regrowth. *The potential for this phenomenon (****pathogen reactivation and regrowth****) appears to be highest when municipal biosolids are processed with* ***thermophilic*** *anaerobic digestion followed by* ***centrifuge*** *dewatering.*
    b. Section 3.0 - Survey of Full-Scale Facilities. This evaluation is focused mostly on operations and production of cake solids with little emphasis to evaluating the pathogen concern. None of the facilities presented utilize TPAD followed by centrifuge dewatering.
    c. Section 4.5 - Regulatory and other site specific considerations. Based on the information presented in the literature review, **pathogen reactivation and regrowth** is a potential **disadvantage for centrifuge dewatering**.

3. Based upon the information presented in #1 and #2 above, it is not worth the risk for the City to proceed with using Centrifuge technology for this application.

4. Even if pathogen sudden increase and regrowth were not a concern, to allay any concerns the City may have that you are passing up on a cost effective dewatering solution, please consider the following.
    a. As presented in Table 5.3, the NPW difference between the Centrifuge and the Screw Press was about 7%. For this type of simple/conceptual analysis, when the NPW

difference is less than 10%, it is commonly accepted practice to consider the options to be equal from a cost standpoint.

b. Without pilot testing, there is no basis for assigning Centrifuge with significantly dryer cake solids over the other options (5% dryer than Screw Press and 6% dryer than Belt Filter Press). In doing so, this provides an unsupported significant advantage to Centrifuge. Although it would seem intuitive that Centrifuge would always produce dryer cake, actual side-by-side experience supports that this is not always the case.
c. Without more detailed design, there is no basis at this conceptual level to assign a building square footage to the Screw Press that is 40% larger than the other options. Doing so imparts a significant disadvantage to the cost of the Screw Press option.
d. If adjustments were made to provide more balance for items like b. and c. above, the NPW difference would be even less than 7%.
e. The ranking/scoring analysis presented in Table 6.1 is very sensitive. Small justifiable adjustments can swing the analysis away from Centrifuge. As a minimum, it would at least make the options more equal. Also, inclusion of line items for “noise potential/control” and “odor generation at land application site” would have worked against Centrifuge.

Technology Recommendation

1. Screw Press and Belt Filter Press remain viable options. The H&S report concluded in Table 5.3 that Screw Press and Belt Filter Press had the same NPW and then in Table 6.1 ranked Screw Press better the Belt Filter Press.

2. Based upon a reworking of Table 5.3 for Screw Press and Belt Filter Press (Table 5.3 Revised is attached), Screw Press now has a lower NPW than Belt Filter Press. However, it is a difference of less than 3%, so these two technologies should still be considered equal from a cost standpoint. Adjustments were made in Table 5-3 Revised to the following factors.
   a. Power cost revised from $0.09/kWh to $0.07/kWh (per City direction)
   b. Hauling costs revised from $32/wet ton to $27.50/wet ton (per City direction)
   c. Building footprint for Screw Press reduced to the same size as Belt Filter Press

3. The scoring/ranking technique used in Table 6.1 is not conducive when there are only two options. However, we agree that the following advantages noted by H&S for using Screw Press over Belt Filter Press are still valid.
   a. Better containment of odors
   b. Easier to operate
   c. Easier to maintain
   d. Less corrosion potential to surrounding area

4. Given no significant NPW cost savings, there are sufficient non-cost advantages to recommend Screw Press for the SWWRF Dewatering Project.

What are the Next Steps?

1. Obtain agreement/consensus from City staff to proceed with Screw Press.
2. Develop a more detailed conceptual design of the dewatering facility using Screw Press (including size, equipment layout, and materials of construction).
3. Emphasis of conceptual design will be to reduce construction cost while not compromising the functionality and durability of the facility.
4. Prepare an opinion of construction cost.

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Table 5.3 (REVISED)
City of St. Petersburg SWWRF Biosolids Dewatering
Cost Comparison of Dewatering Options

Interest Rate:	5.0%	**Electricity Cost (per kWh):**	$0.07
Time Period (yrs):	20	**Maintenance Staff Rate ($/hr):**	$30.00
Operation Staff Rate ($/hr):	$30.00	**Active polymer cost (per lb):**	$2.22
Sludge % Solids Input:	3.50%	**Hauling Costs ($/wet ton):**	$27.50
MAX30 Sludge Rate (Mgal/week):	1.39	**Treatment Cost for Return ($/lb):**	$5.00

Category	Characteristic	Screw Press	Belt Press
	Number of Duty Units	4	2
	Sludge feed rate (gpm)	34.6	69
	Sludge % solids output	17%	16%
	Net product (dry tons / day)	29.1	29
	Capture Rate (%)	90%	95%
	Net product (wet tons / week)	1,078	1,209
	Active Polymer use (lbs/dry ton)	35	30
	Polymer use (lbs/week)	7,126	6,106
	Power Use (kWh/DT)	0.5	30
	Power use (kWh/week)	102	6,106
Hours of Operation and O&M Manhours Required	Unit hours operated/week per unit	168	168
	Unit hours operated/day per unit	24	24
	Days operated per week	7	7
	Operator hours/hour operated	0.040	0.125
	Maintenance hours/hour operated	0.001	0.010
	PM hours/week per unit	0.001	0.020
	Total operation hours per week	7	21
	Total Maintenance hours per week	1	2
Initial Capital and Annual O&M Costs	Estimated annual oper ($/yr) [A]	$10,920	$32,760
	Estimated annual maint ($/yr) [B]	$1,560	$3,120
	Estimated annual parts ($/yr) [C]	$500	$15,000
	Polymer cost ($/yr) [D]	$822,587	$704,923
	Electrical cost ($/yr) [E]	$371	$22,227
	Hauling costs ($/yr) [F]	$1,541,540	$1,727,611
	Plant Return Treatment Cost ($/yr) [G]	$29,100	$14,539
	Total Initial Capital Cost	$8,000,000	$7,800,000
	Annual Costs Land Application [A+B+C+D+E+F+G]	$2,400,000	$2,500,000
	Net PW for Annual Costs Land Application	$29,909,000	$31,156,000
	Land Application 20-year Net Present Worth ($)	**$37,900,000**	**$39,000,000**

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Anaerobically digested biosolids odor generation and pathogen indicator regrowth after dewatering

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ABSTRACT

The objective of this research was to investigate whether a preferential stimulation of microorganisms in anaerobically digested biosolids can occur after dewatering and if it can lead to pathogen indicator regrowth and odor generation upon storage. Laboratory incubation simulating biosolids storage indicates that both odorant generation, based on total volatile organic sulfur compound concentrations (TVOSCs) and pathogen indicator regrowth, based on fecal coliform densities follow similar formation and reduction patterns. The formation and reduction patterns of both odor compounds and fecal coliforms imply that groups of microorganism are induced if shearing disturbance is imposed during dewatering, but a secondary stabilization can be achieved soon after 1–2 weeks of storage. The occurrence of the induction is likely the microbial response to substrate release and environmental changes, such as oxygen, resulting from centrifuge shearing. The new conditions favor the growth of fecal coliforms and odor producing bacteria, and therefore, results in the observed fecal coliforms regrowth and odor accumulation during subsequent storage. However, when both substrate and oxygen deplete, a secondary stabilization can be achieved, and both odor and fecal coliforms density will drop.

1. Introduction

Biosolids reuse for land application is not only economical but also beneficial to resource recycling. Biosolids are composed of mostly organic matter, with nutrient levels at roughly 55, 30, and 1.5 g/kg for N, P, and K respectively (Wallace et al., 2009). Organic matter is one of the most important attributes of soil quality, and applications of biosolids on farmlands have shown improved soil aggregation, C and N storage, water retention, nutrient availability, and overall health of pastures (National Research Council, 1993; Wallace et al., 2009). Anaerobic digestion is widely adopted by many wastewater treatment facilities for biosolids stabilization. In addition to solids reduction, biological activity of biosolids is greatly reduced through anaerobic digestion. However, recent reports have indicated that odor generation can occur and pathogen indicators can reactivate and regrow after dewatering, especially when centrifuge dewatering is used (Adams et al., 2004; Cheung et al., 2003; Erdal et al., 2003; Hendrickson et al., 2004; Higgins et al., 2006a, 2007; Iranpour and Cox, 2006; Qi et al., 2007). Reactivation was defined as the sudden increase of culturable bacteria immediately after dewatering, while

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regrowth was the continued growth of bacteria upon further storage of dewatered biosolids (Higgins et al., 2007; Qi et al., 2008). Though many biosolids can experience both reactivation and regrowth, regrowth was found to be independent of reactivation (Higgins et al., 2008; Qi et al., 2008), and as high as 10^9 cells/g DS (dry solids) of *E. coli* regrowth was reported (Higgins et al., 2008). Offensive odor is not currently regulated and yet drew the most concern from the public; therefore, it was recommended by the US National Research Council to be included in the future biosolids disposal standards (National Research Council, 2002). Densities of coliform indicators, on the other hand, are already regulated by the US Environmental Protection Agency, and thus regrowth of fecal coliform can potentially impact the ability to meet regulations. Though pathogen indicators are not pathogenic, their regrowth may imply growth of actual pathogens and consequently an increased health risk. This is especially true for pathogenic bacteria such as *Salmonella* that are closely related to *E. coli*, which had already been reported by some for their regrowth (Higgins et al., 2008; Zaleski et al., 2005).

Biosolids odor has long been one of the major issues for the wastewater treatment utilities. Odors are typically a problem for dewatered biosolids since digested liquid biosolids usually show low to no odor (Adams et al., 2004). Major biosolid odor compounds were identified to be volatile organic sulfur compounds (VOSCs) including methanethiol (MT), dimethyl sulfide (DMS), and dimethyl disulfide (DMDS), which are all microbial degradation byproducts of sulfur containing amino acids, methionines, and cysteines (Adams et al., 2004; Higgins et al., 2006a). MT was observed to be the dominant VOSCs during biosolids storage (Higgins et al., 2006a), and can be produced by several bacteria and fungi, including *E. coli* and other bacteria that are known to present in biosolids (Onitake, 1938; Segal and Starkey, 1969; Weimer et al., 1999). Methanogens were also shown to be the key VOSCs degraders, and recovery of methanogensis activity during biosolids storage can lead to odor removal (Sipma et al., 2002; Higgins et al., 2006a). For long-term storage, odorous volatile aromatic compounds (OVACs) were suspected to contribute to the persistent odor that remains due to their resistance to degradation under field storage conditions (Chen et al., 2006a). Since residual proteins are the precursors for odorant production (Novak et al., 2006), methods attempting to reduce bioavailability of proteins, such as metal binding, had shown success in odor control (Chen et al., 2007).

Biosolids pathogen indicator regrowth, including fecal coliforms and *E. coli*, is a new but yet pressing issue for the wastewater treatment utilities. Recent reports showed that stabilized liquid biosolids exhibit active microbial activity after polymer conditioning and centrifuge dewatering, and pathogen indicators can regrow to as high as just before digestion (Cheung et al., 2003; Erdal et al., 2003; Hendrickson et al., 2004; Higgins et al., 2007; Iranpour and Cox, 2006; Qi et al., 2007). Based on a recent research survey conducted by a team sponsored by the Water Environment Research Foundation, the observed regrowth seems to be associated with centrifuge dewatering (Higgins et al., 2008). Moreover, in addition to fecal coliform, pathogens such as *Salmonella* were also found to experience regrowth in Class B biosolids (Higgins et al., 2008). Understanding the mechanisms of how and why pathogen indicators regrow is, therefore, an important step to future developments on regrowth control and prevention.

Since biosolids odor production and pathogen indicator regrowth are both signs of microbial activity during storage, it is hypothesized that similar mechanisms are behind both phenomena. The goal of this research was to investigate the mechanisms of biosolids odor production and pathogen indicator regrowth, and observe factors that contribute to the stimulation of microbial growth from the originally stable liquid biosolids.

2. Materials and methods

2.1. *Plant description and sample collection*

Five municipal wastewater treatment plants with anaerobic digestion, operating at various digestion time–temperature combinations and configurations, were analyzed in this research. Detailed specifications of these treatment plants can be found in Table 1. For dewatered cakes, all samples were collected from the immediate cake exit point of the centrifuge or belt filter press (BFP), and liquid biosolids were collected at the closest point to the dewatering equipment prior to polymer addition. Duplicate samples were collected aseptically with sterile containers and tools, stored immediately in either wet ice (for microbial culture), dry ice (for molecular DNA analysis), or room temperature (for odor analysis), and analyzed within 24 h of collection.

2.2. *Effect of shearing*

2.2.1. *Field analysis – centrifuge vs belt filter press*

Two field samples, one with centrifuge dewatering (Pre-Past-1) and one with belt filter press dewatering (Meso-1), were collected and analyzed side by side for their total volatile organic sulfur compounds (TVOSCs) production and fecal coliform regrowth. Separate and extensive work on TVOSCs production and fecal coliforms regrowth were conducted previously and the two plants of choice had shown consistent and typical TVOSCs and fecal coliform regrowth profiles based on prior experiences (Adams et al., 2007; Higgins et al., 2008).

2.2.2. *Field analysis – high solids vs low solids centrifuge*

A field study was conducted at the Meso-2 plant, which was equipped with two types of centrifuges. One centrifuge,

Table 1 – Operational Data for the Sampled Wastewater Treatment Plants.

Plant	Temperature (°C)	SRT	Configuration	EPA Class A/B
Pre-past-1	1st: 66 2nd: 35	1st: 2 h 2nd: 29 d	2 stages in series	A
Meso-1	1st: 35 2nd: unheated	1st: 30 d 2nd: 40 d	2 stages in series	B
Meso-2	36	22 d	Parallel	B
Meso-3	38	32 d	Parallel	B
Thermo-1	55	15–20 d	CSTR in Parallel	B

Humboldt, operating at 2200 rpm speed and 2.3 rpm differential, dewatered biosolids to solid contents ranging between 30 and 34%, and is termed high solids (HS) centrifuge in this report. A second centrifuge, a Centrysis modified Bird, operating at 1100 rpm speed and 1.6 rpm differential, produced lower solid contents (26–30%), and is termed low solids (LS) centrifuge in this report. Both centrifuges received the same liquid biosolids feed with identical polymer dose, and both operated at flow rates between 300 and 450 gal/min. The HS centrifuge was set to operate at higher bowl differential speed, and thus resulted in a higher level of cake shear by the internal scroll conveyer.

2.2.3. Laboratory dewatering and shearing simulation

A laboratory experiment simulating the field belt filter press and centrifuge dewatering was used to observe *the effects of shearing on biosolids TVOSCs production and fecal coliforms regrowth. Anaerobically digested liquid biosolids collected from Prepast-1 plant was used for this experiment.* Three key steps were included in the laboratory protocol: polymer conditioning, dewatering, and shearing.

Liquid biosolids were first conditioned to their optimum polymer dose (OPD) based on the capillary suction time (Higgins et al., 2006b). Once OPD is achieved, the majority of liquid water was removed by centrifuging at 3000× *g* for 10 min in a 250 mL Nalgene bottle, which typically results in solids contents around 15%. To increase solids content matching field cakes and to simulate the belt filter press dewatering, centrifuged pellets were further dewatered by a Crown Press, a laboratory scale belt filter press simulator (Phipps&Bird, Richmond, VA). Finally, to simulate centrifuge shear, the cake was processed through a KitchenAid meat-grinder apparatus that pushes the cake forward using a scroll-conveyor (similar to the internal part of an actual full-scale centrifuge), followed by extrusion through a small opening at the end of the conveyor. Various amounts of passes were used to provide different levels of shear to the cakes. For the purpose of this research, 90 kg, 4 min of belt filter pressing was used to generate biosolids with cake solid ranging between 28 and 33%, and 0, 5, or 10 shearing passes were used to observe shearing impacts on TOVSCs production and fecal coliforms regrowth. Though the setting does not provide identical simulation to the field scale dewatering process, it allowed us to produce cakes of similar solid contents with minimal to high shear, which mimic belt filter press and centrifuge cakes, respectively.

2.3. Effect of substrates

2.3.1. Substrate addition to belt filter press cakes

Belt filter pressed cakes typically do not experience regrowth in storage and therefore, this test was to see if substrate is the growth limiting factor that is responsible for fecal coliforms regrowth. To accomplish this, belt filter press dewatered cakes collected from Meso-1 plant was used and surface-applied with 1 mL of the stock food substrate solution (3 g/L of glucose/bacto-peptone in 9:1, filter-sterilized) in each 30 g of cakes. Since mixing would introduce undesired shearing, the containers were rolled around for about 1 min to provide needed mixing with minimal shear. An identical amount of de-ionized (DI) water was spiked in another 30 g of cakes to serve as the control. Both treatment and control were incubated at 35 °C for 24 h, and fecal coliform densities were analyzed at time 0 and 24 h.

2.3.2. Substrate addition and shearing to stabilized liquid biosolids

Stabilized digested liquid biosolids from Meso-1 plant was also collected and used to evaluate both shearing and substrate effects on fecal coliforms regrowth. Exactly 10 mL of the stock substrate solution or sterile DI water was incorporated into each 300 mL of treatment and control biosolids. Samples were immediately blended for 2 min at high speed in a Waring Blender (EPA Method 1680) and analyzed for their fecal coliform densities by multiple tubes – most probable number (MPN) analysis. The left-over blended samples were stored in the blender jar at 35 °C for 24 h to test for potential impact on regrowth. After 24 h of storage, the samples were subjected to a quick 10 s blending before dilutions and MPN analysis.

2.3.3. Methionine addition to sheared and un-sheared cakes

Methionine is a known TVOSCs precursor (Higgins et al., 2006a) *and thus was used to evaluate the precursor effect on odor generation.* For methionine addition tests, 0.005 mmol of methionine was introduced into each 10 g of belt filter press dewatered cakes (Meso-1) through 1 mL of pH 7.2, 50 mM phosphate buffer, with the same mixing process as the substrate tests. The same 1 mL phosphate buffer without methionine was applied to cakes to serve as the control. Both un-sheared BFP cakes and BFP cakes with 5-pass shearing were spiked with either methionine or phosphate buffer and compared side-by-side for their TVOSCs generation.

2.4. Bound protein extraction and quantification

Bound proteins are defined here as the fraction of proteins in biosolids that is easily extracted and thus are considered bioavailable to microbial degradation for odor production (Higgins et al., 2006a). Bound proteins were collected through extractions of 10 g biosolids with 100 mL of pH 8, 50 mM phosphate buffer, followed by centrifugation at 3000× *g* for 10 min, and filtration through a 4 μm glass membrane (Higgins et al., 2006a). The recovered filtrates were quantified for their protein concentrations using the Bio-Rad RC DC Protein Assay Kit (Hercules, CA) with a SpectraMax M2 Microplate Reader (Molecular Device, Sunnyvale, CA). Triplicate analyses were conducted and concentrations were expressed as relative to the known bovine serum albumin (BSA) standards.

2.5. TVOSCs and methane profile analysis

Methane and volatile organic sulfur compounds (VOSCs), including MT, DMS, and DMDS, were measured and monitored daily using a standard laboratory procedure for odor profile analysis, which was described in detail previously (Higgins et al., 2006a). In brief, each 10 g of dewatered biosolids were incubated in a sealed 160 mL serum bottle at 25 °C. Target compounds were monitored daily from the head-space for its methane and VOSCs concentrations using a HP GC-FID until VOSCs decreased to below the detection limits, which typically took around 20 days. Total VOSCs (TVOSCs), which is the sum of the sulfide-weighted MT, DMS, and DMDS concentrations (1MT + 1 DMS + 2 DMDS), were used for the purpose of this research to represent total odor production. For each treatment, duplicate bottles of samples were prepared and analyzed.

2.6. Fecal coliforms/*E. coli* regrowth and enumeration

For regrowth experiments, each 30 g of biosolids were transferred to separate sterile containers and stored at 35 °C to allow for bacterial growth. Sacrifice biosolids samples were monitored periodically using the USEPA Method 1680 (USEPA, 2005) to determine fecal coliforms densities. In brief, serially diluted samples were enriched in lauryl tryptose broth (LTB), and incubated at 35 °C for up to 48 h. Positives tubes were transferred to EC broth and incubated in water bath at 44.5 °C for 24 h, where gas production indicates presence of fecal coliforms. *E. coli* were enumerated by membrane filtration as described in Standard Method 9222 (Standard Methods, 1998) with m-ColiBlue24® medium (HACH Company, Loveland, Colorado) and incubated at 35 °C for 24 h. In most cases, samples were analyzed at days 0, 1, 2, 4, and 7, which were found sufficient to demonstrate their regrowth profile. Determination of most probable numbers of fecal coliforms was done by using the MPN calculation software available at the USEPA website.

2.7. *E. coli* and total microbial DNA extraction and quantification

A solvent based DNA extraction method providing high DNA recoveries was used to better represent total microbial contents in biosolids (Chen et al., 2006b). Total DNA was determined by staining extracted DNA with the Quant-iT™ PicoGreen® (Invitrogen, Carlsbad, CA) and quantified by a SpectraMax M2 Fluorescent Microplate Reader (Molecular Device, Sunnyvale, CA). Triplicate samples were analyzed along with known concentrations of Lambda DNA as the reference standards. *E. coli* was also quantified for their total DNA copies through a previously developed real-time polymerase chained reaction (rt-PCR) protocol (Chen et al., 2006b). The detection limit for this protocol was estimated to be around 50,000 *E. coli*/g dry solids. Triplicate analyses were performed and log-averages of *E. coli* copies are reported here.

2.8. Data and statistical analysis

For odor analyses, duplicate sample bottles were analyzed and only average data are presented here. In general, percent deviations were below 10% of the average value. For fecal coliforms regrwoth, the 95% confidence intervals were generally within 0.5-log. The *t* tests were used for paired-comparisons and significance are reported at $p < 0.05$. For MPN analysis, a chi-squared distribution was constructed and used to testify their differences at $p < 0.05$ (Haas et al., 1999). An Excel spreadsheet was developed specifically for this statistical analysis and is available upon request.

3. Results and discussion

3.1. Effects of shearing on biosolids odor generation and coliform regrowth

3.1.1. Centrifuge vs belt filter press (BFP) dewatering

In recent years, biosolids odor production has been identified to be the results of post-dewatering residual microbial activity, which generates gaseous malodor through protein degradation (Higgins et al., 2006a; Novak et al., 2006). Recently, the observed regrowth of pathogen indicators after biosolids dewatering has raised concerns by many, which is undoubtedly also a phenomenon of residual microbial activities (Higgins et al., 2007; Iranpour and Cox, 2006; Qi et al., 2007). Fig. 1A presents a composite odor and regrowth profile of a dewatered biosolids sample from a wastewater treatment plant (Pre-past-1) using pre-pasteurization/mesophilic anaerobic digestion followed by centrifuge dewatering. The results indicate that both TVOSCs production and fecal coliforms regrowth have a similar trend, in that they both increased soon after dewatering, peaked after a few days, and decreased to low levels within two weeks. A similar trend was also observed in centrifuge dewatered cakes with mesophilic, thermophilic, and pre-pasturization operations (Chen et al., 2008). A second biosolids sample obtained from another wastewater treatment plant using mesophilic anaerobic digestion (Meso-1) followed by belt filter press (BFP) dewatering, on the other hand, did not show any odor accumulation or display any fecal coliforms regrowth (Fig. 1B). Similar observations were reported from other mesophilic plants with BFP dewatering (data not published), but unfortunately, none of the thermophilic or pre-pasteurization plants that were sampled used BFP dewatering and thus cannot provide further verification. However, based on current available results, all evidence seems to indicate that centrifuge dewatering is the key factor in TVOSCs generation and fecal coliforms regrowth, which is independent from digestion types. Centrifuge dewatering produces biosolids with high solid contents, which provides savings on post-disposal handling for the utilities. However, shearing of biosolids imposed during centrifuge dewatering has been reported to result in elevated odor accumulation during storage (Erdal et al., 2008), and now a similar problem seems to occur with regrowth of pathogen indicators.

3.1.2. Field high solids vs low solids centrifuges

To observe the effect of shearing on odor production and fecal coliforms regrowth, two cakes from the same digester (Meso-2) but dewatered by two separate centrifuges of various shearing stresses were analyzed. Meso-2 plant is equipped with two types of centrifuges, one operated at 2200 rpm with 2.3 rpm bowl differential which corresponded to more shear and higher solids content (HS). The second centrifuge operated at 1100 rpm with 1.6 rpm bowl differential and corresponded to less shear and lower solids content (LS). Solids contents for the HS and LS cakes collected were 33% and 29%, respectively. Note that, at the time of this experiment, the laboratory was unable to perform fecal coliform analysis and thus only *E. coli* were enumerated, although research has shown that the majority of

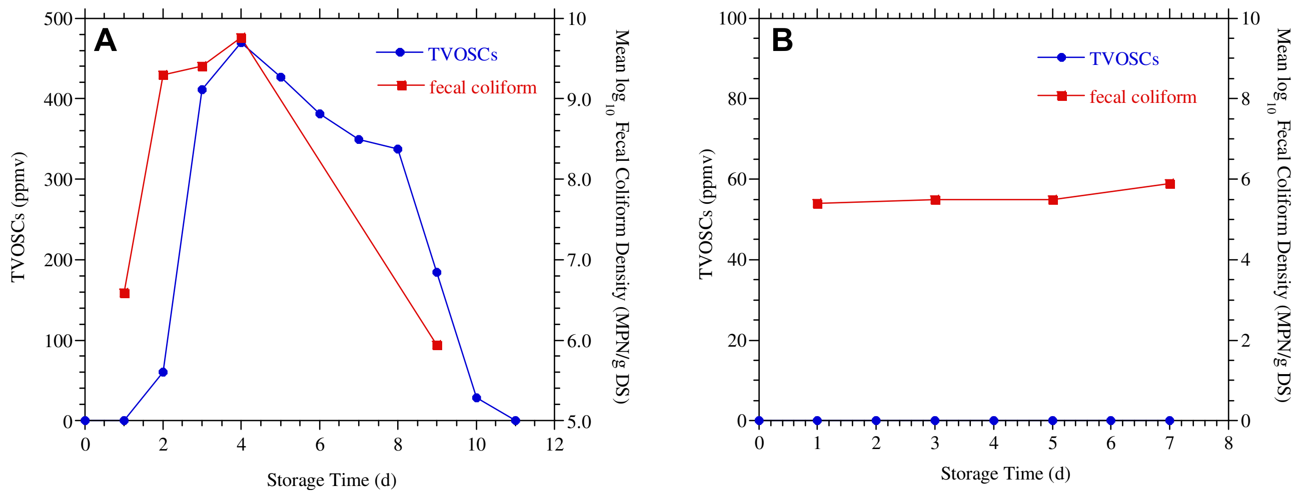

Fig. 1 – TVOSCs production and fecal coliforms regrowth profiles of A) centrifuge dewatered biosolids, and B) belt filter press dewatered biosolids at a storage temperature of 25 °C (Plant A: pre-pasteurization/mesophilic anaerobic digestion; Plant B: mesophilic anaerobic digestion).

biosolids fecal coliforms are *E. coli* and regrowth patterns of the two are comparable (Higgins et al., 2006b). Fig. 2 showed that, when cakes were subjected to high shearing, more TVOSCs were produced compared to cakes that were subjected to low shearing. At peak days, approximately twice the TVOCs concentration and *E. coli* density were observed from the HS cake compared to the LS cake (note that *E. coli* is expressed in log scale).This increase is significant on TVOSCs production ($p < 0.05$), but only marginal on *E. coli* ($p = 0.07$). Overall, there was not a clear separation between the regrowth curves of HS and LS biosolids. This was likely due to the fact that the level of difference was within 1-log between the two samples. While the level of increase was sufficient for odor comparison, it was within the typical analytical variances for microbial enumeration to show any significance. On the timing wise, the odor and regrowth peaks were not right on top of each other. This is likely because 1) *E. coli* are just one of the many odor producers in biosolids. Therefore, their growth may indicate odor production but the peak odor is the collective effect of all odor-producing bacteria, and 2) several substrates released during biosolids dewatering can support *E. coli* growth, but proteins may not be the first priority substrate. Therefore, their degradation and odor production may not match the growth of *E. coli*. The LS cakes also produced a higher amount of methane than the HS cakes (Fig. 3), indicating that shearing negatively impacts methanogenic activities, which is consistent with prior reports (Chen et al., 2005; Higgins et al., 2006a). The experiment, again, demonstrates the negative impact of shearing on odor production but, however, was unable to see its impact on *E. coli* regrowth with the level shear increase.

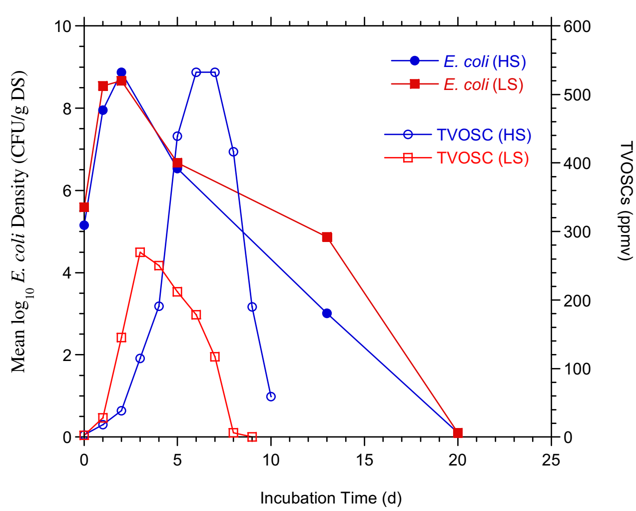

Fig. 2 – TVOSCs production and *E. coli* regrowth profiles of two centrifuge dewatered cakes from a mesophilic anaerobic digestion plant. The plant is equipped with two centrifuges, one produces high solids cakes (HS), and the other produces low solids cakes (LS). Reprinted with permission from *Proceedings of Water Environment Federation Specialty Conference, Residuals and Biosolid 2008*, March 30–April 2 2008,Phildelphia, Pennsylvania. Copyright© 2008 Water Environment Federation, Alexandria, Virginia.

The impacts of centrifuge on odor production were investigated by several researchers and some mechanisms were proposed, which include 1) shearing release of proteins and substrates for microbial degradation, 2) shearing inhibition of methanogenic populations, and 3) inhibition of methanogenic population by the increase of solids content (Chen et al., 2005; Erdal et al., 2008; Higgins et al., 2006a; Kiene et al., 1986; Oremland et al., 1989; Qi et al., 2008). It is likely that similar mechanisms may also be behind the observed pathogen indicator regrowth.

3.1.3. *Laboratory simulation of centrifuge dewatering*

A separate laboratory experiment simulating both belt filter press and centrifuge dewatering was also conducted on liquid biosolids collected from the Pre-past-1 plant. Fig. 4 shows the results of the laboratory shearing test, where 0 pass was believed to be similar to the belt filter press process. The pressed cakes were then subjected to 5 and 10 conveying

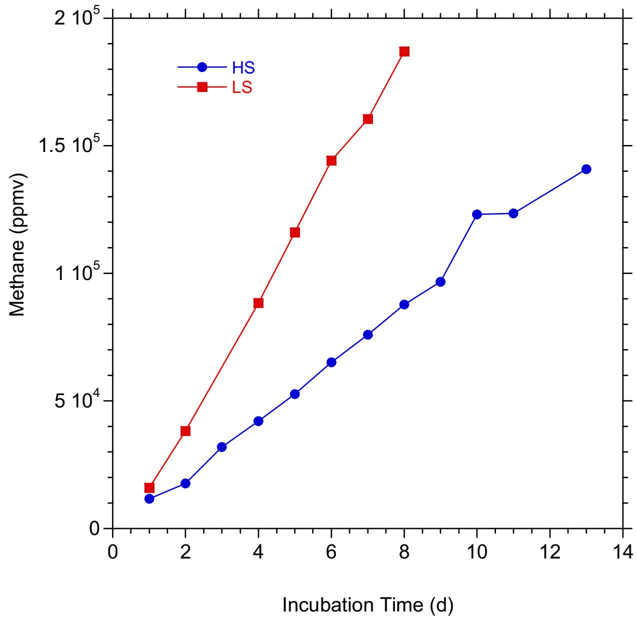

Fig. 3 – Methane production profiles of two centrifuge dewatered cakes from a mesophilic anaerobic digestion plant. The plant is equipped with two centrifuges, one produces high solids cakes (HS), and the other produces low solids cakes (LS).

passes to simulate the internal conveying scroll of a decanter centrifuge at two levels of shearing force. The results indicate that the more shear that is applied to biosolids, the greater the odor and regrowth during subsequent storage. Fecal coliform density of the 10-pass cakes grew up to as high as 5-log increase from the original (<8 MPN/g DS) after 2 days of storage, while TVOSCs accumulated past 1000 ppmv. Comparing to 0 pass cake, both 5 and 10 pass cakes showed significant increase on both TVOSCs and fecal coliforms ($p < 0.05$). Between the two sheared cakes, though the 10-pass cake showed significant increase on TVOSCs compared to the 5-pass cake, there was no apparent difference on fecal coliforms regrowth. This is similar to the field experiment where only less than 1-log of increase was observed, and therefore, the impact from additional 5 passes seemed minimal. The 0 pass cake also showed a low level of fecal coliforms regrowth (up to 3-log) without producing any observable TVOSCs. This is possibly due to the fact that the level of regrowth was not as high as those typically observed on odor producing cakes; however, additional work is needed in order to verify this hypothesis. Increased shear also resulted in decreased methane production (Fig. 5), indicating perturbations on the methanogenic population. Methanogens are known TVOSC degraders and damages of their population would result in increased TVOSC accumulation (Higgins et al., 2006a). Although a previous report has indicated potential impacts of solids content on fecal coliform regrowth (Qi et al., 2008), the solid content of all samples in this experiment were identical and thus was not a factor in this experiment. Oxygen, on the other hand, was not excluded in the process, and could potentially impact the experiment. Oxygen was previously found to induce fecal coliforms regrowth (Qi, 2008), and is inhibitive to methanogenic growth. Since oxygen can be potentially introduced during cake shearing, further work is needed to exclude its effect.

3.2. *Mechanisms of shearing impact on odor generation and fecal coliforms regrowth*

3.2.1. *Impact of substrates on fecal coliforms regrowth*

It was previously reported that centrifuge shearing of biosolids releases soluble sulfur-containing proteins which become odor precursors in subsequent biosolids storage (Erdal et al., 2008; Higgins et al., 2006a; Novak et al., 2006). In addition to proteins, other organics are likely released during shearing and thus serve as substrates for microbial growth. An experiment was conducted to investigate the role of external food substrate on the observed regrowth phenomenon. A BFP cake was collected for the purpose of this experiment that, unlike centrifuged cake, have minimal substrate release during dewatering based on the shearing-substrate release hypothesis. Quantification of fecal coliforms was performed on day 1

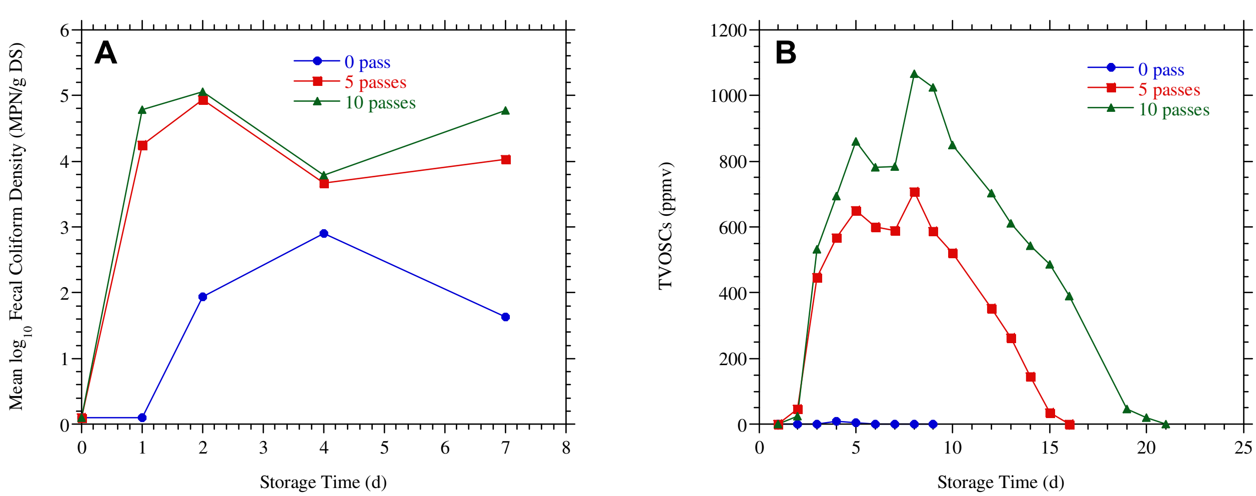

Fig. 4 – A) Fecal coliform regrowth profile, and B) odor production profile of dewatered biosolids with pre-pasteurization/mesophilic anaerobic digestion subjecting to various amounts of shearing passes.

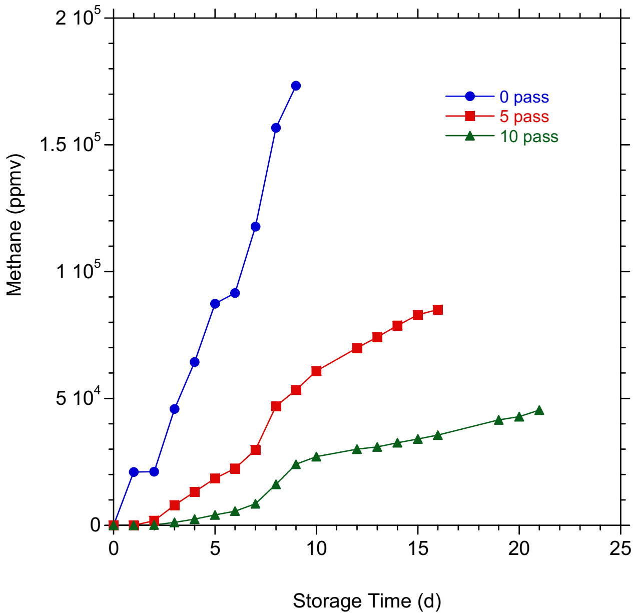

Fig. 5 – Methane production profile of dewatered biosolids with pre-pasteurization/mesophilic anaerobic digestion subjecting to various amounts of shearing passes.

immediately after collection and subsequently analyzed on day 2 after it was spiked with 1 mL of sterile substrate (glucose/bacto-peptone mixture) and water control for 24 h Fig. 6A shows that fecal coliform density increased almost 2 orders of magnitude in biosolids spiked with substrate compared to the water control, which indicates that substrate is the limiting factor for microbial growth in biosolids, and provision of substrates stimulates microbial growth. Similar stimulation of fecal coliforms growth was also observed when shearing is imposed to liquid biosolids, which is further amplified with the addition of substrates (Fig. 6B). In both experiments, both control samples showed slight increase in fecal coliforms, which was likely due to the unavoidable agitation, such as mixing to obtain homogeneous samples, during sample preparations at day 0. Overall, these 2 tests implied that substrates are stimulant for microbial activity in biosolids, and substrates release resulting from centrifuge shearing is likely the cause of the observed fecal coliforms regrowth. When the released substrates contain odor precursor, odor can be generated. Since a previous report has indicated that microbial consumption of centrifuge released soluble proteins and polysaccharides occurs during biosolids storage (Higgins et al., 2006a), the observed reduction of fecal coliforms at the later storage stage is, therefore, likely due to the depletion of available substrates.

3.2.2. *Impact of substrates on TVOSCs production*

A separate test, using BFP cake plus laboratory shearing, was conducted to verify the role of proteins in biosolids shearing through protein extraction/quantification and methionine addition. Bound protein content, the measurement of the easily extracted soluble proteins suggestive of the bioavilable proteins, showed that biosolids contain more bioavailable proteins in sheared cake than the non-sheared control, which also resulted in increased TVOSCs accumulation (Figs. 7 and 8). Addition of methionine, a TVOSCs precursor, also showed corresponding increase in TVOSCs production (Fig. 8). However, the level of TVOSCs increase was a lot higher in cake subjected to shear than those without shear, even though an identical amount of methionine was added in both treatments. Assuming 100% conversion of methionine into TVOSCs, a total of 766 ppmv increase in TVOSCs was expected; however, only 39 ppmv peak concentration increase was observed in cake without shear, compared to the 488 ppmv increase in the sheared cake. Clearly, in addition to releasing food substrates, changes in microbial activity had also occurred to result in this observation. Past research has also shown potential shearing impacts on microbial composition and activity, especially the methanogen population, and links to the observed odor accumulation (Adams et al., 2007; Erdal et al., 2008; Higgins et al., 2006a). Overall, the results showed that although available protein/amino acids were the source of odor during biosolids storage, changes of microbial activity through shearing can amplify the odor problem to a much larger extent.

3.2.3. *E. coli vs total microbial population*

During the dewatering process, biosolids are exposed to oxygen when water is removed. Continuous flow decanter centrifuges contain an internal scroll conveyer that can break up dewatered cakes further, and therefore, the produced cakes can likely experience more oxygen exposure. Anaerobic digestion creates predominantly anaerobic bacteria, including both oxygen tolerant and non-tolerant anaerobes, which are susceptible to oxygen exposure. Oxygen non-tolerant anaerobic bacteria, which unable to produce oxidant scavengers, can even be killed when exposed to oxygen (Rolfe et al., 1978). On the other hand, fecal coliforms, being facultative anaerobic bacteria that prefer oxygen as the terminal electron acceptors, can thrive under aerobic condition. Oxygen exposure during dewatering process, therefore, creates a selective advantage toward fecal coliforms over other bacteria, which likely contributes to the observed increase of fecal coliforms during initial storage. This advantage quickly disappears as the storage condition turns anaerobic with the depletion of oxygen. Using molecular DNA techniques, it was observed that *E. coli* DNA increased more than one order of magnitude even though total microbial DNA decreased by 50% after storing biosolids for 2 days (Fig. 9). This result supports the hypothesis that after centrifuge dewatering and during the initial stage of biosolids storage, the overall environment favors establishment of *E. coli* over the bulk average population. The observed decrease in background DNA was likely the destruction of oxygen non-tolerant anaerobes. However, since *E. coli* is only a pathogen indicator, whether the environment also favors true pathogens needs to be verified. Though, recent reports did indicate *Salmonella*, also a facultative anaerobe, can follow a similar regrowth pattern if not completely destroyed during digestion (Higgins et al., 2008). On the odor perspective, it was reported that oxygen can potentially disturb methanogens, the key TVOSCs degraders in biosolids, which results in early accumulation of TVOSCs that later dissipates when oxygen depletes and methanogens reestablish (Chen et al., 2005; Higgins et al., 2006a). Overall, oxygen exposure creates selective advantage for *E. coli* regrowth, and a disadvantage for methanogenic odor removal.

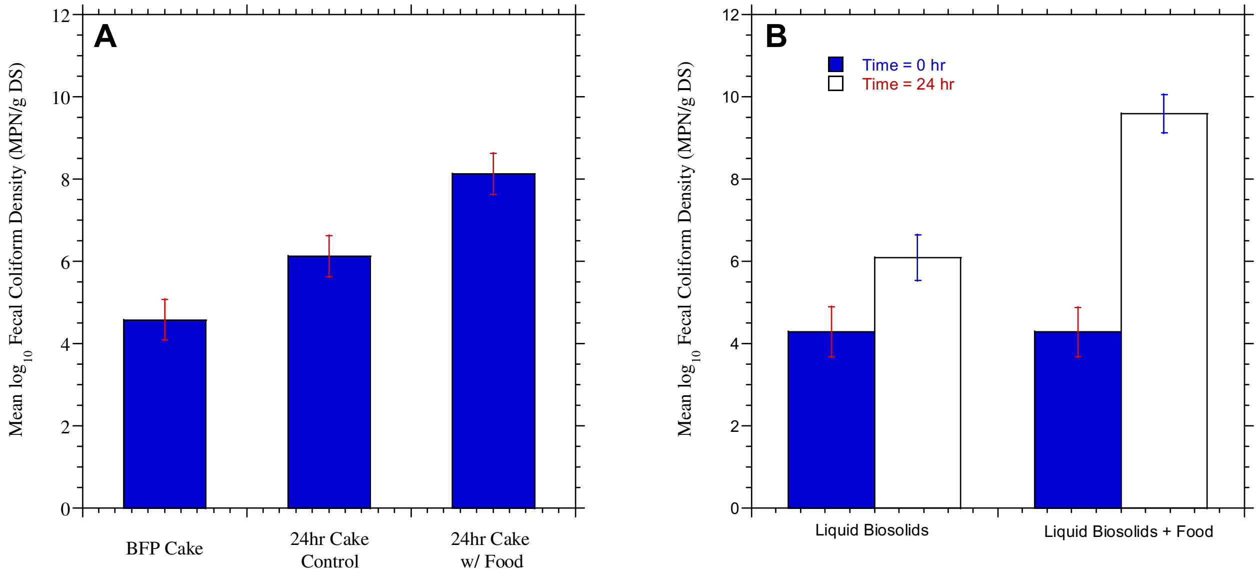

Fig. 6 – Induction of fecal coliform regrowth by substrates addition to A) belt filter press (BFP) dewatered cakes, and B) digested liquid biosolids from a mesophilic anaerobic plant. The liquid biosolids were also subjected to 2 min of blender shearing prior to 24 h incubation. Error bars represent 95% confidence interval and there is a statistical significance between substrates treatments and the controls (chi-distribution, $p < 0.05$).

Although results presented here demonstrate the high possibility of TVOSCs generation and fecal coliforms regrowth for centrifuge dewatered cake, both TVOSCs and fecal coliforms profiles indicate that a secondary stabilization can occur with lengthened storage time, which can potentially be used for both odor and regrowth control. Storage temperature, however, has been shown to impact the length of time required for complete odor removal, in which longer time is required at lower temperature (Chen et al., 2005). A similar temperature impact was also observed for pathogen indicator regrowth (data not shown). Therefore, storage temperature should be carefully taken into consideration if the utility is to rely on additional storage time for both odor and fecal coliforms destruction.

In summary, based on the current results, the authors believe that biosolids subjecting to high shearing during dewatering can release substrates, including proteins. The released substrates can provide fecal coliforms regrowth, while the released proteins can be degraded to form TVOSCs odor. Shearing possibly also introduced oxygen and thus impacts

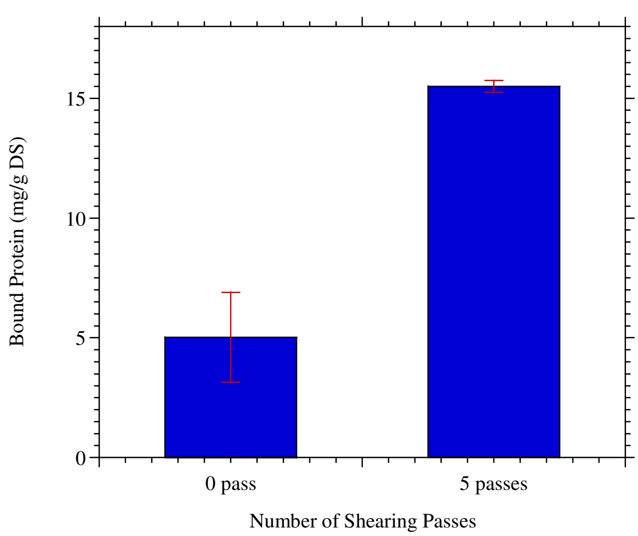

Fig. 7 – Bound protein concentrations of BFP dewatered cakes from a mesophilic anaerobic plant, and after subjecting to 5 laboratory shearing passes. Error bars represent 1 standard deviation ($n = 3$) and there is a statistical significance between the two treatments (t-test, $p < 0.05$).

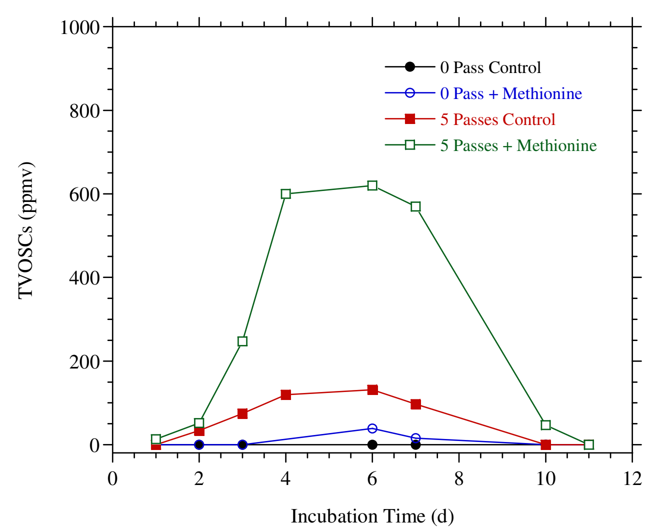

Fig. 8 – Total volatile organic sulfur compounds (TVOSCs) production profiles of BFP cakes from a mesophilic anaerobic plant, BFP cake with 5 shearing passes, and cakes with 0.005 mmol methionine addition per 10 g cakes.

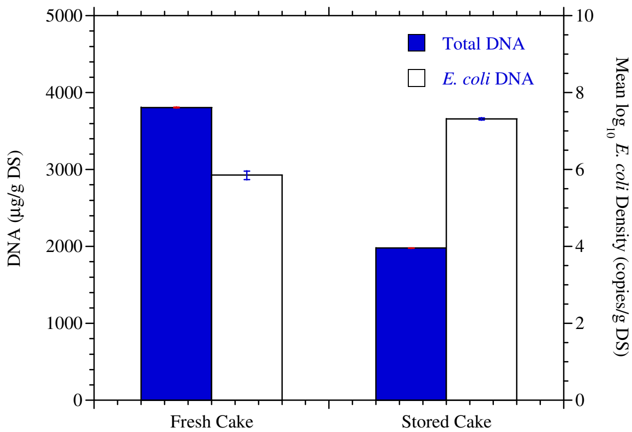

Fig. 9 – Total bacterial and *E. coli* DNA of centrifuge dewatered biosolids with mesophilic anaerobic digestion (Meso-3) and the same biosolids subjecting to 2 days of storage at room temperature. Error bars represent 1 standard deviation ($n = 3$) and there is a statistical significance between fresh and store cakes on both total DNA and *E. coli* DNA (*t*-test, $p < 0.05$).

methanogenic activity, which consequently increased TVOSCs accumulation. In addition, oxygen provided a selective growth advantage to fecal coliforms over other obligate anaerobes, and therefore facilitated their growth. However, given enough time for biosolids storage, both oxygen and substrate will be depleted and would result in a drop in both TVOSCs and fecal coliforms.

4. Implications of research

The results presented in this work indicate that both biosolids odor production and fecal coliforms regrowth seem to coexist, in that when high level of fecal coliforms regrowth is observed, organic sulfur odors are likely to accumulate. The results also demonstrated that centrifuge shearing of biosolids likely released odor precursor and food substrates, which resulted in the observed odor accumulation and fecal coliforms regrowth. This finding implies that attempts in preventing release, facilitating removal, or reducing availability of odor precursors and food substrates can likely control both odors and regrowth simultaneously. However, biosolids may also expose to oxygen during dewatering which can also result in increased odor and fecal coliforms growth. Prevention of biosolids from oxygen stress, therefore, can likely also mitigate the problems.

One should also understand that, though closely related, both phenomena are not mutually exclusive. In other words, they do not always coexist. For example, a biosolids sample can exhibit organic sulfur odor without fecal coliforms regrowth if odor producers are not fecal coliforms or *E. coli*. Literatures indicate that many microorganisms are known to produce the enzyme, methionine-γ-lyase, that converts methionine into MT (Segal and Starkey, 1969; Weimer et al., 1999; Coombs and Mottram, 2001), and therefore, their presence can also produce odor despite the absence of *E. coli*. In addition, TVOCs can also be accumulated if only the methanogenic population is damaged, while little or no growth advantage favors fecal coliforms. This was demonstrated previously where addition of BES (2-bromoethanesulfonic acid), a methanogen inhibitor, would result in accumulation of TVOSCs (Chen et al., 2005; Qi, 2008). Similarly, if methanogens are injured at a relatively higher extent than fecal coliform, odor can prolong even after fecal coliform has achieved a secondary stabilization. Methanogens are known to be a sensitive population and their recovery from an environmental perturbation can be much longer than other microorganisms due to their slow growth, which explains observations of odor problems with certain environmental stresses (Chen et al., 2005).

On the other hand, coliform regrowth can also occur without experiencing odor if the provided food substrates are not odor precursors. In such a case, coliforms can grow without generation of any odorous metabolites. Another possibility is the production of a different group of odorants, such as organic volatile aromatic compounds (OVACs), whose production profile is different from what is observed for fecal coliforms regrowth (Chen et al., 2006a). OVACs were found to produce after TVOSCs dissipate and can persist for an extended period of time. Unlike TVOSCs, OVACs are difficult to degrade and since OVACs have low threshold concentrations to human olfactory, it is likely that humans can still experience odor from OVACs residuals even after stabilization of fecal coliforms. However, since OVACs are also known metabolic byproducts of protein degradation, the aforementioned treatment approaches should also reduce their production.

The results from this work showed that microorganisms in digested biosolids can still be induced if disturbed, which results in undesirable odor and fecal coliform growth. Therefore, minimal agitation is recommended when handling biosolids in order to maintain their stability. For example, choosing a low shearing dewatering method will allow reduction of odor and coliform growth. Furthermore, conveyance, loading/unloading, spreading, and incorporation of bioslids are all operations that can potentially introduce shear to the biosolids, and therefore precaution should be taken to minimize shear.

Biosolids odor has always been one of the major issues for wastewater utilities and was identified to be the principal complaints from the public based on a report released by the National Research Council (National Research Council, 2002). Although there is no current regulation on biosolids odor, it was highly recommended by the NRC based on civilian concerns. Fecal coliforms density, on the other hand, is one of the principal limits for biosolids land application. For Class A biosolids, since regulations stipulate that biosolids should contain less than 1000 MPN fecal coliform/g DS, occurrence of regrowth will likely jeopardize their reuse. However, research showed that no pathogens were recovered despite regrowth of fecal coliforms in Class A biosolids, and thus pursuit of an alternative pathogen indicator was recommended (Higgins et al., 2008). For Class B biosolids, wastewater utilities are not required to perform routine monitoring of fecal coliforms as long as a PSRP (Processes to Significantly Reduce Pathogens) treatment process is used for stabilization (USEPA, 1994). Therefore, despite potentially exceeding Class B fecal coliform limit and likely experiencing regrowth of pathogenic *Salmonella* (Higgins et al., 2008), biosolids can still be considered as Class B for disposal and reuse. This does not necessarily indicate any danger to the public, because it was the intention of Class B designation to allow low level of pathogens to remain in biosolids that do not pose any immediate threat to the public health (USEPA, 2003). The required site restriction after land application allows time for pathogen to die-off in soil, where native soil microorganisms are predominant.Future efforts should, therefore, be focused on continued monitoring of pathogen die-off during, and beyond site-restriction, especially when biosolids are again disturbed by farming activities.

5. Conclusions

Overall, both odor production and fecal coliforms regrowth during biosolids storage are indicators of residual microbial activity. Microorganisms in stabilized biosolids can still be induced upon centrifuge dewatering, which releases food substrates. Oxygen stress also likely contributes to both phenomena where it increases odor through suppressing methanogenic activity, and increases fecal coliforms regrowth by providing an environment benefitting their growth. As substrates and oxygen deplete, both odor and fecal coliforms density gradually decrease until a new stabilization is reached.

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WERF ROSI Project – Do We Need a Revised Time-Temperature Requirement to Achieve Class A Biosolids

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ABSTRACT

Sudden increase (SI) of indicator bacteria, such as *E. coli*, in dewatered cake has been reported in processes that utilize thermophilic pretreatment followed by digestion or thermophilic digestion. The SI typically occurs when centrifuge dewatering is utilized. Increases of up to 4 or 5 orders of magnitude have been measured. The objective of this research was to investigate if increased time-temperature would better inactivate the indicator organisms and prevent SI. The work examined a range of time and temperature both in the lab and full-scale systems. The results suggested that an increased time-temperature for thermal treatment was associated with plants that did not have SI. In addition, a field trial with a pre-pasteurization plant showed that increasing the pre-pasteurization temperature from about 68 to the mid 70s decreased the extent of SI. Overall the results are supportive of revising the time-temperature for complete inactivation of indicator bacteria. However, this increased time-temperature regime is likely not necessary for the inactivation of *Salmonella,* as other research has shown that SI did not occur for *Salmonella*.

INTRODUCTION

Regrowth, odors and sudden increase (ROSI) are issues for some utilities that employ anaerobic digestion and different dewatering technologies (Higgins et al., 2008). These issues are more prevalent with centrifuge dewatering. As show in Figure 1, "sudden increase" (SI) refers to the large increase in indicator bacteria such as *E. coli* and/or fecal coliforms (FC) that can occur immediately after dewatering. This SI is mainly an issue for processes that utilize thermophilic treatment, and it is not observed to occur to the same extent in mesophilic processes. Higgins et al., (2007 and 2008) suggested that SI observed after centrifuge dewatering of thermally treated biosolids was due to the presence of indicator bacteria that became non-culturable after thermal treatment, and were 'reactivated' after centrifuge dewatering. In other words, the bacteria were present but the standard culturing methods did not recover them after the thermal treatment and/or digestion. However, after centrifuge dewatering, the bacteria reactivated, meaning they became culturable in the standard culturing media. Regrowth is the additional increases in indicator bacteria observed during cake storage in which the bacteria can grow due to available substrates. Similarly, regrowth of other organisms is also supported, and this growth is also accompanied by the production of odor causing compounds resulting in odorous biosolids cakes.

The overall goal of the WERF ROSI project is develop approaches to manage the issues of regrowth, odors, and sudden increase of indicator and pathogenic bacteria in biosolids. The project entails two phases. The first phase is focused on filling critical research gaps that will provide the fundamental insights for developing solutions to these issues which includes method development. The second phase will focus on developing and implementing solutions in the field.

The objectives of the first phase of the work were specifically to evaluate alternative methods for enumeration of FC and *E. coli* after thermophilic treatment, reevaluate the time-temperature requirements for achieving complete inactivation of pathogens and indicator bacteria, characterize the persistent odorants that occur in cakes during storage, and investigate methods for controlling ROSI at the lab scale.

The focus of this paper is the work associated with the evaluation of the existing time-temperature requirement to achieve Class A biosolids to determine if it should be revised in light of the findings of this research.

RESEARCH APPROACH

In this portion of the research, samples were collected from field sites employing thermophilic treatment to determine if they were experiencing SI. In addition, experiments were performed to investigate alternative methods to enumerate indicator bacteria, FC and *E. coli*, after thermophilic treatment, and compare these methods to the commonly used Method 1680 promulgated by the U.S. EPA for use with Class A biosolids (EPA, 2005). Using some of these alternative methods, time-temperature experiments were performed to evaluate the effects on inactivation rates and how enumeration methods could impact these outcomes.

RESULTS

The EPA time-temperature requirements for Class A biosolids are shown in Figure 1. There are basically two curves, Curve D is for biosolids with concentrations less than 7% and will also be treated for greater than 30 minutes. Curves A, B, and C are for conditions where the biosolids are greater than 7% solids (Curve A), less than 7% solids but heated by contact with warm gasses or immiscible liquids (Curve B), or sludges with less than 7% solids but treated in a process for less than 30 minutes (Curve C) (EPA, 2003).

The requirements are derived in part by the Zone of Safety defined by Feachem et al. (1980) for different organisms which is shown on the graph. In addition, EPA utilized data for egg-nog from the Public Health Service (PHS) to further derive their time-temperature curves (EPA, 2003). As shown on the graph, the EPA curves reside within the Feachem Zone of Safety, and are more stringent than the PHS egg-nog requirements at the higher temperatures.

In addition to the time-temperature requirement, the final product must have fecal coliform densities below 1000 MPN/g DS or *Salmonella* densities less than 3 per 4 g DS.

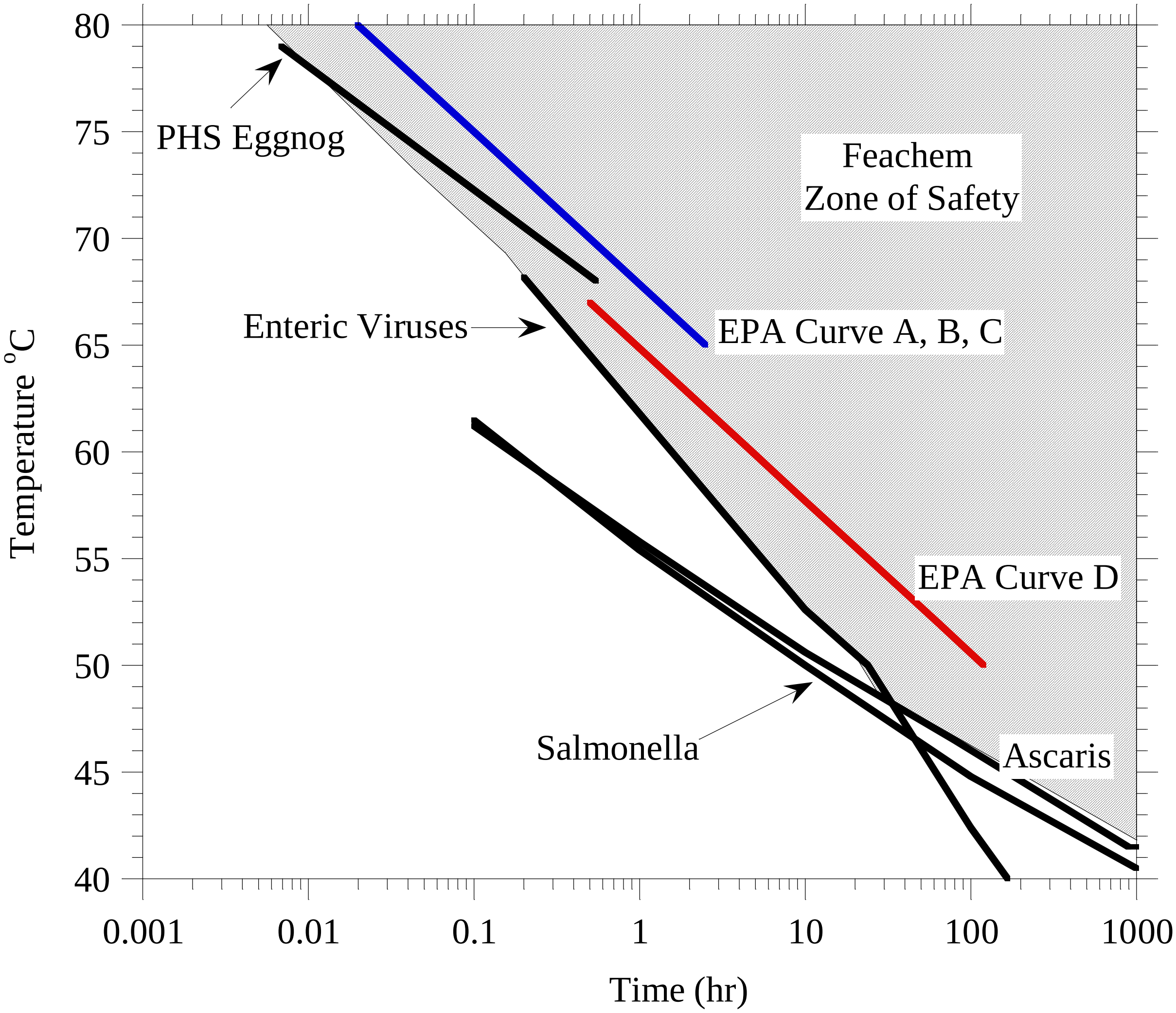

Figure 1. EPA Time-Temperature Requirements to Achieve Class A Biosolids.

Data from the Higgins et al (2008) has shown that thermophilic plants that meet the time-temperature requirement for Class A biosolids can also meet the requirement of less than 1000 MPN FC/g DS after digestion. However, after dewatering, sudden increase can occur (along with regrowth) which results in densities of FC that no longer meet this FC limit. Higgins et al. (2006) suggested that Method 1680 was providing false negative results after thermal treatment/digestion, and the bacteria were actually present but not enumerated. After dewatering, the enumeration method was able to culture these organisms, which explains the large increase in a relatively short amount of time (less than 20 minutes). Figure 2 shows data points for several full-scale systems that met the EPA time-temperature requirement, but did not meet the FC requirement after dewatering. In addition, laboratory studies in which *E. coli* and/or sludges were thermally treated for a given time-temperature have shown that *E. coli* can recover from the thermal treatment. This data from our study and from the literature are also included on the graph.

The results from this analysis clearly show that the EPA time temperature requirements may not be adequate for complete inactivation of the indicator bacteria, mainly *E. coli*.

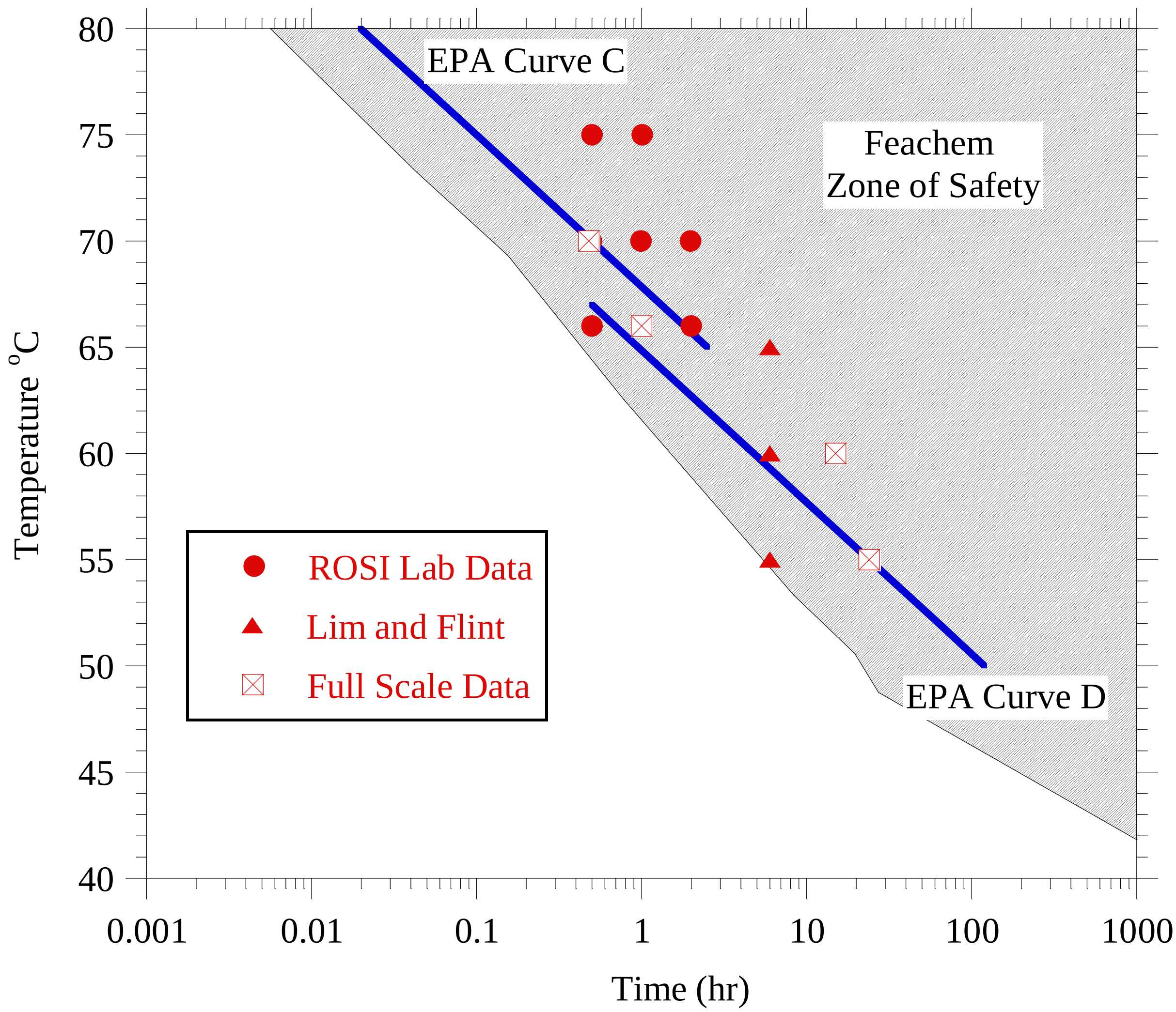

Figure 2. EPA time-temperature curves showing data points where FC and/or *E. coli* could be recovered even after being subjected to the specific time-temperature regime.

To further develop this concept, additional time-temperature experiments were performed beyond the EPA time-temperature requirements, and data from several plants that exceeded the time-temperature requirement and did not observe SI were plotted. This graph is shown in Figure 3. The results suggest that shifting the time-temperature requirement could completely inactivate the indicator organisms and eliminate the issue of sudden increase and regrowth in Class A thermophilic systems. Further testing is needed to better verify this curve, but the initial results are interesting in that they have a similar slope to the existing EPA curves, they are just offset to the right.

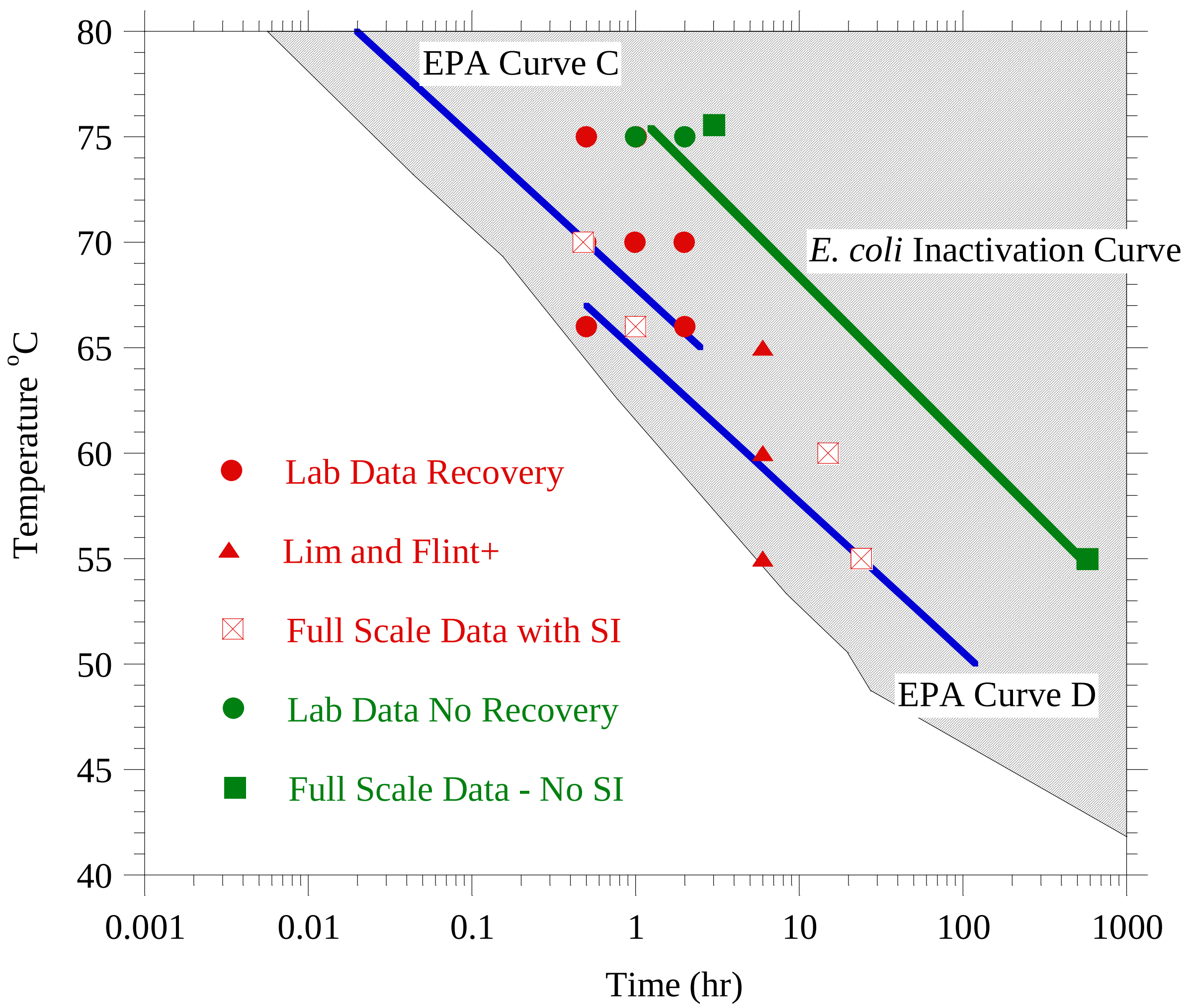

Figure 3. EPA time-temperature curves showing data points where FC and/or *E. coli* could be recovered even after being subjected to the specific time-temperature regime – these points are shown in red and include both lab and full-scale data. The green points represent time-temperature combination in which FC and/or *E. coli* could not be recovered for lab data or in the case of full-scale data, SI was not observed.

Field Trial.

To examine the efficacy of the revised time-temperature curve, a full scale trial was performed in which the temperature of pre-pasteurization was been increased from the mid to high 60s °C to about 75 °C with a time of about 2 hours. This plant had historically had SI and regrowth after centrifuge dewatering. The plant also made a good case study since several years of data had been collected related to SI as part of this project and previous WERF projects.

During the trial the FC and *E. coli* densities in the cake were measured. The results plotted over time for the sampling before and after the temperature increase are presented in Figure 4. The graph shows *E. coli* densities and the mean pre-pasteurization temperature measured during the prior 15 days before the *E. coli* sampling event. Interestingly, the density of *E. coli* decreased as the temperature increased beginning in 2009. Unfortunately, the temperature increases were not consistent and some decreases occurred, but the general trend showed that as temperature increased the cake *E. coli* decreased. A plot of the cake *E. coli* versus the pre-pasteurization temperature is shown in Figure 5. A good correlation exists between the pre-pasteurization temperature and the cake *E. coli*. The results so far support the conclusion that higher time-temperatures could help utilities achieve Class A requirements in terms of the FC limit of 1000 per gram DS

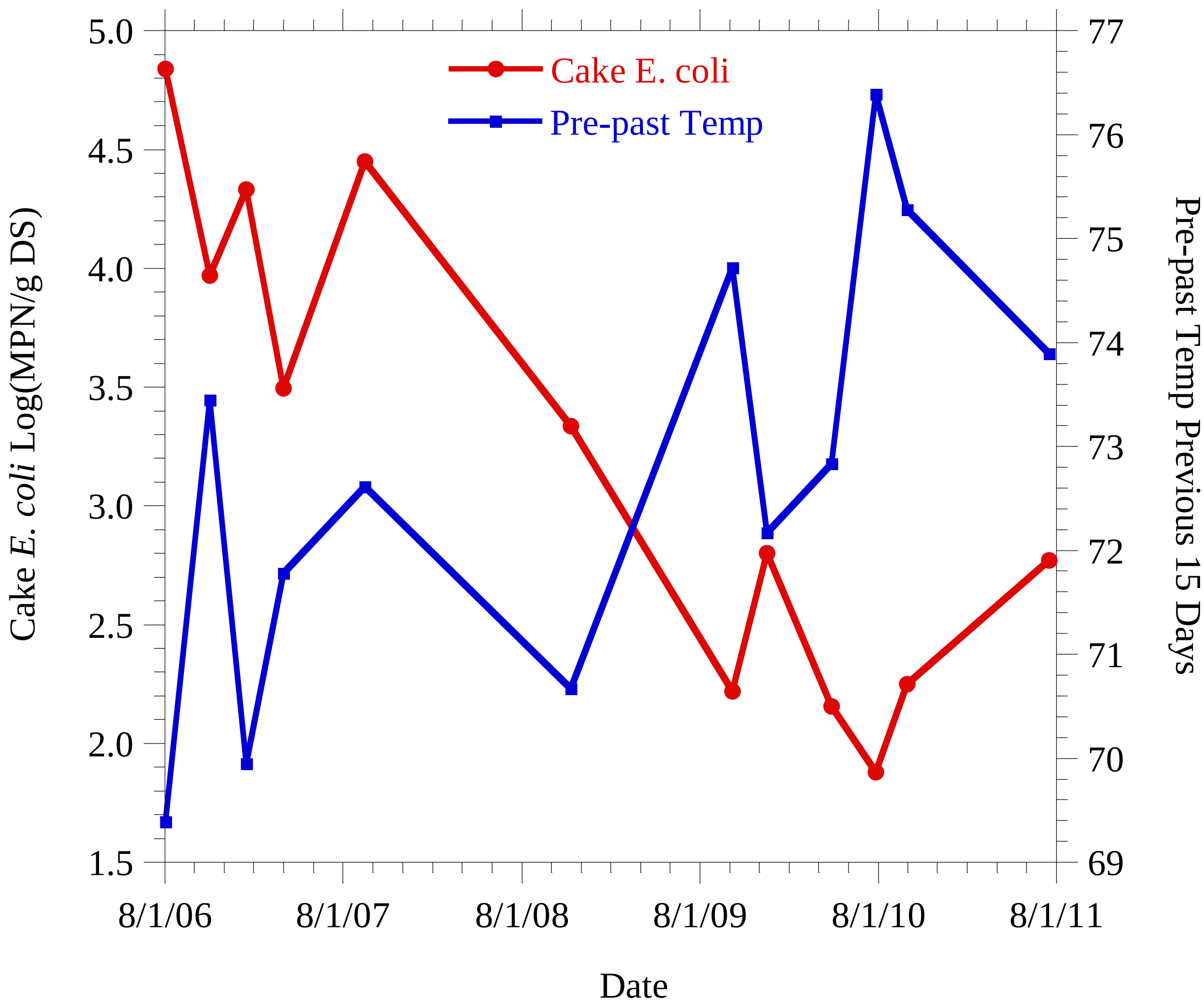

Figure 4. Effect of temperature of pre-pasteurization on the *E. coli* in the cake after centrifuge dewatering at a full-scale plant that utilizes pre-pasteurization followed by mesophilic digestion and centrifuge dewatering.

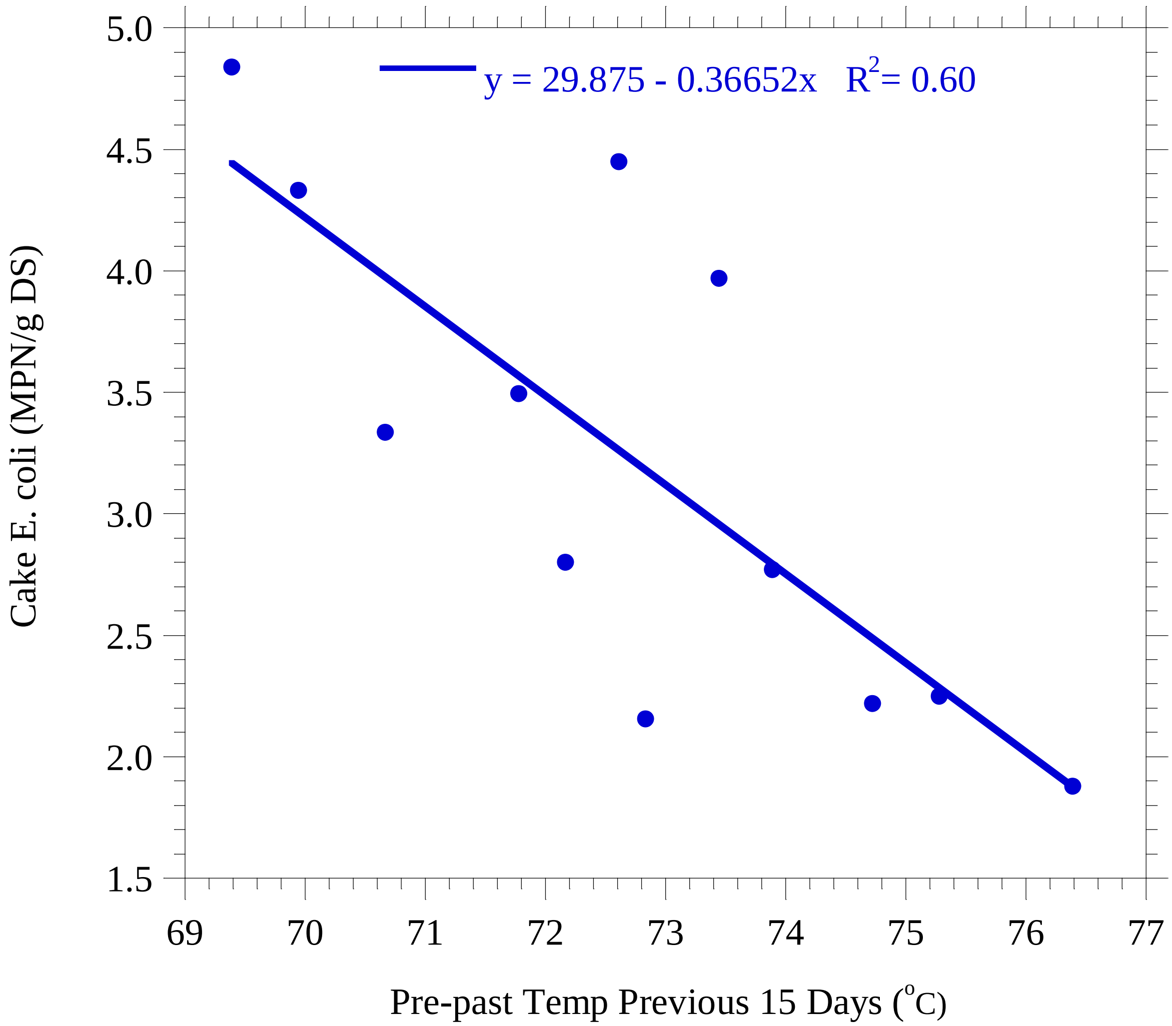

Figure 5. Correlation between the cake *E. coli* density and the mean pre-pasteurization temperature for the 15 days prior to the *E. coli* sampling event.

Overall, the results suggest that and increased time-temperature regime may be necessary for complete inactivation of the indicator bacteria, namely FC and *E. coli*. It should be noted that the suggested need for an increase in the time-temperature requirement is for meeting the fecal coliform requirement, and not necessarily the *Salmonella* requirement. Chen et al. (2011) showed that for all the Class A plants using thermophilic treatment that had SI of fecal coliforms, no SI of *Salmonella* was measured, and all met the *Salmonella* requirement.

SUMMARY

The results from this study have shown that the time-temperature requirements promulgated by the EPA might not be sufficient for complete inactivation of the indicator bacteria, resulting in SI and regrowth after dewatering of thermophilically treated biosolids. The research has also suggested that increasing the time-temperature requirement may result in complete inactivation.

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The Effect of Digestion and Dewatering on Sudden Increases and Regrowth of Indicator Bacteria after Dewatering

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ABSTRACT: Several investigators have reported higher densities of indicator bacteria after dewatering of anaerobically digested biosolids. The increases appear to occur at two points in the biosolids process: the first, referred to as ''sudden increase'', occurs immediately after dewatering; the second, ''regrowth'', occurs during storage over longer periods. The objectives of this study were to examine the effect of digestion and dewatering processes on sudden increase and regrowth of fecal coliform and *E. coli*. Samples were collected from five thermophilic and five mesophilic digestion processes, with either centrifuge or belt filter press dewatering. Sudden increase typically was observed in the thermophilic processes with centrifuge dewatering and was not observed in the mesophilic processes with either centrifuge or belt filter press dewatering. Regrowth was observed in both thermophilic and mesophilic processes with centrifuge dewatering but not belt filter press dewatering. *Water Environ. Res.*, **83,** 773 (2011).

KEYWORDS: biosolids, digestion, reactivation, resuscitation, regrowth, *E. coli*, fecal coliform.

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Introduction

Researchers and utilities have reported high densities of indicator organisms such as fecal coliform and *E. coli* immediately after dewatering of anaerobically digested biosolids. Before dewatering, densities of indicator organisms were significantly lower (Cheung et al., 2003; Erdal et al., 2003 and 2004; Hendrickson et al., 2004; Higgins et al., 2007; Iranpour et al., 2003; Monteleone et al. 2004; Qi et al., 2007). Higgins et al., (2007) delineated these increases into two separate phenomena. The first increase occurs immediately after dewatering as measured by increased densities in the cake. This initial, immediate increase after dewatering is termed ''sudden increase'', which does not ascribe a specific mechanism to the phenomena, but rather describes the observation in a non-mechanistic term. The second increase occurs during longer term storage of cakes (>24 hours) and has been termed ''regrowth''.

Several theories have been proposed and investigated to explain the sudden increase immediately after dewatering. For example, researchers suggested that the dewatering process caused floc breakup, which led to increased enumeration efficiency during culturing methods used to enumerate fecal coliforms; other research suggested that the high counts were because of regrowth of bacteria present in the samples (Cheung et al., 2003; Monteleone et al. 2004; Qi et al., 2007). Higgins et al. (2007) suggested that during thermophilic digestion, some bacteria can become nonculturable, which means the bacteria were still present and potentially viable, but they did not grow using the standard culturing method (SCM) such as the Standard Method 9221 B/E or U.S. Environmental Protection Agency's (U.S. EPA) Method 1680 (American Public Health Association et al., 2005; U.S. Environmental Protection Agency, 2005). As a result, the bacteria were not enumerated, and centrifuge dewatering resulted in ''reactivation'' or ''resuscitation'' of the bacteria. The term reactivation or resuscitation is defined here as the transition where bacteria become culturable when previously they were nonculturable in the same SCM.

Higgins et al. (2007) used quantitative polymerase chain reaction (qPCR) to enumerate *E. coli* after digestion/before dewatering and also immediately after dewatering. The results showed that the densities based on copies of *E. coli* DNA were not significantly different before and after dewatering, despite the large difference in densities measured by the SCMs. These results supported the nonculturable/reactivation concept to describe the sudden increase. Enumeration of copies of DNA by molecular techniques such as qPCR, however, does not distinguish between live and dead cells. As a result, the DNA densities that were measured cannot be definitively associated with viable cells. Contamination of the process also has been suggested as a possible mechanism to account for the sudden increase (Baddeley et al., 2009, Higgins et al., 2007).

Regrowth occurs over several days, depending on temperature, and appears to be the result of bacteria growth in the cake because of readily available substrates and nutrients (Higgins et al., 2007). The mechanism of regrowth appears less controversial than the mechanism of sudden increase.

Although the mechanisms have yet to be fully elucidated, the effect of these increases is important because they can result in densities of indicator bacteria exceeding regulatory require-

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ments. The objectives of this research were to investigate the incidences of sudden increase and regrowth from different full-scale digestion and dewatering processes to determine if certain processes or process combinations were more or less likely to experience these phenomena.

Methods and Materials

Overview. Samples were collected from five mesophilic anaerobic, four thermophilic anaerobic, and one thermophilic aerobic digestion processes. The digestion processes were followed by different dewatering processes. Table I provides a summary of the different processes sampled and pertinent operational parameters. The plants were located across North America including in the United States and Canada. Typically, samples were collected before and after digestion, during storage after digestion (if applicable), and after dewatering. After collection, the samples were preserved using appropriate methods before analysis using standard culturing and molecular methods. In some cases, cake samples were also stored at 35 °C in the laboratory under aseptic conditions and sampled periodically to evaluate the regrowth during storage. This temperature was used because it is near-optimum temperature for growth of *E. coli*, and the purpose of the test was to determine if regrowth occurred in the cake during storage.

Sampling and Enumeration of Fecal coliform and *E. coli* by Culturing Methods. Triplicate samples of biosolids cake were collected aseptically using 120-mL sterile containers for each sampling point. Liquid biosolids samples were collected aseptically and placed in 1-L sterile containers. After collection, all samples were immediately stored in wet ice and shipped by priority overnight courier for laboratory analysis. Samples were analyzed according to U.S. EPA Method 1680 and Standard Methods (American Public Health Association et al., 2005; U.S. Environmental Protection Agency, 2005). The procedure outlined in Method 1680 was used to prepare the samples through homogenization using a Waring blender. The blender containers were 500 mL, stainless steel, Nalgene (Rochester, New York) vessels with lids and were sterilized by autoclaving. For liquid (undewatered) biosolids, 300 mL of the biosolids was placed in a Waring blender. For dewatered cake samples, 30 g of the sample were aseptically weighed and added to the blender vessel containing 270 mL of sterile phosphate buffered water according to Standard Method 9050C (SM9050C). Samples were blended for two minutes at 18 000 rpm.

The fecal coliform (MF) analyses were conducted according to SM9222D using m-fecal coliform media incubated at 44.5 ± 0.2 °C for 24 hours. The fecal coliform most probable number (MPN) procedure (SM9221B/E) also was used for enumerating fecal coliform. The MPN is a two-step procedure in which a presumptive or enrichment test for total coliform is performed first using a lauryl tryptose broth followed by fecal coliform enumeration using EC-media and incubation at 44.5 °C. As a side note, U.S. EPA Method 1680 for enumeration of fecal coliform is adapted from SM9221 B/E. The key difference is that SM221B allows for the use of bromocresol purple or gas production as an indicator for a positive result for total coliforms, and U.S. EPA Method 1680 relies only on gas production. The *E. coli* were enumerated using the procedures described in SM9221F, which simply adds the *E. coli*-specific 4-methylumbilliferyl-beta-D-glucuronic acid (MUG) reagent to the media so that *E. coli* can be enumerated along with fecal coliforms (American Public Health Association et al., 2005).

Enumeration of *E. coli* Using Molecular Methods. *E. coli* was chosen as the target bacteria to enumerate using qPCR. Real-time PCR was used to enumerate *E. coli* based on the number of copies of *E. coli* DNA present in the sample. The technique is based on the use of a real-time PCR system, which detects real-time fluorescence signals after every PCR amplification cycle. The concentration of unknown target DNA is then determined through amplification plot analysis along with an external known target DNA standard. This technique provides a method to enumerate the bacteria that does not rely on their culturability.

Sample Collection for Analysis. Triplicate samples of biosolids were collected aseptically using 120-mL sterile containers for each sampling point. Samples for dewatered biosolids to be analyzed by PCR were stored immediately in dry ice. Samples for liquid biosolids were first centrifuged at 14 000 *x g* for five minutes using a tabletop mini-centrifuge to remove liquid water; biosolids pellets were stored along with dewatered biosolids in dry ice. All samples were shipped to the laboratory on dry ice using a priority overnight courier for DNA analysis.

Extraction. A 100-mg sample of wet dewatered biosolids was weighed directly into a Lysing Matrix E tube (QBIOgene, Carlsbad, California), and 750 μL of lysis buffer (100 mM tris-HCl, 100 mM sodium EDTA, 1.5 M NaCl, and 1% hexadecyl-methylammonium bromide [CTAB], pH 8) was added. For liquid sludge, samples were first centrifuged at 14 000 *x g* for five minutes. Then 200 mg of the wet pellet, which had similar dry weight to the 100-mg wet dewatered biosolids, were used as the starting material. Bacterial cells were then homogenized with a FastPrep® Instrument at 5.5 speed for 30 seconds, followed by centrifugation at 14 000 *x g* for 10 minutes. The supernatant was collected in a clean 2-mL microtube, and the pellet was re-extracted twice each with 500 μL of lysis buffer. Then 5 μL of 20 mg/mL protease K was added to the combined extract and incubated at 55 °C for 30 minutes. Next, 200 μL of 20% SDS was added and incubated at 65 °C for two hours, during which the samples were completely mixed every 30 minutes. After incubation, the samples were centrifuged at 14 000 *xg* for 10 minutes, and the supernatant was placed in a clean 5-mL microtube for purification.

The DNA was purified through two phenol/chloroform/isoamyl alcohol extractions, followed by one chloroform extraction. Approximately 0.6 volumes of ice-cold isopropanol was then added, and DNA was precipitated overnight at −20 °C. The precipitated DNA was pelleted by centrifuging at 16 000 *xg*, 4 °C for 10 minutes, followed by two 70% alcohol washes, air drying, and redissolving in 500 μL of TE buffer. If necessary, the DNA extract was further purified using the Wizard® Genomic DNA Purification Kit to remove humic substances following the instruction manual (Promega, Madison, Wisconsin). All extracted DNA was stored at −80 °C to prevent degradation until analyses were performed.

Primer Design for Reverse Transcription Polymerase Chain Reaction. The *gadAB* gene was used as the target for *E. coli* quantification, and primers were designed using the PrimerQuest^{SM} software provided by Integrated DNA Technologies (Coralville, Iowa) (Chen et al., 2006). The primer pairs contained a forward primer 5′ - GCG TTG CGT AAA TAT

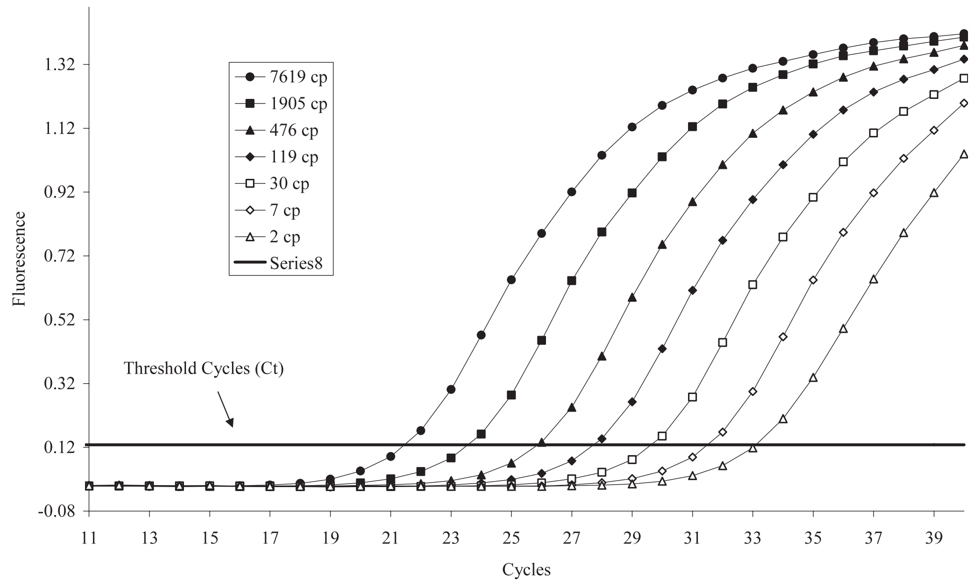

Figure 1—Amplification plot for *E. coli* standards.

GGT TGC CGA - 3′ (gadrt-1); and a reverse primer 5′ - CGT CAC AGG CTT CAA TCA TGC GTT - 3′ (gadrt-2), which yield a final 305 bp PCR product. Both primers were analyzed through BLAST for their specificity to *E. coli* which compares these sequences to known sequences in the database to determine if the primers will be specific for the target organisms, in this case *E. coli*.

Reverse Transcription Polymerase Chain Reaction Analysis and Standard Curve Validation. The SYBR Green I dye reverse transcription polymerase chain reaction (RT-PCR) method was chosen for the quantification of *E. coli* with the Stratagene MX3005P Real-Time PCR system (La Jolla, California). They SYBR Green I dye binds to the double strand DNA structure (PCR products) and emits fluorescence signals, which were measured at the end of each PCR cycle, thus allowing the monitoring of PCR products during amplification cycles. Each PCR reaction contained 12.5 μL of the Brilliant® SYBR® Green QPCR Master Mix from Stratagene (La Jolla, California); 0.5 μM of each primer; 30 nM of reference dye (Rox); 10 μL of 10 ng sample DNA; and DNase/RNase free water to a final volume of 25 μL. The PCR program contains a 10-minute initial denaturation at 95 °C, followed by 40 cycles each of denaturation at 95 °C for 30 seconds, annealing at 57 °C for one minute, and extension at 72 °C for 30 seconds. The program also includes a final dissociation curve analysis for quality assurance/quality control of PCR products.

Serially diluted *E. coli* DNA ranging from 2 to 7620 copies was used as an external DNA standard for each RT-PCR analysis. Ten nanograms of *Pseudomonas putida* DNA also was included in each standard serving as the background DNA. Duplicates or triplicates of each sample were run for each RT-PCR assay. Figure 1 shows an example of an amplification plot. The horizontal line indicates the threshold cycles (*Ct*) of each plot for standard curve construction. The threshold cycle is defined as the cycle where the fluorescence signal is significantly above background, and is shown to be inversely proportional to the log quantity of the initial target amount. The standard curve for this experiment had an *R*-square of 0.988 indicating good consistencies and accuracy of the developed method (Figure 2). Figure 3 shows the final dissociation curve of the PCR products with only one single peak, indicating no nontarget DNA was amplified. The concentrations of unknown DNA samples analyzed together with the standards were then determined using the standard curve equation. This method allowed sensitive detection of a single copy of *E. coli* DNA in each reaction, which was approximately 10 000 to 20 000 *E. coli* per gram dry solid.

Statistical Analyses. Triplicate analyses were performed on all field samples and most laboratory tests except for a few laboratory most probable number (MPN) tests. Triplicate analyses typically are used to account for sample variation, especially for those collected in the field. Some laboratory tests, with proper mixing before sampling, were performed without replication (only on MPN tests) because the high number of samples that needed to be processed imposed time limitations on the number of replicates that could be performed. Statistical analysis is still feasible for these tests because of the replications built within the MPN method.

For samples with replication, the mean was calculated using the geometric mean. For statistical comparisons between samples, $\log_{10}$ transformation was first performed, and the one-way analysis of variance (ANOVA; *F* statistics) was used to evaluate differences among all treatments. Further pair-wise comparisons were performed to determine significant differences between paired treatments if desired, using either the least significant difference (LSD) or Tukey's method.

The MPN test uses multiple or replicate tubes for each dilution, which, through appropriate statistical analysis, provides an estimate of microbial densities and confidence intervals. It does not, however, allow users to compare sample means between different treatments based on this confidence interval. Because the MPN procedure has "internal" replication (or multiple) tubes for each of the dilution series of the test, however, certain statistics could still be performed for treatment comparisons (Haas et al., 1999). The method is based on a null hypothesis that the MPN result of the dilution experiment for

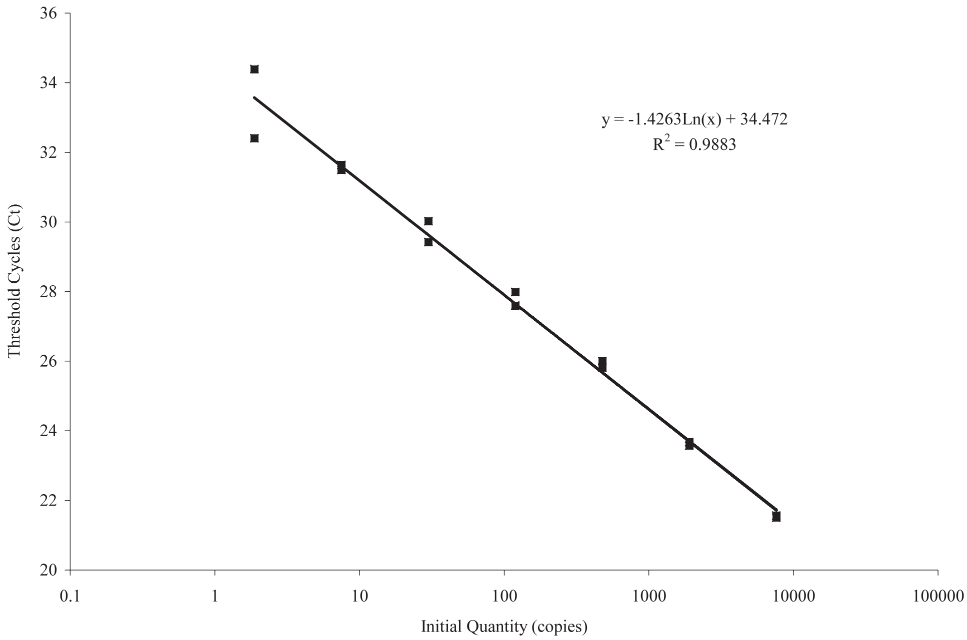

Figure 2—*E. coli* DNA standard curve.

two samples are fit by a common mean. A likelihood ratio was then constructed and tested against the chi-squared distribution with a critical value of 0.05. Examination of Poisson distribution or goodness of fit of each set of MPN measurement was also tested to assure consistency between dilution and within the sample. A spreadsheet was created to perform this calculation and is available (with instructions) upon request. The equations and procedures are summarized by Haas et al. (1999).

Results

Ten different full-scale plants were sampled that used either mesophilic or thermophilic digestion, with either centrifuge or belt-filter press dewatering. The details for the specific processes are provided in the subsequent sections and are summarized in Table 1. By sampling the different processes, the effect of digestion temperature, reactor configuration, and dewatering process on sudden increase and regrowth could be investigated. It should be noted that by sampling different plants, the inherent sludge characteristics would differ and could affect some of the findings. The results are presented in the following sections.

Indicators Densities Associated with Thermophilic Digestion Processes. Four different thermophilic anaerobic processes were sampled: single-stage thermophilic digestion; three-stage thermophilic (reactor in series) process configuration; prepasteurization followed by mesophilic digestion; and temperature-phased anaerobic digestion (TPAD) with a thermophilic batch process followed by mesophilic digestion. One autothermal thermophilic aerobic digestion (ATAD) process also was evaluated. Table 1 provides a summary of the plant operational criteria.

Single-Stage Thermophilic Digestion. A thermophilic, anaerobic digestion facility was sampled that had two digesters in parallel, followed by storage (approximately one day solids retention time [SRT]) before dewatering with a high solids centrifuge. The thermophilic digesters operated with an SRT of approximately 17 days and temperature of 55 °C. Figure 4 shows the mean $\log_{10}$ of the fecal coliform and *E. coli* densities measured by SCMs and qPCR for each step in the process. The influent fecal coliform and *E. coli* measured by SCM and qPCR were similar at approximately 7.5 $\log_{10}$ MPN or copies/g dry solids. During digestion the difference between the two methods increased and the qPCR values were greater than the SCM, which was particularly true for Digester 2. During the sampling period, Digester 2 was undergoing some maintenance that increased the solids retention time in the digester, which may explain why the SCM did not measure culturable *E. coli* in the sample from this digester. The qPCR densities were similar for both digesters, as shown in Figure 4.

Effluent from the digesters was discharged to a storage tank, which had a culturable fecal coliform and *E. coli* densities of approximately 2.5 $\log_{10}$ MPN/g dry solids. In comparison, the qPCR density remained in the range of 5 $\log_{10}$ copies/g dry solids, a difference of about three orders of magnitude. Immediately after dewatering, the cake sample measured by both methods had similar densities of approximately 4.5 $\log_{10}$ MPN/g dry solids. This indicates the *E. coli* enumerated by the SCMs increased by approximately two orders of magnitude immediately after dewatering. The retention time in a high solids centrifuge is less than approximately 15 minutes, which is not enough time for this increase to be accounted for by growth. Storage of the cake for 24 hours at 35 °C resulted in an additional increase of about one order of magnitude for the fecal coliform densities measured by SCM and the *E. coli* density measured by qPCR. Unfortunately, the *E. coli* test using the SCM did not use enough dilutions to obtain an actual density; although, based on the data, the density was greater than 2.5 $\log_{10}$ MPN/g dry solids.

Multistage Thermophilic Digestion. A second thermophilic digestion process was sampled. This process used three reactors in series, followed by a storage tank before dewatering with a high-solids centrifuge. The reactor in series configuration provides a plug-flow like configuration, which typically is more

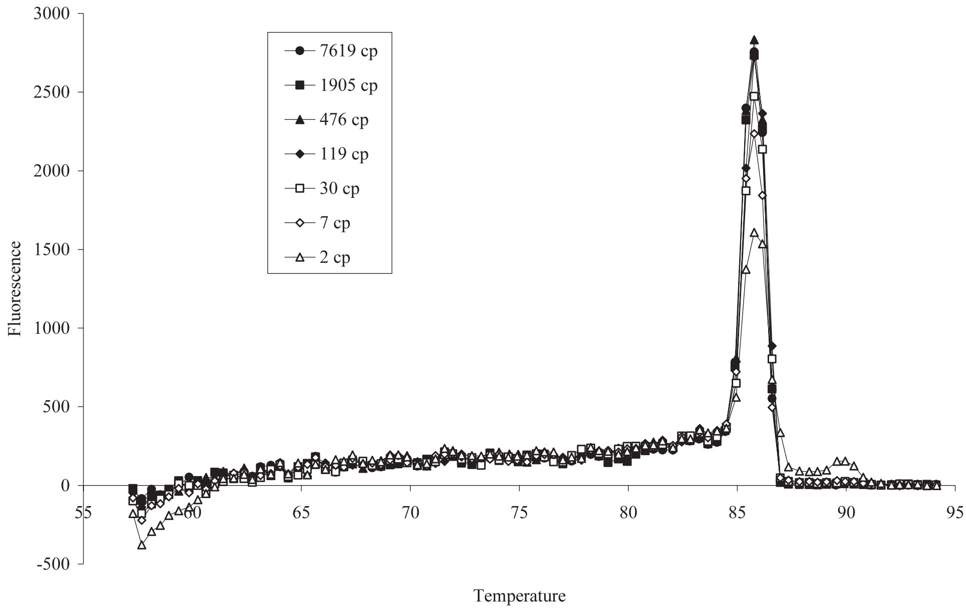

Figure 3—Dissociation curve of the final polymerase chain reaction (PCR) products (SCM = standard culturing method; qPCR = quantitative PCR; FC = fecal coliform; EC = *E. coli*; DS = dry solids).

efficient for achieving desired conditions when compared to completely mixed reactors. The first stage had an SRT of approximately 17 days with a temperature of 56 °C. The second and third stage each had an SRT between one and two days and a temperature of 56 °C. The storage tank had an SRT of approximately one day, with typical temperatures between 42 and 52 °C.

Figure 5 shows the fecal coliform and *E. coli* densities measured by the SCM and qPCR for the digester influent, the effluent from each stage, and the dewatered cake. Similar to other samples, the digester influent ranged from 7 to 8 $\log_{10}$/g dry solids for each of the different measures. After the first stage of digestion, the SCM did not enumerate any fecal coliform or *E. coli*, however, qPCR measured approximately 4.2 $\log_{10}$ copies/g dry solids. No fecal coliform or *E. coli* were measured in the effluent from the second or third stage by either method. The detection limit for the qPCR method was approximately 4 $\log_{10}$ cells/g dry solids. Similarly, no *E. coli* were measured in the cake samples immediately after centrifugation, indicating no sudden increase occurred. Samples from the onsite cake storage hopper had fecal coliform and *E. coli* densities of approximately 1.5 $\log_{10}$/g dry solids.

Table 1—Summary of plant process data and sudden increase and regrowth evaluation (CSTR = continuous-flow stirred-tank reactor; BFP = belt filter press).

	Digestion						
Plant	Configuration: series or parallel	Solids retention time	Temperature	U.S. EPA Class A or B	Dewatering	Indicator sudden increase	Indicator regrowth
Single-stage thermophilic	CSTR in parallel	15–20 days	55 °C	B	High-speed centrifuge	Yes	Yes
Multistage thermophilic	4 CSTR in series	~18/1.5/1.5/1 days	55 °C	A	High-speed centrifuge	No	No
Prepasturization/mesophilic	Prepasteruization/ mesophilic	2 hours/ 19 days	66/35 °C	A	High-speed centrifuge	Yes	Yes
Temperature-phased anaerobic	Thermo/mesophilic in series	15/20 days	58/36 °C	A	High-speed centrifuge	Yes	Yes
Autothermal thermophilic aerobic	4 Reactors in Series	18 days total	40/50/60/60 °C	A	High-speed centrifuge BFP	Yes No	Yes Not tested
Mesophilic with centrifuge	Parallel	32 days	38 °C	B	High-speed centrifuge	No	Yes
Mesophilic with BFP	Series	25–30 days	36 °C	B	BFP	No	No
Mesopilic with centrifuge	Parallel	22 days	36 °C	B	High-speed centrifuge	Yes	Yes
Mesophilic with BFP	Series	70 days	37 °C	B	BFP	No	No
Mesophilic with BFP	Series	24 days	36 °C	B	BFP	No	No

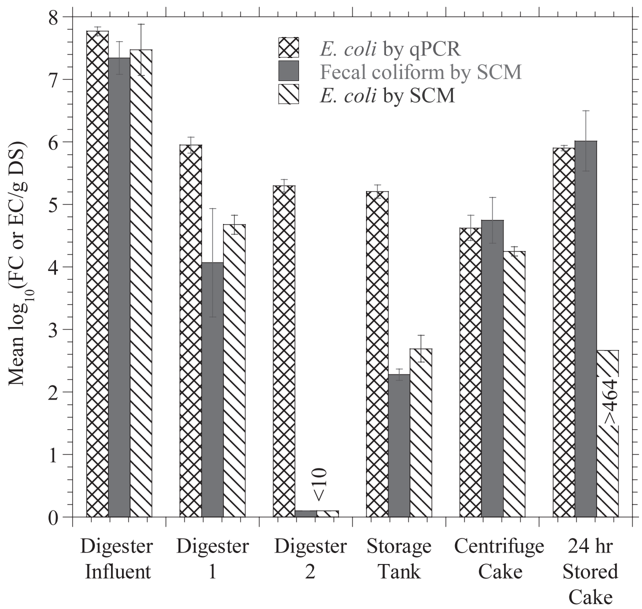

Figure 4—Fecal coliform and *E. coli* density measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a single-stage thermophilic digestion process with high solids centrifugation dewatering. (error bars represent one standard deviation) (SCM = standard culturing method; DS = dry solids).

Prepasteurization Followed by Mesophilic Digestion. The pre-pasteurization process uses a temperature of approximately 66 °C for a minimum of 45 minutes to meet the U.S. EPA time-temperature requirement for Class A biosolids (U.S. Environmental Protection Agency, 2003). Prepasteurization was followed by mesophilic digestion and centrifuge dewatering. Figure 6 shows the fecal coliform and *E. coli* densities measured by the SCMs and qPCR. The densities of fecal coliform and *E. coli* in the undigested sludge was approximately 7 log_{10}/g dry solids for both the SCM and qPCR tests. After prepasteurization, the densities of fecal coliform and *E. coli* measured by the SCM were below the detection limit; the qPCR results remained at approximately 7 log_{10} copies/g dry solids for *E. coli*. After digestion, the SCM densities remained below detection, and the qPCR density of *E. coli* decreased by approximately two orders of magnitude to 5 log_{10} copies/g dry solids. After centrifuge dewatering, the cake samples had fecal coliform and *E. coli* densities between 3.5 and 5 log_{10}/g dry solids, which matched well with the qPCR data. The cake that passed through a screw conveyor had similar densities, and the cake from the storage hopper had densities of approximately 6 log_{10}/g dry solids measured by both qPCR and SCMs.

Temperature-Phased Anaerobic Digestion. The temperature-phased anaerobic digestion (TPAD) process uses batch thermophilic treatment at 58 °C to meet the U.S. EPA time-temperature requirement, followed by mesophilic digestion with an SRT of approximately 20 days at 36 °C. Dewatering is performed using a high-solids centrifuge. For this sample set, qPCR was only performed on the digester influent, digester effluent, and centrifuge cake; it was not performed on the cake after storage. Figure 7 shows the qPCR and SCM results for fecal coliform and *E. coli*. The influent densities were between 6.5 and

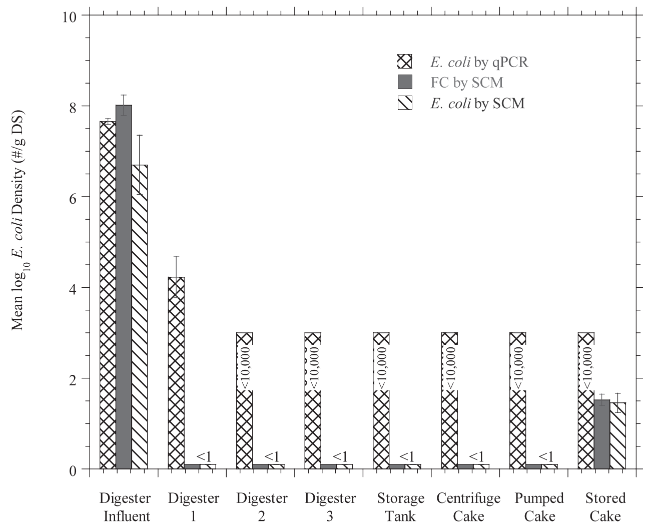

Figure 5—Fecal coliform and *E. coli* density measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a three stage thermophilic digestion process with high solids centrifugation dewatering (error bars represent one standard deviation).

7.0 log_{10}/g dry solids; after digestion the densities were less than 3 log_{10}/g dry solids by the SCM. The *E. coli* densities measured by qPCR were below the detection limit after digestion and centrifugation, and the detection limit for this test was approximately 4.9 log_{10} copies/g dry solid. After dewatering, the fecal coliform and *E. coli* densities measured in the cake increased by approximately one order of magnitude compared to before dewatering, and the densities in the 24-hour stored cake increased several orders of magnitude to approximately 7 log_{10}/g dry solids.

Autothermal Thermophilic Aerobic Digestion. The autothermal thermophilic aerobic digestion (ATAD) process used four reactors in series, each with an SRT of 4.5 days, and temperatures of 40, 50, 60, and 60 °C, respectively. A dewatering trial was performed to compare centrifuge and belt filter press (BFP) dewatering. Only fecal coliform analyses by SCM were performed by the plant for this study; because of the circumstances, no qPCR data was collected. The results from the sampling are shown in Figure 8. Fecal coliform densities decreased in each reactor, and were below the detection limit in ATAD reactors 4 and 5. The cake produced by the BFP remained below the detection limit for the analyses, but the centrifuge cake increased by approximately three orders of magnitude, which showed that a sudden increase occurred for the centrifuge but not for the BFP. A centrifuge cake sample stored for 10 days had a density of 7.7 log_{10} fecal coliform/g dry solids, showing that regrowth occurred in the centrifuge cake. Storage of the BFP cake was not performed.

Indicators Densities Associated with Mesophilic Digestion Processes. Five different mesophilic anaerobic digestion processes were sampled. The plants included operations that used reactors in series and in parallel and those that used belt filter press and centrifuge dewatering.

Mesophilic Digestion with Centrifuge Dewatering. The mesophilic digestion with centrifuge dewatering process used single-stage digesters in parallel followed by a storage tank and centrifuge dewatering. Digestion temperature was 38 °C and the

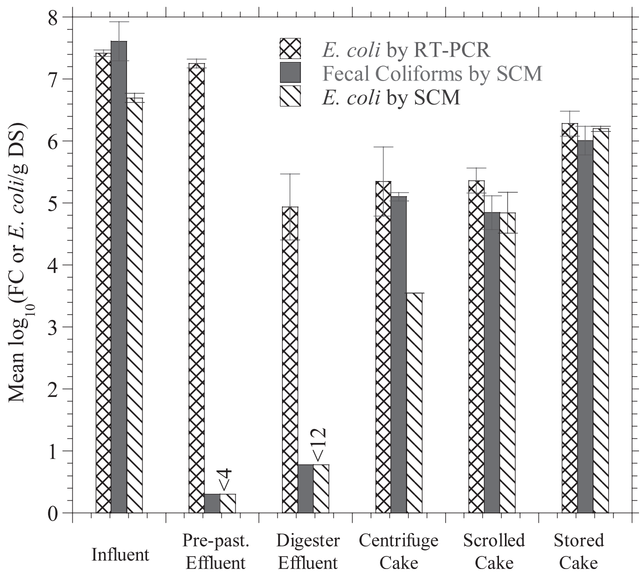

Figure 6—Fecal coliform (FC) and *E. coli* density measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a pre-pasteurization followed by mesophilic digestion process with high solids centrifugation dewatering (error bars represent one standard deviation) (RT-PCR = reverse transcription PCR; SCM = standard culturing method; DS = dry solids).

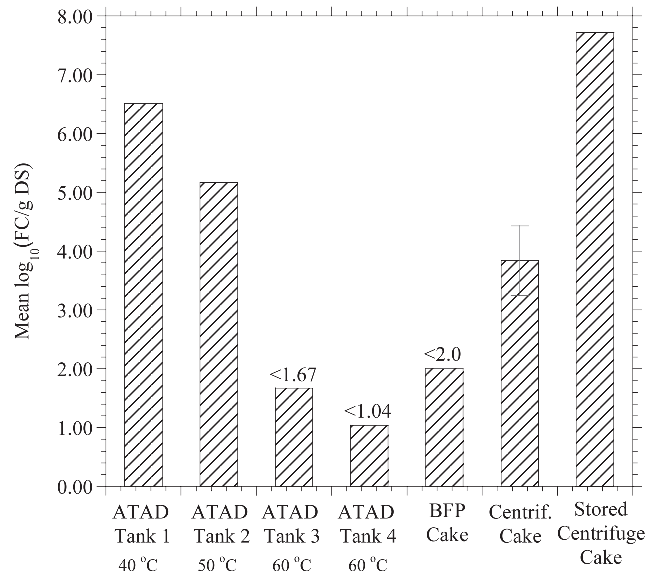

Figure 8—Fecal coliform standard culturing methods in an temperature-phased anaerobic digestion (TPAD) process with four reactors in series with high-solids centrifugation dewatering and belt filter press dewatering.

SRT was 32 days. The cake was pumped via cake pumps to a storage silo on site. Figure 9 shows the densities of fecal coliform and *E. coli* measured by SCM and qPCR for each stage in the process. The densities measured by qPCR and SCM match well throughout the process, including after digestion. In this

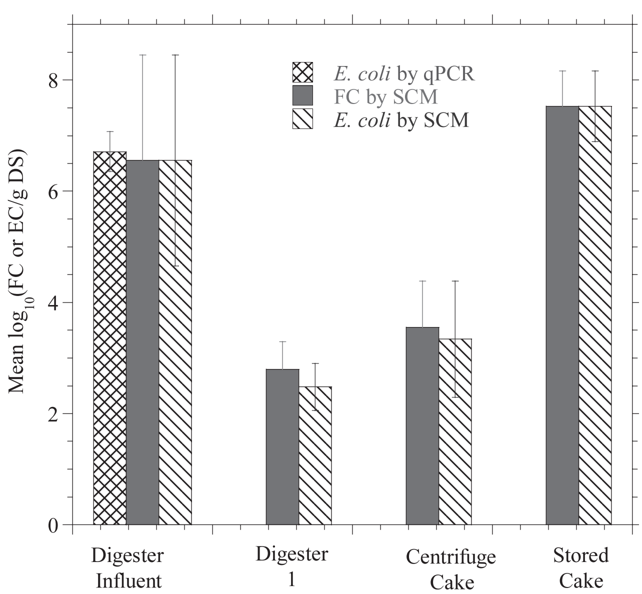

Figure 7—Fecal coliform and *E. coli* density measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a temperature-phased anaerobic digestion (TPAD) process with high-solids centrifugation dewatering (error bars represent one standard deviation).

process, no sudden increase was observed after centrifuge dewatering, although an increase associated with regrowth was measured in the stored cake from the silos.

Mesophilic Digestion with Belt Filter Press Dewatering. The mesophilic digestion with BFP dewatering used two reactors in series. The first mesophilic reactor had an SRT of approximately 15 days, and the second reactor had an SRT of 10 to 15 days. Each stage operated at a temperature of 36 °C. Digested biosolids were discharged into a storage tank, which had an SRT of 7 to 14 days before being dewatered on a BFP. The fecal coliform and *E. coli* results for this process (Meso-2) are shown in Figure 10. The influent densities were in the typical range, and the first stage of digestion reduced the densities of fecal coliform and *E. coli* by approximately one order of magnitude measured by the SCM and qPCR. The second stage of digestion also reduced the densities by one order of magnitude as did the storage tank.

After BFP dewatering, no increase in the culturable densities were measured, although an anomalous increase in the qPCR density was measured. This increase likely was due to an error because in almost all cases, the qPCR density measured after dewatering was equal to or less than that measured before dewatering.

Mesophilic Digestion with Centrifuge Dewatering. The mesophilic digestion with centrifuge dewatering used conventional, single-stage, mesophilic anaerobic digestion with and SRT of 22 days and a temperature of 36 °C. Both high- and low-speed centrifuges were used for dewatering. During this trial, samples were collected only from the high-speed centrifuge. Figure 11 shows the fecal coliform and *E. coli* results from this testing (Meso-3). No sudden increase was observed after centrifuge dewatering, although, as discussed later, regrowth did occur after centrifugation as measured by *E. coli* and fecal coliform densities after 24 hours of storage.

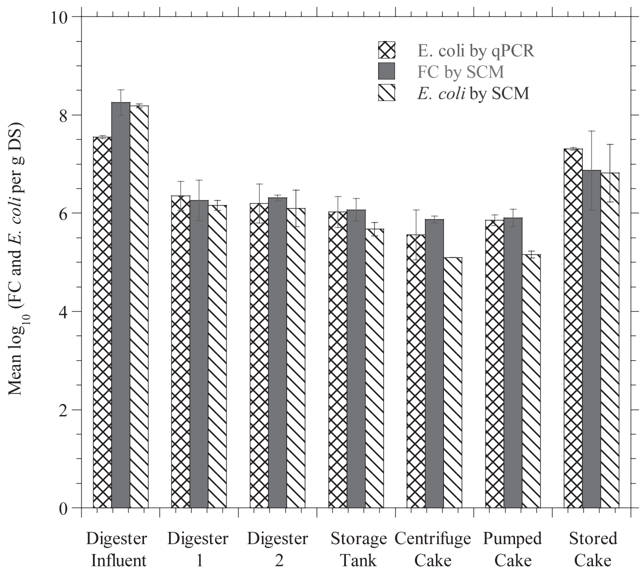

Figure 9—Fecal coliform and *E. coli* densities measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a mesophilic digestion process with high-solids centrifuge dewatering (error bars represent one standard deviation) (SCM = standard culturing method).

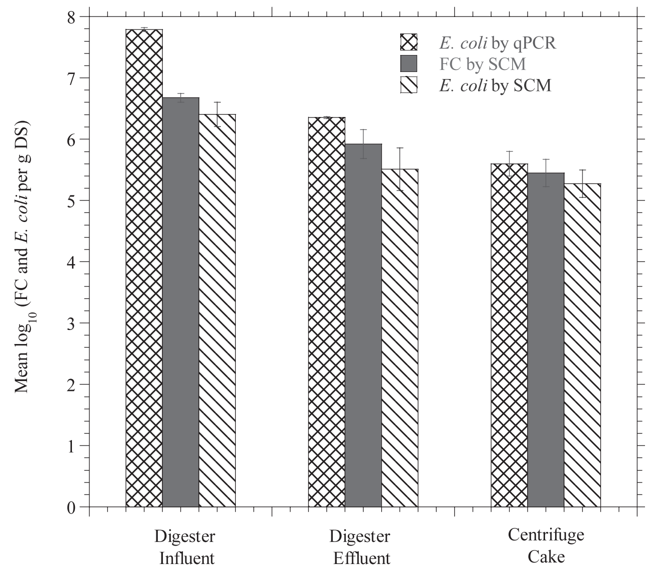

Figure 11—Fecal coliform and *E. coli* densities measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a mesophilic digestion process with centrifuge dewatering (error bars represent one standard deviation) (SCM = standard culturing method).

Evaluation of Regrowth from Thermophilic and Mesophilic Processes

For several of the plants, samples were collected from onsite storage. The processes that included centrifuge dewatering often showed some increased densities of indicator organisms during storage, which is thought to be attributed to regrowth. To further investigate regrowth, several sets of samples were collected in which the cake was stored in the laboratory, and the densities of the indicator bacteria were measured at regular intervals. The results from this testing is provided in the following sections.

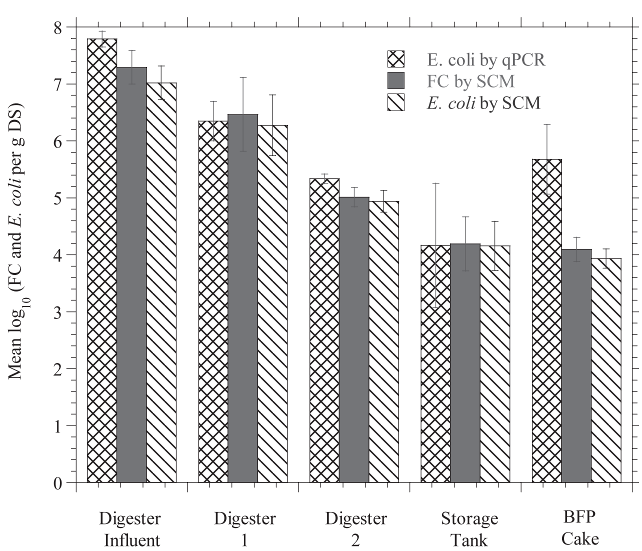

Figure 10—Fecal coliform and *E. coli* densities measured using quantitative polymerase chain reaction (qPCR) and standard culturing methods in a mesophilic digestion process with belt filter press dewatering (error bars represent one standard deviation) (SCM = standard culturing method).

Regrowth from Thermophilic Processes with Centrifuge Dewatering. Cake samples from both thermophilic digestion processes were stored in the laboratory, and fecal coliform and *E. coli* densities were measured at regular intervals using the SCM. The fecal coliform densities measured during storage are presented in Figure 12. For clarity, the *E. coli* data was not included in the graph, however, the *E. coli* and fecal coliform densities were equivalent for the majority of testing. This was observed for most of the samples, which indicates that fecal coliform are composed primarily of *E. coli*. The single-stage thermophilically digested cake showed a rapid increase in fecal coliform (and *E. coli* density; data not shown), during the first few days of storage, with a peak density near 10^8 fecal coliform/g dry solids. After reaching the peak, the fecal coliform density decreased during the next 60 days of storage. The prepasteurization process cake had a similar regrowth curve: densities increased and reached a peak after one day of storage and began to decrease after that. In comparison, no regrowth was measured in the cake from the multistage thermophilic process, further evidence that this process was able to inactivate the indicator bacteria through the process.

Regrowth from Mesophilic Processes with Centrifuge Dewatering. The fecal coliform densities measured during cake storage of the two mesophilic processes with centrifuge dewatering are shown in Figure 13 (Meso-1 and Meso-3). Similar to the thermophilic processes with centrifuges, the densities increased and reached a peak density within the first one to two days of storage and decreased after that. The peak densities reached levels between 7.5 and 9 $\log_{10}$/g dry solids, which are greater than typical raw, undigested sludges.

Regrowth from Mesophilic Processes with Belt Filter Press Dewatering. Cake samples were collected from the three mesophilic digestion processes with BFP dewatering (Meso-2, 4, and 5). The density of indicator bacteria did not increase as they did with the centrifuge cakes, as shown in Figure 14. Typically, the densities remained approximately

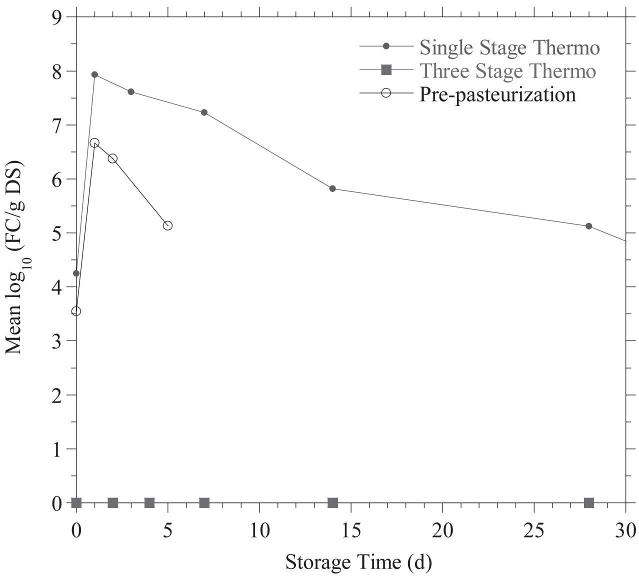

Figure 12—Fecal coliform density measured during storage of cake samples from the thermophilic processes.

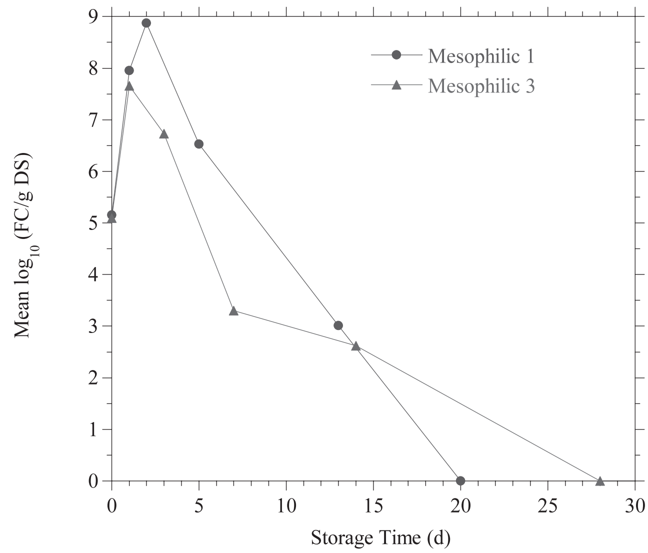

Figure 13—Fecal coliform density measured during cake storage mesophilic processes with centrifuge dewatering.

equivalent for several days followed by a slow decrease during further storage.

Discussion

Evaluation of Sudden Increase. Based on results of this study and the literature, it appears that sudden increase is more likely to occur in higher temperature processes that are greater than or equal to 50 °C. In the case of the plants with prepasteurization—TPAD, ATAD and single-stage thermophilic digestion—each had high solids centrifuges for dewatering and each experienced some level of sudden increase from 1 to 4 orders of magnitude. The multistage thermophilic process, however, did not experience any sudden increase. The ATAD process with BFP dewatering did not experience sudden increase. The data agree well with the literature. Monteleone et al. (2004) showed that a pre-pasteurization process followed by mesophilic digestion and BFP dewatering did not experience sudden increase after dewatering. They did find, however, that two similar prepasteurization processes with centrifuge dewatering experienced sudden increase.

In contrast, the mesophilic digestion processes did not show statistically significant differences between the fecal coliform and *E. coli* measured before and after dewatering. This was true for both centrifuge and BFP dewatering processes. The results suggest that sudden increase was less likely to occur with mesophilic processes. Similar observations were reported by Flemming et al. (2009), who reported that three out of five mesophilic plants with centrifuge dewatering did not experience increased densities of *E. coli* or fecal coliform immediately after dewatering. The two plants in that study that did measure greater densities showed an increase of less than one order of magnitude. Similarly, Sylvester et al. (2008) performed a side-by-side dewatering trial using a BFP and centrifuge to dewater biosolids from an enhanced enzymic hydrolysis (EEH) process. They performed the trial over a six-day period and found that every sample of the centrifuge cake had greater *E. coli* densities when compared to the feed sludge and that every sample from the BFP had densities that were less than the feed sludge. The results from this study and the literature clearly demonstrate that both thermophilic digestion and centrifuge dewatering play a role in sudden increase.

According to the nonculturable hypothesis, the qPCR results for *E. coli* after digestion could be an indicator of the potential for sudden increase. In other words, the difference between the qPCR results and the SCM results after digestion could represent some fraction of potentially nonculturable bacteria. This difference could help predict the potential of sudden increase. Interestingly, the data from this study help support this theory. For example, the qPCR data for the thermophilic digestion processes are able to indicate the potential for sudden increase as shown by the difference between the qPCR and the SCM densities measured after digestion and before dewatering. In the case of the prepasteurization and the single-stage thermophilic plant, the qPCR densities were greater than the SCM densities. After the

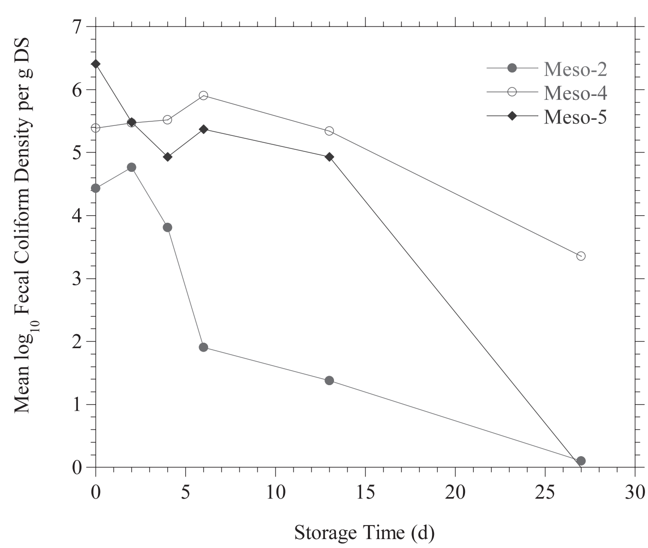

Figure 14—Fecal coliform density measured during cake storage from mesophilic processes with belt filter press (BFP) dewatering.

centrifuge dewatering process, the densities of fecal coliform and *E. coli* as measured by SCMs increased to levels similar to those measured by qPCR; however, the qPCR result did not change significantly between the two samples. The qPCR densities were below detection for the three-stage thermophilic and the TPAD process, so similar comparisons cannot be made.

In contrast, the qPCR densities measured in the mesophilic samples after digestion were similar to the SCM densities. This indicates there is less potential for sudden increase to occur because there is less potential for nonculturable bacteria. This was the case because after dewatering, no large differences were measured in the densities of indicator bacteria by the SCM.

The qPCR results are interesting because they are indicative of the potential for sudden increase to occur based on the testing in this study. The data show that the samples with significantly greater qPCR densities of *E. coli* compared to SCM densities before dewatering and following thermophilic treatment were most likely to experience sudden increase when centrifuges were used for dewatering.

Evaluation of Regrowth. The results show that regrowth occurs with both thermophilic and mesophilic processes and is more prevalent when centrifuge dewatering is used compared to BFP dewatering. Regrowth was observed in five out of six cake samples produced by centrifuge dewatering. None of the four cake samples produced by BFP dewatering had observable regrowth during the 24-hour storage period. The results also indicate that regrowth can occur in the absence of sudden increase. For example, the mesophilic processes(Meso-1 and Meso-3) with centrifuges for dewatering did not experience sudden increase, yet regrowth occurred during cake storage.

The results suggest that the dewatering process is a key factor affecting regrowth, with the centrifuge dewatering creating a cake with a significantly greater likelihood of regrowth. These results agree with the literature. For example, Flemming et al. (2009) reported that five out of five mesophilic digestion processes with centrifuge dewatering experienced increased densities of fecal coliform and *E. coli* during cake storage compared with one mesophilic process with BFP dewatering, which did not experience regrowth.

The prevalence of regrowth after centrifuge dewatering compared to BFP dewatering could be a result of the shear experienced by the cake during the former process (Murthy et al., 2004). The shear imparted to the cake may release substrate that supports growth of the bacteria during storage. It is interesting to compare the regrowth of fecal coliform and *E. coli* with the production of odors from centrifuged cake. Research has shown that the production of volatile organic sulfur compounds is linked to odors. Centrifuged cakes can produce high concentrations of organic sulfur compounds, which will peak within a few days of storage and then decrease over time (Higgins et al., 2006; Novak et al., 2006). This is similar to the pattern seen in this study for the regrowth of fecal coliform and *E. coli*. Cakes produced by BFP dewatering typically have very low odors and contain little organic sulfur; in this study, BFP cakes did not experience regrowth.

Researchers have hypothesized that the shear during centrifuge dewatering can release protein that supports the growth of bacteria and production of odorous compounds, which are byproducts of protein degradation (Higgins et al., 2008). It is also possible that the released substrate supports regrowth of the indicator bacteria and production of odorous compounds.

Research Implications

The research has several important implications. From a regulatory standpoint, increases in fecal coliform observed during sudden increase or regrowth can result in densities exceeding the U.S. EPA's requirements for Class A and Class B biosolids. For example, because Class A biosolids may be used without site restrictions, all Class A material must be tested to show that the microbiological requirements are met at the time that it is ready for use or disposal. In addition to process requirements, Class A biosolids must meet one of the following requirements: (1) density of fecal coliforms in the sewage sludge is less than 1000 MPN /g total solids (dry weight basis), or (2) density of *Salmonella* sp. bacteria in the sewage sludge is less than 3 MPN/4 g of total solids (dry weight basis) (U.S. Environmental Protection Agency, 2003). This research shows that the Class A process meets the fecal coliform requirement after thermophilic digestion, but that after dewatering, the solids no longer meet this requirement because of sudden increase. Similarly, mesophilic anaerobic digestion processes all met the Class B, Alternative 1 requirement of 2 million fecal coliform/g dry solids after digestion, but the mesophilic processes with centrifuge dewatering had densities greater than 2 million after storage of the cake because of regrowth. Meeting this requirement is not necessary under Class B, Alternatives 2 and 3.

If the sudden increase is a result of the resuscitation of bacteria that became nonculturable because of thermophilic treatment, then the results challenge U.S. EPA's current time-temperature requirements for achieving Class A biosolids for fecal coliforms. Because fecal coliform are indicators, however, it does not mean that the biosolids do not meet the criteria for *Salmonella*, which represent actual pathogens. The companion paper to this one explores sudden increase and regrowth of *Salmonella* and other pathogens and indicator bacteria (see Chen et al., 2011).

Similarly, the results suggest the need for changes in the current requirements for vector attraction reduction as noted in this research with mesophilic anaerobic digestion processes. One method for meeting federal and some state requirements for vector attraction reduction is to show that the anaerobic digestion process achieves a 38% volatile solids reduction (VSR) (U.S. Environmental Protection Agency, 2003). All the plants in this study met the VSR requirement, yet the biosolids still contained biodegradable organic matter that became more readily available after centrifuge dewatering, leading to available substrate that can support regrowth of bacteria.

Summary and Conclusions

Based on the research performed as part of this study, the following conclusions can be made:

- Sudden increase appears to be more prevalent in thermophilic processes that are followed by centrifuge dewatering compared to BFP dewatering.
- Sudden increase does not appear to be a significant concern for mesophilic processes with centrifuges or BFP dewatering.
- Regrowth has been observed for both thermophilic and mesophilic digestion processes, and is prevalent when these processes are coupled with high-solids centrifuge dewatering. When these processes are coupled with BFP dewatering, regrowth is less likely to occur.
- Regrowth can occur in the absence of sudden increase, as is the case with mesophilic processes.

- Quantitative PCR appears to be a good predictor for the potential of sudden increase to occur after high-solids centrifugation, which supports the ''reactivation'' or ''re-suscitation'' hypothesis to explain the sudden increase that occurs after centrifuge dewatering.
- Additional research is needed to examine a larger sample set of processes to gain a better understanding of the effects of digestion and dewatering on the reactivation and regrowth of indicator organisms.

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Do Alternate Bacterial Indicators and Pathogens Increase after Centrifuge Dewatering of Anaerobically Digested Biosolids?

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ABSTRACT: The objectives of this research were to evaluate the potential for sudden increase and/or regrowth of alternative bacteria as either indicators or pathogens after dewatering of thermophilic and mesophilically digested biosolids. The results showed that, in general, for thermophilic processes, even when a statistically significant ($p<0.05$) sudden increase and regrowth occurred for fecal coliforms, *Escherichia coli*, and *Enterococci*, it did not occur for *Salmonella* or *Aeromonas*. For the mesophilic process evaluated, sudden increase did not occur, but regrowth occurred for fecal coliforms, *E. coli*, *Enterococci*, and *Salmonella*. The results have implications for Class A and B biosolids regulations, as both fecal coliform and *Salmonella* are part of the regulatory limits. The results also suggest that the public health risks are minimal, as a result of the potential sudden increase and regrowth that may occur. *Water Environ. Res.*, **83,** 2057 (2011).

KEYWORDS: sudden increase, regrowth, *Salmonella*, fecal coliforms, biosolids.

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Introduction

Beneficial reuse of biosolids is an excellent example of a sustainable practice. The use of biosolids as a soil amendment closes the loop on the recycling of valuable nutrients and organic matter. Land application of biosolids has been shown to improve crop yields, improve soil carbon content, and even increase the drought resistance of plants (Lal, 2004; Zhang et al., 2009). Despite the value of land application, the use of biosolids can be controversial, and opposition can occur related to the odors associated with the practice and concerns related to public safety. The principle concerns related to public safety include the presence of metals and potential exposure to pathogens. The U.S. Environmental Protection Agency (U.S. EPA) (Washington, D.C.) has promulgated regulations to address these safety concerns. For example, limits on the quantity of different metals are included in the regulations.

In the case of pathogens, U.S. EPA has several sets of regulations. In general, biosolids are classified as Class A or Class B. Class B biosolids must meet the requirements of Processes to Significantly Reduce Pathogens (PSRP), which, in most cases, are met through a specified time–temperature regime achieved during pre- or post-digestion treatment or during digestion of solids (U.S. EPA, 2003). Another option is that the Class B biosolids could be monitored for the presence of fecal coliforms (FCs), and the geometric mean must be below 2 million FC/g dry solids. It is recognized that Class B biosolids could have pathogens present, and, to minimize risk to the public, site restrictions are used at the land-application site. For example, the site restrictions include measures to restrict public access and reduce potential vectors for transmission of pathogens until natural attenuation has minimized potential public safety risks (U.S. EPA, 2003).

In the case of Class A biosolids, the spirit of the law is that the biosolids will be essentially pathogen-free (U.S. EPA, 2003). To meet the Class A requirement, many facilities are moving toward thermophilic processes that treat the biosolids for a given time and temperature specified by the U.S. EPA requirements (U.S. EPA, 2003). Such processes included temperature-phased anaerobic digestion (TPAD), pre-pasteurization followed by mesophilic digestion, or simple batch thermophilic digestion. In addition to meeting the time–temperature requirement, the biosolids must be sampled and meet requirements of either less than 1000 most probable number (MPN) per gram of dry solids (DS) of FC or less than 3 *Salmonella*/4 g DS. It should be stressed that the regulations stipulate "or", not "and", which provides the utility with an option of the organism to monitor. Fecal coliforms are, of course, indicators of potential pathogens, while *Salmonella* are potential bacterial pathogens.

Research during the last few years has shown that fecal coliforms and/or *E. coli* densities can increase after certain combinations of digestion and dewatering processes (Chen et al., 2011; Cheung et al., 2003; Erdal et al., 2003, 2004; Gardner and Ormeci, 2010; Hendrickson et al., 2004; Higgins et al., 2007; Iranpour and Cox, 2006; McDonald, 2008; Monteleone et al., 2004; Qi et al., 2007; Sylvester et al., 2008). *E. coli* have been shown to be the main fecal coliform organism in digested biosolids. In Europe, the regulations on biosolids typically focus on *E. coli* rather than fecal coliform. The increases in indicator organisms have been characterized to occur as two different phenomena. In some cases, the densities can increase immediately after dewatering, and this has been termed *sudden increase* or *SI* (Chen et al., 2011). Storage of dewatered cakes for longer periods (hours to days) can result in additional increases, and

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Table 1—Summary of organisms enumerated in biosolids samples and methods used for their enumeration.

Organism	Indicator/Pathogen	Methods	Reference
Fecal coliforms	Indicators	U.S. EPA method 1680	U.S. EPA (2005a)
E. coli	Indicator, some potential pathogenic strains	U.S. EPA method 1680 with MUG according to APHA 9221F	U.S. EPA (2005a) APHA et al. (2005)
Enterococcus	Indicator, some potential pathogenic strains	APHA 9230B	APHA et al. (2005)
Salmonella	Potential pathogen	U.S. EPA method 1682	U.S. EPA (2005b)
Aeromonas	Potential pathogen	APHA 9260L	APHA et al. (2005)
Aerobic endospores	Used as bacterial tracer	APHA 9218B	APHA et al. (2005)

this increase has been termed *regrowth* (Higgins et al., 2007). The research has shown that sudden increase is more prevalent with thermophilic digestion processes coupled with centrifuge dewatering and that, in these cases, regrowth can occur after the sudden increase (Chen et al., 2011). The sudden increase associated with thermophilic, Class A plants often results in densities greater than the Class requirements of 1000 MPN/g DS, and the additional increases associated with regrowth can result in densities exceeding the Class B requirement for fecal coliforms (Chen et al., 2011). Mesophilic processes with centrifuge dewatering typically do not experience large sudden increase, but often have regrowth during cake storage. The regrowth can lead to densities of indicators much greater than the Class B requirements of 2 million/g DS.

The mechanisms for sudden increase and regrowth have been studied, and some researchers have suggested that sudden increase is the result of the resuscitation of bacteria that became reversibly non-culturable during thermophilic treatment, yet were not completely inactivated (Higgins et al., 2007), and others have suggested alternative mechanisms, such as contamination (Baddeley et al., 2009). Regrowth has been attributed to the release of substrate during dewatering, which supports growth of bacteria (Higgins et al., 2007), or the removal of inhibitory substances, which allows growth (Gardner and Ormeci, 2010).

No studies have examined the possible sudden increase and regrowth of actual bacterial pathogens and alternative bacterial indicators in both thermophilic and mesophilic processes with centrifuge dewatering. The objectives of this research were to examine the potential for sudden increase and regrowth of bacterial pathogens and alternative indicators in the biosolids. As a secondary goal, the research was aimed at also assessing the levels of actual pathogens and alternative indicators in biosolids both before and after treatment.

Alternative Indicators and Pathogenic Bacteria in Biosolids

There are a number of different bacterial pathogens and/or indicators that may warrant exploration based on the recommendations of the December, 2003 WERF Workshop on Indicators for Pathogens in Wastewater, Biosolids, and Stormwater and in the National Research Council's 2002 publication, *Biosolids Applied to Land: Advancing Standards* (National Academy of Science, 2002). U.S. EPA also has provided additional insight to bacteria that the project should include for testing (Meckes, 2006). A summary of the potential bacteria to examine is provided in Table 1. The rationale for including or excluding each of these bacteria in the testing is provided below. Interestingly, a number of these organisms have been reported to enter a reversible non-culturable state. As a result, they may be subject to sudden increase and/or regrowth after dewatering, similar to the indicator bacteria fecal coliform and *E. coli*.

Fecal Coliform. This group of organisms currently is used as one of the standards for Class A and Class B biosolids. In addition, they have been shown to experience sudden increase and regrowth after dewatering, as discussed previously. Therefore, collecting fecal coliform results at the same time as measuring other pathogens will provide some valuable information on their use as an indicator organism.

E. coli. *E. coli* are one of the most widely used fecal indicator organisms in the water and wastewater industry worldwide. Research has shown that sudden increase and regrowth can occur with *E. coli*. *E. coli* have been shown to be the main fecal coliform organism in biosolids, and often the fecal coliform and *E. coli* densities in biosolids samples are the same or very close (Chen et al., 2011; Fleming et al., 2009; Higgins et al., 2007). Similar to fecal coliform, collecting *E. coli* data will provide some valuable information on their use as an indicator organism, and they also provide a specific target for enumeration using molecular techniques, such as quantitative polymerase chain reaction (qPCR).

Enterococci. This genus of bacteria is found in the intestinal tract of all warm-blooded animals, which includes humans. They are more resistant to thermal inactivation than fecal coliforms (Gantzer et al., 2001, Viau and Peccia, 2009) and have been considered as an alternative indicator to fecal coliforms in wastewater and a good candidate as an indicator for biosolids. This is currently the indicator organism used in the evaluating the microbiological quality of recreational waters. In addition, they are the leading cause of nosocomial infections, and several species are problematic, as a result of their antibiotic resistance (He and Jiang, 2005; Moellering, 1992). *Enterococcus faecalis* has been shown to become reversibly non-culturable and therefore may be able to resuscitate and regrow after dewatering, similar to the indicator bacteria fecal coliform and *E. coli* (Heim et al., 2002; Lleò et al., 1998, 2001; Pfeffer et al., 2006).

Salmonella spp. *Salmonella* is one of the principal pathogens of concern in biosolids and was included in the U.S. EPA 503 regulations. It can be present in raw wastewater and in sludges, although generally at low densities. It is used as one of the organisms for regulatory requirements related to Class A and Class B biosolids. *Salmonella* exposure typically is through contaminated foods, such as raw meats, poultry, and eggs, and can cause gastrointestinal distress including nausea, vomiting, diarrhea, cramps, and fever. *Salmonella* have been shown to become non-culturable with the ability to be resuscitated (Gupte et al., 2003; Reissbrodt et al., 2002).

Aeromonas spp. *Aeromonas* has been listed as an emerging bacterial pathogen. However, there is little data available on its

Table 2—Summary of plant process data for digestion and dewatering.

Plant	Digestion: Configuration: series/parallel	SRT	Temperature	U.S. EPA Class A or B	Dewatering
Pre-Past-1	Pre-pasteruization/ meso	1 hours/19 days	66/35°C	A	High-solids centrifuge
TPAD-1	Thermo/meso in series	15/20 days	58/36°C	A	High-solids centrifuge
Thermo-1	CSTR in parallel	15 to 20 days	55°C	B	High-solids centrifuge
Thermo-2	Four CSTRs in series	~18/1.5/1.5/1 day	55°C	A	High-solids centrifuge
Meso-1	Parallel	22 days	36°C	B	High-solids centrifuge

occurrence in biosolids. *Aeromonas* is associated with warm-blooded animals and is being considered by the U.S. EPA as a possible indicator of fecal contamination, although it is not considered a fecal bacterium (U.S. EPA, 2006). *Aeromonas* can cause diarrheal illness and non-intestinal infection, such as wound infections, septicemia, and endocarditis. Several researchers have reported that *Aeromonas hydrophilia* could enter a reversible viable but non-culturable state (Sun et al., 2000; Wai et al., 2000), although Rahman et al. (2001) reported results that showed that the non-culturable state was not reversible. Because the *Aeromonas* spp. can potentially become non-culturable, they represent a good target organism to examine for sudden increase and regrowth in biosolids. In addition, preliminary testing of the methodology for enumeration of *Aeromonas* appears to provide reproducible results in biosolids.

Aerobic Spore-Formers. Aerobic endospores are ubiquitous in biosolids, with densities reported of approximately 10^5 CFU/g dry weight. Meckes and Rhodes (2004) recently found that bacterial aerobic endospores and *Clostridium perfringens* endospores have similar densities in alkaline-treated biosolids and found that aerobic endospores are more resistant to lime treatment than *C. perfringens*. Also, because of the ease of analysis, bacterial aerobic endospores may be preferable to *C. perfringens* endospores for biosolids screening.

Methodology

Plant Information. A total of five wastewater treatment plants, four with thermophilic anaerobic process and one with mesophilic anaerobic process, were sampled for this research. All of the plants used centrifuge dewatering. Table 2 lists designations of plant numbers, digestion time and temperature, and reactor configuration (in series or in parallel). Prepast-1 was sampled three times over the course of approximately 5 months to evaluate possible changes over time that might occur at the same plant.

Sample Collection. For each sampling event, the undigested sludge feed, digested liquid biosolids just before centrifuge dewatering, and dewatered cake right after the centrifuge were collected for analysis. Figure 1 shows typical sampling points for each plant sampling. All sampling tools and containers were sterilized before sampling date, and aseptic techniques were used for sample collection. All collected samples were stored immediately in a cooler containing wet ice and shipped priority overnight to the Hoosier Microbiology Laboratory (HML) in Muncie, Indiana, for microbial analysis. Subsamples of the dewatered cake were stored at 35°C for an additional 24 hours, to evaluate bacterial regrowth. It should be noted that the rate and extent of regrowth will be affected by temperature, but, for the purpose of this study, 35°C was used. This temperature was used because other research has shown that storage piles of fresh cake can maintain their temperature for relatively long periods of time (Eschborn et al., 2006). For the extended regrowth study, a subset was sent to Bucknell University (Lewisburg, Pennsylvania) in a separate cooler, and sacrifice sub-samples were stored in sterile containers and incubated at 35°C.

Microbial Analysis. *Culturing Methods.* All bacterial analyses using culturing methods were performed at HML. The HML is a National Environmental Laboratory Accreditation Program (NELAP)-accredited laboratory that is involved in all aspects of microbiological testing and research. Triplicate samples were analyzed for each sampling location. The MPN of both fecal coliforms and *Salmonella* were determined following U.S. EPA methods 1680 and 1682, respectively (U.S. EPA, 2005a, 2005b, 2006). *Enterococci* were analyzed according to *Standard Method* 9230B (APHA et al., 2005) Aerobic endospores were enumerated using method 9218B (APHA et al., 2005). *Aeromonas* were analyzed using method 9260L, with a temperature of 80°C for 12 minutes, and using a pour plate approach instead of membrane filtration (APHA et al., 2005).

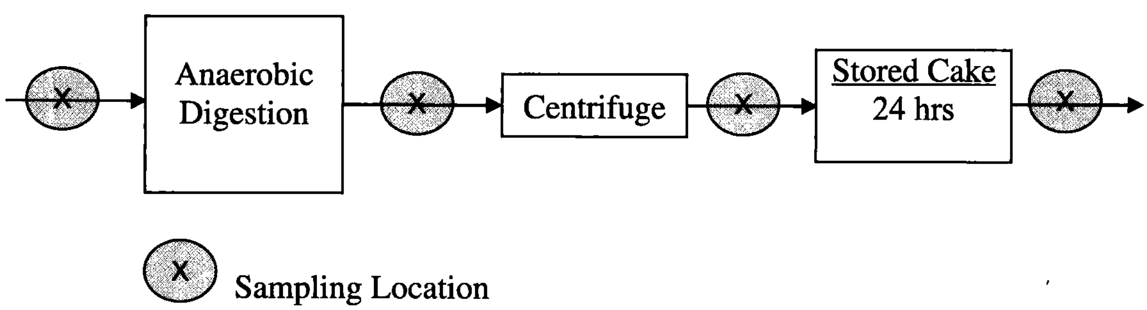

Figure 1—Typical sampling locations for bacterial testing at utilities.

Table 3—Summary of bacterial densities for Pre-Past-1 sampled in November, as measured by culturing methods. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by an asterisk, as described in the footnotes.*

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*Enterococci* (MPN/g DS)	*Aeromonas* (MPN/g DS)	*Salmonella* (MPN/4g DS)
Pre-past feed	7.66 ± 0.65*	7.05 ± 0.17	6.35 ± 0.34	3.30 ± 0.41	1.21 ± 0.03
Digester feed	<0.64	<0.64	1.27 ± 0.64	−0.02 ± 0.27	<0.30
Digester effluent	<0.98	<0.98	1.66 ± 0.71	2.33 ± 0.17	<0.60
Cake	3.97 ± 0.12*	3.97 ± 0.12*	3.79 ± 0.81	0.29 ± 0.31*	<−0.50

* Significantly different from digester effluent (p<0.05).

Molecular Methods. In addition to the culturing method, *E. coli* and *Enterococci* were enumerated using molecular methods. The *E. coli* enumeration was performed using real-time polymerase chain reaction (RT-PCR) already developed by the authors (Chen et al., 2006). *Enterococci* were enumerated by RT-PCR using an adaptation of the method of He and Jiang (2005). An MPN-PCR method for *Salmonella* enumeration also was used in two sample sets, in which the *Salmonella* PCR method was used to confirm the presence of *Salmonella* in addition to the culturing method.

Statistical Analysis. Triplicate analyses were performed for all samples collected, and data were log-transformed before any statistical analysis. If any of the replicate data were below the detection limit, the value was adopted at 50% of detection limit for the purpose of statistical analysis, and, when one of the triplicate data exceeded the detection range, the data point was not included in the analysis, because this value could vary considerably (Pitkanen et al., 2007). The data from the enumeration tests were first log-transformed, and the student's t-test was used to compare differences between the MPN and qPCR enumeration of *E. coli* and *Enterococci*, with significance reported at p<0.05 (Guardabassi et al., 2002; Hamilton et al., 2005). The same test also was used to compare digester effluent and centrifuge cake of the qPCR methods. For all others, the one-way analysis of variance (ANOVA) first was used to compare differences among digester effluent, centrifuge cake, and the 24-hour cake, followed by the least significant difference tests for paired comparisons, with significance reported at p<0.05.

In this paper, *sudden increase* is defined to occur if a statistically significant (p<0.05) increase in density is measured immediately after dewatering (in the centrifuge cake), compared with the sample taken before dewatering. Similarly, *regrowth* is defined as a statistically significant increase in density after 24 hours of storage when compared with the centrifuge cake taken immediately after dewatering.

Results

The sampling of the five different plants was performed over a 6-month period. The results from each sampling event are provided in the following sections.

Pre-Past-1. The first plant used pre-pasteurization followed by mesophilic digestion, and dewatering was performed on high solids centrifuges, as described in Table 2. The typical cake solids measured during the sampling events ranged between approximately 25 and 27%. This plant was sampled three different times to develop an understanding of how the densities of indicators and pathogens might change over time. The sampling was performed three times over a 6-month period, in the months of November, January, and April. The results from the first sampling in November did not include the full suite of analyses, and the results are summarized in Table 3. It is interesting to note that, after pre-pasteurization and digestion, the indicator densities of fecal coliform and *E. coli* were below the detection limit of the test; however, immediately following centrifuge dewatering, the fecal coliform and *E. coli* experienced a sudden increase of approximately 3 orders of magnitude. A similar sudden increase was observed for *Enterococci*, but not *Aeromonas* or *Salmonella.* No regrowth tests were performed for this sampling event.

The second sampling occurred 2 months later, in January, and included the full suite of testing, including qPCR for *E. coli* and *Enterococci* on the samples, and a 24-hour storage sample to measure for potential regrowth. The results are summarized in

Table 4—Summary of bacterial densities for Pre-Past-1 sampled in January, as measured by culturing methods and qPCR. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by letters, as described in the footnotes.

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*E. coli* (copies/g DS)	*Enterococci* (MPN/g DS)	*Enterococci* (copies/g DS)	*Salmonella* (MPN/4g DS)	*Aeromonas* (MPN/g DS)	Aerobic endospores (cfu/g DS)
Digester feed	7.30 ± 0.27[a]	7.26 ± 0.34	8.06 ± 0.03	6.93 ± 0.17	8.29 ± 0.08[b]	−0.07 ± 0.03	0.79 ± 0.24	4.73 ± 0.09
Digester effluent	0.73 ± 0.32	0.73 ± 0.32	5.90 ± 0.30[b]	2.39 ± 0.57	6.65 ± 0.12[b]	<0.20	1.72 ± 0.22	4.13 ± 0.11
Centrifuge cake	4.33 ± 0.30[a]	4.33 ± 0.30[a]	6.04 ± 0.09	3.99 ± 0.72[a]	6.86 ± 0.17[b]	<0.00	−0.18 ± 0.31[a]	5.13 ± 0.74
24-hour cake	6.74 ± 0.50[c]	6.74 ± 0.50[c]	Not available	6.67 ± 0.17[c]	Not available	<0.00	3.02 ± 0.74[c]	5.03 ± 0.51

[a] Significantly different from digester effluent (p<0.05).
[b] Significantly different from culturing method (p<0.05).
[c] Significantly different from centrifuge cake (p<0.05).

Table 5—Summary of bacterial densities for Pre-Past-1 sampled in April, as measured by culturing methods and qPCR. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by letters, as described in the footnotes.

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*E. coli* (copies/g DS)	*Enterococci* (MPN/g DS)	*Enterococci* (copies/g DS)	*Salmonella* (MPN/4g DS)	*Aeromonas* (MPN/g DS)	Aerobic Endospores (cfu/g DS)
Digester feed	6.88 ± 0.41[a]	6.25 ± 0.76	7.84 ± 0.03	5.92 ± 0.42	8.25 ± 0.09[b]	1.72 ± 0.37	1.89 ± 0.15	4.97 ± 0.03
Digester effluent	0.58 ± 0.52	0.58 ± 0.52	<5.45	1.86 ± 0.14	7.16 ± 0.17[b]	<0.34	2.15 ± 0.24	4.23 ± 0.05
Centrifuge cake	3.72 ± 0.61[a]	3.48 ± 0.37[a]	<5.46	3.63 ± 0.37[a]	6.96 ± 0.20[b]	<−0.05	0.25 ± 0.11[a]	5.10 ± 0.03
24-hour cake	7.40 ± 0.42[c]	6.96 ± 0.31[c]	Not available	5.62 ± 0.52[c]	Not available	<−0.05	0.84 ± 0.48	5.32 ± 0.12

[a] Significantly different from digester effluent ($p<0.05$).
[b] Significantly different from culturing method ($p<0.05$).
[c] Significantly different from centrifuge cake ($p<0.05$).

Table 4. Similar to the November sampling, a significant sudden increase ($p<0.05$) was observed for fecal coliform, *E. coli*, and *Enterococci*, and an increase was seen for aerobic endospores that was not statistically significant. It is interesting to note that the qPCR results for the *E. coli* and *Enterococci* densities before and after dewatering were not significantly different. No increase in Salmonella or *Aeromonas* was observed immediately after dewatering.

Regrowth was observed for fecal coliform, *E. coli*, *Enterococci*, and *Aeromonas*, but not for aerobic endospores or *Salmonella*. The results for the third sampling are shown in Table 5. The results were consistent with the previous sampling events and showed a sudden increase of indicators, but not *Salmonella*. The consistency of results confirms that sudden increase and regrowth are not necessarily a transient event and can occur over time at the same plant.

TPAD-1 Process. The TPAD-1 plant uses batch thermophilic digestion to meet the U.S. EPA time–temperature requirement for Class A biosolids, followed by mesophilic digestion before centrifuge dewatering. Previous reports had shown that sudden increase and regrowth of indicator bacteria was measured at this facility (Higgins et al., 2007). The results from the sampling event are shown in Table 6. After digestion, the densities of fecal coliform were below the 1000 MPN/g DS required by the Class A regulations. However, a non-significant ($p>0.05$) sudden increase of approximately 1 order of magnitude was observed for fecal coliform and *E. coli*; a significant ($p<0.05$) sudden increase of approximately 2 orders of magnitude was observed for *Enterococci*; and an increase of approximately 1 order of magnitude was observed for aerobic endospores. The density of *Aeromonas* decreased by approximately 1 order of magnitude after dewatering. A sudden increase was not observed for *Salmonella*. The *Enterococci* DNA densities measured by qPCR showed no differences before and after dewatering, although the culturing densities changed, similar to the results for the Pre-Past-1 facility. The *E. coli* DNA densities were below the detection limit after digestion and dewatering, preventing a similar comparison.

A significant ($p<0.05$) regrowth was observed in the cake after 24 hours of storage for fecal coliform, *E. coli*, *Enterococci*, and *Aeromonas*, but not for *Salmonella* or aerobic endospores.

Thermo-1 Process. The Thermo-1 process uses single-stage thermophilic digestion, with two completely stirred tank reactors (CSTRs) in parallel. The digestion temperature is 55°C, with a typical solids retention time (SRT) of approximately 15 to 20 days. Although the process is thermophilic, it is not operated to be a Class A process, because it does not use a batch configuration. Dewatering of the digested biosolids is performed on high-solids centrifuges, and the mean cake solids percentage of the samples was 33%.

The sampling showed a significant ($p<0.05$) sudden increase for fecal coliform, *E. coli*, *Enterococci*, and aerobic endospores, but not for *Salmonella*, as shown in Table 7. The qPCR results for *E. coli* were not statistically different, but were for *Enterococci*, when comparing samples before and after dewatering. Significant regrowth ($p<0.05$) also was observed for fecal coliform, *E. coli*, *Enterococci*, *Aeromonas*, and aerobic endospores, but not for *Salmonella*.

Thermo-2 Process. The Thermo-2 process comprises four complete-mix reactors in series. The first reactor has an SRT of

Table 6—Summary of bacterial densities for TPAD-1, as measured by culturing methods and qPCR. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by letters, as described in the footnotes.

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*E. coli* (copies/g DS)	*Enterococci* (MPN/g DS)	*Enterococci* (copies/g DS)	*Salmonella* (MPN/4g DS)	*Aeromonas* (MPN/g DS)	Aerobic endospores (cfu/g DS)
Digester feed	6.55 ± 1.90[a]	6.55 ± 1.90	6.71 ± 0.36	5.63 ± 0.46	7.29 ± 0.66	0.25 ± 0.35	2.74 ± 0.66	4.55 ± 0.53
Digester effluent	2.79 ± 0.50	2.48 ± 0.42	<4.90	2.02 ± 0.29	5.94 ± 0.19[b]	<0.04	1.22 ± 0.09	4.64 ± 0.18
Centrifuge cake	3.55 ± 0.83	3.34 ± 1.04	<4.90	4.14 ± 0.24[a]	6.08 ± 0.10[b]	<0.08	0.04 ± 0.17[a]	5.54 ± 0.20[a]
24-hour cake	7.33 ± 0.77[c]	7.33 ± 0.77[c]	Not available	5.26 ± 0.72[c]	Not available	<0.08	2.02 ± 0.42[c]	5.71 ± 0.31

[a] Significantly different from digester effluent ($p<0.05$).
[b] Significantly different from culturing method ($p<0.05$).
[c] Significantly different from centrifuge cake ($p<0.05$).

Table 7—Summary of bacterial densities for Thermo-1, as measured by culturing methods and qPCR. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by letters, as described in the footnotes.

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*E. coli* (copies/g DS)	*Enterococci* (MPN/g DS)	*Enterococcis* (copies/g DS)	*Salmonella* (MPN/4g DS)	*Aeromonas* (MPN/g DS)	Aerobic endospores (cfu/g DS)
Digester feed	7.52 ± 0.58[a]	7.42 ± 0.54	7.76 ± 0.05	6.19 ± 0.08	8.44 ± 0.1[b]	>3.22	1.19 ± 0.71	4.58 ± 0.05
Digester effluent	2.62 ± 0.26	2.41 ± 0.47	4.93 ± 0.61[b]	1.49 ± 0.20	5.83 ± 0.06[b]	1.27 ± 0.02	0.56 ± 0.40	4.22 ± 0.12
Centrifuge cake	4.52 ± 0.10[a]	4.35 ± 0.20[a]	6.14 ± 0.07[b]	3.74 ± 0.08[a]	6.32 ± 0.08[a,b]	<−0.10	−0.13 ± 0.19[a]	5.35 ± 0.04[a]
24-hour cake	7.62 ± 0.14[c]	7.62 ± 0.14[c]	Not available	6.87 ± 0.16[c]	Not available	<−0.10	0.86 ± 0.06[c]	5.84 ± 0.08[c]

[a] Significantly different from digester effluent ($p<0.05$).
[b] Significantly different from culturing method ($p<0.05$).
[c] Significantly different from centrifuge cake ($p<0.05$).

approximately 18 days, while the next three reactors have SRTs between 1 and 1.5 days. All reactors have a temperature of 55°C. The solids are dewatered on a high-solids centrifuge, and the mean cake solids of the samples was 31.5%.

The digester influent had typical levels of fecal coliform and *E. coli,* and the *Salmonella* densities were greater than other samples, with a mean density greater than 3.1 $\log_{10}$ MPN/g DS, as shown in Table 8. Interestingly, the fecal coliform and *E. coli* were all below the detection limit after digestion, and no sudden increase or regrowth was observed after dewatering of these indicators. Similarly, no sudden increase or regrowth was observed for *Enterococci, Salmonella,* or *Aeromonas.* An increase of approximately 1 order of magnitude was observed for the aerobic endospores, but no additional regrowth occurred during the 24 hours of cake storage. These results are similar to other sampling of this plant, which has consistently shown that sudden increase and regrowth of indicators did not occur (Chen et al., 2011; Higgins et al., 2007).

Meso-1 Process. The Meso-1 process uses conventional mesophilic digestion with a mean SRT of 22 days and operating temperature of 36°C to produce a Class B biosolids. The digester effluent is dewatered using high-solids centrifuges, with typical solids contents between 30 and 33%.

No significant ($p<0.05$) sudden increase was observed for any of the bacteria, except for the aerobic endospores (Table 9). Significant regrowth was observed for fecal coliform, *E. coli,* and aerobic endospores after 24 hours of storage. The qPCR results before and after centrifuging did not show any increases and were significantly lower after centrifuging.

Significant regrowth was observed for the indicators fecal coliform, *E. coli, Enterococci,* and aerobic endospores, and an increase in *Salmonella* of at least 0.65 $\log_{10}$ MPN/g DS was observed. A statistical analysis could not be performed for *Salmonella* because, after 24 hours of storage, all the densities were above the detection threshold of the test. No regrowth was observed for *Enterococci* or *Aeromonas.*

To further investigate regrowth, a regrowth study was performed in a second sampling of Meso-1 and included additional testing after 7 days of storage. This second sampling again showed regrowth of *Salmonella,* and the densities increased to greater than 2 $\log_{10}$ MPN/4 g DS for the 1- and 7-day samples, as shown in Figure 2. The results show that the occurrence of regrowth was consistent for both sampling events.

Discussion and Implications

Comparisons of Fecal Coliform and *Salmonella* Sudden Increase and Regrowth. Fecal coliform and *Salmonella* are important to compare, because they are both part of the biosolids regulations. The results from this research show that, for thermophilic processes that had sudden increase of indicators, such as fecal coliform and *E. coli,* no sudden increase was observed for the pathogen *Salmonella,* which is also part of the regulations. Similarly, no regrowth was observed for *Salmonella* in samples from any of the thermophilic processes, even when regrowth was observed for the other indicators. Similar results were reported by Iranpour and Cox (2006), who found that fecal coliform densities increased after centrifugation of thermally treated biosolids, but *Salmonella* did not increase. For the mesophilic processes, regrowth was observed in the cake for both the indicators and *Salmonella,* but not a sudden increase.

There are several possible reasons to explain the lack of sudden increase and regrowth of *Salmonella* when it occurred for fecal coliform and *E. coli* in the same process. The time–

Table 8—Summary of bacterial densities for Thermo-2, as measured by culturing methods and qPCR. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by letters as described in the footnotes.

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*E. coli* (copies/g DS)	*Enterococci* (MPN/g DS)	*Enterococci* (copies/g DS)	*Salmonella* (MPN/4g DS)	*Aeromonas* (MPN/g DS)	Aerobic endospores (cfu/g DS)
Digester feed	7.48 ± 0.12[a]	7.48 ± 0.13	8.11 ± 0.04[b]	6.14 ± 0.41	8.60 ± 0.21[b]	>2.18	2.83 ± 0.24	4.74 ± 0.14
Digester effluent	<1.02	<1.02	5.46 ± 0.42[b]	<1.02	7.01 ± 0.24[b]	<0.15	0.33 ± 0.31	4.53 ± 0.12
Centrifuge cake	<0.81	<0.81	<4.90	<0.81	6.79 ± 0.37[b]	<−0.10	<−1.00	5.47 ± 0.01[a]
24-hour cake	<3.81	<3.81	Not available	<3.81	Not available	<−0.10	<−0.22	5.50 ± 0.02

[a] Significantly different from digester effluent ($p<0.05$).
[b] Significantly different from culturing method ($p<0.05$).

Table 9—Summary of bacterial densities for Meso-1, as measured by culturing methods and qPCR. Values represent the mean log value of the densities plus or minus one standard deviation. Statistical differences are denoted by letters, as described in the footnotes.

Sample	Fecal coliform (MPN/g DS)	*E. coli* (MPN/g DS)	*E. coli* (copies/g DS)	*Enterococci* (MPN/g DS)	*Enterococci* (copies/g DS)	*Salmonella* (MPN/4g DS)	*Aeromonas* (MPN/g DS)	Aerobic endospores (cfu/g DS)
Digester feed	6.68 ± 0.07[a]	6.41 ± 0.20	7.79 ± 0.03[b]	5.40 ± 0.41	8.38 ± 0.06[b]	>2.30	2.11 ± 0.07	4.61 ± 0.06
Digester effluent	5.92 ± 0.24	5.51 ± 0.35	6.35 ± 0.02[b]	4.92 ± 0.02	7.72 ± 0.15[b]	1.55 ± 0.08	1.17 ± 0.40	4.66 ± 0.09
Centrifuge cake	5.45 ± 0.22[a]	5.27 ± 0.22	5.60 ± 0.20	5.23 ± 0.10	7.30 ± 0.14[b]	1.65 ± 0.01	0.83 ± 0.09	5.51 ± 0.10[a]
24-hour cake	6.94 ± 0.22[c]	6.94 ± 0.22[c]	Not available	5.60 ± 0.27	Not available	>2.30	0.83 ± 0.13	6.13 ± 0.02[c]

[a] Significantly different from digester effluent ($p<0.05$).
[b] Significantly different from culturing method ($p<0.05$).
[c] Significantly different from centrifuge cake ($p<0.05$).

temperature relationship for the destruction of organisms typically follows first-order decay and is affected by a number of parameters, such as heating rates, sample matrix, pH, concentration of ions, type of organism, specific strains of an organism, and initial concentration of the organism (Lang and Smith, 2008, Valdramidis et al., 2006; Wagner et al., 2009). When comparing *E. coli* and *Salmonella* in a sludge treatment process, all the environmental factors are equivalent, such as pH, sample matrix, and ion concentrations. In addition, the response of *E. coli* and *Salmonella* species to thermal treatment is fairly similar. For example, a study by Lang and Smith (2008) showed that the D-value, which is the time to achieve a 1-log reduction in viable organisms at a given temperature, was between 4.4 and 7.1 minutes for *E. coli*, while, for *Salmonella*, the D-values were between 3.6 and 7.7 minutes, which indicates that these bacteria have similar thermal inactivation rates. The main difference, then, is the initial densities of the bacteria. *E. coli* are present in raw sludge at much higher densities compared with *Salmonella*. For example, data from this study showed the *E. coli* to range between approximately 6.5 and 7.5 $\log_{10}$ MPN/g DS, while, for *Salmonella*, the densities ranged from below detection to values greater than approximately 3 $\log_{10}$ MPN/4 g DS. Although some of the *Salmonella* densities were above the values for the given dilution set, they were generally orders of magnitude lower in

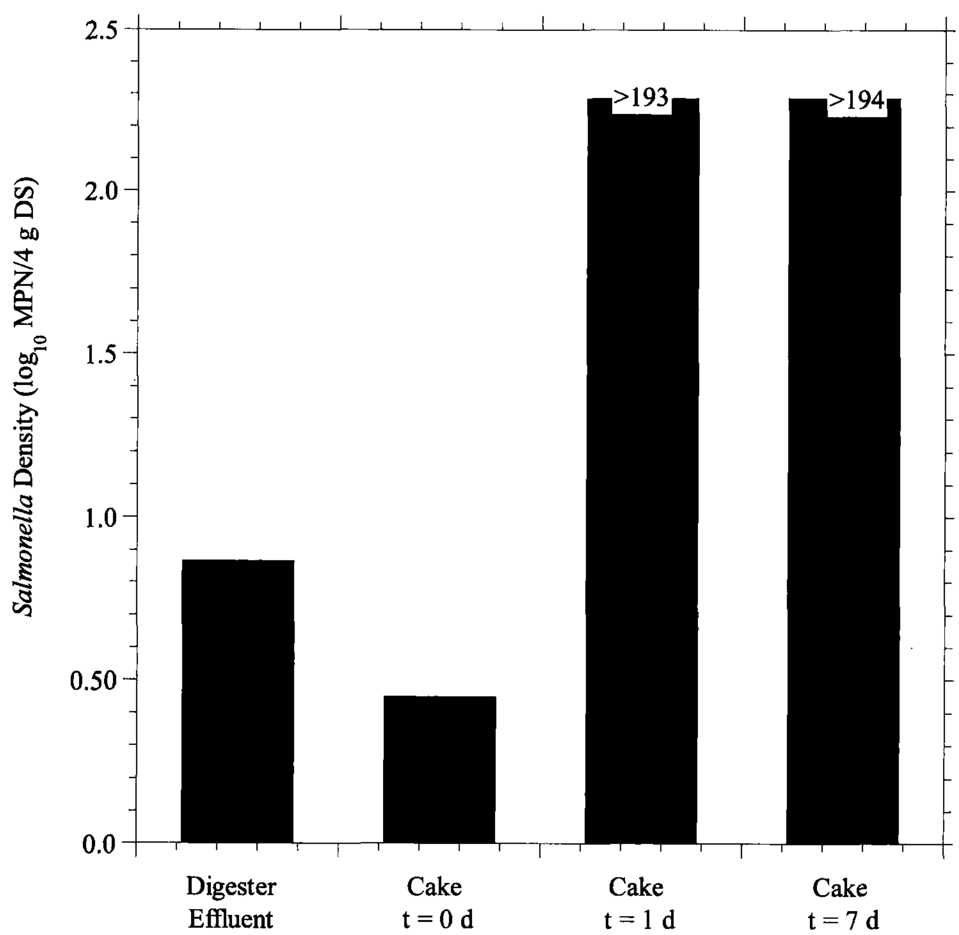

Figure 2—Regrowth of *Salmonella* from Meso-1 plant during cake storage.

the raw sludge when compared with fecal coliform or *E. coli* or the alternate indicator of *Enterococci*. This agrees well with other research. For example, Flemming et al. (2009) reported that *Salmonella* densities in raw sludge ranged from below detection to 3.53 $\log_{10}$ MPN/g DS, while fecal coliform ranged between 6.3 and 7.9 $\log_{10}$ MPN/g DS. The difference in the initial densities can be a factor, because first-order kinetics typically are used to describe inactivation rates of bacteria to thermal treatment.

If the goal of Class A thermophilic treatment is to achieve a 4-log reduction in the bacterial densities, this would lead to the elimination of *Salmonella*, while it potentially could leave several logs of *E. coli* in the sample. As a result, fecal coliform and *E. coli* appear to be conservative indicators.

Evaluation of Other Indicators and Pathogens. The other indicators and potential pathogens, such as *Enterococci* and *Aeromonas*, provide some interesting comparisons. The *Enterococci* results were similar to the fecal coliform and *E. coli* results, in terms of sudden increase and regrowth occurrence in the thermal processes. However, the *Enterococci* densities after thermophilic treatment typically were greater than the fecal coliform and *E. coli* densities, despite having lower densities in the raw sludges. Research has shown that *Enterococci* are more resistant to thermal treatment compared with *E. coli*, which could explain their greater densities. It is also interesting to note that the qPCR results were similar to those of *E. coli*, in terms of their relative densities compared with those from culturing methods before and after digestion. The qPCR densities after digestion typically were greater than the culturing methods, which indicated the potential for sudden increase to occur after digestion. Viau and Peccia (2009) reported similar results for *Enterococci* in thermally treated biosolids.

The *Aeromonas* results contrasted those of fecal coliform, *E. coli*, and *Enterococci*, in that their densities always decreased after centrifugation rather than increased. It is not clear why this would occur. Similar to *E. coli*, they are gram-negative, facultative organisms, but they are not naturally intestinal bacteria.

Similarly of interest is the increase up to 1 log measured for the aerobic endospores in four of the six sampling events for which they were measured. The aerobic endospores were used as a tracer through the system, as it was assumed that their densities would not change throughout the processes, as a result of their heat resistance. The consistent increase of up to approximately 1 log occurred for all the samples, and the reason for this is unknown. One possibility is that the conditions in the cake allowed for better sporulation of the aerobic endospores. Another possibility is that the cake from the centrifuges allowed easier mixing and dispersion, which increased enumeration through floc-breakup, although this mechanism had been discounted by several researchers (Cheung et al., 2003; Qi et al., 2007).

Regulatory Implications. From a regulatory point-of-view, the lack of sudden increase and regrowth of *Salmonella* allows thermophilic, Class A processes to meet the regulatory requirements, because monitoring results must show that either fecal coliform is below 1000 MPN/g DS or that *Salmonella* is below 3 MPN/4 g DS (U.S. EPA, 2003). According to U.S. EPA, the goal of the Class A requirements is that pathogen densities are below the detection limit (U.S. EPA, 2003). As a result, it appears that the thermophilic processes sampled in this study would meet this goal and the Class A requirements, despite the sudden increase and regrowth of the indicator fecal coliform. Additional testing at the Pre-Past-1 facility showed that the digester effluent and digester cake were free of enteric viruses and helmith ova (data not shown), further supporting this conclusion.

For Class B processes that experience regrowth, and sometimes a limited sudden increase, the regulations could still be met through the PSRP alternative, which requires the use of a specific process, such as anaerobic digestion, that meets the time and temperature requirement (U.S. EPA, 2003). For example, use of an anaerobic digestion process with an SRT of 15 days and a minimum operating temperature of 35°C would meet the PSRP requirement and would not require monitoring of fecal coliforms (U.S. EPA, 2003). However, an alternative to meeting the Class B requirement is to monitor for fecal coliform density, and, for that alternative, the geometric mean of the densities must be below 2 million FC/g DS. In this case, regrowth would result in densities greater than the requirements, and alternatives would be needed to meet the requirements.

Public Health Implications. From a public health perspective, the results show that the intent of Class A processes to achieve a pathogen-free product appear to be met, despite potentially high densities of indicators that can occur after sudden increase and regrowth. U.S. EPA recognized that, for composted products, some residual fecal coliform can persist, even when actual pathogens, such as *Salmonella*, are eliminated (U.S. EPA, 2003), and this also may be the case for the thermophilically treated Class A biosolids. Recognizing this potential for composted biosolids was the reason that U.S. EPA allowed monitoring of either fecal coliform or *Salmonella*. As a result, the risks to public health appear to be minimal, because the product appears to be pathogen-free.

Similarly, for Class B biosolids, the public health risks resulting from sudden increase and regrowth appear to be minimal. Within the regulations, it is accepted that Class B biosolids will potentially contain pathogens. However, public health protection is achieved through restrictions in the usage of Class B biosolids. For example, U.S. EPA imposes site restrictions for the use of Class B biosolids, which restrict public access, animal grazing, and crops that can be grown on fields where Class B biosolids have been applied. The site restrictions are imposed for time periods that allow natural attenuation of pathogens that occur in the environment (U.S. EPA, 2003). As a result, the use of site restrictions would be the key factor that would minimize public health risks, and not pre-defined absolute densities of the organisms. In fact, the 2 million/g DS requirement was not based on a risk assessment, but on achievable reductions of the conventional technology for solids digestion and stabilization processes. The changes in levels of the bacteria resulting from regrowth would not greatly affect the risk models outlined by Pepper et al. (2006), and risks are likely to remain low, as described by other researchers (Brooks et al., 2005; Gerba et al., 2008).

It should be noted that the results from this study are limited to five different plants, although the results agree with the few other studies that have been reported. Additional testing is needed to further investigate these issues. This testing should include additional plants with different processes and multiple sampling events to further develop a database of bacterial densities in these processes.

Summary and Conclusions

The potential for alternative bacterial indicators and potential pathogens to exhibit sudden increase and regrowth after digestion and centrifuge dewatering of biosolids was examined. The evaluations included fecal coliforms, *E. coli*, *Enterococci*, *Salmonella*, *Aeromonas*, and aerobic endospores. Based on an evaluation of the results, the following conclusions were made:

- For thermophilic processes that experienced sudden increase and regrowth of the conventional indicators fecal coliform and *E. coli*, no sudden increase or regrowth was observed for *Salmonella*, the bacterial pathogen used for regulatory requirements of Class A biosolids in the United States.
- For thermophilic processes, *Enterococci* did show sudden increase and regrowth for processes that also had sudden increase and regrowth of fecal coliform and *E. coli*. However, *Aeromonas* did not increase after dewatering of the thermophilic or mesophilic processes.
- A significant sudden increase was not observed for any of the organisms enumerated from the mesophilic digestion, but regrowth did occur for fecal coliform, *E. coli*, and *Salmonella*.
- The results suggest that thermophilic digestion processes that are designed to meet Class A requirements using time and temperature appear to meet the spirit of the law, in that the pathogen levels in the product are below detection. In addition, because *Salmonella* also are part of the Class A regulations, the systems also met the letter of the law.
- Although regrowth of *Salmonella* occurred in the mesophilic biosolids, the public health risks appear low because of the site restrictions required as part of the Class B biosolids.

Credits

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