FINAL

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Conceptual Design Report

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

7 JULY 2021

Note: The Conceptual Design Report is a dynamic document that will change as conditions and information change. The Conceptual Design Report herein represents the decisions and conditions at the time it was published and is subject to change.

Addenda

Note: All addenda are attached to the end of the CDR.

1. Wet Electrostatic Precipitators (WESPs) dated December 3, 2021.

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1.1 PROJECT DESCRIPTION AND OBJECTIVES

At its two largest wastewater treatment facilities, Bissell Point Wastewater Treatment Facility (WWTF) and Lemay WWTF, the Metropolitan St. Louis Sewer District (MSD) uses incineration for its biosolids stabilization and disposal process. At both facilities, multiple hearth incinerators (MHI) installed in the 1960s (and upgraded at various times since) are used for incinerating sludge cake from the dewatering process.

At Bissell Point, six MHI incinerators were originally installed, but only four of the incinerators remain in service with two that are off-line and no longer operational or permitted. At Lemay, four MHI incinerators were originally installed, but only three remain in service with the fourth off-line and no longer operational or permitted.

The existing MHIs at both facilities have reached the end of their useful life. They require significant maintenance attention. Additionally, the 2016 Sewage Sludge Incineration Maximum Achievable Control Technology (SSI MACT) regulations state that once an existing incinerator has incurred maintenance and modifications with a total cumulative cost of over 50% of the original purchase cost of the incinerator unit, then that unit is no longer deemed “existing” and is considered “new”. A “new” incinerator, under the 2016 SSI MACT regulations, is subject to more stringent air emissions requirements. MSD had determined that any future investments to improve the MHIs may result in their being re-classified as “new.” Therefore, MSD has decided to replace the existing MHIs at each facility with new fluidized bed incinerators (FBIs).

New fluidized bed incineration systems will be constructed at both the Bissell Point WWTF and Lemay WWTF. Each system will include an incinerator reactor, heat exchangers, blowers, emissions control equipment, ash handling equipment, ductwork, controls, and associated items. Energy generation from heat recovery systems will not be included with the initial FBI construction, but space allocations and piping modifications to add this in the future will be provided.

New sludge dewatering processes will also be provided at both WWTFs. Centrifuges will be used to dewater a combined blend of primary sludge, WAS, and scum flow prior to incineration. Sludge cake will be conveyed from the dewatering centrifuges via screw conveyors and hydraulically driven piston pumps.

All new equipment and related systems associated with the new incineration and dewatering processes will be located in a new Solids Processing Building constructed at both Bissell Point and Lemay facilities. All existing incineration and dewatering equipment and buildings at each facility will be demolished and removed. The new Solids Processing Buildings will include truck receiving stations for sludge cake hauled from other facilities; and truck-loading stations for transporting sludge cake from these facilities to alternative locations.

Both facilities will be constructed under one project using a fixed-price design-build project delivery method. A design-build team will be selected based upon a technical scope of work and fixed price submitted by proposing design-build teams in response to a request for proposal issued by MSD. The fluidized bed incineration system will be pre-selected by MSD using a qualifications based selection process. As a part of the design-builder request for proposal process, the proposing design-build teams will work with the pre-selected FBI system supplier to include a scope of work and cost that they negotiate with them into their overall project scope and cost.

1.2 REGULATORY AGENCIES

Both the Bissell Point and the Lemay facilities are regulated by the Missouri Department of Natural Resources (MDNR). Additionally, MHI air emissions are permitted by the City of St. Louis for Bissell Point WWTF and by St. Louis County for Lemay WWTF.

1.3 PERMITTING

A number of permits at the federal, state and local levels will be required for the construction of new FBI facilities at Lemay WWTF and Bissell Point WWTF.

1.3.1 Federal Permitting Requirements

A Notice of Proposed Construction or Alteration may be required at both sites through the Federal Aviation Administration (FAA) if construction occurs of an object which has the potential to affect navigable airspace. The Design-Builder will own this permit and review periods are typically between 1-2 months.

1.3.2 State Permitting Requirements

Several permits are required through MDNR's Air Pollution Control program, Water Pollution Control program, and Waste Management program that are applicable to both sites. These permits include:

Table 1-1 State Permitting Requirements

PERMIT	ANTICIPATED OWNERSHIP	GENERAL SCHEDULE	NOTES
MDNR Air Pollution Control			
Construction Permit	Owner holds Permit with Design-Builder (D-B) Input	4 months	
Part 70 Operating Permit	Owner holds Permit with D-B Input	20 months	A modification application must be filed within 12 months after commencing operation
MDNR Water Pollution Control			
Land Disturbance Stormwater General Permit	D-B	N/A	Permit may not be required since both Lemay and Bissell Point are CSO facilities
Wastewater Facility Construction Permit	Owner holds Permit with D-B Input	6 months	May not be required unless SRF funding is expected

PERMIT	ANTICIPATED OWNERSHIP	GENERAL SCHEDULE	NOTES
Modification to existing Missouri State Operating Permit	Owner holds Permit with D-B Input	N/A	Owner will handle modification to the existing permits
MDNR Waste Management			
Solid Waste Disposal or Processing Construction Permit	Owner holds Permit with D-B Input	6 months	
Sludge Incinerator Permit	Owner holds Permit with D-B Input	6 months	

1.3.3 Local Permitting Requirements

Because the Lemay and Bissell Point WWTFs are located in St. Louis County and St. Louis City, respectively, each have different local permitting requirements. Permits required through St. Louis County for the Lemay WWTF are listed below;

Table 1-2 Lemay WWTF Local Permitting Requirements

PERMIT	ANTICIPATED OWNERSHIP	GENERAL SCHEDULE	NOTES
St. Louis County Permits			
BMP Construction Permit	Design-Builder (D-B)	1 month	Lemay WWTF is a CSO facility and stormwater is written into the wastewater permit
Land Disturbance Permit	D-B	1 month	Also requires St. Louis DOT, Parking, Circulation and Lighting committee plan review
Building Permit	D-B	1 month	Also requires St. Louis DOT, Parking, Circulation and Lighting committee plan review
Electrical Permit	D-B	1 month	Also requires St. Louis DOT, Parking, Circulation and Lighting committee plan review
Mechanical Permit	D-B	1 month	Also requires St. Louis DOT, Parking, Circulation and Lighting committee plan review
Plumbing Permit	D-B	1 month	Also requires St. Louis DOT, Parking, Circulation and Lighting committee plan review
Demolition Permit	D-B	1 month	Also requires approval from St. Louis County Waste Management

PERMIT	ANTICIPATED OWNERSHIP	GENERAL SCHEDULE	NOTES
			and St Louis County Air Pollution Control

Permits required through St. Louis City for the Bissell Point WWTF are listed below;

Table 1-3 Bissell Point WWTF Local Permitting Requirements

PERMIT	ANTICIPATED OWNERSHIP	GENERAL SCHEDULE	NOTES
St. Louis City Permits			
BMP Construction Permit	Design-Builder (D-B)	1 month	Bissell Point WWTF is a CSO facility and stormwater is written into the wastewater permit
Building Permit	D-B	2 weeks	
Demolition Permit	D-B	2 weeks	Permit is valid for a term of 30 days and must be obtained by a demolition contractor certified by the City
Electrical Permit	D-B	2 weeks	Permit is applied for, approved and issued through online permitting system
Mechanical Permit	D-B	2 weeks	Permit is applied for, approved and issued through online permitting system
Plumbing Permit	D-B	2 weeks	Permit can either be applied for through the online permitting process or through City Hall
Fire Prevention Permit	D-B	2 weeks	

2.0 Existing Treatment Facilities

2.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

2.1.1 Facility and Site Description

The Bissell Point Wastewater Treatment Facility (WWTF) is a secondary treatment facility located adjacent to the Mississippi River north of downtown St. Louis, Missouri at 10 East Grand Avenue. The facility was originally constructed as a primary treatment facility and commenced operation in 1970. Two-stage secondary treatment facilities were added and started up in 1992 and 1993. The preliminary and primary treatment systems are designed to handle a flow of 350 million gallons per day (mgd). The secondary treatment facilities are designed for a peak flow of 250 mgd.

The Bissell Point WWTF provides wastewater treatment to the 89 square mile Bissell Point Service Area. Combined sewers serve an area of approximately 40 square miles located with the limits of the City of St. Louis, and various municipalities in St. Louis County that are located west and north of the City of St. Louis. The Bissell Point watershed also receives thickened undigested solids pumped into its collection system from the Coldwater WWTF. From the service area, two deep interceptor tunnels, one from north of the Bissell Point facility and one from the south of the facility, convey wastewater flows to the Bissell Point Pump Station, which is located on the Bissell Point WWTF site property. This pump station pumps flow into the WWTF.

Treatment at Bissell Point headworks consists of grit removal and comminution. Coarse bar rack screens are located within the Bissell Point Pump Station. Primary flow is aerated in pre-aeration tanks, clarified in primary clarifiers, and pumped to trickling filters. Flow from the trickling filters go through secondary clarifiers and is disinfected before being discharged to the Mississippi River. The facility previously utilized an activated sludge system following the trickling filters, however this has been out of service since 2006. Primary treated flows above 250 mgd are diverted around secondary treatment and combined with secondary effluent prior to discharge to the Mississippi River. Solids from the facility are co-thickened, dewatered with belt filter presses, and then fed to multiple hearth incinerators.

2.1.2 Utilities

The Bissell Point WWTF is served by:

Potable water – City of St. Louis
Natural Gas – Spire
Electricity - Ameren

2.1.3 Headworks and Primary Treatment Processes

Following the bar rack screens located at the Bissell Point Pump Station, the Headworks facilities consist of grit removal and comminution. Fine screens do not currently exist at the Bissell Point WWTF, but a project has been established for them to be designed and installed prior to the new fluidized bed incinerators coming on-line. Grit removal consists of six detritus tanks, each rated at

80 mgd. Wastewater then flows through 7 comminutors with 3/8” slots and each rated for 60 mgd. Typically, six comminutors are on-line at all times with one unit as a stand-by. However, the actual number of units in service depends upon plant flow conditions.

Primary treatment facilities consist of pre-aeration tanks followed by primary clarifiers. There are four 2-pass pre-aeration basins, each rated at 100 mgd. The basins are 152.5 feet long by 23 feet wide and a side water depth of 15-feet. Three positive-displacement rotary lobe blowers provide air to stainless steel coarse bubble tube diffusers in the basins.

Primary clarification is provided by eight (with six typically in operation) rectangular primary clarifiers with chain and flight solids-collection equipment. Each clarifier is rated at 60 mgd and is 312-feet long by 86-feet wide, with a side water depth of 13 feet.

2.1.4 Secondary Treatment Processes

Secondary treatment consists of trickling filters with final clarification. The facility is set up for activated sludge treatment process following the trickling filters, but this process has been out of service since approximately 2006.

There are six trickling filters with each filter rated at 50 mgd and being 132 feet in diameter with a 32 feet media depth. Flow from the trickling filters do not enter the now abandoned aeration tanks and goes directly to the secondary clarifiers.

Clarification is achieved by twelve secondary clarifiers each rated at 25 mgd. Each clarifier is 150 feet in diameter with a 16 feet side water depth.

Plant effluent disinfection is by chlorination using sodium hypochlorite. There are two facilities for the sodium hypochlorite feed. One facility provides disinfection of both secondary treated effluent downstream of the secondary clarifiers and primary treated flow that is diverted around secondary treatment. The primary effluent disinfection facility is no longer used. Final effluent is dechlorinated at the Effluent Pump Station by adding sodium bisulfate at the bisulfate building. Final discharge is to the Mississippi River.

2.1.5 Existing Solids Treatment and Handling Processes

The Bissell Point WWTF generates primary solids and trickling filter solids which are co-thickened in primary clarifiers to approximately 3% total solids. Grease wastes are trucked to the facility and unloaded to manholes upstream from the pre-aeration tanks. Grease and scum are collected from the primary clarifiers, pumped to scum concentrators and then conveyed to two sludge wells by progressive cavity pumps where they are combined with the co-thickened sludge pumped from the primary clarifiers.

Currently the combined solids are dewatered to approximately 25% to 30% total solids using belt filter presses; of which there are 15 units but not all are continually used. Filtrate from the belt filter presses is returned to the primary clarifiers. The dewatered cake from the presses is discharged onto belt conveyors. MSD's County facilities (Lower Meramec, Grand Glaize, and Fenton) haul solids by truck to Bissell Point WWTF and unload dewatered solids to Bissell's sludge receiving station, where the solids are pumped to the same dewatered cake belt conveyors. The belt conveyors convey the sludge cake to six equalization bins. Hydraulic piston pumps are used to feed the dewatered cake from the equalization bins to the MHIs. The exhaust gases from the incinerators are conditioned using wet scrubbers and the resultant ash from the MHI process is pumped (in slurry form) to two ash lagoons on site. After drying in the lagoons, ash is hauled for disposal to MSD's Prospect Hill Landfill.

2.1.6 NPDES Operating Permit

The Bissell Point WWTF operates under NPDES permit number MO-0025178.

2.1.7 Air Emissions

It is anticipated that MSD will be able to obtain a new air permit under the Minor New Source Review (NSR) program for the new fluidized bed incinerators constructed at Bissell Point WWTF.

Emissions from the new FBI system will be primarily regulated under 40 CFR 60, Subpart LLLL, for USEPA MACT 129 pollutants, while emissions of beryllium are regulated under 40 CFR 503. Emission limits for the new FBI system at Bissell Point WWTF are shown in the table below. A continuous emission monitoring (CEM) system will be provided for each of the incinerators. Each incinerator will include a stack with the CEM system immediately upstream of the stack and downstream of the induced draft (ID) fan.

Table 2-1 New FBI System Regulatory Emissions Limits

POLLUTANT	EMISSION LIMIT*
Oxides of nitrogen (NOx)	30 ppmvd
Carbon monoxide (CO)	27 ppmvd
Hydrochloric acid (HCl)	0.24 ppmvd
Sulfur dioxide (SO2)	5.3 ppmvd
Particulate matter (PM)	9.6 mg/dscm
PCDD/PCDF, TMB	0.013 ng/dscm
PCDD/PCDF, TEQ	0.0044 ng/dscm
Cadmium (Cd)	0.0011 mg/dscm
Lead (Pb)	0.00062 mg/dscm
Mercury (Hg)	0.001 mg/dscm
Beryllium (Be)	10 grams/24 hours
Fugitive emissions	5%

**MACT 129 concentrations are corrected to 7% O2*

2.2 LEMAY WASTEWATER TREATMENT FACILITY

2.2.1 Facility and Site Description

The Lemay Wastewater Treatment Facility (WWTF) is a secondary treatment facility located adjacent to the Mississippi River in unincorporated south St. Louis County at 201 E. Hoffmeister Avenue. The facility began operating in 1968 and has been upgraded several times, including adding activated sludge treatment facilities which were placed into service in 1985. The plant has a secondary treatment design capacity of 210 mgd and a peak wet weather capacity of 340 mgd.

The Lemay Service Area consists of approximately 120 square miles encompassing a portion of the City of St. Louis and a portion of south St. Louis County. The combined sewer area is approximately 35 square miles of the Lemay Service Area, while the remaining area is served by a separated sewer system. The majority of wastewater flow to the Lemay Service Area is collected by the River Des Peres Foulwater Interceptor (RDP FWI). The FWI originates at the western limit of the service area, generally follows the path of the River Des Peres, and transports both the separate sanitary and combined sewers to Lemay Pump Station No. 1, which is located near the Lemay WWTF. Running parallel to the Mississippi River, the Mississippi River Tunnel runs both north and south of the River Des Peres confluence with the Mississippi River. This tunnel collects flow in the areas along the River north and south of the Lemay WWTF and transports flow to Lemay Pump Station No. 3, which is located at the same property as Lemay Pump Station No. 1. Both Lemay Pump Station No. 1 and Lemay Pump Station No. 3 convey flow to the Lemay WWTF and include coarse screens prior to pumping.

The Lemay WWTF includes both dry weather and wet weather treatment processes; including grit removal, fine screening, and primary clarification for headworks and primary treatment. Secondary treatment consists of plug flow activated sludge and secondary clarification. Dry weather flow is disinfected through an ultraviolet (UV) system; and the wet weather flow is disinfected through chlorination prior to discharge to the Mississippi River. Waste activated sludge is co-thickened with primary sludge from both the dry weather and wet weather clarifiers in the dry weather primary clarifiers. Sludge from the dry weather primary clarifiers (which includes sludge pumped from the wet weather primary clarifiers) is pumped to a sludge receiving well, and then conveyed to belt filter presses for dewatering, prior to stabilization via the MHI's with ash conveyed to the ash lagoons and ultimately disposed of in the Prospect Hill Landfill.

2.2.2 Utilities

The Lemay WWTF is served by:

Potable water – Missouri American Water Company
Natural Gas – Spire
Electricity - Ameren

2.2.3 Headworks and Primary Treatment Processes

The dry weather process consists of four 75 mgd detritus grit tanks, five 60 mgd capacity fine screens with ¼” spacing, and eight primary clarifiers (six full width with two half size) that are 185 feet long, 80 feet wide, and 10 feet deep with chain and flight collection equipment.

The wet weather process consists of two 46 mgd detritus grit tanks, three 50 mgd capacity fine screens with ¼” spacing, and four 130-feet diameter, 12.6-feet side water depth primary clarifiers that are each rated at 21.5 mgd.

2.2.4 Secondary Treatment Processes

Activated sludge is accomplished through eight plug flow, complete mix aeration basins. Each tank is separated into four passes. Return activated sludge is fed into the first pass of each basin. Basin dimensions are 203 feet by 80 feet with a side water depth that varies between 15 and 17 feet. Six tanks have fine bubble ceramic diffusers and two tanks have fine bubble membrane diffusers. Aeration air is provided by four single stage centrifugal blowers (three constant speed and one variable speed). Typically, only the variable speed blower is used.

Final clarification is achieved with twelve 150 feet diameter clarifiers with a 12 feet side water depth. Typically, all twelve clarifiers are kept in service.

UV disinfection (vertical bulbs) is used for dry weather flow and sodium hypochlorite chlorination (together with sodium bisulfite for de-chlorination) provide disinfection prior to discharging to the Mississippi River.

2.2.5 Existing Solids Treatment and Handling Processes

Primary clarifier solids and waste activated solids (WAS) are co-thickened in the dry weather primary clarifiers to approximately 3% total solids. Scum is collected from the primary and secondary clarifiers, pumped to scum thickeners and then conveyed to three sludge wells and combined with the co-thickened primary and WAS flow.

Currently the combined solids are dewatered by belt filter presses to approximately 28% total solids. There are six belt filter presses, but not all are continually used. Polymer is used as part of the dewatering process. Filtrate from the belt filter presses is returned to the dry weather primary clarifiers. The dewatered cake from the presses is discharged to belt conveyors and screw conveyors, which convey it to two equalization basins. Belt conveyors are used to feed the dewatered cake from the equalization bins to four multiple hearth incinerators (one of which is no longer in service). MHI exhaust gases are treated using wet scrubbers; and the ash is pumped in slurry form to three ash lagoons located off site. After drying in the lagoons, ash is dredged and hauled for disposal to MSD’s Prospect Hill Landfill. Waste heat is recovered downstream from each MHI and conveyed to a waste heat boiler to generate medium pressure steam for building heat across the facility.

2.2.6 NPDES Operating Permit

The Lemay WWTF operates under NPDES permit number MO-0025151.

2.2.7 Air Emissions

It is anticipated that MSD will be able to obtain a new air permit under the Minor New Source Review (NSR) program for the new fluidized bed incinerators constructed at Lemay WWTF.

Emissions from the new FBI system will be primarily regulated under 40 CFR 60, Subpart LLLL, for USEPA MACT 129 pollutants, while emissions of beryllium are regulated under 40 CFR 503. Emission limits for the new FBI system at Lemay WWTF are shown in the table below. A CEM system will be provided for each of the incinerators. Each incinerator will include a stack with the CEM system immediately upstream of the stack and downstream of the ID fan.

Table 2-2 New FBI System Regulatory Emissions Limits

POLLUTANT	EMISSION LIMIT*
Oxides of nitrogen (NOx)	30 ppmvd
Carbon monoxide (CO)	27 ppmvd
Hydrochloric acid (HCl)	0.24 ppmvd
Sulfur dioxide (SO2)	5.3 ppmvd
Particulate matter (PM)	9.6 mg/dscm
PCDD/PCDF, TMB	0.013 ng/dscm
PCDD/PCDF, TEQ	0.0044 ng/dscm
Cadmium (Cd)	0.0011 mg/dscm
Lead (Pb)	0.00062 mg/dscm
Mercury (Hg)	0.001 mg/dscm
Beryllium (Be)	10 grams/24 hours
Fugitive emissions	5%

**MACT 129 concentrations are corrected to 7% O2*

3.0 Solids Quantities and Characteristics

Solids quantities for the Bissell Point WWTF and Lemay WWTF were developed as part of Technical Memorandum (TM) 4 Solids Quantities and Characteristics, which is included in Appendix D. Solids quantities were based on an evaluation of recent (2016 through 2019) solids data from the facilities with adjustments to account for:

- Re-allocation of solids currently hauled to Bissell Point that are produced in the Grand Glaize, Fenton, and Lower Meramec WWTFs from the Bissell Point WWTF to the Lemay WWTF
- Implementation of chemical phosphorus (ChemP) nutrient removal in the future
- Additional solids that will be captured and conveyed to WWTFs for treatment after future implementation of CSO improvements
- Process changes that will be implemented at the Lower Meramec WWTF, whose sludge will be conveyed (either by pumping or hauling) to the Lemay WWTF

3.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

3.1.1 Bissell Point Solids Quantities

A summary of current design solids quantities for the Bissell Point WWTF is shown in Table 3-1.

Table 3-1 Bissell Point WWTF Current Design Solids Quantities

Description	PS, dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	90.8	22.2	0.8	113.8	50.8	-
Normal, MM	124.7	23.8	-	148.5	50.9	1.3
Normal, PW	191.5	23.6	-	215.1	37.5	1.9
Flood Stage, MM	189.0	36.0	2.5	227.5	35.4	2.0
Flood Stage, PW	248.1	30.7	3.0	281.8	30.5	2.5

AA = Annual Average; MM = Max Month; PW = Peak Week; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day.

A summary of future design solids quantities for a 25-year planning period (through year 2045) for the Bissell Point WWTF is shown in Table 3-2.

Table 3-2 Bissell Point WWTF Future Design Solids Quantities

Description	PS[1], dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	111.8	22.2	0.8	134.8	42.9	-
Normal, MM	144.3	23.8	-	168.1	44.9	1.2
Normal, PW	223.2	23.6	-	246.8	32.6	1.8
Flood Stage, MM	211.6	36.0	2.5	250.1	32.2	1.9
Flood Stage, PW	266.6	30.7	3.0	300.3	28.7	2.2

[1] *Increased solids in the future are from chemical solids associated with ChemP nutrient removal.*

AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day.

3.1.2 Bissell Point Solids Characteristics

Physical characteristics of the cake solids currently produced at the Bissell Point WWTF are shown in Table 3-3.

Table 3-3 Bissell Point WWTF Solids Physical Characteristics

Item	Cake %TS	PS Fraction, %	VS Fraction, %
Average	29.7	79.4	50.8
Range*	23.8 - 38.0	52.7 - 90.8	32.0 - 66.0
Average w/o Flood Stage	29.2	79.2	52.4
Range* w/o Flood Stage	23.5 - 37.4	51.8 - 90.7	34.0 - 66.7
Average Flood Stage	33.4	No Data	39.1
Range* Flood Stage	26.1 - 39.7	No Data	29.0 - 58.0

*5th to 95th Percentile

3.2 LEMAY WASTEWATER TREATMENT FACILITY

3.2.1 Lemay Solids Quantities

A summary of current design solids quantities for the Lemay WWTF is shown in Table 3-4.

Table 3-4 Lemay WWTF Current Design Solids Quantities

Description	PS, dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Solids County Plants, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal Operation, AA	27.5	22.3	1.9	22.0	73.7	60.1	-
Normal Operation, MM	34.7	25.9	-	28.6	89.2	54.4	1.2
Normal Operation, PW	47.6	30.6	-	35.2	113.4	52.4	1.5
Flood Stage, MM	32.7	33.0	3.9	40.9	110.4	47.2	1.5
Flood Stage, PW	43.3	46.2	4.7	52.3	146.5	38.7	2.0

AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day.

A summary of future design solids quantities for a 25-year planning period (through year 2045) for the Lemay WWTF is shown in Table 3-5.

Table 3-5 Lemay WWTF Future Design Solids Quantities

Description	PS[1], dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Solids County Plants, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	56.2	22.3	16.3	19.8	114.6	56.4	-
Normal, MM	71.3	25.9		25.7	122.9	49.9	1.1
Normal, PW	82.4	30.6	-	31.7	144.7	52.6	1.3
Flood Stage, MM	69.6	33	26.8	35.8	165.2	50.8	1.5
Flood Stage, PW	83.6	46.2	33.4	48.7	211.9	43.6	1.9

[1] *Increased solids in the future are from chemical solids associated with ChemP nutrient removal*

AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day.

3.2.2 Lemay Solids Characteristics

Physical characteristics of the cake solids currently produced at the Lemay WWTF are shown in Table 3-6.

Table 3-6 Lemay WWTF Solids Physical Characteristics

Item	Cake %TS	PS Fraction, %	VS Fraction, %
Average	28.9	53.7	60.1
Range*	23.9 - 36.2	18.3 - 76.7	42.0 - 75.0
Average w/o Flood Stage	28.6	54.9	61.6
Range* w/o Flood Stage	23.8 - 35.8	21.7 - 76.8	45.0 - 75.0
Average Flood Stage	30.8	45.2	51.1
Range* Flood Stage	25.3 - 37.8	7.6 - 75.2	37.0 - 72.0

*5th to 95th Percentile

4.0 Sludge Handling and Dewatering Systems

New sludge handling and dewatering processes will be provided for both Bissell Point and Lemay WWTFs and will be located within each facility's new Solids Processing Building. The sludge handling system will consist of existing primary sludge pumps pumping thickened primary and secondary sludge to new blended sludge wells. Dewatering systems for each WWTF will consist of centrifuges to dewater sludge from the blended sludge wells to produce cake to feed into the FBIs.

Details of the existing solids thickening and dewatering systems and evaluation of dewatering system alternatives for the new dewatering facilities are included in Technical Memorandum TM 6, Dewatering Facilities and TM 19, Primary Sludge Pumping. Technical memorandum TM 15 includes information on sludge cake conveyance technologies. These TMs are included in Appendix D. Details of the new sludge handling and dewatering facilities are provided in this section. Refer to Appendix B and C for preliminary process flow diagrams for the sludge handling and dewatering process at each WWTF. The new dewatering system will be designed to process solids at the rates as indicted in Section 3.0 and will operate 24 hours a day, 7 days a week.

4.1 BISSELL POINT WWTF BASIS OF DESIGN

4.1.1 Primary Sludge Pumping

The new sludge processing facilities will connect to the existing primary sludge and scum pumping systems. However, system upgrades may be required to accommodate future solids conditions. TM 19 provides a summary of the constraints of this system.

Bissell Point currently co-settles and thickens primary sludge and waste secondary sludge (WSS) in Primary Clarifiers 1 thru 8. The combined sludge from the primary clarifiers is pumped to one of two blended sludge wells by recessed impeller primary sludge pumps. There are two primary sludge pumps per pair of primary clarifiers and all 8 pumps discharge to a common discharge line.

WAS is currently pumped to the head of the plant, and it is eventually co-settled and thickened with the primary sludge in the primary clarifiers and pumped to the blended sludge tanks. It is assumed that this strategy for disposal of WAS will continue in the future and that WSS conveyance does not need to be directly addressed as part of this project.

Typically, one pump operates at a time and the primary sludge pumps and tank withdrawal valves are cycled by timer. The plant recently installed a new microwave density meter to maintain thickened sludge within a set range withdrawn from the primary clarifiers. The pumps are variable speed and pump speed is adjusted to maintain a target level in the sludge blend tanks. Plant operations staff indicated that when solids thickness increases or when production exceeds the capacity of the incineration system, they artificially increase the thickened sludge withdrawal rate from the primary clarifiers and from the sludge blend tank, and bypass incineration to recycle excess flow to the head of the plant in order to keep sludge moving in the pipes to reduce the chances of clogging, as well as to avoid excessive thickening of sludge in the primary clarifiers.

In addition, as discussed in TM 19 there are limits with regards to sludge thickness that can be reliably handled by recessed impeller pumps. Plant operations staff reported that the pumps currently operate reliably, but there are historical sludge thickness data points well in excess of the maximum thickness recommended by the pump manufacturer. It was recommended keeping the sludge thickness below 10% for reliable sludge pumping.

In addition to the pumping system changes in solids loading rates, the discharge head of the existing primary sludge pumps will change in the future in order to discharge to new blended sludge wells located in the new Solids Processing Building. To verify existing sludge pumps capability, a preliminary pipe routing was developed, and the pumping system was modeled. Refer to TM 19, Primary Sludge Pumping Evaluation, for details of the pumping system evaluation. The model looked at high and low water surface elevations (WSE) at flow rates at peak week flood loading, and at different sludge thicknesses including minimum of 5%, average of 5.5% and maximum of 10% total solids.

Table 4-1 summarizes the results of the pump system modeling. Operating the existing pumps at reduced speeds between 87% to 96%, the existing pumps will meet the design primary sludge pumping requirements over the range of primary sludge thickness. The existing pumps can be reused, but the design builder will need to verify the existing pumps can meet design conditions based on their design.

Table 4-1 Primary Pump Modeling Results – Bissell Point WWTF

SLUDGE THICKNESS	FUTURE PS FLOW	MODELED (HIGH WSE)	MODELED (LOW WSE)
5% Sludge	1,000 gpm	1,000 gpm, 81-ft, 93% Speed	1,000 gpm, 73-ft, 89% Speed
5.5% Sludge	909 gpm	909 gpm, 81-ft, 91% Speed	909 gpm, 73-ft, 87% Speed
10% Sludge	500 gpm	500 gpm, 107-ft, 96% Speed	500 gpm, 99-ft, 93% Speed

Table 4-2 provides information to be used for the existing primary sludge pumps as part of determining if those pumps will pump thickened primary and WSS sludge from the primary clarifiers to the new Sludge Blending Bin located inside the new Solids Processing Building.

Table 4-2 Existing Primary Sludge Pump – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Primary Sludge Pumps	
Number of pumps	8
Type of pump	Recessed impeller
Manufacturer and model number	Wemco 4” Model C
Pump rated capacity and total head	800 gpm, 133 ft
Rated head, ft	105 ft
Pump motor size	75 hp
Provide with AFD	Yes
Power supply	480V, 60Hz, 3 phase

4.1.2 Scum System

Primary scum is currently pumped by one of 5 recessed impeller pumps. There are dedicated pumps for primary clarifier tanks 1 and 8 with one pump serving a pair of tanks for the other 6 tanks. The scum pumps discharge to a common discharge pipe, then scum flows through the plant tunnels to one of two scum concentrators located in the existing thickener building.

Secondary scum is currently pumped to upstream of the primary clarifiers, where it is removed along with the primary scum and pumped to the scum concentrators. It is assumed that this strategy for disposal of secondary scum will continue in the future and that secondary scum conveyance does not need to be directly addressed as part of this project. In addition to the scum collected, fats, oils, and grease (FOG), which is currently dumped ahead of the primary clarifiers, is also be collected as part of the scum system. The existing scum pumps will be reused to pump scum to the new scum concentrators in the new Solids Processing Building.

New scum concentrators, scum tanks with a mixer, concentrated scum pumps, and concentrated scum grinder will all be installed in the new Solids Processing Building. The concentrated scum will be discharged into the heated concentrated scum storage tank where the scum will be kept in a semi-liquid condition for pumping from the storage tank with scum pumps to either the blended sludge wells or to the incinerator feed pump inlet. Table 4-3 provides the basis of design for the scum concentrator system.

Table 4-3 Scum Concentrator System Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Scum Concentrator	
Number of units	2 (1 duty/1 standby)
Feed solids concentration range, % total Solids, dry	0.5 to 2.0
Discharge solids concentration range, % total solids, dry	25 to 50
Inflow rate, gpm	200
Tank minimum retention time, min	20
Number of units	2 (1 duty/1 Standby)
Mixer mixing system	Vertical, impeller
Type of concentrated scum pump	Progressing cavity with AFD
Pump rated capacity, gpm	30
Type of concentrated scum grinder	Inline
Grinder rated capacity gpm	30

4.1.3 Dewatered Sludge Cake Receiving Station

A new cake receiving station will receive dewatered sludge cake from trucks from other facilities and convey it to the incinerator feed system. The receiving station will consist of a cake receiving bin, including a grizzly screen and sliding frame, and cake pumps to pump the cake to the incinerator feed bins. Space will also be provided in the station for a future cake receiving system. Piston type pumps will pump the cake from the station to the incinerator feed bins. To reduce pressure loss in the cake discharge piping, lubricating pumps will be provided to pump plant effluent service water (SRW) through a slip ring to deliver a thin layer of lubrication water to the inside perimeter of the cake pipe. Table 4-4 provides the basis of design for the dewatered sludge receiving station. Technical Memorandum TM-7 provides additional information pertaining to the sludge cake receiving station.

Table 4-4 Dewatering Sludge Receiving Station Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Dewatered Sludge Cake Receiving Station	
Type of sludge	Municipal raw blended primary and secondary
Dewatered sludge feed rate, max wet tons per hour	25
Volumetric sludge feed rate range, gpm at 25% solids	24 to 120
Cake solids concentration range, % total solids, dry	25 to 35
Cake density range, lb per cubic foot	60 to 70
Cake Receiving Bin	
Number of units	1 cylindrical with cover and sliding frame discharge, coated carbon steel construction
Bin loading rate range, dry tons per day	27 to 134
Sliding frame drive	Hydraulic
Cake Receiving Pump Feeder	
Number of units	2 (1 duty, 1 standby)
Type of feeder	Twin screw, hydraulic or electric drive. Feeder oriented parallel to pump.
Cake Receiving Pump	
Number of units	2 (1 duty, 1 standby)
Type of pump	Piston, twin cylinder, single discharge
Capacity per unit, gpm	64 at 25% TS; 54 at 30% TS
Turndown, %	30% of capacity (20 gpm)

Cake solids concentration, by weight, %	25 to 35
Maximum discharge pressure, psig	1,500
Pump drive type	Hydraulic
HPU motor, hp	As determined by Design-Builder
Pipeline Lubrication Pump	
Number of units	2 (1 per cake pump), progressive cavity
Lubrication fluid	Plant effluent service water (SRW)

4.1.4 Blended Sludge Well

Blended sludge wells will be provided in the new Solids Processing Building for blending co-thickened primary sludge and waste activated sludge with concentrated scum. Each tank will be provided with a pumped mixing system utilizing mixing pumps and nozzles located inside the tank. Table 4-5 provides the basis of design for the blended sludge well and mixing system.

Table 4-5 Blended Sludge Wells and Mixing System Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Blended Sludge Wells	
Number	2
Minimum hydraulic retention time, minutes	30
Blended media	Co-thickened PS and WAS and concentrated scum
Solids concentration range, % total solids, dry	1.5 to 10
Blended Sludge Well Mixing System	
Type of mixing system	Pumped
Number of mixing nozzles per tank	2 plus 1 scum suppression.
Number of pumps	3 (2 duty/1 standby), horizontal centrifugal chopper with AFD
Pump rated capacity and total head	As determined by design-builder

4.1.5 Centrifuge Feed Pumps

Centrifuge feed pumps will be provided to send blended sludge from the blended sludge well to centrifuges for dewatering. A dedicated pump will be provided to each centrifuge. Table 4-6 provides the basis of design for the centrifuge feed pumps and grinders.

Table 4-6 Dewatering Centrifuge Feed Pumps Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Centrifuge Feed Pumps	
Number of pumps	8 (one per centrifuge)
Type of pump	Progressing Cavity with AFD
Pump rated capacity, gpm	300
Rated head, ft	As determined by design-builder
Centrifuge Feed Pump Grinder	
Number of grinders	8 (one per centrifuge)
Type of grinder	Inline
Grinder rated capacity gpm	300

4.1.6 Dewatering Centrifuges

Currently, sludge is dewatered using belt filter presses. The new dewatering system will use centrifuges for dewatering. Refer to TM 6, Dewatering Technology Evaluation, for details of the dewatering system evaluation.

Due to potential for increased grit loading to the centrifuges during peak solids production (flood events), measures to minimize centrifuge wear due to abrasive solids will be included in the centrifuge design. These include duplex stainless steel as the material of construction for the bowl and scroll flight and scroll wear protection using sintered tungsten carbide tiles from two flights before feed port through the solids discharge port.

The centrifuge specification will be written to allow both electric and hydraulic backdrive units as equals, along with listing specific acceptable centrifuge manufacturers of both technologies.

In order to provide adequate capacity for the future 2045 design solids load, the dewatering system design will include eight centrifuges. There will be one redundant centrifuge to handle flows during the future flood condition peak week solids loading condition; and two redundant centrifuges for the future maximum month solids loading rate under high river level conditions. Table 4-7 provides the basis of design for the dewatering centrifuges.

Table 4-7 Dewatering Centrifuges Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Dewatering Centrifuge	
Type	High solids, horizontal, solid bowl
Number of units	8
Solids loading rate, each, dry pph	3,500

Feed solids concentration, %TS, average (range)	5 (4 to 10)
Hydraulic loading rate, each, gpm	300
Bowl size range, inches	27.5 to 30
Minimum G-volume, gal	450,000
Polymer solution feed concentration, %	0.15 to 0.50
Maximum polymer dose, lb active/dt	65
Minimum dewatered cake solids, %TS	25

The sludge feed line to each centrifuge will be provided with connections to inject polymer into the feed sludge to improve dewatering. Each centrifuge will be provided with a chute to send dewater sludge cake to an incline conveyor. Also, each centrifuge will be provided with a centrate connection which will be piped to a drainage sump within the Solids Processing Building. From this sump, the centrate will be pumped to the plant influent conduit. SRW will be provided for centrifuge in place cleaning on normal shutdown and for flushing solids from the centrifuges following an emergency centrifuge stop.

4.1.7 Dewatered Sludge **Cake** Conveyors

Incline screw conveyors will transfer cake from the centrifuges to the incinerator feed bins. Each dewatering centrifuge will be provided with an incline conveyor. On centrifuge startup the centrifuge will produce slop sludge that will need to be sent to drain. The incline conveyor will operate in reverse, to allow the slop sludge to be drained from the lower end of the conveyor. Flushing water will be provided to the incline conveyors, to help flush slop down into the drain. Once a centrifuge is producing dewatered cake, the conveyor will stop reversing and the cake will be sent to one of the cross conveyors or directly into the incinerator feed bin. Electrically actuated slide gates located in the discharge chutes will open or close based on where dewater sludge is being sent. Table 4-8 provides the basis of design for the dewatered sludge conveyors.

Table 4-8 Dewatered Sludge Conveyors Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Centrifuge Discharge Conveyors	
Number of conveyors	8 (one per centrifuge)
Type of conveyor	Incline, shaftless screw, reversing
Volumetric capacity, cf/hr, each	340
Mass capacity, lb/hr, each	15,300
Diameter, inches	As determined by Design-Builder
Length, feet	As determined by Design-Builder
Dewatered Sludge Cross Conveyors	

COMPONENT	BASIS OF DESIGN
Number of conveyors	2
Type of conveyor	Shaftless screw,reversing
Volumetric capacity, cf/hr, each	680
Mass capacity, lb/hr, each	30,600
Diameter, inches	As determined by Design-Builder
Length, inches	As determined by Design-Builder

4.1.8 Dewatered Cake Pumping System

The dewatered cake pumping system will consists of incinerator feed bins with sliding frame type cake discharge. The cake from the feed bins will discharge directly into a twin screw feeder which will force the dewatered cake into the incinerator feed pump inlet. Piston type pumps will pump the cake to the incinerators, where electrically actuated valves will open allowing cake to be fed to the selected feed nozzle on each incinerator. To reduce pressure loss in the cake discharge piping, lubricating pumps will be provided to pump SWR through a slip ring to deliver a thin layer of lubrication water to the inside perimeter of the cake pipe. Table 4-9 provides the basis of design for the for the incinerator feed bins and pumps.

Table 4-9 Incinerator Feed Bins and Pumps Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Incinerator Feed Bin	
Number of units	4 cylindrical with cover and sliding frame discharge, coated carbon steel construction
Design loading rate, dry lb/hour	8,000 at 25% TS; 7,000 at 30%
Sliding frame drive	Hydraulic
Incinerator Feed Pump Feeder	
Number of units	8 (4 duty, 4 standby)
Type of feeder	Twin screw, hydraulic or electric drive, feeder orientation parallel to pump
Incinerator Feed Pump	
Number of units	8 (4 duty, 4 standby)
Type of pump	Piston, twin cylinder, single discharge
Capacity per unit, gpm	64 at 25% TS; 54 at 30% TS
Turndown, %	30% of capacity (20 gpm)
Cake solids concentration, by weight, %	25 to 35

COMPONENT	BASIS OF DESIGN
Maximum discharge pressure, psig	1,500
Pump drive type	Hydraulic
Pipeline Lubrication Pump	
Number of units	16 (2 per feed pump, 1 duty/1 standby), progressive cavity
Lubrication fluid	Plant effluent (SWR)
Design lubrication injection rate, gpm	As determined by Design-Builder

4.1.9 Polymer System

The polymer storage, make-up and feed systems will be designed for liquid mannich polymer based on the lifecycle cost savings as compared to emulsion polymer and the District's long-term successful use of mannich polymer. Bulk storage tanks will be provided with transfer pumps, which will also be used to recirculate the viscous mannich polymer. Batch tanks will be provided to dilute mannich polymer in order to reduce the viscosity. Polymer feed pump units will draw from the batch tanks, post-dilute the polymer solution down to feed concentration and deliver the polymer solution directly into the dewatering feed lines upstream of each centrifuge.

The mannich polymer system will be designed to accommodate batch polymer solutions of 0.5 to 1.0% mannich polymer by volume and provide a minimum of 15 minutes for dissolution of the mannich polymer. The mannich polymer systems will be designed to deliver polymer solution feed concentrations of 0.2 to 0.4% mannich polymer by volume for centrifuge dewatering.

Since mannich polymer storage life is short, one to three months before degradation of the polymer begins, bulk storage volume shall be limited. Bulk storage tanks to be sized to provide a minimum of 15 days storage of mannich polymer for average solids production conditions and a minimum of 7 days storage for peak solids production conditions. Bulk storage to accommodate mannich polymer solution concentrations of 4.0%.

The polymer make-up and feed system will be designed to accommodate emulsion polymer in order to provide flexibility to adapt to future changes in dewatering feed sludge characteristics and market conditions. The mannich polymer system basis of design are shown in Table 4-10.

Table 4-10 Polymer System Basis of Design – Bissell Point WWTF

POLYMER	BASIS OF DESIGN
Mannich Polymer	
Neat polymer active polymer solids concentration range, % by weight	4 to 6
Specific Gravity	1.01

POLYMER	BASIS OF DESIGN
Viscosity range, centipoise	25,000 to 40,000
Emulsion Polymer	
Neat polymer active polymer solids concentration range, % by weight	30 to 55
Specific Gravity	1.03
Viscosity range, centipoise	200 to 2,000
Polymer Feed	
Polymer feed solution concentration % by weight	0.5 to 1.0
Specific Gravity	1.00
Polymer Dosage as 100% active polymer	
Minimum, lbs active polymer / dry ton of solids	--
Average, lbs active polymer / dry ton of solids	20
Maximum, lbs active polymer / dry ton of solids	20

The basis of design for the polymer system equipment is shown in Table 4-11.

Table 4-11 Polymer System Equipment Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Polymer Bulk Storage Tank	
No of tanks	4 vertical, cylindrical, hinged lid, FRP
Hours of Storage	
At average solids load / average polymer dose	TBD
At maximum solids load / maximum polymer dose	TBD
Polymer Transfer Pump	
Number of pumps	2 (1 duty, 1 standby), progressing cavity
Fluid type	Neat mannich polymer
Solids concentration range, %	4 to 6
Mannich Pump	
Number of pumps	3 (2 duty, 1 standby), progressing cavity
Fluid type	Neat mannich polymer
Solids concentration range, %	4 to 6

COMPONENT	BASIS OF DESIGN
Polymer Blending Chamber	
Number of units	3 (2 duty, 1 standby), polymer blending units
Polymer capacity range, gph per blender	60 to 600
Dilution water (SWR) capacity range, gpm per blender	20 to 200
Polymer Batch Tank	
No of tanks	3 vertical, cylindrical, FRP
Tank volume, min, gal	3,000
Polymer Solution Feed Pump	
No of pumps	8 (1 per centrifuge), progressing cavity
Fluid type	Mannich polymer solution
Solids concentration range, %	0.5 to 1.0

4.2 LEMAY WWTF DEWATERING SYSTEM BASIS OF DESIGN

4.2.1 Primary Sludge Pumping

The new sludge processing facilities will connect to the existing primary sludge and scum pumping system. However, system upgrades may be required to accommodate future solids conditions. TM 19 provides a summary of the constraints of this system.

The Lemay WWTF currently co-settles and thickens primary sludge and secondary waste activated sludge (WAS) in Primary Clarifiers 1 thru 8. The combined sludge from the primary clarifiers is pumped to the blended sludge well by recessed impeller primary sludge pumps. Four of these pumps serve the east clarifier tanks and four serve the west clarifier tanks. There are common suction and discharge lines for both the east and west sides, and there is a normally closed crossover between the discharge force mains.

WAS from the secondary clarifiers is currently pumped to upstream of the primary clarifiers, where it is co-settled and thickened with the primary sludge and pumped to the blended sludge tank. It is assumed that this strategy for disposal of WAS will continue in the future and that WAS conveyance does not need to be directly addressed as part of this project.

Typically, one primary sludge pump on the east and one on the west operate at a time and the tank withdrawal valves are cycled by timer with times automatically adjusted by the control system to attempt to balance sludge blanket levels in the clarifier tanks. The pumps are recessed impeller variable speed type with and pump speed adjusted to maintain a target level in the sludge blend tank. Plant operations staff indicated that when solids thickness increases or when production exceeds the capacity of the incineration system, they artificially increase the thickened sludge withdrawal rate from the primary clarifiers and from the sludge blend tank, and bypass incineration to recycle excess flow to the head of the plant in order to keep sludge moving in the pipes to reduce the chances of clogging, as well as to avoid excessive thickening of sludge in the primary clarifiers.

Future solids loading to Lemay, which will increase due to the following items, is detailed in TM 9, Incinerator Design Criteria.

- Chemical phosphorus removal solids
- Increase in CSO solids due to system improvements
- Addition of solids from County plants (Grand Glaize, Fenton, and Lower Meramec). Options for receiving sludge from these County plants will be reviewed at a later time outside this project. The primary sludge pumping system for Lemay was analyzed both with and without the County plant solids.

In addition, as discussed in TM 19, there are limits with regards to sludge thickness that can be reliably handled by recessed impeller pumps. Plant staff reported that the pumps currently operate reliably, but pump operation could be affected by future changes in sludge thickness or sludge characteristics resulting from the introduction of County plant solids, the implementation of chemical phosphorus removal solids, or other factors.

In addition to the main primary clarifiers, the Lemay WWTF has four circular wet weather primary clarifiers (Primary Clarifiers 9-12) with 6 wet weather recessed impeller sludge pumps (one duty pump per tank with a swing pump per pair of tanks). When originally constructed, the common discharge pipe from the sludge pumps discharged to the common discharge pipe from the west primary clarifiers' sludge pumps. However, this caused operational problems when both sets of pumps were operating simultaneously so a new discharge to upstream of the main primary clarifiers was constructed. The original discharge to the west primary clarifiers' sludge discharge pipe remains, however the wet weather primary sludge pumps typically discharge to upstream of the main primary tanks where the wet weather sludge is co-settled with the main plant flow primary sludge.

It is assumed that the wet weather primary sludge pumps will discharge upstream of the main primary clarifiers in the future and that the pumps will not be modified or replaced as part of this project. When the location and configuration of the new dewatering facility is determined, the wet weather primary sludge pumps should be analyzed to determine if they are capable of pumping to the new sludge well as a backup strategy. If the pumps are not capable, the connection to the west primary clarifiers' sludge discharge pipe should be removed.

In addition to the pumping system changes due to increased solids loading rates, the discharge head of the existing centrifugal pumps will change in the future to discharge to new blended sludge wells located at the new Solids Processing building. To verify existing sludge pumps capability, a preliminary pipe routing was developed, and the pumping system was modeled. Refer to TM 19, Primary Sludge Pumping Evaluation, for details of the pumping system evaluation. The model looked at high and low water surface elevations (WSE) at flow rates at peak week flood loading, and at different sludge thicknesses including minimum of 3% and maximum of 7%.

Table 4-12, summarizes the results of the pump system modeling. Operating the existing pumps at reduced speeds between 64% to 92%, the existing pumps will meet the design primary sludge pumping requirements over the range of primary sludge thickness. The existing pumps can be reused, but the design builder needs to verify the existing pumps can meet design conditions based on their design.

Table 4-12 Primary Pump Modeling Results - Lemay WWTF

SLUDGE THICKNESS	FUTURE FLOW REQUIRED	MODELED (HIGH WSE)	MODELED (LOW WSE)
3% Sludge	1,176 gpm (w/ county plant solids)	588 gpm, 50-ft, 88% Speed 588 gpm, 42-ft, 82% Speed	588 gpm, 47-ft, 85% Speed 588 gpm, 39-ft, 79% Speed
	906 gpm (w/o county plant solids)	453 gpm, 35-ft, 73% Speed 453 gpm, 29-ft, 68% Speed	453 gpm, 32-ft, 70% Speed 453 gpm, 26-ft, 64% Speed
7% Sludge	504 gpm (w/ county plant solids)	252 gpm, 66-ft, 94% Speed 252 gpm, 56-ft, 87% Speed	252 gpm, 63-ft, 92% Speed 252 gpm, 53-ft, 84% Speed
	388 gpm (w/o county plant solids)	194 gpm, 63-ft, 91% Speed 194 gpm, 53-ft, 83% Speed	194 gpm, 60-ft, 88% Speed 194 gpm, 50-ft, 81% Speed

Table 4-13 provides information on the existing primary sludge pumps that will pump thickened primary and WAS sludge from the primary clarifiers to the new Sludge Blending Bin located inside the new Solids Processing Building.

Table 4-13 Existing Primary Sludge Pump – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Primary Sludge Pumps	
Number of pumps	8
Type of pump	Recessed impeller
Manufacturer and model number	Wemco 4” Model C
Pump rated capacity and total head	400 gpm, 133 ft
Rated head, ft	72 ft
Pump motor size	
Provide with AFD	Yes
Power supply	480V, 60Hz, 3 phase

4.2.2 Scum System

Primary and secondary scum both currently flow via gravity to the combined scum well located at the Blower and Thickener Building. From there, two Vaughan centrifugal chopper pumps convey the scum to DAF/thickener tanks for thickening. Only two of the six DAF/thickener tanks are operable, and they are currently operated as thickening tanks without adding air while skimming the concentrated scum from the tank water surface. From the DAF/thickener tanks, two Moyno progressing cavity pumps convey the concentrated scum through the plant tunnels to the blended sludge well.

Currently, only two of the six DAF/thickener tanks are operable and plant maintenance staff have repurposed parts from the other tanks to keep these two tanks functioning. As such, improvements to the existing scum thickening process are recommended to increase system reliability. New scum pumps will be installed to pump diluted scum directly to the new Solids Processing Building. This would allow construction of new scum concentrating equipment in the new Solids Processing Building and would minimize the required modifications at the Blower and Thickener Building. There is the potential to repurpose a portion of the current concentrated scum discharge piping that runs through the tunnels from the Blower and Thickener Building to the blended sludge well for the conveyance of dilute scum. This option would need to be evaluated further during subsequent design phase.

New scum concentrators, scum tanks with a mixer, concentrated scum pumps, and concentrated scum grinders will all be installed in the new Solids Processing Building. The system will intermittently accept and dewater surface skimmings collected from the surface of primary and secondary clarifiers. New scum pumps will be provided to pump scum to the new scum concentrators. The concentrated scum will be pumped into a heated concentrated scum storage tank where the scum will be kept in a semi-liquid condition for pumping from the storage tank with concentrated scum pump to either the blended sludge wells or to the incinerator feed pump inlet. Table 4-14 provides the basis of design for the blended sludge well and mixing system.

Table 4-14 Scum Concentrator System Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Raw Scum Pump	
Number of pumps	2 (1 duty/1 standby)
Type of pump	Recessed impeller with AFD
Location	Existing Blower and Thickener Building
Scum Concentrator	
Number of units	2 (1 duty/1 Standby)
Feed solids concentration range, % total Solids, dry	0.5 to 2.0
Discharge solids concentration range, % total solids, dry	25 to 50
Inflow rate, gpm	200
Tank minimum retention time, min	20
Mixer mixing system	Vertical, impeller
Type of concentrated scum pump	Progressing cavity with AFD
Pump rated capacity, gpm	30
Type of concentrated grinder	Inline

COMPONENT	BASIS OF DESIGN
Grinder rated capacity, gpm	30

4.2.3 Dewatered Sludge Cake Receiving Station

A new cake receiving station will receive dewatered sludge cake from trucks from other facilities and convey it to the incinerator feed system. The receiving station will consist of a cake receiving bin, including a grizzly screen and sliding frame, and cake pumps to pump the cake to the incineration feed bins. Space will also be provided in the station for a future cake receiving station. Piston type pumps will pump the cake from the station to the incinerator feed bins. To reduce pressure loss in the cake discharge piping, lubricating pumps will be provided to pump plant effluent water (PEW) through an inline slip ring to deliver a thin layer of lubrication water to the inside perimeter of the cake pipe. Table 4-15 provides the basis of design for the dewatered sludge receiving station. Technical Memorandum TM-7 provides additional information pertaining to the sludge cake receiving station.

Table 4-15 Dewatering Sludge Receiving Station Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Dewatered Sludge Cake Receiving Station	
Type of sludge	Municipal raw blended primary and secondary
Dewatered sludge feed rate, max wet tons per hour	25
Volumetric sludge feed rate range, gpm at 25% solids	24 to 120
Cake solids concentration range, % total solids, dry	25 to 35
Cake density range, lb per cubic foot	60 to 70
Cake Receiving Bin	
Number of units	1 cylindrical with cover and sliding frame discharge; coated carbon steel construction
Bin loading rate range, dry tons per day	27 to 134
Cake Receiving Pump Feeder	
Number of units	2 (1 duty, 1 standby)
Type of feeder	Twin screw, hydraulic or electric drive. Feeder orientated parallel to pump.
Cake Receiving Pump	
Number of units	2 (1 duty, 1 standby)
Type of pump	Piston, twin cylinder, single discharge

COMPONENT	BASIS OF DESIGN
Capacity per unit, gpm	64 at 25% TS; 54 at 30% TS
Turndown, %	30% of capacity (20 gpm)
Cake solids concentration, by weight, %	25 to 35
Maximum discharge pressure, psig	1,500
Pump drive type	Hydraulic
Maximum HPU motor, hp	As determined by Design-Builder
Pipeline Lubrication Pump	
Number of units	2 (1 per pump), progressive cavity
Lubrication fluid	Plant effluent water, PEW

4.2.4 Blended Sludge Well

Blended sludge wells will be provided in the new Solids Processing Building for blending co-thickened primary sludge and waste activated sludge with concentrated scum. Each tank will be provided with a pumped mixing system utilizing mixing pumps and nozzles located inside the tank. Table 4-16 provides the basis of design for the blended sludge well and mixing system.

Table 4-16 Blended Sludge Wells and Mixing System Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Blended Sludge Wells	
Number	2
Minimum hydraulic retention time, minutes	30
Blended media	Co-thickened PS and WAS and concentrated scum
Solids concentration range, % total solids, dry	1.5 to 10
Blended Sludge Well Mixing System	
Type of mixing system	Pumped
Number of mixing nozzles per tank	2 plus 1 scum suppression.
Number of pumps	3 (2 duty/1 standby), horizontal centrifugal chopper with AFD
Pump rated capacity and total head	As determined by design-builder

4.2.5 Centrifuge Feed Pumps

Centrifuge feed pumps will be provided to send blended sludge from the blended sludge well to centrifuges for dewatering. A dedicated pump will be provided to each centrifuge. Table 4-17 provides the basis of design for the centrifuge feed pumps and grinders.

Table 4-17 Dewatering Centrifuge Feed Pumps Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Centrifuge Feed Pumps	
Number of pumps	6 (one per centrifuge)
Type of pump	Progressing cavity with AFD
Pump rated capacity, gpm	300
Rated head, ft	As determined by design-builder
Centrifuge Feed Pump Grinder	
Number of grinders	6 (one per centrifuge)
Type of grinder	Inline
Grinder rated capacity gpm	300

4.2.6 Dewatering Centrifuges

Currently, sludge is dewatered using belt filter presses. The new dewatering system will use centrifuges for dewatering. Refer to TM 6, Dewatering Technology Evaluation, for details of the dewatering system evaluation.

Due to potential for increased grit loading to the centrifuges during peak solids production (flood events), measures to minimize centrifuge wear due to abrasive solids will be included in the centrifuge design. These include duplex stainless steel as the material of construction for the bowl and scroll flight and scroll wear protection using sintered tungsten carbide tiles from two flights before the feed port through the solids discharge port.

The centrifuge specification will be written to allow both electric and hydraulic backdrive units as equals, along with listing specific acceptable centrifuge manufacturers of both technologies.

In order to provide adequate capacity for the future 2045 design solids load, the dewatering system design will include six centrifuges. There will be one redundant centrifuge to handle flows during the future flood condition peak week solids loading condition; and two redundant centrifuges for the future maximum month solids loading rate under high river level conditions. Table 4-18 provides the basis of design for the dewatering centrifuges.

Table 4-18 Dewatering Centrifuges – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Dewatering Centrifuge	

COMPONENT	BASIS OF DESIGN
Type	High solids, horizontal, solid bowl
Number of units	6
Solids loading rate, each, dry pph	3,500
Feed solids concentration, %TS, average (range)	5 (3 to 10)
Hydraulic loading rate, each, gpm	300
Bowl size range, inches	27.5 to 30
Minimum G-volume, gal	450,000
Polymer solution feed concentration, %	0.15 to 0.50
Maximum polymer dose, lb active/dt	65

The sludge feed line to each centrifuge will be provided with connections to inject polymer into the feed sludge to improve dewatering. Each centrifuge will be provided with a chute to send dewatered sludge to an incline conveyor. Also, each centrifuge will be provided with a centrate connection and will be piped to a drainage sump within the Solids Processing Building. From this sump, the centrate will be pumped to the plant influent. PEW will be provided for centrifuge in place cleaning on normal shutdown and for flushing solids from the centrifuges following an emergency centrifuge stop.

4.2.7 Dewatered Sludge Cake Conveyors

Incline screw conveyors will transfer dewatered cake from the centrifuges to the incinerator feed bins. Each dewatering centrifuge will be provided with an incline conveyor. On centrifuge startup the centrifuge will produce slop sludge that will need to be sent to drain. The incline conveyor will operate in reverse, to allow the slop sludge to be drained from the lower end of the conveyor. Flushing water will be provided to the incline conveyors, to help flush slop down into the drain. Once a centrifuge is producing dewatered cake, the conveyor will stop reversing and the dewatered cake will be sent to one of the cross conveyors, or directly into the incinerator feed bin. Electric actuated slide gates located in the discharge chutes will open or close based on where dewatered sludge is being sent. Table 4-19 provides the basis of design for the dewatered sludge conveyors.

Table 4-19 Dewatered Sludge Conveyors Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
<u>Centrifuge Discharge Conveyors</u>	
Number of conveyors	6 (one per centrifuge)
Type of conveyor	Incline, shaftless screw, reversing
Volumetric capacity, cf/hr, each	340
Mass capacity, lb/hr, each	15,300

COMPONENT	BASIS OF DESIGN
Diameter, inches	As determined by Design-Builder
Length, inches	As determined by Design-Builder
Dewatered Sludge Cross Conveyors	
Number of conveyors	2
Type of conveyor	Shaftless screw, reversing
Volumetric capacity, cf/hr, each	680
Mass capacity, lb/hr, each	30,600
Diameter, inches	As determined by Design-Builder
Length, inches	As determined by Design-Builder

4.2.8 Dewatered Cake Pumping System

The dewatered cake pumping system will consists of incinerator feed bins with sliding frame type cake discharge. The cake from the feed bins will discharge directly into a twin screw feeder which will force the dewatered cake into the incinerator feed pump inlet. These feed pumps are piston type and will pump the cake to the incinerators, where electric actuated valves will open allowing cake to be fed to the selected feed nozzle on each incinerator. To reduce pressure loss in the cake discharge piping, lubricating pumps will be provided to pump PEW through a slip ring to deliver a thin layer of lubrication water to the inside perimeter of the cake pipe. Table 4-20 provides the basis of design for the for the dewatered sludge feed bins and pumps.

Table 4-20 Incinerator Feed Bins and Pumps – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Incinerator Feed Bin	
Number of units	3cylindrical with cover and sliding frame discharge, coated carbon steel construction
Design loading rate, dry lb/hour	8,000 at 25% TS; 7,000 at 30%
Sliding frame drive	Hydraulic
Incinerator Feed Pump Feeder	
Number of units	6 (3 duty, 3 standby)
Type of feeder	Twin screw, hydraulic or electric drive, feeder orientation parallel to pump
Incinerator Feed Pump	
Number of units	6 (3 duty, 3 standby)
Type of pump	Piston, twin cylinder, single discharge

COMPONENT	BASIS OF DESIGN
Capacity per unit, gpm	64 at 25% TS; 54 at 30% TS
Turndown, %	30% of capacity (20 gpm)
Cake solids concentration, by weight, %	25 to 35
Maximum discharge pressure, psig	1,500
Pump drive type	Hydraulic
Pipeline Lubrication Pump	
Number of units	12 (2 per feed pump, 1 duty/1 standby), progressive cavity
Lubrication fluid	Plant effluent water, PEW
Design lubrication injection rate, gpm	As determined by Design-Builder

4.2.9 Polymer System

The polymer storage, make-up and feed systems will be designed for liquid mannich polymer based on the lifecycle cost savings as compared to emulsion polymer and the District's long-term successful use of mannich polymer. Bulk storage tanks will be provided with transfer pumps, which will also be used to recirculate the viscous mannich polymer. Batch tanks will be provided to dilute mannich polymer in order to reduce the viscosity. Polymer feed pump units will draw from the batch tanks, post-dilute the polymer solution down to feed concentration and deliver the polymer solution directly into the dewatering feed lines upstream of each centrifuge.

The mannich polymer system will be designed to accommodate batch polymer solutions of 0.5 to 1.0% mannich polymer by volume and provide a minimum of 15 minutes for dissolution of the mannich polymer. The mannich polymer systems will be designed to deliver polymer solution feed concentrations of 0.2 to 0.40% mannich polymer by volume for centrifuge dewatering.

Since mannich polymer storage life is short, one to three months before degradation of the polymer begins, bulk storage volume shall be limited. Bulk storage tanks to be sized to provide a minimum of 15 days storage of mannich polymer for average solids production conditions and a minimum of 7 days storage for peak solids production conditions. Bulk storage to accommodate mannich polymer solution concentrations of 4.0%.

The polymer make-up and feed system will be designed to accommodate emulsion polymer in order to provide flexibility to adapt to future changes in dewatering feed sludge characteristics and market conditions. The mannich polymer system design criteria are shown in Table 4-21.

Table 4-21 Polymer System Design Criteria – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Mannich Polymer	
Neat polymer active polymer solids concentration range, % by weigh	4.0 to 6.0
Specific Gravity	1.01
Viscosity range, centipoise	25,000 to 40,000
Emulsion Polymer	
Neat polymer active polymer solids concentration range, % by weigh	30 to 55
Specific Gravity	1.03
Viscosity range, centipoise	200 to 2,000
Polymer Feed	
Polymer feed solution concentration % by weight	0.5 to 1.0
Specific Gravity	1.00
Polymer Dosage as 100% active polymer	
Minimum, lbs active polymer / dry ton of solids	--
Average, lbs active polymer / dry ton of solids	20
Maximum, lbs active polymer / dry ton of solids	20

The basis of design for polymer system equipment design criteria are shown in **Error! Reference source not found.**4-22.

Table 4-22 Polymer System Equipment Design Criteria – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Polymer Bulk Storage Tank	
No of tanks	4 vertical, cylindrical, hinged lid, FRP
Hours of Storage	
At average solids load / average polymer dose	TBD
At maximum solids load / maximum polymer dose	TBD
Polymer Transfer Pump	
Number of pumps	2 (1 duty, 1 standby), progressing cavity
Fluid type	Neat mannich polymer

COMPONENT	BASIS OF DESIGN
Solids concentration range, %	4 to 6
Capacity	TBD
Mannich Pump	
Number of pumps	3 (2 duty, 1 standby), progressing cavity
Fluid type	Neat mannich polymer
Solids concentration range, %	4 to 6
Capacity	TBD
Polymer Blending Chamber	
Number of units	3 (2 duty, 1 standby), polymer blending units
Polymer capacity range, min, gph per blender	60 to 600
Dilution water (PER) capacity range, min, gpm per blender	20 to 200
Polymer Batch Tank	
No of tanks	3 vertical, cylindrical, FRP
Tank volume, min, gal	3,000
Polymer Solution Feed Pump	
No of pumps	6 (1 per centrifuge) progressing cavity
Fluid type	Mannich polymer solution
Solids concentration range, %	0.5 to 1.0
Pump Capacity, gpm	2 to 20

5.0 Fluidized Bed Incineration

5.1 FLUIDIZED BED INCINERATION SYSTEM PROCESS EQUIPMENT

Each new fluidized bed incinerator (FBI) system to be installed in a new Solids Processing Building at Bissell Point and Lemay WWTFs consists of a fluidized bed reactor, sludge cake feed system, natural gas feed systems, fluidizing and purge air blowers, heat exchangers, air pollution control equipment, an exhaust gas induced draft (ID) fan, ductwork, a stack, and associated electrical and instrumentation and control systems. In the North American sewage sludge incinerator market, the standard approach has been for a single FBI system supplier to design and supply the bulk of these components to ensure that 1) the equipment and controls support the basic combustion process, 2) interconnected components are fully coordinated and compatible with each other, and 3) there is a single source of responsibility for overall system performance. This project will follow this approach with the identification of FBI System Supplier's scope of supply for the FBI system delineated in the project specifications.

5.2 BISSELL POINT WWTF FBI SYSTEMS BASIS OF DESIGN

Four fluidized bed incinerator systems will be installed at the Bissell Point WWTF. Installing four units will allow for three units sized for the future maximum month condition with the fourth unit available to process solids above the maximum month production and to provide capacity when units are out of service for maintenance. Design criteria for the Bissell Point FBI systems are provided in the following sections. Refer to Appendix B for preliminary process flow diagrams of the incineration process.

5.2.1 Fluidized Bed Reactor

The fluidized bed reactor is a refractory lined cylindrical vessel of varying diameters in which combustion of the sludge cake and auxiliary fuel (natural gas) occurs. Outside air is filtered and pressurized by a multi-stage centrifugal blower (fluidizing air blower) and pre-heated across the primary heat exchanger to approximately 1,200 °F with heat from the reactor exhaust gas. This fluidizing air enters the wind box at the base of the reactor and passes up through nozzles of a refractory arch or metal plate into the sand bed section. This air both fluidizes the sand bed and serves as the combustion air for sludge cake which is pumped into the sand bed. At approximately 1300°F in this bed, the volatile portion of this cake is quickly combusted with the exhaust gases rising to an overbed (freeboard) space where combustion of any unburned material is completed at elevated temperatures of approximately 1500°F. Exhaust gases then exit the top of the reactor through refractory lined ductwork in route to the primary heat exchanger.

Spray water nozzles are provided along the roof of the reactor to spray potable water (PRW) to dampen exhaust gases temperature in excess of 1600 °F which could damage the primary heat exchanger.

Each FBI will be provided with a preheat burner to provide heat during startup of the FBI. Each burner will be provided with a natural gas fuel train with safety and control valves for proper operation of the fuel system. Combustion air for the preheat burner will be supplied from the fluidizing air blower. Air and natural gas will be supplied to multiple gas injectors for each FBI. Air will also be provided from the fluidizing air blower and fuel from the natural gas delivery system skid. Each gas skid will be provided with a fuel gas train with safety and control valves for proper operation of the fuel system. An over-fire air system will also be installed to supply air from the fluidizing air blower to the overbed area.

Table 5-1 summarizes the basis of design criteria for the fluidized bed reactor at Bissell Point WWTF.

Table 5-1 Fluidized Bed Reactor Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Fluidized Bed Reactor	*Combustion of Sludge Cake*
Number	4 (1 per FBI system)
Nominal design capacity (dtpd each)	83
Firm nominal capacity (dtpd)	250
Installed nominal capacity (dtpd)	334
Bed outside diameter (ft)	15.7
Capacity at flood conditions (dtpd each)	92 (at 33.4%TS, 32.2 %VS)
Capacity at normal conditions (dtpd each)	75 (at 29.7%TS, 50.8%VS)
Preheat Burner	*Preheat FBI*
Number	4 (1 per FBI system)
Fuel type	Natural gas (NG)
Heat output, min, million Btu/hr	20.0
Fluidizing Air Blower	*Fluidizing and Combustion Air*
Number	4 (1 per FBI system)
Type	Multi-stage, centrifugal blower, variable speed
Design fluidizing air (scfm)	9,750
Minimum fluidizing air (scfm)	8,800
Purge Air Blower	*Purge air for NG nozzles and cooling air to expansion joint, sight glasses*
Number	5 (1 duty per FBI system/1 standby)
Type	Rotary lobe

5.2.2 Heat Exchangers

Exhaust gases from the fluidized bed reactor enter the top section of a shell-and-tube-type primary heat exchanger and then pass downward through the tubes and exit the bottom section. Filtered outside air from the fluidizing air blower enters the bottom of the primary heat exchanger and passes upward through the shell side around the tubes, countercurrent to the exhaust gases. The resultant preheated fluidizing air leaves the top side of the heat exchanger and is routed down into the reactor wind box. A bypass duct and damper are provided between the primary heat exchanger fluidizing air inlet and outlet and a damper is provided on the primary heat exchanger inlet for temperature control of the air entering the wind box.

Exhaust gases from the primary heat exchanger then enter the bottom section of a double shell type conditioning heat exchanger and then pass upward through the inner shell and exit the top section. Cleaned exhaust gases downstream of the wet scrubber pass downward in between the shells and run countercurrent to the exhaust gases. The resultant conditioned air is then routed to the granular activated carbon (GAC) adsorber system. A bypass duct and damper are provided between the conditioning heat exchanger exhaust inlet and outlet for temperature control of the air entering the GAC adsorber system.

Table 5-2 summarizes the basis of design criteria for the primary and conditioning heat exchangers at Bissell Point WWTF.

Table 5-2 Heat Exchangers Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Primary Heat Exchanger	*Pre-heating of Fluidizing Air*
Number	4 (1 per FBI system)
Type	Shell (refractory lined) and tube
Temperature Rating (°F)	1,850
Exhaust Gas Inlet Temperature (°F)	1,500
Pre-Heated Air Outlet Temperature (°F)	1,200
Conditioning Heat Exchanger	*Conditioning of Air Entering GAC Adsorber System*
Number	4 (1 per FBI system)
Type	Double Shell
Temperature Rating (°F)	1,600
Exhaust Gas Inlet Temperature (°F)	1,200
Conditioned Air Outlet Temperature (°F)	As coordinated with GAC adsorber system requirements

5.2.3 Wet Scrubber System

Exhaust gases from the heat exchangers are routed to the wet scrubber system to remove pollutants, including particulate matter (PM), metals (lead, cadmium, and beryllium), and acid gases (SO_2 and HCl). Exhaust gases first flow down through a refractory lined quench section where it is cooled with plant effluent water to adiabatic, saturated conditions; this section removes the larger sized PM. Cooled exhaust then flows upward through a series of impingement trays or a packed tower to condense out moisture; this section primarily removes the acid gases. Finally, the cooled exhaust flows upward through multiple fixed venturis with high pressure plant effluent water injected to control pressure drop; this section primarily removes fine PM and metals. The resultant ash and scrubber water form a slurry in the extended base of the wet scrubber which is then pumped to the ash lagoons.

Table 5-3 summarizes the basis of design criteria for the wet scrubber system at Bissell Point WWTF.

Table 5-3 Wet Scrubber System Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Quench Section	*Cooling Exhaust Gases*
Number	4 (1 per wet scrubber)
Type	Downflow, refractory lined
Plant effluent water (SRW), gpm	350
Impingement Tray Section	*Condensing Moisture*
Number	4 sets (3 trays per wet scrubber)
Type	Upflow, dual orifice impingement trays, extended base sump
Plant effluent water (SRW), gpm	800
Fixed Venturis Section	*Removing Fine PM and Metals*
Number	4 sets (12 to 16 venturi tubes per wet scrubber)
Type	Upflow with separately mounted booster water pumps
Plant effluent water (SRW), gpm	260 (boosted pressure)
Upper Tray Section	*Polishing*
Number of units	4 (1 tray per wet scrubber)
Type	Upflow, dual orifice impingement tray above venturis
Plant effluent water (SRW), gpm	50
Mist Eliminator Section	*Demisting for Downstream Air Pollution Control*
Number	4 (1 per wet scrubber)
Type	Upflow, one level of mesh style eliminator pads
Potable quality water (PW), (gpm)	50
Venturi Section Water Booster Pumps	*Venturis Pressure Drop Control*
Number	5 sets, (4 duty sets, 1 venturi inlet pump and 1 venturi throat booster water pumps per scrubber, 1 standby set)
Type	Vertical, multi-stage centrifugal constant and variable speed
Venturi section pressure drop	As required

5.2.4 Granular Activated Carbon (GAC) Adsorber System

A GAC adsorber system will be provided for each FBI system to clean exhaust gases downstream of the wet scrubbers. The GAC system will consist of a fine particulate filter, a high efficiency particulate air (HEPA) filter, startup heater skid, and GAC adsorber vessels. Filters will provide removal of additional fine particulate and metals (beryllium, lead and cadmium) to prevent fouling of the GAC beds.

Cleaned exhaust gases downstream of the wet scrubber are routed through the conditioning heat exchanger to heat the cleaned exhaust above the dew point; this temperature is necessary to prevent condensation on the GAC bed which impacts removal efficiency and can cause heating. The heated cleaned exhaust gases are then routed through the filters and then into one of two parallel adsorber vessels and down through one or two layers of GAC fixed bed media. The GAC is designed to remove mercury, dioxins, and furans by adsorbing the pollutants to the media. This media will need to be periodically disposed of in a hazardous waste landfill and replaced. In addition to upstream demisting, filtration, and heating, the GAC adsorber system will include a startup heater skid. The startup heater skid will consist of startup air fan and electric heater. The startup air is filtered and heated and sent to the GAC adsorber vessel to preheat the vessel bed before being brought into service. A bypass duct and damper will be provided around the GAC absorber system to bypass the exhaust gases directly to the stack

Table 5-4 summarizes the basis of design criteria for the GAC adsorber system at Bissell Point WWTF.

Table 5-4 GAC Adsorber System Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Fine Particulate Filter	*Remove fine particulate*
Number	4 (1 per FBI system)
Type	Filter roll with automatic advancement of filter
High Efficiency Particulate Air Filter	*Remove metals (lead, cadmium, beryllium)*
Number	8 (1 duty/1 standby per FBI system)
Type	HEPA filters in parallel for redundancy during replacement
Granular Activated Carbon Adsorber	*Remove Mercury, Dioxins and Furans*
Number	8 (2 duty in parallel per FBI system)
Type	Downflow
Cleaned Exhaust Inlet Temperature, °F	As required and coordinated w/conditioning heat exchanger
Startup Heater Skid	*Pre-Heat GAC Adsorber at Startup*
Number	4 (1 per GAC adsorber system)
Type	Blower with electric heater
Exhaust flow, acfm	As required

5.2.5 Induced Draft (ID) Fan and Exhaust Stack

Each FBI system will be provided with an induced draft (ID) fan and exhaust stack. The ID fan will pull exhaust gases from the FBIs, through heat exchangers, wet scrubber and GAC system and discharge the exhaust gases out to a free-standing stack located outside of the building. Exhaust flow will be controlled by a pneumatically actuated control valve located in the inlet of each induced draft fan. A continuous emission monitoring system (CEMS) will be provided to monitor exhaust gas constituents, including carbon monoxide and oxygen, and exhaust gas temperature. Table 5-5 summarizes the basis of design criteria for the induced draft fan and exhaust stack at Bissell Point WWTF.

Table 5-5 Induced Draft Fan and Exhaust Stack Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Induced Draft Fan	*Convey exhaust gas through air pollution control equipment*
Number	4 (1 per FBI system)
Type	Centrifugal fan, variable speed
Exhaust flow, acfm	As required
Exhaust Stack	*Exhaust gas discharge to atmosphere*
Number	4 (1 per FBI system)
Type	Vertical, cylindrical steel

5.2.6 Selective Non-Catalytic Reduction (SNCR) System

If required, a SNCR system could be added to each FBI systems to remove NOx and assure SSI MACT compliance. SNCR systems inject aqua ammonia directly into the freeboard section of the fluidized bed reactor to reduce NOx (NO and NO_2) into nitrogen gas and water vapor. SNCR systems include injection lances, distribution panels, chemical feed systems, and chemical storage tanks. NOx can also be controlled by temperature and excess air control, which given the low volatile content of the solids at Bissell Point WWTF, is likely sufficient for MACT compliance. As a result, an SNCR system will not be provided initially at Bissell Point; however, space will be allocated for a future installation if required and the system will be included as an add alternate from the FBI System Supplier as part of the Design-Build Proposal.

5.2.7 Acid Gas Removal

Removal of acid gas (SO_2 and HCl) is achieved in the wet scrubber system. Should the alkalinity of the plant effluent water added to the wet scrubber drop, additional alkalinity may be required for sufficient removal of the acid gas. This alkalinity is typically added to the system as liquid caustic (sodium hydroxide). As a result, a caustic storage and feed system is provided to inject caustic into the upper tray section of the wet scrubber if/when needed.

5.2.8 Contingency Operations

In the event the new FBI system at Bissell Point WWTF is not able to process the sludge cake produced at the plant (due to either mechanical issues, operational issues, or extremely high solids loading), valves installed in the cake piping downstream of the centrifuges and prior to incineration will divert the cake to a truck loadout station. Trucks can either haul cake to Lemay WWTF for processing or, if required, to an alternative disposal location (e.g. landfill).

5.3 LEMAY WWTF FBI SYSTEMS BASIS OF DESIGN

Three fluidized bed incinerator systems will be installed at the Lemay WWTF. Installing three units will allow for two units sized for the future maximum month condition with the third unit available to process solids above the maximum month production and to provide capacity when units are out of service for maintenance. Design criteria for the Lemay FBI systems are provided in the following sections. Refer to Appendix C for a preliminary process flow diagram of the incineration process.

5.3.1 Fluidized Bed Reactor

The fluidized bed reactor is a refractory lined cylindrical vessel of varying diameters in which combustion of the sludge cake and auxiliary fuel (natural gas) occurs. Outside air is filtered and pressurized by a multi-stage centrifugal blower (fluidizing air blower) and pre-heated across the primary heat exchanger to approximately 1,200 ^{o}F with heat from the reactor exhaust gas. This fluidizing air enters the wind box at the base of the reactor and passes up through nozzles of a refractory arch or metal plate into the sand bed section. This air both fluidizes the sand bed and serves as the combustion air for sludge cake (and natural gas) which is pumped into the sand bed. At approximately 1300^{o}F in this bed, the volatile portion of this cake is quickly combusted with the exhaust gases rising to an overbed (freeboard) space where combustion of any unburned material is completed at elevated temperatures approximately 1500^{o}F. Exhaust gases then exit the top of the reactor through refractory lined ductwork in route to the primary heat exchanger.

Spray water nozzles are provided along the roof of the reactor to spray potable water (PRW) to dampen exhaust gases temperature in excess of 1600 ^{o}F which could damage the primary heat exchanger.

Each FBI will be provided with a preheat burner to provide heat during startup of the FBI. Each burner will be provided with a natural gas fuel train with safety and control valves for proper operation of the fuel system. Combustion air for the preheat burner will be supplied from the fluidizing air blower. Air and natural gas will be supplied to multiple gas injectors for each FBI. Air will also be provided from the fluidizing air blower and fuel from the natural gas delivery system skid. Each gas skid will be provided with a fuel gas train with safety and control valves for proper operation of the fuel system. An over-fire air system will also be installed to supply air from the fluidizing air blower to the overbed area.

Table 5-6 summarizes the basis of design criteria for the fluidized bed reactor at Lemay WWTF.

Table 5-6 Fluidized Bed Reactor Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Fluidized Bed Reactor	*Combustion of Sludge Cake*
Number	3 (1 per FBI system)
Nominal design capacity (dtpd each)	83
Firm nominal capacity (dtpd)	165
Installed nominal capacity (dtpd)	249
Bed outside diameter (ft)	17.5

COMPONENT	BASIS OF DESIGN
Capacity at flood conditions (dtpd each)	91 (at 30.8 %TS, 50.8 %VS),
Capacity at normal conditions (dtpd each)	83 (at 28.9 %TS, 60.1 %VS)
Preheat Burner	*Preheat FBI*
Number	3 (1 per FBI system)
Fuel type	Natural gas (NG)
Heat output, min, million Btu/hr	20.0
Fluidizing Air Blower	*Fluidizing and Combustion Air*
Number	3 (1 per FBI system)
Type	Multi-stage, centrifugal blower, variable speed
Design fluidizing air (scfm)	9,950
Minimum fluidizing air (scfm)	8,950
High Pressure Water Pumps	*Cooling exhaust gases coming out of FBI*
Number	2 per FBI system(1 duty/1 standby)
Type	Regenerative turbine
Fluid	Potable water (PRW)
Flow rate, max, gpm	20
Purge Air Blower	*Purge air for NG nozzles and cooling air to expansion joint, sight glasses*
Number	4 (1 duty per FBI system/1 standby)
Type	Rotary lobe
Discharge pressure, min, psig	300

5.3.2 Heat Exchangers

Exhaust gases from the fluidized bed reactor enter the top section of a shell and tube type primary heat exchanger and then pass downward through the tubes and exit the bottom section. Filtered outside air from the fluidizing air blower enters the bottom of the primary heat exchanger and passes upward through the shell side around the tubes, countercurrent to the exhaust gases. The resultant preheated fluidizing air leaves the top side of the heat exchanger and is routed down into the reactor wind box. A bypass duct and damper are provided between the primary heat exchanger fluidizing air inlet and outlet and a damper is provided on the primary heat exchanger inlet for temperature control of the air entering the wind box.

Exhaust gases from the primary heat exchanger then enter the bottom section of a double shell type conditioning heat exchanger and then pass upward through the inner shell and exit the top section. Cleaned exhaust gases downstream of the wet scrubber pass downward in between the shells countercurrent to the exhaust gases. The resultant conditioned air is then routed to the GAC adsorber system. A bypass duct and damper are provided between the conditioning heat exchanger cleaned exhaust inlet and outlet for temperature control of the air entering the GAC adsorber system.

Table 5-7 summarizes the basis of design criteria for the primary and conditioning heat exchangers at Lemay WWTF.

Table 5-7 Heat Exchangers Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Primary Heat Exchanger	*Pre-heating of Fluidizing Air*
Number	3 (1 per FBI system)
Type	Shell (refractory lined) and tube
Temperature Rating (°F)	1,850
Exhaust Gas Inlet Temperature (°F)	1,500
Pre-Heated Air Outlet Temperature (°F)	1,200
Conditioning Heat Exchanger	*Conditioning of Air Entering GAC Adsorber System*
Number	3 (1 per FBI system)
Type	Double Shell
Temperature Rating (°F)	1,600
Exhaust Gas Inlet Temperature (°F)	1,200
Conditioned Air Outlet Temperature (°F)	As coordinated with GAC adsorber system requirements

5.3.3 Wet Scrubber System

Exhaust gases from the heat exchangers are routed to the wet scrubber system to remove pollutants, including particulate matter (PM), metals (lead, cadmium, and beryllium), and acid gases (SO_2 and HCl). Exhaust gases first flow down through a refractory lined quench section where it is cooled with plant effluent water (PEW) to adiabatic, saturated conditions; this section removes the larger sized PM. Cooled exhaust then flows upward through a series of impingement trays or a packed tower to condense out moisture; this section primarily removes the acid gases. Finally, the cooled exhaust flows upward through multiple fixed venturis with high pressure plant effluent water (PEW) injected to control pressure drop; this section primarily removes fine PM and metals. The resultant ash and scrubber water form a slurry in the extended base of the wet scrubber which is then pumped to the ash lagoons.

Table 5-8 summarizes the basis of design criteria for the wet scrubber system at Lemay WWTF.

Table 5-8 Wet Scrubber System Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Quench Section	*Cooling Exhaust Gases*
Number	3 (1 per wet scrubber)

COMPONENT	BASIS OF DESIGN
Type	Downflow, refractory lined
Plant effluent water (PEW) flow, gpm	350
Impingement Tray Section	*Condensing Moisture*
Number	3 sets (3 trays per wet scrubber)
Type	Upflow, dual orifice impingement trays, extended base sump
Plant Effluent Water (gpm)	800
Fixed Venturis Section	*Removing Fine PM and Metals*
Number	3 sets (12 to 16 venturi tubes per wet scrubber)
Type	Upflow with separately mounted booster water pumps
Plant effluent water (PEW) flow, gpm	260 (boosted pressure)
Upper Tray Section	*Polishing*
Number of units	3 (1 tray per wet scrubber)
Type	Upflow, dual orifice impingement tray above venturis
Plant effluent water (PEW) flow, gpm	50
Mist Eliminator Section	*Demisting for Downstream Air Pollution Control*
Number	3 (1 per wet scrubber)
Type	Upflow, one level of mesh style eliminator pads
Potable Quality Water (PRW), gpm	50
Venturi Section Water Booster Pumps	*Venturis Pressure Drop Control*
Number	4 sets, (3 duty sets, 1 venturi inlet pump and 1 venturi throat booster water pumps per scrubber, 1 standby set)
Type	Vertical, multi-stage centrifugal constant and variable speed
Venturi Section Pressure Drop	As required

5.3.4 Granular Activated Carbon (GAC) Adsorber System

A GAC adsorber system will be provided for each FBI system to clean exhaust gases downstream of the wet scrubbers. The GAC system will consist of a fine particulate filter, a high efficiency particulate air (HEPA) filter, startup heater skid, and GAC adsorber vessels. Filters will provide removal of additional final particulate and metals (beryllium, lead and cadmium) to prevent fouling of the GAC beds.

Cleaned exhaust gases downstream of the wet scrubber are routed through the conditioning heat exchanger to heat the cleaned exhaust above the dew point; this temperature is necessary to prevent condensation on the GAC bed which impacts removal efficiency and can cause heating. The heated cleaned exhaust gases are then routed through the filters and then into one of two parallel adsorber vessels and down through one or two layers of GAC fixed bed media. The GAC is designed to remove mercury, dioxins, and furans by adsorbing the pollutants to the media. This media will need to be periodically disposed of in a hazardous waste landfill and replaced. In addition to upstream demisting, filtration, and heating, the GAC adsorber system will include a startup heater skid. The startup heater skid will consist of startup air fan and electric heater. The startup air is filtered and heated and sent to the GAC adsorber vessel to preheat the vessel bed before being brought into service. A bypass duct and damper will be provided around the GAC absorber system to bypass the exhaust gases directly to the stack

Table 5-9 summarizes the basis of design criteria for the GAC adsorber system at Bissell Point WWTF.

Table 5-9 GAC Adsorber System Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Fine Particulate Filter	*Remove fine particulate*
Number	43 (1 per FBI system)
Type	Ultra-high filter roll with automatic advancement of filter
High Efficiency Particulate Air Filter	*Remove metals (lead, cadmium, beryllium)*
Number	6 (1 duty/1 standby per FBI system)
Type	HEPA filters in parallel for redundancy during replacement
Granular Activated Carbon Adsorber	*Remove Mercury, Dioxins and Furans*
Number	6 (2 duty in parallel per FBI system)
Type	Downflow
Cleaned Exhaust Inlet Temperature, °F	As required and coordinated w/conditioning heat exchanger
Startup Heater Skid	*Pre-Heat GAC Adsorber at Startup*
Number	3 (1 per GAC adsorber system)
Type	Blower with electric heater
Exhaust flow, acfm	As required

5.3.5 Induced Draft (ID) Fan and Exhaust Stack

Each FBI system will be provided with an induced draft (ID) fan and exhaust stack. The ID fan will pull exhaust gases from the FBIs, through heat exchangers, wet scrubber and GAC system and discharge the exhaust gases out to a free-standing stack located outside of the building. Exhaust flow will be controlled by a pneumatically actuated control valve located in the inlet of each induced draft fan. A continuous emission monitoring system (CEMS) will be provided to monitor exhaust gas constituents, including carbon monoxide and oxygen, and exhaust gas temperature. Table 5-10 summarizes the basis of design criteria for the induced draft fan and exhaust stack at Bissell Point WWTF.

Table 5-10 Induced Draft Fan and Exhaust Stack Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Induced Draft Fan	*Convey exhaust gas through air pollution control equipment*
Number	3 (1 per FBI system)
Type	Centrifugal fan, variable speed
Exhaust flow, acfm	As required
Exhaust Stack	*Exhaust gas discharge to atmosphere*
Number	3 (1 per FBI system)
Type	Vertical, cylindrical steel

5.3.6 Selective Non-Catalytic Reduction (SNCR) System

If required, an SNCR system could be added to the FBI systems to remove NOx and assure SSI MACT compliance. SNCR systems inject aqua ammonia directly into the freeboard section of the fluidized bed reactor to reduce NOx (NO and NO_2) into nitrogen gas and water vapor. SNCR systems include injection lances, distribution panels, chemical feed systems, and chemical storage tanks. NOx can also be controlled by temperature and excess air control, which given the low volatile content of the solids at Lemay, is likely sufficient for MACT compliance. As a result, an SNCR system will not be provided at Lemay; however, space will be allocated for a future installation if required and the system will be included as an add alternate from the FBI System Supplier as part of the Design-Build Proposal.

5.3.7 Acid Gas Removal

Removal of acid gas (SO_2 and HCl) is achieved in the wet scrubber system. Should the alkalinity of the plant effluent water added to the wet scrubber drop, additional alkalinity may be required to sufficiently removal the acid gas. This alkalinity is typically added to the system as liquid caustic (sodium hydroxide). As a result, a caustic storage and feed system is provided to inject caustic into the upper tray section of the wet scrubber if/when needed.

5.3.8 Contingency Operations

In the event the new FBI system at Lemay WWTF is not able to process the sludge cake produced at the plant (due to either mechanical issues, operational issue, or extremely high solids loading), valves installed in the cake piping downstream of the centrifuges and prior to incineration will divert the cake to a truck loadout station. Trucks can either haul cake to Bissell Point WWTF for processing or, if required, to an alternative disposal location (e.g. landfill).

6.0 Energy Recovery

6.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

The energy recovery analysis for Bissell Point WWTF completed as part of Technical Memorandum (TM) 11, Energy Recovery, included with Appendix D, showed that each of the energy recovery alternatives evaluated had a substantial capital cost and higher operational complexity that was not justified for the anticipated annual savings that could be achieved. Therefore, energy recovery at Bissell Point WWTF will not be included with this project.

To accommodate the option for adding energy recovery in the future, the system will be configured such that a take-off duct is included following the primary heat exchanger for re-routing of waste heat to a future adjacent building, which would house a waste heat boiler, steam turbine, and steam system.

6.2 LEMAY WASTEWATER TREATMENT FACILITY

The energy recovery analysis for Lemay WWTF completed as part of TM 11, included with Appendix D, showed that each of the energy recovery alternatives evaluated had a substantial capital cost and higher operational complexity that was not justified for the anticipated annual savings that could be achieved. Therefore, energy recovery at Lemay WWTF will not be included with this project.

To accommodate the option for adding energy recovery in the future, the system will be configured such that a take-off duct is included following the primary heat exchanger for re-routing of waste heat to a future adjacent building, which would house a waste heat boiler, steam turbine, and steam system.

The existing steam system for providing building heat and other various uses across the Lemay treatment facility will either be abandoned (the waste heat boilers associated with the existing MHIs are well past their design life and require considerable effort to keep operational) or reused (steam piping system) in areas. Therefore, a new source of heat will be required for building heat and other uses at the facility. Sources for new building heat are discussed further in Section 15 of this report.

7.0 Ash Handling and Disposal

7.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

Table 7-1 summarizes Bissell Point WWTF's projected future solids loading and volatile solids content, with a resultant estimate for ash production.

Table 7-1 Bissell Point WWTF Future Design Solids and Ash Quantities

Description	Total Solids, dtpd	% Volatile Solids	Estimated Ash Production, dtpd
Normal, AA	134.8	42.9	77.0
Normal, MM	168.1	44.9	92.6
Normal, PW	246.8	32.6	166.3
Flood Stage, MM	250.1	32.2	169.6
Flood Stage, PW	300.3	28.7	214.1
AA = Annual Average; MM = Max Month; PW = Peak Week; dtpd = dry tons per day.			

The flood stage maximum month (MM) estimated ash production will serve as the basis of design for sizing ash handling system components.

Technical Memorandum TM 10 provides additional information pertaining to ash, ash handling systems, and disposal.

7.1.1 Ash Handling System Basis of Design

Ash produced in the FBIs will exit the reactor within the exhaust and be removed within the wet scrubber of the downstream air pollution control system. Ash within the exhaust will be slurried by the quench, impingement tray, and venturi water of the wet scrubber system and drained to the base of the wet scrubber. This base (sump) will serve as the ash slurry wetwell for a pair of adjacently located abrasion resistant centrifugal pumps. These variable speed pumps will act in a duty/standby arrangement with each pump sized to accommodate the maximum ash slurry produced by an FBI train and automated to maintain a level range within the wetwell. Four abrasion resistant ash slurry piping headers, one for each pair of pumps, will extend from the ash slurry pumps out to the ash lagoons. Ash settles within the lagoons and the water will be continuously decanted back to the head of the plant. Settled ash will continue to be periodically dredged from the lagoons and directed to landfill or beneficial reuse (e.g. soil amendment). One lagoon will normally be in service and the other in standby mode or undergoing dredging. Previously identified improvements required to the existing ash lagoons for their continued use will be made. These improvements pertain to the deteriorating floor of the existing lagoons, which during high Mississippi River levels, allows groundwater to infiltrate the lagoons. Technical Memorandum TM 10 provides additional information on the Bissell Point WWTF ash lagoons.

Table 7-2 summarizes the basis of design criteria for the ash handling system at Bissell Point WWTF.

Table 7-2 Ash Handling System Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Ash Slurry Wetwell	*Wet Scrubber Sump*
Number	4 (one per FBI train)
Capacity (gallons)	7,500
Wet scrubber water (gpm)	1,500
Ash Slurry Pumps	*Pumping of Ash Slurry*
Number	8 (2 duty/standby pumps per FBI train)
Type	Horizontal End Suction Centrifugal – Abrasion Resistant
Capacity (gpm)	1,600
Drive Type	Variable Speed
Ash Slurry Piping	*Transfer of Ash Slurry to Ash Lagoons*
Number	4 (one per pair of ash slurry pumps)
Type	Abrasion resistant (e.g. HDPE or basalt-lined steel)
Ash slurry transfer velocity (ft/sec)	5 to 8
Diameter (inches)	8 to 10
Ash Lagoons	*Existing Ash Storage Lagoons – Repurposed for New FBI Systems*
Number	2
Type	Rectangular, concrete and brick lined
Capacity (cubic yards each)	75,000
Ash Storage Duration (months each)	10 to 12

7.2 LEMAY WASTEWATER TREATMENT FACILITY

Table 7-3 summarizes Lemay WWTF's projected future solids loading and volatile solids content, with a resultant estimate for ash production.

Table 7-3 Lemay WWTF Future Design Solids Quantities

Description	Total Solids, dtpd	% Volatile Solids	Estimated Ash Production, dtpd
Normal, AA	111.6	56.4	48.7
Normal, MM	122.9	49.9	61.6
Normal, PW	144.7	52.6	68.6
Flood Stage, MM	165.2	50.8	81.3
Flood Stage, PW	211.9	43.6	119.5
AA = Annual Average; MM = Max Month; PW = Peak Week; dtpd = dry tons per day.			

The flood stage maximum month (MM) estimated ash production will serve as the basis of design for sizing ash handling system components.

7.2.1 Ash Handling System Basis of Design

Ash produced in the FBIs will exit the reactor within the exhaust and be removed within the wet scrubber of the downstream air pollution control system. Ash within the exhaust will be slurried by the quench, impingement tray, and venturi water of the wet scrubber system and drained to the base of the wet scrubber. This base (sump) will serve as the ash slurry wetwell for a pair of adjacently located abrasion resistant centrifugal pumps. These variable speed pumps will act in a duty/standby arrangement with each pump sized to accommodate the maximum ash slurry produced by an FBI train and automated to maintain a level range within the wetwell. Three abrasion resistant ash slurry piping headers, one for each pair of pumps, will extend from the ash slurry pumps out to the two existing ash lagoons. Ash settles within the lagoons and the water will be continuously decanted back to the head of the plant. Settled ash will continue to be periodically dredged from the lagoons and directed to landfill or beneficial reuse (e.g. soil amendment). One lagoon will normally be in service and the other in standby mode or undergoing dredging.

Table 7-4 summarizes the basis of design criteria for the ash handling system at Lemay.

Table 7-4 Ash Handling System Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Ash Slurry Wetwell	*Wet Scrubber Sump*
Number	3 (one per FBI train)
Capacity (gallons)	7,500
Wet Scrubber Water (gpm)	1,500
Ash Slurry Pumps	*Pumping of Ash Slurry*
Number	6 (2 duty/standby pumps per FBI train)
Type	Horizontal End Suction Centrifugal – Abrasion Resistant
Capacity (gpm)	1,600
Drive Type	Variable Speed
Ash Slurry Piping	*Transfer of Ash Slurry to Ash Lagoons*
Number	3 (one per pair of ash slurry pumps)
Type	Abrasion resistant (e.g. HDPE or basalt-lined steel)
Ash slurry transfer velocity (ft/sec)	5 to 8
Diameter (inches)	8 to 10
Ash Lagoons	*Existing Ash Storage Lagoons*
Number	2 in service, 1 out of service
Type	Rectangular, clay/ liner with rock lining
Capacity (cubic yards each)	40,000
Ash Storage Duration (months each)	8 to 10

8.0 Solids Processing Facilities

8.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

8.1.1 Solids Processing Building

A new Solids Processing Building will be constructed at the Bissell Point WWTF that will contain both the new dewatering process equipment as well as the new fluidized bed incineration process equipment and all associated dewatering and incineration items. The building size will be approximately 150 feet by 300 feet and will contain multiple levels, including a below grade basement for the dewatering process area. The building will also contain a trucked sludge cake receiving station and a sludge cake truck loading station. The new building will be built in the grassy area east of the existing Solids Handling Building and west of the existing ash lagoons. Refer to Appendix B for conceptual level building plans.

8.1.2 Sludge Cake Loadout Station

Depending on the solids processing capacity at Bissell Point WWTF, there may be times when the solids loading exceeds the available capacity of the Bissell Point FBI systems. Under this scenario, MSD will have the option to haul Bissell Point sludge cake to Lemay WWTF for processing or to landfill for disposal. To support this contingency operation, a new sludge cake loadout station will be provided in the truck drive through bay of the new Solids Processing Building.

Sludge cake from the centrifuge dewatering equipment will be collected in incinerator cake feed bins prior to incineration. Each cake bin will have two hydraulic piston pumps (duty/standby) for feeding sludge cake to the incinerator reactors. During a contingency loadout operation, at least one of these pumps can be used to redirect cake to the sludge cake loadout station through a dedicated cake loadout header and valves. This header will extend along the truck drive through bay with multiple drop points and valves. The drop points will be located to allow a truck trailer to be filled from a single location. Each drop point will be equipped with a flexible rubber sleeve or retractable chute on the end to extend the cake discharge into the trailer and minimize splashing of wet cake.

Table 8-2 summarizes the basis of design criteria for the sludge cake loadout station at Bissell Point WWTF. Technical Memorandum TM 18 provides additional information pertaining to the sludge cake loadout station.

Table 8-1 Sludge Cake Loadout Station Basis of Design – Bissell Point WWTF

COMPONENT	BASIS OF DESIGN
Sludge Cake Loadout Station	*Located in Truck Drive Through Bay of Solids Processing Building*
Cake Loadout Piping	*Transfer of Sludge Cake to Truck Loadout*
Type	Schedule 80 Steel
Diameter (inches)	10 – 12
Cake Loadout Valves	*Transfer of Sludge Cake to Truck Loadout*
Number	2 – 4

COMPONENT	BASIS OF DESIGN
Type	High pressure ball, motor actuated
Diameter (inches)	10 – 12

8.1.3 Odor Control

A new odor control system to collect and treat foul air from the dewatering facilities at Bissell Point WWTF is planned to be constructed as part of this project. In order to inform production of design criteria for the new odor control system, odor sampling was completed at both Bissell Point and Lemay WWTFs in September 2020. The sampling plan detailing the types of samples that were collected and documentation of the sampling results are presented in TM 6 Attachments E and F, respectively.

The foul air sources that will require odor control are the following:

- Blended sludge wells
- Centrifuges
- Incinerator feed bins
- Cake receiving bay including receiving bins
- Scum concentrator
- Cross conveyors
- Truck loading bay

Because the Bissell Point WWTF is in an industrial area, the risk of odor complaints is relatively low. Therefore, foul air from all dewatering sources, except the truck loading bay, will be conveyed to a two-stage odor control system consisting of a biofilter followed by a carbon adsorber. From the truck loading bay foul air will be conveyed to a high-velocity dispersion fan rather than to a separate odor control system.

The odor control system for the dewatering facilities of the Solids Processing Building will be as follows:

COMPONENT	BASIS OF DESIGN
Biofilters	2 cells – 12’ x 25’ x 13’-6” OAH
Airflow rate	3,700 cfm each cell at 40 sec empty bed residence time (EBRT
Inlet H2S concentration, ppmv	25 (average), 70 (peak)
Odor loading, D/T	19,000 (average), 38,000 (peak)
Inlet fans	2 (1 duty, 1 standby) – 7400 cfm at 8” w.c.
Carbon Scrubber	1 – 7,400 cfm unit, 10 feet diameter

For the truck cake loading area, a high speed dispersion fan on will be located on the roof. It will be rated at 9,000 scfm.

8.1.4 Demolition

Demolition options were developed in TM 17 and will be incorporated into the design-build procurement documents.

As part of the project, the Solids Handling Building will be demolished, along with the emission stack, unused ash storage silo, and the two circular, out of service circular sludge holding tanks. Refer to Figure 8-1.

The design-build contractor will also be responsible for the removal of all equipment within the buildings identified for demolition. Prior to design-build contracting, MSD will identify and move all equipment they intend to repurpose at Bissell Point WWTF or other facilities.

The Gravity Thickening and Maintenance Center will not be demolished, but it would be prudent to consider removal of the out-of-service gravity belt thickeners as part of demolition. This may require creating an opening in the roof and removing these units with a crane.

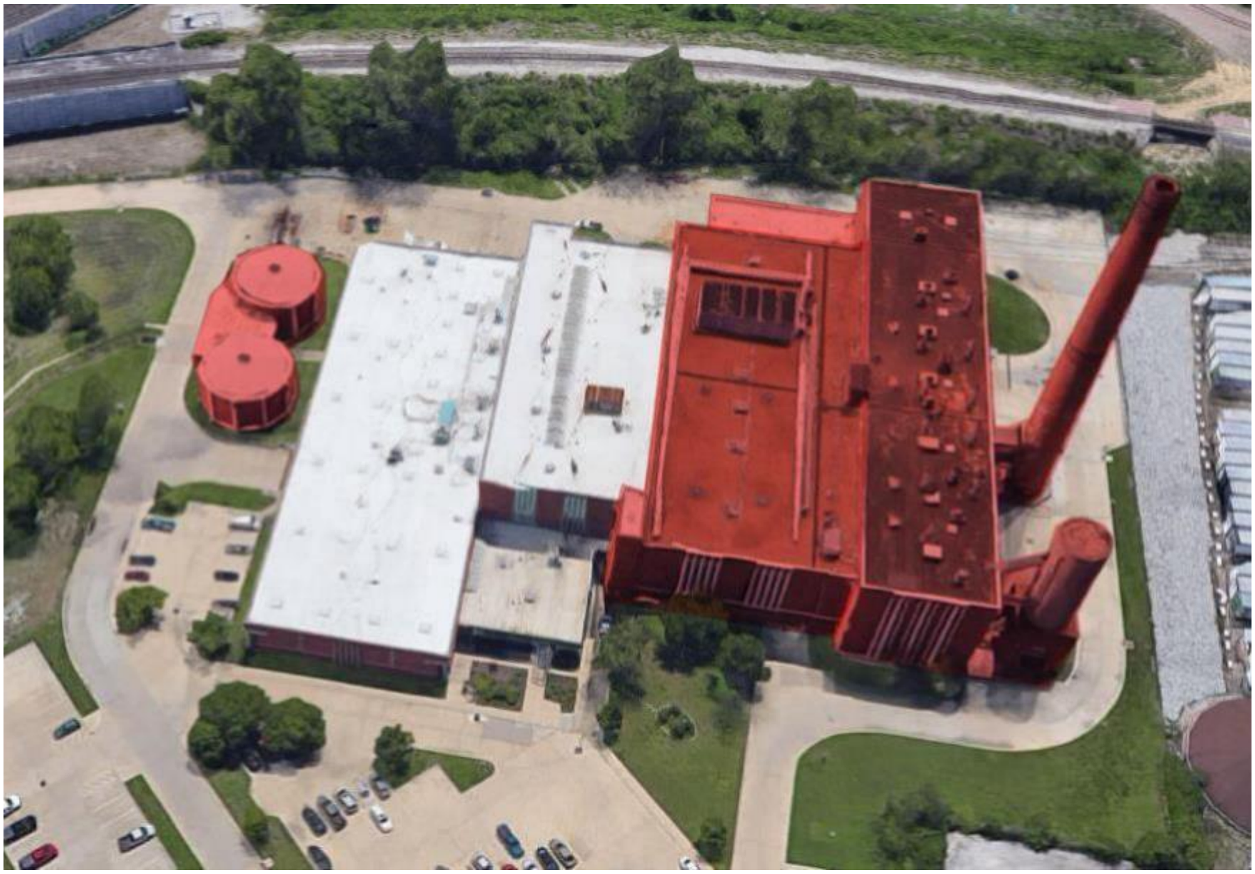


Figure 8-1 Bissell Point Demolition: Recommended demolition shown in red.

8.2 LEMAY WASTEWATER TREATMENT FACILITY

8.2.1 Solids Processing Building

A new Solids Processing Building will be constructed at the Lemay WWTF that will contain both the new dewatering process equipment as well as the new fluidized bed incineration process equipment and all associated dewatering and incineration items. The building size will be approximately 150 feet by 250 feet and will contain multiple levels, including a below grade basement for the dewatering process area. The building will also contain a trucked sludge cake receiving station and a sludge cake truck loading station. The new building will be constructed in the area made available after the demolition of the plant's existing Maintenance Building. Refer to Appendix C for conceptual level building plans.

8.2.2 Sludge Cake Loadout Station

Depending on the solids processing capacity at Lemay WWTF, there may be times when the solids loading exceeds the available capacity of the Lemay FBI systems. Under this scenario, MSD will have the option to haul Lemay sludge cake to Bissell Point WWTF for processing or to landfill for disposal. To support this contingency operation, a new sludge cake loadout station will be provided in the truck drive through bay of the new Solids Processing Building.

Sludge cake from the centrifuge dewatering equipment will be collected in incinerator cake feed bins prior to incineration. Each cake bin will have two hydraulic piston pumps (duty/standby) for feeding sludge cake to the incinerator reactors. During a contingency loadout operation, at least one of these pumps can be used to redirect cake to the sludge cake loadout station through a dedicated cake loadout header and valves. This header will extend along the truck drive through bay with multiple drop points and valves. The drop points will be located to allow a truck trailer to be filled from a single location. Each drop point will be equipped with a flexible rubber sleeve or retractable chute on the end to extend the cake discharge into the trailer and minimize splashing of wet cake.

Table 8-6 summarizes the basis of design criteria for the sludge cake loadout station at Lemay WWTF. Technical Memorandum TM 18 provides additional information pertaining to the sludge cake loadout station.

Table 8-6 Sludge Cake Loadout Station Basis of Design – Lemay WWTF

COMPONENT	BASIS OF DESIGN
Sludge Cake Loadout Station	*Located in Truck Drive Through Bay of Solids Processing Building*
Cake Loadout Piping	*Transfer of Sludge Cake to Truck Loadout*
Type	Schedule 80 Steel
Diameter (inches)	10 – 12
Cake Loadout Valves	*Transfer of Sludge Cake to Truck Loadout*
Number	2 – 4
Type	High pressure ball, motor actuated
Diameter (inches)	10 – 12

8.2.3 Odor Control

A new odor control system to collect and treat foul air from the dewatering facilities at Lemay WWTF is planned to be constructed as part of this project. In order to inform production of design criteria for the new odor control system, odor sampling was completed at both Bissell Point and Lemay WWTFs in September 2020. The sampling plan detailing the types of samples that were collected and documentation of the sampling results are presented in TM 6 Attachments E and F, respectively.

The foul air sources that will require odor control are the following:

- Blended sludge wells
- Centrifuges
- Incinerator feed bins
- Cake receiving bay including receiving bins

- Scum concentrator
- Cross conveyors
- Truck loading bay

Because of the potential sensitivity of the surrounding residential and commercial community with respect to odors, the odor control approach for the Lemay WWTF dewatering facilities is to combine all foul air (with the exception of the truck cake loading area) and treat the air in a 2-stage biofilter and activated carbon adsorption odor control system.

The odor control system for the dewatering facilities of the Solids Processing Building will be a two-stage system consisting of a biofilter followed by a carbon scrubber as follows:

COMPONENT	BASIS OF DESIGN
Biofilters	2 cells – 12’ x 25’ x 13’-6” OAH
Airflow rate	3,200 cfm each cell at 45 sec empty bed residence time (EBRT)
Inlet H2S concentration, ppmv	15 (average), 25 (peak)
Odor loading, D/T	40,000 (average), 80,000 (peak)
Inlet fans	2 (1 duty, 1 standby) – 6,400 cfm at 8” w.c.
Carbon Scrubber	2 – 6,400 cfm units at 3.6 sec EBRT, 9 feet diameter each

Odor control for the truck cake loading area will be a carbon adsorber as follows:

COMPONENT	BASIS OF DESIGN
Carbon Adsorber	2 – dual bed carbon bed adsorbers at 9,000 cfm capacity each at 3.71 EBRT (1-duty, 1 standby)
Carbon Adsorber fans	2 (1 duty, 1 standby) – 9,000 cfm at 12” w.c.

8.2.4 Demolition

Demolition options were developed in TM 17 and will be incorporated into the design-build procurement documents.

As part of the project, the Incineration and Filter Building, the Maintenance Building, and emissions stack will be demolished. Additionally, selective demolition of areas within the Grit and Screenings Building will be demolished, but the superstructure of the building will remain. This building will be converted to use as a maintenance facility, and any demolition performed will be based upon converting the building to this new use. The area of the existing Maintenance Building will be the location of the new Solids Processing Building, and all demolition work at this area will need to be completed in such a manner for the new building’s construction.

The design-build contractor will also be responsible for the removal of all equipment within the buildings identified for demolition. Prior to DB contracting, MSD should identify and move all equipment that can be repurposed at Lemay or other facilities.

8.2.5 New Maintenance Facility

With the demolition of the existing Maintenance Building, a new maintenance facility that provides all the functions provided by the building (maintenance activity, shop areas, storage, receiving, and employees spaces such as offices, locker rooms, and meeting areas) will need to be constructed as part of this project.

The existing Grit and Screenings Building will be converted to be used as the new maintenance facility. All equipment within the Grit and Screenings Building will be removed and selective demolition and improvements will be made to the interior space. The superstructure of the building will be kept, with some improvements required such as a new roof and some brick repairs. Multiple levels would be used within the existing buildings, with floors constructed within the large open space that extends to the lower level of the building. A floor will be provided for employee needs such as office spaces, locker rooms (both men’s and women’s), lunch room, and a conference room. An at-grade floor will be for shop areas, maintenance activity space, receiving, and some parts storage. Additional storage will be provided in other floor areas.

9.0 Site Work / Utilities

For both the Bissell Point and Lemay treatment facilities, the new Solids Processing Building will be constructed in areas within the facility's property.

9.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

The new Solids Processing Building at the Bissell Point WWTF will be constructed in an area between the existing Gravity Thickening and Maintenance Facility and the ash storage lagoons at the southeast corner of the plant site. This area is relatively flat and grass-covered with an existing plant service road to its west. The existing ash slurry pipes that feed into the ash lagoons will need to be relocated. Appendix B includes a site plan that shows the existing topography of the site.

Plant utilities will need to be routed to the site of the new building, including electrical feeds, potable water, non-potable water, sanitary sewers, and natural gas. (The existing natural gas feed to the facility site will need to be verified against expected new natural gas demand as a result of this project.) Existing plant roads will be used to access the new building, and additional roads and parking areas may be required at specific areas of the new building. Site restoration will be included for the areas of the buildings and other items demolished as a part of the project.

A geotechnical investigation was completed for the area. The report from this investigation is summarized in Section 10 of this report.

9.2 LEMAY WASTEWATER TREATMENT FACILITY

The new Solids Processing Building at the Lemay WWTF will be constructed in the area where the existing Maintenance Building resides. There is a significant slope in this area, and the new building will be built into this slope. Extensive grading will be required to make this area usable for the new building once the existing Maintenance Building has been demolished and the area cleared of debris. Appendix C includes a site plan that shows the existing topography of the site.

Existing plant utilities currently routed to the existing Maintenance Building may need to be rerouted to the new building, depending on where utility needs are for the Solids Processing Building. These utilities include electrical feeds, potable water, non-potable water, sanitary sewers, and natural gas. (The existing natural gas feed to the facility site will need to be verified against expected new natural gas demand as a result of this project.) Existing plant roads will be used to access the new building, and additional roads and parking areas may be required at specific areas of the new building. Site restoration will be included for the areas of the buildings and other items demolished as a part of the project.

A geotechnical investigation was completed for the area. The report from this investigation is summarized in Section 10 of this report.

10.0 Geotechnical

Geotechnical investigations for this project have been completed in two phases at both the Bissell Point WWTF and the Lemay WWTF. The intent of the first phase of these investigations was to complete a general evaluation of the existing site geology and subsurface conditions so as to determine if there are any significant subsurface features that are prohibitive to new construction, or present unnecessary risk for new construction. The first phase investigations were not intended to be the basis for a full geotechnical evaluation that could be used as a basis of design for the building's foundation system or other project requirements, such as excavation. Second phase geotechnical investigations were conducted with the intent of providing detailed, specific information for the design-build proposers to help with their building foundation designs as well as construction activity such as excavation, excavation support systems, and trenching. If either the first phase or second phase geotechnical investigations do not provide all the information design-build proposers need, it will be the responsibility of the design-build teams to perform further investigations.

As part of the first phase Bissell Point WWTF geotechnical investigation, two soil borings were made in the grassy area between the existing Maintenance Facility and the ash storage lagoons at the southeast corner of the plant site, the proposed site for the new Solids Processing Building. The borings were made on March 18 and 20, 2020.

The Bissell Point site has been covered with fill to, presumably, raise the grade above river flood elevation. Fill soil extends to depths of approximately 24 to 29 feet below present ground surface. The fill consists primarily of lean clay and fat clay. Underlying the fill soils are natural alluvial deposits consisting of silts, lean clays, silty sand, and sand. The alluvial deposits are to depths of 35 to 40 feet. Apparent limestone was encountered underlying the native alluvium soils at a depth of approximately 60 to 62 feet. The anticipated MSD excavation classification is Excavation Class C for the depth of the boring and Excavation Class A for the limestone bedrock. Groundwater was encountered during drilling at a depth of 36 feet, however this level will fluctuate on seasonal variations, the water level in the Mississippi River, and other unknown considerations.

As part of the first phase Lemay WWTF geotechnical investigation, three soil borings were made in the area of the existing Maintenance Building and existing Grit and Screening Building. These borings were made March 18 through 26, 2020. Two borings were also made in the grassy area immediately west and adjacent to the facility's rectangular primary clarifiers on June 4, 2020. Since the completion of these borings, the area of the existing Maintenance Building has been selected as the site for the new Solids Processing Building. However, in this report, the results of the borings in that area as well as in the area west of the rectangular primary clarifiers have been summarized herein.

The Lemay site lies on a bluff area adjacent to the Mississippi River which is underlain by St. Louis Limestone, a bedrock susceptible to the development of karst features such as sinkholes, caves, widened joints, and an irregular bedrock surface. Generally, fill soil was encountered in the upper 5.5 to 9 feet of the borings (with no fill soil at one boring) consisting of lean clay with some sand and gravel. Underlying the fill (and from the surface of one boring) are loessial soils consisting of lean clays. Residual soils, generally lean-to-fat clays derived from weathering of the limestone bedrock, were encountered beneath the loessial deposits. Limestone bedrock was encountered at depths ranging from 15.1 to 32.0 feet. Groundwater was not encountered.

11.0 Architectural

11.1 BISSELL POINT WASTEWATER TREATMENT FACILITY

11.1.1 Solids Processing Building – Architectural Character

The new Solids Processing Building will be built just east of the existing Thickening Building and Maintenance Center and should visually blend with this existing structure. The existing building is a red brick structure with several accent bands of brick and cast stone. The building has a flat (low-sloped) roof with parapets capped with cast stone. The roofing is white thermoplastic polyolefin TPO) membrane roofing over ridged insulation. The roof insulation shall have at least an R-30 value and be protected with a coverboard. To protect against the corrosive environment of a wastewater plant, all interior and exterior doors shall be stainless steel or aluminum. All finishes in the Solids Processing Building including door hardware shall be selected for durability in a corrosive environment.

11.1.2 Solids Processing Building - Building Codes

- 2018 International Building Code (adopted 08/01/2018)
- 2018 International Energy Conservation Code (adopted 08/01/2018)
- 2018 International Property Maintenance Code (adopted 08/01/2018)
- 2009 Uniform Plumbing Code (10/19/2018)
- 2018 International Mechanical Code (adopted 08/01/2018)
- 2018 International Fuel Gas Code (adopted 08/01/2018)
- 2017 National Electrical Code (adopted 08/01/2018)
- City of St. Louis Zoning Ordinance 59979 (adopted 07/30/1986)
- Revised Municipal Code (current version)

11.2 LEMAY WASTEWATER TREATMENT FACILITY

11.2.1 Solids Processing Building – Architectural Character

The new Solids Processing Building shall have an appearance that blends with the architectural character of the existing buildings at the Lemay Wastewater Treatment Facility. Most of the existing building exteriors are a combination of blonde modular brick, white precast concrete panels, and white metal panels. The buildings have flat roofs (low-sloped) with parapets. The coping on the parapets are cast stone or prefinished metal. The roofing design shall be energy efficient with a white membrane and a minimum R-30 value insulation. A coverboard shall be provided over the insulation for added protection from hail and other impacts. To protect against the corrosive environment of a wastewater plant, all interior and exterior doors shall be stainless steel or aluminum. All finishes in the Solids Processing Building including door hardware shall be selected for durability in a corrosive environment.

11.2.2 Solids Processing Building - Building Codes

- 2015 International Building Code (adopted 04/01/2020)
- 2015 International Energy Conservation Code (adopted 04/01/2020)
- 2015 International Property Maintenance Code (adopted 04/01/2020)
- 2015 Uniform Plumbing Code (10/01/2019)
- 2015 International Mechanical Code (adopted 04/01/2020)
- 2015 International Fuel Gas Code (adopted 12/05/2019)
- 2014 National Electrical Code (adopted 10/01/2019)
- St. Louis County Zoning Ordinance Chapter 1003 (current version)

11.2.3 New Maintenance Facility

The existing Grit and Screenings Building at the Lemay WWTF will be converted to be used as a new maintenance facility. The exterior of the building will not be changed, and the interior of the building will be modified to meet its new intended use as a maintenance facility. Therefore, the architectural character of the building will not change as no modifications will be made to the building's exterior. All building codes listed for the Solids Processing Building will be applicable, as will the 2018 International Existing Building Code.

12.0 Structural

12.1 GENERAL

This section presents the design criteria and basis of structural design associated with the new Solids Processing Building to be constructed at both the Bissell Point WWTF and Lemay WWTF as well as other structural design items, such as converting the existing Grit and Screenings Building at the Lemay WWTF to a maintenance facility. The intent of this section is to identify the applicable codes, define the design criteria, and establish the minimum design requirements. All work will be completed in accordance with the local codes and other requirements applicable to the structural design of facilities located within a wastewater treatment facility.

To understand the applicable requirements of structural design, note that the Bissell Point WWTF is located within the City of St. Louis and the Lemay WWTF is located within St. Louis County.

12.2 APPLICABLE CODES, STANDARDS, AND DESIGN CRITERIA

12.2.1 Design Codes

Design Codes are:

International Building Code 2015
ASCE 7-10
AISC 14th Edition
ACI 318, 350

Occupancy is Category 4.

12.2.2 Design Loads

Live loads are (ASCE 7-10):

Walkways and Elevated Platforms: 60 psf
Corridors: 80 psf
Offices: 50 psf
Partitions: 15 psf
Roof Construction: 20 psf
Stairs and exitways: 100 psf
Light storage areas: 125 psf
Heavy Storage: 250 psf

Wind loads are:

Ultimate Wind Speed: 120
Exposure: C
Importance Factor: 1.15

Snow loads are:

Ground Snow Load: 20 psf
Exposure Factor: C
Importance Factor: 1.2

Thermal Factor: 1.0

Seismic loads area:

	Bissell Point WWTF	Lemay WWTF
Ss	0.439	0.540
S1	0.157	0.180
Site Class	E	D
Sds	0.547	0.428
Sd1	0.440	0.240
Seismic Design Category	D	D
Importance Factor	1.5	1.5

Crane Loads (Impact factors per ASCE 7-10):

Solids Processing Building - Dewatering Equipment Design Bridge Crane Load: TBD
Solids Processing Building – Incineration Equipment Design Bridge Crane Load: TBD

12.2.3 Corrosion Protection

Protection against corrosion will be provided for the following areas and chemicals and/or exposure:

Storage Tank Chemicals
  Sodium hydroxide
  Ammonia
Environmental Exposure
  Sulfates
Structural Steel: Galvanized or Coated
Metal Fabrications: Stainless steel
Concrete: Type 2 cement for soil exposed, foundations

12.2.4 Materials

Materials of construction will be:

Concrete: 4,000 psi minimum
CMU: f'm = 2,500 psi minimum
Steel: A572 (Grade 50)
Interior and exterior grating and walkways: Aluminum

12.2.5 Building Performance Criteria

Building performance shall be:

Floor Slab Differential Settlement: less than 1 inch
Building drift: per ASCE 7
Partition Walls: Non-absorptive
Building Differential Settlement: 2 inches (1 inch if supporting piping systems)

12.3 FOUNDATIONS

Relatively heavy loads are anticipated for the proposed Solids Processing Buildings at both Bissell Point WWTF and Lemay WWTF that will house the new fluidized bed incinerator equipment as well as solids dewatering process equipment. The existing fill and underlying native soils encountered in the geotechnical borings may not have enough strength to support heavily loaded structures without excessive settlement. Ground improvement or deep foundations may be required to support the anticipated loads. Potential ground improvements include removing and replacing the existing soils or strengthening the soils through mechanical and/or chemical means. Several options are available that include soil mixing with lime products or installation of stone columns below foundations. Deep foundation elements such as auger cast-in-place piles, driven piles, or drilled shafts could support relatively heavy loads, but may have to be extended to bedrock or socketed into bedrock at depths below 60 feet.

12.4 SOLIDS PROCESSING BUILDING (BISSELL POINT AND LEMAY) – SUPERSTRUCTURE

For the incineration process side of the Solids Processing Building, the space required for the enclosure of the specified equipment demands a 'high bay' approach to the superstructure. The equipment clear height requirements are in the range of 50'. The roof will be designed to span the width of this side of the building, approximately 100 feet, without using interior columns. Intermediate walkways for equipment access are required. Equipment service and parts replacement requirements will have an impact on the superstructure geometry and loading. The superstructure may be required to support hanging equipment, monorail systems, partition supports, and service walkways.

The main frame assumed layout is based upon future removal through the roof of the Fluidized Bed Reactor, the Primary Heat Exchanger, the Impingement/Venturi Wet Scrubber, and the GAC Adsorber. All other equipment is assumed to be lifted using a truck mounted crane that will be able to park in an open, truck accessible area between each of the incinerator reactors at the grade level of the building.

For the dewatering process side of the Solids Processing Building, a basement along with three levels will be used for locating the different equipment along with employee occupied areas such as administrative offices, control rooms, and locker rooms. Starting at the basement level and going up, the:

- Basement area will contain polymer feed equipment, sludge wells and drainage sumps with associated pumping and piping, and sludge cake receiving bins and pumps associated with the dewatered sludge truck receiving areas.
- First level will contain a scum concentrator room, electrical room, and employee locker rooms.
- Second level will contain the dewatered sludge collection bins, cross-connection screw conveyors, incinerator feed pumps, and ceiling mounted monorails.
- Third level will contain the centrifuges, a bridge crane that spans the entire centrifuge area, and employee spaces such as a control room, offices, conference room, and restrooms.

A framing system will be designed that supports the loads of all levels for this side of the building. The roof will be designed to span the centrifuge level for the width of the dewatering process side of the building, approximately 50 feet, without using interior columns at the centrifuge equipment level.

a. Footprint

Bissell Point WWTF Solids Processing Building:	150’ x 300’ (approx.)
Lemay WWTF Solids Processing Building:	150’ x 250’ (approx.)

b. Basement

This is a 20’ deep depression open to the building space above. The basement walls are to consist of cast in place concrete. Periodic compression struts can be used to limit wall stresses. The foundation and base slab shall be able to resist buoyancy forces.

c. Base Slab

The base slab shall consist of cast in place concrete designed to support the building superstructure, process equipment, and walkway and platform frames. This base slab shall transfer these applied loads to the foundation system or onto supporting soils.

d. Superstructure

The building frame shall have an open clear volume from floor to roof for the incinerator area and the dewatering area will have multiple floors with interior columns. The building frame is required to resist all applied vertical and lateral loads.

e. Roof Construction

The roof system shall act as a diaphragm to transfer lateral loads to the perimeter building elements. This can be performed with a metal deck or cross bracing within the roof structure. The roof structure is to clear span the 100’ over the incinerator area, and 50’ over the dewatering area.

The required clear height (59’ assumed) of the structure is based upon the total of the equipment height, hoisting and movement clearances and bridge crane depth.

f. Wall Construction

The exterior walls are to be designed to transfer applied lateral loads to the building frame and have a durable interior envelope consisting of concrete or CMU.

12.5 SOLIDS PROCESSING BUILDING (BISSELL POINT AND LEMAY) – PLATFORMS AND WALKWAYS

Platforms and walkways are required at various elevations for equipment operation and servicing. Each piece of equipment has particular elevation requirements for the platforms. These elements are to be ground mounted or building superstructure supported and structurally independent of the equipment. Stair systems shall be provided integral to the platforms and walkways and shall provide plant personnel convenient access to all the platforms and walkways either from a slab level or from adjacent platforms and walkways.

13.0 Electrical

13.1 GENERAL

This section describes the basis of the electrical design for the installation of a new dewatering process, incinerators and associated systems and buildings at both the Bissell Point WWTF and Lemay WWTF. Electrical design will be based on system reliability, system efficiency, life safety considerations, and process requirements, as well as site specific requirements. All electrical work will be in accordance with local and state codes, the criteria outlined in this section, and other requirements applicable to the electrical design of a wastewater treatment facility.

13.2 APPLICABLE CODES AND STANDARDS

In addition to the applicable building codes and standards identified in other sections, the electrical system designs will also be based on but not limited to the following publications and standards:

- National Fire Protection Agency (NFPA) including the following
    - National Electrical Code (NEC/NFPA 70)
    - Standard for Electrical Safety in the Workplace (NFPA 70E)
    - Standard for Fire Protection in Wastewater Treatment and Collection Facilities (NFPA 820)
- Underwriters Laboratories Inc. (UL)
- National Electrical Manufacturers Association (NEMA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Insulated Cable Engineers Association (ICEA)
- Illuminating Engineers Society (IES)
- International Energy Conservation Code (IECC)
- American National Standards Institute (ANSI)
- Occupational Safety and Health Act (OSHA)
- International Building Code (IBC)

13.3 ELECTRICAL SERVICE

Electrical service to both Bissell Point WWTF and Lemay WWTF is provided by Ameren Missouri. No new service from Ameren is expected for this project. Power feeds to the new facilities will be taken from the existing medium voltage power distribution located at each plant.

Maintaining continuous operation of dewatering and incineration and other essential process equipment is critical. Continuous operation can be accomplished by careful construction sequencing. This will require maintaining one power feed (at minimum) to the existing dewatering and incineration facilities throughout the construction of the new dewatering and incineration facilities.

13.4 POWER DISTRIBUTION

The power distribution to the Solids Processing Building will be 4160/2400 Volt, three-phase, three wire, 60 Hz. The new power distribution system will consist of medium voltage switchgear with a Main-Tie-Tie-Main configuration and an automatic throw-over system to accommodate redundant feeds. Each Solids Processing Building will normally be fed from redundant main feeders with a tie breaker open. On the loss of a main feeder, the corresponding main breaker would open and the tie breaker would close, allowing the unaffected main feeder to power the entire switchgear. Upon return of power to the main feeder, the power would be transferred back to the normal configuration.

Bissell Point Power Distribution

The Building #4 Electrical Substation (construction scheduled for completion summer 2021) will provide redundant power feeds to the new Solids Processing Building. The redundant feeds will be from separate buses. The first feed will be from the spare 1200A breaker on Bus W. The second feed will be from a 1200A breaker on Bus D that will transition from feeding the existing Substation #3.

The Administration Building, Maintenance Shop and Thickener Building will be kept operational. This will be accomplished by back feeding from the new Solids Processing Building directly to the Maintenance Shop and Thickener Building. The following MCCs serve the Administration Building, the Maintenance Shop and Thickener Building: 15MCC1, 2, 3, 4, & 5. Brief power outages to the Administration Building, Maintenance Shop and Thickener Building will be required for the transfer of these feeds.

The existing Solids Handling Building will no longer require electrical power since it is planned to be demolished. A minimum of one electrical feed to Substation #3 must remain in service until the Solids Handling Building is removed from service, decommissioned, and demolished.

Lemay Power Distribution

The existing outdoor Medium Voltage Switchgear S2 will provide redundant power to the new Solids Processing Building. The redundant feeds will be from separate buses. The first feed will be from the 1200A breaker 3 on Bus 1. The second feed will be from the 1200A breaker 11 on Bus 2. Both feeds currently power the existing Maintenance Building (to be demolished) and the existing Incinerator & Filter (I&F) Building (to be demolished). The transition of the redundant feeds from S2 must be sequenced one bus at a time to maintain incinerator operations during construction.

Prior to Maintenance Building demolition, temporary feeds to switchgear S1 in the I&F Building must be installed in order to maintain operations during construction. Except for coordinated outages, two medium voltage power supplies must be maintained to S1 at all times until the I&F Building is removed from service, decommissioned, and demolished.

The Administration Building will be kept operational. This will be accomplished by back feeding from the new Solids Processing Building directly to the Administration Building MCC P4. In addition, there are certain loads that are connected to an emergency back-up generator. The generator will be kept and a new MCC will be installed to refeed the existing emergency power equipment. This equipment includes (1) generator, (2) emergency lighting, (3) drainage well(s), (4) primary control building P5N emergency power bus, and (5) compressor(s).

The existing Grit and Screening Building will be repurposed as a new Maintenance Building. The interior of the building will be cleared out and the space will be converted for use as maintenance and storage, general offices, locker rooms, and administrative purposes. The existing Grit and Screening Building Medium Voltage Starter Panel M1 and Unit Substation U4 are powered by redundant 4160V feeds originating at Medium Voltage Switchgear S2. Installed in 1976, M1 and U4 are nearing end of useful life. It is recommended that they be removed and new electrical distribution equipment be installed.

Demolition and installation will need to be sequenced to maintain operation for the UV Building which is fed from M1 in the Grit and Screening Building. The UV Building has a 4 month off season in which a single feed may be acceptable. During the eight month disinfection season, dual feeds must be maintained at all times except for coordinated outages.

13.5 EXISTING EQUIPMENT CONDITION ASSESSMENT

The following tables list electrical equipment that will be affected by the construction of the Solids Processing Buildings. The tables include details on the condition assessment and the recommended action on modifications if needed.

Equipment Condition Assessment – Bissell Point

Building	Equipment ID / Description	Condition Assessment	Recommended Action
Building No. 4 Electrical Substation	Main Switchgear	-New condition. -Installation to be complete Summer 2021	-Feed new Solids Processing Building from this location
Substation No. 3	4160V Switchgear with Double Ended Unit Substation	-Very poor condition. -Has had major duct bus failures -Reaching end of life.	-Transition loads to the Thickener Building and Maintenance Shop to new permanent feeds from the Solids Processing Building. -Leave in service until Sludge Building is taken out of service, decommissioned, and demolished.
Thickener Building	15MCC1 15MCC2 15MCC3 15MCC4	-Fair condition -Feeds Admin Building and Maintenance Shop loads -GE 8000 Series MCC -Located in Electrical Room 207	-Keep in place -Install permanent main feeds from Solids Processing Building
Maintenance Shop	15MCC5	-Fair condition -Feeds Maintenance Shop loads -GE 8000 Series MCC -Located on shop floor	-Keep in place -Install permanent main feed from Solids Processing Building
Sludge Disposal Building	Power Panels PP-B, C, D, E, F, H, I, J, K, N, P, R, S, T, U	-Various conditions	-Leave in service until Sludge Building is taken out of service, decommissioned, and demolished.
Sludge Storage Building	Power Panel PP-G	-Poor condition -End of life	-Demolish or abandon in place

Equipment Condition Assessment – Lemay

Building	Equipment ID / Description	Condition Assessment	Recommended Action
Outdoor Substation	Medium Voltage Switchgear S2	-Dated but functional -Auto transfer and power monitoring updates in 2012-13 as part of UV Building project	-Reuse existing feeders for the Solids Processing Building
Maintenance Building	MCC-P16	-Building to be demolished	-Demolish
Incinerator & Filter Building	Medium Voltage Switchgear S1	-Building to be demolished	-Install temporary feeds to switchgear S1 prior to Maintenance Building demolition in order to maintain operations during construction. -Two MV power supplies must be maintained to S1 at all times until the I&F building is removed from service, decommissioned, and demolished
Grit & Screening Building	Medium Voltage Starter Panel M1	-Nearing end of useful life -Installed in 1976	-Replace with new medium voltage power distribution for new Maintenance Building. -Sequence work to maintain operation for the UV Building fed from M1.
Grit & Screening Building	Unit Substation U4	-Nearing end of useful life -Installed in 1976	-Replace with new low voltage power distribution for new Maintenance Building
UV Building	68TX-001 68TX-002	-Good condition -Installed 2012-13	-Refeed from new Maintenance Building

13.6 ELECTRICAL LOADS

The electrical loads are projected to include the following.

Solids Processing Electrical Loads – Bissell Point

Load Description	Connected Load (HP/KVA)	Connected Full Load Amps	Max Running Full Load Amps
Fluidizing Air Blower No. 1	650	96	96
Fluidizing Air Blower No. 2	650	96	96
Fluidizing Air Blower No. 3	650	96	96
Fluidizing Air Blower No. 4	650	96	0
ID Fan No. 1	650	96	96
ID Fan No. 2	650	96	96
ID Fan No. 3	650	96	96
ID Fan No. 4	650	96	0
Transformer No. 1	3000	416	312
Transformer No. 2	3000	416	0
Subtotal		**1601**	**888**
Inrush (25% of largest Load)		24	24
25% Spare		406	228
Total		**2031**	**1140**

Solids Processing Electrical Loads – Lemay

Load Description	Connected Load (HP/KVA)	Connected Full Load Amps	Max Running Full Load Amps
Fluidizing Air Blower No. 1	650	96	96
Fluidizing Air Blower No. 2	650	96	96
Fluidizing Air Blower No. 3	650	96	0
ID Fan No. 1	650	96	96
ID Fan No. 2	650	96	96
ID Fan No. 3	650	96	0
Transformer No. 1	3000	416	312
Transformer No. 2	3000	416	0
Subtotal		**1408**	**696**
Inrush (25% of largest Load)		24	24
25% Spare		358	180
Total		**1790**	**900**

13.7 ENVIRONMENTAL CLASSIFICATIONS

There will be four possible area designations used for interior work: (1) hazardous; (2) corrosive; (3) wet; and (4) indoor dry. Materials of construction and construction techniques will vary based on the area designation.

Hazardous Areas: Methane gas and hydrogen sulfide gas are the primary concerns in hazardous areas. Electrical devices and equipment will be located outside hazardous areas whenever practical. An electrical room with a separate ventilation system and exterior access doors is recommended adjacent to areas with hazardous environments. Where electrical devices are located within hazardous areas, explosion-proof enclosures, vapor barriers, and intrinsically safe wiring will be utilized, as appropriate.

Corrosive Areas: Hydrogen sulfide and chemical storage areas are the primary concerns for corrosive environments. Boxes and enclosures will be NEMA 4X rated to minimize corrosion on electrical enclosures in these areas. Conduits will be either aluminum or PVC coated steel. Electrical supports will be stainless steel or PVC coated steel.

Non-Hazardous Non-Corrosive Wet Areas: Outdoor areas and indoor damp or hose-down areas will be designated as wet. Boxes and enclosures will be NEMA 4X rated. Equipment such as light fixtures will be UL wet location listed.

Indoor, Dry Areas: Climate controlled areas protected from unwanted moisture shall be designated dry. Boxes and enclosures will be NEMA 12 rated.

13.8 SEISMIC

At Lemay WWTF and Bissell Point WWTF, seismic design will meet the requirements of the International Building Code. In addition at Lemay WWTF, St. Louis County’s seismic code block is required to identify the equipment that requires anchorage and sway bracing details.

13.9 EXTERIOR SITE DESIGN

13.9.1 Site Lighting

Outdoor lighting will be provided for building egress points and any roadway and parking areas. Target illumination at these locations will be 1 foot-candle minimum. Lamps will be controlled individually by integral photocells.

Building Perimeter and Entrances

- Fixture type: Wall pack, LED, integral photocell
- Mounting: Surface, above doorways

Site and Roadway Lighting

- Fixture type: Roadway, LED, integral photocell
- Mounting: Pole, 35 foot round tapered aluminum

13.9.2 Underground Duct Banks

Underground duct banks will be used to connect the plant incoming substation to the Solids Processing Building main switchgear. Underground duct banks will also be used for routing other cables including communication cables (copper or fiber optic ethernet).

Any new duct banks will be concrete-encased rigid non-metallic conduits. Duct banks will be reinforced when run under areas subject to vehicle traffic. Power and control circuits will be run in separate conduits. Separate hand holes will be installed to separate power and control circuits.

13.9.3 Grounding

The building will be grounded per NEC requirements using a ground ring system that will be bonded to building structural steel and underground metallic piping. In general, any switchgear, motor control line-ups, switchboards, MCCs or lightning protection systems will be connected to the building grounding system. The neutrals of any wye-connected transformers will be solidly grounded to the grounding system. Circuits within raceways will be provided with a ground conductor, except for instrumentation circuits.

13.9.4 Lightning Protection

Lightning protection will be installed if recommended by an NFPA 780 risk assessment. If needed, a lightning protection plan will be developed by a lightning protection system designer to include air terminals and down conductors for connection to the building grounding system.

13.10 INTERIOR BUILDING DESIGN

13.10.1 Indoor Lighting

International Energy Conservation Code (IECC) lighting system requirements will be followed utilizing both manual and automatic control, where applicable, to maximize energy efficiency. Typical manual lighting control will be by local low voltage momentary contact wall-mounted switches. Automatic control will be via occupancy sensors and/or automatic time switch control devices, as applicable based on area type as detailed below.

Illumination levels will follow the IESNA Lighting Handbook recommendations as determined by area usage or area designation. Generally, process areas and electrical rooms will be lit to 30 foot-candles and hallways and egress paths will be lit to a minimum of 10 foot-candles.

Emergency lighting will be ensured by lighting inverter battery backup. All emergency lighting will be sized to provide appropriate egress lighting for 90 minutes.

Industrial Unclassified Rooms

- Fixture type: Industrial 4-foot LED
- Mounting: Surface
- Lighting control: Local wall mounted switches with timer or occupancy sensor.

Industrial Hazardous Classified Rooms

- Fixture type: Class I, Division 1 rated LED
- Mounting: Surface
- Lighting control: Local wall mounted switches with timer or occupancy sensor.

Industrial Corrosive Rooms

- Fixture type: Industrial non-metallic 4-foot LED
- Mounting: Surface
- Lighting control: Local wall mounted switches with timer or occupancy sensor.

Industrial Process Rooms

- Fixture type: Industrial high-bay LED
- Mounting: Surface, above process areas
- Lighting control: Local wall mounted switches with timer or occupancy sensor.

13.10.2 Enclosures

Electrical equipment enclosures will be the following:

- Hazardous areas: NEMA 7 explosion proof
- Corrosive areas: NEMA 4X aluminum or non-metallic
- Non-Hazardous Non-Corrosive Wet Areas: NEMA 4X
- Indoor dry: NEMA 12

13.10.3 Raceways

Conduits will primarily be surface mounted. The minimum size for exposed conduit for all areas will be 3/4-inch. Conduit embedded in slabs will be minimized as is practical, and conduits that are embedded will be rigid non-metallic conduits transitioning to PVC-coated rigid aluminum at slab penetrations. Raceway type will be selected based upon the area classification.

13.10.4 Fire Alarm

Fire alarms will follow local codes and be modelled after other buildings on the treatment plant site. The fire alarm detection system will be developed by a fire protection system designer. A fire alarm control panel is recommended to alarm the plant SCADA for trouble or alarm conditions.

14.0 Instrumentation and Control

14.1 GENERAL

This section describes the basis of the Instrumentation and Control (I&C) design for the installation of new dewatering equipment, incinerators and associated systems at both the Bissell Point WWTF and Lemay WWTF. The existing Plant Control Systems (PCS) will be modified to provide reliable monitoring and control of the equipment and process conditions. All I&C work will be in accordance with local and state codes, the criteria outlined in this section, and other requirements applicable to the I&C design of a wastewater treatment facility.

14.2 INSTRUMENTATION AND CONTROL REQUIREMENTS

The I&C system design will adhere to Black & Veatch engineering standards except when accommodating specific MSD standards or requests. Specific equipment preferences not already identified will be elicited from the MSD's staff during the design phase. The following describes design features that will be implemented or considered during detailed design.

14.3 INSTRUMENTATION STANDARDS

Instrumentation will be provided to support the monitoring and control of the new dewatering equipment, incinerators and ancillary systems. Instruments will be provided as inputs to alarm abnormal system operation, pending problems, or safety hazards. Standard signals from the instrumentation will be 4-20 mA with a HART protocol overlay where available for ease of calibration. The following types of instrumentation will be provided:

Level Instrumentation: Depending on the application, smart-type differential pressure sensing level transmitters, non-contacting ultrasonic level transmitters, or non-contacting radar level transmitters will be used.

Pressure Instrumentation: Smart-type pressure transmitters will be provided as required to measure pressures or differential pressures.

Flow Instrumentation: Magnetic type flow meters will be provided to measure any liquid or sludge flows. Thermal dispersion type flow meters will be provided to measure any gas flows. The manufacturer's recommendations for minimum straight runs of pipe upstream and downstream of the meter will be strictly adhered to. If possible, flow conditioners (for gas flow measurements) will be provided to condition the flow profile to enhance the flow measurement.

Temperature Instrumentation: Resistance thermal detectors (RTDs) and smart-type temperature transmitters will be provided as required to measure temperatures.

14.4 I/O SIGNAL STANDARDS

Analog field instrumentation will utilize 4-20 mA DC type signals. Four-wire type instruments will be powered by 120 volts AC. Discrete input signals will utilize 120-volt AC signals to the PCS. All discrete output signals will be 120-volt AC type and provided with interposing relays for isolation. When available, Ethernet communication will be used transfer data from equipment to the PCS.

Vendor provided equipment with Programmable Logic Controllers (PLCs) will be specified to utilize Ethernet based communications for control and monitoring from the PCS. The Ethernet protocol will be specified to be EtherNet/IP to be compatible with the Allen-Bradley PLCs used in the plants. Redundant Field Device System Integrator (FDSI) modules will be used to allow this Ethernet communication with the EcoStruxure Foxboro Distributed Control System (DCS) by Schneider Electric. Based on the amount of data, dedicated FDSI modules will be provided for each incinerator control system. In addition, FDSI modules will be provided for the ancillary systems. The number of modules used for these systems will be dependent on the amount of data exchanged between the control systems.

14.5 PLANT CONTROL SYSTEM

The existing PCS at each plant will be modified to monitor and control the new incinerators and their ancillary systems. At each plant, an EcoStruxure Foxboro DCS by Schneider Electric is used as the PCS. As described above, redundant FDSI modules will be provided to allow Ethernet communication with the incinerator PLCs and other ancillary system PLCs. In addition, new I/O modules will be provided as required to monitor and control instruments or equipment that are not provided with a PLC-based control system.

For the incinerators and the ancillary equipment that are provided with PLC based control systems, Allen-Bradley PLCs will be specified. Lemay WWTF has already standardized on Allen-Bradley, so these PLCs will match other PLCs already in use at the plant. At Bissell Point WWTF, they will convert from using GE PLC’s to Allen-Bradley. In general, these equipment control systems will provide all of the control of the associated equipment, and the PCS at each plant will be used to monitor the equipment, allow the operator to enter setpoints, and send operator initiated discrete commands. The equipment control systems will have the ability to run autonomously without dependence on the PCS.

14.6 SYSTEM CONFIGURATION

Programming and configuration modifications to the existing PCS will be provided by MSD. At a minimum, the modifications will include additions to the tag database as well as developing or modifying HMI graphic display screens, system databases, and reports. This will include the configuration of all new FDSI modules. For equipment provided with a dedicated control system, the equipment supplier will be required to coordinate with the MSD programmer so that the data exchanges are properly configured in both control systems. Any new HMI screens associated with the dewatering process, the incinerators or ancillary systems will be developed based on the P&IDs provided in the design documents and typical screens provided by the equipment suppliers.

14.7 CONTROL SYSTEM DESIGN STANDARDS

P&ID drawings will be developed to show the new dewatering equipment, incinerators and all associated ancillary systems for each plant. The drawing format will follow standard Black & Veatch drawing procedures. Drawings are schematic in nature and will not show every fitting or miscellaneous valve. The device tag numbering convention will be based on the MSD tagging convention. Valves smaller than 4-inches will generally not be provided with tag numbers on the drawings, except for valves requiring power and/or control. Pipeline size and process stream will generally be indicated on the P&ID.

14.8 EQUIPMENT CONTROL MODES

In general, all process equipment will be operated in one or more of the following control modes:

Local Manual: The equipment is manually controlled from a local control panel/station or from the MCC (if no local control station exists).

Local Automatic: The equipment is automatically controlled locally by the packaged equipment PLC or through hardwired interlocking scheme.

Remote Manual: The equipment is controlled manually through the PCS based upon commands issued from an operator workstation computer. For equipment controlled by the PCS, the appropriate discrete output or analog output signals will be sent as issued by the operator. For equipment provided with a PLC, such commands are received by the local equipment PLC and converted into physical outputs to the field devices.

Remote Automatic: The equipment is controlled automatically through the PCS based upon measured process parameters, or calculated values received from field devices, or remote equipment PLCs and upon commands and set points issued from an operator workstation computer. For equipment controlled by the PCS, the appropriate discrete output or analog output signals will be sent to control the process accordingly. For equipment provided with a PLC, such commands, set points, and process values are received by the local equipment PLC from the PCS through the Ethernet communication link between the control systems. The local PLC will adjust the equipment accordingly, through physical outputs, to meet the process set point. Some equipment may have more than one remote automatic mode of control.

The control mode will be selectable, where applicable, based on local/off/remote and hand/off/remote switches located at the devices, MCC, and device control panels. Selector switch position feedback will be wired to the PCS or equipment PLC, allowing an operator using an operator workstation computer to know whether a device is being automatically controlled and to determine if remote control from the workstation is active.

Some non-process equipment will be provided with local manual controls only. Packaged equipment items that are normally provided with local automatic controls will be specified with such. The PCS will be used to monitor packaged equipment and, where applicable, provide remote initiation of the packaged controls. In general, the PCS will not provide parallel controls matching those provided with the packaged equipment.

In addition to hardwired equipment safety interlocks and permissives, where such interlocks and permissive signals are monitored by the PCS or the equipment's PLC, the PCS or equipment PLC will discontinue the control output to equipment concurrent with the equipment's interruption by the hardwired circuit.

15.0 Building Mechanical - HVAC / Plumbing

15.1 GENERAL

This section presents the criteria and basis of mechanical design associated with the plumbing and heating, ventilating, and air conditioning (HVAC) for the new Solids Processing Building at both the Bissell Point WWTF and Lemay WWTF, the new Maintenance Facility at Lemay WWTF, as well as new building heat for existing buildings at the Lemay WWTF. The intent of this section is to define the design criterion, establish the minimum design requirements, and describe the mechanical systems. The selection of the systems will be based on operating performance, system efficiency, life safety considerations, long-term durability, redundancy, local representation/service, ease of operation as well as site and specific requirements identified by the project team or Owner as described herein.

15.2 APPLICABLE CODES AND STANDARDS

In addition to the applicable building codes and standards previously identified, the system designs will also be based on but not limited to the following publications and standards:

- American Society of Plumbing Engineers (ASPE) Handbooks.
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Handbooks and Standards.
- Sheet Metal and Air Conditioning Contractor National Association (SMACNA) Handbooks.
- National Fire Protection Association Recommended Practices (NFPA) and Manuals.
- Recommended Standards for Sewage Works - Great Lakes - Upper Mississippi River Board of Sanitary Engineers (10 States Standards).
- Occupational Safety and Health Act (OSHA) Standards Manual.

15.3 LOCATION & METEOROLOGICAL DESIGN CRITERIA

The table below describes the design criteria that will be used for the building mechanical systems design at Lemay WWTF and Bissell Point WWTF.

Table 15-1 Location and Meteorological Design Criteria

CRITERIA	VALUE
Site Elevation, above sea level, ft	413
Site Location[(a)]	
St. Louis Downtown AP, IL, USA	
North Latitude, degrees	38.571
West Longitude, degrees	90.157
Ambient Design Temperatures (b)	
Winter, design dry bulb, F	12.7
Summer, design dry bulb/mean coincident wet bulb, F	92.7/76.3
Climate Zone	4A

CRITERIA	VALUE
Climate Data	
Mean Daily Dry Bulb Temperature Range, F	20.2
Rainfall Intensity (c)	
Actual, inches/hour	3.2
Design, inches/hour	
Primary Roof Drains	3.5
Secondary (emergency) Roof Drains	3.5

(a) The site location is for determining representative weather data for both Bissell Point WWTF and Lemay WWTF but is not necessarily the specific project location.
(b) The winter and summer design temperatures are based on the ASHRAE frequency levels 99 percent and 1.0 percent, respectively.
(c) The actual rainfall intensity rate is based on a 60-minute duration and 100 year return period.

15.4 MATERIALS

Materials will be selected giving preference to those materials that require the least maintenance and have the longest life. These are summarized in the table below.

Table 15-2 Mechanical Systems Materials

SYSTEM	MATERIALS
Storm Drainage Systems	Cast Iron
Sanitary Drainage Systems	Cast Iron
Water Systems	Copper
Natural Gas Systems	Steel (above grade) Polyethylene (buried)
Plumbing Fixtures	Vitreous China, Cast Iron, Enameled Steel, Stainless Steel, or Composites
Ductwork	Galvanized Steel, Aluminum, 316 Stainless Steel

15.5 SEISMIC

The seismic design will comply with the “Seismic Design Requirements for Nonstructural Components” of the latest edition of American Society of Civil Engineers Standard ASCE/SEI 7, “Minimum Design Loads for Buildings and Other Structures”.

15.6 PLUMBING DESIGN

15.6.1 Storm Drainage Systems

Existing storm drainage systems will remain in place at the new Lemay Maintenance Facility. Primary and secondary roof drainage systems will be provided for all flat roofed areas of the Solids Processing Buildings at both the Lemay and Bissell Point facilities. The primary systems will consist of roof drains and interior piping which will discharge above grade to splash blocks and to a below grade storm drainage system when available and necessary to prevent a nuisance. The secondary system will consist of overflow roof drains set at an elevation two inches above the primary roof drains. There will be one overflow roof drain for each primary roof drain. The overflow roof drains will be piped on the interior of the building independently from the primary system and will discharge above grade to splash blocks.

All horizontal storm drainage piping within structures will be sized based on a slope of 1/8-inch per foot. To facilitate maintenance, cleanouts will be installed throughout the primary and secondary storm drain systems. The location will be in accordance with the applicable code requirements. Cleanouts will be the same size of pipe up to 4 inches and for larger pipe sizes, the cleanouts will be 4 inches in size. Piping materials will be cast iron soil pipe with hubless or bell and spigot joints for above grade locations and bell and spigot joints for below grade locations.

15.6.2 Sanitary Drainage Systems

General floor drainage will be provided in Storage Areas, Truck Receiving Areas, Dewatering Areas, and Incinerations Areas of both Bissell Point WWTF and Lemay WWTF Solids Processing Buildings. Funnel receptors will be located adjacent to equipment with equipment drains. Where practical, receptors will be located to serve multiple equipment drains. Drains will be provided at overhead doors to collect any water off vehicles or wind driven rain that enters the building when the door is open. Trench drains will be provided in areas were floor washdowns via hosing will be done.

In finished areas, floor drainage will be provided in the restrooms, lockers, and janitor closets.

The existing sanitary drainage system at the new Lemay Maintenance Facility will remain in place and be modified to accommodate the facility's repurposing. Existing sump pumps and associated controls and accessories will be demolished and replaced. Floor drains and funnel receptors will be provided as required for new equipment needs. Drainage piping from new floor drains and funnel receptors will be tied into the existing sanitary system and will be vented and provided with cleanouts per code requirements.

All floor drains, bell-up drains, and plumbing fixtures connected to the sanitary drainage system will be provided with traps and vents. Where individual vents cannot be provided for each trap due to physical constraints, a combination waste and vent system will be utilized for floor drains and funnel receptor drains. All other drains will be individually vented. Piping materials will be cast iron soil pipe with hubless or bell and spigot joints for above grade locations and bell and spigot joints for below grade locations.

All plumbing fixtures and floor drains located on the floor at or above grade will discharge by gravity to the plant sanitary sewer. Below grade floors of both Bissell Point WWTF and Lemay WWTF Solids Processing Buildings and the Lemay Maintenance Facility will drain to sumps with duplex submersible type sewage pumps. The sump pumps will discharge to the sanitary sewer system.

15.6.3 Water Piping Systems

Potable water from the existing sites' potable water piping will be supplied to the domestic water fixtures and emergency shower/eyewash fixtures. The water pressure available at each site will be determined and booster pumps will be installed if there is not sufficient pressure to meet the Solids Processing Buildings' needs. Where the water pressure exceeds 80 psig, pressure reducing stations will be provided to reduce the water pressure. Water metering equipment will be provided at each building supplied with potable water. Piping materials will consist of soft annealed copper tubing with flared fittings for buried sizes 2-inch and smaller and type K hard drawn copper tubing with solder joint fittings for above grade piping.

All materials in contact with the potable water will comply with the Safe Drinking Water Act of 1986 as amended by the Reduction of Lead in Drinking Water Act of 2011. All plumbing fittings and fixtures intended to convey or dispense water for human consumption will comply with the requirements of NSF/ANSI 61 and NSF/ANSI 372 for low lead.

Protection of the potable water system will be in accordance with local codes or standards. Reduced pressure principle backflow preventers will be provided on the water supply to non-potable water systems. Vacuum breakers will be provided on hose faucets and wall hydrants served by the potable water system when a non-potable water system is not available.

Domestic hot and cold water will be provided to plumbing fixtures as required. A water heater and blending valve will be provided in the cold- water supply to the emergency shower/eyewash fixtures to permit tepid water temperatures (60°F to 90°F) to be supplied to the fixtures.

Hose faucets and 1-1/2-inch hose valves will be provided in unfinished areas that may require periodic washdown. Frostproof wall hydrants will be provided at intervals around the exterior of the structures.

In the Solids Processing Buildings at both the Bissell Point and Lemay facilities, a non-potable water system consisting of piping downstream of a backflow preventer on the potable water system, will be provided for process equipment as required. Hose faucets and wall hydrants with integral vacuum breakers will be provided as necessary for washdown and irrigation needs in and around the structure. Potable hot and cold water will be provided for domestic plumbing fixtures and to service sinks if required in process areas of the facilities.

In the new Lemay Maintenance Facility, the existing cold water supply (potable) will be demolished downstream of the cold water existing water meter. New potable water piping will be supplied to the new domestic water fixtures and emergency shower/eyewash fixtures. The existing protected water supply (non-potable) will be demolished downstream of the existing protected water meter. New non-potable water piping will be supplied to new process equipment and washdown fixtures. The existing flush effluent piping system and accessories will be demolished.

15.6.4 Natural Gas Piping System

Natural gas piping and pressure regulation will be provided at each building for building heat, domestic and process water heaters as necessary. Natural gas will be provided from existing metered supplies on each site. A pressure reducing valve will be located adjacent to the facilities to reduce gas pressure before entry into the building. The natural gas building service entrances will be located and protected from accidental damage by equipment, settlement, or vibration. The natural gas service into each facility will be located above-grade. Piping materials will consist of polyethylene pipe with butt fusion joints for buried sizes 3-inch and larger and socket fusion joints for buried sizes 2-inch and smaller. For above-grade and interior locations, pipe will consist of schedule 40 black steel with butt-welding fittings for 2-1/2 inch and larger and socket welding or malleable iron fittings for 2 inch and smaller.

Natural gas piping will be connected into the existing natural gas distribution piping located at Lemay WWTF site and routed to the new natural gas boilers to be installed in the new Lemay WWTF Maintenance Facility. Available natural gas pressure and flow at Lemay WWTF will be evaluated and piping will be sized and located accordingly.

15.6.5 Plumbing Fixtures

Plumbing fixtures will be selected for durability and ease of maintenance and housekeeping. Water closets will be wall mounted flushometer valve type. All fixtures will be of the high efficiency (1.28 gpf) type. Plumbing fixtures accessible to the disabled will be provided in accordance with Federal and State requirements.

Storage type water heaters located downstream from a backflow prevention device will be protected by use of an expansion tank.

Emergency shower and eyewash stations will be located in areas where injurious corrosive materials are handled or stored. The emergency fixtures will be located in well lit, highly visible, accessible locations on the same level as the hazard with an obstruction free travel path. The station will be plumbed to a tepid water supply as described in the water supply piping paragraph designed to provide 15 minutes of flow. A floor drain will be located under the emergency shower. Each emergency shower and eyewash station will have an alarm device for local and remote alarms. The local alarm will consist of an audible and visible alarm light.

In each of the Solids Processing Buildings and Lemay Maintenance Facility, water closets, urinals, and lavatories will be provided in the restrooms as necessary, a janitor's sink and domestic water heater will be provided in janitor’s closets, and a kitchen sink and domestic fixtures will be provided in the Employee Lunch/Break Room. Process water heaters will be provided to supply hot water for dewatering processes as necessary.

15.7 HEATING, VENTILATION, AND AIR CONDITIONING

The following is a description of the HVAC systems that will be included on the project.

15.7.1 Indoor Design Conditions

The table below describes the indoor design conditions that will be used for the design of the HVAC system.

Table 15-3 Indoor Design Conditions

	DESIGN TEMPERATURES (F) (1)				
	SUMMER	WINTER			
AREA	DESIGN	DESIGN	SETPOINT	VENTILATION REQUIREMENTS	VENTILATION NOTES
Bissell Point WWTF Solids Processing Building					
Polymer Storage Area	102	60	55	6 AC/HR (I)	1
Truck Receiving Area	102	60	55	6 AC/HR (I)	1
Incineration Area	102	60	55	6 AC/HR (I)	1
Mechanical Areas	102	60	55	6 AC/HR (I)	1
Storage Areas/Janitor Closets	102	60	55	6 AC/HR (I)	1
Dewatering Area	102	60	55	6 AC/HR (C)	1, 2
Scum Concentrator Area	102	60	55	6 AC/HR (C)	1, 2
Electrical Equipment Rooms	85	60	55	See Vent. Notes	4
Personnel Offices	78	72	72	See Vent. Notes	4
Corridors/Break Rooms	78	72	72	See Vent. Notes	4
Restrooms/Lockers	78	72	72	See Vent. Notes	3, 4
Control Room	78	72	72	See Vent. Notes	4
Lemay WWTF Solids Processing Building					
Polymer Storage Area	102	60	55	6 AC/HR (I)	1
Truck Receiving Area	102	60	55	6 AC/HR (I)	1
Incineration Area	102	60	55	6 AC/HR (I)	1
Mechanical Areas	102	60	55	6 AC/HR (I)	1
Storage Areas/Janitor Closets	102	60	55	6 AC/HR (I)	1
Dewatering Area	102	60	55	6 AC/HR (C)	1, 2
Scum Concentrator Area	102	60	55	6 AC/HR (C)	1, 2

	DESIGN TEMPERATURES (F) (1)				
	SUMMER	WINTER			
AREA	DESIGN	DESIGN	SETPOINT	VENTILATION REQUIREMENTS	VENTILATION NOTES
Electrical Equipment Rooms	85	60	55	See Vent. Notes	4
Personnel Offices	78	72	72	See Vent. Notes	4
Corridors/Break Rooms	78	72	72	See Vent. Notes	4
Restrooms/Lockers	78	72	72	See Vent. Notes	3, 4
Control Room	78	72	72	See Vent. Notes	4
Lemay WWTF Maintenance Building					
Mechanical Areas	102	60	55	6 AC/HR (I)	1
Storage Areas/Janitor Closets	102	60	55	6 AC/HR (I)	1
Garage	102	60	55	6 AC/HR (I)	1
Restrooms/Lockers	78	72	72	See Vent. Notes	3, 4
Electrical Equipment Rooms	85	60	55	See Vent. Notes	4
Shop/Working Areas	78	72	72	See Vent. Notes	4
Personnel Offices	78	72	72	See Vent. Notes	4
Corridors/Break Rooms	78	72	72	See Vent. Notes	4

(1) Indoor conditions reflect operating temperatures for personnel comfort, code/standard recommendations, or equipment protection.

AC/HR - designates air changes per hour.
(I) - designates the ventilation system operates intermittently.
(C) - designates the ventilation system operates continuously.

Notes:

1. The ventilation system will be sized on the more restrictive of the AC/HR listed or the airflow required to maintain the indoor design temperature based on the summer outside design temperature.
2. Additional intermittent ventilation will be provided if required to maintain the indoor design temperature based on the summer outside design temperature.
3. The exhaust rate will be based on the most stringent requirement of: 0.5 CFM per square foot of floor area; 50 CFM per water closet or urinal; or 100 CFM minimum.
4. The ventilation rate will be based on the exhaust requirements or as required by ASHRAE 62, whichever is more stringent.

15.7.2 HVAC General Requirements

Intakes

Outdoor air intakes will be designed to manage rain entrainment in accordance with the latest ASHRAE standards. Louvers will be selected to limit water penetration to a maximum of 0.01 oz/ft^2 of louver free area at the maximum intake velocity. Corrosion resistant screens will cover the openings with openings of 1/2 inch.

Air Filtration

Outdoor air will be filtered for areas serving air-conditioned areas. Filtration will consist of 2 inch disposable pleated media filters with a minimum efficiency reporting value (MERV) based on ASHRAE 52.2 guidelines of at least 6.

Internal Load Factors

Heating and cooling loads will be calculated in accordance with ASHRAE Standard 183-2007. Internal heat gains will be included in the calculations based on the following:

- Lighting: 1.3 watts/sq ft (unless otherwise indicated)
- People: 230 btuh/person sensible and 190 btuh/person latent (seated, light work)
- Equipment: Equipment heat loss from equipment anticipated to operate simultaneously

Ductwork

Ductwork will be sized for 0.08 inch water column per 100 feet for a friction loss. Ductwork will be insulated for air conditioning systems, outside air, and heating systems. Insulation will consist of duct liner tested to be resistant to mold growth and erosion under a standardized test method. Insulated plenums will be externally insulated and include drain provisions for removal of any moisture that may carryover through the outside air louver.

Outside Air

Air conditioning and ventilation will be provided in offices and other normally occupied areas in accordance with ASHRAE Standards 55 and 62.

15.7.3 Heating Systems

Space heating will be provided by either individual natural gas or electric unit heaters in both Solids Processing Buildings. The heaters will be located to provide uniform space heating of the area served. Each unit heater will be controlled by an adjustable wall mounted thermostat. Electric wall heaters will be provided in restroom areas for supplemental heat.

Heat recovery will not be a part of the new incinerator systems. Therefore building heat provided by the waste heat boilers associated with the Lemay WWTF multiple heart incinerators will no longer be available and will need to be replaced. Natural gas boilers (one duty, one standby) will be installed in the Maintenance Building at Lemay and tied into the existing steam and heating water system that provides heating for that building (the existing Grit and Screening Building). Auxiliary areas fed by this equipment will be the two trash buildings and the Primary Control Building.

As much as can be done, a new heating system for the Blower and Thickener Building will use the existing steam system of that building. An auxiliary area fed by this system would be the biofilters.

A heating system for the Administration Building will be installed by MSD outside of this project.

Refer to the building heat alternatives descriptions included in Technical Memorandum No. 11: Energy Recovery for more information.

Boiler combustion air will be provided by outside air openings. The opening dimensions will be based on the boiler heating input capacity.

15.7.4 Ventilation Systems

In both Solids Processing Buildings and the Lemay Maintenance Facility, the ventilation systems will consist of continuous and intermittent systems. The continuous ventilation systems serving the Dewatering Areas and other NFPA 820 Classified areas of each building will consist of a continuous gas-fired makeup air unit for supply and power roof ventilators for exhaust. The makeup air unit will be controlled by a local "ON-OFF" selector switch and the power roof ventilators will be controlled by a local "ON-OFF-AUTO" selector switch. When the power roof ventilator selector switches are in the "AUTO" position, the power roof ventilators will be interlocked with the makeup air unit. The makeup air will be filtered and tempered to the room design temperature before supplied to the space. A thermostat will modulate the discharge air temperature to the design space temperature.

The intermittent ventilation systems will serve Incineration Areas, Storage Areas, Mechanical Areas, Garages, Truck Receiving Areas, and other normally unoccupied non-NFPA 820 classified spaces in the Solids Processing Buildings and Maintenance Facility. The systems serving these spaces will consist of fans, louvers, dampers, and sheet metal ductwork. The ventilation systems will be designed to promote removal of exhaust air from all portions of the ventilated space. The ventilation systems will be arranged to avoid short-circuiting of supply and exhaust air from the space. Control dampers in the supply and exhaust systems will be used to isolate the spaces from ambient conditions upon system shutdown. The systems will be controlled by local “ON-OFF-AUTO” selector switches. When the switches are in the “AUTO” position, control will be from associated thermostats.

15.7.5 Exhaust Air Systems

Dedicated exhaust systems will be provided as needed for laboratories located in the Solids Processing Buildings and shop/working areas in the Lemay Maintenance Facility. Exhaust fans serving these areas will be located outdoors to prevent system leaks from entering the building. The exhaust discharges will be a minimum of 10 feet above the adjacent roof lines directed in a vertical up direction. Exhaust ductwork will be constructed of type 316 stainless steel.

15.7.6 Air Conditioning Systems

Electrical Equipment Rooms in each Solids Processing Building and the Lemay Maintenance Facility will be air conditioned with wall mounted or rooftop packaged air conditioning units. The units will be mounted on an exterior wall accessible from grade or accessible from the facility rooftop. The units will be equipped with an economizer to provide outdoor air for cooling when outdoor air conditions are suitable for cooling.

Personnel Offices, Restrooms, and Control Rooms and other normally occupied spaces in each Solids Processing Building and the Lemay Maintenance Facility will be served by air conditioning systems consisting of single zone, constant volume, packaged air conditioning units/heat pumps. Each air conditioning unit/heat pump will be provided with a backup emergency electric heating coil. Each unit will be controlled by a remote wall mounted thermostat to maintain the desired space temperature. Additional zoning can be provided with Variable Air Volume (VAV) systems if there is a desire for more flexibility and temperature control throughout the spaces being served.

Restrooms and Janitor Closets will be exhausted by power roof ventilators. Each fan will be controlled by a local "ON-OFF-AUTO" selector switch. When the selector switch is in the "AUTO" position, the fan will be interlocked with the air conditioning unit/heat pump serving this area of the building.

15.7.7 Building Control Systems

The HVAC controls will consist of automatic industrial grade electromechanical and electronic controls. Control component enclosures will be selected based on the environment where they are installed. Typical controls will consist of the following:

- Differential pressure indication across supply and exhaust fans designed to operate continuously to indicated fan flow or failure. Where insufficient differential pressure occurs due to limited ductwork, motor current switches will be used.
- Duct mounted smoke detectors where systems have airflows greater than 2000 CFM and are capable of spreading smoke beyond the enclosing walls, floors and ceilings of the room or space in which the smoke is generated.
- Differential pressure gauge and differential pressure switch with alarm across air filters.
- Electric thermostats for control of intermittent ventilation systems to start and stop equipment operation.
- Electric thermostats or electronic sensors to control heating equipment for maintaining the leaving air temperature within the design temperature range.
- Electric thermostats for detection and alarming of low air temperatures.
- Programmable electric thermostats for control of packaged air conditioning systems.

A microprocessor-based standalone system or building automation system (BAS) is not anticipated for the facilities due to the environment and simplicity of the HVAC systems. However, if deemed preferable by the City, a BAS system can be incorporated to replace the electric and electronic controls and provide central monitoring, operation, and management of the HVAC systems.

16.0 FBI System Selection and Cost

16.1 INCINERATOR SYSTEM SUPPLIER EVALUATION

A qualifications based process will be used for the preselection of the Fluidized Bed Incinerator (FBI) System Supplier (or suppliers). The preselection process will be based upon first a Request for Qualifications (RFQ) issued by MSD that requests corporate information, fluidized bed incineration system experience, project team information and other items from interested FBI System Suppliers. Interested suppliers will submit a Statement of Qualifications document which will be evaluated by MSD, ultimately leading to the preselection of a FBI System Supplier (or suppliers). The preselected FBI System Supplier (or suppliers) will then be included as a part of the design-build Request for Proposal for all design-build proposers to negotiate scope of supply and work as well as contractual terms and conditions.

16.2 OPINION OF COST

The overall cost for the fluidized bed incineration system (both plants) being designed and furnished by the FBI System Supplier is estimated to be $120,000,000.

16.3 SCHEDULE

The anticipated schedule for the FBI equipment preselection process will be:

MSD issues the FBI System Supplier Preselection RFQ: March 17, 2021
Statement of Qualifications submitted to MSD: April 16, 2021
Issue Notice of Preselection for FBI System Supplier(s): June 2021

17.0 Design-Build Project Delivery

17.1 FIXED PRICE DESIGN-BUILD

This project will be executed using a Fixed Price Design-Build project delivery. MSD's Owner's Representative will prepare a Request for Proposal (RFP) that will be issued to design-build teams. In response to the RFP, the design-build teams will develop a fixed price to perform the work based upon their design for the work. The selected Design-Builder will perform the work based upon the completion of their design and for the fixed price established by their proposal in response to the RFP.

17.2 DESIGN-BUILDER REQUEST FOR PROPOSAL AND EVALUATION/SELECTION

Conceptual Documents (also referred to as 30% Documents or bridging documents) will be prepared by MSD's Owner's Representative. These Conceptual Documents will include both drawings and specifications as part of the Request for Proposal (RFP) issued to prospective design-build teams. Based upon these Conceptual Documents as well as additional preliminary design completed by the design-build teams, each design-build team will submit a Technical Proposal and a Fixed Price Proposal to perform the work. MSD, with assistance from the Owner's Representative, will evaluate and score the Technical Proposals received, followed by opening the Fixed Price Proposals. Selection of the Design-Builder will be based upon the combined scoring of the Technical Proposals and Fixed Price Proposals. The selected Design-Builder will perform the work, for which the scope will be based upon the completion of their design, for the fixed price established by their Fixed Price Proposal.

17.3 OPINION OF COST

The overall project cost is estimated to be within the range of $500,000,000 to $550,000,000. This overall cost includes the cost of the dewatering system and fluidized bed incineration system along with the installation of these systems. The cost also includes purchase and installation of all other equipment, all costs associated with the new Solids Processing Building, engineering fees for the Design-Build team, Design-Builder insurance, overhead and profit, and general conditions.

17.4 SCHEDULE

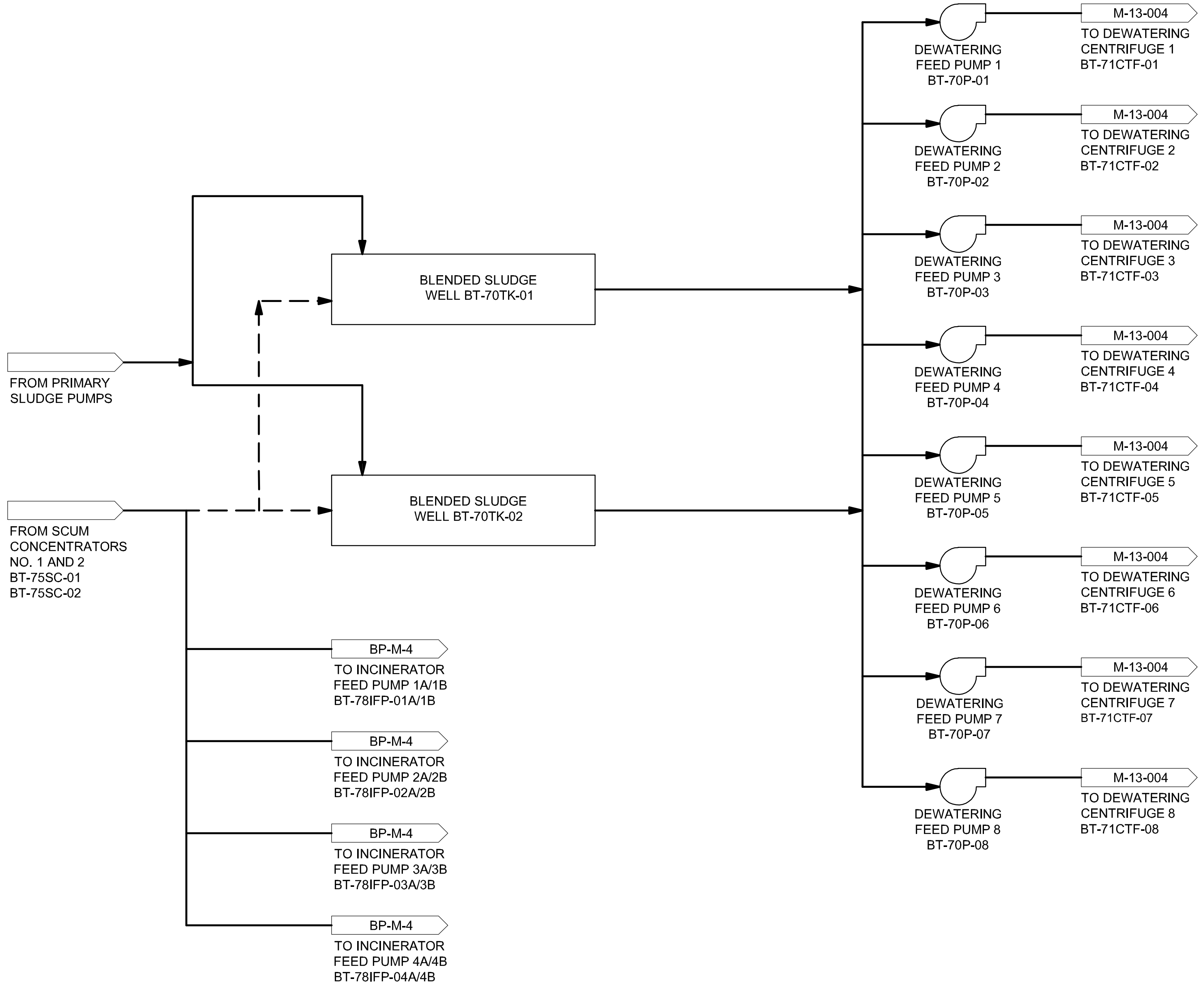
The anticipated overall project schedule will be:

MSD issues the FBI System Supplier Preselection RFQ: March 17, 2021
FBI System Supplier Preselection SOQs submitted to MSD: April 16, 2021
Issue Notice of Preselection for FBI System Supplier(s): June 2021
MSD issued Design-Builder Request for Qualifications: July 7, 2021
Design-Builder Statement of Qualifications submitted to MSD: September 24, 2021
Complete Design-Builder RFP Conceptual Documents: September 21, 2021
Issue Design-Builder RFP to short-listed teams: December 24, 2021
Receive design-build team proposals: June 24, 2022
Issue Design-Builder Notice of Award: September 2022
Issue Design-Builder Notice to Proceed: March 2023
Project Completion: October 2026

Appendix A – List of Abbreviations and Acronyms

AA – Annual Average
APs/dT –
CSO – Combined sewer overflow
DCS – Distributed Control System
dtpd – dry tons per day
FDSI – Field device system integrator
FWI – Foulwater interceptor
GAC – Granular activated carbon
HEPA – High efficiency particulate air
HMI – Human machine interface
HVAC – Heating, ventilating and air conditioning
ID – Induced draft
MACT – Maximum Allowable Control Technology
mgd – million gallons per day
mg/dscm – milligrams per dry standard cubic meter
MHI – Multiple hearth incinerator
MM – maximum month
MSD – Metropolitan St. Louis Sewer District
ng/dscm – nanograms per dry standard cubic meter
PCS – Plant control system
PLC – Programmable logic controller
PM – Particulate matter
ppmvd – parts per million by volume, dry
PS – Primary sludge
PW – Peak week
RDP – River Des Peres
RTD – Resistance thermal detector
SNCR – Selective non-catalytic reduction
SPC – Sorbent polymer composite
SSI – Sewage sludge incinerator
TF – Trickling filter
TM – Technical memorandum
TS – Total solids
UHF – Ultra high filter
VS – Volatile solids
WAS – Waste activated sludge
WESP – Wet electrostatic precipitator
WWTF – Wastewater treatment facility

Appendix B – Bissell Point: Process Flow Diagrams, Site Plan, Preliminary Plan and Profile Sheets



PRELIMINARY - NOT FOR CONSTRUCTION

NO. BY CHK APP

REVISIONS AND RECORD OF USE

DATE

BLACK & VEATCH

Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

BISSELL POINT WASTEWATER TREATMENT FACILITY

MECHANICAL PROCCESS
DEWATERING FEED - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-003
SHEET
OF

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D10000
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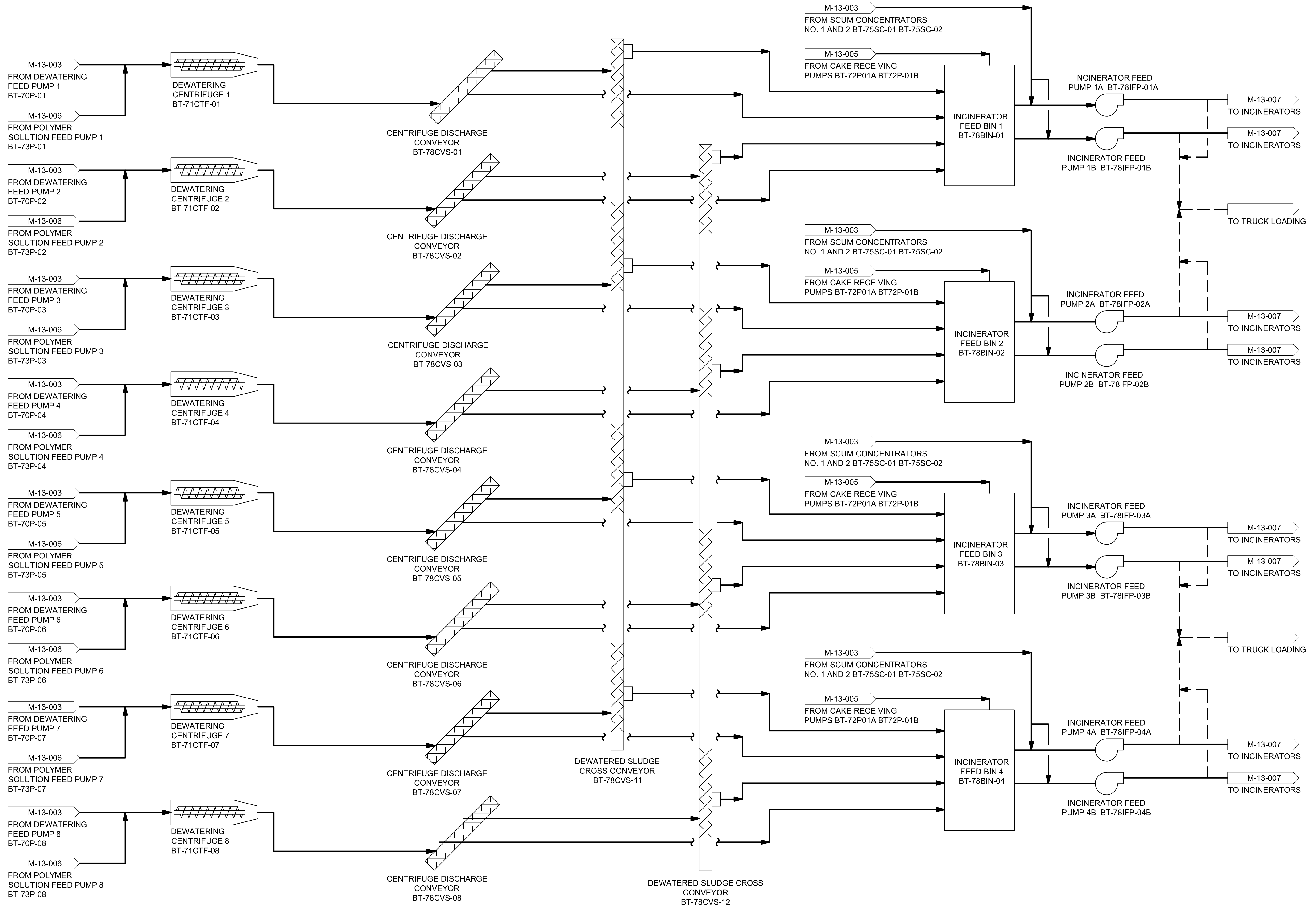

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NO. BY CHK APP
REVISIONS AND RECORD OF USE
DATE

BLACK & VEATCH
Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

BISSELL POINT WASTEWATER TREATMENT FACILITY

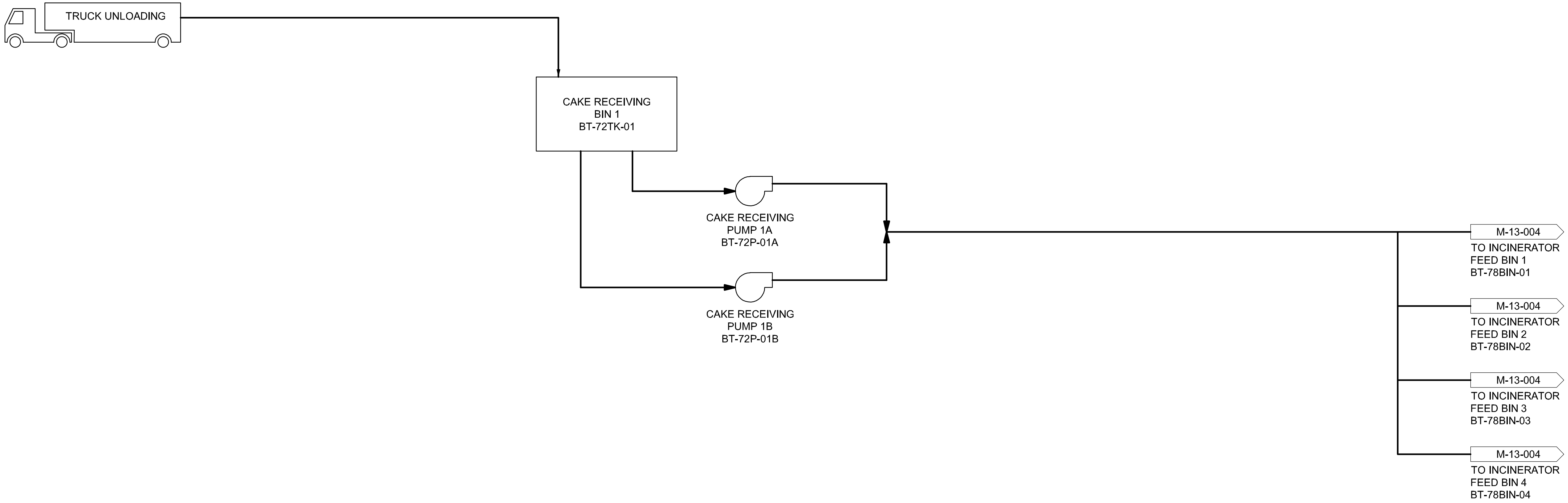
MECHANICAL PROCCESS
DEWATERING AND CONVEYANCE - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-004
SHEET
OF



PRELIMINARY - NOT FOR CONSTRUCTION

NO.	BY	CHK	APP	REVISIONS AND RECORD OF USE	DATE

BLACK & VEATCH

Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

BISSELL POINT WASTEWATER TREATMENT FACILITY

MECHANICAL PROCCESS
CAKE RECEIVING - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-005
SHEET
OF

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D10000
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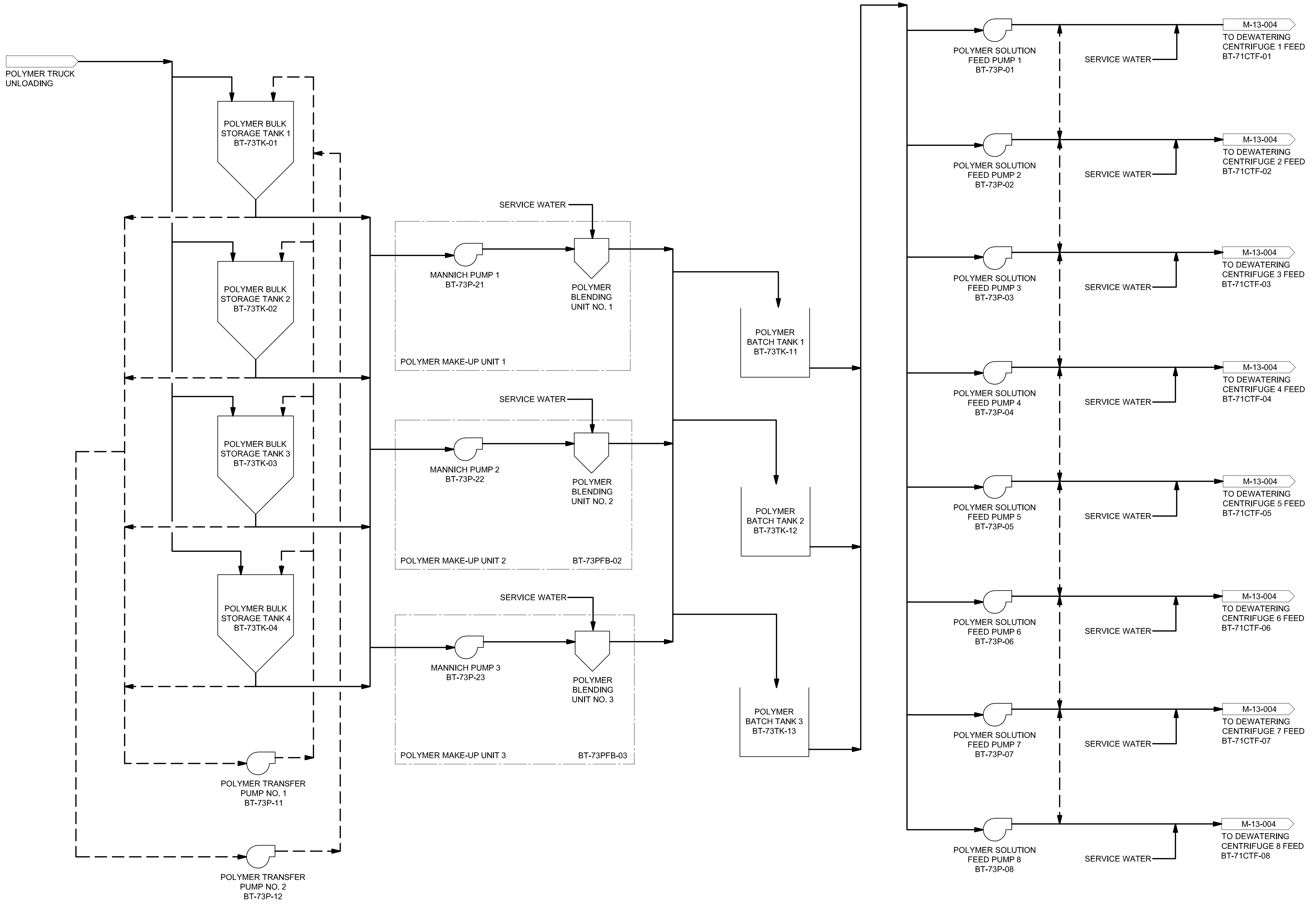

PRELIMINARY - NOT FOR CONSTRUCTION

NO.	BY	CHK	APP

REVISIONS AND RECORD OF USE

DATE

BLACK & VEATCH

Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

BISSELL POINT WASTERWATER TREATMENT FACILITY
MECHANICAL PROCCESS
POLYMER STORAGE AND FEED - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-006
SHEET
OF

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D10000
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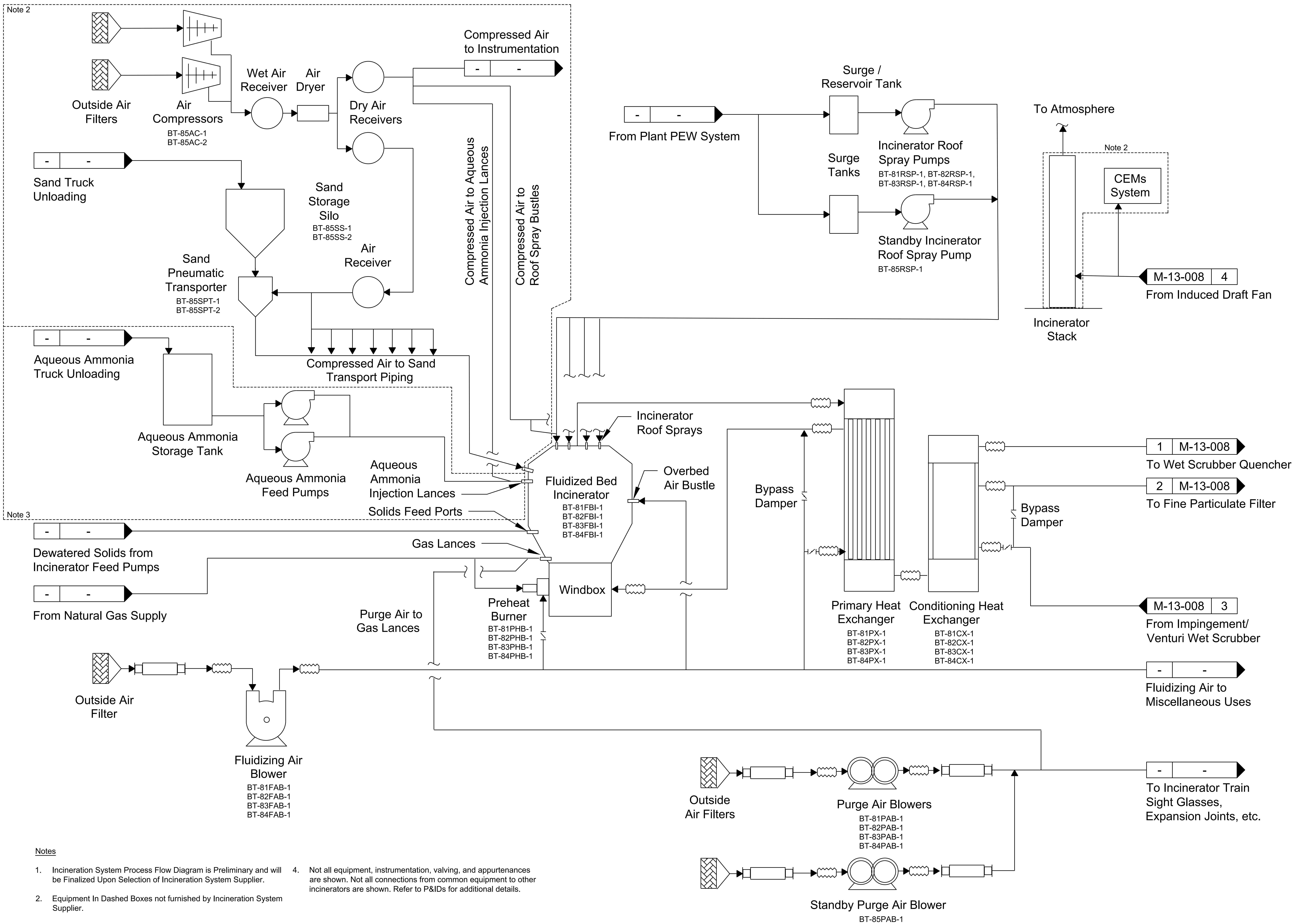

Notes

1. Incineration System Process Flow Diagram is Preliminary and will be Finalized Upon Selection of Incineration System Supplier.
2. Equipment In Dashed Boxes not furnished by Incineration System Supplier.
3. Aqua Ammonia not initially furnished by Incineration System Supplier; however, building space and other provisions will be required for possible future installation.
4. Not all equipment, instrumentation, valving, and appurtenances are shown. Not all connections from common equipment to other incinerators are shown. Refer to P&IDs for additional details.

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP	REVISIONS AND RECORD OF USE	DATE

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Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSEL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSEL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
PROCESS FLOW DIAGRAM - INCINERATION (1 OF 2)

DESIGNED: JLH
DETAILED: JLH
CHECKED: JJH
APPROVED: JJH
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-007
SHEET
OF

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D10000
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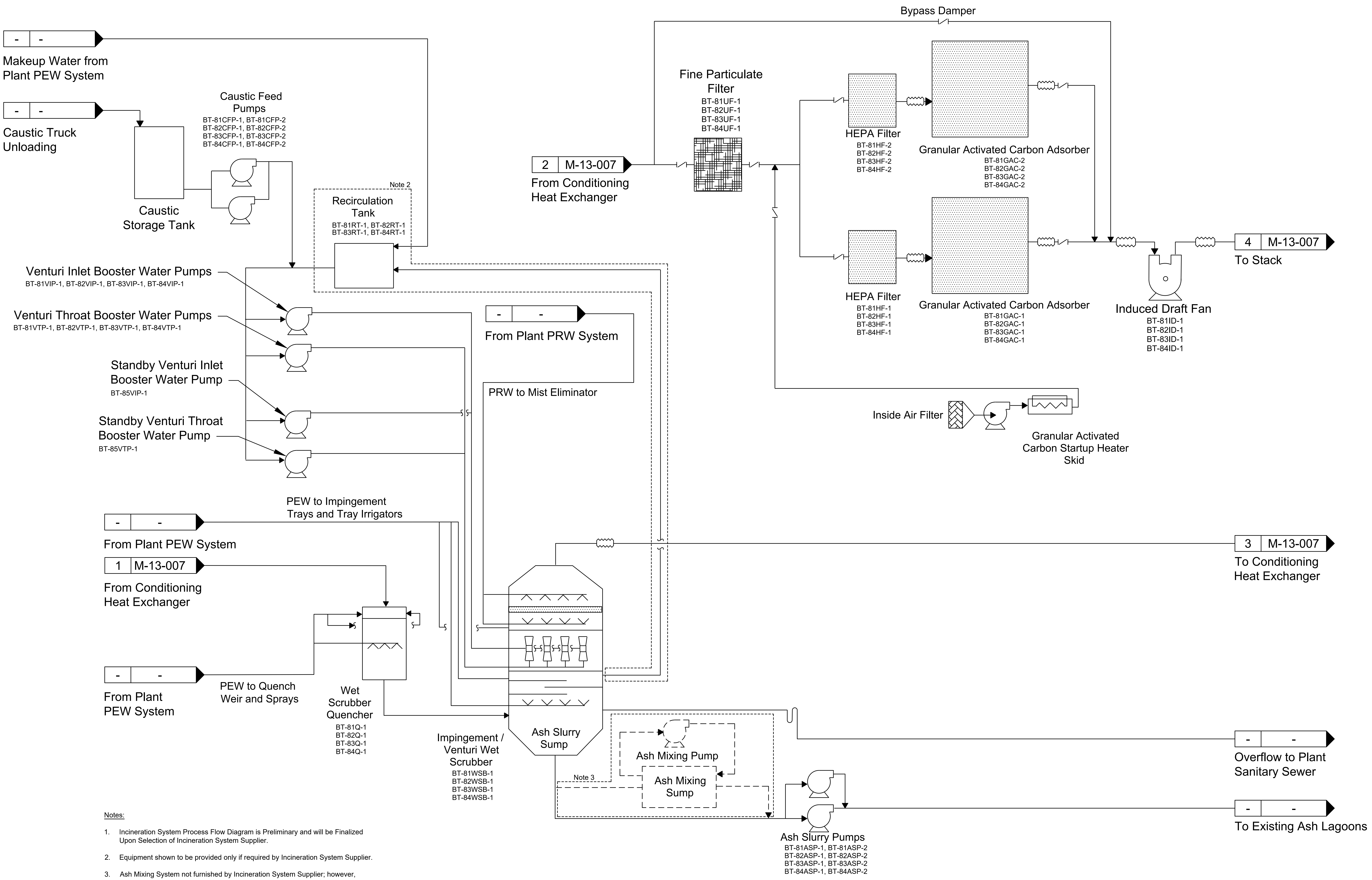

Notes:

1. Incineration System Process Flow Diagram is Preliminary and will be Finalized Upon Selection of Incineration System Supplier.
2. Equipment shown to be provided only if required by Incineration System Supplier.
3. Ash Mixing System not furnished by Incineration System Supplier; however, building space and other provisions will be required for possible future installation.
4. Not all equipment, instrumentation, valving, and appurtenances are shown. Not all connections from common equipment to other incinerators are shown. Refer to P&IDs for additional details.

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP

REVISIONS AND RECORD OF USE

DATE

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Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSEL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSEL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
PROCESS FLOW DIAGRAM - INCINERATION (2 OF 2)

DESIGNED: JLH
DETAILED: JLH
CHECKED: JJH
APPROVED: JJH
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-008
SHEET
OF

FD10000
D10000
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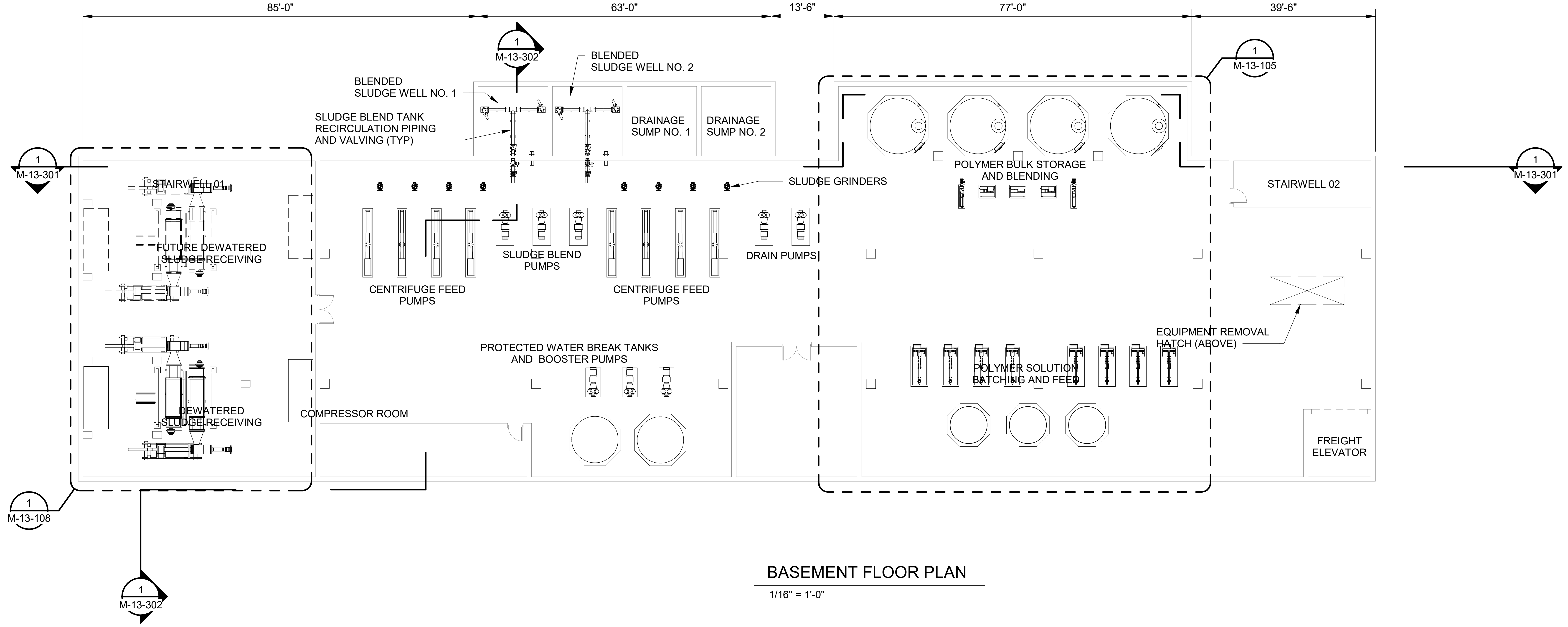

BASEMENT FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'
1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP	REVISIONS AND RECORD OF USE	DATE

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSELL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - BASEMENT FLOOR
PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT
MEASURE 1" THEN DRAWING
IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-101
SHEET
OF

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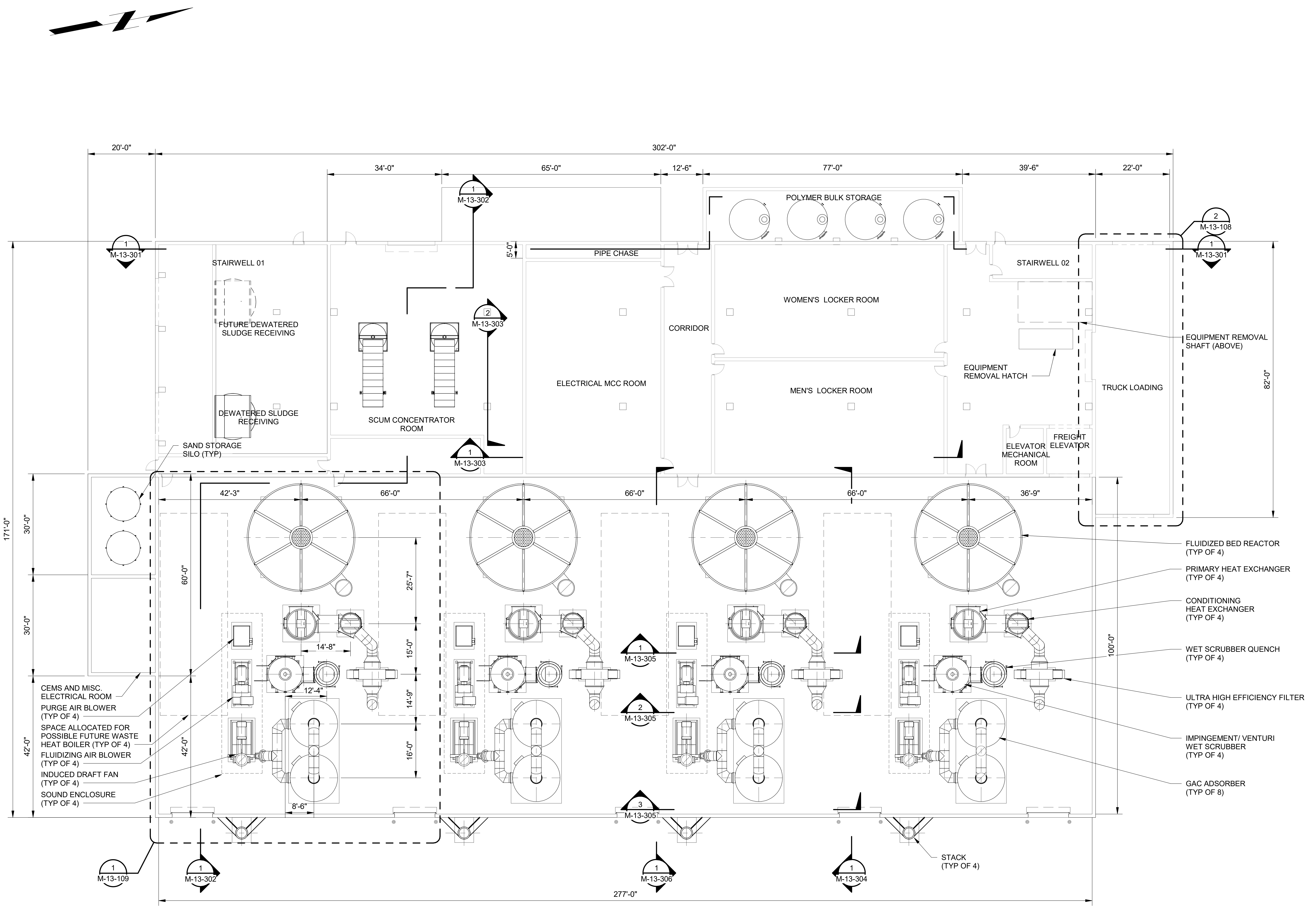

GROUND FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'

1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP

REVISIONS AND RECORD OF USE

DATE

BLACK & VEATCH

Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSELL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - GROUND FLOOR PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-102
SHEET
OF

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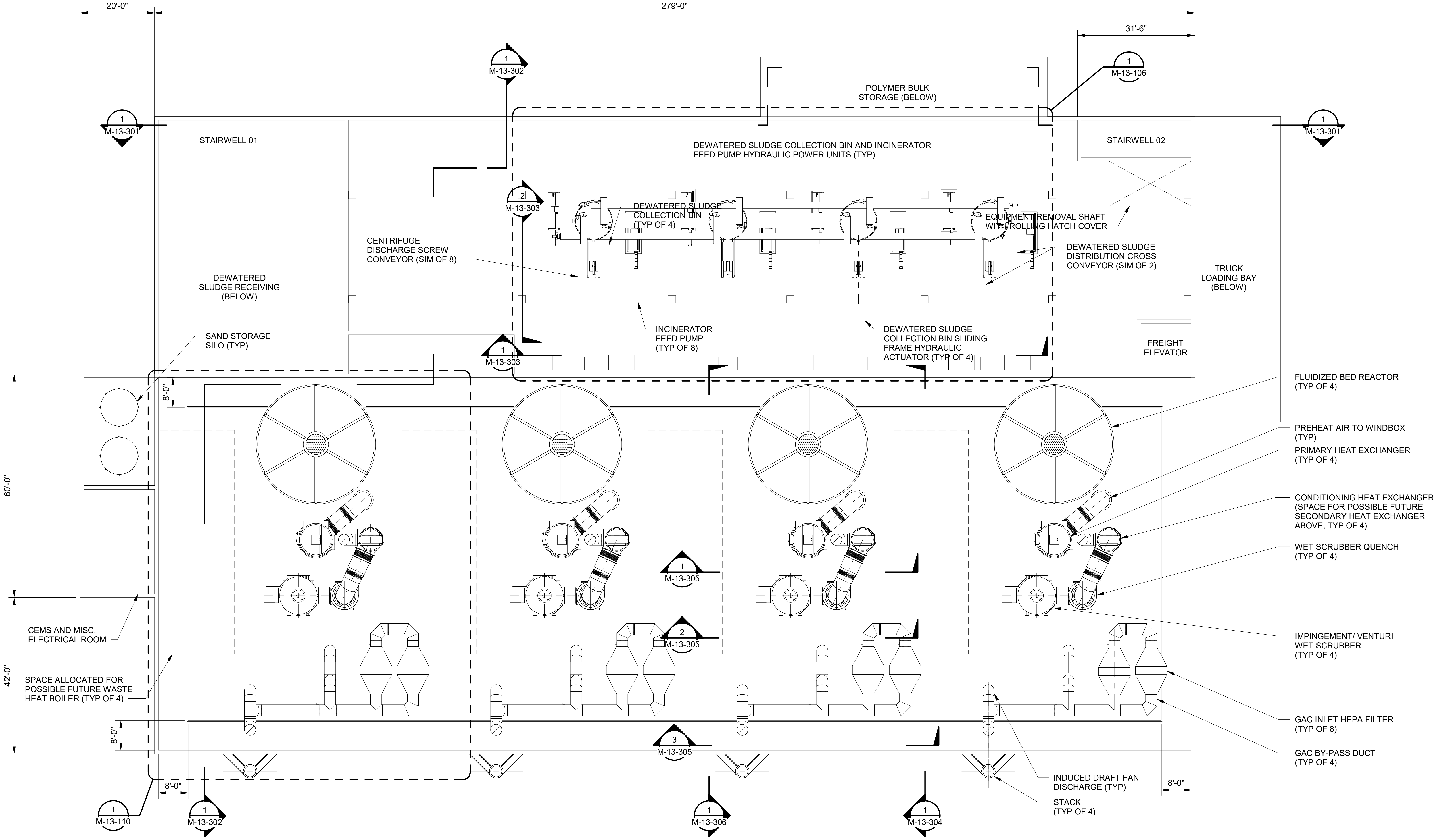
GENERAL SHEET NOTES

SHEET KEYNOTES



SECOND FLOOR PLAN
1/16" = 1'-0"

16' 12' 8' 4' 0' 16' 32'
1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO. | BY | CHK | APP
DATE
REVISIONS AND RECORD OF USE

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSELL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - SECOND FLOOR PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-103
SHEET
OF

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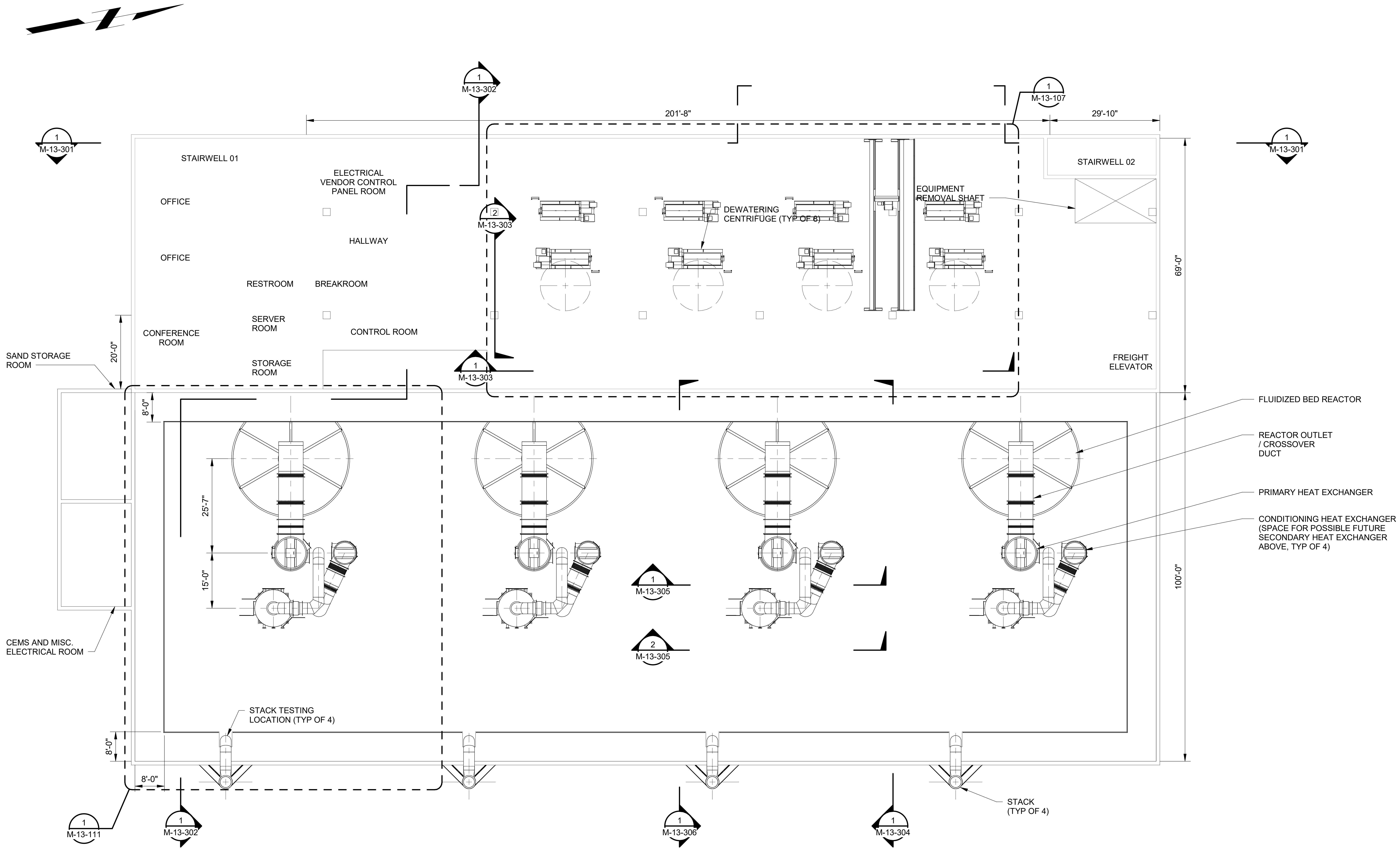

THIRD FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'

1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP

REVISIONS AND RECORD OF USE

DATE

BLACK & VEATCH

Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSELL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - THIRD FLOOR PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-104
SHEET
OF

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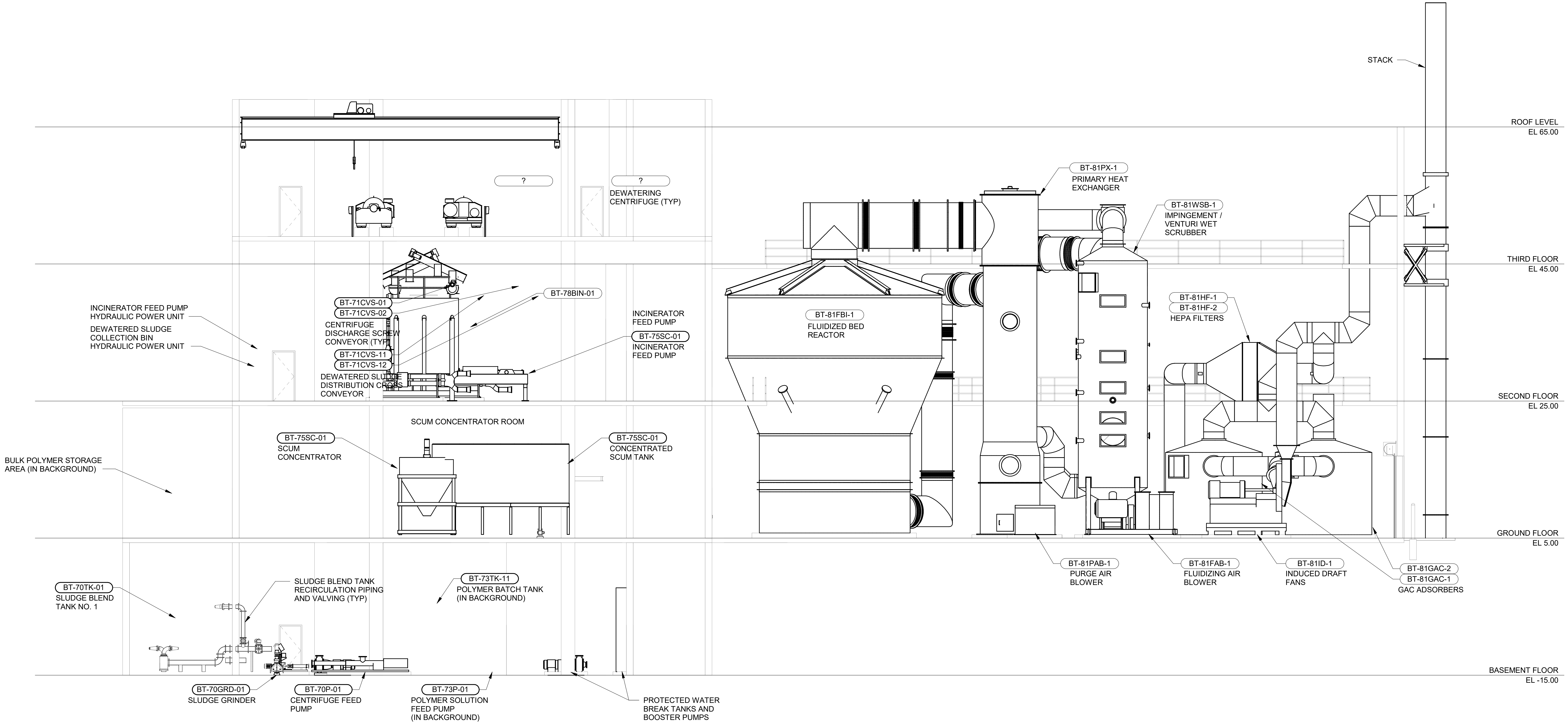

1
M-13-101
SECTION
1/8" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP

REVISIONS AND RECORD OF USE

DATE

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

BISSELL POINT WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - OVERALL BUILDING
SECTIONS (2 OF 2)

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-13-302
SHEET
OF

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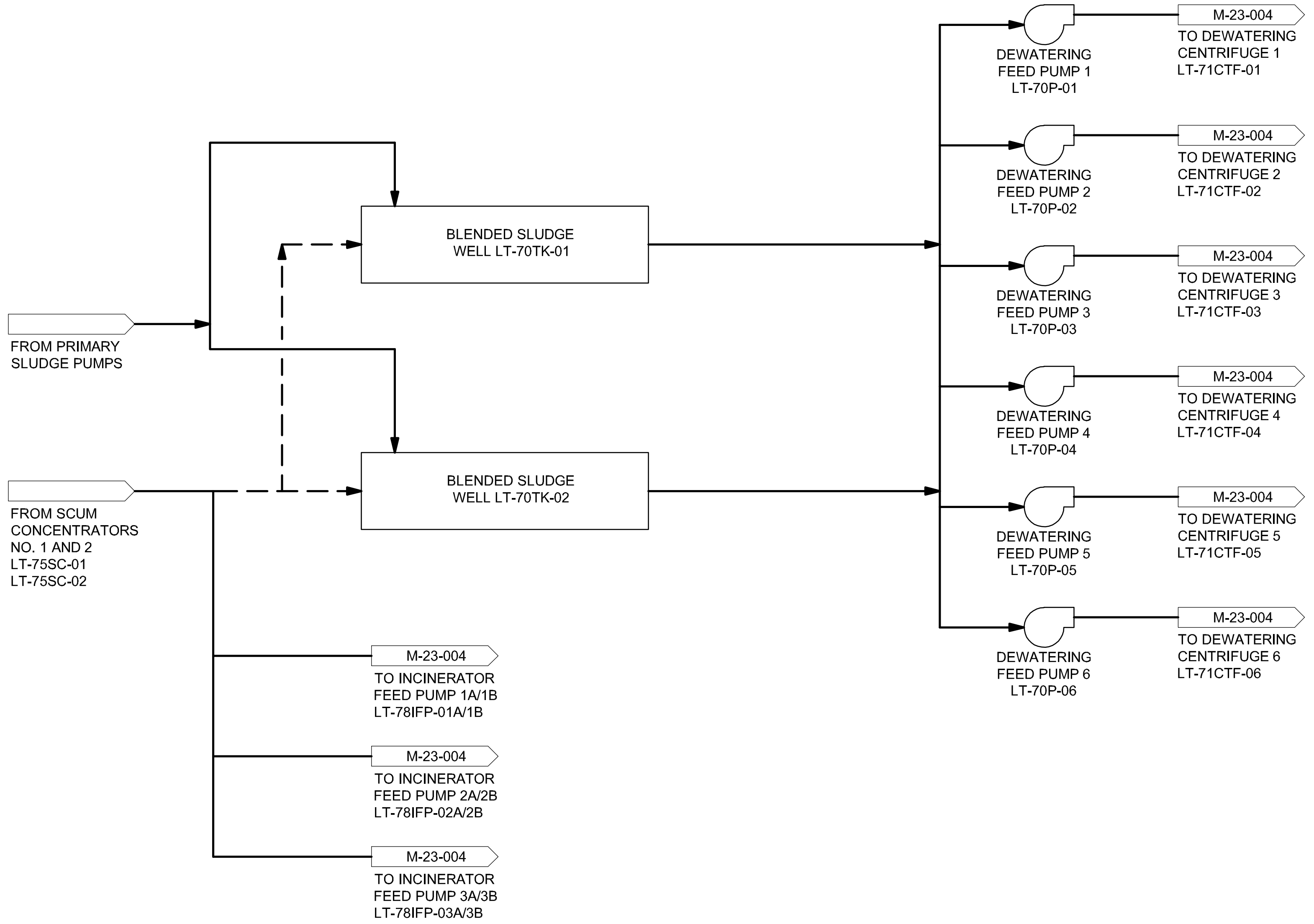
Appendix C – Lemay: Process Flow Diagrams, Site Plan, Preliminary Plan and Profile Sheets



PRELIMINARY - NOT FOR CONSTRUCTION

NO. BY CHK APP
REVISIONS AND RECORD OF USE
DATE

BLACK & VEATCH
Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

LEMAY WASTEWATER TREATMENT FACILITY

MECHANICAL PROCCESS
DEWATERING FEED - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-003
SHEET
OF

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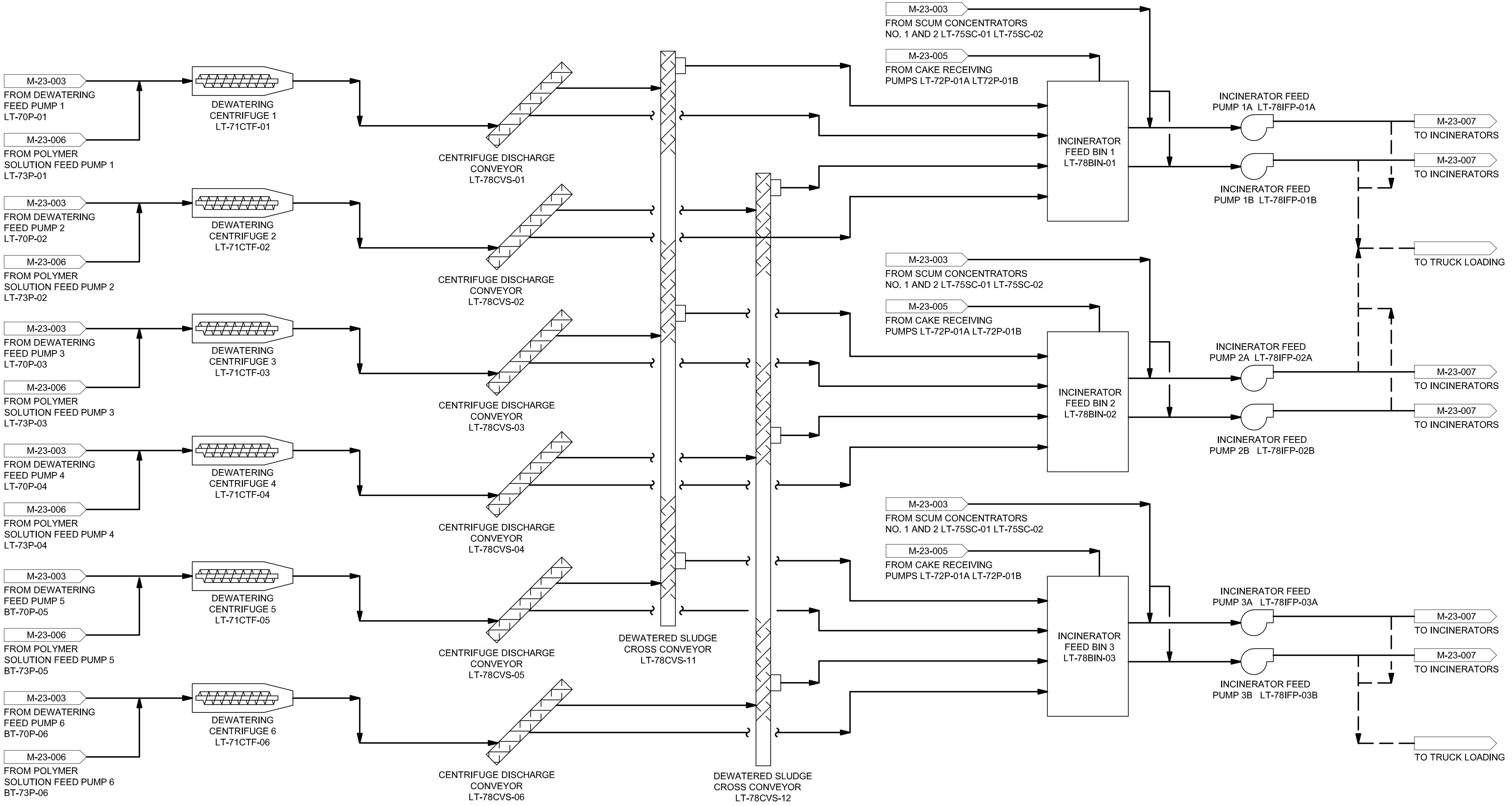

PRELIMINARY - NOT FOR CONSTRUCTION

NO. BY CHK APP
REVISIONS AND RECORD OF USE
DATE

BLACK & VEATCH
Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

LEMAY WASTEWATER TREATMENT FACILITY

MECHANICAL PROCCESS
DEWATERING AND CONVEYANCE - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-004
SHEET
OF

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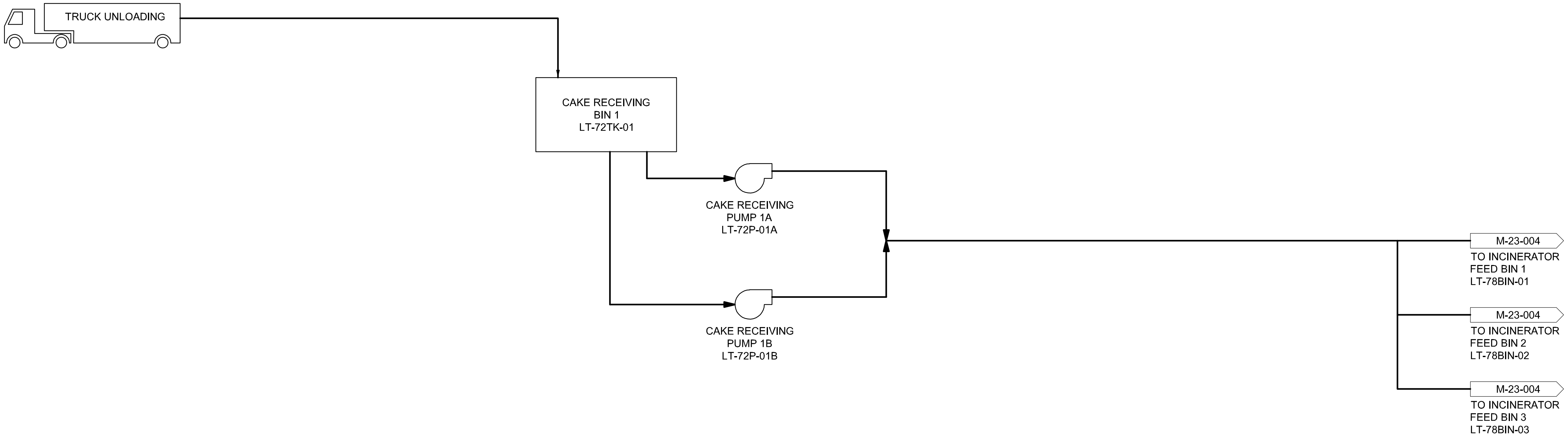

PRELIMINARY - NOT FOR CONSTRUCTION

DATE	REVISIONS AND RECORD OF USE	NO.	BY	CHK	APP

BLACK & VEATCH

Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

LEMAY WASTEWATER TREATMENT FACILITY

MECHANICAL PROCESS
CAKE RECEIVING - PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JANUARY 2021

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-005
SHEET
OF

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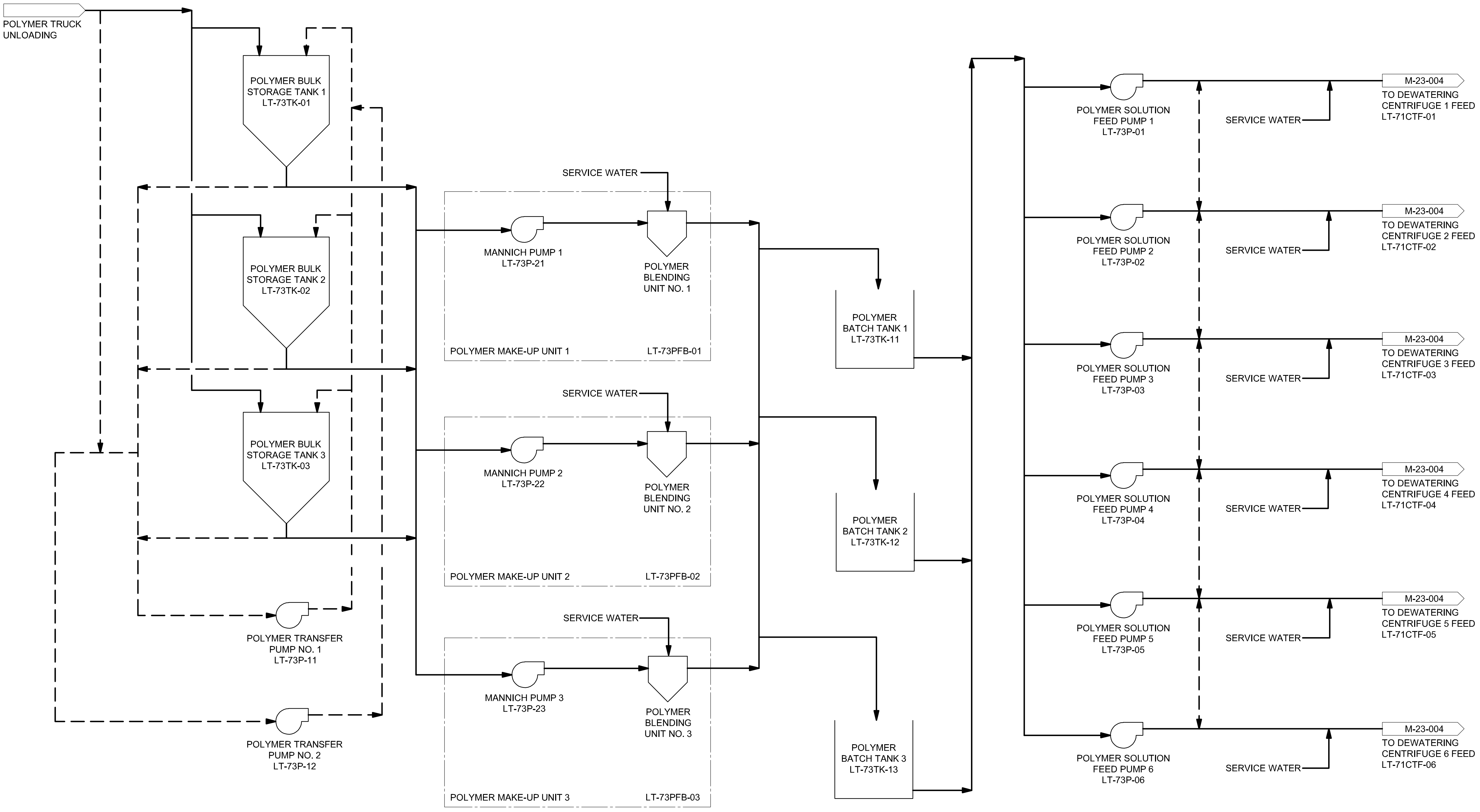

PRELIMINARY - NOT FOR CONSTRUCTION

NO. BY CHK APP
REVISIONS AND RECORD OF USE
DATE

BLACK & VEATCH
Brown AND Caldwell

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
DESIGN-BUILDER REQUEST FOR PROPOSAL

LEMAY WASTEWATER TREATMENT FACILITY

MECHANICAL PROCESS
POLYMER STORAGE AND FEED PROCESS FLOW DIAGRAM

DESIGNED:
DETAILED:
CHECKED:
APPROVED:
DATE: JUNE 2020

0 1/2 1
IF THIS BAR DOES NOT
MEASURE 1" THEN DRAWING
IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-006
SHEET
OF

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D10000
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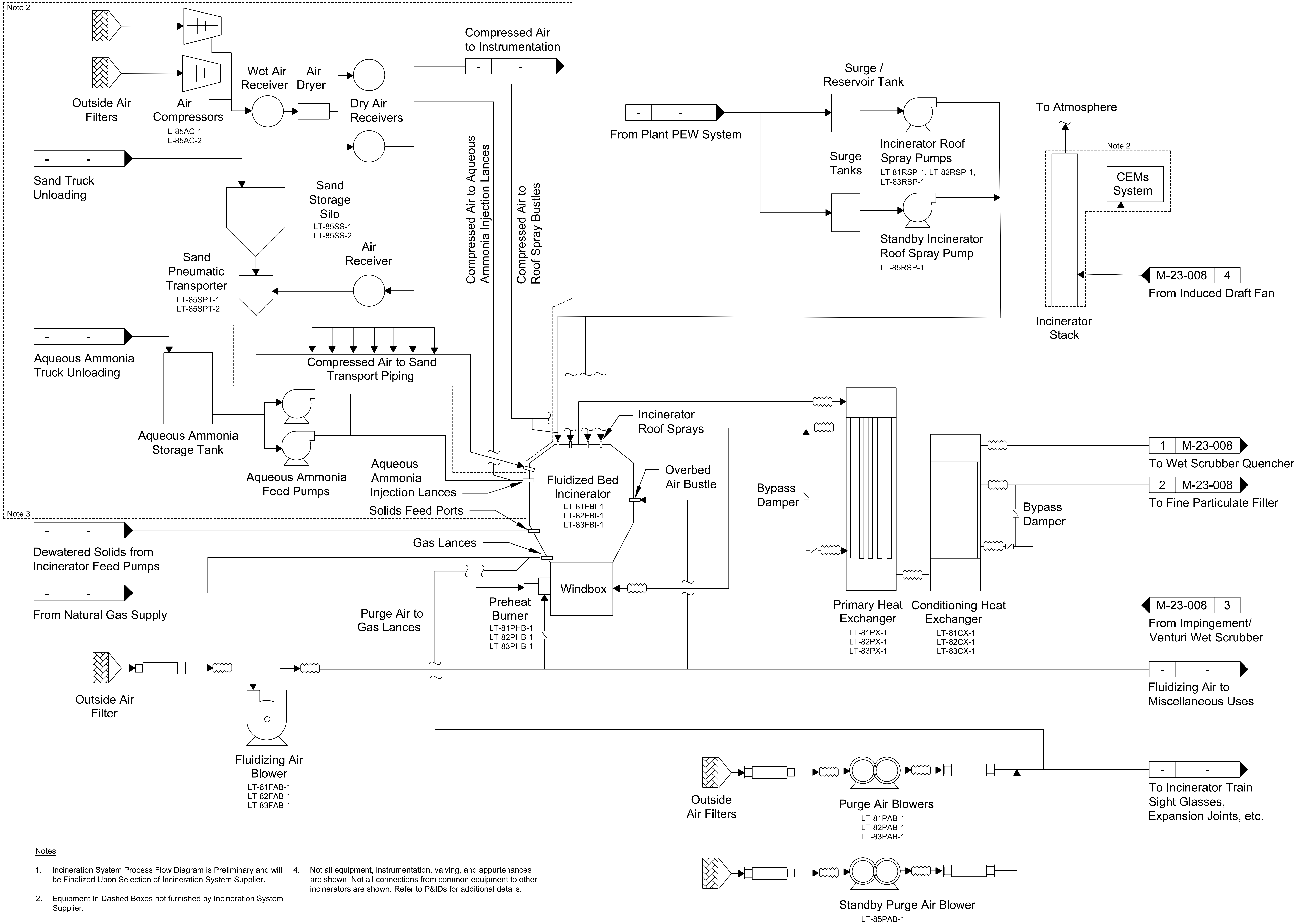

Notes

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3. Aqua Ammonia not initially furnished by Incineration System Supplier; however, building space and other provisions will be required for possible future installation.
4. Not all equipment, instrumentation, valving, and appurtenances are shown. Not all connections from common equipment to other incinerators are shown. Refer to P&IDs for additional details.

PRELIMINARY - NOT FOR ISSUE

NO. BY CHK APP
REVISIONS AND RECORD OF USE
DATE

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSEL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
PROCESS FLOW DIAGRAM - INCINERATION (1 OF 2)

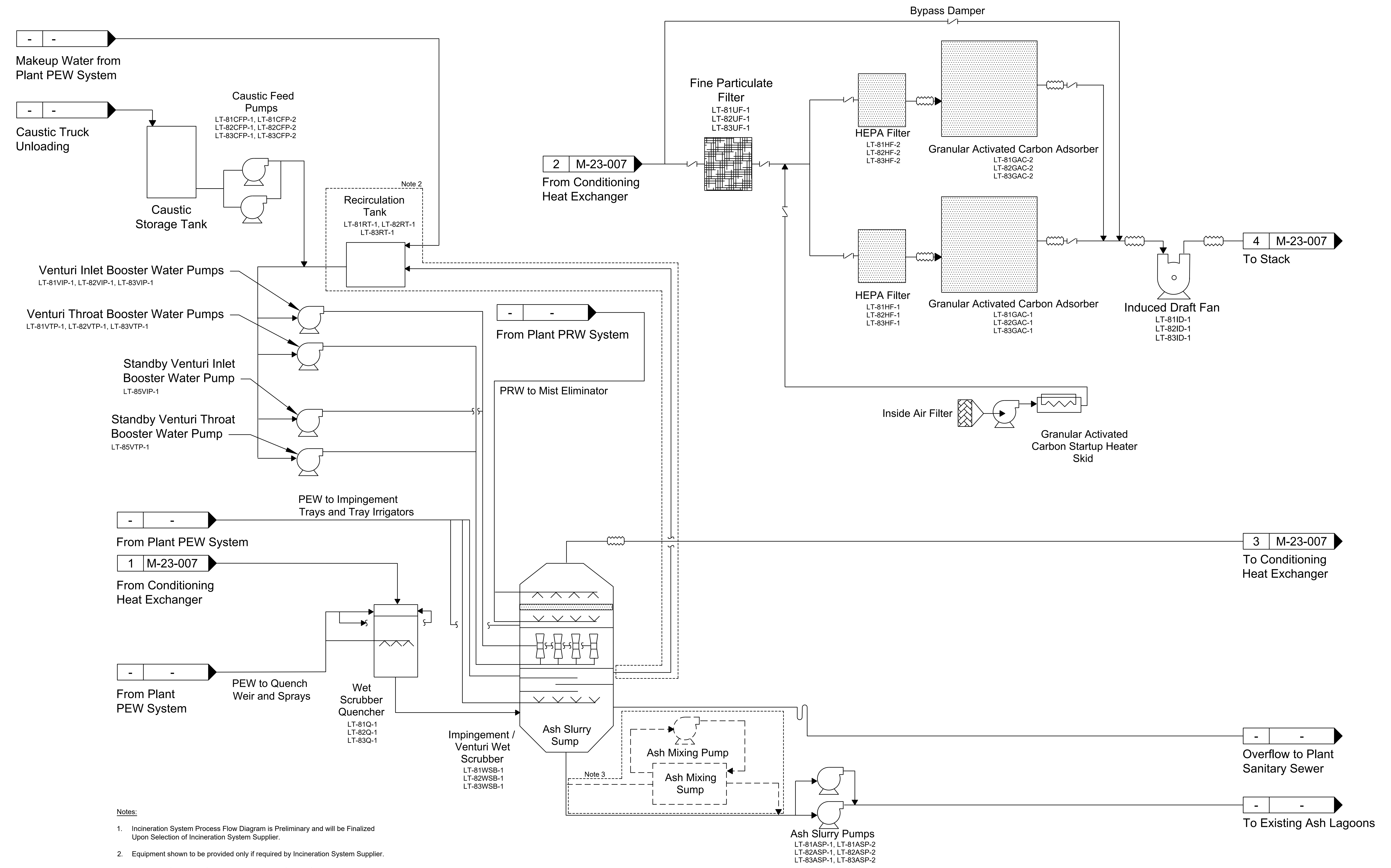
DESIGNED: JLH
DETAILED: JLH
CHECKED: JJH
APPROVED: JJH
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-007
SHEET
OF

FD10000
D10000
PLOTTED: 7/13/2021 8:20 AM FILE: C:\pw_working\bvw_americas\d0816245\M-23-007.dwg



Notes:

1. Incineration System Process Flow Diagram is Preliminary and will be Finalized Upon Selection of Incineration System Supplier.
2. Equipment shown to be provided only if required by Incineration System Supplier.
3. Ash Mixing System not furnished by Incineration System Supplier; however, building space and other provisions will be required for possible future installation.
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PRELIMINARY - NOT FOR ISSUE

NO. BY CHK APP
REVISIONS AND RECORD OF USE
DATE

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSEL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
PROCESS FLOW DIAGRAM - INCINERATION (2 OF 2)

DESIGNED: JLH
DETAILED: JLH
CHECKED: JJH
APPROVED: JJH
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-008
SHEET
OF

FD10000
D10000
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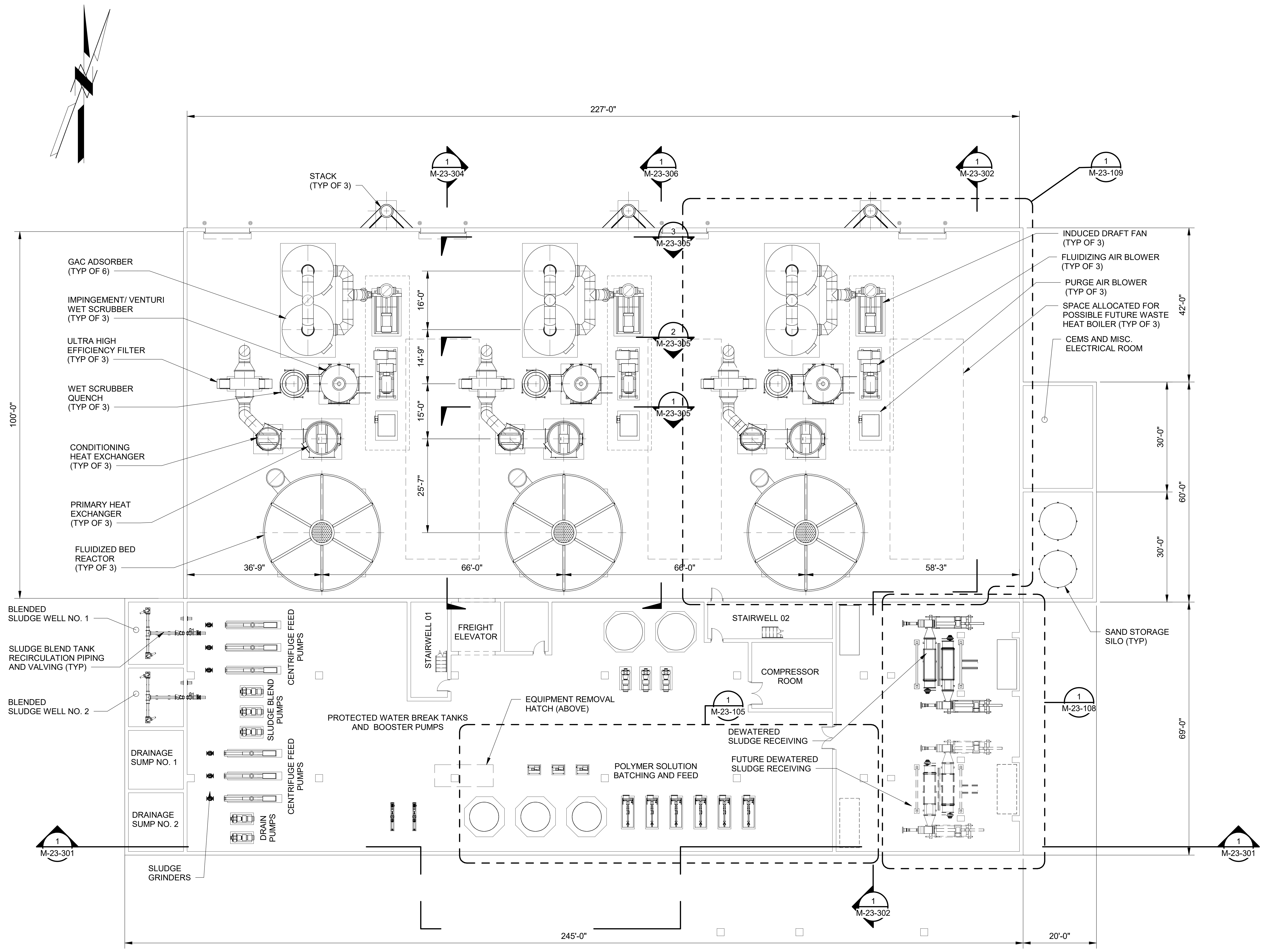


BASEMENT FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'

1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP

DATE	REVISIONS AND RECORD OF USE

BLACK & VEATCH

Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - BASEMENT FLOOR PLAN

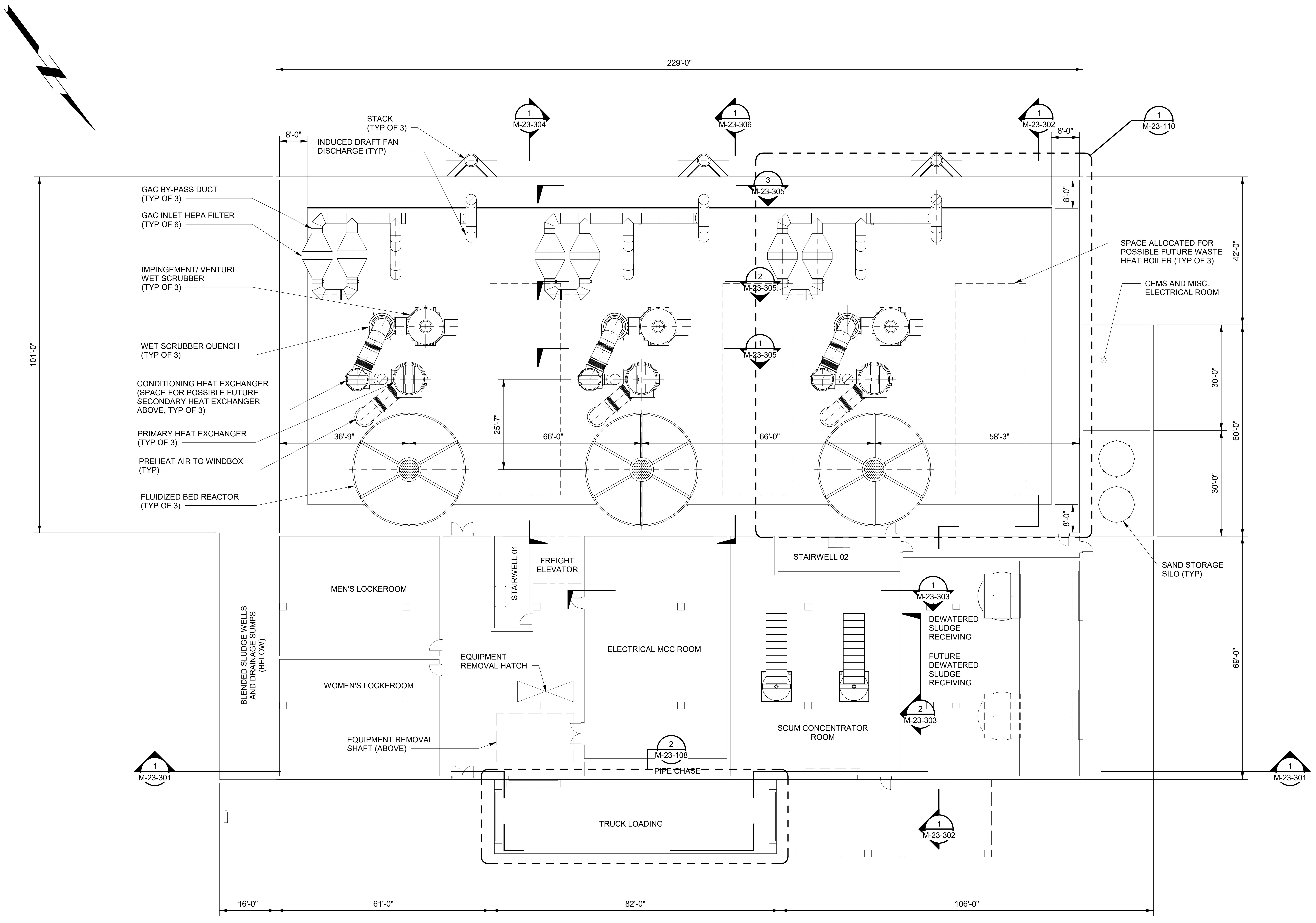
DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-101
SHEET
OF

PLOTTED: 7/14/2021 9:58:01 AM
D10000



GROUND FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'

1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP	REVISIONS AND RECORD OF USE	DATE

BLACK & VEATCH

Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - GROUND FLOOR PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-102
SHEET
OF

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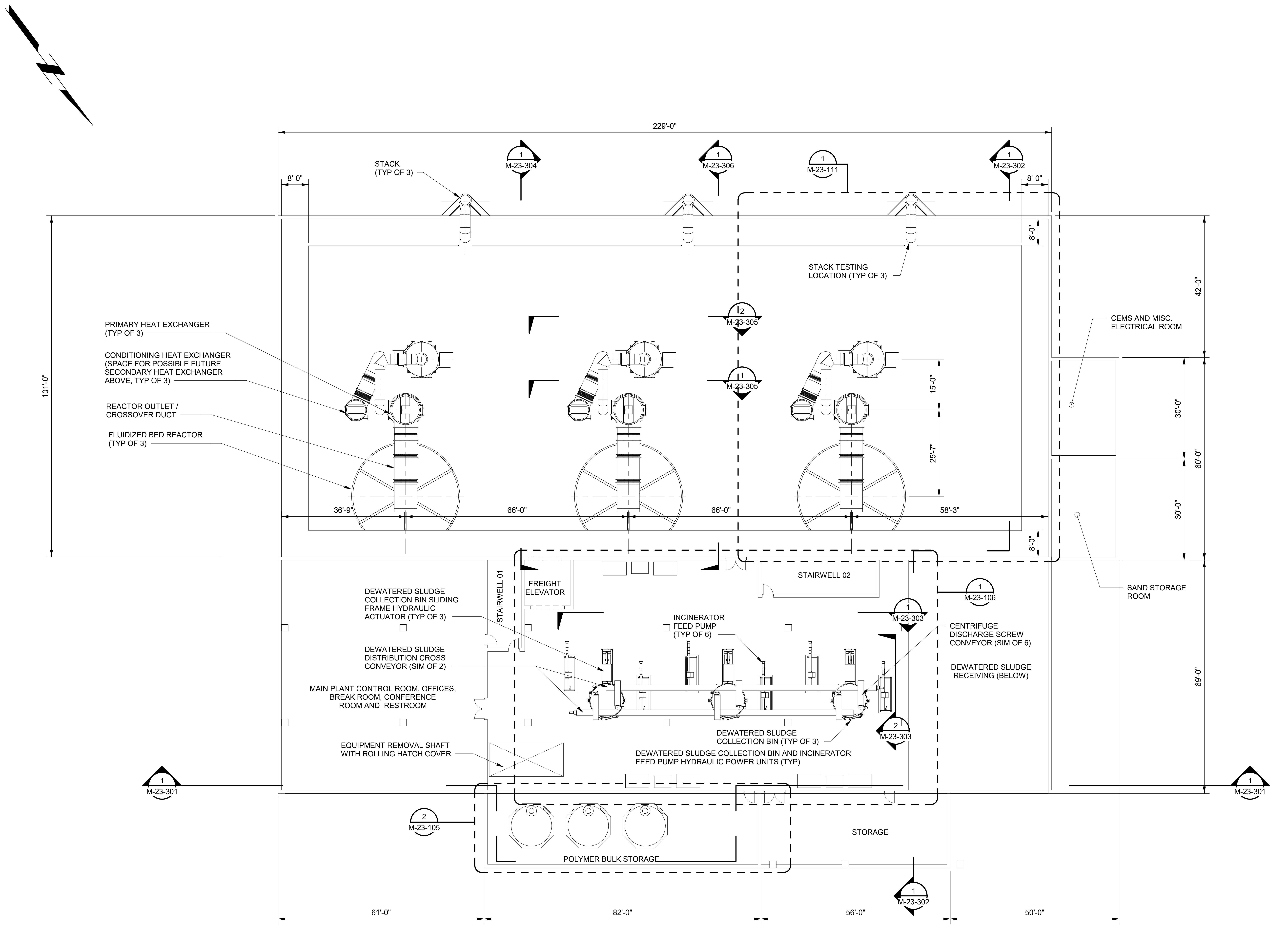

SECOND FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'

1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

NO.	BY	CHK	APP	REVISIONS AND RECORD OF USE	DATE

BLACK & VEATCH

Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - SECOND FLOOR PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

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PROJECT NO.
401975

M-23-103

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OF

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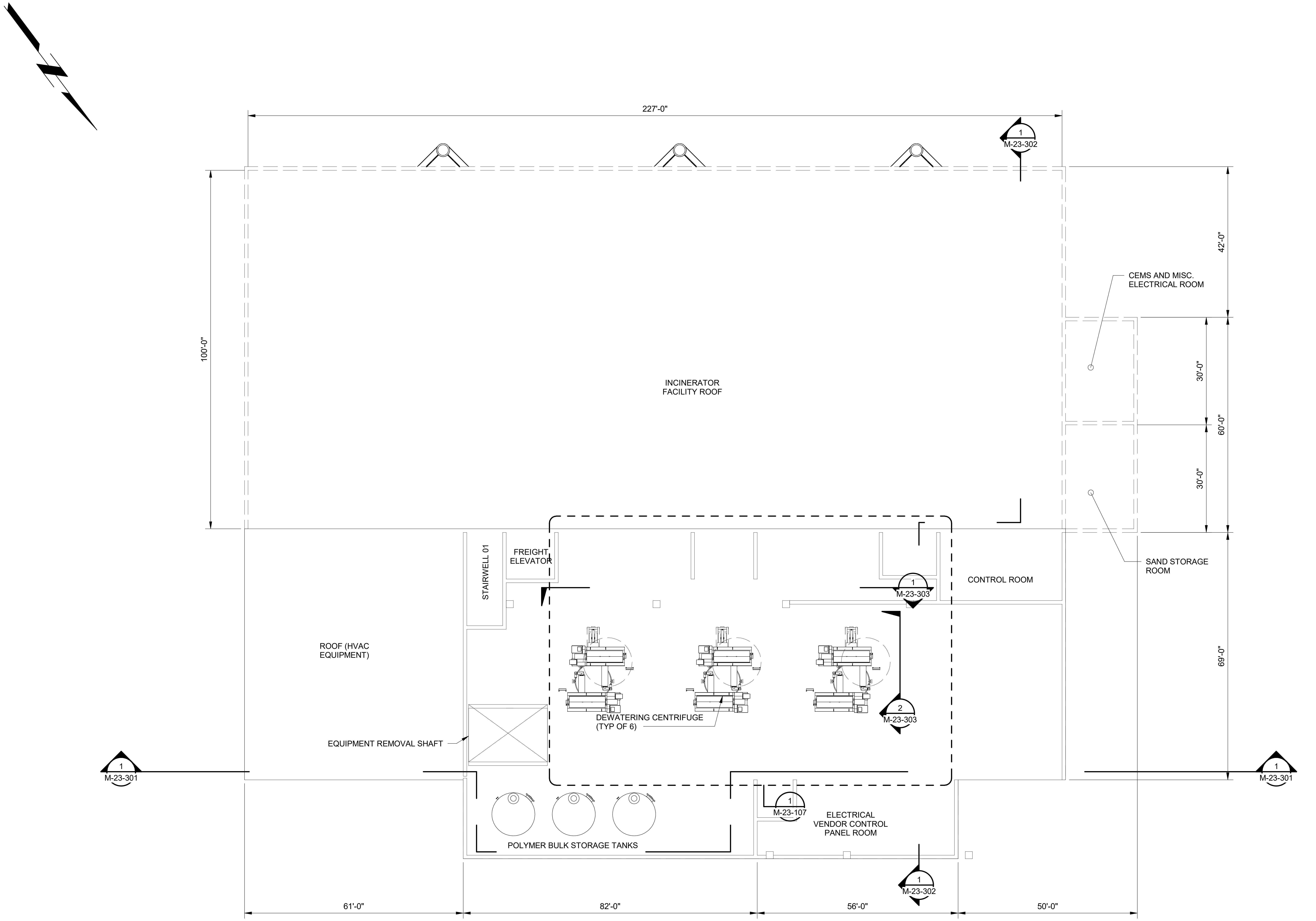

THIRD FLOOR PLAN

1/16" = 1'-0"

GENERAL SHEET NOTES

SHEET KEYNOTES

16' 12' 8' 4' 0' 16' 32'
1/16" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

DATE	REVISIONS AND RECORD OF USE	NO.	BY	CHK	APP

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - THIRD FLOOR PLAN

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-104
SHEET
OF

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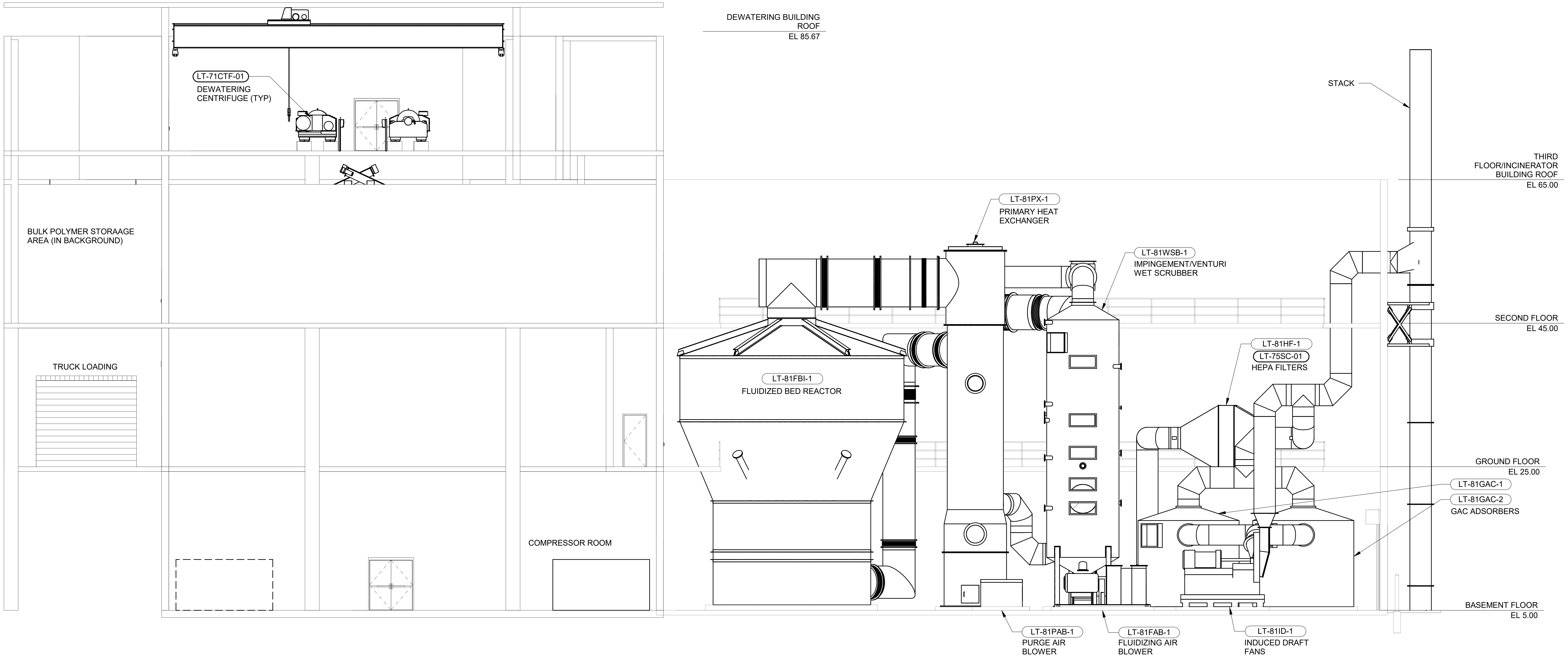

1 SECTION
M-23-101 1/8" = 1'-0"

PRELIMINARY - NOT FOR ISSUE

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NO.	BY	CHK	APP	REVISIONS AND RECORD OF USE	DATE

BLACK & VEATCH
Black & Veatch Corporation
Saint Louis, Missouri

METROPOLITAN ST LOUIS SEWER DIST
BISSELL POINT & LEMAY FLUIDIZED BED INCINERATORS
FBI EQUIPMENT PRESELECTION

LEMAY WASTEWATER TREATMENT FACILITY
PROCESS MECHANICAL
SOLIDS PROCESSING BUILDING - OVERALL BUILDING
SECTIONS (2 OF 2)

DESIGNED: CMS
DETAILED: VAP
CHECKED:
APPROVED:
DATE: NOVEMBER 2020

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IF THIS BAR DOES NOT
MEASURE 1" THEN DRAWING
IS NOT TO FULL SCALE

PROJECT NO.
401975

M-23-302
SHEET
OF

Appendix D – Technical Memorandums

FINAL

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum No. 04: Solids Quantities and Characteristics

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

21 APRIL 2021

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction and Facility Overview

The purpose of this memorandum is to establish solids quantities and characteristics for sizing and selecting equipment and systems for the Bissell & Lemay WWTF Fluidized Bed Incinerators (FBI) Project. This memorandum includes a review of current and future facility solids processes, a summary of previous data sets and solids projections, an evaluation of recent solids data, and recommended solids quantities and characteristics to use for the Bissell Point and Lemay Wastewater Treatment Facilities (WWTFs).

Section 1.1 summarizes information regarding wastewater treatment facilities (WWTF) that will contribute solids for fluid bed incineration at the Bissell Point WWTF and the Lemay WWTF. Information includes current and future facility solids processing along with a summary of past reviews of solids quantities.

1.1 CURRENT FACILITY SOLIDS PROCESSING

MSD's overall jurisdiction is subdivided into five services areas:

- Bissell Point Service Area served by the Bissell Point WWTF
- Coldwater Creek Service Area served by the Coldwater Creek WWTF
- River Des Peres Service Area served by the Lemay WWTF
- Lower Meramec Service Area served by the Grand Glaize, Fenton and Lower Meramec WWTFs
- Missouri River Service Area served by the Missouri River WWTF

The Missouri River WWTF will not supply solids to either of the future FBI systems at the Bissell Point or Lemay WWTFs and is not reviewed further in this memorandum. A Solids Processing Diagram including current information on facilities and inter-facility solids transfers for the MSD solids management system is shown in Figure 1-1. Table 1-1 provides a summary of WWTF information related to current solids processing at those facilities.

1.2 FUTURE FACILITY SOLIDS PROCESSING

A Solids Processing Diagram including information on future facilities and inter-facility solids transfers for the MSD solids management system is shown in Figure 1-2. Table 1-2 provides a summary of WWTF information related to future solids processing at those facilities. New improvements shown in italics in the table reflect preliminary concepts as identified in MSD's June 2018 Solids Handing Technical Memorandum and will be further evaluated for need, size and technology type. Major changes to the facilities and solids treatment at the facilities include;

- FBIs will replace multiple hearth incinerators (MHIs) at the Bissell Point and Lemay WWTFs
- Solids from Grand Glaize will be conveyed to the Lower Meramec WWTF collection system and processed with other influent solids at the plant. Solids from the Lower Meramec WWTF will be conveyed by force main to Lemay WWTF instead of being hauled to Bissell Point WWTF
- The Fenton WWTF will be eliminated, with solids from the facility sent to Lower Meramec

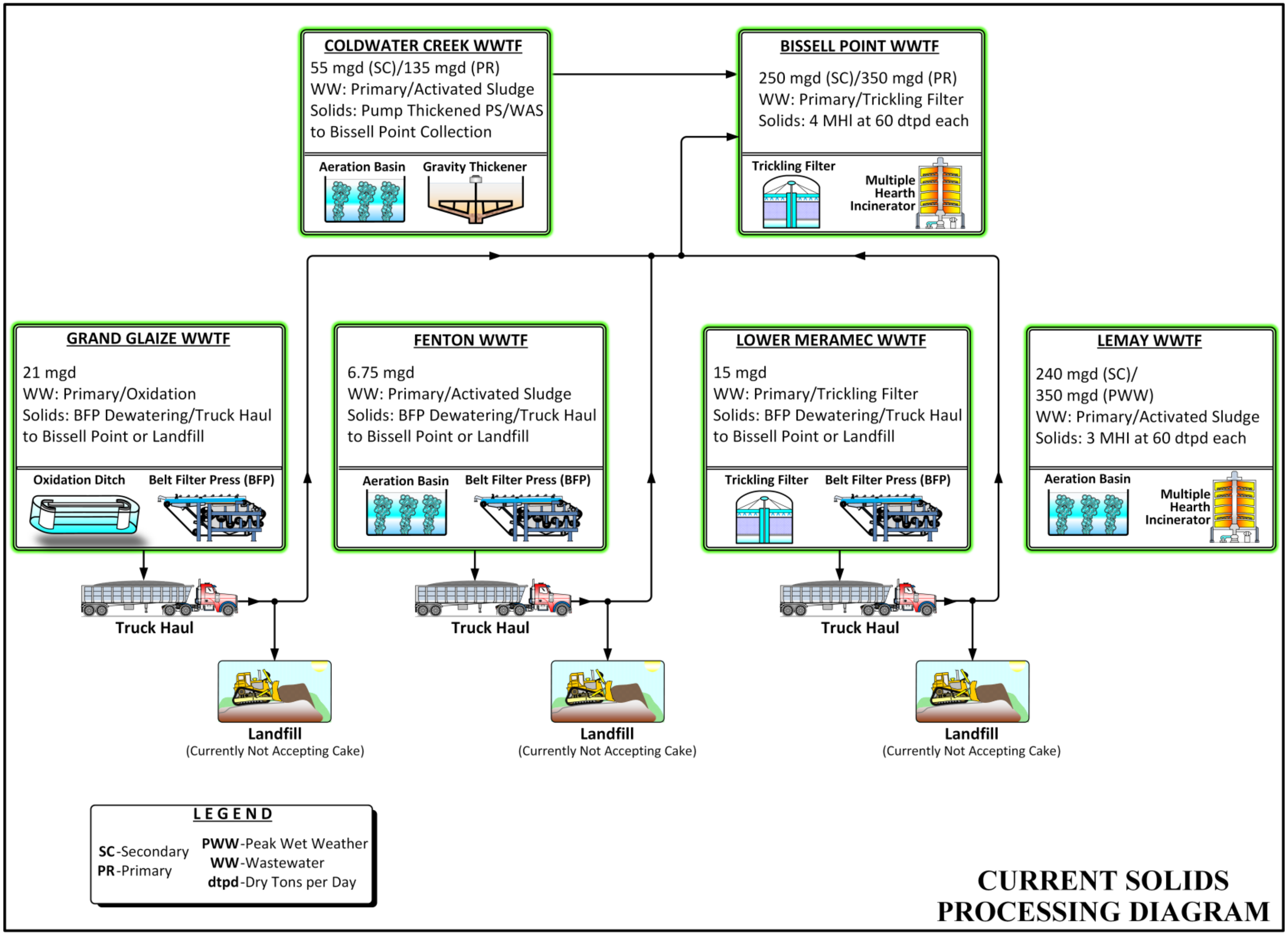

Figure 1-1 Current WWTF Solids Processing Diagram

Table 1-1 Current WWTF Solids Processing Summary.

WWTF	FLOW, MGD	WASTEWATER TREATMENT	SOLIDS TREATMENT	SLUDGE TRANSFER
• Bissell Point	• 250 Secondary • 350 Primary	• Grit removal • Primary clarifiers • Trickling filters • Waste activated sludge (pumped to head of grit tanks)	• 8 Primary clarifiers co-thicken PS and TF sludge • 12 GBTs • 2 Scum concentrators • 2 Sludge wells • Cake receiving station, with 2 cake piston pumps • 13 two-meter BFPs, 250 gpm each • 5 Equalization bins, 10 cy each • 5 Cake piston pumps with equalization bins • 6 MHIs, 60 dtpd each (2 decommissioned) • 2 Ash sluice tanks • 2 Ash lagoons	• Thickened sludge received from Coldwater Creek in collection system • Hauled grease, septage and other wastes received upstream of pre-aeration tanks • Cake from Grand Glaize, Fenton, and Lower Meramec received in receiving station which is pumped to dewatering area • Wet ash hauled to Prospect Hill Landfill
• Coldwater Creek	• 55 Secondary • 135 Primary	• Primary clarifiers • Waste activated sludge	• 4 Primary clarifiers • 3 Primary grit/sludge separators • 1 Primary sludge gravity thickener • 7 Final clarifiers • 6 WAS storage tanks	• Thickened sludge pumped to Bissell Point collection system
• Lemay	• 240 Secondary • 350 Peak Wet Weather	• Primary clarifiers • Waste activated sludge • Grit basins	• 7 Primary clarifiers co-thicken PS and WAS • 3 Sludge wells • 12 Final clarifiers • 2 Activated sludge wells • 6 two-meter BFPs, 250 gpm each • 4 MHIs, 60 dtpd each (1 decommissioned) • 4 Waste heat boilers (2 decommissioned) • 3 Ash slurry ponds (1 decommissioned)	• No sludge transfers • Wet ash hauled to Prospect Hill Landfill
• Lower Meramec	• 43 Secondary • 60 Primary	• Primary clarifiers • Trickling filters	• 2 Primary clarifiers • 2 Final clarifiers • 3 Grit/sludge separators	• Cake hauled to Bissell Point or landfill

WWTF	FLOW, MGD	WASTEWATER TREATMENT	SOLIDS TREATMENT	SLUDGE TRANSFER
			• 2 Gravity thickeners • 2 BFPs	
• Grand Glaize	• 21	• Primary clarifiers • Oxidation ditch	• 4 Primary clarifiers • 4 Final clarifiers • 2 Gravity thickeners • 2 BFPs	• Cake hauled to Bissell Point or landfill
• Fenton	• 6.75	• Primary clarifier • Waste activated sludge	• 1 Primary clarifier • 2 Final clarifiers • 1 Gravity thickener • 1 BFP	• Cake hauled to Bissell Point or landfill

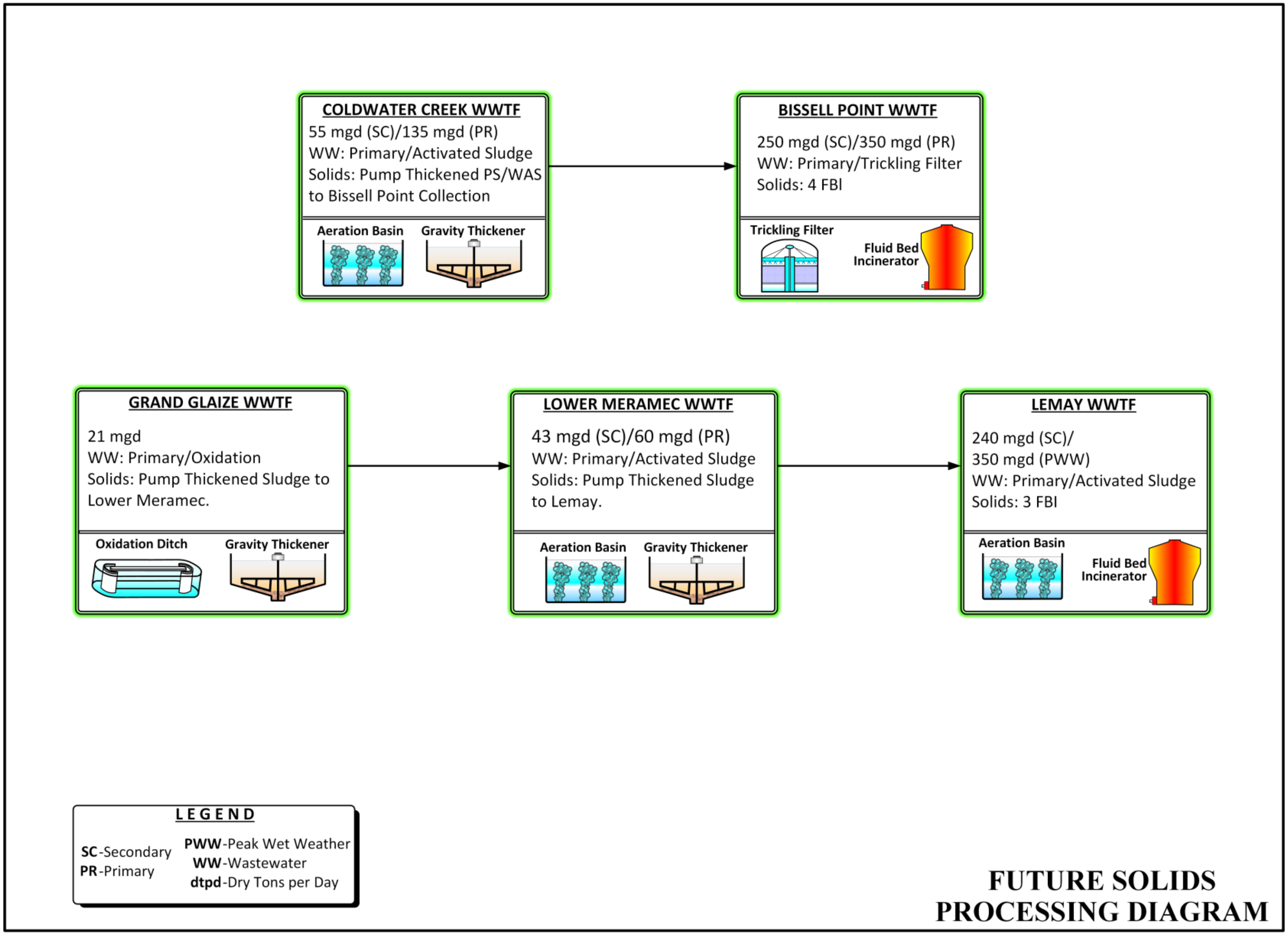

Figure 1-2 Future WWTF Solids Processing Diagram

Table 1-2 Future WWTF Solids Processing Summary.

WWTF	FLOW, MGD	WASTEWATER TREATMENT	SOLIDS TREATMENT	SLUDGE TRANSFER
• Bissell Point	• 250 Secondary • 350 Primary	• Grit removal • Primary clarifiers • Trickling filters (near term, possible use long term) • Waste activated sludge (possible use long term if required for BNR)	• 8 Primary clarifiers co-thicken PS and TF sludge • 12 GBTs • 2 Scum concentrators • *Sludge wells*[1] • *Cake receiving station*[1] • *Dewatering (centrifuges or screw presses)* [1] • *Equalization bins*[1] • *Cake piston pumps*[1] • *4 FBIs, 83 dtpd each* [1] • *FBI heat recovery system*[1] • *2 Ash lagoons*[1]	• Thickened sludge received from Coldwater Creek in collection system • Hauled grease, septage and other wastes received upstream of pre-aeration tanks • *Ash hauled to Prospect Hill Landfill, another landfill, or beneficially used*[1]
• Coldwater Creek	• 55 Secondary • 135 Primary	• Primary clarifiers • Waste activated sludge	• 4 Primary clarifiers • 3 Primary grit/sludge separators • 1 Primary sludge gravity thickener • 3 Final clarifiers • 1 WAS gravity thickener	• Thickened sludge pumped to Bissell Point collection system
• Lemay	• 240 Secondary • 350 Peak Wet Weather	• Primary clarifiers • Waste activated sludge • Grit basins • Planned future high-rate clarification facility to treat CSO storage tunnel flow	• 7 Primary clarifiers co-thicken PS and WAS • *3 Sludge wells*[1] • 12 Final clarifiers • *2 Activated sludge wells*[1] • *Cake receiving station*[1] • *Dewatering (centrifuges or screw presses)* [1] • *Equalization bins*[1] • *Cake piston pumps/conveyors*[1] • *3 FBIs, 83 dtpd each* [1] • *FBI heat recovery system*[1] • *2 Ash slurry ponds*[1]	• Thickened sludge received from Lower Meramec force main • *Ash hauled to Prospect Hill Landfill, another landfill, or beneficially used*[1]

WWTF	FLOW, MGD	WASTEWATER TREATMENT	SOLIDS TREATMENT	SLUDGE TRANSFER
• Lower Meramec	• 43 Secondary • 60 Primary	• Primary clarifiers • Waste activated sludge	• 2 Primary clarifiers • 2 Final clarifiers • 3 Grit/sludge separators • 2 Gravity thickeners	• Thickened sludge pumped to Lemay
• Grand Glaize	• 21	• Primary clarifiers • Oxidation ditch	• 4 Primary clarifiers • 4 Final clarifiers • 2 Gravity thickeners	• Thickened sludge pumped to Lower Meramec collection system

[1] New improvements in italics reflect preliminary concepts and will be further evaluated for need, size and technology type.

2.0 Bissell Point WWTF Solids Quantities and Characteristics

This section summarizes information about historical solids loadings at the Bissell Point WWTF and develops recommended design solids quantities and characteristics for sizing the future FBI system.

2.1 PREVIOUS SOLIDS DATA REVIEW AND PROJECTIONS

Historical solids quantities and characteristics have been reviewed as part of the Comprehensive Solids Handling Master Plan (SMP), prepared by Black & Veatch (B&V), and the Solids Handling Technical Memorandum (SH TM), prepared by MSD and dated June 2018, and solids projections were developed as part of the SMP and the Comprehensive Ammonia & Nutrient Removal Plan (A&NRP), prepared by B&V and issued in two reports, dated November 2016 and May 2018. Table 2-1 summarizes data from these sources as follows:

- SMP Phase I, TM2 Facility Summaries and Solids Projections (SMP1 TM2) dated October 2009 – Evaluation of historic data from 2006 to 2008 and future solids projections based on 2008. Aeration basins were removed from service January 2008, so data from this year was judged most representative.
- SMP Phase II, TM1 Bissell Point WWTP Solids Processing Alternatives Evaluation (SMP2 TM1) dated September 2010 – Future solids projections based on modeling for biological nutrient removal (BNR) at the facility
- SH TM – Evaluation of historic data from 2006 to 2017 (MM and Peak Week (PW) data excludes solids hauled from Lower Meramec, Grand Glaize, and Fenton and data from 2017 when a gate failure caused a high influx of river solids)
- A&NRP – Future solids projections based on modeling for chemical and biological nutrient removal at the facility

Table 2-1 Bissell Point WWTF Previous Solids Data Review and Projections

DESCRIPTION	INFLUENT, MGD	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
SMP1 TM2 – Data (2006-2008), AA	126.8	58.1	34.5	92.6	54.3
SMP1 TM2 – Data, (2006-2008), MM	211.3	44.9	127.8	172.7	66.0
SMP1 TM2 - Solids Projections, AA	134.6	80.2	27.9	111.7	48.4
SMP1 TM2 - Solids Projections, MM	179.1	135.7	37.0	177.3	33.3
SMP2 TM1 – Solids Projections (BNR), AA		62.0	24.5	89.1	58.2
SMP2 TM1 – Solids Projections (BNR), MM		75.0	48.0	125.7	58.0
SH TM – Data (2006-2017), AA				105.6	
SH TM – Data (2006-2016), MM				249.3	
SH TM – Data (2006-2016), PW				382.0	
A&NRP – Solids Projections, AA*				149 - 200	

*Solids projections vary from nutrient study based on multiple alternatives evaluated

Based on historical data, maximum month (MM) values greatly exceed typical annual average (AA) values, as well as previous solids projections. The effect that flooding has on unusually high MM solids quantities will be reviewed further in the next section.

2.2 RECENT SOLIDS DATA

Data for June 1, 2016 through May 31, 2019 was evaluated regarding solids quantities and characteristics and represents three years of recent data. To understand the impact that flooding has on solids quantities and characteristics, the data was evaluated for three categories, including; 1) all data including months when the Mississippi River was above flood stage, 2) months having periods above flood stage excluded, and 3) months that had periods above flood stage. For Bissell Point flood stage was based on a river level above 21 feet at the Mel Price Station. Table 2-2 summarizes information from the recent solids data evaluation.

Table 2-2 Bissell Point WWTF Recent Solids Quantities

DESCRIPTION	INFLUENT, MGD[1]	PS, DTPD[2]	WAS/TF, DTPD[3]	COUNTY PLANTS, DTPD[4]	TOTAL SOLIDS, DTPD[5]	% VOLATILE SOLIDS	PEAKING FACTOR
All data, AA	116.5	90.8	22.2	14.2	127.2	50.8	-
All data, MM	187.0	189.0	36.0	21.4	246.4	35.4	1.9
All data, PW	152.7	248.1	30.7	17.1	295.9	30.5	2.3
Data w/o Flooding, AA	109.4	83.0	22.0	13.8	118.8	52.4	-
Data w/o Flooding, MM	108.3	124.7	23.8	14.3	162.8	50.9	1.4
Data w/o Flooding, PW	175.7	191.5	23.6	14.3	229.4	37.5	1.9
Flooding Data, MM	187.0	189.0	36.0	21.4	246.4	35.4	1.9
Flooding Data, PW	152.7	248.1	30.7	17.1	295.9	30.5	2.3

[1] Influent flows for MM and PW are based on the associated flows that occurred during solids MM and PW periods, respectively

[2] Calculated based on total solids and WAS/TF values.

[3] Calculated based on historical values and historical WAS to TS factors of 11% and 16% for PW and MM, respectively.

[4] County Plants quantity based on solids hauled from the Grand Glaize, Fenton, and Lower Meramec WWTFs to Bissell Point WWTF

[5] Total solids are based on solids conveyed to the incinerators and includes solids hauled from County Plants

Note: Data for April and May 2017 was excluded from the table because a gate failure resulted in abnormal intrusion of river solids.

Evaluation of data from flood stage and non-flood stage conditions confirms that flooding has a significant impact on MM and PW quantities. Figure 2-1 shows monthly volatile and fixed solids (inert) quantities, with flood stage months shown with a dark border. Figure 2-2 shows daily volatile and fixed solids (ash) quantities along with river levels.

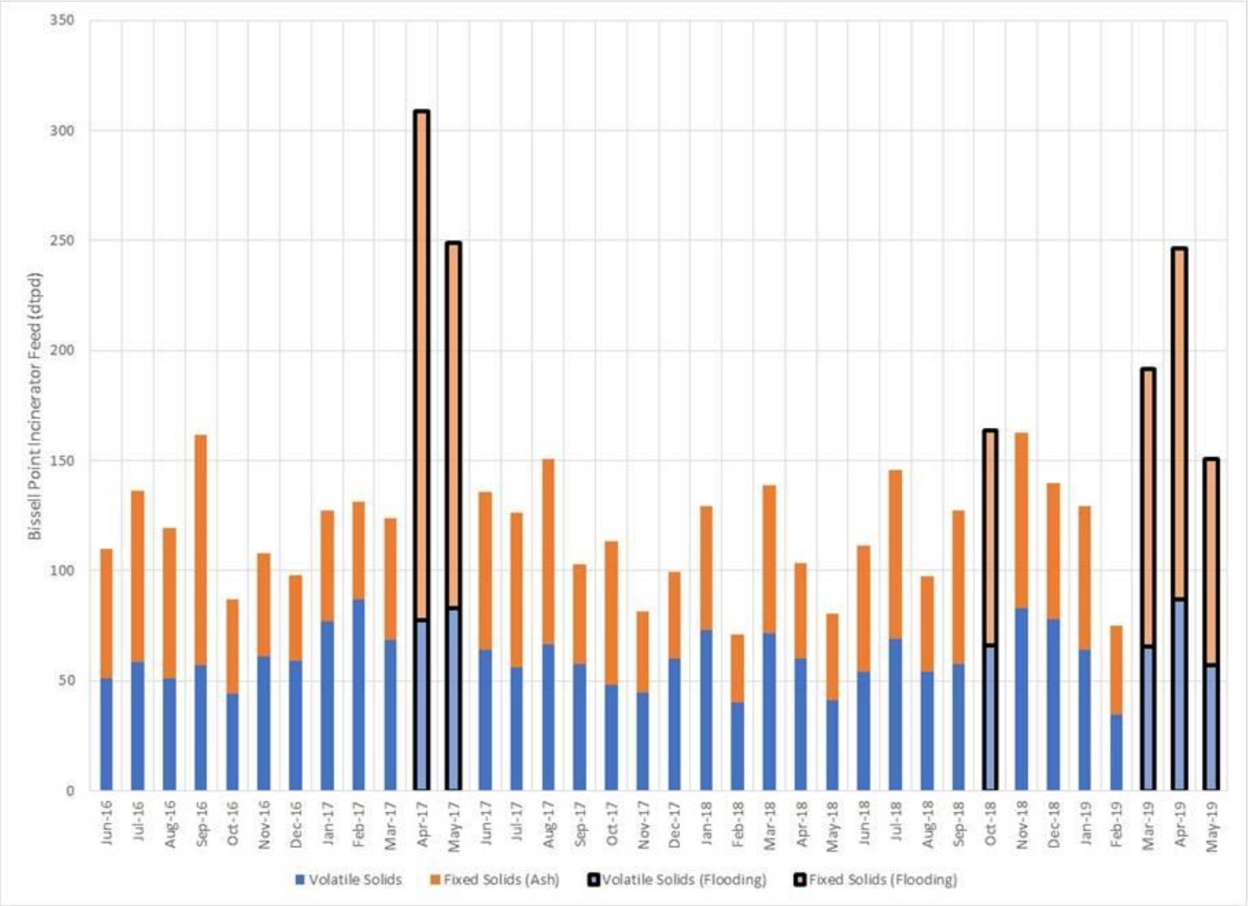

Figure 2-1 **Bissell Point WWTF Recent Monthly Solids Quantities and Volatile Solids**

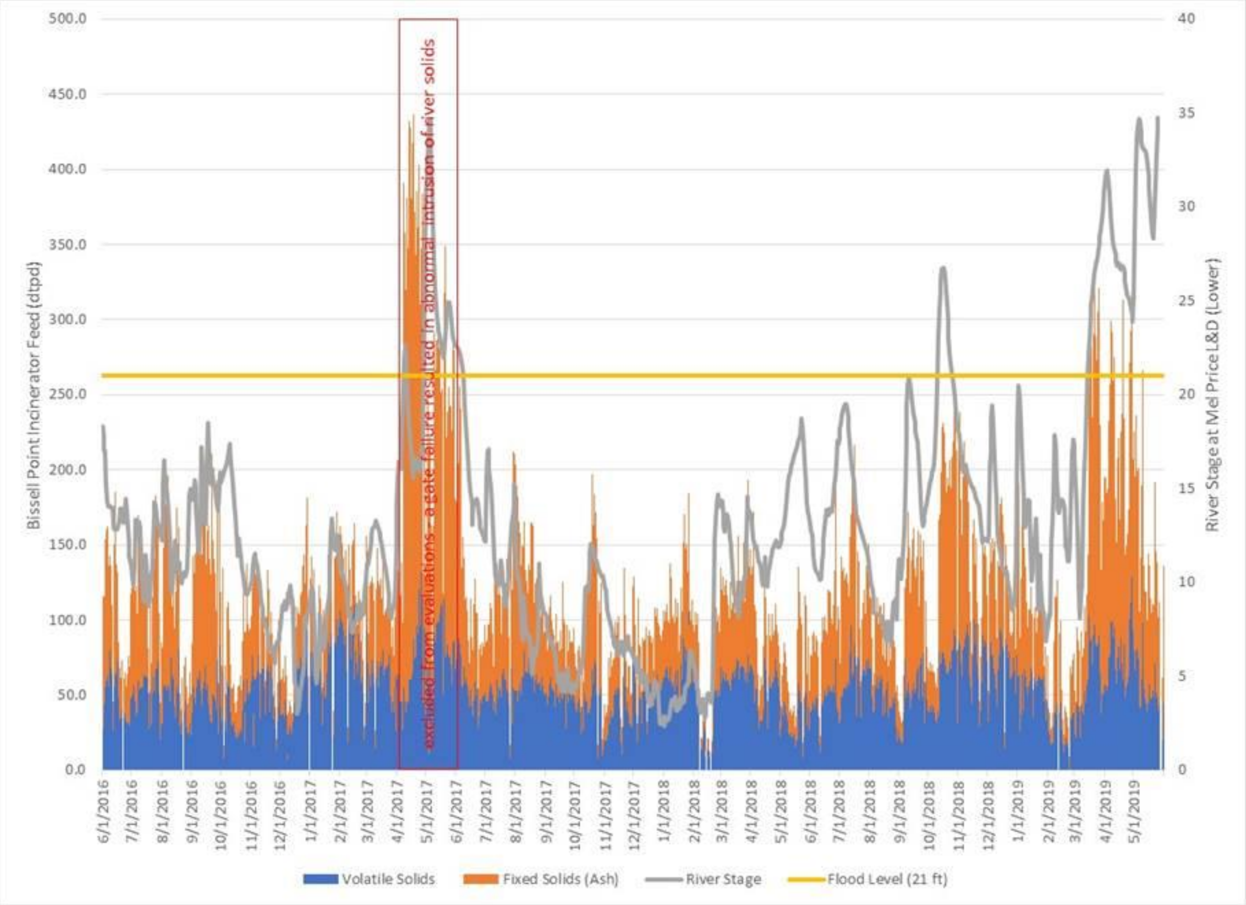

Figure 2-2 **Bissell Point WWTF Recent Daily Solids Quantities and Volatile Solids**

Given that data from the Solids Handling TM identified a MM of 249.3 dtpd, and data from the last three years identified MM production of 313 dtpd (April 2017) and 246 dtpd (April 2019), these high MM events occur with some regularity and may not be anomalies. Repairs to flood gates and other efforts to reduce intrusion may lead to some reduction in the peak values. This improvement may be offset as new equipment ages or flood waters find new intrusion locations after some locations are better sealed.

Currently, the District processes peak loads in the multiple hearth incinerators (MHIs) even though those loads can exceed the nominal total solids capacity of the units, 240 dtpd. As a combustion device, a MHI's capacity is limited by the heat input to the unit, the amount of moisture evaporated, and the quantity of inert solids to process. During flooding, inert (ash) quantities increase substantially (254% based on MM), but volatile quantities show a smaller increase (35% based on MM) compared to non-flooding conditions. With additional inert material, dewatering equipment can produce a cake with higher solids and lower water content. The combination of lower volatile and moisture content in incinerator feed during flood condition allows the units to have a higher capacity on a total-solids throughput basis.

Solids characteristics based on recent facility data is shown in Table 2-3, and includes categories for: 1) all data, 2) with flood stage data excluded and, 3) only flood stage data.

Table 2-3 Bissell Point WWTF Recent Solids Characteristics

ITEM	BFP FEED %TS	CAKE %TS	PS FRACTION, %	VS FRACTION, %
Average	5.7	29.7	79.4	50.8
Range*	3.0-9.6	23.8-38.0	52.7-90.8	32.0-66.0
Average w/o flood stage	5.4	29.2	79.2	52.4
Range* w/o flood stage	3.0-8.5	23.5-37.4	51.8-90.7	34.0-66.7
Average flood stage	8.1	33.4	No Data	39.1
Range* flood stage	3.6-11.1	26.1-39.7	No Data	29.0-58.0

*5th to 95th Percentile

During flood stage, dewatering feed sludge can be as high as 11% total solids. The centrifugal pumps used to feed the belt filter presses can pump sludge with this high solids, but sometimes sludge needs to be recirculated in the primaries if it sets too long, and the belt filter presses can plug.

2.3 DESIGN SOLIDS QUANTITIES PROJECTIONS AND CHARACTERISTICS

Because of the different solids quantities and characteristics between normal and flooding conditions, design values for both conditions were developed for consideration in selecting and sizing solids processing systems, including storage and bottleneck issues. Design solids quantities projections and characteristics were developed based on the following criteria:

- Nominal planning period of 25 years, to 2045
- Bissell Point and Coldwater WWTFs' service areas are mature with little growth expected, as identified in the SMP and SH TM and confirmed by the close correlation of average solids rates from 2006 to 2017, 105.6 dtpd, and recent data (June 2016 to May 2019), 113.0 dtpd, (with County WWTFs contribution removed)
- No significant change to the wastewater treatment or thickening processes at the Bissell Point and Coldwater WWTFs
- Recent data (June 2016 to May 2019) quantities are used as the basis for design quantities, with exclusion of solids contributions from Lower Meramec, Grand Glaize, and Fenton WWTFs, since these will be sent to the Lemay WWTF in the future
- No reduction in solids due to gate repairs will be taken, since it is likely that the gates will be in similar condition at some time in the planning period to the recent period condition
- The future impact of nutrient removal (post-2030) will be based on chemical phosphorus (ChemP) removal and no nitrogen removal (as indicated in the September 10, 2019 Technical Steering Meeting)

- MSD has entered into a consent decree to construct combined sewer overflow (CSO) tunnels and a sanitary sewer overflow (SSO) tunnel as part of the Long Term Control Plan (LTCP). MSD has provided estimates of the additional solids that will be captured as a result of the LTCP and these estimates were used in developing the total design solids quantities.

Table 2-4 shows design solids quantities for normal operation and flood conditions without CSO/SSO and Chem P removal adjustments.

Table 2-4 Bissell Point WWTF Design Solids Quantities without ChemP and CSO

DESCRIPTION	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
Normal, AA	90.8	22.2	113.0	50.8
Normal, MM	124.7	23.8	148.5	50.9
Normal, PW	191.5	23.6	215.1	37.5
Flooding Data, MM	189.0	36.0	225.0	35.4
Flooding Data, PW	248.1	30.7	278.8	30.5

Design solids characteristics will be based on the recent solids data and are shown in Table 2-3.

The Comprehensive Ammonia & Nutrient Removal Plan study evaluated two alternatives for the Bissell WWTF based on permitted influent capacity. Alternative 2A, based on biological nitrogen removal and chemical phosphorus removal, projected AA solids production of 200 dtpd, and Alternative 2B, based on biological nitrogen and phosphorus removal, projected AA solids production of 149 dtpd. During the September Technical Steering Meeting, MSD staff indicated that future nutrient removal should be based on chemical phosphorus removal and no nitrogen removal. Criteria used to develop additional solids quantities based on chemical phosphorus removal are shown in Table 2-5. For these calculations, it was assumed that ferric chloride will be used for phosphorous removal at a molar ratio of 2.5 (Fe/P Molar ratio) and a safety factor of 1.35 (for injecting chemical upstream of the primary clarifiers) in order to achieve a total phosphorous concentration of 0.5 mg/l in the plant effluent. Table 2-6 shows design solids quantities for the Bissell Point WWTF if the additional solids from chemical phosphorus removal are included in design values.

Table 2-5 Bissell Point WWTF Chemical Phosphorus Removal Criteria

DESCRIPTION	INFLUENT FLOW, MGD	INFLUENT TP, MG/L	EFFLUENT TP, MG/L	P REMOVED, DTPD	CHEM USE, DTPD	CHEMICAL SLUDGE, DTPD
Normal, AA	116.5	4.6	0.5	2.0	19.0	21.0
Normal, MM	108.3	4.6	0.5	1.9	17.7	19.6
Normal, PW	175.7	4.6	0.5	3.0	28.7	31.7
Flooding Data, MM	187.0	3.1	0.5	2.0	20.6	22.6
Flooding Data, PW	152.7	3.1	0.5	1.7	16.8	18.5

Table 2-6 Bissell Point WWTF Design Solids Quantities with Chemical P Removal

DESCRIPTION	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
Normal, AA	111.8	22.2	134.0	42.9
Normal, MM	144.3	23.8	168.1	44.9
Normal, PW	223.2	23.6	246.8	32.6
Flooding Data, MM	211.6	36.0	247.6	32.2
Flooding Data, PW	266.6	30.7	297.3	28.6

Sizing FBI systems and associated facilities for the additional quantities associated with chemical phosphorus removal will not have a significant impact on equipment, as shown in the table above. Implementation of a different nutrient removal approach or changes to treatment processes at the Bissell Point or Coldwater WWTFs could lead to greater solids projections that would be impactful. To accommodate possible future (and unanticipated) increases to solids quantities, it is recommended that the new FBI building be located on the plant site so that a future building expansion could be accommodated.

Implementation of the LTCP will result in more solids being captured and sent to the Bissell Point WWTF for treatment, because of implementation of storage improvements at the CSO Outfalls 51 and 52, which are scheduled for completion in 2020. MSD provided estimates of the additional solids that will be captured as a result of the LTCP, which are summarized in Table 2-7.

Table 2-7 Bissell Point Service Area Annual Untreated Overflows and Captured Solids

DESCRIPTION	OVERFLOWS, MG	ASSOCIATED SOLIDS, TONS TSS
Untreated overflows: Pre-LTCP	250	421
Untreated overflows: Post-LTCP	70	118
Captured for treatment	180	303

Per the LTCP there were 29 overflow events per year. Solids were apportioned for a greater number of events during maximum month and peak week than average, to reflect that these events would likely occur during high river conditions when solids production is highest at the facility.

A summary of current design solids quantities for the Bissell Point WWTF is shown in Table 2-8. Current design solids quantities include CSO solids, but not the solids that would occur from future implementation of chemical phosphorus removal.

Table 2-8 Bissell Point WWTF Current Design Solids Quantities

Description	PS, dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	90.8	22.2	0.8	113.8	50.8	-
Normal, MM	124.7	23.8	-	148.5	50.9	1.3
Normal, PW	191.5	23.6	-	215.1	37.5	1.9
Flood Stage, MM	189.0	36.0	2.5	227.5	35.4	2.0
Flood Stage, PW	248.1	30.7	3.0	281.8	30.5	2.5

A summary of future design solids quantities for the Bissell Point WWTF is shown in Table 2-9. Future design solids quantities include CSO solids and the solids that would occur from future implementation of chemical phosphorus removal.

Table 2-9 Bissell Point WWTF Future Design Solids Quantities

Description	PS[1], dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	111.8	22.2	0.8	134.8	42.9	-
Normal, MM	144.3	23.8	-	168.1	44.9	1.2
Normal, PW	223.2	23.6	-	246.8	32.6	1.8
Flood Stage, MM	211.6	36.0	2.5	250.1	32.2	1.9
Flood Stage, PW	266.6	30.7	3.0	300.3	28.7	2.2

3.0 Lemay WWTF Solids Quantities and Characteristics

This section summarizes information about historical solids loadings at the Lemay WWTF (and contributing WWTFs) and develops recommended design solids quantities and characteristics for sizing the future FBI system.

3.1 PREVIOUS SOLIDS DATA REVIEW AND PROJECTIONS

Similar to the Bissell WWTF, historical solids quantities and characteristics for the Lemay WWTF have been reviewed as part of the SMP and the SH TM and solids projections were developed as part of the SMP and the A&NRP. Evaluations in the SH TM included solids from the Lower Meramec Service Area (LMSA) and data for this area from the SMP and A&NRP is included for comparison. Table 3-1 summarizes data from these sources as follows:

- SMP Phase I, TM2 Facility Summaries and Solids Projections (SMP1 TM2) – Evaluation of Lemay WWTF historic data from 2006 to 2008 and future solids projections based on the data with adjustments to account for improved infiltration control and expanded wet weather capacity. Evaluation of LMSA historic data from 2017 to 2019 and future solids projections based on conversion of Lower Meramec to an activated sludge process and future growth in Lower Meramec WWTF service area, but no growth in Fenton and Grand Glaize WWTFs service areas.
- SMP Phase II, TM2 Lemay WWTP Solids Processing Alternatives Evaluation (SMP2 TM2) dated September 2010 – Future solids projections based on SMP Phase I, TM2
- SMP Phase II, TM5 Lower Meramec WWTP Alternative Evaluation (SMP2 TM5) – Future solids projects based on SMP Phase 1, TM2
- SH TM – Evaluation of historic data from 2006 to 2017, data includes both Lemay and Lower Meramec service areas
- A&NRP – Future solids projections based on modeling for chemical and biological nutrient removal at the facility

In Table 3-1 Lemay (L) data is shown in regular font, Lower Meramec Service Area (LMSA) data is shown in italic font and combined data (L+LMSA) is shown in bold font.

Table 3-1 Lemay WWTF and LMSA Previous Solids Data Review and Projections

DESCRIPTION*	INFLUENT, MGD	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
SMP1 TM2 – Lemay Data (2006-2008), AA	121	17.0	30.1	47.1	54.8
SMP1 TM2 – Lemay Data, (2006-2008), MM	201	21.0	64.0	85.0	50.4
SMP1 TM2 – Lemay Solids Projections, AA	142	21	30.1	51.1	50.5
SMP1 TM2 – Lemay Solids Projections, MM	241	30	64	94	45.5
SMP1 TM2 – LMSA Data, AA				*17.9*	
SMP1 TM2 – LMSA Data, MM				*26.2*	
SMP1 TM2 – LMSA Solids Projections, AA	*56*			*39.2*	*75*

DESCRIPTION*	INFLUENT, MGD	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
SMP1 TM2 – LMSA Solids Projections, MM	*76*			*53.2*	*75*
SMP1 TM2 – L+LMSA Solids Projections, AA				**90.3**	**61.1**
SMP1 TM2 – L+LMSA Solids Projections, MM				**147.2**	**56.2**
SH TM – L+LMSA (2006-2017), AA				**66.3**	
SH TM – L+LMSA (2006-2016), MM				**97.9**	
SH TM – L+LMSA (2006-2016), PW				**117.2**	
A&NRP – Lemay Solids Projections, AA**				185 - 250	
*A&NRP – LMSA Solids Projections, AA***				*127 – 145*	
A&NRP – L+LMSA Solids Projections, AA**				**312 - 395**	

*Lemay (L) data is only for Lemay WWTF, LMSA data includes the Lower Meramec Service Area, including Lower Meramec, Grand Glaize, and Fenton WWTFs, L+LMSA data includes the Lemay WWTF and Lower Meramec Service Area WWTFs

**Solids projections vary from nutrient study based on multiple alternatives evaluated

3.2 RECENT SOLIDS DATA

Data for June 1, 2016 through May 31, 2019 for Lemay WWTF was evaluated regarding solids quantities and characteristics and represents recent data. The recent data was evaluated similar to the Bissell WWTF data to understand the impact that flooding has on solids quantities and characteristics. For Lemay WWTF flood stage was based on a river level above 30 feet at the St. Louis Station. Table 3-2 summarizes information from the recent solids data evaluation.

Table 3-2 Lemay WWTF Recent Solids Quantities

DESCRIPTION	INFLUENT, MGD	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS	PEAKING FACTOR
All Data, AA	121.5	27.5	22.3	49.8	60.1	-
All Data, MM	235.6	32.7	33.0	65.7	47.2	1.3
All Data, PW	256.9	43.3	46.2	89.5	38.7	1.8
Data w/o Flooding, AA	105.8	28.1	21.4	49.5	61.6	-
Data w/o Flooding, MM	155.0	34.7	25.9	60.6	54.4	1.2
Data w/o Flooding, PW	147.3	47.6	30.6	78.2	52.4	1.6
Flooding Data, MM	235.6	32.7	33	65.7	47.2	1.3
Flooding Data, PW	256.9	43.3	46.2	89.5	38.7	1.8

Figure 3-1 shows monthly volatile and fixed solids (ash) quantities, with flood stage months shown with a dark border. Figure 3-2 shows daily volatile and fixed solids (ash) quantities along with river levels.

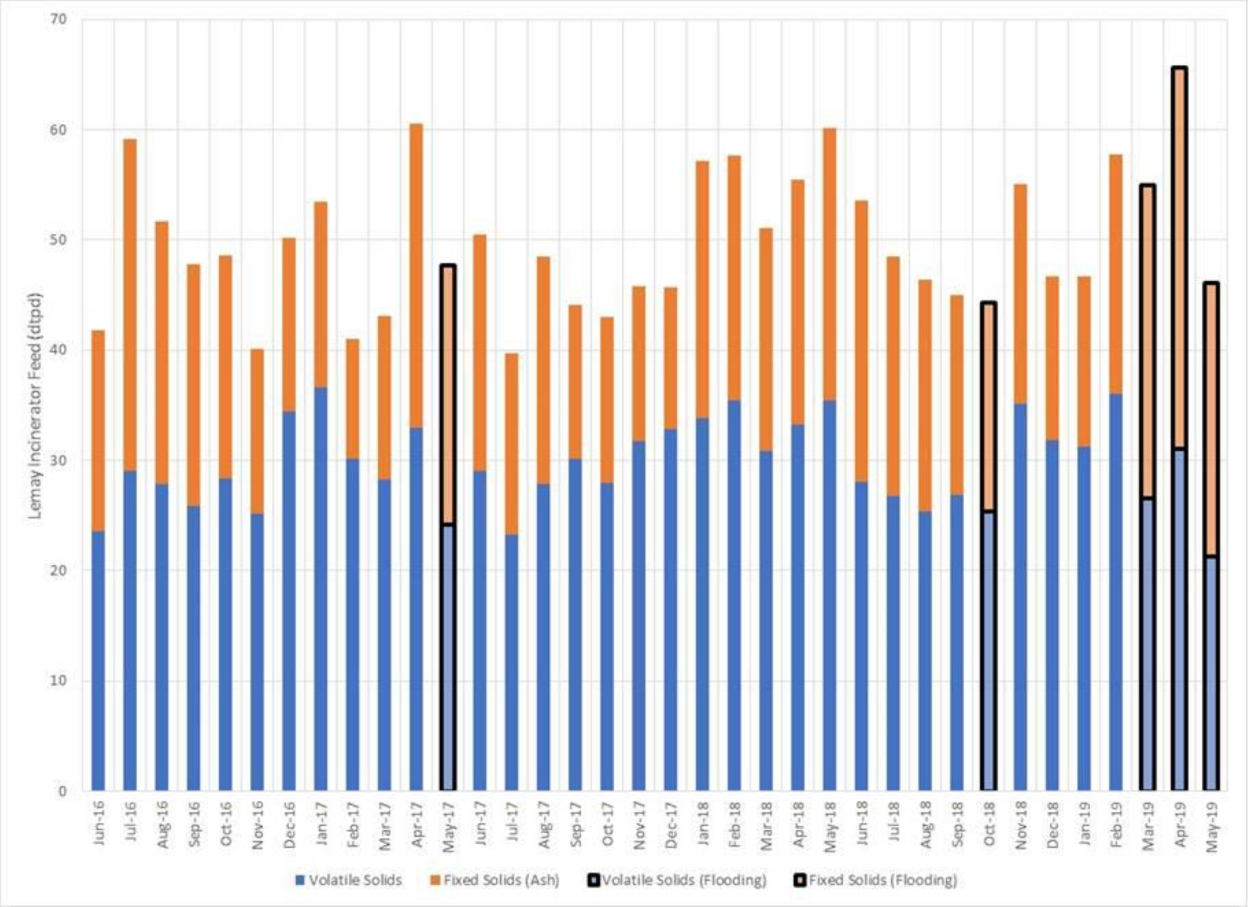

Figure 3-1 **Lemay WWTF Recent Monthly Solids Quantities and Volatile Solids**

Based on recent data, flood conditions had less impact on the maximum month solids quantities at the Lemay WWTF as compared to the Bissell Point WWTF. District staff indicated that the configuration of the flood gates associated with the Bissell Point WWTF service area may have made that facility more susceptible to intrusion of river solids and that improvements to the Lemay WWTF collection system to reduce inflow and infiltration have had a positive impact.

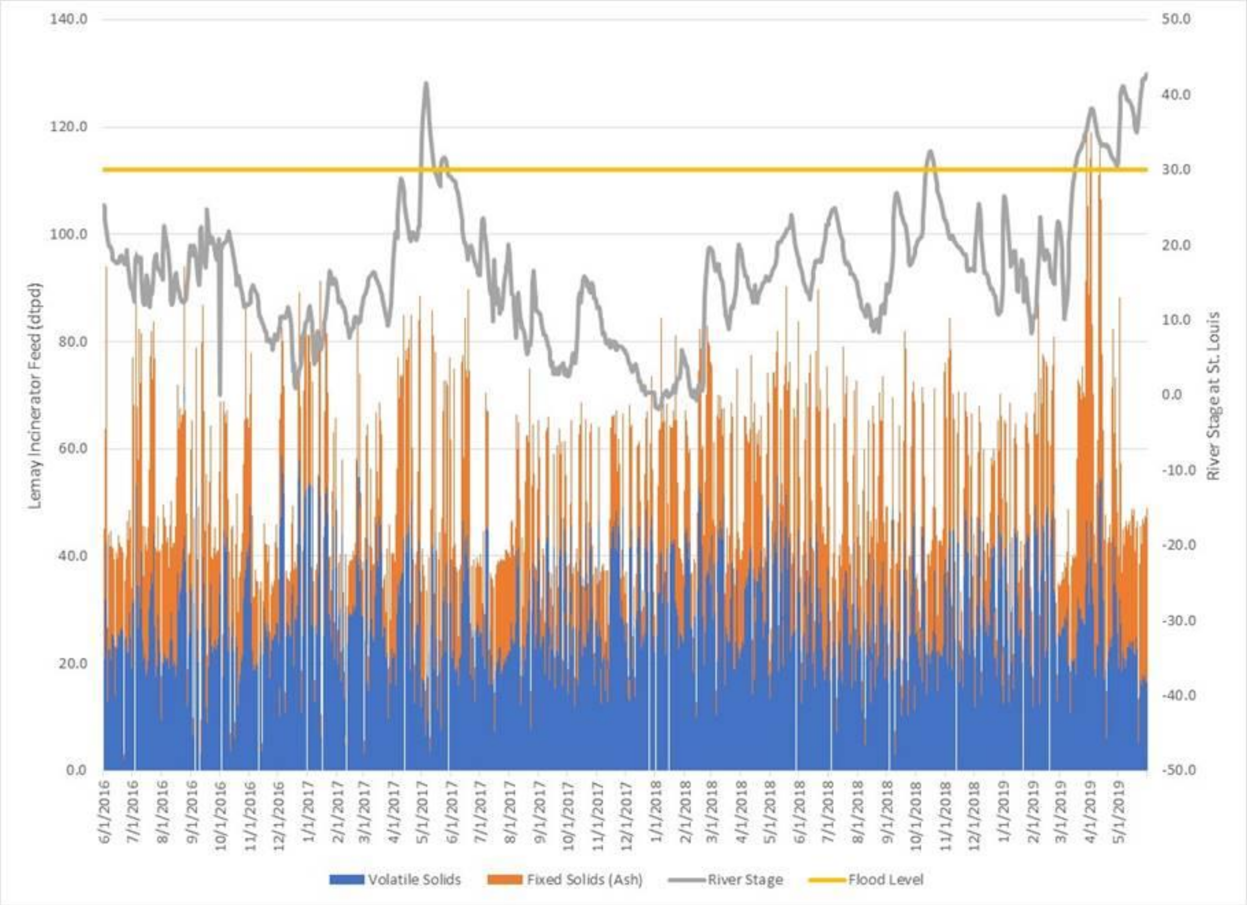

Figure 3-2 Lemay WWTF Recent Daily Solids Quantities and Volatile Solids

Solids characteristics based on recent facility data is shown in Table 3-3, and includes categories for: 1) all data, 2) with flood stage data excluded and, 3) only flood stage data.

Table 3-3 Lemay WWTF Recent Solids Characteristics

ITEM	BFP FEED %TS	CAKE %TS	PS FRACTION, %	VS FRACTION, %
Average	3.6	28.9	53.7	60.1
Range*	1.9 - 6.2	23.9 - 36.2	18.3 - 76.7	42.0 - 75.0
Average w/o flood stage	3.5	28.6	54.9	61.6
Range* w/o flood stage	1.8 - 5.7	23.8 - 35.8	21.7 - 76.8	45.0 - 75.0
Average flood stage	4.4	30.8	45.2	51.1
Range* flood stage	2.2 - 6.9	25.3 - 37.8	7.6 - 75.2	37.0 - 72.0

*5th to 95th Percentile

Data for June 1, 2016 through May 31, 2019 for Lower Meramec, Grand Glaize, and Fenton WWTFs were also evaluated regarding solids quantities. Table 3-4 summarizes information from the recent solids data evaluation for these facilities.

Table 3-4 Lower Meramec, Grand Glaize, and Fenton WWTFs Recent Solids Quantities

DESCRIPTION	INFLUENT, MGD	SOLIDS TO INCINERATION, DTPD	SOLIDS TO LANDFILL, DTPD	TOTAL SOLIDS, DTPD	PEAKING FACTOR
Lower Meramec, AA	11.6	4.4	0.5	4.9	-
Lower Meramec, MM (w/o FS*)	12.5	4.4	1.8	6.2	1.3
Lower Meramec, MM (FS*)	36.1	7.3	0.0	7.3	1.5
Grand Glaize, AA	13.7	7.5	0.4	7.9	-
Grand Glaize, MM (w/o FS*)	14.2	8.5	1.5	10.0	1.3
Grand Glaize, MM (FS*)	18.4	11.3	0.0	11.3	1.4
Fenton, AA	4.9	2.3	0.4	2.7	-
Fenton, MM (w/o FS*)	3.7	3.2	0.0	3.2	1.2
Fenton, MM (FS*)	15.1	1.1	6.2	7.3	2.7

*FS = Flood Stage

The District is designing improvements for the Lower Meramec WWTF as part of the Expansion Phase II project and is planning to convert the facility from a trickling filter to activated sludge process. Information on this project is outlined in HDR's Lower Meramec WWTF Expansion Phase II Predesign Report Draft dated December 2019. MSD provided solids projections developed by the project design engineer, HDR, representing conditions after treatment conversion and inclusion of solids from the Fenton WWTF for several cases. One of the cases included the addition of solids from Grand Glaize WWTF, which are shown in Table 3-5).

Table 3-5 Lower Meramec WWTF Expansion Phase II Solids Projections

DESCRIPTION	SOLIDS, DTPD
Total Solids, AA	19.8
Total Solids, MM	35.8
Total Solids, PW	48.7

3.3 DESIGN SOLIDS QUANTITIES PROJECTIONS AND CHARACTERISTICS

Design solids quantities projections and characteristics were developed based on the following criteria:

- Nominal planning period of 25 years, to 2045
- Lemay, Grand Glaize and Fenton WWTFs' service areas are mature with little growth expected, as identified in the SMP and SH TM and confirmed by the close correlation of average solids rates from 2006 to 2017, 66.3 dtpd, and recent data (June 2016 to May 2019), 65.3 dtpd,

- No significant change to the wastewater treatment processes at the Lemay and Grand Glaize WWTFs
- The Fenton WWTF will be decommissioned with wastewater from the service area conveyed to the Lower Meramec collection system. Solids from the Grand Glaize WWTF will be conveyed to the Lower Meramec WWTF collection system. Solids from Lower Meramec WWTF will be pumped by a force main to the Lemay WWTF.
- The Lower Meramec WWTF will be converted from a trickling filter plant to an activated sludge plant. Solids projections provided by MSD from the design engineer, HDR, for the Lower Meramec WWTF Expansion Phase II project will be used to estimate solids from the Lower Meramec WWTF, including solids from the Fenton Service Area and the Grand Glaize WWTF.
- Recent data (June 2016 to May 2019) quantities as the basis for design quantities for the Lemay WWTF
- MSD has entered into a consent decree to construct combined sewer overflow (CSO) tunnels and a sanitary sewer overflow (SSO) tunnel as part of the Long Term Control Plan (LTCP). MSD has provided estimates of the additional solids that will be captured as a result of the LTCP and these estimates were used in developing the total design solids quantities.
- The future impact of nutrient removal (post-2030) will be based on chemical phosphorus removal and no nitrogen removal (as indicated in the September 10 2019 Technical Steering Meeting), except for the Lower Meramec WWTF which are based on projections for future conditions after completion of the Lower Meramec WWTF Expansion Phase II project.

Table 3-6 shows design solids quantities for normal operation and flood conditions.

Table 3-6 Lemay WWTF Design Solids Quantities

DESCRIPTION	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS FROM COUNTY PLANTS, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
Normal Operation, AA	27.5	22.3	19.8	69.6	60.1
Normal Operation, MM	34.7	25.9	25.0	85.6	54.4
Normal Operation, PW	47.6	30.6	31.2	109.4	52.4
Flooding Data, MM	32.7	33.0	33.3	99.0	47.2
Flooding Data, PW	43.3	46.2	46.8	136.3	38.7

Design solids characteristics will be based on the recent solids data and are shown in Table 3-3.

The Comprehensive Ammonia & Nutrient Removal Plan study evaluated two alternatives for the Lemay WWTF based on permitted influent capacity. Alternative 5A, based on modified step feed and biological phosphorus removal, projected AA solids production of 185 dtpd, and Alternative 5B, based on moving bed bioreactor and chemical phosphorus removal, projected AA solids production of 250 dtpd. During the September 10, 2019 Technical Steering Meeting, MSD staff indicated that future nutrient removal should be based on chemical phosphorus removal and no nitrogen removal. Criteria used to develop additional solids quantities based on chemical phosphorus removal for the Lemay, Lower Meramec, and Grand Glaize WWTFs are shown in Table 3-7, Table 3-8, and Table 3-9, respectively. For the Lemay WWTF it was assumed that ferric chloride will be used for phosphorous removal at a molar ratio of 2.5 (Fe/P Molar ratio) and a safety factor of 1.35. Table 3-10 and Table 3-11 shows design solids quantities for the County WWTFs and the Lemay WWTF, respectively, if the additional solids from chemical phosphorus removal are included in design values.

Table 3-7 Lemay WWTF Chemical Phosphorus Removal Criteria

DESCRIPTION	INFLUENT FLOW, MGD	INFLUENT TP, MG/L	EFFLUENT TP, MG/L	P REMOVED, DTPD	CHEMICAL USE, DTPD	CHEMICAL SLUDGE, DTPD
Normal, AA	121.5	6.0	0.5	2.8	25.9	28.7
Normal, MM	155.0	6.0	0.5	3.6	33.0	36.6
Normal, PW	147.3	6.0	0.5	3.4	31.4	34.8
Flooding Data, MM	235.6	4.0	0.5	3.4	33.5	36.9
Flooding Data, PW	256.9	4.0	0.5	3.8	36.5	40.3

Table 3-8 Lower Meramec WWTF Chemical Phosphorus Removal Criteria

DESCRIPTION	INFLUENT FLOW, MGD	INFLUENT TP, MG/L	EFFLUENT TP, MG/L	P REMOVAL, DTPD	CHEMICAL USE, DTPD	CHEMICAL SLUDGE, DTPD
Normal, AA	16.0	5.4	0.5	0.3	3.1	3.4
Normal, MM	20.2	5.4	0.5	0.4	3.9	4.3
Normal, PW	25.3	5.4	0.5	0.5	4.8	5.3
Flooding Data, MM	23.0	4.4	0.5	0.4	3.6	4.0
Flooding Data, PW	37.9	4.4	0.5	0.6	5.9	6.5

Table 3-9 Grand Glaize WWTF Chemical Phosphorus Removal Criteria

DESCRIPTION	INFLUENT FLOW, MGD	INFLUENT TP, MG/L	EFFLUENT TP, MG/L	P REMOVAL, DTPD	CHEMICAL USE, DTPD	CHEMICAL SLUDGE, DTPD
Normal, AA	13.7	5.1	0.5	0.3	2.5	2.8
Normal, MM	14.2	5.1	0.5	0.3	2.6	2.9
Normal, PW	21.6	5.1	0.5	0.4	3.9	4.3
Flooding Data, MM	18.4	5.0	0.5	0.3	3.3	3.6
Flooding Data, PW	32.4	5.0	0.5	0.6	5.7	6.3

Table 3-10 County WWTFs Design Solids Quantities with Chemical P Removal

DESCRIPTION	LOWER MERAMEC TOTAL SOLIDS, DTPD	GRAND GLAIZE TOTAL SOLIDS, DTPD
Normal, AA	15.3	10.7
Normal, MM	19.3	12.9
Normal, PW	24.0	16.8
Flooding Data, MM	25.9	14.9
Flooding Data, PW	34.6	25.0

Table 3-11 Lemay WWTF Design Solids Quantities with Chemical P Removal

DESCRIPTION	PS, DTPD	WAS/TF, DTPD	TOTAL SOLIDS FROM COUNTY PLANTS, DTPD	TOTAL SOLIDS, DTPD	% VOLATILE SOLIDS
Normal, AA	56.2	22.3	25.9	104.4	53.2
Normal, MM	71.3	25.9	32.2	129.4	47.9
Normal, PW	82.4	30.6	40.8	153.8	50.7
Flooding Data, MM	69.6	33	40.9	143.5	45.6
Flooding Data, PW	83.6	46.2	59.6	189.3	40.6

Implementation of the LTCP will result in more solids being captured and sent to the Lemay WWTF for treatment, because of implementation of CSO tunnels and an SSA tunnel which have various construction dates. MSD provided estimates of the additional solids that will be captured as a result of the LTCP, which are summarized in Table 3-12.

Table 3-12 Lemay Service Area Annual Untreated Overflows and Captured Solids

DESCRIPTION	OVERFLOWS, MG	ASSOCIATED SOLIDS, TONS TSS
Pre-LTCP Untreated Overflows		
To River Des Peres	5,693	
To RDP tributaries	363	
To Mississippi River	216	
Total untreated overflows	**6,272**	**7,689**
Post-LTCP Untreated Overflows		
To River Des Peres	1,177	
To RDP tributaries	0	
To Mississippi River	251	
Total untreated overflows	**1,428**	**1,751**
Captured for Treatment	**4,844**	**5,938**

Per the LTCP there were 62 overflow events per year associated with the River Des Peres and tributaries. Table 3-13 provides a summary of information regarding the CSO and SSO tunnels associated with the LTCP for the Lemay Service Area.

Table 3-13 Lemay Service Area CSO and SSO Tunnel Summary

TUNNEL	STORAGE, MG	COMPLETION DATE
Deer Creek Sanitary Tunnel (SSO)	48	2023
Lower & Middle River Des Peres Storage Tunnel (CSO)	231	2037
River Des Peres Tributaries Storage Tunnel (CSO)	28	2035
Upper River Des Peres Storage Tunnel (CSO)	30	2039

Based on tunnel completion dates, solids from the Deer Creek Sanitary Tunnel were apportioned to Current Design Solids Quantities and solids from all tunnels were apportioned to Future Design Solids Quantities. Solids were apportioned for a greater number of events during maximum month and peak week than average, to reflect that these events would likely occur during high river conditions when solids production is highest at the facility.

A summary of current design solids quantities for the Lemay WWTF is shown in Table 3-14. Current design solids quantities include CSO solids from tunnels that will be completed near the time that the new solids facilities will come on line, but not from tunnels to be constructed later, nor the solids that would occur from future implementation of chemical phosphorus removal.

Table 3-14 Lemay WWTF Current Design Solids Quantities

Description	PS, dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Solids County Plants, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal Operation, AA	27.5	22.3	1.9	22.0	73.7	60.1	-
Normal Operation, MM	34.7	25.9	-	28.6	89.2	54.4	1.2
Normal Operation, PW	47.6	30.6	-	35.2	113.4	52.4	1.5
Flood Stage, MM	32.7	33.0	3.9	40.9	110.4	47.2	1.5
Flood Stage, PW	43.3	46.2	4.7	52.3	146.5	38.7	2.0

A summary of future design solids quantities for the Lemay WWTF is shown in Table 3-15. Future design solids quantities include CSO solids from all tunnels and the solids that would occur from future implementation of chemical phosphorus removal, except for the County Plants. Future solids loadings for the County Plants were based on solids quantities developed for the Lower Meramec WWTF Expansion Phase II project, because these reflected projections based on conversion of the plant to an activated sludge process and for the highest nutrient removal rate alternative.

Table 3-15 Lemay WWTF Future Design Solids Quantities

Description	PS[1], dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Solids County Plants, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	56.2	22.3	16.3	19.8	114.6	56.4	-
Normal, MM	71.3	25.9		25.7	122.9	49.9	1.1
Normal, PW	82.4	30.6	-	31.7	144.7	52.6	1.3
Flood Stage, MM	69.6	33	26.8	35.8	165.2	50.8	1.5
Flood Stage, PW	83.6	46.2	33.4	48.7	211.9	43.6	1.9

Solids projections, including the impact of using Chem P loadings, use of Lower Meramec Phase II projections for County Plants, and approach to apportioning CSO solids, was reviewed at the Management Meeting on December 23, 2019. It was agreed to use the solids projections identified as Bissell Point and Lemay WWTF Future Design Solids Quantities as the basis for sizing new infrastructure associated with the project. As with the Bissell Point WWTF, to accommodate possible future facilities to process unanticipated solids quantities it is recommended that the new FBI building be located on the plant site so that a future building could be located adjacent to it.

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum No. 06:

Dewatering Facilities

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

27 OCTOBER 2020

Technical Memorandum 06

Brown AND Caldwell

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Prepared for: Metropolitan St. Louis Sewer District

Project Title: Bissell & Lemay WWTF Fluidized Bed Incinerators

BC Project No.: 153644

Technical Memorandum No. 06

Subject: Dewatering Facilities

Date: October 27, 2020

To: Bently Green, PE, Black & Veatch Project Manager

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** Licensed in other states*

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AA	Annual Average
BC	Brown and Caldwell
BFP	Belt Filter Press
BNR	Biological Nutrient Removal
BV	Black & Veatch
dtpd	Dry tons per day
FBI	Fluidized Bed Incinerator
gpd	Gallons per day
gpm	Gallons per minute
LCCE	Lifecycle cost evaluation
MHI	Multiple Hearth Incinerators
MM	Maximum Month
O&M	Operation and Maintenance
ppd	Pounds per day
PW	Peak Week
TM	Technical Memorandum
TS	Total Solids
VS	Volatile Solids
WAS	Waste-Activated Sludge
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

1.0 Introduction and Background

The Metropolitan St. Louis Sewer District (District) has undertaken a project to provide new fluidized bed incineration (FBI) facilities at the District's Bissell Point and Lemay wastewater treatment facilities (WWTF). The new incineration facilities at Bissell Point WWTF will include dewatering and incineration of raw sludge from the District's Coldwater Creek WWTF in addition to biosolids derived from the Bissell Point WWTF collection system. Raw sludge is pumped from the Coldwater Creek WWTF to the Bissell Point collection system. The new incineration facilities at the Lemay Wastewater Treatment Facility will include dewatering and incineration of raw biosolids from three District wastewater treatment facilities (Grand Glaize, Fenton and Lower Meramec) in addition to that derived directly from the Lemay collection system.

Both Bissell Point and Lemay currently utilize belt filter presses for dewatering. As part of the FBI project, alternative dewatering technologies will be evaluated to support selection of a dewatering technology for implementation for the new incineration facilities. The objective of this technical memorandum (TM 06) is to evaluate dewatering technologies as well as polymer, dewatered sludge conveyance and odor control support systems.

2.0 Existing Plant Information and Proposed Improvements

2.1 EXISTING BISSELL POINT WWTF TREATMENT PROCESS

The existing Bissell Point WWTF liquid stream treatment process includes course bar screens, grit removal, comminutors, primary clarifiers, trickling filters and secondary clarifiers. The District plans to replace the comminutors with fine screens in the near future.

Existing Bissell Point WWTF solids treatment facilities are summarized in TM-04: Solids Quantities and Characteristics. Thickened sludge from Coldwater WWTF is pumped to the Bissell Point collection system and received in the influent flow to Bissell Point. Primary and secondary sludge generated at Bissell Point WWTF are co-settled and thickened in primary clarifiers and pumped to a dewatering-feed sludge well in the Sludge Disposal Building. Dewatered sludge from Grand Glaize, Fenton and Lower Meramec WWTFs is currently hauled to Bissell Point and received at the Sludge Disposal Building for incineration along with dewatered sludge produced at Bissell Point. Lastly, Bissell Point receives grease, septage and other wastes from private waste haulers upstream of either the grit removal process or pre-aeration tanks.

Scum is collected from primary and secondary clarifiers and directed to scum concentration equipment. Concentrated scum is conveyed to the sludge well for blending with the thickened sludge. Blended sludge is pumped from the sludge well to the belt filter presses for dewatering. Feed sludge is conditioned with mannich polymer, dewatered and conveyed to equalization bins for incinerator feed.

Ferrous chloride is sometimes added to the dewatering-feed sludge wells during periods of dry weather (typically July – September when H2S builds up in the system) to minimize operator exposure to hydrogen sulfide in the dewatering room. Bissell Point WWTF is located in an industrial area and no odor control is currently provided for the existing dewatering facility. The current dewatering operational schedule is 24 hours per day and 7 days per week.

2.2 EXISTING LEMAY WWTF TREATMENT PROCESS

The existing Lemay WWTF liquid stream treatment process includes pre-aeration, fine screens, grit removal, primary clarifiers, aeration basins and secondary clarifiers. A recent expansion project added a wet weather treatment train including four additional primary clarifiers with grit removal.

Existing Lemay WWTF solids treatment facilities are summarized in TM-04: Solids Quantities and Characteristics. Primary and waste activated sludge generated at Lemay WWTF are co-settled and thickened in primary clarifiers and pumped to a dewatering-feed sludge well in the Incinerator and Filter Building. Daily and rain/flood event peak sludge production is equalized in the primary clarifiers in order to maintain a steady feed rate to the dewatering and incineration system. Scum is collected from primary and secondary clarifiers and directed to scum concentration equipment. Concentrated scum is conveyed to the dewatering-feed sludge well for blending with the thickened sludge. Blended sludge is pumped from the dewatering-feed sludge well to the belt filter presses for dewatering. Dewatering feed sludge is conditioned with mannich polymer, dewatered and conveyed to equalization bins for incinerator feed.

Ferrous chloride is sometimes added to the dewatering-feed sludge wells during periods of dry weather (typically July – September when H2S builds up in the system) to minimize operator exposure to hydrogen sulfide in the dewatering room. Due to the location of Lemay WWTF near a residential area, odor control facilities were added to treat foul air from the existing dewatering facility. The current dewatering operational schedule is 24 hours per day and 7 days per week.

2.3 PROPOSED SOLIDS TREATMENT IMPROVEMENTS

Coldwater WWTF sludge will continue to be pumped to the Bissell Point WWTF collection system. Dewatered sludge from Fenton, Grand Glaize, and Lower Meramec WWTFs will no longer be hauled to Bissell Point WWTF. Instead, the District plans to direct solids from Fenton and Grand Glaize to Lower Meramec WWTF for capture and construct a new sludge transfer pump station and forcemain to convey these solids from Lower Meramec to Lemay for blending with solids captured at Lemay. These improvements are described in TM-05 Lower Meramec WWTF Sludge Pump Station and Forcemain.

The District has indicated future chemical phosphorus removal should be assumedfor both Bissell Point and Lemay utilizing ferric chloride. A future high-rate treatment system is planned in the late 2030s for Lemay to treat CSO tunnel discharge. New dewatering and incineration facilities will be provided at both plants and the existing dewatering and incineration facilities will be abandoned. The new dewatering facilities will include sludge wells and dewatering equipment with polymer storage, make-up and feed and conveyance equipment for transfer of dewatered sludge to new incinerator-feed equalization bins. Foul air collection and odor control treatment will be provided at both the Bissell Point and Lemay facilities. Although, odor control is not currently provided for the Bissell Point solids handling building, plant operations staff have requested for odor control to be provided for the new dewatering and incineration facilities.

3.0 Solids Production and Characteristics

Bissell Point and Lemay WWTF design solids quantities and characteristics were initially developed in TM No. 04: Solids Quantities and Characteristics. Further analysis was conducted, and design solids quantities were refined and published in TM-09: FBI Design Criteria. The most recent figures are summarized in this TM for convenient reference.

3.1 BISSELL POINT BLENDED SLUDGE PRODUCTION AND CHARACTERISTICS

The design basis for this project includes solids from Coldwater Creek WWTF and Bissell Point WWTF collections systems. Bissell Point WWTF blended thickened sludge production (primary and secondary sludge) is provided in Table 3-1 based on a planning horizon of year 2045.

The Bissell Point WWTF influent solids loading has a causal relationship to the Mississippi River water level. More specifically, historical data shows influent non-volatile solids increase substantially during flood events. This increase in influent non-volatile solids is reflected by a corresponding decrease in the volatile solids fraction as shown in Table 3-1. Blended sludge production including future implementation of chemical phosphorus removal is also provided.

Table 3-1. Bissell Point WWTF Blended Sludge Production

Condition	Blended Sludge Production, CURRENT		Blended Sludge Production, FUTURE	
	Total Solids, dtpd	Volatile Solids, %	Total Solids, dtpd	Volatile Solids, %
Normal, AA	113.8	50.8	134.8	42.9
Normal, MM	148.5	50.9	168.1	44.9
Normal, PW	215.1	37.5	246.8	32.6
Flood stage, MM	227.5	35.4	250.1	32.2
Flood stage, PW	281.8	30.5	300.3	28.7

Design solids characteristics are based on recent solids data shown in Table 3-2. Bissell Point solids characteristics are also impacted by flood events.

Table 3-2. Bissell Point WWTF Design Solids Characteristics

Condition	PS Fraction, % average, range	Volatile Solids, % average, range
Normal average	79, 53 – 91	51, 32 – 66
Flood stage average	No Data	39, 29 - 58

1. *Range provided is 5th to 95th percentile.*

Bissell Point WWTF primary solids fraction of sludge produced is relatively high for municipal wastewater treatment plant sludge and the volatile solids fraction of total solids is relatively low. Generally, high primary solids fraction and low volatile solids contribute to relatively high solids concentrations for blended thickened sludge and a relatively high belt filter press dewatered sludge average solids concentration. This is reflected in the recent historical average thickened sludge solids concentrations 5.4 %TS (8.1 %TS for flood conditions) and the historical average dewatered sludge solids concentration of 29 %TS (33 %TS for flood conditions). Operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which likely indicates an increase in gritty abrasive material during these events.

3.2 LEMAY SOLIDS PRODUCTION AND CHARACTERISTICS

The design basis for this project includes solids from Fenton, Grand Glaize, Lower Meramec and Lemay WWTF collections systems. These solids will be blended with Lemay thickened sludge prior to dewatering. Lemay WWTF blended sludge production is provided in Table 3-3 based on a planning horizon of year 2045.

The Lemay WWTF influent solids loading has a causal relationship to the Mississippi River water level. More specifically, historical data shows influent non-volatile solids increase substantially during flood events. The increase in influent non-volatile solids during flood events is reflected by a corresponding decrease in the volatile solids fraction as shown in Table 3-3. Blended sludge production including future implementation of chemical phosphorus removal is also provided.

Table 3-3. Lemay WWTF Blended Sludge Production

	Blended Sludge Production, CURRENT		Blended Sludge Production, FUTURE	
Condition	Total Solids, dtpd	Volatile Solids, %	Total Solids, dtpd	Volatile Solids, %
Normal, AA	73.7	60.1	111.6	56.4
Normal, MM	89.2	54.4	122.9	49.9
Normal, PW	113.4	52.4	144.7	52.6
Flood stage, MM	110.4	47.2	165.2	50.8
Flood stage, PW	146.5	38.7	211.9	43.6

1. *Solids production includes solids from Fenton, Grand Glaize and Lower Meramec WWTF.*

Design solids characteristics based on recent solids data are provided in Table 3-4. Lemay solids characteristics are also impacted by flood events.

Sludge pumped from Lower Meramec WWTF to Lemay WWTF will be un-thickened to facilitate operability of the long forcemain (over 10 miles long). As a result, the volumetric flow rate of Lower Meramec WWTF sludge is significant in relation to the Lemay WWTF sludge. Blending Lower Meramec sludge with Lemay sludge will cause a reduction in the blended sludge solids concentration versus Lemay WWTF thickened sludge solids concentration historical averages, which have recently been 3.5 %TS (range 1.8 – 5.7) for normal and 4.4 %TS (range 2.2 – 6.9) for flood conditions. Lower Meramec transfer sludge management is considered in a separate TM. For this TM, it is assumed that the sludge will be thickened to at least 3% TS at Lemay and blended with the Lemay sludge.

Table 3-4. Lemay WWTF Design Solids Characteristics

Condition	PS Fraction, % average, range	Volatile Solids, % average, range
Normal	54, 18 – 77	60, 42 – 75
Flood stage	45, 7.6 – 75	51, 37 – 72

1. Range provided is 5th to 95th percentile.

Activated sludge secondary treatment is provided at Lemay. Waste activated sludge typically does not thicken as well as some other municipal wastewater treatment plant sludges. This is reflected in the recent historical average thickened sludge solids concentration 3.5 %TS (4.4 %TS for flood conditions) for Lemay versus 5.4 %TS (8.1 %TS flood) for Bissell Point. The historical average dewatered sludge solids concentration for Lemay has been 29 %TS (31 %TS for flood conditions). Before installation of the fine screens, operations staff noted increased wear on belt filter press belts during periods of peak solids production, which indicates an increase in debris during these events. Since installation of the fine screens, wear on the belt filter press belts has been significantly reduced.

4.0 Dewatering Facility Alternatives

This section provides conceptual design criteria as well as a description and evaluation of primary equipment alternatives for the new dewatering facilities.

4.1 BLENDED SLUDGE PRODUCTION AND CHARACTERISTICS

In order to optimize the dewatering process performance, selection of equipment, dewatering feed conditioning and operational practices must carefully consider the production rate and characteristics of sludge directed to dewatering. At both Bissell Point and Lemay WWTFs, no additional treatment is provided in advance of dewatering for thickened sludge withdrawn from the primary clarifiers. For that reason, blended sludge characteristics and flows to dewatering are substantially the same as presented in an earlier section of this TM. Blended sludge production for dewatering feed is summarized in Tables 4-1 and 4-2. Blended sludge production is shown for multiple conditions with and without flood stage and future chemical phosphorus removal solids, Lower Meramec sludge and CSO solids. The blended sludge production provided includes the following assumptions and will serve as the basis for sizing dewatering equipment.

- Planning period of 25 years (2045)
- Lower Meramec transfer sludge is thickened at Lemay to a minimum of 3.0 %TS.
- Reference TM-04 Solids Quantities and Characteristics and TM-09 FBI Design Criteria for additional solids production development details.

Table 4-1. Bissell Point WWTF Blended Sludge Production

CONDITION	FLOOD STAGE	FUTURE SOLIDS	MASS FLOW, LB/DAY	VOLUMETRIC FLOW, GAL/DAY
Average Annual	No	No	227,600	681,800
Maximum Month	Yes	No	455,000	1,090,500
Peak Week	Yes	No	563,600	1,350,700
Maximum Month	Yes	Yes	500,200	1,198,800
Peak Week	Yes	Yes	600,600	1,439,400

1. Assumes thickening of Bissel Point sludge to 4.0 %TS (5.0 %TS for flood conditions).

Table 4-2. Lemay WWTF Blended Sludge Production

CONDITION	FLOOD STAGE	FUTURE SOLIDS	MASS FLOW, LB/DAY	VOLUMETRIC FLOW, GAL/DAY[1]
Average Annual	No	No	147,400	588,800
Maximum Month	Yes	No	220,800	882,000
Peak Week	Yes	No	293,000	1,170,400
Maximum Month	Yes	Yes	330,400	1,319,800
Peak Week	Yes	Yes	423,800	1,692,800

1. Assumes thickening of Lemay and Lower Meramec transfer sludge to 3.0 %TS

Both Bissell Point and Lemay will receive and dewater solids from other collection systems. With the addition of solids from other collection systems comes an increased likelihood of variability for the blended sludge characteristics. Also, blended sludge characteristics will vary during flood events and with the addition of future chemical phosphorus removal solids. Due to this anticipated variability, it is critical to provide a dewatering system with adequate flexibility to accommodate these conditions while still meeting performance expectations.

4.2 BLENDED SLUDGE PEAK PRODUCTION MANAGEMENT AND EQUALIZATION

Historically, peak solids production has been processed by dewatering and incineration facilities with excess solids beyond the dewatering and incineration system feed rate being attenuated in the primary clarifiers. The capability of the existing upstream facilities for attenuation of design solids production above the capacity of the dewatering system should be evaluated to determine impacts on dewatering, primary clarifier effluent quality and plant final effluent equality.

4.3 DEWATERING SYSTEM PERFORMANCE REQUIREMENTS

A continuous 24 hours per day and 7 days per week dewatering operating schedule will be maintained, which is typical for treatment plants of this size and appropriate to coordinate with the recommended operational requirements of incineration equipment. Based on the dewatering operating schedule, estimated blended sludge characteristics (including PS fraction, and volatile solids fraction), continuation of upstream attenuation of solids production above the dewatering system capacity and anticipated optimal incinerator feed requirements, the following performance requirements will serve as the basis for design for the dewatering system.

Table 4-3. Dewatering System Performance Requirements

CONDITION	BISSELL POINT WWTF		LEMAY WWTF	
Flood Conditions?	Yes	Yes	Yes	Yes
Future Solids Condition?	No	Yes	No	Yes
Maximum Solids Loading Rate, dry lb/hr	23,500	25,000	12,200	17,700
Maximum Hydraulic Loading Rate, gpm	940	1,000	810	1,180
Minimum Dewatered Sludge Solids Concentration, %TS	25	25	25	25
Minimum Solids Capture, %	95	95	95	95

4.4 DEWATERING TECHNOLOGIES

There are many proven mechanical dewatering technologies in the market. Each of these technologies utilize different principles to separate liquid and solid phases in combined streams. The advantages and disadvantages of these technologies vary in their performance, power consumption, operating simplicity, maintenance requirements, utility demands, footprint and more. This section will focus on three dewatering technologies that have a strong record of success in the North American municipal wastewater treatment market: centrifuge, screw press and belt filter press (BFP). An overview of the pros and cons of these three dewatering technologies is provided in Table 4-4.

Table 4-4. Dewatering Technology Pros and Cons

CENTRIFUGE	SCREW PRESS	BELT FILTER PRESS
Pros • High solids capture (>95%) • Low equipment footprint to capacity ratio • Low operator attention requirements due to automation • Fully enclosed, mitigating odor control considerations and housekeeping • Low wash water usage • Typically produces a relatively higher dewatered sludge solids concentration	**Pros** • Low rotational speed reduces parts wear and maintenance • Low noise, low vibration • Low wash water usage • Low power consumption • Fully enclosed, mitigating odor control considerations and housekeeping • Mechanical simplicity • Low operator attention requirements due to automation	**Pros** • Low power consumption • Relatively simple operation • District familiarity • Low rotational speed reduces parts wear and maintenance • Low noise, low vibration
Cons • High power consumption per machine relative to other technologies	**Cons** • Large footprint to capacity ratio	**Cons** • Open belt design requires greater odor control design considerations

CENTRIFUGE	SCREW PRESS	BELT FILTER PRESS
• High noise level • High rotational speed leads to more long-term maintenance • High speed creates large dynamic loads effecting building structural considerations • Subject to accelerated wear from high grit loads due to high-speed operation • Centrifuge start-up and shut-down results in wet "sloppy" sludge which should be conveyed away from cake handling (usually routed to centrate).	• Dry equipment weight is high leading to structural considerations • Fewer municipal installations compared to centrifuge and BFP • Has not consistently demonstrated 95% solids capture • May be subject to accelerated wear due to high grit loads due to tight tolerances • May produce a relatively lower dewatered sludge solids concentration	• Open belt design increases housekeeping requirements • Large amount of wash water required due to continuous belt washing • Greater risk of operator exposure to machine parts • Operator has more exposure to sludge and odor • Requires greater operator attention • Large footprint to capacity ratio

4.4.1 Centrifuge

A centrifuge utilizes the operating principle of centrifugal force to decrease the settling time of a suspended solid particle in a liquid stream. A centrifuge is composed of two cylinders, rotating at slightly different speeds. The outer cylinder, commonly referred to as the bowl, rotates at high speed creating a centrifugal force. This force drives solids to the wall of the bowl at accelerations of up to 3,000 gravitational units (Gs). The added centrifugal force increases the terminal (settling) velocity of the solid particles. This greatly decreases the amount of time required for suspended solid particles to separate from the liquid stream versus normal gravity clarification. Refer to Figure 4-1 for a picture of a dewatering centrifuge.

Figure 4-1. Dewatering Centrifuge
(Courtesy of Alfa Laval)

The inner flighted cylinder of a centrifuge is commonly referred to as the scroll. The scroll rotates at a slightly different speed from the bowl. This differential speed allows the scroll flights to convey solids collected along the bowl periphery towards the solids discharge end. Near the solids discharge the bowl diameter gradually decreases, creating a conical section referred to as the beach. The scroll transports the solids up the beach angle and out of the liquid stream. Solids travel up the beach provides for additional dewatering before discharge out of the centrifuge.

The clarified liquid stream discharged from a centrifuge is referred to as centrate. The centrate will discharge on the opposite end of the centrifuge from the dewatered sludge discharge. Clarified liquid will flow through the machine to the liquid discharge. A liquid level in the centrifuge will build along the bowl wall and overflow a concentric weir installed on the liquid discharge end of the bowl. Refer to Figure 4-2 for a graphic displaying centrifuge solids separation.

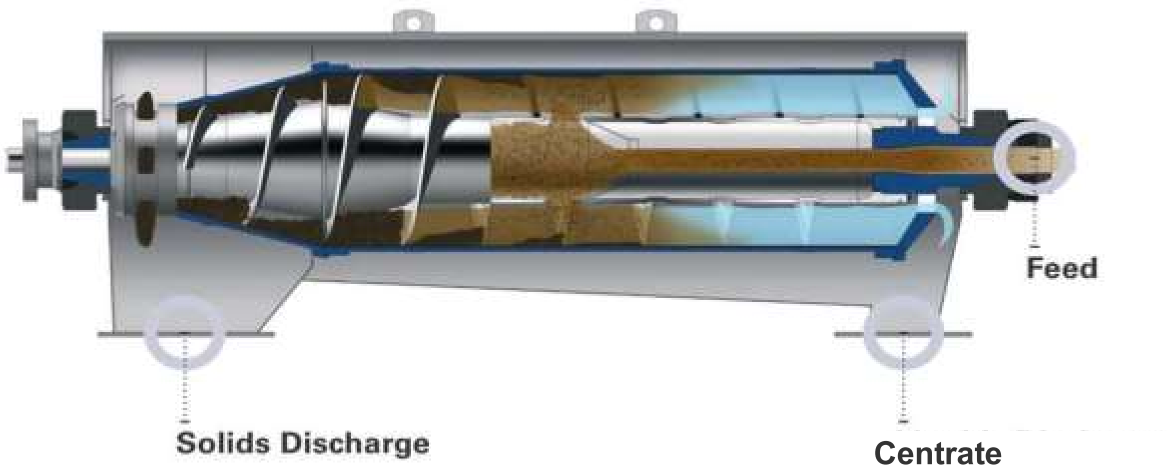


Figure 4-2. Centrifuge Cross-section
Image courtesy of Flottweg

Multiple operational adjustments are critical for maintaining the solids separation performance in a centrifuge. These include the following:

- Polymer dose rate
- Bowl speed
- Bowl and scroll differential speed
- Sludge feed rate

Centrifuges are common at larger municipal wastewater treatment plants primarily due to their high capacity to footprint relationship. In other words, the space requirement for centrifuges is low relative to the solids dewatering capacity provided. This is a mature proven technology with multiple well-respected manufacturers active in the U.S municipal wastewater market. The electrical power requirement for centrifuges is typically high relative to other dewatering technologies, however manufacturers have made recent improvements to significantly improve the centrifuge efficiency. Centrifuge maintenance may be provided by trained operations staff or through a manufacturer service program. Extended service and training programs are also available through most major centrifuge manufacturers. Centrifuges are subject to accelerated wear when significant amounts of grit are present in feed sludge. Some manufacturers will provide equipment with replaceable abrasion resistant wear surfaces to prevent damage to equipment.

4.4.2 Screw Press

A screw press applies filtration principles to separate solid and liquid phases in combined sludge streams. Sludge is typically pumped to a flocculation tank after polymer conditioning for building of floc prior to entering the screw press feed hopper. The screw slowly rotates and conveys feed sludge into and through the drum. A flighted expanding shaft diameter screw gradually increases mechanical pressure as sludge travels through a porous drum to force separation and drainage of liquid from the sludge. Solids are then conveyed axially by the flighted shaft to the machine discharge. An adjustable plug at the drum discharge provides backpressure on the discharging sludge for further dewatering.

An image of a typical screw press is presented in Figure 4-3.

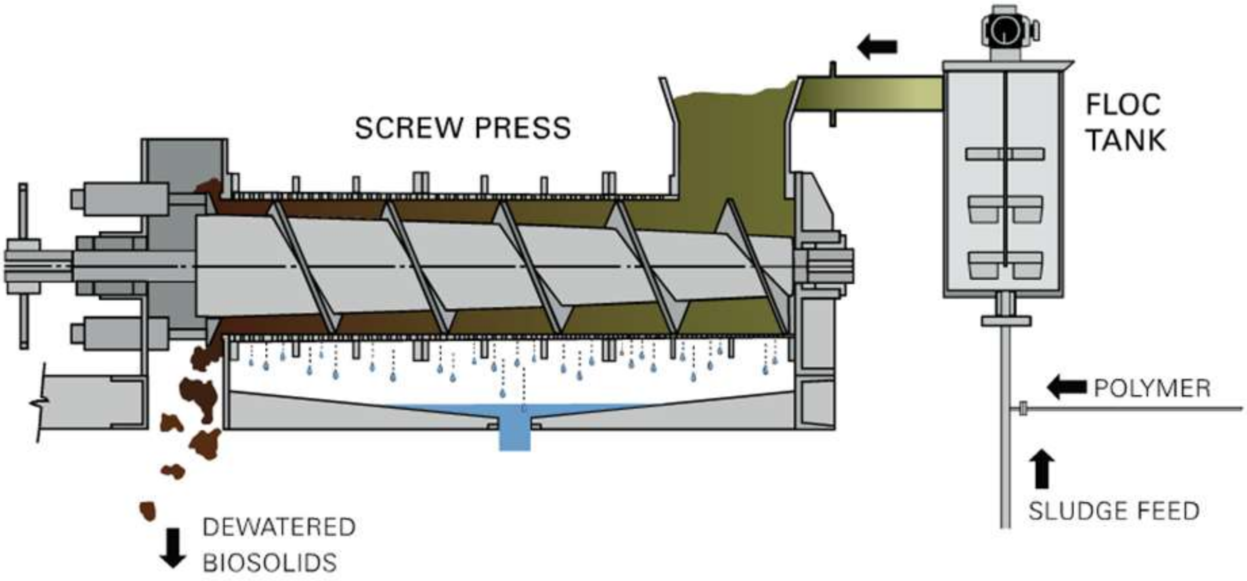


Figure 4-3. Screw Press
Image courtesy of FKC

The slow rotational speed allows for the use of a small electric motor to turn the screw, thus minimizing energy requirements. The slow rotating speed also reduces wear and maintenance requirements and provides a high level of reliability. The screw press is intended for continuous service and typically provided with an automatic spray system for cleaning of the porous drum screen.

Screw presses are typically automated with little operator input. The operational adjustments that can be made are summarized below:

- Sludge feed rate
- Polymer dose rate
- Screw rotational speed
- Discharge back pressure setting

Screw speed controls the residence time of the sludge in the drum and the back pressure setting provides for additional dewatering by finding the optimal back-pressure to encourage release of water from the sludge. Compared to centrifuges and belt filter presses, screw presses are relatively newer to the municipal wastewater market and as such have a somewhat less robust installation base. Historically, they have also been more limited in capacity, though certain manufacturers have recently been working to increase capacity of available units. Huber and FKC are two of the most well-known and experienced (within the US) manufacturers, but their current products only have maximum rated capacities of around 100-150 gpm. The relatively low capacity typically requires more screw press units than other dewatering technologies, and more dewatering units require more associated support equipment (feed pumps, polymer pumps, cake conveyance, etc). Schwing and Ishigaki currently offer larger screw presses, but with limited installation experience. Huber has indicated they are developing a higher capacity screw press unit. Differences between manufacturers can include items such as sludge feed (e.g., direct pipe feed or feed through a flocculation tank), screw removal and screen construction and cleaning.

4.4.3 Belt Filter Press

A belt filter press is a dewatering device that relies on principles of filtration to separate solid and liquid phases. A flocculation tank is typically provided immediately upstream of the BFP. After conditioned sludge is conveyed across a gravity drainage section on top of the BFP, mechanical pressure is applied to sludge sandwiched between two tensioned filter cloths, referred to as belts. Those belts pass through a serpentine of decreasing-diameter rolls to increase the pressure in the interstitial space between belts. The pressure exerted by the belt and roller configuration supplies the force for separating liquid and solid phases in the combined stream. The serpentine pathway of the belts also imparts shear to the compressed solids, further aiding in dewatering. A BFP has three distinct sections performing critical operational steps for the dewatering process:

- Gravity zone: free-draining water is drained by gravity through a porous belt
- Wedge zone: solids are prepared for pressure application
- Pressure zone: medium and then high pressure is applied to the solids

A photograph of a typical BFP is shown in Figure 4-4.

Figure 4-4. Belt Filter Press
Image courtesy of Alfa Laval

In addition to two-belt models, some manufacturers offer three-belt filter presses. The primary advantage of the three-belt model is independent control over the gravity zone to support optimization of dewatering. A diagram of a three-belt filter press is provided in Figure 4-5.

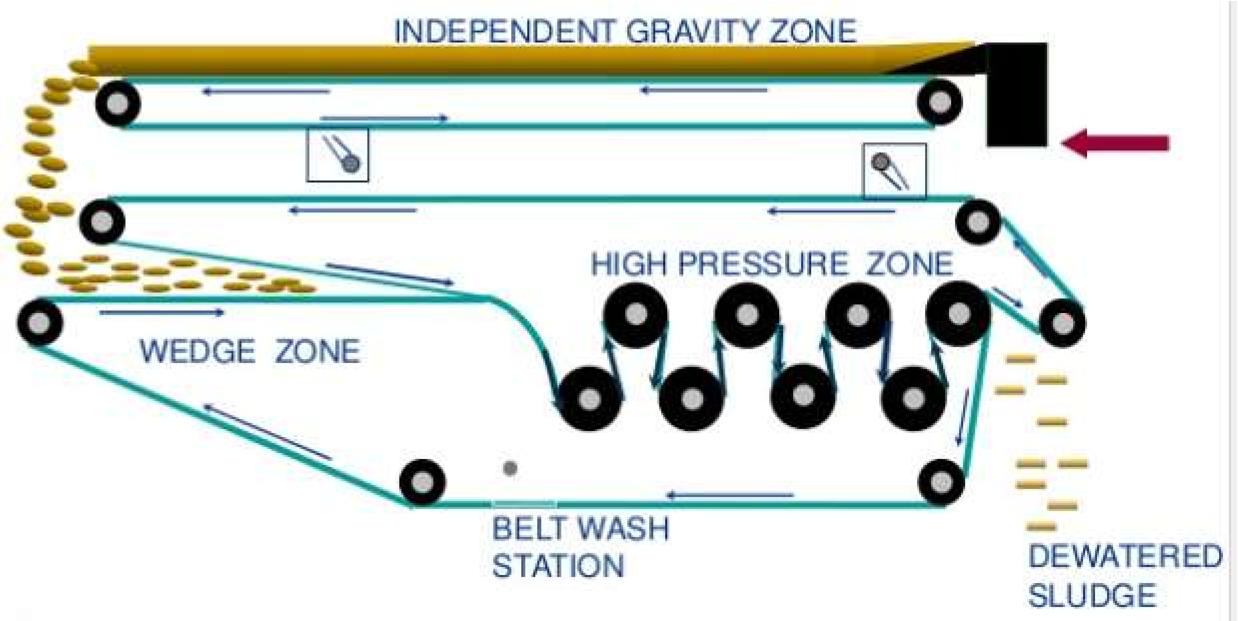


Figure 4-5. Belt Filter Press Cross-Section
Image courtesy of Alfa Laval

The dewatered sludge cake discharges after the high-pressure zone. The cake will typically come off of the belt as a thin sheet before falling into a chute or collection bin. A scraper is typically installed in the discharge zone to clean the belt of residual cake after discharge. A spray system is also provided to clean the belts before they are cycled back to the feed/gravity zone area.

Multiple drive rollers, belt washers, and belt steering (tracking) rollers are provided within the BFP. Operational adjustments include feed rate, belt speed, belt tension, belt type, and wedge adjustment. Polymer addition and polymer/sludge mixing are also critical factors.

BFPs are manually adjusted and require more operator attention than centrifuge or screw press.

BFPs are preferred by many municipal wastewater treatment plants for reliable low-tech dewatering. They rely on slow-moving belt compression in contrast with other higher speed and more complex dewatering technologies. This is a mature proven technology with multiple well-respected manufacturers active in the U.S municipal wastewater market. BFPs generally require more space relative to centrifuges for the units themselves as well as access walkways and maintenance space. Maintenance and housekeeping requirements can also be relatively high and operator exposure to solids and odor is higher unless enclosed units are provided.

Odor control hoods are commonly provided over BFPs to evacuate odorous air and require a more substantial ventilation system. Belt filter presses can be provided with covers to contain odors and reduce foul air withdrawal rate requirements. However, the covers are sometimes viewed as an impediment to optimal belt filter press operation since the gravity zone is no longer visible.

The impact of dewatering equipment wash water flow of the recycle stream on plant processes should also be evaluated since BFPs require a continuous spray to clean the belts discharging a relatively high flow of wash water.

4.4.4 Design Conditions

Dewatering technology alternatives were compared using a lifecycle cost evaluation (LCCE). The LCCE compares the relative cost of each dewatering alternative over a 20-year period to provide an economic basis for consideration when selecting a dewatering technology. The loading and characteristics of blended sludge fed to dewatering were input into the evaluation. The assumptions included in the LCCE are based upon manufacturer-supplied information and experience with similar facilities.

An initial LCCE was completed for the dewatering technologies discussed in Sections 4.4.1 – 4.4.3. The initial LCCE assumptions are summarized in Table 4-5 below. Due to the limited number of high-capacity screw press installations to date, an alternative for a more proven screw press capacity (Alternative 2) was evaluated in addition to the high-capacity screw press (Alternative 2A).

Table 4-5. Initial LCCE Inputs and Assumptions

DESCRIPTION	VALUE	UNITS
General Assumptions		
Period of analysis	2025 - 2044	-
Dewatering unit operating schedule	24	hrs/day

DESCRIPTION	VALUE	UNITS
Dewatering unit operating schedule	7	days/wk
Escalation Rate	2.5	%
Discount Rate	4.0	%
Building Cost	300	$/sf
Markups		
Contractor general requirements	12.0	%
Construction contingency	35.0	%
Engineering, legal and administrative	20.0	%
Blended Sludge Fed to Dewatering		
Bissell Point, AA	226,000	lb/day
Bissell Point, AA with chemical P removal	268,000	lb/day
Lemay, AA	139,200	lb/day
Lemay, AA with chemical P removal	208,800	lb/day
Dewatering Feed Characteristics		
Bissell Point, average solids concentration	5.7	%TS
Lemay, average solids concentration	3.6	%TS
Centrifuge (Alternative 1)		
Solids loading rate capacity	3,500	lb/hr
Average polymer dose (mannich)	6	lb APS/dT
Average solids capture	98	%
Bissell Point average dewatered sludge solids concentration	32	%TS
Lemay average dewatered sludge solids concentration	31	%TS
Power consumption	0.30	kW/gpm
Screw Press (Alternative 2)		
Solids loading rate capacity	1,000	lb/hr
Average polymer dose (mannich)	6	lb APS/dT
Average solids capture	95	%TS
Bissell Point average dewatered sludge solids concentration	27	%
Lemay average dewatered sludge solids concentration	26	%
Connected power	10	HP
Screw Press (Alternative 2A – High Capacity)		

DESCRIPTION	VALUE	UNITS
Solids loading rate capacity	3,000	lb/hr
Average polymer dose (mannich)	6	lb APS/dT
Average solids capture	95	%TS
Bissell Point average dewatered sludge solids concentration	27	%
Lemay average dewatered sludge solids concentration	26	%
Connected power	18	HP
Belt Filter Press (Alternative 3)		
Bissell Point solids loading rate capacity[2]	3,000	lb/hr
Lemay solids loading rate capacity[3]	2,000	lb/hr
Average polymer dose (mannich)	5	lb APS/dT
Average solids capture	97	%TS
Bissell Point average dewatered sludge solids concentration	30	%
Lemay average dewatered sludge solids concentration	29	%
Connected power	20	HP
Utilities		
Electrical rate	$0.077	$/kWh
Mannich polymer cost	$1.90	$/lb active solids
Emulsion polymer cost	$2.85	$/lb active solids
Odor control, capital cost	$40	$/CFM
Labor	50,000	$/year

Bissell Point WWTF belt filter press solids loading rate is reflective of current performance of existing belt filter press equipment.

Lemay WWTF belt filter press solids loading rate should consider historical belt filter press loading rates and characteristics of the multiple sludge streams to be directed to Lemay dewatering.

Performance shown for centrifuge and screw press is based on experience with similar facilities and input from equipment manufacturers.

For the LCCE, new dewatering facility odor control facilities are assumed to be provided at both Bissell Point and Lemay. The need for odor control at the new Bissell Point dewatering facility should be evaluated further since it is not currently provided.

4.4.5 Alternatives Development

Centrifuge, screw press and belt filter press technology alternatives were evaluated for this analysis with two sizing alternatives for screw presses. The District has expressed interest in evaluating large high-capacity screw presses. Due to the small installation list and limited screw press offerings in this capacity, a lower capacity screw press with a longer track record was also evaluated.

Equipment and operational requirements are summarized in Tables 4-6 and 4-7. The number of installed dewatering units shown are based on the following minimum redundancy criteria.

- Two fully redundant standby units for maximum month conditions
- One fully redundant unit provided for peak week conditions

Redundancy of dewatering equipment can be revisited during the detailed design depending on the final configuration of dewatering, conveyance and incinerator equipment. The equipment footprints shown include space for the additional dewatering equipment required to meet future loading with the addition of chemical phosphorus removal solids.

Table 4-6. Bissell Point WWTF Alternatives Development

	Centrifuge Alt. 1	Screw Press Alt.2	Screw Press Alt 2A	Belt Filter Press Alt 3
Number of installed units (duty + standby)	8	25	9	9
Number of installed units (duty + standby) with chemical P solids	8	26	10	10
Equipment footprint required, ft^2	3,070	10,820	7,710	8,350
2045 Annual polymer usage, lb active polymer solids x 10^3	294	294	294	245
2045 Annual power consumption, 10^3 kWh	2,150	3,950	1,590	1,720

Table 4-7. Lemay WWTF Alternatives Development

	Centrifuge Alt. 1	Screw Press Alt.2	Screw Press Alt 2A	Belt Filter Press Alt 3
Number of installed units (duty + standby)	5	13	5	7
Number of installed units (duty + standby) with chemical P solids	6	17	7	9
Equipment footprint required, ft^2	2,390	7,330	6,310	7,570
2045 Annual polymer usage, lb active polymer solids x 10^3	229	229	229	191
2045 Annual power consumption, 10^3 kWh	2,120	2,980	1,210	2,110

Although individual centrifuge dewatering equipment typically has a higher power consumption than screw press or belt filter press equipment, the LCCE considers the power consumption of the total number of units required for each alternative (including ancillary equipment such as feed pumps and dewatered sludge conveyance) as well as odor control power consumption. The greater odor control air flow requirements of a belt filter press system resulted in a higher odor control power consumption for that alternative. These factors are included in the annual power consumption provided in Tables 4-6 and 4-7.

4.4.6 Dewatering Technology Evaluation

A dewatering technology lifecycle cost evaluation was developed to compare the value of each alternative. Only cost components that yielded differences between dewatering technologies were considered. The information used to develop the LCCE came from multiple sources. This included vendor-supplied proposals for equipment, vendor-supplied budget estimates for specific utilities (i.e.

mannich polymer), information supplied by the District, and estimates based upon best practice and experience.

Table 4-8. LCCE Development Method

No.	Title	Description
1	Standard Assumptions	Develop standard assumptions for a multitude of values including, but not limited to: • Project escalation and discount rates • Markups pertaining to overhead and construction costs • Equipment installation cost rates • Utility and labor cost rates • Technology alternatives budget cost • Technology alternatives performance values (capacity, cake solids conc., polymer usage, labor requirements) • Plant operating schedule
2	Design Basis	Review and create design basis for 20-year lifecycle analysis.
3	Equipment Sizing	Calculate the number of installed units required based upon design basis.
4	Equipment Footprint	Upon completion of equipment sizing, develop the approximate total footprint requirement for the dewatering technology alternatives based upon manufacturer provided equipment dimensions and maintenance space requirements.
5	Capital Costs	Develop relative capital cost estimates utilizing equipment sizing, footprint, and standard assumptions. The capital costs only include costs that are substantially different between technology alternatives.
6	Operating and Maintenance Costs	Develop O&M costs across the 20-year lifecycle period. These costs are based upon average system throughput.
7	Replacement and Repair Costs	Develop R&R costs based upon standard practices and previously developed assumptions.
8	Net Present Value	Escalate each cost category and then discount back to 2020 dollars to calculate the net present value for the year of analysis.

Based on the alternatives developed, capital and operating costs were produced and returned to net present values (2020 dollars) for ease of comparison. Results for construction of new facilities and significant operating costs are presented in Tables 4-9 and 4-10. Because the dewatered sludge solids concentration varies between dewatering technologies, and the additional water conveyed to incineration with a lower solids concentration impacts incinerator operational costs, these costs are also provided below for cost evaluation of each alternative.

Capital and operating costs are relative only and do not represent complete alternative costs. These costs are provided for the purpose of evaluation only and should not be used for budget planning.

Table 4-9. Bissell Point WWTF LCCE Results

	Centrifuge Alt. 1	Screw Press Alt.2	Screw Press Alt 2A	Belt Filter Press Alt 3
Dewatering capital cost w/ markups, \$ x 10^6 (2020 dollars)	12.2	35.0	22.4	17.3
Dewatering 20-year Operating Cost, \$ x 10^6 (2020 dollars)	12.4	16.1	12.0	11.0
Incineration 20-year Operating Cost, \$ x 10^6 (2020 dollars)	9.33	18.5	18.5	12.6
Total Net Present Cost (2020 dollars)	33.9	69.6	52.9	41.0

1. Incineration capital costs were determined to be substantially the same for all dewatering alternatives and were therefore excluded from this evaluation.

Table 4-10. Lemay WWTF LCCE Results

	Centrifuge Alt. 1	Screw Press Alt.2	Screw Press Alt 2A	Belt Filter Press Alt 3
Dewatering capital cost w/ markups, \$ x 10^6 (2020 dollars)	9.19	23.1	16.2	15.5
Dewatering 20-year Operating Cost, \$ x 10^6 (2020 dollars)	9.64	11.6	8.65	9.29
Incineration 20-year Operating Cost, \$ x 10^6 (2020 dollars)	3.62	10.8	10.8	6.19
Total Net Present Cost (2020 dollars)	22.5	45.5	35.6	30.9

1. Incineration capital costs were determined to be substantially the same for all dewatering alternatives and were therefore excluded from this evaluation.

For both Bissell Point and Lemay, the LCCE net present value results for dewatering favor centrifuge. Primary differentiators are the number of units required and the footprint space requirements corresponding to the number and size of the units. Comparative dewatering equipment space requirements are provided in Attachment A. The number of units and the building space required have a cascading effect on other costs for dewatering equipment and building support systems.

The LCCE results are sensitive to the unit cost of polymer, the polymer dose and the dewatered sludge solids concentration, which impacts the incineration operating costs. A shift in these three parameters could close the gap between centrifuge and belt filter press enough to consider the LCCE results equal given the level of accuracy for this evaluation. It is not anticipated any shift in these three parameters would close the gap between centrifuge and either screw press alternative.

4.4.7 Initial Dewatering Technology Rating

In order to support decision-making, dewatering technologies were rated for both economic and non-economic factors using a weighted rating system. The final weighted scores are shown in Table 4-11 and the full dewatering technology rating is provided in Attachment C. The alternative rating scale used was 4 = lowest cost, highest performance, most beneficial and 1 = highest cost, lowest performance, least beneficial.

Economic rating has two criteria: capital cost and the present worth O&M cost for each dewatering technology alternative. The capital cost weighted scores were determined by taking the average of the capital costs for each dewatering technology at Bissell Point WWTF and Lemay WWTF. The average capital costs for dewatering technologies were then compared and rated. The present worth 20-year O&M costs for dewatering and incineration at Bissell Point and Lemay were summed individually and then averaged for each dewatering technology. The average present worth O&M costs for each dewatering technology were then compared and rated in a similar fashion to the capital costs.

Non-economic rating includes the following criteria: proven experience, operations and maintenance impacts, operational complexity, ability to handle variations in feed sludge characteristics, ability to resist wear due to abrasive solids, and washwater requirements (impact to treatment process). Dewatering technologies received a rating for each of the non-economic rating criteria.

In conclusion, the centrifuge and the belt filter press received a higher overall rating than the screw press alternatives for this project.

Table 4-11. Dewatering Technology Rating

WEIGHTED SCORES FOR ALTERNATIVES	
Alternative 1 - Centrifuge	3.5
Alternative 2 - Screw Press	1.6
Alternative 2A - Screw Press (High Capacity)	2.2
Alternative 3 - Belt Filter Press	2.9

4.4.8 LCCE Updates Post-Bench Test and Dewatering Workshops

Initial receipt of LCCE results and discussion during the first dewatering workshop on December 10, 2019 led to the exclusion of Belt Filter Presses (Alt. 3) and low-capacity Screw Presses (Alt 2) from further consideration as a dewatering alternative for the FBI Project. Bench testing of the remaining technologies - centrifuge and high-capacity screw press - was conducted by manufacturers during December 2019 and January 2020. After developing generalized conclusions based upon the manufacturers results, the LCCE was compiled again with updated assumptions. These updates can be found below in Table 4-12 and Table 4-13.

Table 4-12. Bissell Point Updated LCCE Inputs and Assumptions

PREVIOUS	NEW	UNITS	DESCRIPTION
Bissell Point Sludge			
297.3	300.3	dtpd	Sludge production, peak week, future design
134.0	134.8	dtpd	Sludge production, annual average, future design
278.8	281.8	dtpd	Sludge production, peak week, current
113.0	113.8	dtpd	Sludge production, annual average, current
2031	2035	lb/day	Future solids design start
Alt_1A - Centrifuge, Mannich			
3,500	3,500	lb/hr	Centrifuge capacity, 30" bowl diameter
32	31	%	Centrifuge cake TS w/w
6.0	11.0	lb/ton	Centrifuge polymer dose, pounds of active polymer per dry ton solids
1	24	hr/day	Centrifuge labor addition
Alt_2A - Screw Press, Mannich			
3,000	3,000	lb/hr	Screw Press capacity
27	25	%	Screw Press cake TS w/w
6.0	7.5	lb/ton	Screw Press polymer dose, pounds of active polymer per dry ton solids
1	1	hr/day/unit	Screw Press labor unit
Dewatering Equipment Purchase Costs			
440,000	670,000	$/unit	Centrifuge
673,000	673,000	$/unit	Screw Press (High Capacity)
Incineration Auxiliary Fuel Cost			
327,107	570,000	$/yr	Centrifuge at current solids quantities and dewatered sludge concentration
708,219	950,000	$/yr	Centrifuge at future solids quantities and dewatered sludge concentration
834,750	1,210,000	$/yr	Screw Press at current solids quantities and dewatered sludge concentration
1,310,439	1,700,000	$/yr	Screw Press at future solids quantities and dewatered sludge concentration

1. *Centrifuge labor addition PREVIOUS units were 1 hr/day/unit. New assumption units are hrs/day.*

Table 4-13. Lemay Updated LCCE Inputs and Assumptions

PREVIOUS	NEW	UNITS	DESCRIPTION
Lemay Sludge			
189.3	211.9	dtpd	Sludge production, peak week, future design
104.4	111.7	dtpd	Sludge production, annual average, future design
136.3	146.5	dtpd	Sludge production, peak week, current

PREVIOUS	NEW	UNITS	DESCRIPTION
69.6	73.7	dtpd	Sludge production, annual average, current
2031	2035	lb/day	Future solids design start
Alt_1A - Centrifuge, Mannich			
3,500	3,500	lb/hr	Centrifuge capacity, 30" bowl diameter
31	30	%	Centrifuge cake TS w/w
6.0	11.0	lb/ton	Centrifuge polymer dose, pounds of active polymer per dry ton solids
1	24	hr/day	Centrifuge labor addition
Alt_3A - Screw Press, Mannich			
3,000	3,000	lb/hr	Screw Press capacity
26	24	%	Screw Press cake TS w/w
6.0	7.5	lb/ton	Screw Press polymer dose, pounds of active polymer per dry ton solids
1	1	hr/day/unit	Screw Press labor unit
18	18	HP	Screw Press connected horsepower
Dewatering Equipment Purchase Costs			
440,000	670,000	$/unit	Centrifuge
673,000	673,000	$/unit	Screw Press (High Capacity)
Incineration Auxiliary Fuel Cost			
59,625	30,000	$/yr	Centrifuge at current solids quantities and dewatered sludge concentration
308,106	380,000	$/yr	Centrifuge at future solids quantities and dewatered sludge concentration
395,379	480,000	$/yr	Screw Press at current solids quantities and dewatered sludge concentration
811,066	1,060,000	$/yr	Screw Press at future solids quantities and dewatered sludge concentration

1. *Centrifuge labor addition PREVIOUS units were 1 hr/day/unit. New assumption units are hrs/day.*

Updates the LCCE were completed upon agreement of the new inputs and assumptions stated above. The new inputs altered the scale of difference between centrifuge and high-capacity screw presses. The new results indicated high-capacity screw presses were nearly as cost-effective over the 20-year evaluation period. The difference in NPV was considered with the accuracy range of the analysis. This conclusion led to further discussion with MSD regarding the dewatering technology selection. Updated LCCE results can be viewed in Table 4-14 below.

Table 4-14. Updated LCCE Results

	Bissell Point		Lemay	
	Centrifuge Alt. 1	Screw Press Alt.2A	Centrifuge Alt. 1	Screw Press Alt.2A
Dewatering capital cost w/ markups, \$ x 10^6 (2020 dollars)	17.0	23.2	12.8	16.7
Dewatering 20-year Operating Cost, \$ x 10^6 (2020 dollars)	22.5	14.0	18.1	10.7
Incineration 20-year Operating Cost, \$ x 10^6 (2020 dollars)	12.1	23.4	3.1	12.2
Total Net Present Cost (2020 dollars)	51.7	60.6	34.1	39.6

In addition to updating the LCCE assumptions, another important factor was altered once the bench testing results were summarized and new assumptions were generated. It was realized that the lower total solids concentration predicted in the screw press dewatered sludge would have an effect on the sizing and cost of incineration equipment downstream of the dewatering process. An initial cost estimate was generated to understand this difference in incineration equipment capital costs. The results of this analysis concluded there would be a $17M price difference at Bissell and a $6M price difference at Lemay. These costs do not include markups and are equipment costs associated with incineration only.

4.4.9 Updated Dewatering Technology Ranking

The conclusions of the updated dewatering LCCE led to further discussion with MSD operations and engineering staff to determine the preliminary selected dewatering technology. Updated subjective weighted rating scores were developed based on economic and non-economic factors and are summarized in Table 4-15.

Table 4-15. Updated Dewatering Technology Rating

WEIGHTED SCORES FOR ALTERNATIVES	
Alternative 1 - Centrifuge	3.5
Alternative 2A - Screw Press (High Capacity)	3.1

The final ratings indicated centrifuge to be more valued as a dewatering technology. These final ratings are an amalgam of ratings developed by MSD Operations and Engineering staff with input from Black & Veatch and Brown and Caldwell. The final ratings are included in Attachment C.

4.4.10 Dewatering Technology Recommendations

Below is a list of considerations for dewatering technology selection.

- Dewatered sludge solids concentration is a key performance parameter for these dewatering facilities given the additional operational costs incurred for incineration equipment if more water is conveyed to incinerators with the dewatered sludge.
- Given the sizable cost difference in the final LCCE results favoring centrifuges, careful consideration should be given to weigh the anticipated operational benefits of screw presses against the additional lifecycle costs. Furthermore, the anticipated screw press operational benefits should be viewed as less certain for the high-capacity screw presses due to the limited number of installations at this time.
- The dewatering system should provide for adequate operational flexibility to accommodate the anticipated variations in dewatering feed characteristics from multiple wastewater treatment plants as well as flood events and future process upgrades. Centrifuges and belt filter presses typically provide greater operational adjustability to accommodate these variations. Measures to allow flexibility to accommodate variable sludge characteristics related to future process changes (i.e. chemical phosphorus removal) and flood/storm conditions should be included in equipment specifications and dewatering system design.
- Adequate mixing of blended sludge streams should be provided to insure a homogenous mixture of dewatering feed sludge.
- Consider the potential for increased grit loading to dewatering system equipment during periods of peak solids production (flood events) in the context of equipment selection and design. Although subject to accelerated belt wear, belt filter presses typically do not experience as much equipment wear as centrifuges due to processing of abrasive solids. Measures to minimize dewatering technology wear from abrasive solids should be included in equipment specifications and dewatering system design.
- Consider providing the capability to route concentrated scum to the incinerator feed bins for blending with dewatered sludge as an alternative to routing to the blended sludge wells. If concentrated scum is routed exclusively to the blended sludge well, centrifuge and screw press dewatering equipment may be subject to build-up of scum and blended sludge wells may develop a floating scum mat over time. Also, the Lemay staff have noted the presence of plastic fragments in the concentrated scum that, although not anticipated to cause damage to the dewatering equipment, could bypass dewatering thus eliminating any potential dewatering-related operational issues.
- Consider both economic and non-economic factors.
- Consider operations staff capabilities and preferences. Centrifuges are very common dewatering equipment for plants of this size but operate at high speeds (2,500-3,000 rpm) and are typically more complex to operate and maintain than screw press or belt filter press. Even so, MSD operations are as robust and proven as operations staff anywhere and would be expected to successfully operate centrifuges if this technology were to be implemented.
- Due to the current limited number of installations in North America, high-capacity screw presses should be vetted by checking references and site visits to confirm satisfactory performance prior

to advancing further in the dewatering technology selection process. Although screw presses in general have a good track record for municipal dewatering service, the newer high-capacity units are not yet considered proven.

- Consider phased manufacturer bench-scale testing and on-site pilot testing to further confirm the performance assumed for centrifuge and screw press and the corresponding LCCE results. UPDATE: Bench-scale testing was performed in January for centrifuge, belt filter press and screw press and again in May for centrifuge with samples drawn during high river conditions. Bench test results are summarized in Attachment D.
- Site visits are recommended to similar facilities with incineration and dewatering by centrifuge or screw press in order to gain a full understanding of operational considerations for each dewatering technology. UPDATE: Site visits were made to Cleveland Southerly and Westerly WWTPs and Cincinnati's Mill Creek WWTP for centrifuge and to Bradenton and St. Petersburg, Florida for screw press installations.

4.5 POLYMER MAKE-UP AND FEED

The dewatering feed is conditioned with polymer prior to introduction into the dewatering equipment. The conditioning process promotes improved floc formation that yields more efficient dewatering. The use of polymer to condition sludge prior to dewatering yields a net cost savings due to better solids capture resulting in less solids recycled back to the liquid stream and decreased moisture in dewatered sludge. For large facilities such as Bissell Point and Lemay WWTFs, polymer consumption can be high resulting a significant annual polymer cost. Consideration of and investment in optimization of the polymer make-up and feed system is typically worthwhile to insure efficient polymer use and control of annual polymer cost.

Polymers are long chain organic molecules that promote flocculation of solid particles in combined solid and liquid streams. Polymer chains can vary in length from a few thousand monomer units to millions of monomer units. Also, these organic molecules can possess either a negative (anionic), positive (cationic), or neutral charge. The traits desired from a polymer are determined by the characteristics of the sludge. Cationic polymers are common for conditioning of municipal wastewater sludges in order to attract negatively charged particles. The long chain of the polymers is utilized to form bridges between individual solid particles. This bridging effect helps particles aggregate and improve the separation of solid particles from the liquid phase in the combined stream. A representation of the bridging effect is shown below in Figure 4-6.

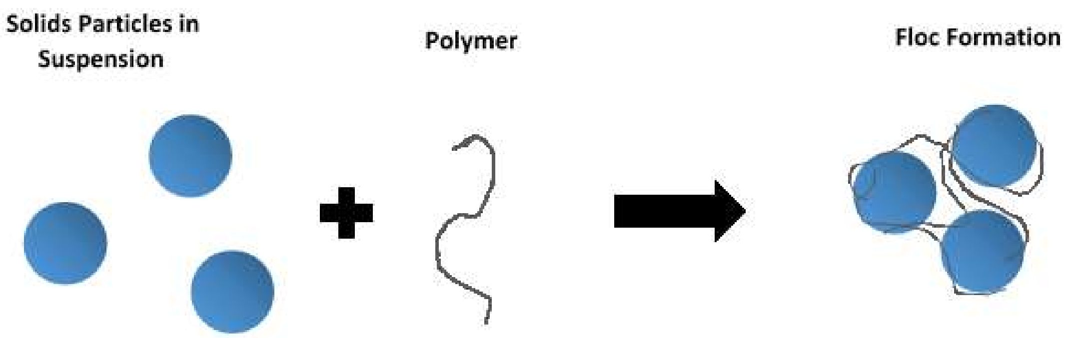


Figure 4-6. Polymer-Sludge Bridging

4.5.1 Polymer Make-up Systems

Polymer make-up systems activate and dilute polymer and prepare the solution for blending with dewatering feed. The advantages and disadvantages of polymer make-up systems for liquid and dry polymer vary in their performance, cost, maintenance requirements, footprint and more. This section will focus on two make-up systems for liquid and dry dewatering polymer. An overview of the pros and cons of these systems is provided in Table 4-16.

Table 4-16. Polymer Make-up System Pros and Cons

LIQUID POLYMER	DRY POLYMER
Pros • Lower system capital cost • Limited handling of polymer required at delivery • Operations staff familiarity based on long-term historical use	**Pros** • Generally lower life-cycle cost for larger systems • Lower cost for dry polymer • Reduced risk of polymer spillage • Smaller mixing and aging tank volume requirement • Longer polymer storage life (1-2 years)
Cons • Higher cost for liquid polymer • Potential price volatility for emulsion polymer since approximately 60% of emulsion polymer is oil • Bulk liquid polymer storage and containment required • Relatively shorter polymer storage life (approximately 3-6 months) • Relatively larger mixing/aging tanks and solution feed pumps are required for emulsion due to volume of oil	**Cons** • Higher system capital cost • Requires unloading of polymer from delivery truck and placement in storage • Potential for dust related house-keeping requirements • Dry polymer is more sensitive to room humidity

4.5.1.1 Liquid Emulsion Polymer

Liquid emulsion polymers are characterized by the suspension of active polymer gels immersed in an oil phase matrix. Normally, polymers of this type possess an active polymer solids concentration of 30 to 60 percent by weight at the time of delivery by the manufacturer. The gel droplets immersed in the oil matrix contain numerous polymer chains tightly wound and dissolved in water. The polymer chain must be unwound to expose the active sites for effective solids separation to occur once mixed with the dewatering feed stream. The unwinding of the polymer chains and subsequent dilution is referred to as activation.

Bulk receiving and storage facilities for liquid emulsion polymer are required. Liquid emulsion polymers are activated through dilution with water to a concentration equal to or less than 1% activity by weight. Concentrated polymer is pumped from its storage location to a polymer activation system. This is typically an equipment package provided by the vendor. The polymer is mixed with a high velocity water jet before introduction into the activation chamber. The polymer is mixed in stages within the activation chamber to produce a diluted/activated polymer. Liquid emulsion polymer solution may be aged in tanks for a short duration before combining with sludge in order to make the most efficient use of polymer. Age tanks allow the polymer chains to further uncoil and also provide equalization for the activation system instead of requiring a completely on-demand system. Due to the increased polymer efficiency provided by liquid emulsion polymer aging, additional tankage for aging can be economically advantageous for liquid emulsion polymer system serving large facilities where a lot of polymer is consumed. The activated polymer solution should be used quickly due to deterioration of the quality of polymer performance within 24 hours after activation.

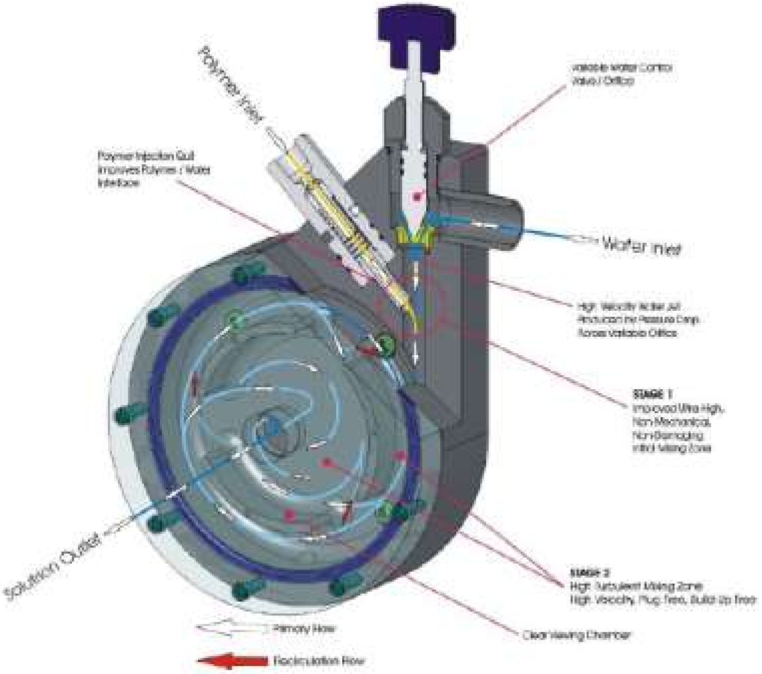


Figure 4-7. Emulsion Polymer Mixing/Activation
Image courtesy of VeloDyne

Figure 4-8. Emulsion Polymer Make-up System
Image courtesy of VeloDyne

4.5.1.2 Liquid Mannich Polymer

Both Bissel Point and Lemay WWTFs have been using liquid mannich polymer for many years. Liquid mannich polymer has proven to be an effective dewatering feed conditioning agent for the blends of raw sludge at these plants. Since this type of polymer is effective for conditioning of dewatering feed at both plants, the plants are able to take advantage of the low dose and cost advantage of liquid mannich polymer.

Liquid mannich polymer is delivered in solution and the polymer solids never separate or settle so no mixing of bulk liquid storage is required to keep the polymer solids in suspension. However, it is important to maintain circulation of the viscous mannich polymer so recirculation pumping should be considered. Storage life may be as short as three months after which the polymer may begin to gel. Some plants prefer to limit storage to several weeks to avoid less efficient utilization of degraded mannich polymer.

Liquid mannich polymer is typically delivered at 4-5% solids concentration by weight and transferred to bulk storage tanks. Mannich polymer is then diluted to a lower concentration to reduce viscosity and mixed in batch tanks. Aging is not necessary for mannich polymer. Newer applications typically use a liquid polymer make-up system for optimal introduction of the highly viscous mannich polymer into the dilution water prior to mixing in a batch tank in order to get the most efficient use of the polymer.

Figure 4-9. Liquid Mannich Polymer Make-up System
Image courtesy of SNF Floquip

Liquid mannich polymer is sometimes not effective as a conditioning agent for sludge fed to centrifuge equipment due to the turbulence encountered by flocculated solids fed into high-speed centrifuges. However, most dewatering equipment manufactures provide bench testing services to support optimal polymer selection. It should also be noted that several plants including the Metropolitan Wastewater Treatment Plant (St. Paul) and Stickney Water Reclamation Plant (Chicago) feed mannich polymer for conditioning of centrifuge feed.

4.5.1.3 Dry Polymer

Dry polymers are delivered to sites in powdered form in quantities as small as 50-pound bags up to 2000 pound bulk bags. For large plants, dry polymer bulk delivery and unloading to a silo can be considered. The dry powder polymer possesses an active concentration greater than 95 percent. This polymer requires dissolution and activation before introduction with the dewatering feed stream.

Dry polymer is diluted with water to a concentration less than or equal to 1% by weight. The polymer is mixed within a tank at low speed. It is crucial to ensure proper mixing of the dry polymer to avoid agglomeration. The polymer is then aged 20 minutes to several hours to ensure optimal activation. Figure 4-9 below displays an example dry polymer feeder system.

Figure 4-10. Dry Polymer Feeder with Bulk Bag Frame
Image courtesy of USGI

4.5.2 Polymer-Sludge Mixing

At this point in the process, the polymer chains should be unwound with the active sites exposed and prepared for introduction to the dewatering feed sludge. Good dispersion of the polymer into the feed sludge stream is essential to achieving effective dewatering. The activated polymer can be mixed with the sludge by two methodologies.

The first method injects activated polymer directly into the sludge feed line upstream of the dewatering equipment. Typically, the polymer dosing system will have a ratio controller to meter the polymer in at an operator-set ratio based upon the sludge feed flow rate. Some form of mixing technology will be installed downstream of the injection point to increase the amount of shear in the stream. This will improve the mixing rate of the sludge and polymer. However, it is important that the shear rate in the combined stream does not get too high. This has the potential to break up the formed flocs and decrease the solid-liquid separation performance.

The second method combines the sludge and polymer solution together in a mixing tank prior to introduction into the feed line for the dewatering equipment. This method may be preferred if the sludge or polymer stream is too viscous to ensure proper inline mixing prior to dewatering. This method may also be used to prevent floc degradation due to high turbulence. The mixing tank can combine the polymer and sludge feeds at low shear rates with higher residence times if the flocs are sensitive to turbulence.

4.5.3 Post-Dilution

Post-dilution of polymer solution is a common practice to limit the size requirements for polymer solution mixing and aging tanks for both liquid and dry polymer. By mixing and aging at slightly higher concentration than the optimal dewatering feed polymer solution concentration, smaller tanks can be provided. This is of particular value for liquid emulsion systems due to the additional tank volume required for the emulsion oil. Post-dilution also provides greater operational flexibility by providing the opportunity to adjust polymer solution concentration as it is fed.

A typical post-dilution assembly will add water at a set rate to the polymer solution feed pump discharge upstream of the dewatering feed mixer. A picture of a typical polymer solution feed and post-dilution assembly is provided in Table 4-10.

Figure 4-11. Polymer Feed and Post-Dilution Assembly
Image courtesy of USGI

4.5.4 Polymer Lifecycle Cost Evaluation

The different polymer alternatives were evaluated using a lifecycle cost evaluation (LCCE). This evaluation utilized centrifuge as the dewatering technology. The LCCE compares the relative cost of each polymer alternative over a 20-year period to provide an economic basis for consideration when selecting a polymer. The loading and characteristics of blended sludge fed to dewatering were input into the evaluation. The assumptions included in the LCCE are based upon manufacturer-supplied information, bench testing results, and experience with similar facilities.

The alternatives analyzed in this evaluation were liquid emulsion polymer and liquid mannich polymer. Due to the District’s long history with liquid polymer and the more limited range of dry polymers available, dry polymer was not evaluated. Initial results from this LCCE indicated a substantial difference in net present value (NPV) between the two alternatives in favor of liquid mannich polymer. Based upon this initial result, the LCCE was concluded without further refinement since no reasonable adjustment of inputs could close the gap in NPV between the two alternatives. The capital costs associated with each alternative was small compared to the annual operating costs. The large difference in NPV was mostly attributed to the difference in assumed polymer dosage and assumed polymer unit cost. Both the dosage and unit cost were greater for the liquid emulsion alternative. Therefore, this led to liquid emulsion polymer having a significantly higher NPV. The assumed polymer dosage and unit cost used for this evaluation can be viewed below.

Table 4-17. Polymer LCCE Assumed Dosages and Purchase Prices

PARAMETER	LIQUID EMULSION	LIQUID MANNICH
Dosage, lb APS/dry ton of solids	20.0	11.0
Unit Cost, $/lb APS	$2.85	$1.90

4.5.5 Polymer Make-up and Feed Recommendations

The following polymer make-up and feed recommendations are provided for consideration.

- Consult with polymer supplier and selected dewatering equipment manufacturers to determine the viability of different polymers (liquid emulsion, liquid mannich, dry) for the selected dewatering technology. Note that if centrifuge is selected and testing demonstrates mannich polymer conditioning to be ineffective for this technology, the LCCE should be adjusted to reflect the cost and dose of the selected polymer. UPDATE: Centrifuge technology has been selected for dewatering and mannich polymer is recommended for polymer conditioning pending confirmation from manufacturer bench-scale testing of viability with centrifuge dewatering.
- Consider designing the polymer make-up and feed system to accommodate alternative types of polymer (i.e. mannich system accommodates liquid emulsion polymer) for flexibility to adapt to future changes in dewatering feed sludge characteristics and market conditions. The capability to accommodate an alternative type of polymer will also enable the District to receive bids for multiple types of polymer and ensure optimal polymer costs.
- Evaluate quality of available dilution water sources (i.e. plant effluent vs potable water) and consider impact on polymer system performance.
- Evaluate measures to increase polymer system efficiency such as automated adjustment of polymer dose based on in-line dewatering feed total solids measurement (i.e. Valmet TS meter). Heating of polymer dilution water can sometimes promote more efficient use of polymer but may not be viable in the absence of a waste energy source such as excess digester gas.
- Consider polymer storage and handling options carefully such as vertical cone bottom tanks for liquid emulsion.

4.6 DEWATERED SLUDGE CONVEYANCE

This section considers the conveyance of dewatered sludge from dewatering equipment to incinerator feed bins. For a more complete discussion regarding conveyance, particularly conveyance from the incinerator feed bins to the incinerator equipment, refer the TM-15: Cake Conveyance Alternatives.

Dewatered sludge will be conveyed from dewatering equipment to an equalization bin prior to feeding to incinerators. Conveyance of dewatered sludge is typically accomplished utilizing either pumping or conveyor equipment. To some extent, selection of conveyance equipment will be layout dependent, but with the design of new dewatering facilities, greater flexibility is provided to select conveyance equipment best suited to District preferences. An overview of the pros and cons of cake pump, screw and belt conveyance systems is provided in Table 4-18.

Table 4-18. Dewatered Sludge Conveyance Pros and Cons

CAKE PUMPS	SCREW CONVEYORS	BELT CONVEYORS
Pros • Have lower odor emissions than open conveyors • Promote layout flexibility potentially resulting in building cost savings • Relatively small footprint	**Pros** • Ability to handle varying dewatered sludge consistencies • Enclosed design minimizes odor considerations and housekeeping • Can be outfitted with multiple inlet and discharge points • Relatively simple operation and maintenance	**Pros** • Ability to handle varying dewatered sludge consistencies • Relatively low capital cost • Relatively low energy requirements • Relatively simple operation and maintenance
Cons • Grit in conveyed sludge may result in accelerated wear; appropriate material selection is required • Discharge pipe length should be limited to avoid high pressures and accelerated wear • Variations in dewatered sludge characteristics can impact pumping conditions; design must include flexibility to adjust • Maintenance requirements may be relatively high • Relatively high power requirement • Relatively high capital cost	**Cons** • Lumpy, fibrous, or sticky materials may cause problems • Fixed trough geometry limits routing flexibility • Grit in conveyed sludge may result in accelerated wear	**Cons** • Sludge carryover may cause belt tracking issues • Requires sidewalls minimize cake spillage • Fixed conveyor frame limits routing flexibility • Odor emissions

4.6.1 Cake Pumps

The District has a long history with cake pumping and no doubt a high level of familiarity with the complexities associated with this method of dewatered sludge conveyance. In spite of the challenges pumping a material whose characteristics may vary and challenge those attempting to design an operate, dewatered sludge pumping remains a common approach to facilitate convenient routing in an enclosed system.

Piston and progressive cavity pumps are most common for this application although progressive cavity pumps are limited to shorter distances than piston pumps. Both types of pumps are available from multiple manufacturers and have a long and proven record of service. Due to the friction created by pumping low-moisture dewatered sludge, effort is typically made during design to minimize cake pump discharge piping length and the corresponding pressures. Layout should consider placement of dewatering equipment in close proximity to the incinerator feed equalization bins in order to limit pipe length. Location of dewatering equipment in a building remote from the incinerator feed equalization bins will require careful attention to cake pump design if cake pumps are selected.

Injection of small amount of water or a polymer solution through an injection ring mounted on the cake pump discharge is a common lubrication method to decrease friction at the pipe-to-sludge boundary and the resulting pressure build-up in the discharge pipe. For this project, the impact of liquid addition to the dewatered sludge on incineration should be considered when evaluating this approach.

Also, changes in direction for the sludge piping should be minimized. The use of long sweep elbows should be considered to minimize pressure build-up in the piping system. High pressure rated pipe, flanges and isolation valves are also typically used.

Normally, dewatered sludge conveyance is anticipated to be continuous. But in the event of dewatering equipment shutdown, a method should be provided to evacuate dewatered sludge from the discharge pipe as part of shutdown procedures.

4.6.2 Screw Conveyors

Municipal wastewater dewatered sludge screw conveyors typically consist of an external trough and a rotating internal screw. Screw conveyors can be shafted or shaftless and can be employed in horizontal, inclined, or vertical installation (vertical installations are less common). Screw conveyors are extremely common for dewatered sludge conveyance service and available from many manufacturers with tightly defined industry standards. Screw conveyors can be provided with sealed covers to contain odors and avoid spilling of dewatered sludge. The conveyor covers can be designed with multiple inlets to allow one conveyor to serve multiple dewatered sludge feed points. Multiple discharge points can also be provided on the conveyor trough and controlled with manual or automated discharge slide gates. It is also possible to construct the conveyor covers with odor control connections if desired.

Due to the motion of the internal screw, moving dewatered sludge long distances may change the sludge consistency. However, given the conveyance discharge into the incinerator feed equalization bins, sludge consistency at discharge will be less of a concern than for other installations.

The primary limitation for screw conveyors is limited layout flexibility due to the fixed geometry of the conveyor trough.

Figure 4-12. Screw Conveyor
Courtesy of Custom Conveyor

4.6.3 Belt Conveyors

A belt conveyor is a common method for dewatered sludge conveyance. The simplicity of belt conveyor construction and operation is appealing as is the reliability of belt conveyors.

Belt conveyors use a belt to transport bulk material and can be fed to one or multiple inlet areas along the length of the belt. Bulk material rides on top of the belt, which can be flat, inclined, cleated, or equipped with a trough. Side walls can be provided to minimize spilling of dewatered sludge and belt scrapers provide cleaning of the belt after discharge. and/or cover, etc.

Belt conveyor directional changes are possible by utilizing a manual or automated belt plow to drive sludge off the belt to a discharge or another conveyor. Washboxes may also be provided for more thorough cleaning of conveyor belts.

The primary limitation for belt conveyors is limited layout flexibility due to the fixed geometry of the conveyor frame. Potential spillage of dewatered sludge and odor emissions are also important considerations.

Figure 4-13. Belt Conveyor
Courtesy of Jim Myers and Sons

Figure 4-14. Belt Conveyor Plow
Courtesy of Jim Myers and Sons

5.0 Odor Control Systems

5.1 ODOR CONTROL NEEDS

Bissell Point WWTF is located within an industrial area and its existing dewatering facility does not have odor control. However, the District has requested that an odor control system be included with the construction of the new solids dewatering facility. Since Bissell Point WWTF is located within an industrial area, odor complaints are not a great concern, and the District has no history of receiving complaints. Therefore, the primary odor control goals for Bissell Point WWTF will be to increase operator safety and comfort and meet regulatory requirements. Fence line odors will be limited to marginally above the threshold of human detection for average emissions, allowing for detectable odors to pass the fence line only during maximum emissions periods.

The Lemay WWTF dewatering facilities currently have odor control, using activated carbon adsorption units operating in parallel. The new dewatering facilities will also include odor control to minimize odor complaint potential in the surrounding residential and commercial neighborhood. The degree of odor control (odor removal efficiency) will be such that average concentrations at the nearest fence line location are below the threshold of human detection under average conditions and odors that are marginally above the threshold of human detection under maximum emissions periods.

Similar dewatering facilities requiring odor control will be constructed at each WWTF. The sources that will require odor control at both WWTFs are the following:

- Blended sludge wells
- Centrifuges
- Incinerator feed bins
- Cake receiving bins
- Scum concentrator
- Cross conveyors
- Cake receiving bay
- Truck loading bay

With the exception of the bays, all sources are expected to have high to very high odors, including elevated concentrations of hydrogen sulfide (H_2S), organic sulfides such as methyl mercaptan and dimethyl sulfide, ammonia, amines, and some odorous volatile organic compounds (VOCs). Because of the expected high odor emissions and because of the Lemay WWTF strict odor control requirements, two-stage odor control systems are considered for both odor removal effectiveness and air treatment redundancy in cases where one stage must be taken offline.

5.2 ODOR SAMPLING AND ANALYSIS

In order to inform production of design criteria, odor sampling was completed at both the Bissell Point and Lemay WWTFs in September 2020. The sampling plan detailing the types of samples that were collected and documentation of the sampling results are presented in Attachment E and F, respectively.

A summary of the resulting sampling measurements is presented in Table 5-1. The H_2S concentrations were collected from continuous monitoring using an Acrulog data logger. Measurements were collected continuously for 3 to 5 days at each sampling location. Concentrations ranged from high – generally above 10 parts per million by volume (ppmv) – to very high (generally above 100 ppmv).

Bag samples were also collected at each sampling location and tested for total odor characteristics by an odor panel (St. Croix Sensory). The results shown in the table are presented in units of dilutions-to-threshold (D/T), where the value represents the number of times the sample must be diluted with carbon-filtered “odorless” air to render the air barely detectable by the average human nose. Therefore, the Lemay WWTF blended sludge well odor measurement of 470,000 D/T indicates the odor panel found that the sample would need to be diluted 470,000 times for the odor in the sample to be barely detectable. All listed odor units in the table are very high, including the Lemay WWTF belt filter press odor, which exceeded the maximum measurable D/T by the laboratory.

Table 5.1. Odor Sampling Results Summary

WWTF and Sampling Location		H_2S Concentration (ppmv)		Odor Units (D/T)
		Average	Peak	
Lemay WWTF	Blended sludge well	336	539	470,000
	Belt filter press	25	84	> 600,000
	Cake receiving bin	78	272	39,000
Bissell Point WWTF	Blended sludge well	550	992	140,000
	Belt filter press	41	256	110,000
	Cake receiving bin	4.5	25	39,000
	Scum concentrator	-	-	12,000

Additionally, the sampling program included bag sample collection and laboratory analysis of reduced sulfur compounds (RSCs) using ASTM D5504, which includes quantification of concentrations of 19 organic sulfides and H_2S. Based on previous studies, organic sulfides are known to contribute to the odor emissions footprint for dewatering facilities. Table 5-2 depicts the sampling locations where high concentrations of organic sulfides were detected. Note that the threshold of human detection for methyl mercaptan and dimethyl sulfide are both on the order of 0.001 ppmv or 1 part per billion by volume (ppbv). The highest RSC concentrations measured, which are noted in the table, were methyl mercaptan and dimethyl sulfide. These are commonly found in wastewater treatment facility air emissions; both are odorous.

Table 5.2. Organic Sulfide Laboratory Analysis Results

WWTF Facility	Sampling Location	Organic Sulfide Concentration (ppmv)	
		Methyl Mercaptan [b]	Dimethyl Sulfide [c]
Bissell Point	Blended sludge well	17.0	2.2
Bissell Point	Belt filter press	2.1	0.48
Bissell Point	Cake receiving bin	3.1	0.18
Lemay	Blended sludge well	3.2	0.10
Lemay	Cake receiving bin	12.0	0.71

The main conclusions from the sampling program and analysis were the following:

- H_2S emission concentrations in dewatering processes at both WWTFs were high, with peak values in concentrated headspace areas in some cases at dangerous levels.
- Odor emissions (H_2S, odor units, and organic sulfides) generally were higher at Lemay WWTF than essentially identical process units at Bissell WWTF. Given that the Lemay WWTF is surrounded by residential and commercial properties, compared to the industrial setting at Bissell Point WWTF, this makes odor control at Lemay WWTF critical. However, odor emissions are high enough at both WWTFs to require odor control to prevent offsite impacts.
- Belt filter press (BFP) H_2S, odor units, and organic sulfide sampling measurements were high and consistent with observed odors in the BFP room. The Acrulog was installed just above the cake on the BFP conveyor, which provided a good indication of H_2S potential for the cake itself, as shown in Figure 5-1. Air samples were collected from the same location. Results were directly applied to projected emissions for centrifuges odor emissions in design criteria development.
- The existing activated carbon adsorption odor control efficiency was also tested by collecting air samples from one adsorber's inlet and outlet air. The inlet odor panel measured value was 14,000 D/T and the outlet was 2,600 D/T, a removal efficiency of 81%. This is reasonable odor removal for relatively old carbon adsorbers, indicating that new carbon adsorbers are a reasonable choice of odor control technologies for foul air treatment in these applications.

The high concentrations of H_2S, odor, and organic sulfides indicate a need for odor control at both WWTFs. Additional discussion of the odor testing results and conclusions from the sampling program are provided in Attachment F.

Figure 5-1. Belt Filter Press Acrulog H_2S Monitoring
Lemay WWTF Odor Sampling

5.3 DESIGN CRITERIA DEVELOPMENT

Based on results from the odor sampling task, preliminary odor control design criteria were developed for the new facilities at both WWTFs. The critical design parameters that impact decisions as to the type of odor control technologies designed and constructed are based on calculation of airflow rates and odor loading to future odor control systems.

5.3.1 Airflow Rate Design Criteria

Volumetric airflow rates were calculated to place odorous equipment, enclosures, or rooms under negative pressure at all times. Additionally, ventilation of some odor sources with a highly concentrated odor headspace is considered from an air changes perspective, both to reduce H2S concentration within the space and to provide some degree of dilution of the air stream prior to treatment. Dilution would be a strategic approach to attempt at providing a low enough odor control outlet concentration to keep odor impacts within the WWTF fence lines. For all airflow calculations, conservatively selected odor concentrations and/or safety factors were applied to better assure that selected odor control technologies are viable of offsite impacts elimination or minimization under peak odor loading.

A description of the two airflow rate calculation methods that were evaluated for each odor source, as appropriate, are as follows:

Maintaining a constant negative pressure: The goal of this method is to set the airflow rate equal to what is needed to continuously produce a negative pressure below a cover or within an enclosure. The loading bay odor sources are not evaluated for maintenance of negative pressure because worker comfort and potential safety needs are based on the air change rate method and providing only a slight negative pressure may not provide these conditions. For this analysis, a negative pressure is defined as providing at least -0.1 inches of water column (in w.c.) to the enclosed space. Pilot testing conducted by BC at other wastewater treatment facilities indicated that an airflow rate of 0.5 to 1.0 cfm per square foot of cover area is generally needed to provide sufficient negative pressure on an enclosed space such as the ones evaluated for these WWTF dewatering facilities. Higher values in this range correspond to loose-fitting covers and lower values correspond to tighter fitting covers.

Additionally, some equipment manufacturers recommend minimum airflow rates for creating a negative pressure on their equipment. For example, the centrifuge airflow rates used for this analysis assume an extraction airflow rate of 400 cubic feet per minute (cfm) to be applied to the centrate and cake chutes below the centrifuge. This airflow rate was selected following communication with potential centrifuge suppliers. The need for an additional foul air connection on the centrifuge cover will be considered during the design phase, however, this would not alter the overall airflow extracted from the centrifuge.

Supplying a minimum number of air changes in the enclosed space: This method corresponds to providing a foul air exhaust rate that corresponds to a given number of air changes per hour (ACH) for the headspace. General guidance in historical odor control applications, including in the Water Environment Federation (WEF) Manual of Practice (MOP) Number 25, have indicated that 4 to 6 ACH is appropriate for good evacuation of headspaces beneath covers for minimizing dead spaces and corrosion. In occupied spaces such as rooms or cake receiving bays, the supply airflow rate governs the air change calculation; 12 to 20 ACH is commonly used in the wastewater industry, with higher values used for more odorous spaces or rooms that are frequently inhabited.

Additionally, air change requirements for inhabited spaces may be dictated by the National Fire Protection Association (NFPA) 820 guidance; this analysis assumes that providing a supply airflow rate of 12 ACH is required for the cake receiving and truck loading bays to accommodate NFPA 820. The 12 ACH has been applied in similar BC projects for these types of spaces.

Design foul airflow rates for sources to be sent to the new odor control systems is provided in Tables 5-3 and 5-4 for Bissell Point WWTF and Lemay WWTF, respectively. The sources to be treated by the new odor control systems were provided by Black and Veatch in previous reports. The air change method was used for several sources that include covers with the headspace ventilated to odor control because of the high odor concentrations in the headspace measured in the odor sampling. Using the air change method provides better confidence in reducing corrosion for sources with high H_2S concentrations and will produce a desired dilution effect by reducing odor control inlet concentrations, which accordingly will reduce odor control system outlet concentrations and offsite odor impacts.

Table 5-3. Design Airflow Rates - Bissell Point WWTF

Odor Source	Airflow Rate Calculation Method	Design Airflow per Unit (cfm)	# of Units to be Installed	Total Airflow to New Odor Control (cfm)
Blended sludge wells	6 ACH	650	2	1,300
Centrifuges	Manufacturer recommendation	400	8	3,200
Cross Conveyors	Negative Pressure	50	2	100
Incinerator feed bins	6 ACH	200	4	800
Cake Receiving Bin	6 ACH	200	1	200
Scum Concentrator	Negative Pressure	125	2	250
Cake Receiving Bay	12 ACH	8,000	1	8,000
Truck Loading Bay	12 ACH	8,000	1	8,000
Total airflow rate to odor control =				21,850

Table 5-4. Design Airflow Rates - Lemay WWTF

Odor Source	Airflow Rate Calculation Method	Design Airflow per Unit (cfm)	# of Units to be Installed	Total Airflow to New Odor Control (cfm)
Blended sludge wells	6 ACH	650	2	1,300
Centrifuges	Manufacturer recommendation	400	6	2,400
Cross Conveyors	Negative Pressure	50	2	100
Incinerator feed bins	6 ACH	200	3	600
Cake Receiving Bin	6 ACH	200	1	200
Scum Concentrator	Negative Pressure	125	2	250
Cake Receiving Bay	12 ACH	8,000	1	8,000
Truck Loading Bay	12 ACH	8,000	1	8,000
Total airflow rate to odor control =				20,850

Note that a potential additional odor source – centrate wet wells, which could be constructed at either Lemay or Bissell Point WWTF, or both – are not included in these tables. This is because these are not expected to be necessary unless a process sump is determined to be needed during the design phase. The odor control design will be adjusted to accommodate this additional source, but this is not anticipated to change the results of this evaluation. The design analysis resulted in a recommendation of 6 ACH applied to each well, producing a design foul air extraction rate of 250 cfm total for each WWTF for this source.

5.3.2 Odor Loading Design Criteria

Logged H_2S concentrations and odor panel results from the sampling task were utilized to calculate the expected odor loadings to the new odor control systems. These loadings inform the types of odor control technologies that were considered, and the removal efficiency required to meet offsite impact minimization needs in an effort to keep the number of complaints low. The sampling H_2S and odor data were converted into future loading parameters by applying the following adjustments:

- High-speed centrifugation has been shown in similar applications and research by the Water Environment Research Foundation (WERF) to volatilize higher concentrations of odor constituents than a BFP does with the same feedstock sludge. Therefore, the odor data associated with the centrifuges and downstream process containing dewatered cake were increased by 25%.
- Odor constituents measured in the headspace above the BFP solids were decreased by a factor of 6 to correspond to providing approximately 6 ACH to the centrifuges as a result of extracting 400 cfm from each.
- Measured odor constituents for the headspace above the cake receiving bins, incinerator feed bins, and scum concentrators were decreased by factors 6.6 and 14.3 to correspond to the number of air changes supplied to the spaces given the new design airflow rates.
- Measured odor constituents for the cross conveyors were decreased by a factor of 6 to correspond to providing approximately 6 ACH for that source headspace.

The Bissell Point WWTF and Lemay WWTF odor load H2S concentrations and odor units values are shown in Tables 5-5 and 5-6, respectively.

Table 5-5. Design Source Odor Loadings - Bissell Point WWTF

Odor Source	Design H2S Concentrations (ppmv)		Design Odor Units (D/T)	
	Average	Peak	Average	Peak
Blended sludge wells	89	160	22,600	43,200
Centrifuges	9	53	23,000	46,000
Incinerator feed bins	0.7	3.8	5,900	11,800
Cake receiving bin	0.4	2.5	3,800	7,600
Scum concentrator	1.4	4.2	800	1,600
Cross conveyors	0.8	4.2	6,500	13,000
Cake receiving bay	< 0.1	1	50	1,000
Truck loading bay	< 0.1	1	50	1,000

Table 5-6. Design Source Odor Loadings - Lemay WWTF

Odor Source	Design H2S Concentrations (ppmv)		Design Odor Units (D/T)	
	Average	Peak	Average	Peak
Blended sludge wells	229	332	289,200	578,400
Centrifuges	7	18	156,300	312,600
Incinerator feed bins	12	41	57,300	114,600
Cake receiving bin	8	27	37,300	74,600
Scum concentrator	1.4	4.2	800	1,600
Cross conveyors	13	45	63,300	126,600
Cake receiving bay	< 0.1	1	50	1,000
Truck loading bay	< 0.1	1	50	1,000

The cake receiving bay and truck loading bay are projected to be large airflow (8,000 cfm each) and low odor concentration sources whose foul air will be sent to the new odor control systems. Both bays are expected to be rarely used, and therefore will have minimal to no odors most of the time. Accordingly, the average odor applied to these sources is 50 D/T, which is slightly above background as designated in research compiled by St. Croix sensory on background odor sources.

Because of the low odors anticipated in the bay sources, the 16,000-cfm total airflow rate can be used as a means to dilute the more concentrated air from other sources prior to treatment in the odor control system. Alternatively, it may be more efficient to treat the bay sources separately and send the concentrated foul air from the remaining sources in a smaller odor control system. In this instance, it may be acceptable to control fence line odor emissions from the bay sources separately by dispersing the collected foul air (8,000 cfm each) into the ambient air using high-velocity fans, which promote increased vertical dispersion and reduced offsite odor impacts. A photograph of high-velocity fans installed to disperse foul air from a primary treatment building is shown in Figure 5-2.

Figure 5-2. High-Velocity Exhaust Fans

Used for dispersing low-concentration room air

Design odor loadings were calculated for both odor control strategies (with and without foul air from the bays included in the odor control inlet air stream). Design loadings for each strategy and for each WWTF are presented in Table 5-7 and 5-8, respectively. Note that these are preliminary odor loading calculations and adjustments may be made during the 15% design stage as processes are refined.

Table 5-7. Bissell Point WWTF - Design Odor Loadings

Odor Control Strategy	Design Airflow Rate (cfm)	Odor Loading Parameter			
		Average H_2S (ppmv)	Peak H_2S (ppmv)	Average Odor (D/T)	Peak Odor (D/T)
Diluted air stream: including cake receiving and truck loading bays	22,000	8	20	5,000	10,000
Concentrated air stream: not including cake receiving and truck loading bays	6,000	25	70	19,000	38,000

Table 5-8. Lemay WWTF - Design Odor Loadings

Odor Control Strategy	Design Airflow Rate (cfm)	Odor Loading Parameter			
		Average H_2S (ppmv)	Peak H_2S (ppmv)	Average Odor (D/T)	Peak Odor (D/T)
Diluted air stream: including cake receiving and truck loading bays	21,000	15	25	40,000	80,000
Concentrated air stream: not including cake receiving and truck loading bays	5,000	70	100	160,000	320,000

5.4 ODOR CONTROL ALTERNATIVES DEVELOPMENT

A stand-alone, new odor control facility is required for detailed design of the new dewatering facilities at both Bissell Point WWTF and Lemay WWTF. This section provides details on how odor control alternatives were developed for comparison and recommendations. Because the types of process units are identical and the airflow rates and odor loadings are similar, the same treatment alternatives have been conceived for both WWTFs.

5.4.1 Eliminated Odor Control Technologies

Based on the design loadings, the new odor control systems will need to be able to remove high levels of H_2S, ammonia, nitrogen-containing compounds, and organic sulfides. The following odor control technologies have been eliminated from further consideration:

- **Organic media biofilter:** bulk media biofilters treat odorous compounds by a combination of sorption, biological degradation, and chemical oxidation. Contaminants in the foul air stream are either adsorbed onto the surface of the biofilter media or absorbed by the thin liquid surrounding the media particles, referred to as the biofilm. Organic media biofilters occupy large footprints due to requiring contact times of at least 60 seconds (necessitating greater media volumes) and because media depths are usually limited to 4 to 5 ft. Organic media biofilters also compact relatively quickly; within 2 to 3 years the media must be replaced, with greater frequency occurring due to higher H_2S loads. Therefore, because of expected footprint constraints, capital cost, and regularly media replacement requirements, the organic media biofilters are not preferred and were eliminated from further consideration. Engineered media biofilters are viable technology; these are discussed further in Section 5.4.2.
- **Ionization:** this technology includes reacting a foul air stream with either hydroxl ion radicals or ozone to eliminate odorous compounds. Ionization is relatively new in the wastewater industry, particularly in North America, and has had a varying history of effectiveness. This is particularly the case for high-H_2S applications. There is not a sufficient number of successful applications of ionization treating similar airflows for the technology to be considered.
- **Chemical addition:** chemicals are rarely used in solids handling facilities specifically for odor control of processes in dewatering facilities such as the ones included in this design upgrade. Chemicals (commonly oxidizers such as potassium permanganate) are not typically injected into sludge for odor control due to high costs, limited effectiveness, and/or consistency of odor emissions reduction. Iron addition upstream of dewatering, particularly centrifuges, has been shown to provide some odor reduction in research associated with WERF and in academic studies. However, iron addition alone is unlikely to sufficiently reduce the air stream odorous compounds to preclude the need for vapor-phase treatment to meet fence line odor goals.

5.4.2 Viable Odor Control Technologies

Based on industry experience and successful track-records of odor control for dewatering facilities, the following technologies were considered in this evaluation:

Carbon adsorber: Utilizes dry media (activated carbon and/or potentially infused media) for sorption of odorous compounds and VOCs onto pore sites. Some manufacturers provide different carbon and dry media products that target specific compounds, such as ammonia. The dry media adsorption technology is limited in that the media can be quickly depleted of its sorptive capacity with ongoing high pollutant loads, in particular those that contain high H_2S concentrations. Because of the H_2S concentrations observed at both Bissell and Lemay WWTF, a single-stage carbon adsorption system is not recommended for these applications. This supports the need to upgrade the existing single-stage carbon odor control units at Lemay WWTF.

Engineered media biofilter: Biofilters are a good technology for removal of H_2S and organic sulfides, both of which are present at significant concentrations at the Lemay and Bissell Point dewatering facilities. Additionally, because the foul air is expected to contain elevated ammonia concentrations, a biofilter is an effective technology because ammonia is highly water soluble and readily removed in pre-humidification chambers prior to the foul air entering the media bed. An engineered media biofilter is pictured in Figure 5-3.

Figure 5-3. Engineered Media Biofilter

While organic media biofilters were determined to be too large and requiring excessive operation and maintenance (O&M), engineered media biofilter offer the following advantages: (1) the media is “long-life” and will be guaranteed against compaction for 10 to 20 years, depending on the manufacturer, (2) coatings added to the media surface or infused in the rock provide accelerated biomass growth and pH balancing, which improves overall odor removal efficiency, and (3) the required contact time is lower than what is needed for organic media (typically on the order of 45 seconds).

Biotrickling filter (BTF): this technology is most often used for targeted H_2S reduction and treatment of some lower-molecular weight organic sulfides such as methyl mercaptan. BTFs require a lower contact time than biofilters (typically on the order of 10 to 15 seconds), which often results in more limited removal of non-H_2S compounds. Because of this and given the expected odor loadings for this application, it is assumed that BTFs must be connected in series with a second stage carbon adsorber to meet reasonable fence line odor limits. A picture of two biotrickling filters is shown in Figure 5-4.

Figure 5-4. Biotrickling Filters

Chemical scrubber: Chemical scrubbers are best utilized targeting individual compounds or specific groups of compounds (for example, H_2S and other acidic compounds are treated by alkaline scrubbers using hypochlorite and caustic solutions and acidic scrubbers will target ammonia removal). In this application, a 3-stage chemical scrubber is recommended for removal of ammonia, H_2S, and organic sulfides. Chemical scrubbers are typically poor at VOC removal, which could be problematic as some VOCs may contribute to the overall odor load. Chemical scrubbers also have significant O&M costs associated with labor and chemical use.

Alternatives were developed from these technologies considering single- and two-stage orientations. Two-stage odor control systems are preferred due to the need to treat high odor concentrations and because of their flexibility in that foul air can be bypassed around either stage when maintenance is required on that stage (such as media replacement.

5.4.1 Evaluated Odor Control Alternatives

Based on airflow and odor loading calculations and the odor control technology analysis discussed in Section 5.4.2, the following odor control alternatives were developed (these alternatives are applied both to Bissell Point and Lemay WWTF dewatering odor control needs):

- Alternative 1: Two-stage BTF/carbon treating a dilute air stream
- Alternative 2: Two-stage biofilter/carbon treating a dilute air stream
- Alternative 3: Two-stage BTF/carbon treating a concentrated air stream (foul air extracted from bay sources dispersed into ambient air using a high-velocity fan)
- Alternative 4: Two-stage biofilter/carbon treating a concentrated air stream (foul air extracted from bay sources dispersed into ambient air using a high-velocity fan)
- Alternative 5: Three-stage chemical scrubber treating a dilute air stream

The discussion of the airflow rates and strategies associated with selecting either the dilute air stream or concentrated air stream for odor control is provided in Section 5.3.2.

5.5 ODOR CONTROL ALTERNATIVES EVALUATION

The 5 alternatives presented in Section 5.4.3 were evaluated for calculated fence line odor impacts and life-cycle cost. This section provides the results of the analysis.

5.5.1 Odor Treatment Efficiency and Impact Calculations

The following estimated H_2S and odor removal efficiencies were applied to the technologies that were included in the five alternatives evaluated:

- Chemical scrubber acid stage removes 25% of the odor by eliminating all ammonia
- Each chemical scrubber alkaline stage removes 90% of H_2S and 75% of organic sulfides
- Biotrickling filters remove 90% of H_2S and 50% of inlet odor units
- Biofilters remove 90% of H_2S and 90% of inlet odor units
- Activated carbon/dry media adsorbers remove 90% of H_2S and 90% of inlet odor units

Using these removal efficiencies, the resulting concentrations of H_2S and odor for the Bissell Point and Lemay WWTF odor control alternatives are as shown in Tables 5-9 through 5-13. The fence line H_2S and odor entries in the tables are reflective of modeled dilution associated with treated air dispersion from the points of emission to the fence line. The dilution ratio for the Bissell Point WWTF is estimated at 150:1, based on the distance from the currently located dewatering facilities to the closest fence line location. This assumes treated air stack emissions at a velocity of 2,000 ft/min. A similar dilution ratio was calculated for Lemay WWTF; a dilution ratio of 588:1 is applied for dewatering facility emissions, which is a larger ratio due to the greater distance from the emission point to the fence line.

Table 5-9. Alternative 1 Treatment Efficiencies – BTF/Carbon (Dilute Air Stream)

Odor Control System Location	H_2S Concentration (ppmv)		Odor Units	
	Average	Peak	Average	Peak
Bissell Point WWTF				
Inlet	8	20	5,000	10,000
Stage 1 outlet	0.8	2	2,500	5,000
Stage 2 outlet	0.008	0.02	250	500
Fence line	5.3×10^{-5}	1.3×10^{-4}	1.7	3.3
Human detection threshold	5.0×10^{-4}	5.0×10^{-4}	1.0	1.0
Lemay WWTF				
Inlet	15	25	40,000	80,000
Stage 1 outlet	1.5	2.5	20,000	40,000

Odor Control System Location	H_2S Concentration (ppmv)		Odor Units	
	Average	Peak	Average	Peak
Stage 2 outlet	0.015	0.025	2,000	4,000
Fence line	2.6 x 10^{-5}	4.3 x 10^{-5}	3.4	6.8
Human detection threshold	5.0 x 10^{-4}	5.0 x 10^{-4}	1.0	1.0

Table 5-10. Alternative 2 Treatment Efficiencies – Biofilter/Carbon (Dilute Air Stream)

Odor Control System Location	H_2S Concentration (ppmv)		Odor Units	
	Average	Peak	Average	Peak
Bissell Point WWTF				
Inlet	8	20	5,000	10,000
Stage 1 outlet	0.8	2	500	1,000
Stage 2 outlet	0.008	0.02	50	100
Fence line	5.3 x 10^{-5}	1.3 x 10^{-4}	0.3	0.7
Human detection threshold	5.0 x 10^{-4}	5.0 x 10^{-4}	1.0	1.0
Lemay WWTF				
Inlet	15	25	40,000	80,000
Stage 1 outlet	1.5	2.5	4,000	8,000
Stage 2 outlet	0.015	0.025	400	800
Fence line	2.6 x 10^{-5}	4.3 x 10^{-5}	0.7	1.4
Human detection threshold	5.0 x 10^{-4}	5.0 x 10^{-4}	1.0	1.0

Table 5-11. Alternative 3 Treatment Efficiencies – BTF/Carbon (Concentrated Air Stream)

Odor Control System Location	H_2S Concentration (ppmv)		Odor Units	
	Average	Peak	Average	Peak
Bissell Point WWTF				
Inlet	25	70	19,000	38,000
Stage 1 outlet	2.5	7	9,500	19,000
Stage 2 outlet	0.025	0.07	950	1,900
Fence line	5.3 x 10^{-5}	1.3 x 10^{-4}	6.3	12.7
Human detection threshold	5.0 x 10^{-4}	5.0 x 10^{-4}	1.0	1.0
Lemay WWTF				
Inlet	70	100	160,000	320,000
Stage 1 outlet	7	10	80,000	160,000
Stage 2 outlet	0.07	0.1	8,000	16,000
Fence line	2.6 x 10^{-5}	4.3 x 10^{-5}	13.6	27.2
Human detection threshold	5.0 x 10^{-4}	5.0 x 10^{-4}	1.0	1.0

Table 5-12. Alternative 4 Treatment Efficiencies – Biofilter/Carbon (Concentrated Air Stream)

Odor Control System Location	H_2S Concentration (ppmv)		Odor Units	
	Average	Peak	Average	Peak
Bissell Point WWTF				
Inlet	25	70	19,000	38,000
Stage 1 outlet	2.5	7	1,900	3,800
Stage 2 outlet	0.025	0.07	190	380
Fence line	1.7×10^{-4}	4.7×10^{-4}	1.3	2.5
Human detection threshold	5.0×10^{-4}	5.0×10^{-4}	1.0	1.0
Lemay WWTF				
Inlet	70	100	160,000	320,000
Stage 1 outlet	7	10	16,000	32,000
Stage 2 outlet	0.07	0.1	1,600	3,200
Fence line	2.6×10^{-5}	4.3×10^{-5}	2.7	5.4
Human detection threshold	5.0×10^{-4}	5.0×10^{-4}	1.0	1.0

Table 5-13. Alternative 5 Treatment Efficiencies – 3-Stage Chemical Scrubber (Dilute Air Stream)

Odor Control System Location	H_2S Concentration (ppmv)		Odor Units	
	Average	Peak	Average	Peak
Bissell Point WWTF				
Inlet	8	20	5,000	10,000
Stage 1 outlet	8	20	3,750	7,500
Stage 2 outlet	0.08	0.2	2,900	5,800
Stage 3 outlet	0.008	0.02	900	1,700
Fence line	5.3×10^{-5}	1.3×10^{-4}	5.8	11.6
Human detection threshold	5.0×10^{-4}	5.0×10^{-4}	1.0	1.0
Lemay WWTF				
Inlet	15	25	40,000	80,000
Stage 1 outlet	15	25	30,000	60,000
Stage 2 outlet	0.15	0.25	23,300	46,500
Stage 3 outlet	0.015	0.025	7,000	14,000
Fence line	2.6×10^{-5}	4.3×10^{-5}	11.9	23.7
Human detection threshold	5.0×10^{-4}	5.0×10^{-4}	1.0	1.0

Fence line odor units shown in red in the tables exceed the threshold of human detection of 1.0 indicate alternatives that may not be providing sufficient odor control. Odor removal efficiency calculations for Alternative 3 (2-stage BTF/carbon treatment of a concentrated air stream) and Alternative 5 (chemical scrubbing of a dilute air stream) produce average fence line odor impacts that are significantly higher than 1.0 odor units, which is defined as the threshold of human detection.

Additionally, the Lemay WWTF calculated fence line average odor for Alternative 4 (2-stage biofilter/carbon treatment of a concentrated air stream) is also undesirable given the potential for odor complaints from residents and commercial businesses near the WWTF. Given this assessment, these odor control alternatives were eliminated from further evaluation.

5.5.2 Life-Cycle Cost Alternatives Assessment

Present worth costs for acceptable odor control alternatives (3 at Bissell Point WWTF and 2 at Lemay WWTF) were calculated to compare the alternatives on a life-cycle cost basis. Capital costs were estimated by calculating (1) equipment costs based on a cost per cfm of air treated and (2) installation costs assuming 50% of the equipment cost. Other capital cost components such as engineering, mobilization, structural components, and foul air ducting are not included in the calculation for simplicity. Because of this, the capital costs calculated as part of this odor control evaluation should not be used for planning purposes.

Annual O&M costs include estimates of costs for power (foul air fans), water (for biofilters), media replacement (for carbon adsorbers), and labor. Utility rates for power and water were assumed based on current average rates for the state of Missouri. Labor rates are burdened and are generally reflective of average rates for wastewater treatment plant operators in the United States.

For the purposes of comparison, a discount rate of 4% was incorporated into engineering economic present worth calculations and a life-cycle period of 20 years (a typical life expectancy for odor control treatment systems) was selected. Tables 5-14 and 5-15 present the life-cycle cost comparisons for the Bissell Point and Lemay WWTFs, respectively. For the Bissell Point WWTF Alternative 4 life-cycle cost assessment, it was assumed that the 16,000 cfm of air exhausted from the bays would be treated in two activated carbon adsorbers (single-stage odor control). This was a conservative assumption, given that the bays are projected to be unused the majority of the time, but it was deemed appropriate given the unknown nature of the actual frequency of use and the odor characteristics of the future facilities.

Table 5-14. Life-Cycle Cost Comparison - Bissell Point WWTF

Odor Control Alternative	Capital Cost	Annual O&M Cost	Present Worth
Alternative 1: BTF/carbon 2-stage treatment (diluted air stream)	$2,600,000	$96,000	$3,900,000
Alternative 2: biofilter/carbon 2-stage treatment (diluted air stream)	$3,100,000	$90,000	$4,300,000
Alternative 4: biofilter/carbon 2-stage treatment (concentrated air stream)	$1,500,000	$69,000	$2,400,000

Table 5-15. Life-Cycle Cost Comparison - Lemay WWTF

Odor Control Alternative	Capital Cost	Annual O&M Cost	Present Worth
Alternative 1: BTF/carbon 2-stage treatment (diluted air stream)	$2,500,000	$92,000	$3,800,000
Alternative 2: biofilter/carbon 2-stage treatment (diluted air stream)	$3,000,000	$86,000	$4,200,000

5.6 ODOR CONTROL SYSTEM RECOMMENDATIONS

The following sections provide the odor control system recommendations for the two WWTFs, which are based on the life-cycle cost analysis and the predictions of fence line odor impacts for the various acceptable odor control system alternatives.

5.6.1 Bissell Point WWTF

For the Bissell Point WWTF, the present worth cost of Alternative 4 is the lowest. This alternative assumes a split treatment strategy of conveying the concentrated odorous air to a 2-stage odor control system (biofilter/carbon) while treating foul air from the future cake receiving and truck loading bays separately in single-stage carbon adsorbers. Doing this is forecast to be less than half the capital cost investment of Alternative 2, where the full airflow is treated in a single 2-stage odor control system. This significant cost discrepancy must be considered with the predicted odor offsite impacts that would result from construction of the two alternatives:

- For Alternative 2 (all air conveyed to a biofilter/carbon odor control system), predicted fence line odors are 0.3 D/T under average emissions and 0.7 D/T under peak conditions. Both conditions indicate that detectable odors are not present at the fence line.
- For Alternative 4 (a lower, concentrated air stream is conveyed to a biofilter/carbon odor control system while bay odors are treated separately), predicted fence line odors are 1.3 D/T under average emissions and 2.5 D/T under peak conditions. Both conditions indicate that there will be detectable odors at the fence line, but under average conditions, the odor impacts are slight and just above the threshold of human detection.

Because the Bissell Point WWTF is in an industrial area, the lower cost (capital and life cycle) of Alternative 4 is preferred because the risk of complaints is relatively low. Therefore, BC recommends conveying foul air from all dewatering sources except for the cake receiving and truck loading bay to a two-stage odor control system consisting of a biofilter followed by a carbon adsorber. For planning purposes, foul air is assumed to be captured from the two bays and conveyed to a high-velocity dispersion fan. If it is determined in the future that treatment is needed for those sources, the foul air will be conveyed to a single stage activated carbon adsorber.

5.6.2 Lemay WWTF

For the Lemay WWTF, the present worth cost for Alternative 2 (biofilter/carbon two-stage odor control system) is approximately 10% higher than the Alternative 1 (BTF/carbon two-stage odor control) present worth. However, given the reduction in offsite odor impacts provided by Alternative 2 (fence line odors of 0.7 and 1.4 D/T for average and maximum conditions, respectively) compared to Alternative 1 (fence line odors of 3.4 and 6.8 D/T for average and maximum conditions, respectively), Alternative 2 becomes more desirable than Alternative 1 because of the importance of odor control at Lemay WWTF given the surrounding residential and commercial community. Therefore, the recommended odor control approach for Lemay WWTF dewatering facilities is to combine all foul air and treat the air in a 2-stage biofilter and activated carbon adsorption odor control system.

6.0 Regulatory and Code Considerations

All applicable codes impacting design disciplines will be considered and accounted for in the design. Below are some specific regulatory and code considerations for the dewatering facilities.

- Design for the new dewatering facilities should comply with the requirements of NFPA 820 – Standard for Fire Protection in Wastewater Treatment and Collection Facilities (2020 edition). Areas subject to potentially hazardous conditions will be identified early in the design process for consideration with layout and ventilation systems.
- A building code review will be completed for the new dewatering facilities during preliminary design.
- Local regulatory and air permit requirements related to air/odor emissions will be reviewed during preliminary design.

7.0 General Recommendations and Outstanding Issues

- Review recommendations provided in individual sections of this TM.
- Identify any future treatment process changes that may significantly impact solids production or characteristics for consideration during preliminary design.
- Installation of fine screens at Bissell Point WWTF will protect dewatering equipment and reduce the potential for clogging of pumps, piping or dewatering equipment due to rags and other debris. Also, installation of screening at the Bissell Point FOG receiving station should be considered to provide similar protection.
- Finalize Lower Meramec Phase II Expansion design solids production to be transferred to Lemay from Lower Meramec.
- Consideration should be given to management of un-thickened Lower Meramec transfer sludge at Lemay WWTF. Thickening of this sludge stream is important to avoid a reduction in the dewatering feed solids concentration. Adequate mixing with Lemay sludge to insure a homogenous dewatering feed is also important.
- The capability of the existing facilities upstream of the new dewatering facility for attenuation of design solids production above the capacity of the dewatering system should be confirmed in order to finalize design dewatering system loading requirements.Selection of dewatering technology (centrifuge, screw press or belt filter press); UPDATE: MSD has selected centrifuge for dewatering technology.
- Selection of polymer make-up and feed system (liquid emulsion, liquid mannich or dry)
- Selection of dewatered sludge conveyance equipment (cake pump, screw conveyor or belt conveyor)
- Selection of odor control technology based on odor sampling and analysis.

Limitations

This is a draft memorandum and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It should not be relied upon; consult the final memorandum.

This document was prepared solely for Black and Veatch in accordance with professional standards at the time the services were performed and in accordance with the contract between Black and Veatch and Brown and Caldwell dated May 16, 2019. This document is governed by the specific scope of work authorized by Black and Veatch; 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 Black and Veatch and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

References

Black and Veatch, 2011. *St. Louis MSD Phase II, Phasing and Implementation of Selected Alternatives*. MSD Contract No. 2009145.

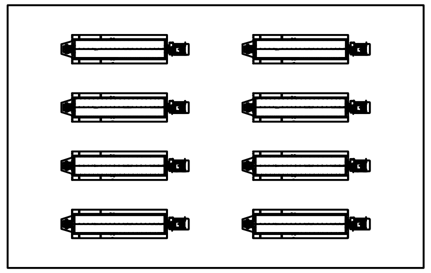
Metcalf & Eddy | AECOM. *Wastewater Engineering Treatment and Resource Recovery.* New York: McGraw-Hill Education, 2014.

Metropolitan St. Louis Sewer District, *Solids Handling Technical Memorandum, Fluidized Bed Incinerators Project 12565, June 2018.*

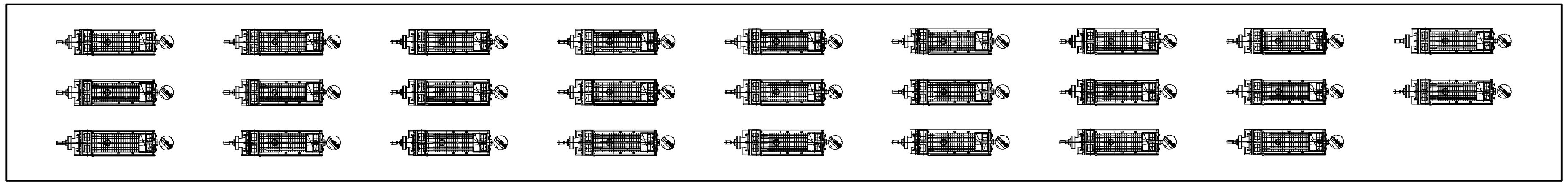
Attachment A: Comparative Dewatering Equipment Space Requirements

Bissell Point WWTF Dewatering Technology Relative Footprint

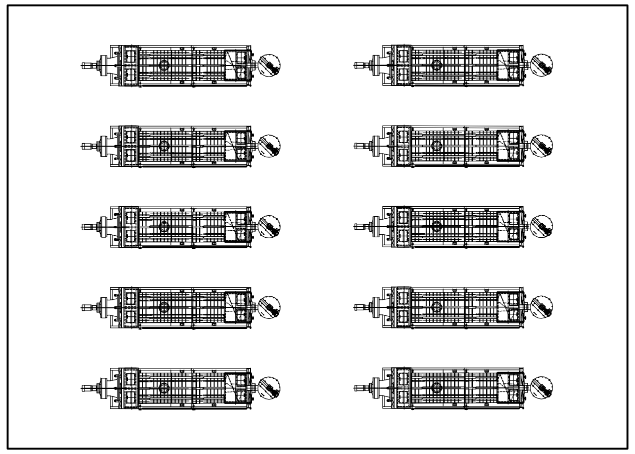
Alternative 1
Centrifuge



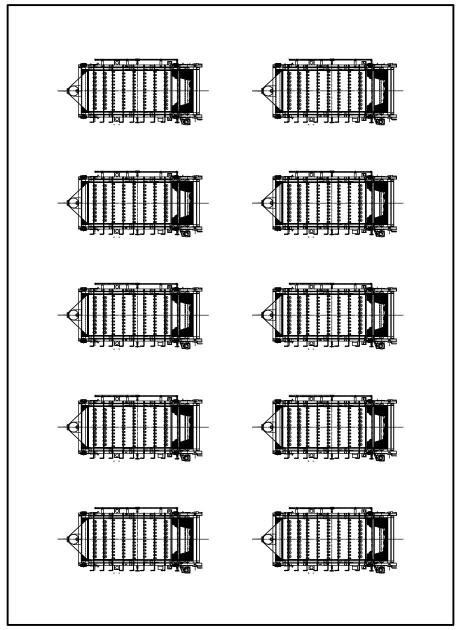
Alternative 2
Screw Press



Alternative 2A
Screw Press
(High Capacity)

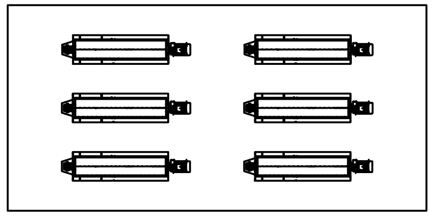


Alternative 3
Belt Filter Press

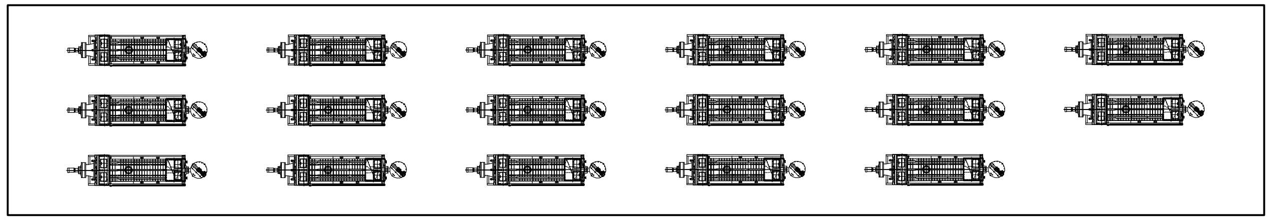


Lemay WWTF Dewatering Technology Relative Footprint

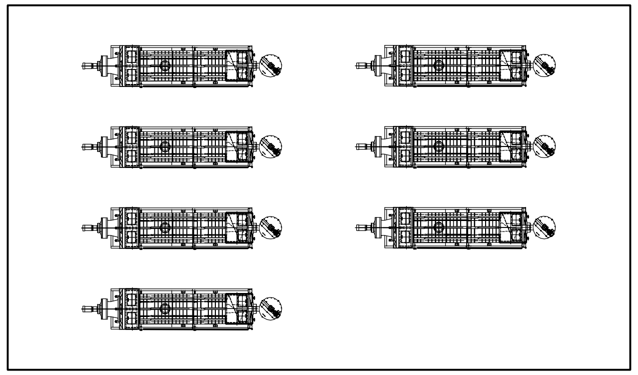
Alternative 1
Centrifuge



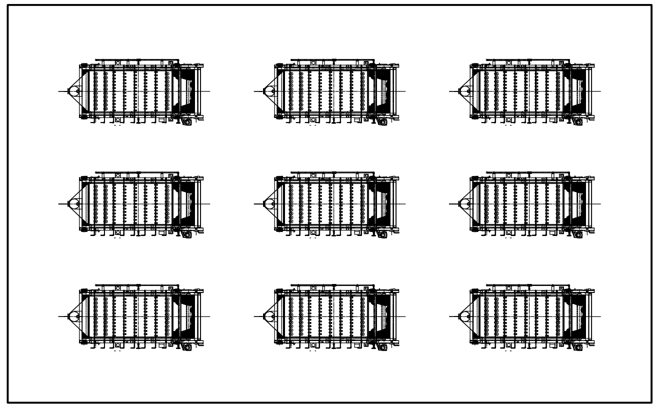
Alternative 2
Screw Press



Alternative 2A
Screw Press
(High Capacity)



Alternative 3
Belt Filter Press



Attachment B: Bissell Point and Lemay Lifecycle Cost Evaluation

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
LCCE SUMMARY

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
LCCE SUMMARY

Net Present Value, 2020 Dollars

		CAPITAL COST	O&M COST	REPLACEMENT AND REPAIR COST	INCINERATION COST	TOTAL COST
Alt_1A	Centrifuge, Mannich	($17,027,611)	($21,453,285)	($1,038,882)	($12,132,040)	**($51,651,818)**
Alt_3A	Screw Press, Mannich	($23,246,854)	($13,182,930)	($804,443)	($23,366,467)	**($60,600,694)**

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
LCCE Assumed Values

*Calculated value

*Lemay linked to cells

BCE Values

No.	Value	Units	Name
Bissell Point Sludge			
1	5.7	%	Dewatering sludge feed total solids concentration
2	300.3	dtpd	Sludge production, peak week, future design
3	134.8	dtpd	Sludge production, annual average, future design
4	281.8	dtpd	Sludge production, peak week, current
5	113.8	dtpd	Sludge production, annual average, current
6	600,600	lb/day	2045 Sludge Production Bissell Point, peak week
7	2035	-	Future solids design start
Escalation			
8	2.5	%	Escalation Rate
9	4.0	%	Discount Rate
Markup Assumptions			
10	12	%	General requirements
11	20	%	Engineering, legal, and administrative
12	35	%	Construction contingency, percentage of overal construction cost
Utilities and Chemical Cost Rates			
13	$0.077	$/KWH	Blended electrical cost
14	$1.90	$/LB	Mannich polymer cost per active pound
15	$2.85	$/LB	Emulsion polymer cost per active pound
16	$40.00	$/CFM	Odor control cost
17	$25.00	$/hr	Labor cost
Alt_1A - Centrifuge, Mannich			
18	3,500	lb/hr	Centrifuge capacity, 30" bowl diameter
19	31	%	Centrifuge cake TS w/w
20	11.0	lb/ton	Centrifuge polymer dose, pounds of active polymer per dry ton of solids
21	24.0	hr/day	Centrifuge labor addition
22	0.30	kW/gpm	Centrifuge electrical consumption rate
23	570,000	$/yr	Incineration auxiliary fuel cost, pre-chem P removal
24	950,000	$/yr	Incineration auxiliary fuel cost, with chem P removal
Alt_3A - Screw Press, Mannich			
25	3,000	lb/hr	Screw Press capacity
26	25	%	Screw Press cake TS w/w
27	7.5	lb/ton	Screw Press polymer dose, pounds of active polymer per dry ton of solids
28	1.0	hr/day/unit	Screw Press labor unit
29	18.0	HP	Screw Press connected horsepower
30	1,210,000	$/yr	Incineration auxiliary fuel cost, pre-chem P removal
31	1,700,000	$/yr	Incineration auxiliary fuel cost, with chem P removal
Dewatering Equipment Purchase Costs			
32	$670,000	/unit	Centrifuge
33	$673,000	/unit	Screw Press (High Capacity)
34	$60,000	/unit	Support equipment per dewatering unit (feed pumps, conveyors, etc.)
Equipment Install Cost Rates			
35	15	%	Equipment installation, percentage of total equipment purchase costs
36	12	%	Mechanical installation, percentage of total equipment purchase costs
37	20	%	Electrical and I&C installation, percentage of total equipment purchase costs
38	15	%	Equipment submittal and testing, percentage of total equipment purchase costs
Equipment Rebuild and Refurbishment Rates			
39	20	%	Centrifuge R&R rate, % of install cost
40	15	%	BFP R&R rate, % of install cost
41	12	%	Screw Press R&R rate, % install cost
Miscellaneous Assumptions			
42	$300	$/sf	Building cost
43	2020	-	Year of analysis
44	1	-	Number of standby dewatering units
45	24	hr/day	Dewatering unit operating schedule
46	7	day/wk	Dewatering unit operating schedule
47	90	%	Exhaust fan efficiency
48	0.5	hr/day/unit	Labor needs for odor control units
49	40	HP	Support equipment power demand per dewatering unit

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
CAPITAL COSTS

Capital Cost Distribution

2020	
2021	
2022	
2023	
2024	25%
2025	75%
2026	
2027	
2028	

Markup Assumptions

General requirements	12.0%
Engineering, legal, and administrative	20.0%
Construction contingency, percentage of overal construction cost	35.0%

Equipment Sizing

Equipment (-)	PW Sludge (lb/day)	Capacity (lb/hr)	No. Duty Units (-)	BCE No. Units (-)	Standby Units (-)	Total No. Purchased (-)
Centrifuge	600,600	3,500	7.15	7	1	8
Screw Press	600,600	3,000	8.34	9	1	10

Capital Cost with Markups

	Alt_1A - Centrifuge, Mannich				Alt_3A - Screw Press, Mannich				
Description	**Quantity**	**Units**	**Unit Cost**	**Total Cost**	**Quantity**	**Units**	**Unit Cost**	**Total Cost**	
Building Adjustment	3,068	sf	$ 300	$ 920,297	7,710	sf	$ 300	$ 2,312,888	
Dewatering Equipment Purchase	8		$ 730,000	$ 5,840,000	10		$ 733,000	$ 7,330,000	
Equipment Submittal and Testing	1			$ 876,000	1			$ 1,099,500	15% equipment purchase cost
Odor Control	3,200	cfm	$ 40	$ 128,000	4,000	cfm	$ 40	$ 160,000	Odor control tab
Equipment Installation				$ 876,000				$ 1,099,500	15% equipment purchase cost
Mechanical and Piping				$ 700,800				$ 879,600	12% equipment purchase cost
Electrical I&C				$ 1,168,000				$ 1,466,000	20% equipment purchase cost
Subtotal				$ 10,509,097				$ 14,347,488	
General requirements fee				$ 1,261,092				$ 1,721,699	
Engineering, legal, and administrative fee				$ 2,354,038				$ 3,213,837	
Construction contingency fee				$ 4,119,566				$ 5,624,215	
Total with Markups				**$ 18,243,792**				**$ 24,907,238**	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
OPERATING AND MAINTENANCE COSTS

Assumptions

Sludge feed conc.		5.7	%	
Schedule		24 7	hr/day day/wk	
Electricity rate	$	0.077	$/kWh	
Polymer rate	$ $	1.90 2.85	$/APS $/APS	Mannich Emulsion
Labor rate	$	25.00	$/hr	

Sludge Production and Throughput

Year	Sludge Production (dtpd)	Sludge Production (lb/day)	Volume (gpm)
2025	113.8	227,600	332
2026	113.8	227,600	332
2027	113.8	227,600	332
2028	113.8	227,600	332
2029	113.8	227,600	332
2030	113.8	227,600	332
2031	113.8	227,600	332
2032	113.8	227,600	332
2033	113.8	227,600	332
2034	113.8	227,600	332
2035	134.8	269,600	394
2036	134.8	269,600	394
2037	134.8	269,600	394
2038	134.8	269,600	394
2039	134.8	269,600	394
2040	134.8	269,600	394
2041	134.8	269,600	394
2042	134.8	269,600	394
2043	134.8	269,600	394
2044	134.8	269,600	394

Alt_1A - Centrifuge, Mannich

Energy consumption rate	0.3	kW/gpm
Odor control fan HP	10.8	HP
Polymer dose	11.0	lb/dt
Labor requirements	24	hr/day.
Odor control labor	0.5	hr/day/unit
Odor control units	2	
Incineration, initial	$ 570,000	/yr
Incineration, Chem P	$ 950,000	/yr

Year	Power Consumption (kWh/yr)	Electrical Cost ($)	Polymer Usage (lb/yr)	Polymer Cost ($)	Duty Units (-)	Labor Cost ($/yr)	Incineration Cost ($/yr)	Total ($/yr)
2025	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2026	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2027	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2028	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2029	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2030	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2031	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2032	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2033	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2034	1,728,853	$ 133,122	457,220	$ 868,718	3	$ 228,281	$ 570,000	$ 1,800,121
2035	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2036	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2037	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2038	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2039	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2040	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2041	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2042	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2043	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979
2044	2,151,578	$ 165,672	541,593	$ 1,029,026	4	$ 228,281	$ 950,000	$ 2,372,979

Alt_3A - Screw Press, Mannich

Connected horsepower	58	HP/unit
Odor control exhaust HP	10.8	HP
Polymer dose	7.5	lb/dt
Labor requirements	1	hr/day/duty equip.
Odor control labor	0.5	hr/day/unit
Odor control units	2	
Incineration, initial	$ 1,210,000	/yr
Incineration, Chem P	$ 1,700,000	/yr

Year	Power Consumption (kWh/yr)	Electrical Cost ($)	Polymer Usage (lb/yr)	Polymer Cost ($)	Duty Units (-)	Labor Cost ($/yr)	Incineration Cost ($/yr)	Total ($/yr)
2025	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2026	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2027	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2028	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2029	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2030	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2031	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2032	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2033	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2034	1,587,137	$ 122,210	311,741	$ 592,308	4	$ 45,656	$ 1,210,000	$ 1,970,173
2035	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2036	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2037	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2038	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2039	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2040	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2041	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2042	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2043	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474
2044	1,587,137	$ 122,210	369,268	$ 701,609	4	$ 45,656	$ 1,700,000	$ 2,569,474

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
REPLACEMENT AND REPAIR COSTS

		Equipment Cost	Service Life (years)	R&R Rate (%)	Annualized RR	Odor Control Media	Total RR
Alt_1A	Centrifuge, Mannich	$ 5,840,000	20	20	$ 58,400	$ 5,500	$ 63,900
Alt_3A	Screw Press, Mannich	$ 7,330,000	20	12	$ 43,980	$ 5,500	$ 49,480

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
ODOR CONTROL

ODOR CONTROL	Centrifuge	Screw Press
B. Equipment Exhaust Air Flow Rate		
Dewatering Machine Ventilation Requirement, CFM per Unit	400	400

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
EQUIPMENT LAYOUT CALCULATIONS

		Alt_1A	Alt_3A	
		Dimensions		
		Centrifuge	**Screw Press**	**Units**
Equipment Dimension	**Width**	256.0	398.0	in
	Length	57.1	81.0	in
Maintenance Dimension	**Width Space**	108.0	150.0	in
	Length Space	60.0	81.0	in
	Units	8	10	

Building Width Dimension, ft.

Equipment Rows	**Centrifuge**	**Screw Press**
1	252	469
2	130	241
3	100	195
4	70	150
5	70	104
6	70	104

Building Length Dimension, ft.

Equipment Rows	**Centrifuge**	**Screw Press**
1	15	20
2	25	34
3	34	47
4	44	61
5	54	74
6	64	88

Building Footprint Dimension, sq. ft

Equipment Rows	**Centrifuge**	**Screw Press**
1	3,714	9,501
2	3,195	8,128
3	3,428	9,222
4	3,068	9,082
5	3,747	7,710
6	4,427	9,111
MIN	3,068	7,710
W	70	104
L	44	74

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
Centrifuge, Mannich
Alt_1A

Year of Analysis	2020
Escalation rate	2.5%
Discount rate	4.0%

	2020 dollars, not escalated					
	Capital Outlays	Annual Running Costs				R&R Costs
	Total Capital	Electrical Cost	Polymer Cost	Labor Cost	Incineration Cost	Total R&R
2020	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 4,560,948	$ -	$ -	$ -	$ -	$ -
2025	$ 13,682,844	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2026	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2027	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2028	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2029	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2030	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2031	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2032	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2033	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2034	$ -	$ 133,122	$ 868,718	$ 228,281	$ 570,000	$ 63,900
2035	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2036	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2037	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2038	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2039	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2040	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2041	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2042	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2043	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900
2044	$ -	$ 165,672	$ 1,029,026	$ 228,281	$ 950,000	$ 63,900

	Escalated dollars						
	Capital Outlays	Annual Running Costs				R&R Costs	
	Total Capital	Electrical Cost	Polymer Cost	Labor Cost	Incineration Cost	Total R&R	Total
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 5,034,433	$ -	$ -	$ -	$ -	$ -	$ (5,034,433)
2025	$ 15,480,882	$ 150,615	$ 982,875	$ 258,279	$ 644,903	$ 72,297	$ (17,589,850)
2026	$ -	$ 154,380	$ 1,007,446	$ 264,736	$ 661,025	$ 74,104	$ (2,161,693)
2027	$ -	$ 158,240	$ 1,032,633	$ 271,355	$ 677,551	$ 75,957	$ (2,215,735)
2028	$ -	$ 162,196	$ 1,058,448	$ 278,139	$ 694,490	$ 77,856	$ (2,271,128)
2029	$ -	$ 166,251	$ 1,084,910	$ 285,092	$ 711,852	$ 79,802	$ (2,327,907)
2030	$ -	$ 170,407	$ 1,112,032	$ 292,219	$ 729,648	$ 81,797	$ (2,386,104)
2031	$ -	$ 174,667	$ 1,139,833	$ 299,525	$ 747,889	$ 83,842	$ (2,445,757)
2032	$ -	$ 179,034	$ 1,168,329	$ 307,013	$ 766,587	$ 85,938	$ (2,506,901)
2033	$ -	$ 183,510	$ 1,197,537	$ 314,688	$ 785,751	$ 88,087	$ (2,569,573)
2034	$ -	$ 188,097	$ 1,227,476	$ 322,555	$ 805,395	$ 90,289	$ (2,633,813)
2035	$ -	$ 239,942	$ 1,490,337	$ 330,619	$ 1,375,883	$ 92,546	$ (3,529,327)
2036	$ -	$ 245,940	$ 1,527,595	$ 338,885	$ 1,410,280	$ 94,860	$ (3,617,560)
2037	$ -	$ 252,089	$ 1,565,785	$ 347,357	$ 1,445,537	$ 97,231	$ (3,707,999)
2038	$ -	$ 258,391	$ 1,604,930	$ 356,041	$ 1,481,676	$ 99,662	$ (3,800,699)
2039	$ -	$ 264,851	$ 1,645,053	$ 364,942	$ 1,518,718	$ 102,154	$ (3,895,717)
2040	$ -	$ 271,472	$ 1,686,179	$ 374,065	$ 1,556,686	$ 104,708	$ (3,993,110)
2041	$ -	$ 278,259	$ 1,728,334	$ 383,417	$ 1,595,603	$ 107,325	$ (4,092,938)
2042	$ -	$ 285,215	$ 1,771,542	$ 393,002	$ 1,635,493	$ 110,008	$ (4,195,261)
2043	$ -	$ 292,346	$ 1,815,831	$ 402,828	$ 1,676,380	$ 112,759	$ (4,300,143)
2044	$ -	$ 299,654	$ 1,861,226	$ 412,898	$ 1,718,290	$ 115,578	$ (4,407,646)

	$ (51,651,818)		**$ (17,027,611)**	**$ (21,453,285)**	**$ (1,038,882)**	**$ (12,132,040)**
	Present Value					
	2020 dollars	Running Total	Capital	O&M	R&R	Incineration
2020	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ (4,303,455)	$ (4,303,455)	$ (4,303,455)	$ -	$ -	$ -
2025	$ (14,457,575)	$ (18,761,029)	$ (12,724,156)	$ (1,143,933)	$ (59,423)	$ (530,063)
2026	$ (1,708,417)	$ (20,469,447)	$ -	$ (1,127,433)	$ (58,566)	$ (522,418)
2027	$ (1,683,777)	$ (22,153,223)	$ -	$ (1,111,172)	$ (57,721)	$ (514,883)
2028	$ (1,659,491)	$ (23,812,714)	$ -	$ (1,095,146)	$ (56,889)	$ (507,457)
2029	$ (1,635,556)	$ (25,448,271)	$ -	$ (1,079,351)	$ (56,068)	$ (500,138)
2030	$ (1,611,967)	$ (27,060,237)	$ -	$ (1,063,783)	$ (55,259)	$ (492,924)
2031	$ (1,588,717)	$ (28,648,954)	$ -	$ (1,048,440)	$ (54,462)	$ (485,815)
2032	$ (1,565,803)	$ (30,214,757)	$ -	$ (1,033,318)	$ (53,677)	$ (478,808)
2033	$ (1,543,219)	$ (31,757,976)	$ -	$ (1,018,415)	$ (52,903)	$ (471,902)
2034	$ (1,520,961)	$ (33,278,937)	$ -	$ (1,003,726)	$ (52,140)	$ (465,096)
2035	$ (1,959,710)	$ (35,238,647)	$ -	$ (1,144,343)	$ (51,388)	$ (763,979)
2036	$ (1,931,445)	$ (37,170,093)	$ -	$ (1,127,838)	$ (50,646)	$ (752,960)
2037	$ (1,903,588)	$ (39,073,680)	$ -	$ (1,111,572)	$ (49,916)	$ (742,100)
2038	$ (1,876,132)	$ (40,949,812)	$ -	$ (1,095,539)	$ (49,196)	$ (731,397)
2039	$ (1,849,073)	$ (42,798,885)	$ -	$ (1,079,738)	$ (48,487)	$ (720,848)
2040	$ (1,822,403)	$ (44,621,288)	$ -	$ (1,064,165)	$ (47,787)	$ (710,451)
2041	$ (1,796,119)	$ (46,417,407)	$ -	$ (1,048,817)	$ (47,098)	$ (700,204)
2042	$ (1,770,213)	$ (48,187,620)	$ -	$ (1,033,689)	$ (46,419)	$ (690,105)
2043	$ (1,744,681)	$ (49,932,301)	$ -	$ (1,018,780)	$ (45,749)	$ (680,152)
2044	$ (1,719,517)	$ (51,651,818)	$ -	$ (1,004,086)	$ (45,089)	$ (670,342)

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
Screw Press, Mannich
Alt_3A

Year of Analysis	2020
Escalation rate	2.5%
Discount rate	4.0%

	2020 dollars, not escalated					
	Capital Outlays	**Annual Running Costs**				**R&R Costs**
	Total Capital	**Electrical Cost**	**Polymer Cost**	**Labor Cost**	**Incineration Cost**	**Total R&R**
2020	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 6,226,810	$ -	$ -	$ -	$ -	$ -
2025	$ 18,680,429	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2026	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2027	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2028	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2029	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2030	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2031	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2032	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2033	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2034	$ -	$ 122,210	$ 592,308	$ 45,656	$ 1,210,000	$ 49,480
2035	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2036	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2037	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2038	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2039	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2040	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2041	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2042	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2043	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480
2044	$ -	$ 122,210	$ 701,609	$ 45,656	$ 1,700,000	$ 49,480

	Escalated dollars						
	Capital Outlays	**Annual Running Costs**				**R&R Costs**	
	Total Capital	**Electrical Cost**	**Polymer Cost**	**Labor Cost**	**Incineration Cost**	**Total R&R**	**Total**
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 6,873,233	$ -	$ -	$ -	$ -	$ -	$ (6,873,233)
2025	$ 21,135,190	$ 138,269	$ 670,142	$ 51,656	$ 1,369,004	$ 55,982	$ (23,420,243)
2026	$ -	$ 141,726	$ 686,895	$ 52,947	$ 1,403,229	$ 57,382	$ (2,342,179)
2027	$ -	$ 145,269	$ 704,068	$ 54,271	$ 1,438,310	$ 58,816	$ (2,400,733)
2028	$ -	$ 148,900	$ 721,669	$ 55,628	$ 1,474,268	$ 60,287	$ (2,460,752)
2029	$ -	$ 152,623	$ 739,711	$ 57,018	$ 1,511,124	$ 61,794	$ (2,522,270)
2030	$ -	$ 156,439	$ 758,204	$ 58,444	$ 1,548,902	$ 63,339	$ (2,585,327)
2031	$ -	$ 160,349	$ 777,159	$ 59,905	$ 1,587,625	$ 64,922	$ (2,649,960)
2032	$ -	$ 164,358	$ 796,588	$ 61,403	$ 1,627,315	$ 66,545	$ (2,716,209)
2033	$ -	$ 168,467	$ 816,503	$ 62,938	$ 1,667,998	$ 68,209	$ (2,784,115)
2034	$ -	$ 172,679	$ 836,915	$ 64,511	$ 1,709,698	$ 69,914	$ (2,853,717)
2035	$ -	$ 176,996	$ 1,016,139	$ 66,124	$ 2,462,107	$ 71,662	$ (3,793,027)
2036	$ -	$ 181,421	$ 1,041,542	$ 67,777	$ 2,523,660	$ 73,453	$ (3,887,853)
2037	$ -	$ 185,956	$ 1,067,581	$ 69,471	$ 2,586,751	$ 75,290	$ (3,985,049)
2038	$ -	$ 190,605	$ 1,094,270	$ 71,208	$ 2,651,420	$ 77,172	$ (4,084,675)
2039	$ -	$ 195,370	$ 1,121,627	$ 72,988	$ 2,717,705	$ 79,101	$ (4,186,792)
2040	$ -	$ 200,255	$ 1,149,668	$ 74,813	$ 2,785,648	$ 81,079	$ (4,291,462)
2041	$ -	$ 205,261	$ 1,178,409	$ 76,683	$ 2,855,289	$ 83,106	$ (4,398,748)
2042	$ -	$ 210,392	$ 1,207,870	$ 78,600	$ 2,926,671	$ 85,183	$ (4,508,717)
2043	$ -	$ 215,652	$ 1,238,066	$ 80,566	$ 2,999,838	$ 87,313	$ (4,621,435)
2044	$ -	$ 221,044	$ 1,269,018	$ 82,580	$ 3,074,834	$ 89,496	$ (4,736,971)

	$ (60,600,694)		**$ (23,246,854)**	**$ (13,182,930)**	**$ (804,443)**	**$ (23,366,467)**
	Present Value					
	2020 dollars	**Running Total**	**Capital**	**O&M**	**R&R**	**Incineration**
2020	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ (5,875,268)	$ (5,875,268)	$ (5,875,268)	$ -	$ -	$ -
2025	$ (19,249,733)	$ (25,125,001)	$ (17,371,586)	$ (706,912)	$ (46,013)	$ (1,125,221)
2026	$ (1,851,058)	$ (26,976,059)	$ -	$ (696,716)	$ (45,350)	$ (1,108,992)
2027	$ (1,824,360)	$ (28,800,419)	$ -	$ (686,667)	$ (44,695)	$ (1,092,997)
2028	$ (1,798,047)	$ (30,598,466)	$ -	$ (676,763)	$ (44,051)	$ (1,077,233)
2029	$ (1,772,114)	$ (32,370,579)	$ -	$ (667,002)	$ (43,415)	$ (1,061,696)
2030	$ (1,746,554)	$ (34,117,134)	$ -	$ (657,382)	$ (42,789)	$ (1,046,383)
2031	$ (1,721,364)	$ (35,838,497)	$ -	$ (647,901)	$ (42,172)	$ (1,031,291)
2032	$ (1,696,536)	$ (37,535,034)	$ -	$ (638,556)	$ (41,564)	$ (1,016,416)
2033	$ (1,672,067)	$ (39,207,101)	$ -	$ (629,346)	$ (40,964)	$ (1,001,757)
2034	$ (1,647,951)	$ (40,855,051)	$ -	$ (620,269)	$ (40,374)	$ (987,308)
2035	$ (2,106,133)	$ (42,961,185)	$ -	$ (699,221)	$ (39,791)	$ (1,367,121)
2036	$ (2,075,756)	$ (45,036,941)	$ -	$ (689,137)	$ (39,217)	$ (1,347,402)
2037	$ (2,045,818)	$ (47,082,759)	$ -	$ (679,197)	$ (38,652)	$ (1,327,969)
2038	$ (2,016,311)	$ (49,099,069)	$ -	$ (669,401)	$ (38,094)	$ (1,308,815)
2039	$ (1,987,229)	$ (51,086,298)	$ -	$ (659,746)	$ (37,545)	$ (1,289,938)
2040	$ (1,958,567)	$ (53,044,865)	$ -	$ (650,231)	$ (37,003)	$ (1,271,333)
2041	$ (1,930,319)	$ (54,975,184)	$ -	$ (640,852)	$ (36,470)	$ (1,252,997)
2042	$ (1,902,477)	$ (56,877,662)	$ -	$ (631,609)	$ (35,944)	$ (1,234,925)
2043	$ (1,875,038)	$ (58,752,699)	$ -	$ (622,499)	$ (35,425)	$ (1,217,113)
2044	$ (1,847,994)	$ (60,600,694)	$ -	$ (613,521)	$ (34,914)	$ (1,199,559)

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
LCCE SUMMARY

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
LCCE SUMMARY

Net Present Value, 2020 Dollars

		CAPITAL COST	**O&M COST**	**REPLACEMENT AND REPAIR COST**	**INCINERATION COST**	**TOTAL COST**
Alt_1A	Centrifuge, Mannich	(\$12,813,038)	(\$17,330,024)	(\$801,516)	(\$3,126,568)	**(\$34,071,146)**
Alt_3A	Screw Press, Mannich	(\$16,715,685)	(\$10,122,666)	(\$589,936)	(\$12,176,728)	**(\$39,605,015)**

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
LCCE Assumed Values

*Calculated value

*Linked to Bissell Point LCCE

BCE Values

No.	Value	Units	Name
Bissell Point Sludge			
1	3.6	%	Dewatering sludge feed total solids concentration
2	211.9	dtpd	Sludge production, peak week, future design
3	111.7	dtpd	Sludge production, annual average, future design
4	146.5	dtpd	Sludge production, peak week, current
5	73.7	dtpd	Sludge production, annual average, current
6	423,800	lb/day	2045 Sludge Production Bissell Point, peak week
7	2035	-	Future solids design start
Escalation			
8	2.5	%	Escalation Rate
9	4.0	%	Discount Rate
Markup Assumptions			
10	12	%	General requirements
11	20	%	Engineering, legal, and administrative
12	35	%	Construction contingency, percentage of overal construction cost
Utilities and Chemical Cost Rates			
13	$0.077	$/KWH	Blended electrical cost
14	$1.90	$/LB	Mannich polymer cost per active pound
15	$2.85	$/LB	Emulsion polymer cost per active pound
16	$40.00	$/CFM	Odor control cost
17	$25.00	$/hr	Labor cost
Alternative 1A - Centrifuge, Mannich Polymer			
18	3,500	lb/hr	Centrifuge capacity, 30" bowl diameter
19	30	%	Centrifuge cake TS w/w
20	11.0	lb/ton	Centrifuge polymer dose, pounds of active polymer per dry ton of solids
21	24.0	hr/day	Centrifuge labor addition
22	0.30	kW/gpm	Centrifuge electrical consumption rate
23	30,000	$/yr	Incineration auxiliary fuel cost, pre-chem P removal
24	380,000	$/yr	Incineration auxiliary fuel cost, with chem P removal
Alternative 3A - Screw Press, Mannich Polymer			
25	3,000	lb/hr	Screw Press capacity
26	24	%	Screw Press cake TS w/w
27	7.5	lb/ton	Screw Press polymer dose, pounds of active polymer per dry ton of solids
28	1.0	hr/day/unit	Screw Press labor unit
29	18.0	HP	Screw Press connected horsepower
30	480,000	$/yr	Incineration auxiliary fuel cost, pre-chem P removal
31	1,060,000	$/yr	Incineration auxiliary fuel cost, with chem P removal
Dewatering Equipment Purchase Costs			
32	$670,000	/unit	Centrifuge
33	$673,000	/unit	Screw Press (High Capacity)
34	$60,000	/unit	Support equipment per dewatering unit (feed pumps, conveyors, etc.)
Equipment Install Cost Rates			
35	15	%	Equipment installation, percentage of total equipment purchase costs
36	12	%	Mechanical installation, percentage of total equipment purchase costs
37	20	%	Electrical and I&C installation, percentage of total equipment purchase costs
38	15	%	Equipment submittal and testing, percentage of total equipment purchase costs
Equipment Rebuild and Refurbishment Rates			
39	20	%	Centrifuge R&R rate, % of install cost
40	15	%	BFP R&R rate, % of install cost
41	12	%	Screw Press R&R rate, % install cost
Miscellaneous Assumptions			
42	$300	$/sf	Building cost
43	2020	-	Year of analysis
44	1	-	Number of standby dewatering units
45	24	hr/day	Dewatering unit operating schedule
46	7	day/wk	Dewatering unit operating schedule
47	90	%	Exhaust fan efficiency
48	0.5	hr/day/unit	Labor needs for odor control units
49	40	HP	Support equipment power demand per dewatering unit

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
CAPITAL COSTS

Capital Cost Distribution

2020	
2021	
2022	
2023	
2024	25%
2025	75%
2026	
2027	
2028	

Markup Assumptions

General requirements	12.0%
Engineering, legal, and administrative	20.0%
Construction contingency, percentage of overal construction cost	35.0%

Equipment Sizing

Equipment	**PW Sludge**	**Capacity**	**No. Duty Units**	**BCE No. Units**	**Standby Units**	**Total No. Purchased**
(-)	**(lb/day)**	**(lb/hr)**	**(-)**	**(-)**	**(-)**	**(-)**
Centrifuge	423,800	3,500	5.05	5	1	6
Screw Press	423,800	3,000	5.89	6	1	7

Capital Cost with Markups

	Alt_1A - Centrifuge, Mannich				**Alt_3A - Screw Press, Mannich**				
Description	**Quantity**	**Units**	**Unit Cost**	**Total Cost**	**Quantity**	**Units**	**Unit Cost**	**Total Cost**	
Building Adjustment	2,388	sf	$ 300	$ 716,348	6,308	sf	$ 300	$ 1,892,363	
Dewatering Equipment Purchase	6		$ 730,000	$ 4,380,000	7		$ 733,000	$ 5,131,000	
Equipment Submittal and Testing	1			$ 657,000	1			$ 769,650	15% equipment purchase cost
Odor Control	2,400	cfm	$ 40	$ 96,000	2,800	cfm	$ 40	$ 112,000	Odor control tab
Equipment Installation				$ 657,000				$ 769,650	15% equipment purchase cost
Mechanical and Piping				$ 525,600				$ 615,720	12% equipment purchase cost
Electrical I&C				$ 876,000				$ 1,026,200	20% equipment purchase cost
Subtotal				$ 7,907,948				$ 10,316,583	
General requirements fee				$ 948,954				$ 1,237,990	
Engineering, legal, and administrative fee				$ 1,771,380				$ 2,310,914	
Construction contingency fee				$ 3,099,915				$ 4,044,100	
Total with Markups				**$ 13,728,197**				**$ 17,909,587**	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
OPERATING AND MAINTENANCE COSTS

Assumptions			
Sludge feed conc.	3.6	%	
Schedule	24	hr/day	
	7	day/wk	
Electricity rate	$ 0.077	$/kWh	
Polymer rate	$ 1.90	$/APS	Mannich
	$ 2.85	$/APS	Emulsion
Labor rate	$ 25.00	$/hr	

Alt_1A - Centrifuge, Mannich			Alt_3A - Screw Press, Mannich		
Energy consumption rate	0.3	kW/gpm	Connected horsepower	58	HP/unit
Odor control fan HP	10.8	HP	Odor control exhaust HP	10.8	HP
Polymer dose	11.0	lb/dt	Polymer dose	7.5	lb/dt
Labor requirements	24	hr/day.	Labor requirements	1	hr/day/duty equip.
Odor control labor	0.5	hr/day/unit	Odor control labor	0.5	hr/day/unit
Odor control units	2		Odor control units	2	
Incineration, initial	$ 30,000	/yr	Incineration, initial	$ 480,000	/yr
Incineration, Chem P	$ 380,000	/yr	Incineration, Chem P	$ 1,060,000	/yr

Sludge Production and Throughput				Alt_1A - Centrifuge, Mannich								Alt_3A - Screw Press, Mannich							
Year	Sludge Production (dtpd)	Sludge Production (lb/day)	Volume (gpm)	Power Consumption (kWh/yr)	Electrical Cost ($)	Polymer Usage (lb/yr)	Polymer Cost ($)	Duty Units (-)	Labor Cost ($/yr)	Incineration Cost ($/yr)	Total ($/yr)	Power Consumption (kWh/yr)	Electrical Cost ($)	Polymer Usage (lb/yr)	Polymer Cost ($)	Duty Units (-)	Labor Cost ($/yr)	Incineration Cost ($/yr)	Total ($/yr)
2025	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2026	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2027	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2028	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2029	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2030	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2031	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2032	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2033	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2034	73.7	147,400	341	1,489,585	$ 114,698	296,108	$ 562,606	2	$ 228,281	$ 30,000	$ 935,585	1,208,002	$ 93,016	201,892	$ 383,595	3	$ 36,525	$ 480,000	$ 993,136
2035	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2036	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2037	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2038	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2039	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2040	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2041	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2042	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2043	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243
2044	111.7	223,400	516	2,213,060	$ 170,406	448,783	$ 852,687	3	$ 228,281	$ 380,000	$ 1,631,374	1,587,137	$ 122,210	305,988	$ 581,378	4	$ 45,656	$ 1,060,000	$ 1,809,243

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
REPLACEMENT AND REPAIR COSTS

		Equipment Cost	Service Life (years)	R&R Rate (%)	Annualized RR	Odor Control Media	Total RR
Alt_1A	Centrifuge, Mannich	$ 4,380,000	20	20	$ 43,800	$ 5,500	$ 49,300
Alt_3A	Screw Press, Mannich	$ 5,131,000	20	12	$ 30,786	$ 5,500	$ 36,286

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
ODOR CONTROL

ODOR CONTROL	Centrifuge	Screw Press	Notes
B. Equipment Exhaust Air Flow Rate			
Dewatering Machine Ventilation Requirement, CFM per Unit	400	400	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
EQUIPMENT LAYOUT CALCULATIONS

		Alt_1A	Alt_3A	
		Dimensions		
		Centrifuge	**Screw Press**	**Units**
Equipment Dimension	**Width**	256.0	398.0	in
	Length	57.1	81.0	in
Maintenance Dimension	**Width Space**	108.0	150.0	in
	Length Space	60.0	81.0	in
	Units	6	7	

Building Width Dimension, ft.

Equipment Rows	**Centrifuge**	**Screw Press**
1	191	332
2	100	195
3	70	150
4	70	104
5	70	104
6	39	104

Building Length Dimension, ft.

Equipment Rows	**Centrifuge**	**Screw Press**
1	15	20
2	25	34
3	34	47
4	44	61
5	54	74
6	64	88

Building Footprint Dimension, sq. ft

Equipment Rows	**Centrifuge**	**Screw Press**
1	2,819	6,726
2	2,452	6,587
3	2,388	7,064
4	3,068	6,308
5	3,747	7,710
6	2,500	9,111
MIN	2,388	6,308
W	70	104
L	34	61

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
Centrifuge, Mannich
Alt_1A

Year of Analysis	2020
Escalation rate	2.5%
Discount rate	4.0%

	2020 dollars, not escalated					
	Capital Outlays	**Annual Running Costs**				**R&R Costs**
	Total Capital	**Electrical Cost**	**Polymer Cost**	**Labor Cost**	**Incineration Cost**	**Total R&R**
2020	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 3,432,049	$ -	$ -	$ -	$ -	$ -
2025	$ 10,296,148	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2026	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2027	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2028	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2029	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2030	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2031	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2032	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2033	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2034	$ -	$ 114,698	$ 562,606	$ 228,281	$ 30,000	$ 49,300
2035	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2036	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2037	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2038	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2039	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2040	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2041	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2042	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2043	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300
2044	$ -	$ 170,406	$ 852,687	$ 228,281	$ 380,000	$ 49,300

	Escalated dollars						
	Capital Outlays	**Annual Running Costs**				**R&R Costs**	
	Total Capital	**Electrical Cost**	**Polymer Cost**	**Labor Cost**	**Incineration Cost**	**Total R&R**	**Total**
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 3,788,340	$ -	$ -	$ -	$ -	$ -	$ (3,788,340)
2025	$ 11,649,146	$ 129,770	$ 636,537	$ 258,279	$ 33,942	$ 55,778	$ (12,763,453)
2026	$ -	$ 133,015	$ 652,450	$ 264,736	$ 34,791	$ 57,173	$ (1,142,164)
2027	$ -	$ 136,340	$ 668,761	$ 271,355	$ 35,661	$ 58,602	$ (1,170,719)
2028	$ -	$ 139,748	$ 685,480	$ 278,139	$ 36,552	$ 60,067	$ (1,199,987)
2029	$ -	$ 143,242	$ 702,617	$ 285,092	$ 37,466	$ 61,569	$ (1,229,986)
2030	$ -	$ 146,823	$ 720,183	$ 292,219	$ 38,403	$ 63,108	$ (1,260,736)
2031	$ -	$ 150,494	$ 738,187	$ 299,525	$ 39,363	$ 64,686	$ (1,292,254)
2032	$ -	$ 154,256	$ 756,642	$ 307,013	$ 40,347	$ 66,303	$ (1,324,561)
2033	$ -	$ 158,113	$ 775,558	$ 314,688	$ 41,355	$ 67,961	$ (1,357,675)
2034	$ -	$ 162,065	$ 794,947	$ 322,555	$ 42,389	$ 69,660	$ (1,391,616)
2035	$ -	$ 246,798	$ 1,234,945	$ 330,619	$ 550,353	$ 71,401	$ (2,434,117)
2036	$ -	$ 252,968	$ 1,265,819	$ 338,885	$ 564,112	$ 73,186	$ (2,494,970)
2037	$ -	$ 259,292	$ 1,297,464	$ 347,357	$ 578,215	$ 75,016	$ (2,557,344)
2038	$ -	$ 265,775	$ 1,329,901	$ 356,041	$ 592,670	$ 76,891	$ (2,621,278)
2039	$ -	$ 272,419	$ 1,363,148	$ 364,942	$ 607,487	$ 78,813	$ (2,686,810)
2040	$ -	$ 279,230	$ 1,397,227	$ 374,065	$ 622,674	$ 80,784	$ (2,753,980)
2041	$ -	$ 286,210	$ 1,432,158	$ 383,417	$ 638,241	$ 82,803	$ (2,822,830)
2042	$ -	$ 293,366	$ 1,467,962	$ 393,002	$ 654,197	$ 84,873	$ (2,893,400)
2043	$ -	$ 300,700	$ 1,504,661	$ 402,828	$ 670,552	$ 86,995	$ (2,965,735)
2044	$ -	$ 308,217	$ 1,542,277	$ 412,898	$ 687,316	$ 89,170	$ (3,039,879)

	$ (34,071,146)		**$ (12,813,038)**	**$ (17,330,024)**	**$ (801,516)**	**$ (3,126,568)**
	Present Value					
	2020 dollars	**Running Total**	**Capital**	**O&M**	**R&R**	**Incineration**
2020	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ (3,238,289)	$ (3,238,289)	$ (3,238,289)	$ -	$ -	$ -
2025	$ (10,490,628)	$ (13,728,917)	$ (9,574,749)	$ (842,135)	$ (45,846)	$ (27,898)
2026	$ (902,669)	$ (14,631,586)	$ -	$ (829,989)	$ (45,185)	$ (27,496)
2027	$ (889,650)	$ (15,521,236)	$ -	$ (818,018)	$ (44,533)	$ (27,099)
2028	$ (876,818)	$ (16,398,054)	$ -	$ (806,220)	$ (43,891)	$ (26,708)
2029	$ (864,172)	$ (17,262,226)	$ -	$ (794,591)	$ (43,258)	$ (26,323)
2030	$ (851,708)	$ (18,113,934)	$ -	$ (783,131)	$ (42,634)	$ (25,943)
2031	$ (839,424)	$ (18,953,358)	$ -	$ (771,836)	$ (42,019)	$ (25,569)
2032	$ (827,317)	$ (19,780,675)	$ -	$ (760,704)	$ (41,413)	$ (25,200)
2033	$ (815,384)	$ (20,596,059)	$ -	$ (749,732)	$ (40,815)	$ (24,837)
2034	$ (803,624)	$ (21,399,683)	$ -	$ (738,918)	$ (40,227)	$ (24,479)
2035	$ (1,351,579)	$ (22,751,261)	$ -	$ (1,006,341)	$ (39,646)	$ (305,592)
2036	$ (1,332,085)	$ (24,083,346)	$ -	$ (991,826)	$ (39,075)	$ (301,184)
2037	$ (1,312,872)	$ (25,396,218)	$ -	$ (977,521)	$ (38,511)	$ (296,840)
2038	$ (1,293,936)	$ (26,690,155)	$ -	$ (963,422)	$ (37,956)	$ (292,559)
2039	$ (1,275,274)	$ (27,965,429)	$ -	$ (949,527)	$ (37,408)	$ (288,339)
2040	$ (1,256,881)	$ (29,222,309)	$ -	$ (935,831)	$ (36,869)	$ (284,180)
2041	$ (1,238,752)	$ (30,461,062)	$ -	$ (922,334)	$ (36,337)	$ (280,082)
2042	$ (1,220,886)	$ (31,681,948)	$ -	$ (909,031)	$ (35,813)	$ (276,042)
2043	$ (1,203,277)	$ (32,885,225)	$ -	$ (895,920)	$ (35,296)	$ (272,061)
2044	$ (1,185,922)	$ (34,071,146)	$ -	$ (882,998)	$ (34,787)	$ (268,137)

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING TECHNOLOGY LIFECYCLE COST EVALUATION
Screw Press, Mannich
Alt_3A

Year of Analysis	2020
Escalation rate	2.5%
Discount rate	4.0%

	2020 dollars, not escalated						Escalated dollars							$ (39,605,015)		$ (16,715,685)	$ (10,122,666)	$ (589,936)	$ (12,176,728)
	Capital Outlays	Annual Running Costs				R&R Costs	Capital Outlays	Annual Running Costs				R&R Costs		Present Value					
	Total Capital	Electrical Cost	Polymer Cost	Labor Cost	Incineration Cost	Total R&R	Total Capital	Electrical Cost	Polymer Cost	Labor Cost	Incineration Cost	Total R&R	Total	2020 dollars	Running Total	Capital	O&M	R&R	Incineration
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ 4,477,397	$ -	$ -	$ -	$ -	$ -	$ 4,942,208	$ -	$ -	$ -	$ -	$ -	$ (4,942,208)	$ (4,224,620)	$ (4,224,620)	$ (4,224,620)	$ -	$ -	$ -
2025	$ 13,432,190	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ 15,197,291	$ 105,239	$ 434,002	$ 41,325	$ 543,076	$ 41,054	$ (16,361,987)	$ (13,448,361)	$ (17,672,981)	$ (12,491,065)	$ (477,183)	$ (33,744)	$ (446,369)
2026	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 107,870	$ 444,852	$ 42,358	$ 556,653	$ 42,081	$ (1,193,814)	$ (943,488)	$ (18,616,469)	$ -	$ (470,301)	$ (33,257)	$ (439,931)
2027	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 110,567	$ 455,974	$ 43,417	$ 570,569	$ 43,133	$ (1,223,659)	$ (929,880)	$ (19,546,350)	$ -	$ (463,517)	$ (32,777)	$ (433,586)
2028	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 113,331	$ 467,373	$ 44,502	$ 584,833	$ 44,211	$ (1,254,251)	$ (916,469)	$ (20,462,818)	$ -	$ (456,832)	$ (32,305)	$ (427,332)
2029	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 116,164	$ 479,057	$ 45,615	$ 599,454	$ 45,316	$ (1,285,607)	$ (903,250)	$ (21,366,068)	$ -	$ (450,243)	$ (31,839)	$ (421,169)
2030	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 119,069	$ 491,034	$ 46,755	$ 614,441	$ 46,449	$ (1,317,747)	$ (890,223)	$ (22,256,291)	$ -	$ (443,749)	$ (31,379)	$ (415,094)
2031	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 122,045	$ 503,309	$ 47,924	$ 629,802	$ 47,610	$ (1,350,691)	$ (877,383)	$ (23,133,674)	$ -	$ (437,349)	$ (30,927)	$ (409,107)
2032	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 125,096	$ 515,892	$ 49,122	$ 645,547	$ 48,801	$ (1,384,458)	$ (864,728)	$ (23,998,402)	$ -	$ (431,041)	$ (30,481)	$ (403,207)
2033	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 128,224	$ 528,790	$ 50,350	$ 661,685	$ 50,021	$ (1,419,069)	$ (852,256)	$ (24,850,658)	$ -	$ (424,824)	$ (30,041)	$ (397,391)
2034	$ -	$ 93,016	$ 383,595	$ 36,525	$ 480,000	$ 36,286	$ -	$ 131,429	$ 542,009	$ 51,609	$ 678,227	$ 51,271	$ (1,454,546)	$ (839,964)	$ (25,690,623)	$ -	$ (418,697)	$ (29,608)	$ (391,659)
2035	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 176,996	$ 842,008	$ 66,124	$ 1,535,196	$ 52,553	$ (2,672,877)	$ (1,484,154)	$ (27,174,776)	$ -	$ (602,533)	$ (29,181)	$ (852,440)
2036	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 181,421	$ 863,058	$ 67,777	$ 1,573,576	$ 53,867	$ (2,739,699)	$ (1,462,748)	$ (28,637,524)	$ -	$ (593,843)	$ (28,760)	$ (840,145)
2037	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 185,956	$ 884,635	$ 69,471	$ 1,612,915	$ 55,213	$ (2,808,191)	$ (1,441,650)	$ (30,079,174)	$ -	$ (585,277)	$ (28,345)	$ (828,028)
2038	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 190,605	$ 906,751	$ 71,208	$ 1,653,238	$ 56,594	$ (2,878,396)	$ (1,420,857)	$ (31,500,031)	$ -	$ (576,836)	$ (27,936)	$ (816,085)
2039	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 195,370	$ 929,419	$ 72,988	$ 1,694,569	$ 58,009	$ (2,950,356)	$ (1,400,364)	$ (32,900,395)	$ -	$ (568,516)	$ (27,533)	$ (804,314)
2040	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 200,255	$ 952,655	$ 74,813	$ 1,736,933	$ 59,459	$ (3,024,115)	$ (1,380,166)	$ (34,280,562)	$ -	$ (560,316)	$ (27,136)	$ (792,714)
2041	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 205,261	$ 976,471	$ 76,683	$ 1,780,357	$ 60,945	$ (3,099,718)	$ (1,360,260)	$ (35,640,822)	$ -	$ (552,235)	$ (26,745)	$ (781,280)
2042	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 210,392	$ 1,000,883	$ 78,600	$ 1,824,866	$ 62,469	$ (3,177,210)	$ (1,340,641)	$ (36,981,463)	$ -	$ (544,270)	$ (26,359)	$ (770,012)
2043	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 215,652	$ 1,025,905	$ 80,566	$ 1,870,487	$ 64,031	$ (3,256,641)	$ (1,321,305)	$ (38,302,768)	$ -	$ (536,420)	$ (25,979)	$ (758,906)
2044	$ -	$ 122,210	$ 581,378	$ 45,656	$ 1,060,000	$ 36,286	$ -	$ 221,044	$ 1,051,553	$ 82,580	$ 1,917,250	$ 65,631	$ (3,338,057)	$ (1,302,248)	$ (39,605,015)	$ -	$ (528,683)	$ (25,604)	$ (747,960)

Attachment C: Dewatering Technology Rating

Updated Dewatering Technology Ratings

		Centrifuge	Screw Press
	OVERALL WEIGHT PERCENTAGE	**ALTERNATIVE SCORING**	
ECONOMIC			
Capital Cost	25%	4	3
Present Worth O&M Costs	20%	4	3
Efficiency: Power	5%	4	4
Efficiency: Polymer	5%	3	4
Efficiency: Fuel Cost for FBI	5%	4	2
NON-ECONOMIC			
Proven Experience and Reliability	8%	4	2
Maintenance Impacts	12%	2	3
Operational Complexity	12%	3	4
Ability to handle variations in feed sludge characteristics	4%	3	3
Ability to resist wear due to abrasive solids	4%	2	3
Washwater Requirements–Impact to Treatment Process			
TOTAL	100%	3.5	3.1

Alternative Rating Scale: 4 = Lowest Cost, Highest Performance, Most Beneficial
1 = Highest Cost, Lowest Performance, Least Beneficial

Dewatering Technology Rating

DECEMBER 2019

		Alt_1 Centrifuge	Alt_2 Screw Press	Alt_2A Screw Press (High Capacity)	Alt_3 Belt Filter Press	Alt_1 Centrifuge	Alt_2 Screw Press	Alt_2A Screw Press (High Capacity)	Alt_3 Belt Filter Press
	OVERALL WEIGHT PERCENTAGE	**ALTERNATIVE SCORING**				**WEIGHTED SCORES FOR ALTERNATIVES**			
ECONOMIC									
Capital Cost	30%	4	1	2	3	1.2	0.3	0.6	0.9
Present Worth O&M Costs	30%	4	1	2	3	1.2	0.3	0.6	0.9
NON-ECONOMIC									
Proven Experience	8%	4	2	1	4	0.32	0.16	0.08	0.32
Operations and Maintenance Impacts	8%	3	3	4	2	0.24	0.24	0.32	0.16
Operational Complexity	6%	2	4	4	3	`0.12	0.24	0.24	0.18
Ability to handle variations in feed sludge characteristics	8%	3	2	2	3	0.24	0.16	0.16	0.24
Ability to resist wear due to abrasive solids	6%	1	2	2	3	0.06	0.12	0.12	0.18
Washwater Requirements–Impact to Treatment Process	4%	4	2	3	1	0.16	0.08	0.12	0.04
TOTAL	100%	25	17	20	22	**3.5**	**1.6**	**2.2**	**2.9**

Alternative Rating Scale: 4 = Lowest Cost, Highest Performance, Most Beneficial…………..1 = Highest Cost, Lowest Performance, Least Beneficial

Attachment D: Bench-Scale Testing Summary Technical Memorandum

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum

WWTF Centrifuge Bench Scale Testing

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

27 OCTOBER 2020

7733 Forsyth Blvd
11th Floor, Suite 1100
Clayton, MO 63105

Prepared for: Metropolitan St. Louis Sewer District (MSD) / Black and Veatch (BV)

Project Title: Bissell Point and Lemay WWTF Fluidized Bed Incinerators

BC Project No.: 153644

Technical Memorandum

Subject: Bissell Point and Lemay WWTF Centrifuge Bench Scale Testing

Date: October 27, 2020

To: Bently Green, PE, Black & Veatch Project Manager

From: Dave Yates, PE, Brown and Caldwell Project Manager

Copy to: Matt Fishman, PE*, Brown and Caldwell Design Manager

Submitted by: ______________________________
Dave Yates, Missouri License No. 2008010469, Expiration 12/31/2020

Prepared by: Jeremy Rosemann

Reviewed by: ______________________________
Al Sehloff, PE*, Senior Technical Engineer

____
Matt Fishman, PE*, Design Manager

** Licensed in other states*

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List of Abbreviations

BC	Brown and Caldwell
BFP	Belt Filter Press
gpm	Gallons per minute
lb/hr	Pounds per hour
MSD	Metropolitan Sewer District
TS	Total solids
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

1.0 Introduction

As part of the Metropolitan St. Louis Sewer District Bissell and Lemay WWTF Fluidized Bed Incinerators (12565) project, multiple horizontal centrifuge manufacturers were engaged to complete laboratory bench testing. The purpose of this testing was to further develop assumptions regarding the technologies' in-process performance. Equipment manufacturers were asked to recommend an equipment model from their portfolio along with that model's specifications and the recommended polymer for this application. The samples were taken at the Bissell Point WWTP (Bissell) and Lemay WWTP (Lemay). The following manufacturers were contacted for bench testing.

Table 1. Centrifuge Manufacturers for Bench Testing

Manufacturer	Laboratory Location
Alfa Laval	104700 Deer Trail Drive Houston, TX 77038 281-985-4488
Andritz	1010 Commercial Blvd. S. Arlington, TX 76001 817-465-5611
Flottweg	10700 Toebben Drive Independence, KY 41051 859-448-2300
GEA	100 Fairway Court Northvale, NJ 07647 913-901-7708

2.0 Testing, Sampling, and Schedule

2.1 Testing

On April 29, 2020 the four centrifuge manufacturers were contacted regarding bench scale testing of the thickened sludge at Bissell and Lemay. The pre-determined sample day was May 4, 2020 to maximize the possibility of river mud existing in the sludge sample. The objective was to anticipate plant-specific performance of centrifuges during high river events and centrifuge performance in general.

The manufacturers were supplied a testing sheet at the time of the initial request correspondence. This sheet provided a summary description of the feed solids stream to dewatering at Bissell and Lemay along with typical performance information for the existing belt filter presses in service. Design solids production numbers relevant at the time of the testing request were provided as a basis for manufacturers' dewatering technology model recommendations and minimum testing objective requirements were provided.

Manufacturers were requested to test sludge samples with the mannich polymer currently utilized at each site and compare dewatering performance against other conditioning polymers chosen by the manufacturer. Based upon the bench testing results, manufacturers then provided a recommended polymer and recommended dewatering equipment along with predicted performance figures. Testing objectives can be viewed in the table below.

Table 2. Bench Testing Objectives

Testing with Plant Polymer
Plant Polymer
Effective chemical dewatering dosages and dilutions required
Anticipated cake solids concentration
Anticipated solids capture
Testing with Recommended Polymer
Recommended dewatering conditioning agent
Effective chemical dewatering dosages and dilutions required
Anticipated cake solids concentration
Anticipated solids capture
Recommended Centrifuge
Recommended dewatering unit
Recommended dewatering unit bowl speed
Anticipated equipment hydraulic loading rate
Anticipated equipment solids loading rate
Anticipated cake solids concentration
Anticipated solids capture
Recommended centrifuge design features for optimal handling of grit and river mud during storm/flood events
Calculated G-Volume at bowl rpm of 2,900 and also at recommended bowl rpm for this installation. G-Volume calculation should include bowl cylinder and discharge cone.

The blank testing sheet can be found in Attachment A.

2.2 Sampling

Sludge

Manufacturers were responsible for supplying test kits for the purpose of obtaining sludge samples. Manufacturers were instructed to arrive at each plant within a pre-determined time frame. Sludge sample collection would then be coordinated with plant staff with assistance from Brown and Caldwell. Manufacturers and/or their reps were to arrive at Lemay at 9:00 AM, May 4, 2020. Collection at Bissell would occur after with a tentative start time of 11:00 AM. Sample collection outside of this window would deem the sludge samples and resulting bench test results invalid for the purposes of this study.

Polymer

The mannich polymers currently utilized for dewatering by MSD at Bissell is Polydyne C-437 and is Polydyne SW-228 at Lemay. Per the testing criteria, manufacturers were required to test dewatering performance with this polymer. Manufacturers were supplied samples of these polymers directly from the District's polymer supplier, which were shipped directly from the supplier to the individual testing laboratories.

2.3 Schedule

Initial email correspondence regarding bench testing for MSD transpired on April 29, 2020. Table 3 lists the dates manufacturers' reports were received Brown and Caldwell. Some reports contained all requested information. The manufacturers that required a follow-up are noted below along with the final receipt of requested information.

Table 3. Bench Testing Sample Preparation and Report Delivery

Manufacturer	Report Delivery Date	Follow-up Required?	Final Report Delivery
Alfa Laval	5/26/2020	YES	
Andritz	6/9/2020	YES	
Flottweg	6/3/2020	YES	
GEA	6/5/2020	YES	

3.0 Bench Testing Results

3.1 Sludge Sample Results

All centrifuge manufacturers supplied test results comparing the current plant polymers (mannich) to their polymer of choice, except GEA. The manufacturers provided results for sludge characteristics along with their centrifuge test results. A comparison of their sludge characteristics can be viewed below. The Mississippi River level at the St. Louis stage was measured to be 24 ft. on May 4, 2020.

Table 4. Manufacturers Sludge Characteristics, Bissell Point

Manufacturer	Inlet Solids, %TS	pH	Ash Content, %	Volatile Solids, %
Alfa Laval	3.48	6.0-7.0	48.8	**51.2**
Andritz	5.12	5.8	57.6	42.4
Flottweg	4.53	6	**56.5**	43.5
GEA	5.29	-	**56.6**	43.4

***Bold** values indicate values calculated from manufacturers' provided information*

Table 5. Manufacturers Sludge Characteristics, Lemay

Manufacturer	Inlet Solids, %TS	pH	Ash Content, %	Volatile Solids, %
Alfa Laval	2.50	6.0-7.0	35.7	**64.3**
Andritz	2.80	5.5	39.2	60.8
Flottweg	1.8	5	**38.3**	61.7
GEA	2.93	-	**37.8**	62.2

***Bold** values indicate values calculated from manufacturers' provided information*

The sludge sample characteristic results from Bissell Point showed a low volatile solids percentage. This was expected as the sampling occurred concurrently with a high Mississippi River level. Typically, a high river level results in increased sludge production and lower volatile solids percentages at the Bissell Point WWTF.

The sludge characteristics at Lemay are indicated to possess a volatile solids percentage in the low to mid-60's. This falls within the normal range for the dewatering process. This was expected as Lemay is less effected by river levels as compared to Bissell Point.

3.2 Alfa Laval

Alfa Laval provided expected performance for centrifuges at both Bissell Point and Lemay. The expected performances were based upon the testing conducted in their laboratory. Their testing was conducted with both the individual plants' polymers and with a polymer recommended by the manufacturer.

Table 6. Alfa Laval Expected Performance, Plant Mannich Polymer

Sample Location	Inlet Solids, %TS	Conditioning	Dosage, lb APS/dry ton solids	Cake Solids %TS	Solids Capture %
Bissell Point	3.48	Polydyne CE-437 (mannich)	13.0 – 13.5	33 – 35	95
Lemay	2.50		12.5 – 13.0	34 – 36	95

Alfa Laval participated in the first round of bench testing in January 2020. The sample tested during this round of bench testing required a higher polymer dose to achieve the same cake solids concentrations. The previous bench testing indicated a polymer dose of 10 – 10.5 lb/ton. This difference is noted by Alfa Laval in their report.

Alfa Laval tested a variety of polymers with their thickened sludge samples from Bissell Point and Lemay. They preferred cationic emulsion polymers as the recommended dewatering polymer. This manufacturer indicated the recommended emulsion polymers produced only slightly better cake solids concentrations than testing with the plant supplied mannich polymers. The emulsion polymer performance was only achieved with approximately twice the dosage rates as compared to the mannich polymer results.

Table 7. Alfa Laval Expected Performance, Recommended Polymer

Sample Location	Inlet Solids, %TS	Conditioning	Dosage, lb APS/dry ton solids	Cake Solids %TS	Solids Capture %
Bissell Point	3.48	Polydyne C-6286 (cationic, emulsion)	20-24	34-36	95
Lemay	2.50	Polydyne C-6286 (cationic, emulsion)	19-23	35-37	95

3.3 Andritz

Andritz conducted bench testing using the current plant mannich polymers along with selected polymers of their choosing. They conducted tests for both belt filter presses and centrifuge. The belt filter press results are not discussed here. To review this testing and their conclusions, please see the attached manufacturer reports.

Andritz has tested the sludge at Bissell Point and Lemay multiple times since 2010. These sludge results are noted in their report. It was noted most importantly that the sludge sample from Bissell Point had a much lower volatile solids percentage than previous tests. It was also noted this sludge has higher abrasiveness than previous samples and other primary/secondary blended sludges. It was also noted that Lemay's sample likely has higher abrasiveness as well.

Table 8. Andritz Test Results, Plant Mannich Polymer, Bissell Point

Spin Time, Minutes	G Force	Type of Test	Polymer	Dosage, lb APS/dry ton solids	Plug Solids, %
5	3000	Tube	CE-437	10.4	20.6
5	2000	Screen		10.4	37.8
5	2500	Screen		10.4	35.7
5	3000	Screen		10.4	36.8
10	3000	Screen		10.4	37.7
20	3000	Screen		10.4	40.7
10	3000	Screen	C-9530 (cationic, emulsion)	17.9	39.2
20	3000	Screen		17.9	41.4

Table 9. Andritz Test Results, Plant Mannich Polymer, Lemay

Spin Time, Minutes	G Force	Type of Test	Polymer	Dosage, lb APS/dry ton solids	Plug Solids, %
5	3000	Tube	SW-228	10.4	15.5
5	2000	Screen		10.4	31.6
5	2500	Screen		10.4	33.2
5	3000	Screen		10.4	34.3
10	3000	Screen		10.4	37.1
20	3000	Screen		10.4	40.2
10	3000	Screen	C-9530 (cationic, emulsion)	17.9	40.5
20	3000	Screen		17.9	41.4

Andritz concluded that the sludge sample received from both plants indicated a large amount of debris and fiber in the dewatering feed, most likely due to the wet weather conditions. They also concluded that the currently utilized mannich polymers at each plant were effective for centrifuge dewatering. This polymer at the tested 10.4 lb/ton dosage resulted in cake solids ranging from 31-40 %TS for Lemay and 34-39 %TS for Bissell Point.

3.4 Flottweg

Flottweg conducted bench testing using the supplied mannich polymers and three polymers of their choosing. The information gathered from the testing is summarized in their report as expected performance numbers.

Table 10. Flottweg Expected Performance

Sample Location	Inlet Solids, %TS	Conditioning	Dosage, ob APS/dry ton solids	Cake Solids, %TS
Bissell Point	4.53	Mannich (not specifically defined)	7-13	25-35
Lemay	1.80		15-25	25-35
Bissell Point	4.53	FW 1006	4-10	25-35
Lemay	1.80	FW 1508	9-15	25-35

Flottweg states that the supplied mannich polymers are not recommended for use in a centrifuge due to “poor shear resistance and a higher chemical consumption”. Their recommendation, with input from MSD’s polymer supplier, is to conduct a series of testing with more shear resistant mannich products. Based upon the conclusions stated by Flottweg the information given regarding the expected performances is based off historical data and does not necessarily reflect the tested performance data.

3.5 GEA

GEA conducted bench testing only with polymers of their choosing. The stated reason was due to the late arrival of the supplied mannich polymers. The polymers tested were all cationic emulsion types: Clarifloc C-6266, Clarifloc C-6267, and Solenis K-274 FLX. The pertinent results of the testing are shown below. Clarifloc C-6267 did not yield cake and the results from these tests are excluded.

Table 11. GEA Testing Results, Bissell Point

Polymer	Dosage, lb APS/dry ton solids	Timing, Pours	Cake Solids, %TS
C-6266	9	10	34
	11	10	34
	12	10	35
	14	10	35
	16	12	36
	17	13	34
	19	13	37
	20	15	35
	22	20	34
	23	20	34
K-274 FLX	7	20	33
	8	20	35
	10	20	36
	11	20	33
	13	20	34
	15	20	35
	16	20	35
	18	20	31
	20	20	35
	21	20	36

Table 12. GEA Testing Results, Lemay

Polymer	Dosage, lb APS/dry ton solids	Timing, Pours	Cake Solids, %TS
C-6266	11	10	34
	14	10	34
	17	10	35
	20	10	35
	22	12	36
	25	13	34

Polymer	Dosage, lb APS/dry ton solids	Timing, Pours	Cake Solids, %TS
	28	13	37
	31	15	35
	34	20	34
K-274 FLX	9	20	34
	12	20	34
	15	20	34
	18	20	34
	21	20	32

For Lemay, GEA concludes that both polymers, C-6266 and K-274 FLX, will yield similar cake solids concentrations: 31 – 34%. They state that the larger range of doses for C-6266 leads to the recommendation of that product for Lemay. For Bissell Point, GEA concludes that both polymers, C-6266 and K-274 FLX, will yield similar cake solids concentrations: 33 – 36%. They believe the dosage ranges for polymers is similar and either product is viable.

3.6 Conclusions

All manufacturers were able to obtain adequate performance dewatering the sludge samples from both Lemay and Bissell Point. Cake solids were indicated to consistently perform higher than 30%. Manufacturers who tested with mannich were able to obtain performances similar to the tests with emulsion polymers. There was concern noted by Flottweg that the mannich polymers currently utilized by the two WWTFs may not be robust enough to consistently hold up to the high shear rates experienced within a centrifuge used for the designed application. There is also concern with the ability of mannichs to consistently dewater the wide range of sludges processed at the two plants. Discussion needs to continue to select the right polymer for the planned dewatering applications.

It was noted by the manufacturers that the sludge samples from both sites contained higher than normal mud and silt. This was expected as the sludge samples were collected during a high river event. It was noted by Andritz that this level mud and silt leads to greater abrasiveness of the sludge. This factor will need to be considered when selecting the centrifuge for this application. It was noted that Bissell Point’s sludge sample contained a low concentration of volatile solids also due to the timing of the sample collection.

Attachment 1

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

BISSELL POINT WWTP INFORMATION	
Solids process flow diagram	Attached
Water Source	Combined sewer system
Current Dewatering Data	
Dewatering equipment	Belt Filter Presses
Dewatering feed conditioning	Mannich polymer
Mannich polymer dose, active pounds of polymer/dry tons feed solids	5
Dewatered cake solids concentration, %TS	30
Dewatering operational schedule	24 hr/day, 7 day/week
Wastewater Treatment	
Treatment process	Grit removal, Primary clarifiers, Trickling filters, Waste activated sludge (not in use), future chemical phosphorus removal
Operational Observations	
Seasonal impacts on dewatering performance	Mississippi River level. Increase in river level (specifically above flood stage) results in increased feed TS% and decreased VS%.
Dewatering Feed Characteristics	
Narrative description of feed solids	Bissell Point WWTF primary solids fraction of sludge produced is relatively high for municipal wastewater treatment plant sludge and the volatile solids fraction of total solids is relatively low. Generally, high primary solids fraction and low volatile solids contribute to relatively high solids concentrations for blended thickened sludge and a relatively high belt filter press dewatered sludge average solids concentration. This is reflected in the recent historical average thickened sludge solids concentrations 5.4 %TS (8.1 %TS for flood conditions) and the historical average dewatered sludge solids concentration of 29 %TS (33 %TS for flood conditions). Operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which likely indicates an increase in gritty abrasive material during these events.
Primary Solids Fraction, % average, range	79, 52-91
Volatile Solids, % average, range	39, 29-58
Thickened solids concentration (basis for equipment sizing)	4.0 - 5.0% TS
Design Solids Production	
Average Annual, dry lb/day	269,600
Average Annual, gal/day	681,000
Peak Week, dry lb/day	600,600
Peak Week, gal/day	1,440,000
Dewatering System Performance Requirements	
Maximum solids loading rate, dry lb/hr	25,000
Maximum hydraulic loading rate, gpm	1,000
Minimum dewatered cake solids conc, %TS	25
Minimum solids capture	95%

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

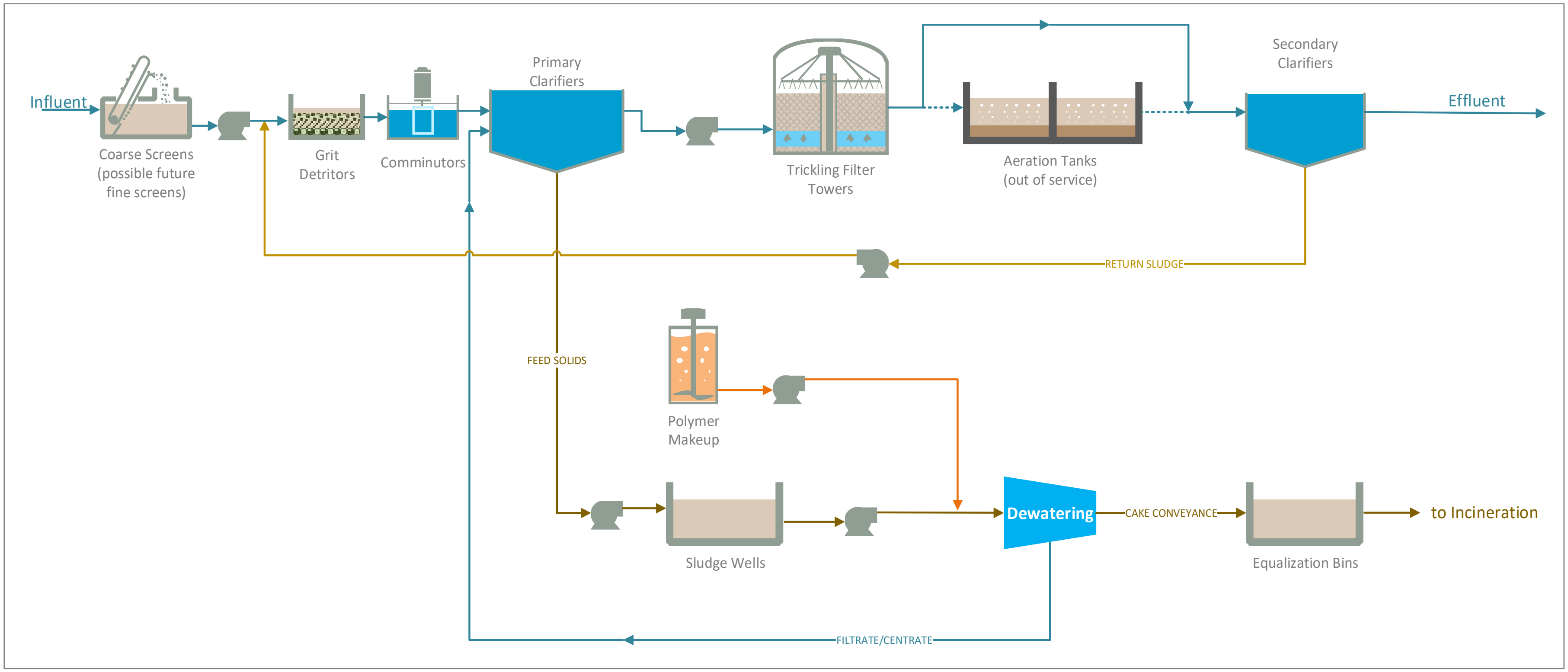
BISSELL POINT BLENDED SLUDGE SAMPLE FORM	
Sample data	
Sample Date	
Rainfall previous 72 hours, inches	
Mississippi River Level, ft	
Temperature, deg F	
pH	
Solids Concentration, %TS	
Volatile solids, % of total solids	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

BISSELL POINT WWTP	
Testing Objectives	
Sample results schedule	*Manufacturers are expected to return results within 3 weeks of receiving sludge sample*
Dewatering equipment to be tested	*CENTRIFUGE*
Testing with Plant Polymer	
Plant Polymer	*Polydyne, Mannich, CE-437*
Effective chemical dewatering dosages and dilutions required	
Anticipated cake solids concentration	
Anticipated solids capture	
Testing with Recommended Polymer	
Recommended dewatering conditioning agent	
Effective chemical dewatering dosages and dilutions required	
Anticipated cake solids concentration	
Anticipated solids capture	
Recommended Centrifuge	
Recommended dewatering unit	
Recommended dewatering unit bowl speed	
Ancticipated equipment hydraulic loading rate	
Anticipated equipment solids loading rate	
Anticipated cake solids concentration	
Anticipated solids capture	
Recommended centrifuge design features for optimal handling of grit and river mud during storm/flood events	
Calculated G-Volume at bowl rpm of 2,900 and also at recommended bowl rpm for this installation. G-volume calculation should include bowl cylinder and discharge cone.	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

Bissell Point General Flow Diagram



METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

LEMAY WWTP INFORMATION	
Solids process flow diagram	Attached
Water Source	Combined sewer system
Current Dewatering Data	
Dewatering equipment	Belt Filter Presses
Dewatering feed conditioning	Mannich polymer
Mannich polymer dose, active pounds of polymer/dry tons feed solids	5
Dewatered cake solids concentration, %TS	30
Dewatering operational schedule	24 hr/day, 7 day/week
Wastewater Treatment	
Treatment process	Pre-aeration, fine screens, grit removal, primary clarifiers, aeration basins, and secondary clarifiers
Operational Observations	
Seasonal impacts on dewatering performance	Mississippi River level. Increase in river level (specifically above flood stage) results in increased feed TS% and decreased VS%.
Dewatering Feed Characteristics	
Narrative description of feed solids	Activated sludge secondary treatment is provided at Lemay. Waste activated sludge typically does not thicken as well as some other municipal wastewater treatment plant sludges. This is reflected in the recent historical average thickened sludge solids concentration 3.5 %TS (4.4 %TS for flood conditions) for Lemay versus 5.4 %TS (8.1 %TS flood) for Bissell Point. The historical average dewatered sludge solids concentration for Lemay has been 29 %TS (31 %TS for flood conditions). Before installation of the fine screens, operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which indicates an increase in debris during these events.
Primary Solids Fraction, % average, range	55, 22-77
Volatile Solids, % average, range	51, 37-72
Thickened solids concentration (basis for equipment sizing)	3.0 - 4.0% TS
Design Solids Production	
Average Annual, dry lb/day	223,200
Average Annual, gal/day	890,000
Peak Week, dry lb/day	423,800
Peak Week, gal/day	1,270,000
Dewatering System Performance Requirements	
Maximum solids loading rate, dry lb/hr	17,700
Maximum hydraulic loading rate, gpm	1,000
Minimum dewatered cake solids conc, %TS	25
Minimum solids capture	95%

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

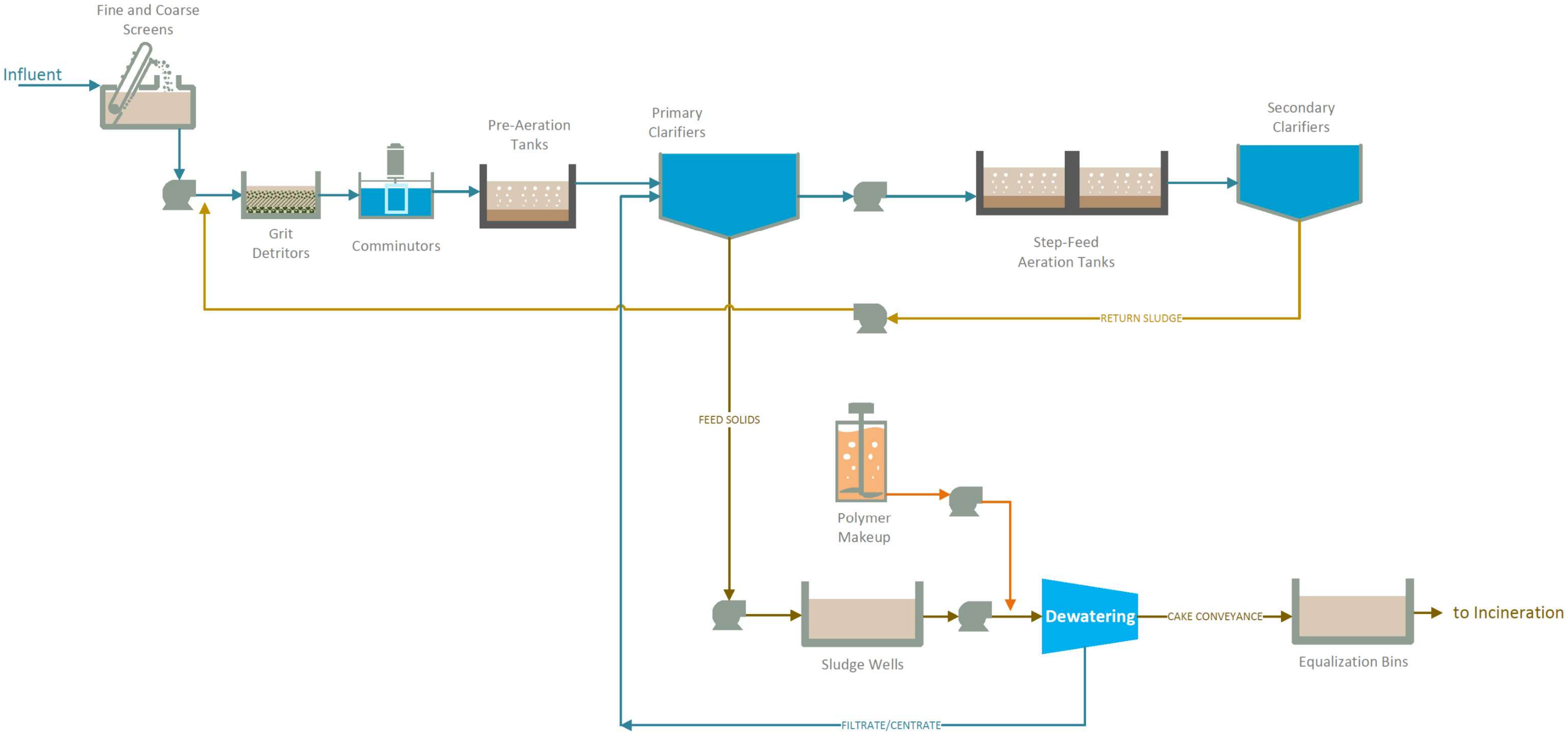
BISSELL POINT BLENDED SLUDGE SAMPLE FORM	
Sample data	
Sample Date	
Rainfall previous 72 hours, inches	
Mississippi River Level, ft	
Temperature, deg F	
pH	
Solids Concentration, %TS	
Volatile solids, % of total solids	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

LEMAY WWTP	
Testing Objectives	
Sample results schedule	*Manufacturers are expected to return results within 3 weeks of receiving sludge sample*
Dewatering equipment to be tested	*CENTRIFUGE*
Testing with Plant Polymer	
Plant Polymer	*Polydyne, Mannich, SW-228*
Effective chemical dewatering dosages and dilutions required	
Anticipated cake solids concentration	
Anticipated solids capture	
Testing with Recommended Polymer	
Recommended dewatering conditioning agent	
Effective chemical dewatering dosages and dilutions required	
Anticipated cake solids concentration	
Anticipated solids capture	
Recommended Centrifuge	
Recommended dewatering unit	
Recommended dewatering unit bowl speed	
Ancticipated equipment hydraulic loading rate	
Anticipated equipment solids loading rate	
Anticipated cake solids concentration	
Anticipated solids capture	
Recommended centrifuge design features for optimal handling of grit and river mud during storm/flood events	
Calculated G-Volume at bowl rpm of 2,900 and also at recommended bowl rpm for this installation. G-volume calculation should include bowl cylinder and discharge cone.	

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

Lemay General Flow Diagram



Attachment 2

Alfa Laval Environmental Laboratory Summary

Reference: Bissell Point WWTP, St Louis, MO

The Alfa Laval environmental laboratory received a sludge sample in May 2020 to test for a centrifuge and estimate its performance.

1) Laboratory sludge characteristics:

Sludge type:	Raw blend of primary and trickling filter, that is co-settled (Iron present??)
Sludge color:	Blackish
Temperature:	69.0F
pH:	6.0-7.0
Ash content:	48.8%
Feed solids, TS:	3.48%

2) Expected performance:	Centrifuge
Cake solids:	33-35%
Capture:	95%
Polymer manufacturer:	Plant, Polydyne C437 (Cationic, Mannich)
Polymer dosage:	276-286 neat lbs/ton
Activity of polymer:	4.64% (assumed to calculate active lbs)
Active polymer dosage:	13.0-13.5 lbs/ton

3) Expected performance:	Centrifuge
Cake solids:	34-36%
Capture:	95%
Polymer manufacturer:	Polydyne C6286 (Cationic, Emulsion)
Polymer dosage:	45-55 neat lbs/ton
Activity of polymer:	43%
Active polymer dosage:	20-24 lbs/ton

Additional emulsion products were tested. This product recommended generated the driest cake at the best dosage. The SW 228 mannich was tested on this sample also. The cake solids and polymer dosage numbers were equal to the current product.

Also, the polymer dosage on this sample on the current product was much higher than the test in January. This cannot be explained by the Alfa Laval laboratory.

Kimberly Wilson
Applications Specialist
Alfa Laval

Alfa Laval Environmental Laboratory Summary

Reference: Lemay WWTP, St Louis, MO

The Alfa Laval environmental laboratory received a sludge sample in May 2020 to test for a centrifuge and estimate its performance.

1) Laboratory sludge characteristics:
   Sludge type: Raw blend of primary and secondary (unknown ratio)
   Sludge color: Blackish
   Temperature: 69.0F
   pH: 6.0-7.0
   Ash content: 35.7%
   Feed solids, TS: 2.50%

2) Expected performance: Centrifuge
   Cake solids: 34-36%
   Capture: 95%
   Polymer manufacturer: Polydyne C437 (Cationic, Mannich)
   Polymer dosage: 264-274 neat lbs/ton
   Activity of polymer: 4.64%
   Active polymer dosage: 12.5-13.0 lbs/ton

Plant product is Polydyne SW228. That product was tested on this sample and produced a slightly lower cake at the same dosage rate as the C437.

3) Expected performance: Centrifuge
   Cake solids: 35-37%
   Capture: 95%
   Polymer manufacturer: Polydyne C6286 (Cationic, Emulsion)
   Polymer dosage: 43-53 neat lbs/ton
   Activity of polymer: 43%
   Active polymer dosage: 19-23 lbs/ton

Kimberly Wilson
Applications Specialist
Alfa Laval

Laboratory Report

METROPOLITAN ST. LOUIS SEWER DISTRICT

Report No's.: L-14312, L-14313
Opportunity No.: 3257185
Application: 2997-00217
Product Home: 502, 546
Product Group: 4418, 4418
Division: 41

Date Report Issued: June 5, 2020
Date Sample Received: May 5, 2020
Author: Shaun Hurst
Copy: Mahoney, Hausegger

ENGINEERED SUCCESS

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TABLE OF CONTENT

ANDRITZ LABORATORY REPORT

COMPANY	:	St. Louis Municipal Sewer District St. Louis, MO
PROJECT	:	Lemay Wastewater Treatment Plant Bissell Point Wastewater Treatment Plant
SAMPLE TYPE	:	L-14312 – Lemay WWTP Co-Settled Primary / Secondary L-14313 – Bissell Point WWTP Co-Settled Primary /Trickling Filter
DATE	:	June 5, 2020

1. Introduction:

Two (2) each five (5) gallon samples were received in the ANDRITZ laboratory on May 5, 2020. One of the samples was co-settled primary / secondary sludge received from the Lemay WWTP and the other sample was co-settled primary / trickling filter sludge from the Bissell Point WWTP. Both samples were sent in for dewatering testing with focus on decanter centrifuge dewatering and the change in characteristics of the sludge during wet weather or high river water level. A previous sample from Bissell Point was received in January 2020. A Lemay WWTP sample was tested in 2010.

2. Objectives:

The specific objectives of these laboratory tests were to:

2.1 Analyze the samples as received for physical properties and compare with previous samples.

2.2 Conduct polymer evaluation with the two (2) Mannich solution style polymers currently used on-site.

2.3 Conduct Belt Filter Press Testing (BFP) with the sample.

2.4 Conduct Centrifuge spin-down testing with the sample.

3. Sample Analysis Results and Observations:

3.1 Sample Analysis Lemay WWTP

The sample from Lemay WWTP (L-14312) was black in color and emitted a septic odor. The sample contained 2.80 %TS total solids, 2.40 %TSS suspended solids and the volatile solids was 60.8 % of TS. The screen analysis indicated a high amount of debris and fiber with 21.7 % of the suspended solids retained on the 30, 50 and 100 mesh sieves. The pH was low at 5.5 and Capillary Suction Time was short at 45.4 seconds. The five-minute spin-down tests with the sample produced high plug solids at 12 – 17 %TS with a comparatively low solids volume at 15 – 23.4 % at G-forces of 1000 to 4000 G's. A sample of cake from existing Belt Filter Presses (BFP) had a dryness of 24.8 %TS

The current Lemay WWTP sample was different from previous samples which may be due to the wet weather or high river levels. The screen analysis indicates more solids retained on the 30, 50 and 100 mesh sieves where grit, sand are typical found. However, the feed solids content was actually lower than anticipated. Previous samples were over 3.0 %TS and closer to the 3.5 %TS reported average. Volatile solids of the current sample was higher than the 51 % average. High volatile solids is typically an indication of more organic and biological material in a sludge. While lower volatile solids indicates higher inorganic material such as sand, silt and grit. Based upon these results, the abrasivity of the sample will be higher than is typical for similar primary / secondary sludge blends.

Photo 3.1.1

3.2 Lemay WWTP Sample Analysis

Lab Number	Reported Range	L-14312	L-10893	L-10752
Date		5/5/20	11/2/10	8/18/10
Total Solids* (%TS @ 105ºC)	3.0 – 4.0	2.84	3.1	4.7
Suspended Solids** (%SS @ 105ºC)		2.40	3.0	4.6
Plug Solids (%TS, @ 1000 G's and 5 min)		12.5	–	–
Plug Solids (%TS, @ 2000 G's and 5 min)		14.6	–	–
Plug Solids (%TS, @ 3000 G's and 5 min)		16.4	–	–
Plug Solids (%TS, @ 4000 G's and 5 min)		17.6	–	–
Spin-Down Volume (%, 1000 G's, 5 min)		23.4	–	–
Spin-Down Volume (%, 2000 G's, 5 min)		19.7	–	–
Spin-Down Volume (%, 3000 G's, 5 min)		17.4	–	–
Spin-Down Volume (%, 4000 G's, 5 min)		15.3	–	–
pH @ 20°C		5.5	5.6	5.4
Conductivity (mS/cm)		NA	–	–
Specific Gravity		1.011	–	–
Solids Specific Gravity (Calculated)		1.6	–	–
Ash Content of Total Solids* (% of TS)		39.2	38.5	58.4
Volatile Solids Content* (% of TS)	51 avg 37 – 72	60.8	61.5	41.6
Capillary Suction Time (sec)		45.4	201.4	172.0
Screened Solids:				
+30 Mesh Fraction (% of SS)		4.3	3.8	3.2
30 x 50 Mesh Fraction (% of SS)		9.5	8.6	1.7
50 x100 Mesh Fraction (% of SS)		7.9	8.0	5.8
100 x 140 Mesh Fraction (% of SS)		4.1	4.6	2.1
140 x 230 Mesh Fraction (% of SS)		1.9	6.5	7.2
230 x 325 Mesh Fraction (% of SS)		4.6	5.5	5.9
-325 Mesh Fraction (% of SS)		67.7	62.9	74.1
Sludge Volume Index (SVI ml/g)		42	32.0	21.6
Settled Solids (1000 ml @ 30 min)		1000	1000	1000
Color		Black	Black	Black
Odor		Septic	Septic	Septic

Table 3.2.1

EPA Methods: *1684, **160.2

3.3 Bissell Point WWTP Sample Analysis

The sample from Bissell Point WWTP had a total solids content of 5.12 %TS and a suspended solids of 4.88 %TSS. The volatile solids were low for a municipal sludge at 42.4 % of TS. The pH was low at 5.8 and CST was 140.4 seconds. The conductivity was high at 2.85 mS/cm. Centrifuge spin-down testing was conducted with the sample for five minutes at 1000 to 4000 G's. The spin-down volume ranged from 25.6 % at 4000 G's up to 33.5 % at 1000 G's. A cake sample from one of the on-site Belt Filter Presses (BFP) had a dryness of 31.5 %TS.

The volatile solids content of the current sample was one of the lowest when compared to five (5) previous samples received from Bissell Point. Low volatile solids content can be an indication of higher inorganic content including sand, grit and silt. The screen analysis had similar percentage of solids on the 30, 50 and 100 mesh sieves when compared to previous samples. A large amount of fiber and grit was seen on the 30 and 50 mesh sieves maybe slightly more than for the previous sample (L-14242). Based upon this, the abrasivity of the sample is definitely higher than for previous samples and significantly higher than for other primary / secondary blended sludge.

Photo 3.3.1

3.4 Lemay WWTP Sample Analysis

Lab Number	Reported Range	L-14313	L-14242	L-10892	L-10751	L-5807
Date		May 2020	Jan 2020	Dec 2010	Aug 2010	Dec 1996
Total Solids* (%TS @ 105ºC)	4.0 – 5.0	5.1	4.4	2.9	6.7	4.0
Suspended Solids** (%SS @ 105ºC)		4.9	3.9	2.8	6.6	3.9
Plug Solids (%TS, @ 1000 G's and 5 min)		15.5	11.7			
Plug Solids (%TS, @ 2000 G's and 5 min)		17.4	13.5			
Plug Solids (%TS, @ 3000 G's and 5 min)		18.1	14.6			
Plug Solids (%TS, @ 4000 G's and 5 min)		19.1	15.5			
Spin-Down Volume (%, 1000 G's, 5 min)		33.5	34.4			
Spin-Down Volume (%, 2000 G's, 5 min)		28.1	30.4			
Spin-Down Volume (%, 3000 G's, 5 min)		26.9	27.8			
Spin-Down Volume (%, 4000 G's, 5 min)		25.6	25.8			
pH @ 20°C		5.8	5.5	5.7	5.2	5.7
Conductivity (mS/cm)		2.85	2.02	–	–	–
Specific Gravity		1.008	1.015	1.0	1.0	1.0
Solids Specific Gravity (Calculated)		1.19	1.51	–	–	–
Ash Content of Total Solids* (% of TS)		57.6	42.3	41.3	63.3	37.1
Volatile Solids Content* (% of TS)	29 – 58	42.4	57.7	58.7	36.7	62.9
Capillary Suction Time (sec)		140.4	660.7	287.1	210.0	383.4
Screened Solids:						
+30 Mesh Fraction (% of SS)		3.8	5.7	7.7	2.2	
30 x 50 Mesh Fraction (% of SS)		7.3	5.5	3.3	3.3	
50 x100 Mesh Fraction (% of SS)		4.5	5.8	4.4	3.5	9.3
100 x 140 Mesh Fraction (% of SS)		2.4	3.6	2.7	1.9	
140 x 230 Mesh Fraction (% of SS)		3.2	10.7	4.7	4.3	7.7
230 x 325 Mesh Fraction (% of SS)		3.4	6.6	4.3	3.2	
-325 Mesh Fraction (% of SS)		75.3	62.1	72.9	81.6	83.0
Sludge Volume Index (SVI ml/g)		20	25	36	15	–
Settled Solids (1000 ml @ 30 min)		990	1000	1000	1000	–
Color		Black	Black	Black	Black	
Odor		Septic	Rubber	Septic	Septic	

Table 3.2.2

EPA Methods: *1684, **160.2

4. Polymer Evaluation Results and Observations:

4.1 Polymer Evaluation

Samples of polymer currently used at each facility were shipped directly from Polydyne to the ANDRITZ laboratory for testing. Both polymers, SW-228 and CE-437, are labeled cationic charged Mannich polymers. Other polymers (C-9530 and C-6286), found to be effective from previous tests, were also evaluated. The two (2) Mannich polymers were diluted to 5 % concentration and the emulsion polymers to 0.5 % concentration. Jar testing was applied to evaluate each polymer with each sludge sample received. The active content of the Mannich polymers of 5 % which was previously reported and used for calculations. The emulsion polymer C-9530 active content was reported at 43 %.

Jar testing with the Lemay WWTP (L-14312) sample indicated that the currently used SW-228 Mannich polymer was effective at 6.3 active lbs/ton TSS (125.2 neat lbs/ton TSS) for a BFP application. After shear testing a higher dosage rate of 9.4 active lbs/ton TSS (187.7 neat lbs/ton) was found necessary for a centrifuge application.

Photo 4.1.1 L-14312 SW-228 Floc

Photo 4.1.2 L-14312 C-9530 Floc

Polymer evaluation with the Bissell Point WWTP sample (L-14313) indicated that CE-437 polymer was effective at a dosage rate of 5.6 active lbs/ton TSS (112.5 neat lbs/ton TSS) for a BFP application. A higher dosage rate was necessary after shear testing for a centrifuge application at 7.2 active lbs/ton TSS (143.5 neat lbs/ton TSS).

Photo 4.1.4 L-14313 CE-437 Floc

Photo 4.1.5 L-14313 C-9530 Floc

4.2 Polymers Evaluation

Polydyne (SNF)	CE-437, SW-228, C-9530, C-6262

Table 4.2.1

5. Belt Filter Press Test Results and Observations:

5.1 Laboratory BFP Test

Belt Filter Press (BFP) tests were conducted with both samples simulating an ANDRITZ 2.0m SMX®-S8 BFP. When using the plant polymer SW-228 for flocculating the Lemay WWTP sample, a cake dryness of 27.0 %TS was achieved from the 2.0m SMX®-S8 BFP simulation. For the Bissell Pt WWTP sample, a cake dryness of 30.9 %TS was achieved simulating the 2.0m SMX®-S8 BFP after flocculation with the plant's CE-437 polymer. Previous test results produced lower cake dryness of 24 – 26 %TS for Bissell Point (L-14242) in January 2020. This increase in cake dryness is most likely due to the lower volatile solids content with the current sample caused by the higher amount of sand, silt and grit from wet weather and flooding conditions.

Photo 5.1.1 L-14312 BFP Cake

Photo 5.1.2 L-14313 BFP Cake

5.2 Laboratory BFP Test

Lab Sample	L-14312	L-14313
Plant	Lemay	Bissell Point
BFP Type	2.0m SMX®-S8	
Polymer Utilized	SW-228	CE-437
Makeup Polymer Dilution (%)	5.0	5.0
Neat Polymer Dosage (lbs/ton TSS)	187.5	112.5
Active Polymer Dosage (lbs/ton TSS)	9.4	5.6
Recommended Belt Type	6093	6093
Throughput (lb TSS/hr)	2283	3000
Throughput (GPM)	190	120
Anticipated Solids Capture (%SS ± 1%)	95	95
Belt Speed (FPM)	15	15
Cake Thickness (mm)	7	8
Cake Solids (%TS)	27.0	30.9

Table 5.2.1

6. Laboratory Centrifuge Test

6.1 Centrifuge Test Results Lemay WWTP, Bissell Point WWTP

Centrifuge spin-down testing at 2000, 2500, and 3000 G’s was conducted with both samples received, using the current Mannich polymers from each facility, as well as an effective emulsion polymer for comparison. Cake dryness of 31 – 40 %TS was achieved from the spin-down tests with the Lemay WWTP sample using SW-228 depending upon G-force and retention time. Cake dryness was higher with the Bissell Point sample at 34 – 41 %TS. The cake was compact and dry from the screen tubes, indicating the centrifuge will operate at relatively high torque levels. Previous centrifuge testing produced cake dryness of 34 – 39 %TS with the Bissell Point WWTP sludge (L-14242, January 2020) and 30 – 36 %TS with the Lemay WWTP sludge (L-10893, December 2010).

Photo 6.1.1 Centrifuge Test Cake

6.2 Laboratory Centrifuge Test

L-14312 – Lemay WWTP

Spin Time (Minutes)	G Force	Type of Test	Polymer Type	Polymer Dosage Rate (active lbs/ton)	Plug Solids (%TS)
5	3000	Tube	None	None	15.5
5	3000	Tube	SW-228	10.4	15.5
5	2000	Screen	SW-228	10.4	31.6
5	2500	Screen	SW-228	10.4	33.2
5	3000	Screen	SW-228	10.4	34.3
10	3000	Screen	SW-228	10.4	37.1
20	3000	Screen	SW-228	10.4	40.2
10	3000	Screen	C-9530	17.9	40.5
20	3000	Screen	C-9530	17.9	41.4

Table 6.2.1

L-14313 – Bissell Point WWTP

Spin Time (Minutes)	G Force	Type of Test	Polymer Type	Polymer Dosage Rate (active lbs/ton)	Plug Solids (%TS)
5	3000	Tube	None	None	18.0
5	3000	Tube	CE-437	10.4	20.6
5	2000	Screen	CE-437	10.4	34.8
5	2500	Screen	CE-437	10.4	35.7
5	3000	Screen	CE-437	10.4	36.8
10	3000	Screen	CE-437	10.4	37.7
20	3000	Screen	CE-437	10.4	40.7
10	3000	Screen	C-9530	17.9	39.2
20	3000	Screen	C-9530	17.9	41.4

Table 6.2.2

7. Conclusions:

The samples received from both Lemay and Bissell Point WWTPs have been different compared to samples tested in the past. Feed solids and volatile solids have changed with each sample received. The screen analysis from all the tests indicated a high amount of large debris and fiber with each sample. The large amount of coarse debris, low volatile solids, and also higher cake dryness are most likely due to the wet weather conditions. A higher amount of these inorganic solids, sand, silt and grit indicates a more abrasive sludge than is typical for primary / secondary sludge.

In regards to polymer selection, the two (2) Mannich polymers supplied were effective for centrifuge dewatering. Centrifuge spin-down results using the Mannich polymers were between 31 – 40 %TS with the Lemay WWTP sample, and 34 – 39 %TS with the Bissell Point WWTP sample.

Attached are photographs of the screen analysis for reference and comparison.

8. Sample Disposition:

The remaining untested sludge will be disposed in accordance with local regulations.

Report Prepared by : Shaun Hurst
Title : Process Engineer

SH/sk

Copies of this report have been distributed to the following:

Original +1cc/	Lab
1 cc/	Chris Mahoney
	Sig Hausegger

Attachments:

A. Photographs

Sample #: L-14312

Photo #1: +30 Mesh Fraction

Photo #2: 30X50 Mesh Fraction

Photo #3: 50X100 Mesh Fraction

Photo #4: 100X140 Mesh Fraction

Photo #5: 140X230 Mesh Fraction

Photo #6: 230X325 Mesh Fraction

Sample #: L-14313

Photo #1: +30 Mesh Fraction

Photo #2: 30X50 Mesh Fraction

Photo #3: 50X100 Mesh Fraction

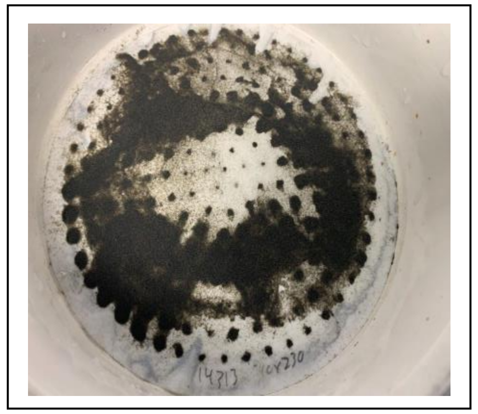


Photo #4: 140X230 Mesh Fraction

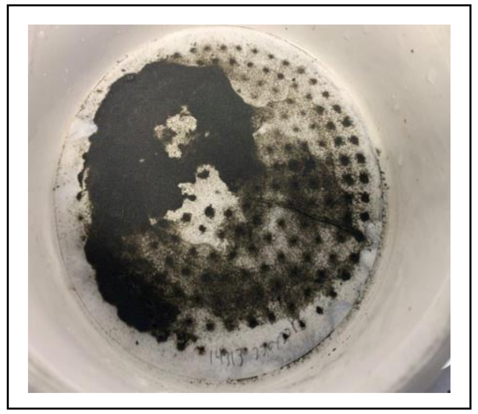
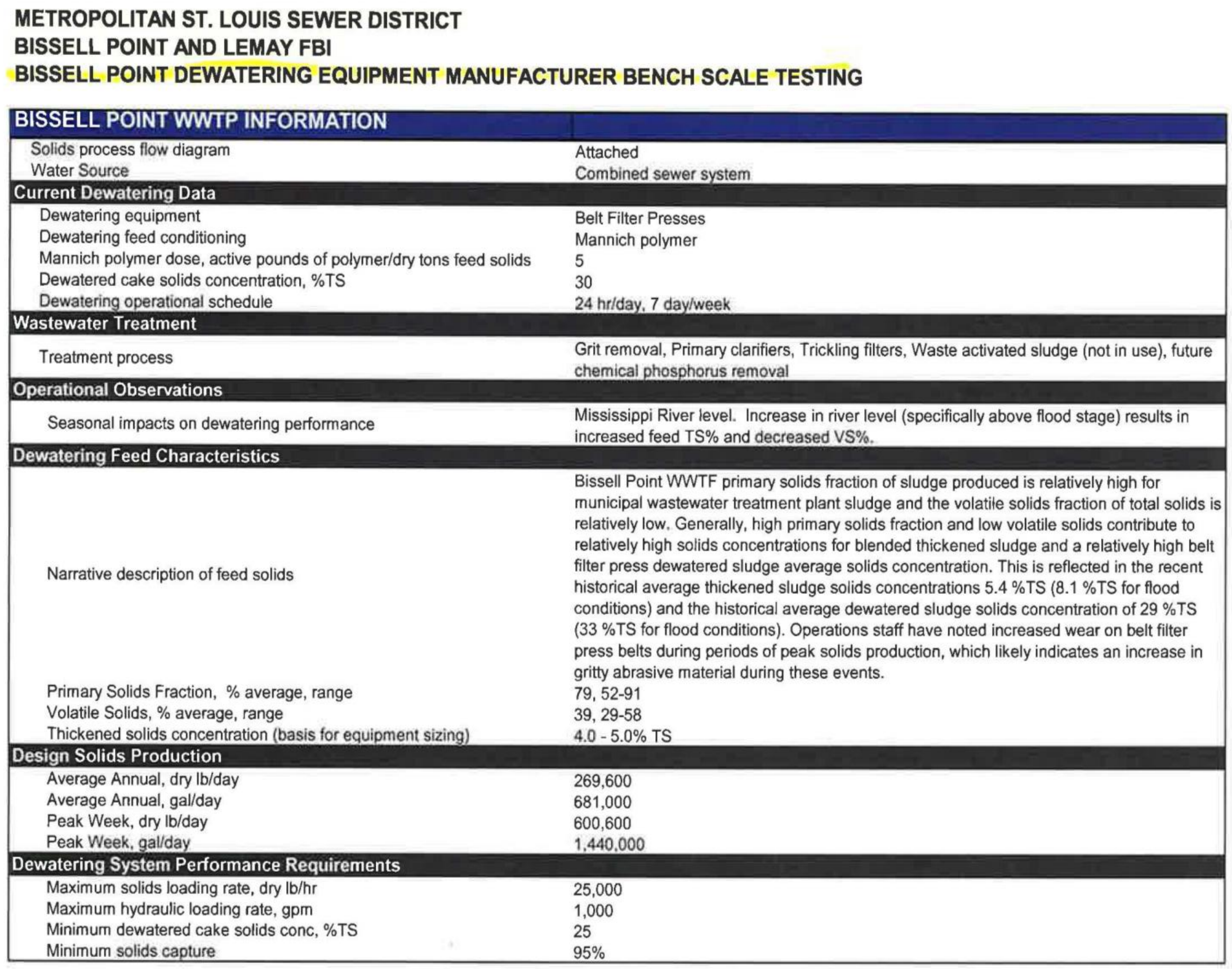


Photo #5: 230X325 Mesh Fraction

B. Plant Diagrams & Information

Bissell Point WWTP

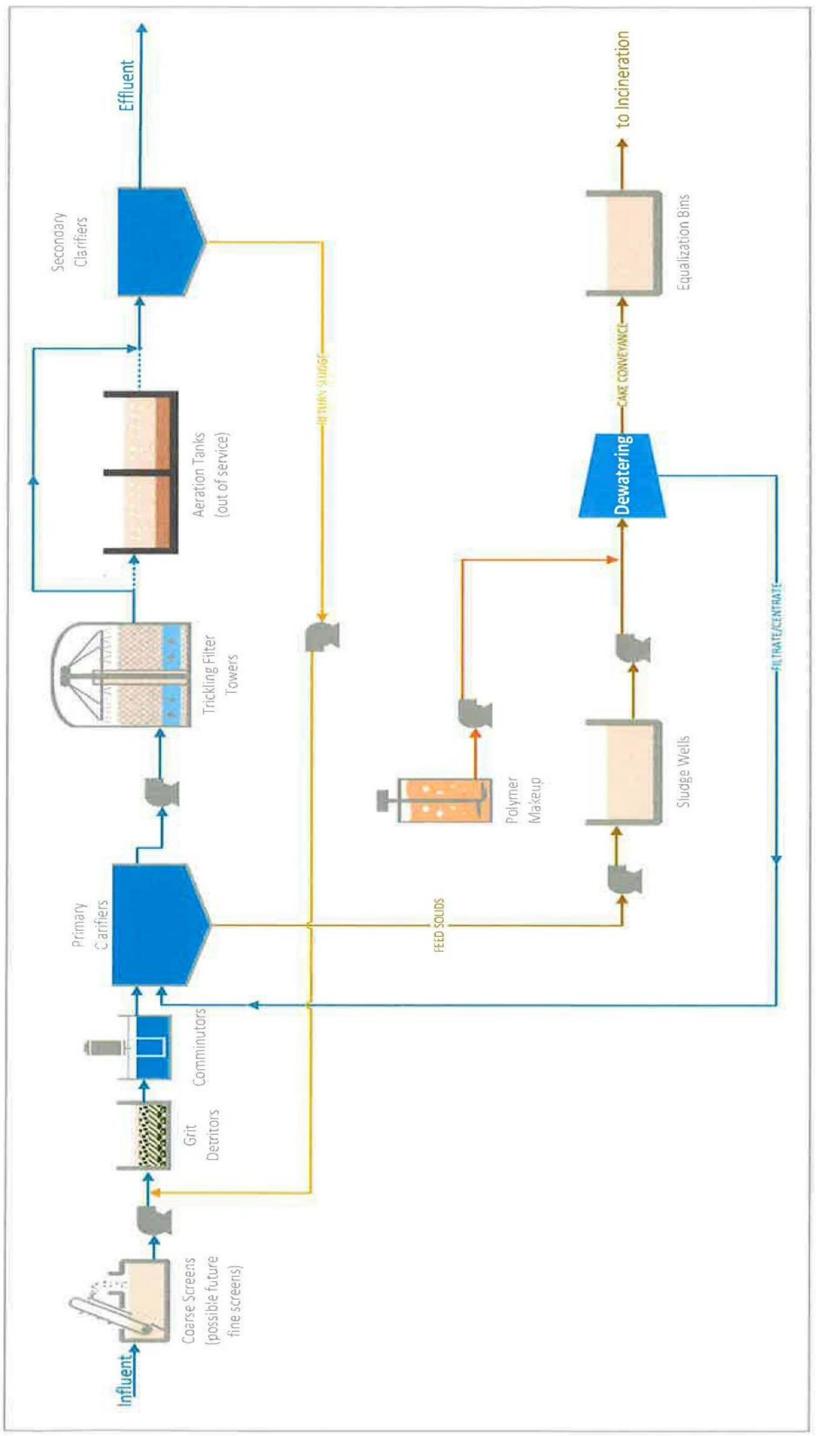


METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

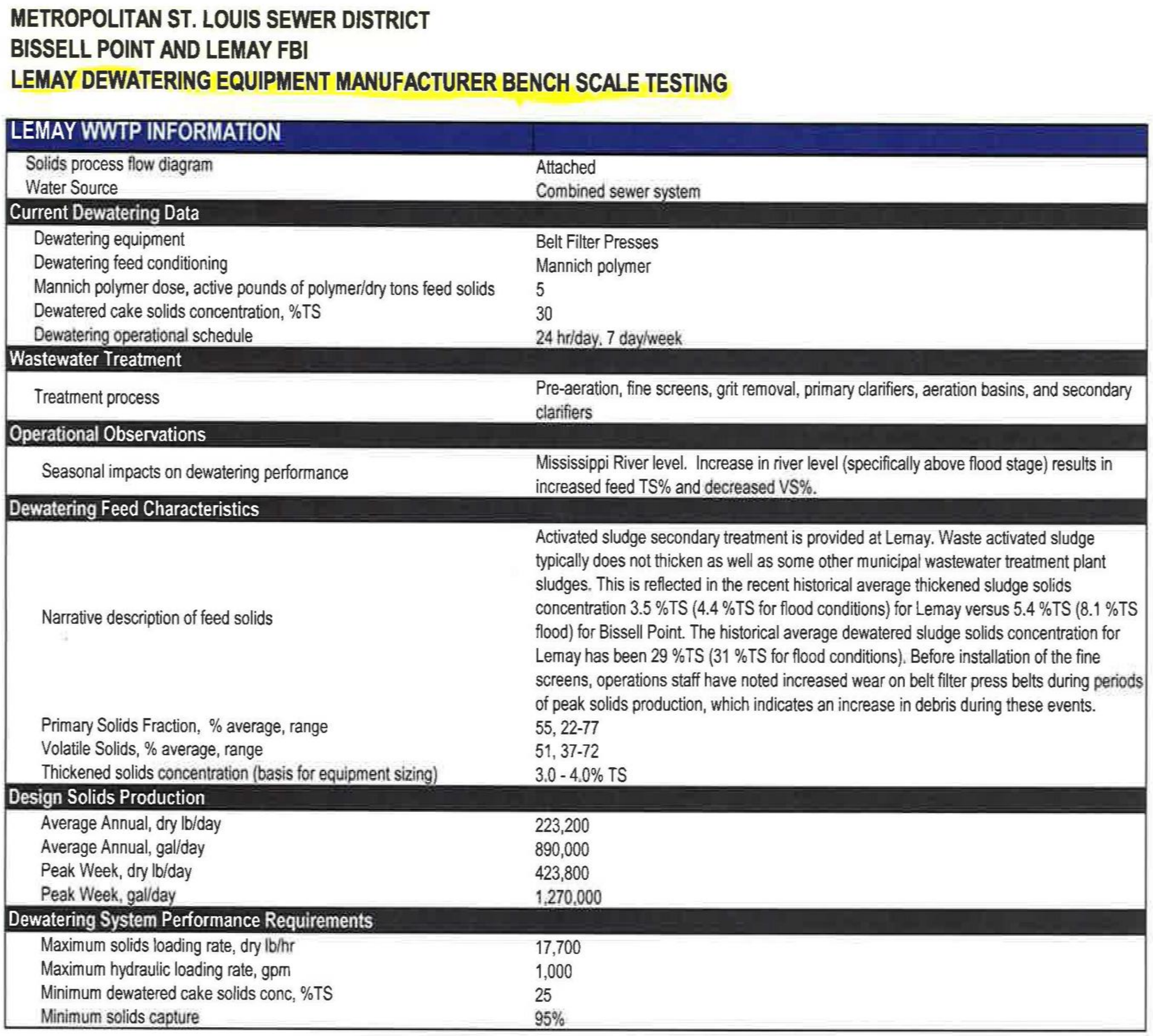
BISSELL POINT WWTP INFORMATION	
Solids process flow diagram	Attached
Water Source	Combined sewer system
Current Dewatering Data	
Dewatering equipment	Belt Filter Presses
Dewatering feed conditioning	Mannich polymer
Mannich polymer dose, active pounds of polymer/dry tons feed solids	5
Dewatered cake solids concentration, %TS	30
Dewatering operational schedule	24 hr/day, 7 day/week
Wastewater Treatment	
Treatment process	Grit removal, Primary clarifiers, Trickling filters, Waste activated sludge (not in use), future chemical phosphorus removal
Operational Observations	
Seasonal impacts on dewatering performance	Mississippi River level. Increase in river level (specifically above flood stage) results in increased feed TS% and decreased VS%.
Dewatering Feed Characteristics	
Narrative description of feed solids	Bissell Point WWTF primary solids fraction of sludge produced is relatively high for municipal wastewater treatment plant sludge and the volatile solids fraction of total solids is relatively low. Generally, high primary solids fraction and low volatile solids contribute to relatively high solids concentrations for blended thickened sludge and a relatively high belt filter press dewatered sludge average solids concentration. This is reflected in the recent historical average thickened sludge solids concentrations 5.4 %TS (8.1 %TS for flood conditions) and the historical average dewatered sludge solids concentration of 29 %TS (33 %TS for flood conditions). Operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which likely indicates an increase in gritty abrasive material during these events.
Primary Solids Fraction, % average, range	79, 52-91
Volatile Solids, % average, range	39, 29-58
Thickened solids concentration (basis for equipment sizing)	4.0 - 5.0% TS
Design Solids Production	
Average Annual, dry lb/day	269,600
Average Annual, gal/day	681,000
Peak Week, dry lb/day	600,600
Peak Week, gal/day	1,440,000
Dewatering System Performance Requirements	
Maximum solids loading rate, dry lb/hr	25,000
Maximum hydraulic loading rate, gpm	1,000
Minimum dewatered cake solids conc, %TS	25
Minimum solids capture	95%

METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
BISSELL POINT DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

Bissell Point General Flow Diagram



Lemay WWTP

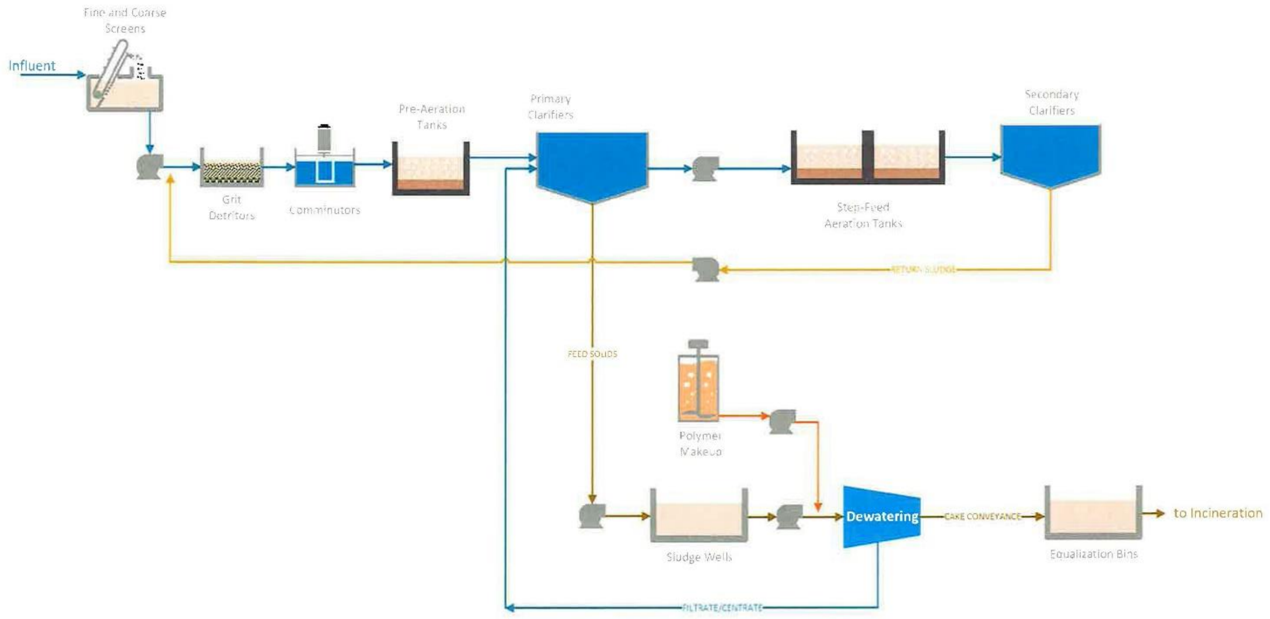


METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING

LEMAY WWTP INFORMATION	
Solids process flow diagram	Attached
Water Source	Combined sewer system
Current Dewatering Data	
Dewatering equipment	Belt Filter Presses
Dewatering feed conditioning	Mannich polymer
Mannich polymer dose, active pounds of polymer/dry tons feed solids	5
Dewatered cake solids concentration, %TS	30
Dewatering operational schedule	24 hr/day, 7 day/week
Wastewater Treatment	
Treatment process	Pre-aeration, fine screens, grit removal, primary clarifiers, aeration basins, and secondary clarifiers
Operational Observations	
Seasonal impacts on dewatering performance	Mississippi River level. Increase in river level (specifically above flood stage) results in increased feed TS% and decreased VS%.
Dewatering Feed Characteristics	
Narrative description of feed solids	Activated sludge secondary treatment is provided at Lemay. Waste activated sludge typically does not thicken as well as some other municipal wastewater treatment plant sludges. This is reflected in the recent historical average thickened sludge solids concentration 3.5 %TS (4.4 %TS for flood conditions) for Lemay versus 5.4 %TS (8.1 %TS flood) for Bissell Point. The historical average dewatered sludge solids concentration for Lemay has been 29 %TS (31 %TS for flood conditions). Before installation of the fine screens, operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which indicates an increase in debris during these events.
Primary Solids Fraction, % average, range	55, 22-77
Volatile Solids, % average, range	51, 37-72
Thickened solids concentration (basis for equipment sizing)	3.0 - 4.0% TS
Design Solids Production	
Average Annual, dry lb/day	223,200
Average Annual, gal/day	890,000
Peak Week, dry lb/day	423,800
Peak Week, gal/day	1,270,000
Dewatering System Performance Requirements	
Maximum solids loading rate, dry lb/hr	17,700
Maximum hydraulic loading rate, gpm	1,000
Minimum dewatered cake solids conc, %TS	25
Minimum solids capture	95%

**METROPOLITAN ST. LOUIS SEWER DISTRICT
BISSELL POINT AND LEMAY FBI
LEMAY DEWATERING EQUIPMENT MANUFACTURER BENCH SCALE TESTING**

Lemay General Flow Diagram



LAB REPORT

No:

Test date:	**5/6/2020**
Laboratory:	**Flottweg US**
Product:	**Wastewater**
Customer:	**Bissell Point WWTP**
Project no.:	

Customer	Bissell Point WWTP

Test Date:	5/6/2020
Application:	Wastewater
Lab Technician:	Tony Kramer
Sales Manager:	John Yatcilla
Customer Contact:	Marcia Kumar

1 Background:

A sludge sample arrived on 5/6/2020 from Bissell Point WWTP to be evaluated for polymer addition. The sample arrived with two Mannich polymers whose characteristics are unknown (charge, structure, and activity). Activity is assumed to be the standard 5% active that is common for many modern Mannich polymers. The following recommendations are based upon the sample as received, and do not take into account unknown variability within the sludge.

2 Test Plan:

The sample was analyzed for both its solids characteristics and some potential metallurgy-limiting properties. The sludge was dried and ashed to determine total solids, and volatile solids fractions. The sample was tested using pH strips, and a Capillary Suction Timer. The sample was then evaluated to select polymers that would likely perform well. The Capillary Suction Timer (CST) measures the filter cake permeability of a product. It is a standard test used to establish a benchmark for variations in sludge character.

A polymer analysis was conducted through a series of cup and jar tests. Preliminary tests were conducted with 100mL samples to reduce sample consumption.

Polymer Selection

The selection process starts with a series of cup tests to select a short list of products for jar testing. The purpose of cup testing is to narrow the range of products to test be eliminating products that do not produce flocs. First, a range of charges are tested, then a range of structures within the most successful charges.

Jar testing is better at approximating the performance of a product in a centrifuge. The sealed container allows more dynamic forces to be applied. Often the dose that was successful in a cup test will not be successful in a jar test, so once a product is chosen to be jar tested, a jar test should be repeated with various doses to find an approximate polymer consumption. This consumption will usually be a little under the polymer consumption required on an optimized centrifuge, depending on throughput. The higher the throughput through a centrifuge, the greater the deviation actual polymer consumption will likely have from the jar test predicted consumption.

3 Results:

Bissell Point WWTP	
Sample pH	6
Capillary Suction Time (s)	388.23
Total Solids Sample (% w/w)	4.53
Total Solids Sample (mg/L)	45318
% of Solids that are Volatile (%)	43.5
% Ashed Content of Sample (%)	2.56
Spin Index	4.44

Cup Test Results:

Based upon the cup tests, three products were chosen to jar test; FW 1005 and FW 1006, as well as the two Mannich Polymers SW 228 and CE 437.

Jar Test Results:

Based upon the jar tests, FW 1005 and FW 1006 would both be effective products for use on this sludge. Of the two, FW 1006 is the preferred product because it produced a clearer centrate. CE 437 may or may not be effective, but would require a much higher dose because it is not likely to hold up well to the shear forces generated during centrifugation.

4 Discussion:

Based upon the lab-trials conducted, the recommended polymers are FW 1006 and FW 1005. Given the dynamic forces that occur within a decanter, it is recommended that both be tested during a pilot trial to determine the most efficient additive. The submitted Mannich polymers, although capable of creating flocks, are not suitable for use in a centrifuge due to poor shear resistance and a higher chemical consumption.

After discussing with David Hordesky (SNF), as additional round of lab testing is recommended using a series of more shear resistant Mannich products. Although he feels they are also not likely to withstand the forces in a centrifuge, he is providing a selection of product samples to be evaluated. Once those samples arrive, a fresh sludge sample would be in order. If the nature of the feed sludge changes before the trial, a new flocculant selection would be recommended.

Based upon the sample as received, dewatering using a horizontal decanter centrifuge is feasible so long as a recommended flocculant is used. Given the jar test results, 7±3 lb active / dry ton of feed is not unreasonable for the FW polymers, and 10±3 lb active / dry ton of feed is not unreasonable for the Mannichs. Based upon reported historic trends, cake solids in the range of 25-35 would be expected, however due to the highly variable nature of the sludge, actual performance would be hard to predict for any given time without a wider range of samples.

The highly variable nature of the feed stream also warrants additional considerations. Likely, that polymer consumption would be different when the volatile content is higher at non-flood stage operations and a peak volatiles sample should also be submitted to expectations can be bracketed. Basically, it isn't that a polymer grabs more or fewer particles per molecule at any given time, but rather that the weight of those particles, and therefore the weight of the entire flock can be greater or lesser depending on the density of those particles being flocculated. Ordinarily, the density of wastewater suspended solids for any given facility tends to be consistent, however mud and silt from flood waters have a much greater density per particle. The result is that there are more particles of biosolids per dry ton and fewer particles of mud per dry ton. Biosolids will have a higher pounds of active polymer per dry ton of feed solids because there are more particles to be flocculated in that ton. Flood sediment will have a lower pounds of active polymer per dry ton of feed solids simply because there are a lot fewer particles to be flocculated in that ton. Likewise, the denser the solids are, the higher cake TS because there is less room for water entrapped in the particles. The less dense the solids are, the lower the cake TS because there is more room for entrapped water inside the particles.

It should be noted that the polymer consumption reported in the jar test results are lower than actual consumption would be during operation. The shear forces applied on the flocs within a decanter will demand more product to maintain a stable floc. Pilot testing is recommended to determine actual performance.

LAB REPORT

No:

Test date: 5/6/2020

Laboratory: Flottweg US

Product: Wastewater

Customer: Lemay WWTP

Project no.:

Customer	Lemay WWTP

Test Date:	5/6/2020
Application:	Wastewater
Lab Technician:	Tony Kramer
Sales Manager:	John Yatcilla
Customer Contact:	Marcia Kumar

1 Background:

A sludge sample arrived on 5/6/2020 from Lemay WWTP to be evaluated for polymer addition. The sample arrived with two Mannich polymers whose characteristics are unknown (charge, structure, and activity). Activity is assumed to be the standard 5% active that is common for many modern Mannich polymers. The following recommendations are based upon the sample as received, and do not take into account unknown variability within the sludge.

2 Test Plan:

The sample was analyzed for both its solids characteristics and some potential metallurgy-limiting properties. The sludge was dried and ashed to determine total solids, and volatile solids fractions. The sample was tested using pH strips. The sample was then evaluated to select polymers that would likely perform well.

A polymer analysis was conducted through a series of cup and jar tests. Preliminary tests were conducted with 100mL samples to reduce sample consumption.

Polymer Selection

The selection process starts with a series of cup tests to select a short list of products for jar testing. The purpose of cup testing is to narrow the range of products to test be eliminating products that do not produce flocs. First, a range of charges are tested, then a range of structures within the most successful charges.

Jar testing is better at approximating the performance of a product in a centrifuge. The sealed container allows more dynamic forces to be applied. Often the dose that was successful in a cup test will not be successful in a jar test, so once a product is chosen to be jar tested, a jar test should be repeated with various doses to find an approximate polymer consumption. This consumption will usually be a little under the polymer consumption required on an optimized centrifuge, depending on throughput. The higher the throughput through a centrifuge, the greater the deviation actual polymer consumption will likely have from the jar test predicted consumption.

3 Results:

Bissell Point WWTP	
Sample pH	5
Total Solids Sample (% w/w)	1.8
Total Solids Sample (mg/L)	18071
% of Solids that are Volatile (%)	61.7
% Ashed Content of Sample (%)	0.69
Spin Index	6.5

Cup Test Results:

Based upon the cup tests, three products were chosen to jar test; FW 1508, FW 1519 and FW 1501, as well as the two Mannich Polymers SW 228 and CE 437.

Jar Test Results:

Based upon the jar tests, FW 1508, FW 1519 and FW 1501 would all be effective products for use on this sludge. Of them, FW 1508 is the preferred product because it produced a slightly clearer centrate and slightly sturdier flocks. Both CE 437 and SW 228 may or may not be effective, but would require a much higher dose because it is not likely to hold up well to the shear forces generated during centrifugation.

4 Discussion:

Based upon the lab-trials conducted, the recommended polymers are FW 1006 and FW 1005. Given the dynamic forces that occur within a decanter, it is recommended that both be tested during a pilot trial to determine the most efficient additive. The submitted Mannich polymers, although capable of creating flocks, are not suitable for use in a centrifuge due to poor shear resistance and a higher chemical consumption.

After discussing with David Hordesky (SNF), as additional round of lab testing is recommended using a series of more shear resistant Mannich products. Although he feels they are also not likely to withstand the forces in a centrifuge, he is providing a selection of product samples to be evaluated. Once those samples arrive, a fresh sludge sample would be in order. If the nature of the feed sludge changes before the trial, a new flocculant selection would be recommended.

Based upon the sample as received, dewatering using a horizontal decanter centrifuge is feasible so long as a recommended flocculant is used. Given the jar test results, 12±3 lb active / dry ton of feed is not unreasonable for the FW polymers, and 20±5 lb active / dry ton of feed for the Mannichs. Based upon reported historic trends, cake solids in the range of 25-35 would be expected, however due to the highly variable nature of the sludge, actual performance would be hard to predict for any given time without a wider range of samples.

The highly variable nature of the feed stream also warrants additional considerations. Likely, that polymer consumption would be different when the volatile content is lower at flood stage operations and a low volatiles sample should also be submitted to expectations can be bracketed.

Basically, it isn't that a polymer grabs more or fewer particles per molecule at any given time, but rather that the weight of those particles, and therefore the weight of the entire flock can be greater or lesser depending on the density of those particles being flocculated. Ordinarily, the density of wastewater suspended solids for any given facility tends to be consistent, however mud and silt from flood waters have a much greater density per particle. The result is that there are more particles of biosolids per dry ton and fewer particles of mud per dry ton. Biosolids will have a higher pounds of active polymer per dry ton of feed solids because there are more particles to be flocculated in that ton. Flood sediment will have a lower pounds of active polymer per dry ton of feed solids simply because there are a lot fewer particles to be flocculated in that ton. Likewise, the denser the solids are, the higher cake TS because there is less room for water entrapped in the particles. The less dense the solids are, the lower the cake TS because there is more room for entrapped water inside the particles.

It should be noted that the polymer consumption reported in the jar test results are lower than actual consumption would be during operation. The shear forces applied on the flocs within a decanter will demand more product to maintain a stable floc. Pilot testing is recommended to determine actual performance.

SLUDGE SCREENING REPORT

LEMAY WWTP & BISSELL POINT WWTP, SAINT LOUIS, MISSOURI

SAMPLE DATE:	**MAY 4, 2020**
TEST DATE:	**MAY 5, 2020**
REPORT DATE:	**MAY 8, 2020**
AUTHOR:	**PINKHASOV, RUVEN**
CRM:	**30267577** **30267578**

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a better world

gea.com

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GEA Mechanical Equipment US, Inc.

GEA Westfalia Separator Division
100 Fairway Court
Northvale, NJ 07647
Phone (201) 767-3900
Fax (201) 767-3901
www.gea.com

May 8, 2020

Jeremy Rosemann, E.I.T.
Metropolitan St. Louis Sewer District
2350 Market Street, Walnut Pl,
St. Louis, MO 63103

RE: Lemay and Bissell Point Wastewater Treatment Plants – 30267577, 30267578

Dear Mr. Rosemann:

Thank you for entrusting GEA to provide Brown and Cladwell with the analysis of the sample provided. We have finished our laboratory testing and the results are provided herein.

Should you have any questions please contact Mr. R. Todd Marshall at +1 (201) 637-9864 or by email at Richard.Marshall@gea.com.

Thank you again it has been a sincere pleasure working with you.

Sincerely,

Ruven Pinkhasov

Ruven Pinkhasov
Lab and Sales Support Manager

SLUDGE SCREENING LAB REPORT

CONTACT INFORMATION

Project Name: Lab Testing – For Centrifuge Dewatering
CRM: 30267577 Lemay WWTP
CRM: 30267578 Bissell Point WWTP

Owner: Metropolitan St. Louis Sewer District
10 East Grand Avenue
St. Louis, MO 63147

Consultant: Jeremy Rosemann
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jrosemann@brwncald.com
+1 (573) 205-4420

Rep Contact: Ari Herrera
Hydro Application Consulting
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GEA Contact: R. Todd Marshall
100 Fairway Court
Northvale, New Jersey 07647

Richard.Marshall@gea.com
+1 (201) 637-9864

EXECUTIVE SUMMARY

Sludge samples and cake samples from Lemay Wastewater Treatment Plant and Bissell Point Wastewater Treatment Plant, both in Saint Louis Missouri, were received by GEA to test in the Northvale laboratory. The testing is to assess the ability of a GEA Decanter Centrifuge to dewater the sludge from the above mentioned plants. GEA will test the samples and attempt to determine polymer dosage requirements and proximate the dryness that will be obtained by dewatering with a centrifugal decanter.

INTRODUCTION

The samples were received by GEA on 5 May 2020 at the Northvale, New Jersey laboratory.

OBJECTIVE

The objective of this test is to investigate the Manich polymers currently used at the facility for centrifuges. Unfortunately the Manich Polymers didn't arrive in time, cross referencing we utilize emulsion polymers and determine the optimal dose (lbs/ton), % cake solids, volume % and clarity of centrate are desirable results.

BACKGROUND

4 L sample of wastewater sludge and a cake sample from both Lemay WWTP and Bissell Point WWTP were sent to the Northvale lab for maximum dewatering testing. Based on the information sheets provided, the following data was obtained.

For the Lemay plant, the following wastewater treatment processes are used, Pre-aeration, fine screens, grit removal, primary clarifiers, aeration basins, and secondary clarifiers. The Mississippi river impacts plant operation as follows, increase in river level, specifically above flood stage, results in increased feed TS% and decreased VS%. Plant currently utilizes a belt filter press for dewatering, and a mannich polymer at a concentration of 5 active pounds/ton to achieve a reported 30% cake dryness.

Activated sludge secondary treatment is provided at Lemay. Waste activated sludge typically does not thicken as well as some other municipal wastewater treatment plant sludges. This is reflected in the recent historical average thickened sludge solids concentration 3.5 %TS (4.4 %TS for flood conditions) for Lemay versus 5.4 %TS (8.1 %TS flood) for Bissell Point. The historical average dewatered sludge solids concentration for Lemay has been 29 %TS (31 %TS for flood conditions). Before installation of the fine screens, operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which indicates an increase in debris during these events.

Volatile solids are reported as 51% (average) with a range of 37 - 72%, while total solids are reported with a range of 3.0 - 4.0%.

Average annual design solids production is 223200 lb/day, and 890000 gal/day. On a peak week the solids production was reported as 423800 lb/day, and 1270000 gal/day.

Client's requirements for the Lemay plant are a solids loading rate of 17700 lb/hour, with a hydraulic loading rate of 1000 gpm, cake dryness of at least 25% and solids capture rate of 95%.

A process flow diagram for the plant can be seen below in figure 1.

For the Bissell Point plant, the following wastewater treatment processes are used, Grit removal, Primary clarifiers, Trickling filters, Waste activated sludge (not in use), future chemical phosphorus removal. The Mississippi river impacts plant operation as follows, increase in river level (specifically above flood stage) results in increased feed TS% and decreased VS%. Plant currently utilizes a belt filter press for dewatering, and a mannich polymer at a concentration of 5 active pounds/ton to achieve a reported 30% cake dryness.

Bissell Point WWTF primary solids fraction of sludge produced is relatively high for municipal wastewater treatment plant sludge and the volatile solids fraction of total solids is relatively low. Generally, high primary solids fraction and low volatile solids contribute to relatively high solids concentrations for blended thickened sludge and a relatively high belt filter press dewatered sludge average solids concentration. This is reflected in the recent historical average thickened sludge solids concentrations 5.4 %TS (8.1 %TS for flood conditions) and the historical average dewatered sludge solids concentration of 29 %TS (33 %TS for flood conditions). Operations staff have noted increased wear on belt filter press belts during periods of peak solids production, which likely indicates an increase in gritty abrasive material during these events.

Volatile solids are reported as 39% (average) with a range of 29 - 58%, while total solids are reported with a range of 4.0 - 5.0%.

Average annual design solids production is 269600 lb/day, and 681000 gal/day. On a peak week the solids production was reported as 600600 lb/day, and 1440000 gal/day.

Client's requirements for the Lemay plant are a solids loading rate of 25000 lb/hour, with a hydraulic loading rate of 1000 gpm, cake dryness of at least 25% and solids capture rate of 95%.

A process flow diagram for the plant can be seen below in figure 2.

FIGURE 1 - BISSELL POINT WWTP FLOW DIAGRAM

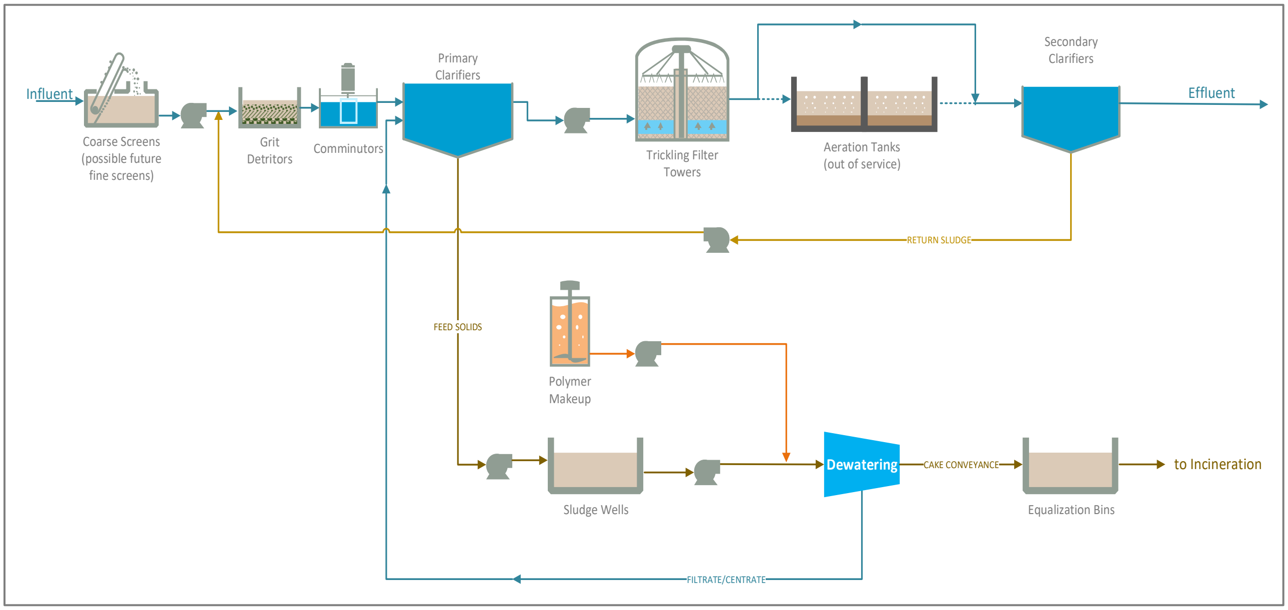
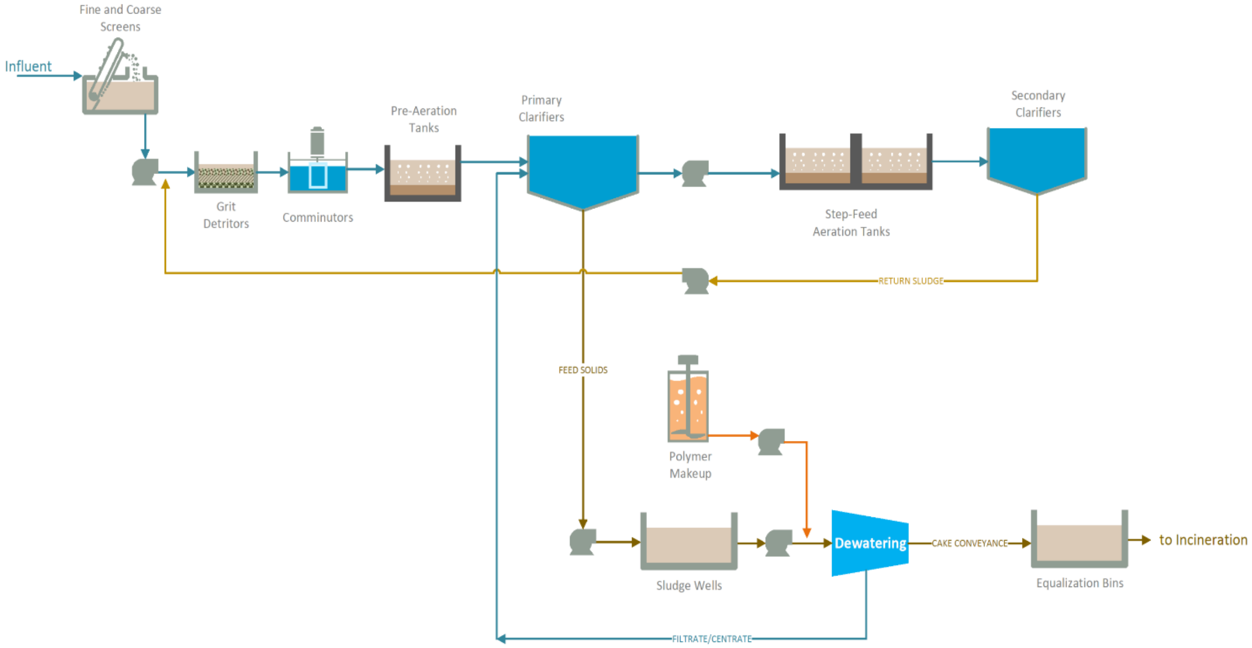


FIGURE 2 - LEMAY WWTP FLOW DIAGRAM



TEST PROCEDURE AND RESULTS

The procedural section of the test has two main constituents – the **fractional solids analysis** and the **polymer jar test**.

For the **fractional solids' analysis**, *total solids, dissolved solids, total suspended solids*, *volatile solids* and *fixed solids* are all determined. Each test involves weighing the sample before been placed in the oven at a specified temperature for a specified time length and weighing the final result. Below are descriptions of these parameters in solid analysis.

Total Solids – Total solids and the nature of solids directly relate to the type and volume of polymer used, type of chemical treatment, and equipment for dewatering

Total Dissolved Solids – Studies of dissolved solids are important in understanding water quality conditions for not only aquatic but for irrigation crops. A sample is evaluated in the lab at 180°C.

Total Suspended Solids – Suspended solids are minute solid particles that remain suspended in water and act as a colloid. Depending on their nature these tiny particles can greatly contribute to the corrosion of metal and the capabilities of water to act as a solvent.

Volatile Solids – The determination of volatile and fixed components is useful in wastewater plant operations because it offers the approximation of the amount of organic matter present in the solids fraction of the waste (*550°C*).

Ash Content – The inorganic constituents remaining after volatile solids are driven off at 550°C. They provide further understanding of water quality.

For the jar tests, a standard approach of selecting a few suitable polymers based on the sludge characteristics and input from polymer manufacturers is used. Mostly, emulsions are tested - dry polymers are a proven, though less preferred option in the lab - because GEA field test units use emulsions.

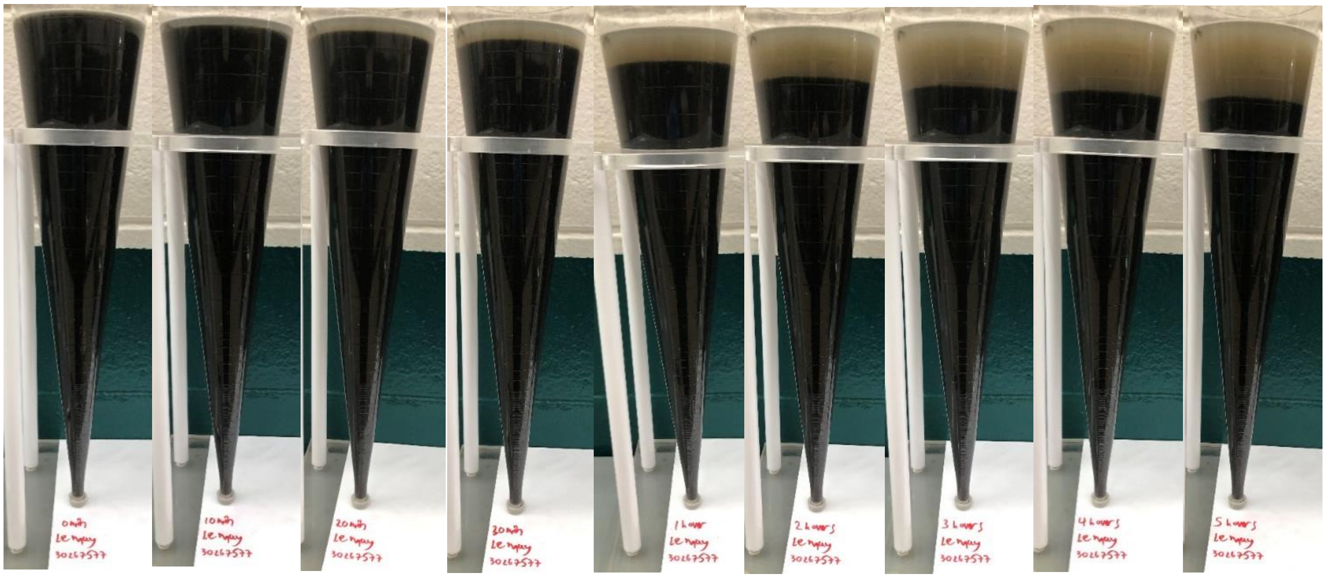
The polymers were diluted to a specified neat concentration of 0.5%. Specified volumes of solution are added to 50 mL of sludge

Incremental volumes of polymer are added to the sludge until overdosing is seen. Flocculated doses are placed in an oven for a 6 hour minimum at 105°C.

RESULTS

An Imhoff cone test was done on the sludge samples, data for which can be found below.

FIGURE 3 – IMAGES OF IMHOFF CONE EXPERIMENT ON LEMAY SLUDGE.



GRAPH 1 – IMHOFF CONE PLOT FOR LEMAY SLUDGE

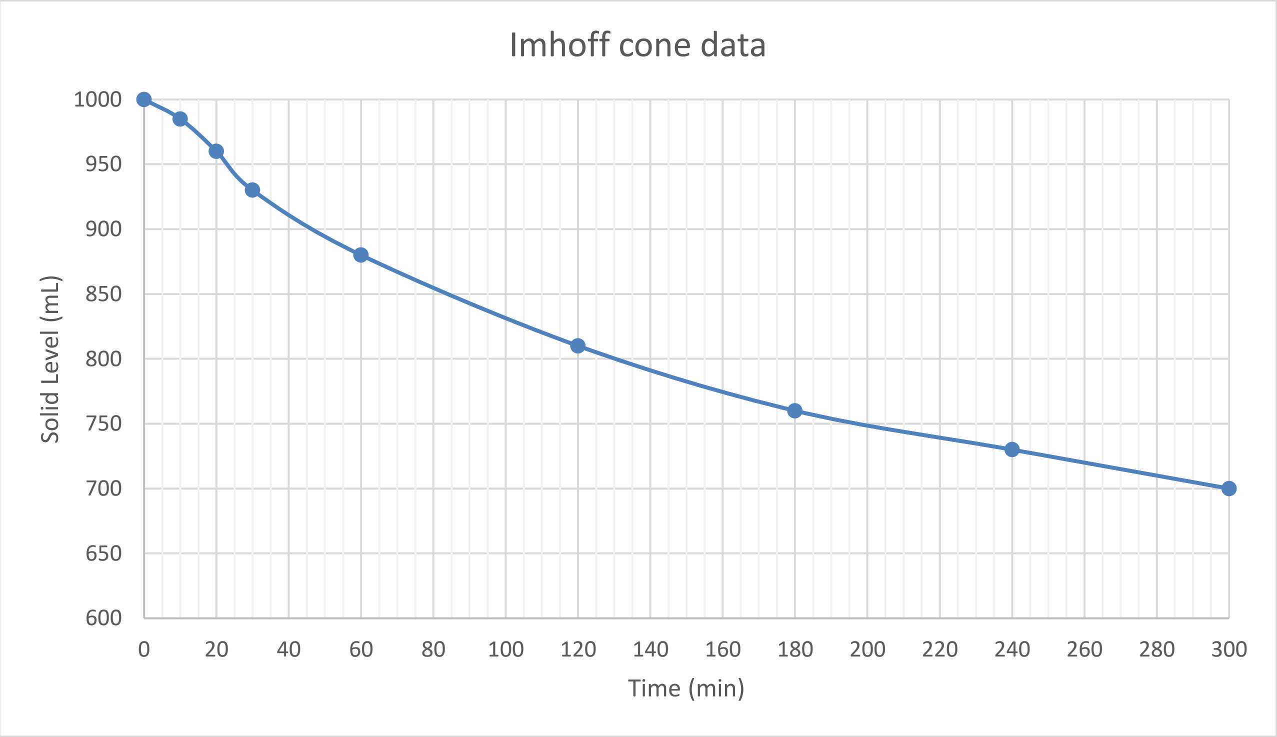
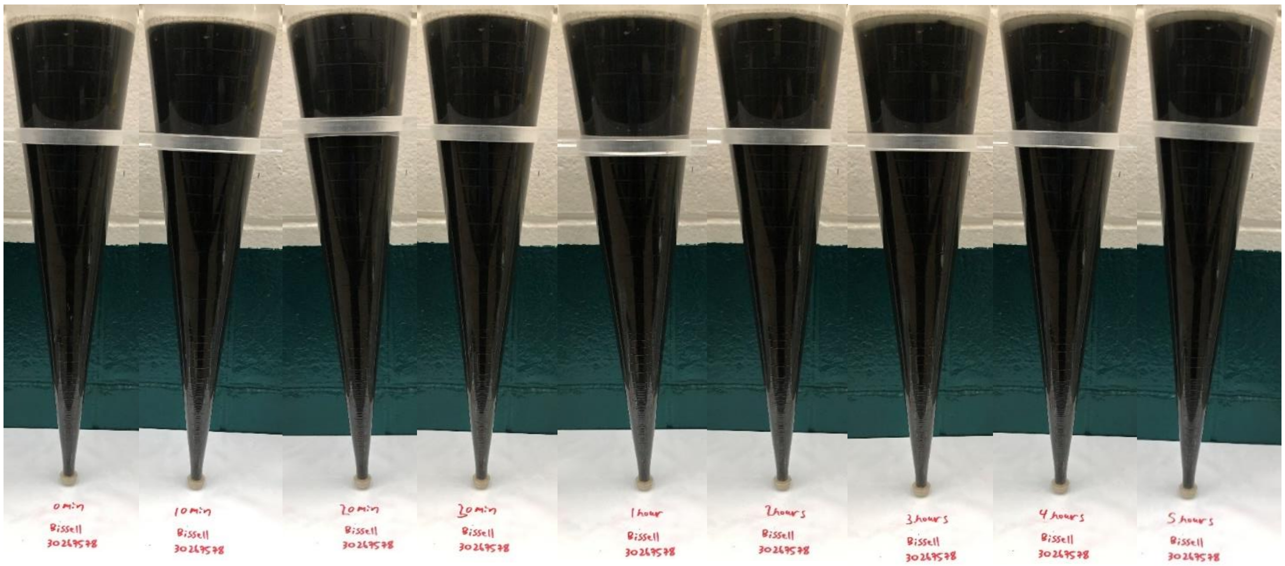
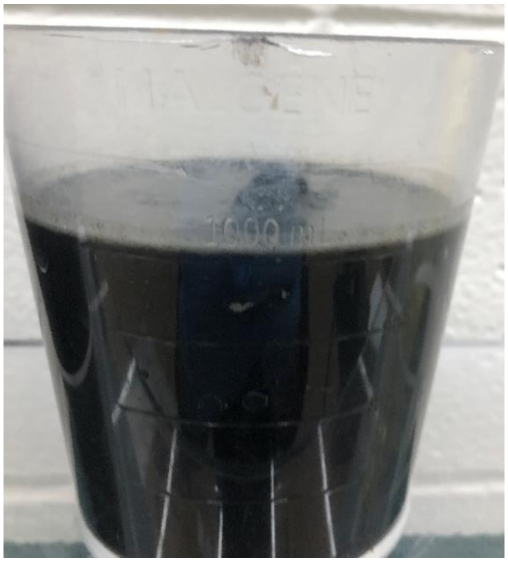


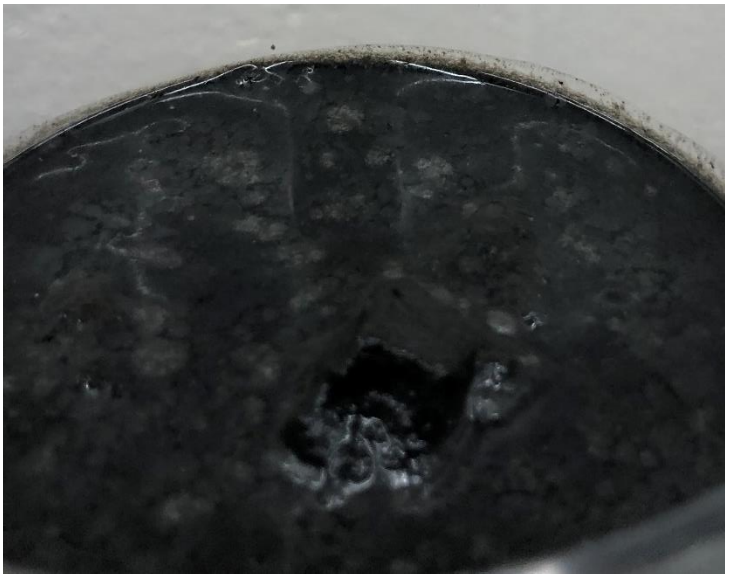
FIGURE 4 – IMAGES OF IMHOFF CONE EXPERIMENT ON BISSELL SLUDGE.



The Bissell Point Imhoff cone showed negligible change, as seen from the figure above.

When pouring the Bissell Point sludge into the Imhoff cone, large debris pieces were noticed.





Above a square piece of sponge with a side of roughly 0.5 inch.

Cake samples were sent from the two plants to test the dryness of the cake that resulted from the current polymer and dewatering equipment on site.

FIGURE 5 – DRYNESS OF CAKE FROM LEMAY WWTP AND BISSELL POINT WWTP.

The top images are of the cake from the plants prior to oven drying, and the bottom pictures are of the cake after oven drying.

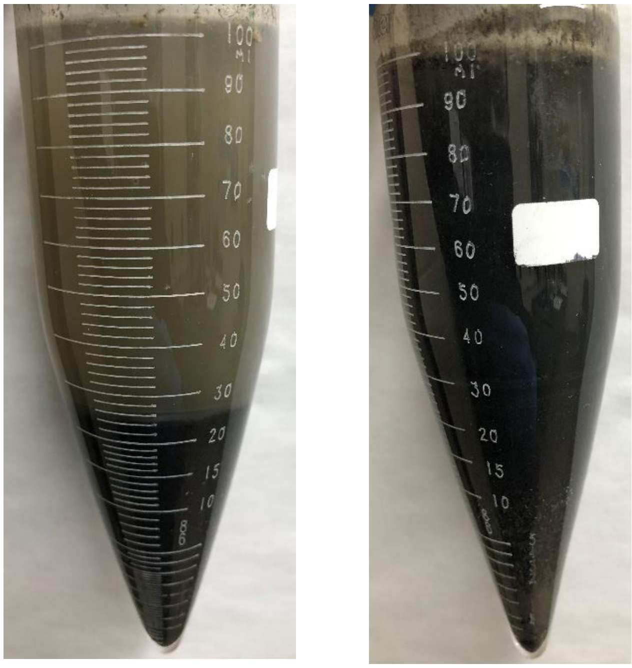
TABLE 1 – LEMAY AND BISSELL POINT CAKE DRYNESS RESULTS

Current plant cake dryness	
Lemay Cake Dryness	31.69%
Bissell Point Cake Dryness	26.76%

Tests were run to find the optimum polymer dosage to achieve maximum total solids the sludge can generate. As seen in Table 1 below, the TS% (total solids) of the Lemay sludge sample is **2.93**% (slightly lower than the **3.0 - 4.0%** noted in the information sheet on the plant), while the TS% of the Bissell Point sludge sample is **5.29%** (higher than the **4.0 - 5.0%** noted in the information sheet on the plant).

Low G spin testing of the sludge samples was performed to visualize the sedimentation. The spin was done for 10 minutes in an IEC LowG Spin Tester with a 2,550 rpm rotor speed generating 1480 x G at the tube tip and 740xG at the 50% v/v tube level. The results of the spin downs can be seen in figure 6 below. The Lemay sludge showed **~24**% v/v solids, and a murky centrate on top, while the Bissell point sludge showed **~30%** v/v solids, which is difficult to see in the figure below due to the dark color of the centrate. The centrate of the Bissel Point sludge had a great amount of unsettleable solids, which contributed to the invisible separation line between the phases.

FIGURE 6 - SPIN OF LEMAY SLUDGE, ON THE LEFT, AND BISSELL POINT SLUDGE, ON THE RIGHT



Fractional solids analysis as described above was conducted on the raw sample to characterize the solids content and the ash/volatile solids ratio. Results of the analysis are shown in Table 2.

TABLE 2- SOLIDS ANALYSIS ON LEMAY AND BISSELL POINT SLUDGE SAMPLES

Solids Type	Lemay Wt. % in Feed	Bissel Point Wt. % in Feed
Dissolved Solids (DS)	0.24	0.39
Total Suspended Solids (TTS)	2.69	4.90
Volatile Solids (VS)	62.2	43.4
Ash Content	37.8	56.6
Total Solids (TS)	2.93	5.29

Optimum polymer dosage was determined via jar testing three polymers. All three were emulsion cationic polymers. Two are from Polydyne (SNF), and the third is from Solenis. The first polymer chosen is Clarifloc **C-6266** from Polydyne, the second is Clarifloc **C-6267** from Polydyne, and the third is K274 FLX from Solenis. See table 3 for the polymer properties.

A volume of polymer is mixed with 50ml of the sludge. The polymer and sludge are then poured, first aggressively, and eventually at a slower pace to allow full contact and reaction.

The successfully flocculated solid mass from each beaker is transferred into a filtration cloth and squeezed until no further moisture is released. The dewatered cakes (for the solutions that successfully flocculated) are then dried at 105°C for a minimum of 6 hours using a Precision Scientific Thelco Benchtop Laboratory Incubator to determine their %TS content. The following two tables show the attributes of each polymer and the cake results of the jar test post drying for successful reactions respectively.

TABLE 3 CHARACTERISTICS OF POLYMERS USED IN THE JAR TESTS.

Polymer Emulsion	Activity (%)	Charge Density	Neat concentration	Type
Clarifloc C-6266	0.41	0.60	0.50	Branched
Clarifloc C-6267	0.41	0.60	0.50	Linear
Solenis K-274 FLX	0.43	0.60	0.50	

TABLE 4: RESULTS FROM TESTING VARIOUS POLYMER DOSAGES ON THE LEMAY SLUDGE SAMPLE

Sample Number	Polymer volume (ml)	Neat Dosage (lbs./ton)	Active Dosage (lbs./ton)	Floc	Timing (Pours)	Dried Cake Solids (%)
Clarifloc C-6266						
1	3	20	8	No	20	N/A
2	4	27	11	Yes	10	31
3	5	34	14	Yes	10	33
4	6	41	17	Yes	10	34
5	7	48	20	Yes	10	33
6	8	55	22	Yes	10	34
7	9	61	25	Yes	10	33
8	10	68	28	Yes	12	34
9	11	75	31	Yes	13	34
10	12	82	34	Yes	15	33
11	13	89	36	No	20	O/D

Table 4 continues on the next page

Sample Number	Polymer volume (ml)	Neat Dosage (lbs./ton)	Active Dosage (lbs./ton)	Floc	Timing (Pours)	Dried Cake Solids (%)
Clarifloc C-6267						
1	3	20	8	No	20	N/A
2	5	34	14	No	20	N/A
3	8	55	22	No	20	N/A
4	10	68	28	No	20	N/A
5	12	82	34	No	20	N/A
K-274 FLX						
1	2	14	6	No	20	N/A
2	3	20	9	Yes	20	34
3	4	27	12	Yes	20	34
4	5	34	15	Yes	20	34
5	6	41	18	Yes	20	34
6	7	48	21	Yes	20	32
7	8	55	23	No	20	O/D

TABLE 5: RESULTS FROM TESTING VARIOUS POLYMER DOSAGES ON THE BISSELL POINT SLUDGE SAMPLE

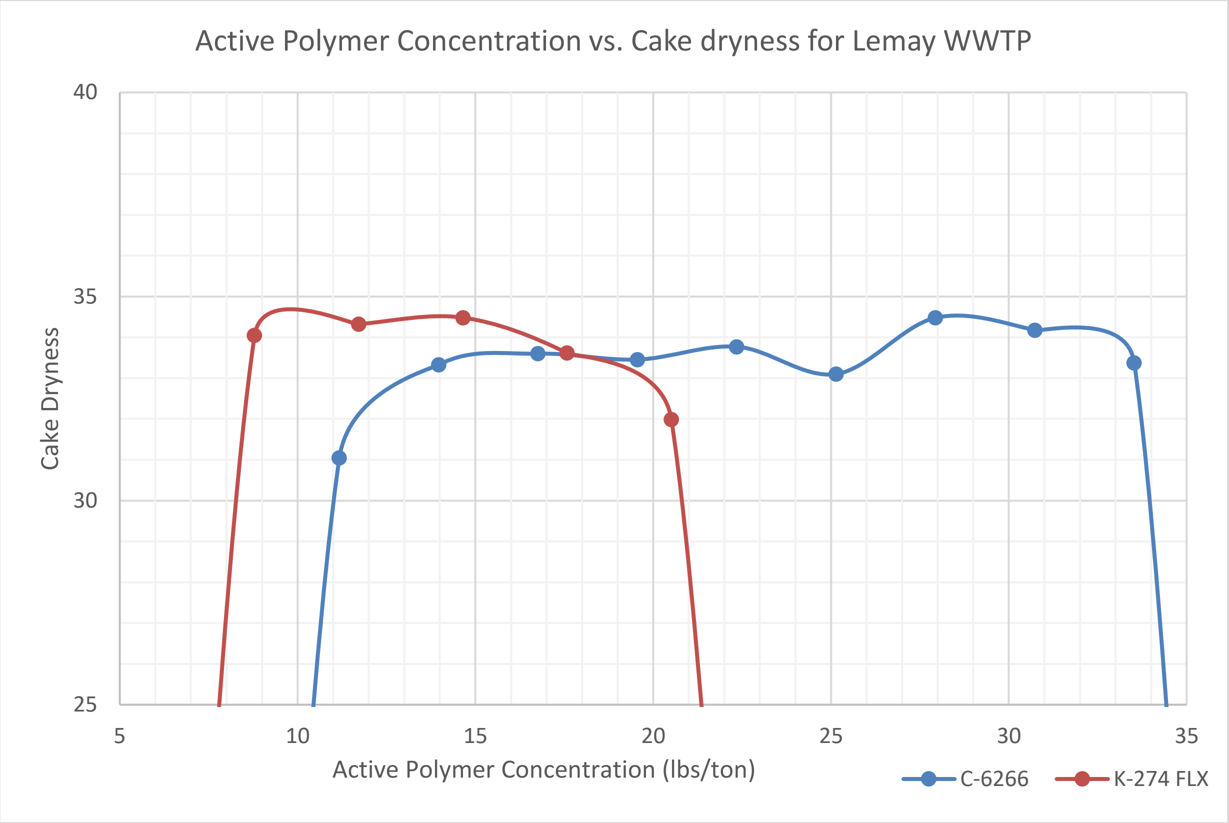
Sample Number	Polymer volume (ml)	Neat Dosage (lbs./ton)	Active Dosage (lbs./ton)	Floc	Timing (Pours)	Dried Cake Solids (%)
Clarifloc C-6266						
1	5	19	8	No	20	N/A
2	6	23	9	Yes	10	34
3	7	26	11	Yes	10	34
4	8	30	12	Yes	10	35
5	9	34	14	Yes	10	35
6	10	38	16	Yes	12	36
7	11	42	17	Yes	13	34
8	12	45	19	Yes	13	37
9	13	49	20	Yes	15	35
10	14	53	22	Yes	20	34
11	15	57	23	Yes	20	34
12	16	60	25	No	20	O/D

Table 5 continues on the next page

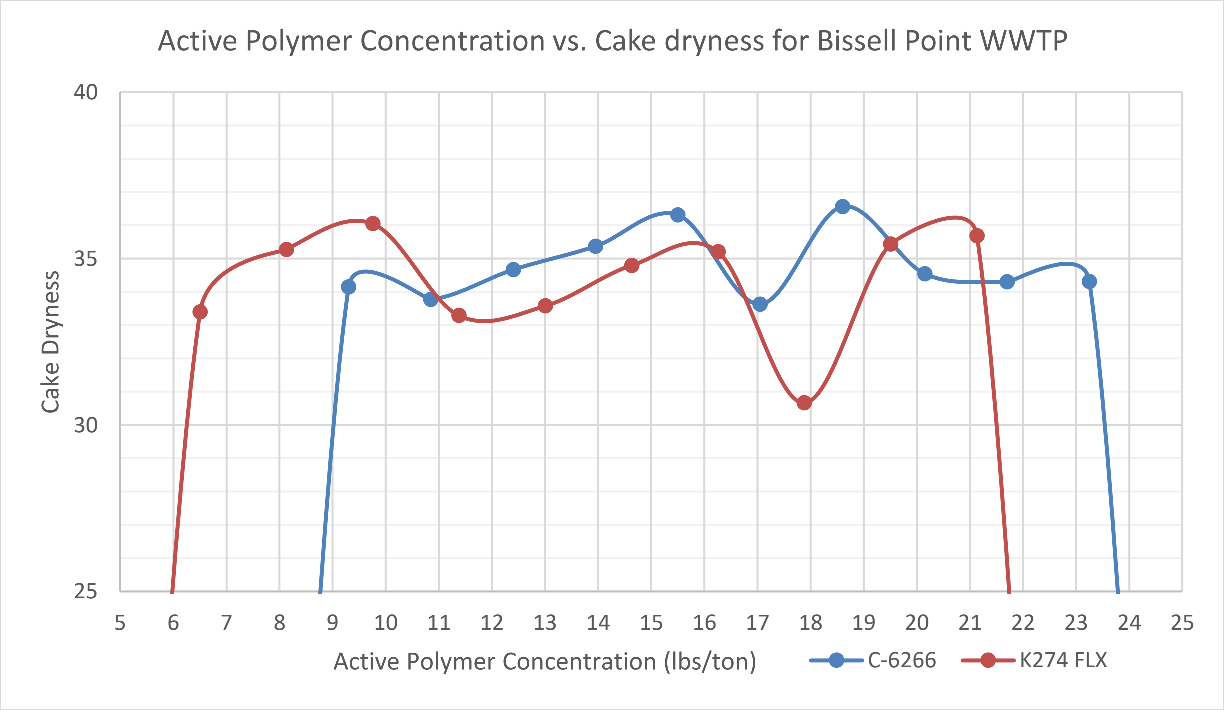
Sample Number	Polymer volume (ml)	Neat Dosage (lbs./ton)	Active Dosage (lbs./ton)	Floc	Timing (Pours)	Dried Cake Solids (%)
Clarifloc C-6267						
1	3	11	5	No	20	N/A
2	5	19	8	No	20	N/A
3	8	30	12	No	20	N/A
4	10	38	16	No	20	N/A
5	12	45	19	No	20	N/A
K-274 FLX						
1	3	11	5	No	20	N/A
2	4	15	7	Yes	20	33
3	5	19	8	Yes	20	35
4	6	23	10	Yes	20	36
5	7	26	11	Yes	20	33
6	8	30	13	Yes	20	34
7	9	34	15	Yes	20	35
8	10	38	16	Yes	20	35
9	11	42	18	Yes	20	31
10	12	45	20	Yes	20	35
11	13	49	21	Yes	20	36
12	14	53	23	No	20	O/D

For Table 4 and Table 5:
n/a = flocculent not stable enough for cake analysis
O/D = the polymer dosage was high – leaving excess polymer and minor flocculent

GRAPH 3 – GRAPH OF DRYNESS PERFORMANCE OF SUCCESSFUL POLYMER TESTED AGAINST THE LEMAY SLUDGE SAMPLE.



GRAPH 4 – GRAPH OF DRYNESS PERFORMANCE OF SUCCESSFUL POLYMER TESTED AGAINST THE BISSELL POINT SLUDGE SAMPLE.



As seen in tables 4 and 5, and in Graphs 3 and 4, the Clarifloc C-6267 led to no stable floc at a wide range of doses for both sludge samples; however, both the SNF Clarifloc C-6266 emulsion polymer, and the Solenis K274 FLX emulsion polymer led to stable flocculation. For the Lemay sludge, both successful polymers resulted in comparable dryness (**31%-34%**), but the range of doses of the C-6266 is larger, ranging from **11-34 lbs./ton active**, compared to that of the K274 FLX polymer (ranging from **9-21 lbs./ton active**), so that polymer will most likely be a better candidate for the Lemay plant. For the Bissell Point sludge, both polymers performed comparably, with both polymers resulting in dryness of **33%-36%** and comparable ranges of **9-23 lbs./ton active** for the C-6266 and **7-21 lbs./ton active** for the K274 FLX.

Because of the success at multiple doses both polymers listed above (C-6266 and K274 FLX) are effective polymers for the sludge sample from the Bissell plant, while only the C-6266 is recommended for the Lemay plant.

Below are sample illustrations of polymer performance (Figures 7, 8 and 9) showing a successful dose of K274 FLX against the Bissell sludge, an overdose of C-6266 against the Bissell sludge, and a successful dose of C-6266 against the Lemay sludge.

FIGURE 7 – A PELLET OF SLUDGE AFTER FLOCCULATION WITH 16 LBS/TON ACTIVE OF K274 FLX AGAINST SLUDGE FROM BISSELL POINT WWTP

FIGURE 8 – OVERDOSE EXAMPLE FOR THE C-6267 POLYMER AGAINST THE BISSELL SLUDGE

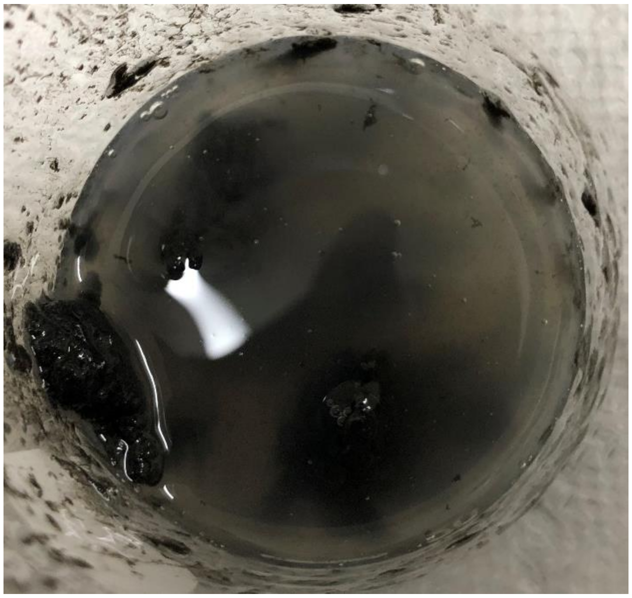


FIGURE 9 – A PELLET OF SLUDGE AFTER FLOCCULATION WITH 22 LBS/TON ACTIVE OF C-6266 AGAINST SLUDGE FROM LEMAY WWTP

OBSERVATIONS AND EXPLANATIONS

An allusion made earlier is that polymer selection for the jar tests primarily comes from experience of experts in the industry, and historical performance for similar sludge. Should a functioning polymer not arise from these reliable sources, the lab relies on its internal polymer performance records for selection. Lastly, there is abundance of literature in-house on polymer selection provided the client is forthcoming in providing information about the plant from which the sludge sample is collected.

The importance of the above-mentioned information cannot be emphasized enough. Plant design, raw water treatment methods and current equipment used in the plant help to establish a process flow for the plant operations. Information on sludge description, sludge treatment and WAS separation directly impact the jar test in the lab through polymer selection and information on the current sludge dewatering process bears an effect on decanter sizing and specifications. The main source of current operations information used in this report for Metropolitan St. Louis Sewer District is the information provided by Brown and Caldwell.

In the determination of cake solids, here are some key observations for the Lemay plant:

A) The **2.93%** feed solids determined in the lab is slightly lower than what was provided in the information sheet for the plant.

B) The lab measured **62.2**% volatile solids in the sample, matching the 37-72% range provided in the information sheets.

C) Both the SNF emulsion polymer and the Solenis emulsion polymer yielded flocs with the same cake dryness. While consideration must be given to variability in the shelf life of polymers; homogenous mixing of polymer; time and strength of crosslinked bonds that occurs during mixing; and the inherent margin of error in the nature of a lab test, it is fairly conclusive that the SNF and Solenis emulsion polymers yielded the same cake dryness, but the SNF polymer yielded it at a larger range of doses, which makes it the preferable of the two polymers.

D) Solids observations for the two polymers tested are comparable - cake solids range of **31-34%** for the **C-6266** polymer¸ compared to **32-34%** for the K274 FLX polymer.

E) The plant's current cake dryness, achieved by drying cake samples from the plant, is **32%**, higher than the reported 30% in the information sheet for the plant.

F) Most importantly, any client can expect repeatability and reliability in the performance of all GEA decanter product lines, and a higher yield of cake solids can be reasonably anticipated versus lab filter cloths.

Here are some key observations for the Bissell Point plant:

A) The **5.29%** feed solids determined in the lab is slightly higher than what was provided in the information sheet for the plant.

B) The lab measured **43.4**% volatile solids in the sample, matching the 29-58% range provided in the information sheets.

C) Both the SNF emulsion polymer and the Solenis emulsion polymer yielded flocs with the same cake dryness. Like mentioned above, while consideration must be given to variability in the shelf life of polymers; homogenous mixing of polymer; time and strength of crosslinked bonds that occurs during mixing; and the inherent margin of error in the nature of a lab test, it is fairly conclusive that the SNF and Solenis emulsion polymers yielded the same cake dryness at comparable doses and dose ranges. Either polymer will be great for dewatering of the sludge from the Bissell Point sludge.

D) Solids observations for the two polymers tested are comparable - cake solids range of **34-37%** for the **C-6266** polymer¸ compared to **31-36%** for the K274 FLX polymer.

E) The plant's current cake dryness, achieved by drying cake samples from the plant, is **27%**, lower than the reported 30% in the information sheet for the plant.

F) Most importantly, any client can expect repeatability and reliability in the performance of all GEA decanter product lines, and a higher yield of cake solids can be reasonably anticipated versus lab filter cloths.

CONCLUSIONS

The dewatering testing for sludge from Lemay WWTP and Bissell Point WWTP at Saint Louis, MO proved to be successful for two different emulsion polymers. For Lemay, the Clarifloc C-6266 from SNF at the four doses of 15, 20, 25 and 30 lbs per ton active dose are excellent starting points for a field case decanter. For Bissell Point, both the Clarifloc C-6266 from SNF and the K274 FLX from Solenis at the three doses of 10, 15 and 20 lbs per ton active dose are excellent starting points for a field case decanter.

Further evaluation of polymer after installation of full scale equipment has historically provided more compaction of the dewatered solids and resulted in higher %TS cake solids based on higher G forces than the lab dewatering methods. The dry cake solids achieved in the lab do serve as a baseline minimum for expectations of the full scale equipment. The lab recommends a field scale decanter be deployed to both Lemay WWTP and Bissell Point WWTP at Saint Louis, MO for more practical, reliable results.

ATTACHMENTS

The following information is attached herein:

INFORMATION SHEETS

Information sheets for the two plants are attached electronically.

End of Report

Attachment E: Odor Sampling Plan Technical Memorandum

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum

WWTF Odor Sampling Plan

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

27 OCTOBER 2020

Technical Memorandum

7733 Forsyth Blvd
11th Floor, Suite 1100
Clayton, MO 63105

Prepared for: Metropolitan St. Louis Sewer District (MSD) / Black and Veatch (BV)

Project Title: Bissell Point and Lemay WWTF Fluidized Bed Incinerators

BC Project No.: 153644

Technical Memorandum

Subject: Bissell Point and Lemay WWTF Odor Sampling Plan

Date: October 27, 2020

To: Bently Green, PE, Black & Veatch Project Manager

From: Dave Yates, PE, Brown and Caldwell Project Manager

Copy to: Matt Fishman, PE*, Brown and Caldwell Design Manager

Submitted by: ______________________________
Dave Yates, Missouri License No. 2008010469, Expiration 12/31/2020

Prepared by: ______________________________
Carol Zuerndorfer

Reviewed by: David W McEwen
____
David McEwen

** Licensed in other states*

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This technical memorandum (TM) provides a sampling plan with details of the field work to be conducted by Brown and Caldwell (BC) and the Metropolitan St. Louis Sewer District (MSD) staff at the Bissell Point (Bissell) and Lemay Wastewater Treatment Facilities (WWTFs). This field work is associated with establishing the design criteria of two new odor control systems to be constructed as part of the Bissell and Lemay WWTF Fluidized Bed Incinerators (FBI) project. This plan was written to provide the MSD and Black and Veatch (BV) teams with an understanding of the sampling locations, quantity of samples to be collected, sampling protocols, and laboratory analysis that are part of the work.

1.0 Background

The MSD has undertaken a project to provide new fluidized bed incineration facilities at MSD's Bissell and Lemay WWTFs. The new incineration facilities at Bissell Point WWTF will include dewatering and incineration of raw sludge from the Coldwater Creek WWTF in addition to the Bissell WWTF biosolids. The new incineration facilities at the Lemay WWTF will include dewatering and incineration of raw biosolids from the Grand Glaize, Fenton, and Lower Meramec WWTFs in addition to the Lemay WWTF biosolids.

An odor control system has been installed and is operating at Lemay WWTF that treats foul air exhausted from the dewatering facility. There are no odor control systems at Bissell WWTF. However, new odor control systems are planned to be constructed at both Bissell and Lemay as part of the current FBI facilities project.

It was recommended in Technical Memorandum 06: Dewatering Facilities (Final, June 2020) that odor sampling be completed at the existing dewatering facilities at both Bissell and Lemay WWTFs and at the existing Lemay WWTF odor control systems. Data collected would inform production of design criteria, include odor loading, airflow rates, and odor removal efficiency requirements.

The Bissell and Lemay WWTF odor testing will be conducted during the summer of 2020, when odors are expected to be highest. Exact dates of sampling are to be determined. No samples will be collected on a Friday due to the laboratories not being available to analyze samples (which require a 24-hour maximum turnaround) on weekends.

2.0 Sampling Program Elements and Equipment

This section contains information on field odor measurements, laboratory analysis, and sampling locations that will comprise the odor sampling program.

2.1 Field Measurements

Field odor measurements will be collected using a hand-held hydrogen sulfide (H_2S) analyzer and Acrulogs. This section describes how these instruments will be used and where they will be installed.

2.1.1 Instantaneous H_2S Field Measurements

BC will use a Jerome 631-X analyzer (pictured in Figure 2-1) to measure H_2S concentrations at and near odorous processes and odor control systems at the Bissell and Lemay WWTFs.

Figure 2-1. Jerome H_2S Analyzer

The Jerome analyzer is a hand-held instrument that provides a single H_2S measurement in typically less than 30 seconds. The instrument is intended for "snapshot" measurements only, not continuous readings. The H_2S measurements collected using the Jerome analyzer are intended to provide an indication of odors in various locations of the WWTF. Values will be recorded and presented in the sampling results TM.

Hydrogen sulfide concentration is measured by the Jerome analyzer down to a resolution of 0.001 parts per million by volume (ppmv), or 1 part per billion by volume (ppbv) and to a maximum of 50 ppmv. This lower bound is approximately equal to the threshold of human detection for H_2S, which is generally accepted to be 0.5 to 1 ppbv. Hydrogen sulfide retains a familiar "rotten egg" odor and is the most prevalent odorous compound in wastewater treatment emissions,.

2.1.2 Continuous H_2S Field Measurements

Continuous H_2S concentrations will be measured and recorded by Acrulog data loggers. The loggers will be installed adjacent to odor sources or within an odor source headspace. This sampling plan assumes that Acrulog PPM monitors will be rented by BC to complete the field H_2S monitoring.

Acrulog PPM monitors are available for H_2S measurements in four ranges (all in ppmv units): 0 to 20, 0 to 50, 0 to 200 and 0 to 1,000. The lower two ranges have a resolution of 0.1 ppmv and the upper two ranges have a resolution of 1 ppmv. The lower ranges provide slightly better data accuracy. Given the expected ranges of H_2S concentrations that will be measured at the dewatering and odor control system processes, Acrulogs used will be a combination of the 0 to 50 and 0 to 200 ppmv ranges.

The loggers will measure and log ambient H_2S concentrations every 2 minutes in the designated sampling locations. Measurements will be collected continuously for 1 week at each location. Two installed Acrulogs are pictured in Figure 2-2 (inside the Pelican case).

To measure H_2S concentrations in the foul air ducts entering the existing odor control system at Lemay, a Low Range Sampling System (LRSS) will be used. The LRSS utilizes a dual-headed pump to draw a sample from flowing air within a duct and deliver a constant flow rate to the Acrulog. Positive pressure flowing air is preferred so that the LRSS is not required to overcome higher negative pressure (suction), which can cause inconsistent measurement accuracy. Two external traps in the LRSS protect the loggers from moisture, which can foul the sensors and cause erroneous readings or shut down the instrument. An LRSS is pictured in Figure 2-2.

Figure 2-2. Installed Acrulogs Inside an LRSS

The Acrulogs continuously measure the H_2S concentration and record measured concentrations in a data file that is downloaded onto a personal computer and analyzed. Measurement times, H_2S concentrations, and temperature data can be displayed in graphical or tabular format and can be reviewed for the entire one-week analysis period or in single day or less. The software provides average, minimum, and maximum concentrations for each device for the week of monitoring.

Acrulogs and the LRSS will be rented from Detection Instruments (Phoenix, AZ) for a one-week rental. The one-week rental does not include time for shipping, either to BC or back to the renter.

2.2 Air Sampling and Laboratory Analysis

The following sections discuss the protocols that will be followed and the equipment that will be used in the Bissell and Lemay WWTF sampling program for measuring odor and compound concentrations.

2.2.1 Air Sample Collection Equipment

Tedlar bag samples will be collected at designated locations using a standard depressurization lung sampling apparatus, also referred to as a vacuum chamber. One vacuum chamber will be rented for the sampling period. A photograph of a typical vacuum chamber is provided in Figure 2-3.

Figure 2-3. Vacuum chamber for Air Sampling using Tedlar bags

The vacuum chamber consists of a pump within an air-tight Pelican case and Teflon sampling tubing, which is connected to the sample ports. Tedlar bags are placed inside of the vacuum chamber and attached to one end of the Teflon tubing as pictured in Figure 2-3. The tubing extends through the Pelican case and is used for collecting the air sample. When the pump is started, it creates a vacuum within the case, drawing air into the Tedlar bag. The vacuum chamber allows air samples to be collected without passing the sample through a pump, where the air could potentially be contaminated.

BC’s protocol includes initially drawing a small volume of air from the source and then emptying the bag entirely prior to collecting the actual sample. This practice of “purging” the bag is conducted to remove odors and odorous compounds that are present on the lining of the Tedlar bag itself, which may be measured in the laboratory analysis in trace concentrations, potentially negatively impacting results.

2.2.2 Air Sample Collection Process

Samples collected in Tedlar bags will be sent to two laboratories for analysis. The following sections summarize the collection methods and requirements for each type of sample included in the program.

Reduced Sulfur Compound (RSC) Samples: The 1-liter (L) Tedlar bag air samples will be tested by ALS Environmental for the concentration of 20 RSCs, all of which are potentially present in wastewater emissions and are considered to be odorous. Collection of 1-L air samples for the RSC testing will take approximately 2-3 minutes for each sample. The laboratory analysis will be ASTM Testing Standard D5504-01, which uses direct injection of a small quantity of the odorous air into a gas chromatograph. The output is provided in units of concentration of the odorous compounds. The method reporting limit (MRL) for the group of compounds ranges from 2.5 to 5.0 ppbv.

Odor Panel Samples: Samples that will be sent to St. Croix Sensory for odor panel analysis will be collected in the identical manner as stated above (using a vacuum chamber), except that the odor panel samples are collected in larger 10-L Tedlar bags. For the odor panel samples it is critical not to fill up the entire 10-L because the air inside the bags tends to expand in flight during shipment to the laboratory; therefore, a filled bag could break in transport. The odor panel laboratory recommends filling the bag approximately 2/3 full, which will provide sufficient air volume to conduct the odor panel testing.

Additionally, duplicate samples will be collected for each source immediately after the first sample. These second samples will be labeled as duplicates and the laboratory will be directed on the chain-of-custody not to analyze the duplicate samples unless the initial sample bag breaks in transport or loses a significant portion of air due to a hole in the bag or from a leaking valve.

The odor panel sample chain-of-custody forms include a column into which the sampler enters the field H_2S concentration of the air in the bags. This is most important for samples that are projected to be high in H_2S concentration (generally greater than 50 ppmv). For these samples, the odor panel laboratory is typically instructed to pre-dilute the air sample prior to testing so as to not exceed the maximum result that the odor panel can provide. Pre-dilution is not anticipated to be needed in this odor sampling. H_2S concentrations will be measured directly off the sample bag by connecting the Jerome analyzer probe to the bag with plastic tubing. This will be the H_2S concentration entered on the chain-of-custody form.

2.2.3 Sample Shipping

This section summarizes the air sample shipping requirements for the Bissell and Lemay WWTF odor sampling program. All sampling equipment, including the vacuum chamber, Tedlar bags, tubing, fittings, and other sampling items, will be shipped to the attention of David Yates at the BC St Louis office prior to the first day of sampling.

The samples that will be analyzed for RSCs will be shipped to the following laboratory:

ALS Environmental
ATTN: Sample Receiving
2665 Park Center Drive
Simi Valley, CA 93065
Phone: +1 805.526.7161

The point of contact for ALS Environmental is Sue Anderson. Sue can be reached at the phone number shown in the above contact information.

The samples that will be shipped for odor panel analysis will be shipped to the following laboratory:

St. Croix Sensory
1150 Stillwater Blvd
ATTN: Sample Receiving
Stillwater, MN 55082
Phone: +1 800.879.9231

The point of contact for St Croix Sensory is Donna McGinley. Donna can be reached at the phone number shown in the above contact information. However, any of the St. Croix Sensory staff that answers the phone will be able to help with the project and answer questions.

All air samples (including both laboratories) will be shipped overnight. This is because the samples are required to be analyzed within 24 hours, since their constituents tend to degrade over time inside the bags. Note that in a case where one or more samples are collected in the early morning hours in St. Louis (Central Time Zone), it is possible that the ALS Environmental Laboratory (Pacific Time Zone) will not yet be open when 24 hours has passed; therefore, the sample(s) will exceed the 24-hour hold time, If this occurs, those results (for the specific samples that exceed the hold time only) will be flagged by the laboratory. However, given that this will be a relatively small amount of time, BC will still use the results in the data analysis.

Each bag shipped to the laboratories for analysis will be labeled with the sample location, name of sample, and date. The sampler will use the BC FedEx account for shipment of all air samples and to return air sampling equipment.

2.2.4 Laboratory Analysis

The following laboratory analysis protocols will be used:

Odor Panel Detection Threshold (DT) and Characterization by EN13725: Measurements of "total odor" of air samples will be conducted using odor panel testing by St. Croix Sensory. Twelve panelists are trained by the laboratory and tested at the start of the day prior to the analysis to confirm that their olfactory senses are within an acceptable range. During the test, samples will be diluted below the threshold of detection and introduced into a gas delivery system, which conveys sample air through 3 cones. The odor panel sniffs air from these cones, 1 of which contains the diluted air sample and 2 of which contains only "odor-free" (carbon-filtered ambient) air.

A series of trials is conducted in which each odor panelist attempts to determine which of the 3 cones contains the sample air. Each trial is "forced choice", meaning the panelist much choose one of the three cones even if they cannot discern the difference and are guessing. For each trial, the laboratory test administrator increases the sample concentration in the gas delivery system and the forced choice is conducted again. Sample concentration increases continue until at least half of the 12-person panel correctly identifies the odorous sample. At that point, the test ends.

The number of successive trials of increasing sample concentration represents how "detectable" the odor is. Therefore, more required concentrations of the diluted sample indicate a less detectable odor. The result of this test is an identification of how many times the air sample must be diluted so that the concentration is at the threshold of human detection (half of the odor panel). This number is referred to as the "detection threshold" and is unitless. The odor panel will also provide a measurement of the concentration of the sample at which the odor can be recognized or described. The number of dilutions required to arrive at this concentration is referred to as the "recognition threshold". Detection threshold is quantified in terms of dilutions-to-threshold or D/T. This value is also frequently referred to as "odor units". Recognition threshold is similarly referred to as R/T.

The odor panel will also provide a characterization of the odor samples, which includes the use of descriptive words such as "vegetable", "medicinal", "offensive", etc. The characterization also includes an assessment of hedonic tone for the sample, which is a measure of the offensiveness of the odor on a scale of -10 to +10, where -10 would be the worst odor the panelist has ever experienced and +10 would be the most pleasant. These determinations are subjective but provide some insight as to the nature of the odor in addition to simply how detectable it is, which will also impact community odor complaints.

Reduced Sulfur Compounds (RSCs) by ASTM D5504: RSC concentration measurements of air samples will be conducted using a gas chromatograph/mass spectrometer (GC/MS); all air samples will be analyzed by ALS Environmental. Most of the 20 measured RSCs have a very low human detection threshold concentration (the minimum concentration of the compound required for the average nose to detect its presence). For example, the detection threshold of H_2S is in the range 0.5 to 1 ppbv and the detection threshold of the reduced sulfur organic compound methyl mercaptan (CH_3SH) is approximately 1.1 ppbv. Reduced sulfur organic compounds are frequently described as smelling like rotten vegetables and garbage. These compounds are commonly found in solids-handling facilities such as dewatering processes. Measurement of RSCs in addition to odor panel analysis is important for wastewater samples as it gives an indication of some of the main compounds that are contributing to the odor. Identification of these compounds is critical in determining the most appropriate odor control technology (or technologies) required to treat the foul air.

3.0 Sample Locations and Schedule

This section provides a description of the sampling locations and a schedule of sampling activities.

3.1 Sample Locations

The odor sampling at the Bissell and Lemay WWTFs will include sample collection from the locations listed in the Table 3-1 matrix. Field and laboratory analysis quantities are provided for each sampling location; air samples will be collected and shipped using the protocols described in Section 2 and laboratory analysis will be conducted as described in Section 2.2.4. Sampling locations will be confirmed during the first day of sampling (Day 0), during which access to the specific sampling locations will also be confirmed. During Day 0, needs for sampling ports and any special requirements, such as ladders or longer tubing, will be determined and coordinated with WWTF staff.

Table 1. Projected Sampling Matrix

Sampling Location	Notes	Logger or Air Sample Quantities		
		Odor Panel [a]	RSCs [b]	Acrulogs [c]
Bissell WWTF belt filter press (BFP)	• Use the Jerome analyzer to measure H_2S in areas surrounding the BFP. Record concentrations. • At area of highest field measured H_2S concentration, collect air samples, extending tubing inside BFP to eliminate room air collection as much as possible. • During a single day, collect 2 samples to be shipped to each laboratory, one in the morning and one in the afternoon. • Use the Jerome analyzer to measure sample H_2S concentration directly off the 10-L sample bag.	2	2	0
Lemay WWTF BFP	• Use the Jerome analyzer to measure H_2S in areas surrounding the BFP. Record concentrations. • At area of highest field measured H_2S concentration, collect air samples, extending tubing inside BFP to eliminate room air collection as much as possible. • During a single day, collect 2 samples to be shipped to each laboratory, one in the morning and one in the afternoon. • Use the Jerome analyzer to measure sample H_2S concentration directly off the 10-L sample bag.	2	2	0
Lemay WWTF dewatering facility odor control inlet	• Install LRSS system and Acrulog prior to air sample collection. LRSS system to be connected to Acrulogs by BC with assistance from MSD. • Collect foul air samples from duct on discharge side of fan, if feasible Otherwise, collect foul air samples on suction side of fan. • Air samples to be collected following observation of variations in field H_2S measurements by Acrulog for at least 30 minutes. Considering general variations in concentrations (if present), collect air samples when H_2S concentrations are observed to be generally highest following initial 30 minutes. • During a single day, collect 2 samples to be shipped to each laboratory, one in the morning and one in the afternoon. • Download data from Acrulog prior to completion of sampling day to confirm loggers are operating correctly.	2	2	1

Sampling Location	Notes	Logger or Air Sample Quantities		
		Odor Panel [a]	RSCs [b]	Acrulogs [c]
Lemay WWTF dewatering facility odor control outlet	• Install LRSS system and Acrulog prior to air sample collection. LRSS system to be connected to Acrulogs by BC with assistance from MSD. • Collect odor control system outlet samples immediately following each odor control system inlet sample.. • Download data from Acrulog prior to completion of sampling day to confirm loggers are operating correctly..	2	2	1

[a] Odor panel measurement of detection threshold, recognition threshold, and characterization by St. Croix Sensory (see Section 2.2.4). Numerical values indicate the number of samples to be collected and analyzed; these values do not include duplicate samples.

[b] Laboratory analysis using ASTM D5504 by ALS Environmental (see Section 2.2.4). Numerical values indicate the number of samples to be collected and analyzed; these values do not include duplicate samples.

[c] Acrulog installation for 1 week each; numerical value indicates number of instruments deployed.

BC will complete a preliminary site visit the day before the first day of air sample collection and Acrulog installation (Day 0) to verify locations, determine additional needs and any further discussions with MSD regarding the odor sampling. Where needed, BC will request that MSD operations staff drill ½-inch sample ports in the ducting at the locations identified during Day 0 of the site visit. The exact locations will be determined based on access limitations and where the least amount of air turbulence is anticipated (furthest from duct bends or foul air fans). MSD will be asked to fill the new drill holes with an appropriately sized stopper or duct tape.

3.2 Proposed Schedule

Table 3-2 provides a schedule of activities for the odor sampling, divided into days since the exact start date of the sampling is not yet known. This schedule will be confirmed with MSD and modified as needed throughout completion of the sampling. Modifications may include revising the listed number of samples collected in Day 1 and Day 2 (if Day 2 is needed) based on system operations, timing, accessibility, and expected odor peaks.

Table 2. Schedule of Odor Sampling Activities

Day	Activities	Notes
Day 0	• Initial site visits at each WWTF, walk-through to observe sampling locations. • Confirm sampling locations. Spot-check of H_2S concentrations with Jerome analyzer may be completed at BFPs (both WWTFs) and at the Lemay WWTF odor control system, if time allows. • Identify operations staff needs or new sample ports (to be drilled by MSD operations staff) or access requirements. MSD will have the option to plug sampling ports following completion. • Confirm that all rented equipment and sampling materials have arrived. Stage equipment at one location on each WWTF site where they will be used (out of the elements).	This is assumed to be accomplished in one afternoon and on the day before Day 1. No sample collection on Day 0.
Day 1	• At Lemay WWTF, install Acrulogs in LRSS to measure continuous H_2S concentrations from odor control system inlet and outlet (2 locations).	Collect odor panel and RSC samples at each location simultaneously by overfilling the 10-L bag and connecting the 10-L bag to the 1-L bag and pushing air into the smaller bag.

Day	Activities	Notes
	• Collect multiple H_2S concentration measurements around Lemay WWTF BFP using Jerome analyzer and record, noting where highest concentrations are measured. • Collect 6 10-L Tedlar bag air samples (total) from Lemay WWTF BFP and odor control system (see Table 3-1) and ship samples overnight delivery to St. Croix Sensory odor panel laboratory. • Collect 6 1-L Tedlar bag air samples (total) from Lemay WWTF BFP and odor control system (see Table 3-1) and ship samples overnight delivery to ALS Environmental laboratory for RSC analysis. • Confirm Acrulog H_2S monitors and LRSS are functioning properly prior to leaving site for the day and contact Acrulog renter (Detection Instruments) with any issues.	Collect duplicate air samples after initial sample collection at each location and label accordingly. IF TIME PERMITS, conduct a portion or all of Bissell WWTF field work and air sampling on Day 1, understanding that there are overnight shipping cutoffs at Fed Ex facilities.
Day 2	• Collect multiple H_2S concentration measurements around Bissell WWTF BFP using Jerome analyzer and record, noting where highest concentrations are measured. • Collect 2 10-L Tedlar bag air samples (total) from Bissell WWTF BFP (see Table 3-1) and ship samples overnight delivery to St. Croix Sensory odor panel laboratory. • Collect 2 1-L Tedlar bag air samples (total) from Bissell WWTF BFP (see Table 3-1) and ship samples overnight delivery to ALS Environmental laboratory for RSC analysis.	Collect odor panel and RSC samples at each location simultaneously by overfilling the 10-L bag and connecting the 10-L bag to the 1-L bag and pushing air into the smaller bag. Collect duplicate air samples after initial sample collection at each location and label accordingly.
Day 7	• Remove all Acrulogs and download data.	BC St Louis staff to complete final removal and download Acrulog data on site at Lemay WWTF to confirm that data has been collected appropriately. BC staff to return rented equipment.

4.0 Staffing and Team Responsibilities

This section provides a list of staff who will be involved in the odor sampling effort and the BC team responsibilities.

4.1 Contact List

Table 4-1 provides contact information for the odor sampling team. All individuals listed in this table will be present and/or available during the sampling event.

Table 3. Contact List

Name	Company	Role	Office Phone	Cell Phone	Email
Becca Coyle	MSD	Bissell Point Plant Manager			rjcoyle@stlmsd.com
John McCarthy	MSD	Bissell Point Asst. Plant Manager			jmccarthy@stlmsd.com
Pat Baldera	BV	Lemay Plant Manager	314.638.5190	314.536.6602	pbaldera@stlmsd.com
Karl Nowak	BV	Lemay Asst. Plant Manager			knowak@stlmsd.com
David Yates	BC	Project Manager	314.296.6143	314.660.3211	dyates@brwncald.com
Matt Fishman	BC	Design Manger	978.983.2032	774.313.8977	twassell@brwncald.com
David McEwen	BC	Odor Control Advisor	919.424.1445	925.367.7842	dmcewen@brwncald.com
Carol Zuerndorfer	BC	Odor Control Lead	978.620.0753		czuerndorfer@brwncald.com

4.2 Team Responsibilities

Following are the assumed responsibilities for the BC and MSD sampling team members:

- BC will provide this sampling plan in draft format to MSD at least 2 weeks prior to the sampling and solicit and incorporate comments. BC will make MSD aware of any changes that impacts the sampling event scope or schedule.
- BC will maintain a hard copy and electronic copy of this sampling plan and update it throughout the odor sampling as changes occur.
- MSD will provide one dedicated operations employee to provide sufficient access to the sampling locations throughout the sampling event. Other MSD employees will be consulted for specific needs throughout the sampling event as necessary, such as those that may be needed to drill and plug sampling taps in air ducting.
- BC will provide up to 2 engineers to conduct the work included in this sampling plan.
- MSD will provide BC with documentation (by email) of any unusual circumstances occurring at the Bissell or Lemay WWTF during the entire sampling period, such as upsets or maintenance activities in the areas where samples are being collected.
- BC and MSD staff will agree to specific sampling locations defined in this protocol following the first day of the sampling event (Day 0).

- For locations where new sampling ports need to be drilled, BC advises that a ½-inch sample port be drilled for insertion of sampling tubing. BC requests that MSD staff be responsible for plugging holes after sampling using stoppers, duct tape, or other materials selected by MSD.
- BC will order all sampling supplies and required field testing equipment for the sampling event, with all equipment and sampling items to arrive at least 2 days prior to the first day of the sampling event (Day 0). All equipment will be directed to the attention of David Yates at the BC St Louis office.
- MSD will identify a location on site at each WWTF to store sampling equipment and paperwork during the sampling program that is out of influence from weather. Note that no sampling equipment or samples need to be kept cold or shipped cold; therefore, refrigeration is not needed.
- BC sampling team will review the BC health and safety plan and sign off on it prior to commencing the first day of the sampling event (Day 0).
- MSD staff will assist BC staff with installation of the Acrulogs as needed. Local BC St Louis staff will remove the Acrulogs after one week of monitoring (Day 7). BC will return the rented equipment to the equipment supplier.

Attachment F: Odor Sampling Field Work and Results

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum: Field Work and Sampling Results

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

27 OCTOBER 2020

Brown AND Caldwell

Technical Memorandum

7733 Forsyth Blvd
11th Floor, Suite 1100
Clayton, MO 63105

Prepared for: Metropolitan St. Louis Sewer District (MSD) / Black and Veatch (BV)

Project Title: Bissell Point and Lemay WWTF Fluidized Bed Incinerators

BC Project No.: 153644

Technical Memorandum

Subject: Bissell Point and Lemay WWTF Field Work and Sampling Results

Date: October 27, 2020

To: Bently Green, PE, Black & Veatch Project Manager

From: Dave Yates, PE, Brown and Caldwell Project Manager

Copy to: Matt Fishman, PE*, Brown and Caldwell Design Manager

Submitted by: ______________________________
Dave Yates, Missouri License No. 2008010469, Expiration 12/31/2020

Prepared by: ______________________________
Carol Zuerndorfer

Reviewed by: David W McEwen
David McEwen

** Licensed in other states*

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This technical memorandum (TM) provides a documentation of the field work and sampling results for an odor sampling event conducted by Brown and Caldwell (BC) and the Metropolitan St. Louis Sewer District (MSD) staff at the Bissell Point and Lemay Wastewater Treatment Facilities (WWTFs). This sampling effort is associated with selecting odor control technologies and establishing design criteria for two new odor control systems to be constructed as part of the Bissell Point and Lemay WWTF Fluidized Bed Incinerators (FBI) design project.

1.0 Background

MSD has undertaken a project to provide new fluidized bed incineration facilities at MSD’s Bissell Point and Lemay WWTFs. The new incineration facilities at Bissell Point WWTF will include dewatering and incineration of raw sludge trucked in from the Coldwater Creek WWTF in addition to the Bissell Point WWTF biosolids. The new incineration facilities at Lemay WWTF will include dewatering and incineration of raw biosolids from the Grand Glaize, Fenton, and Lower Meramec WWTFs in addition to the Lemay WWTF biosolids.

There is an existing activated carbon adsorption odor control system operating at Lemay WWTF that treats foul air exhausted from various sources in the dewatering facility and a separate biotrickling filter (BTF) odor control unit that treats air from the blended sludge well. There are currently no odor control systems at Bissell Point WWTF.

Because of the surrounding neighborhood (residential and commercial areas) at Lemay WWTF, a new odor control system will be constructed as part of the FBI project. Odor control will also be constructed at Bissell Point WWTF as part of the current FBI project. Bissell Point WWTF is located entirely within an industrial area with lower complaint potential than what is assumed for Lemay WWTF; however, expected high odor concentrations associated with the new dewatering facilities has resulted in MSD determining the need to be proactive and install odor control at Bissell Point WWTF as well.

Odor sampling and field testing was completed at the existing Bissell Point and Lemay WWTF dewatering facilities between September 9, 2020 and September 25, 2020. The data collected are being used to inform production of design criteria for odor control implementation at the WWTFs and selection of odor control technologies. Criteria to be developed using the sampling data include foul airflow rates, odor loading, and odor removal efficiency requirements to meet facility fence line requirements.

2.0 Sampling Program Elements and Equipment

This section contains information on sampling locations, field odor measurements, and laboratory analysis results that comprised the odor sampling program.

2.1 FIELD MEASUREMENTS

Field odor measurements were collected using a hand-held hydrogen sulfide (H_2S) analyzer and Acrulogs. This section describes how these instruments were used and where they were installed.

2.1.1 Instantaneous H_2S Field Measurements

A Jerome 631-X analyzer (Figure 2-1) was used to measure H_2S concentrations at and near odorous processes in the Bissell Point and Lemay WWTF dewatering facilities. The Jerome analyzer is a hand-held instrument that provides a single H_2S measurement in typically less than 30 seconds. The instrument was used for “snapshot” measurements only, not continuous readings. The H_2S measurements collected using the Jerome analyzer provided an indication of odors in various locations of the WWTF.

Figure 2-1. Jerome 631-X analyzer used for field H2S measurements

Hydrogen sulfide concentration is measured by the Jerome analyzer down to a resolution of 0.001 parts per million by volume (ppmv), or 1 part per billion by volume (ppbv), and to a maximum of 50 ppmv. This lower bound is approximately equal to the threshold of human detection for H_2S, which is generally accepted to be 0.5 to 1 ppbv. Hydrogen sulfide retains a familiar “rotten egg” odor and is the most prevalent odorous compound in wastewater treatment emissions.

2.1.2 Continuous H_2S Monitoring

Continuous H_2S concentrations were measured with Acrulog data loggers. The loggers were used in areas where H_2S concentrations are measured at the odor source or within an odor source headspace. Ambient H_2S concentrations were recorded every 3 minutes while the loggers were deployed. Measurements were collected continuously for 1 week at each location.

To measure H_2S concentrations in the foul air ducts entering the existing OCU at Lemay, a Low Range Sampling System (LRSS) was used. The LRSS utilizes a dual-headed pump to draw a sample from flowing air within a duct and delivers a constant flow rate to the Acrulog. A setup using an LRSS for the odor testing is shown in Figure 2-2.

Figure 2-2. Installed Acrulogs inside an LRSS

2.2 SAMPLING AND LABORATORY ANALYSIS

Air samples were collected at various dewatering facility locations and shipped to two laboratories for analysis of odor and odorous compounds. This section summarizes the collection and analysis process.

2.2.1 Odor Panel Testing

Bag samples were collected in 10-liter (L) Tedlar bags and shipped to St. Croix Sensory odor panel laboratory for analysis. The laboratory-quantified values for detection threshold (DT) and odor characterization using EN13725. Samples were collected using a vacuum chamber (shown in Figure 2-3), applying protocols described in the *Bissell Point and Lemay WWTF Odor Sampling Plan TM, Brown and Caldwell (June 22, 2020)*.

Figure 2-3. Vacuum chamber apparatus for air sampling

2.2.2 Reduced Sulfur Compound Testing

Air samples were collected and analyzed by ALS Environmental laboratory for 20 reduced sulfur compounds (RSCs) commonly found in wastewater and dewatering facilities. The laboratory used ASTM D5504 to measure concentrations of the selected RSCs, which include organic sulfides such as methyl mercaptan (MM), dimethyl sulfide (DMS), carbonyl sulfide (CS), carbon disulfide (CDS), and dimethyl disulfide (DMDS). H_2S concentrations were also measured by the laboratory as part of the ASTM D5504 protocol.

Air samples were collected in the same manner as the 10-L bags sent to the odor panel tests but using 1-L Tedlar bags instead of a 10-L bag. The 10-L bags were filled first and the 1-L bags for RSC testing were filled by pushing approximately 1 L from the 10-L bag to the 1-L bag using connecting plastic tubing. Doing this assured that the RSC testing was conducted on the same air samples as was used for the odor panel testing. Details associated with the sampling protocols and laboratory analysis method are described in the *Bissell Point and Lemay WWTF Odor Sampling Plan TM, Brown and Caldwell (June 22, 2020*).

3.0 Sample Locations

This section describes the locations and conditions for sampling locations. Field measurements using the Jerome analyzer and Acrulog for H_2S measurements were supplemented in most cases by collecting air samples and shipping to laboratories for analysis as described in Section 2.2. These sampling locations were identified in the sampling plan (*Bissell Point and Lemay WWTF Odor Sampling Plan TM, Brown and Caldwell, June 22, 2020*) and for the most part were kept in execution of the sampling program; however, some locations were modified due to field limitations or to maximize rentals by moving the Acrulogs to other locations when it was clear that H_2S concentrations were minimal in the original location.

3.1 ACRULOG H_2S MONITORING LOCATIONS

Field H_2S monitoring was conducted from September 9 to 25, 2020. Activities included installation and removal of Acrulog loggers and field H_2S analyses using a Jerome analyzer using the protocols described in Section 2.1. Acrulog monitoring was conducted at selected foul air source locations throughout the dewatering facilities as well as at the Lemay WWTF odor control inlet and outlet for one of the carbon adsorbers. The goal of the sampling program was to quantify odor loading associated with the foul air sources to determine loadings for the new odor control systems.

The actual Acrulog installation locations tested by BC in the field differs from those listed in the *Bissell Point and Lemay WWTF Odor Sampling Plan TM, Brown and Caldwell (June 22, 2020*). The sampling locations were finalized in the field based on Jerome analyzer H_2S measurements the in addition to sampler observations and information from WWTF operations staff. Acrulogs installation locations are listed in Table 3-1, along with descriptions of the sampling locations.

Table 3.1. Acrulog Installation Descriptions

Sample	Installation Date	Sampling Location	Condition/Notes
1	9/14/20 – 9/21/20	Bissell Point WWTF blended sludge well	Installed in the headspace above the south blended sludge well.
2	9/14/20 – 9/18/20	Bissell Point WWTF belt filter press (BFP)	Installed just above one of the operating BFPs, hanging the Acrulog as close to the sludge as possible to collect only sludge emissions. This Acrulog was relocated to the cake equalization bin after 4 days of data collection.
3	9/18/20 – 9/21/20	Bissell Point WWTF cake receiving bin	Installed in one of the operating cake equalization bins, hanging the Acrulog as close to the sludge as possible.
4	9/15/20 – 9/22/20	Lemay WWTF blended sludge well	The blended sludge well at Lemay WWTF is enclosed and connected to a BTF odor control unit. There were no access hatches available to easily install the Acrulog in the headspace above the well; therefore, the Acrulog was connected by tubing to a sample port on the foul air duct.
5	9/15/20 – 9/18/20	Lemay WWTF BFP	The Acrulog was installed just above the sludge in one of the operating BFPs, hanging the Acrulog as close to the sludge as possible. This Acrulog was relocated to the cake receiving bin after a few days of data collection.
6	9/22/20 – 9/25/20	Lemay WWTF cake receiving bin	The Acrulog was installed in one of the operating cake receiving bins, hanging the Acrulog as close to the sludge as possible. This Acrulog was initially installed from 9/18 to 9/22, but a malfunction with the logger resulted in only 3 minutes of viable data for that period. A different Acrulog was installed from 9/22 to 9/25 to complete data collection at this source location.

3.2 AIR SAMPLING LOCATIONS

Air samples were collected on September 14 and 15, 2020 using the 10-L and 1-L bags and shipped to the respective laboratories for analysis per the sampling protocol discussed in Section 2.2. A description of the sampling locations is provided in Table 3-2. Most samples were collected in the same location as the Acrulog was installed, as indicated in the table. The samples are listed in the order in which they were collected.

Table 3.2. Air Sample Descriptions

Sample	Sampling Date	Sampling Location	Location Description
1	9/14/20	Bissell Point WWTF blended sludge well	Same as Acrulog installation location.
2	9/14/20	Bissell Point WWTF BFP	Same as Acrulog installation location.
3	9/14/20	Bissell Point WWTF cake receiving bin	Same as Acrulog installation location.
4	9/14/20	Bissell Point WWTF scum concentrator	Scum concentrator headspace.
5	9/15/20	Lemay WWTF blended sludge well	Same as Acrulog installation location.
6	9/15/20	Lemay WWTF BFP	Same as Acrulog installation location.
7	9/15/20	Lemay WWTF cake receiving bin	Same as Acrulog installation location.
8	9/15/20	Lemay WWTF odor control inlet	Activated carbon adsorber inlet duct.
9	9/15/20	Lemay WWTF odor control outlet	Activated carbon adsorber exhaust stack (same unit as inlet).

Other notes relating to the air sampling collection are as follows:

- Initially, the LRSS was intended to be used for Acrulog installation at the carbon adsorber inlet and outlet ducts at Lemay WWTF. However, during the preliminary field check ("Day 0" in the sampling plan) it was discovered that no electrical outlets were installed near the odor control system. Moreover, H_2S concentrations at the odor control inlet are recorded by SCADA. MSD staff provided BC with approximately one year of H_2S data for the Lemay WWTF carbon adsorber odor control units, which were used by BC in analysis and design criteria development in lieu of Acrulog data.
- Based on field observations, it was determined that the 2 air samples per location, as noted in the sampling plan, were not needed to accurately describe the H_2S and odor of those locations. This is supported by observations in the literature that have shown that solids handling facilities do not have the same diurnal variation as liquid-phase treatment process. Additionally, since air samples had to be returned to FedEx by 4 PM each day to make the overnight shipping cutoff time, late afternoon sample collection was not feasible. Therefore, the sampling protocol was revised to collecting one sample per day at the sampling locations.
- H_2S data collected during Day 0 field measurements revealed H_2S concentrations of over 50 ppmv (the highest concentration the Jerome 631-X analyzer can read is 50 ppmv.) at the Bissell Point WWTF BFP surface and up to 40 ppmv at the Lemay WWTF BFP surface and in the cake receiving bin headspace. Given these (unexpectedly high) H_2S measurements, Acrulogs of an appropriate measurement range were installed in those BFP locations to determine the varying H_2S concentrations over time.
- For air samples where Jerome analyzer and/or Acrulog measurements indicated high (greater than approximately 30 ppmv), the collected air samples were diluted by a factor of 10 so that the odor panel measurement did not exceed the lab's upper measurement limit. Dilution was achieved by first filling the 1-L bag with sample air, pushing that sample into the 10-L bag, and then filling the remaining volume of the 10-L bag with ambient (indoor) air.

- Acrulogs installed above the BFPs at both WWTFs were relocated mid-week to the cake receiving bins at the same WWTF. BC determined following Acrulog data observation of 3 days of data that the H_2S concentrations did not vary significantly over time and that the collected data would be sufficient for determining design H_2S loads for the BFP locations.

4.0 Sampling Program Results

This section provides the results of the odor sampling program conducted by BC at the Bissell Point and Lemay WWTFs, including field H_2S testing and results from laboratory analysis of collected air samples.

4.1 CONTINUOUS H_2S TESTING RESULTS

BC compiled H_2S concentration profiles for the Acrulog installation locations listed in Table 3-1. Plots are shown in Figures 4-1 through 4-6. Acrulogs were installed in the blended sludge well headspaces of both WWTFs for approximately 7 days. Acrulogs were installed in the BFP and cake receiving bin headspaces of both WWTFs for approximately 3 to 4 days.

Table 4.1 lists the average and peak H_2S concentrations during the testing period for the locations where the Acrulogs were installed. These concentrations are directly incorporated to calculation of odor control system inlet design criteria for the systems to be installed as part of the FBI project.

Table 4.1. Acrulog H_2S Measurements

Sampling Location		H_2S Concentration (ppmv)	
		Average	Peak
Lemay WWTF	Blended sludge well	336	539
	BFP surface (above sludge)	25	84
	Cake equalization bin	78	272
Bissell Point WWTF	Blended sludge well	550	992
	BFP surface (above sludge)	41	256
	Cake equalization bin	4.5	25

Observations from the Acrulog data include the following:

- The tubing connecting the Acrulog to the foul air duct at the Lemay WWTF blended sludge well filled with moisture (condensate) partway through the recording period, as shown in Figure 4-2. During this time the Acrulog readings fell to almost zero. After the tube was cleared, the Acrulog began reading correctly again. Acrulog measurements collected while the tube was filled are not used for data analysis or determining design loadings; average and peak H_2S concentrations listed in Table 4-1 and shown in Figure 4-2 do not include the period of essentially zero H_2S.
- The Acrulogs installed in the blended sludge well headspace and BFP surface at both WWTFs measured very high H_2S concentrations and will be a significant source of H_2S for the future odor control units, including the future centrifuges, where foul air will also be pulled from a confined location (cake chutes).

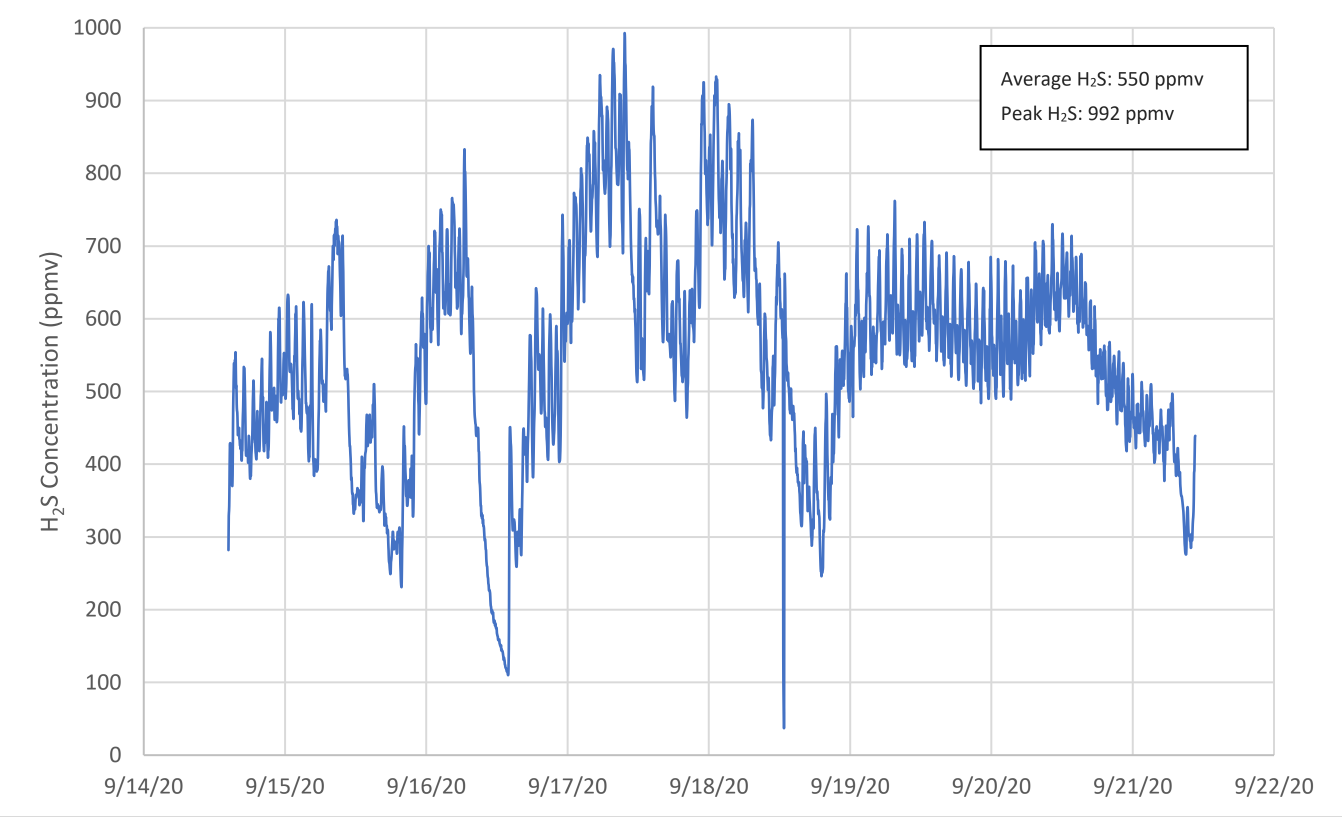


Figure 4-1. Bissell Point WWTF blended sludge well Acrulog H_2S monitoring plot

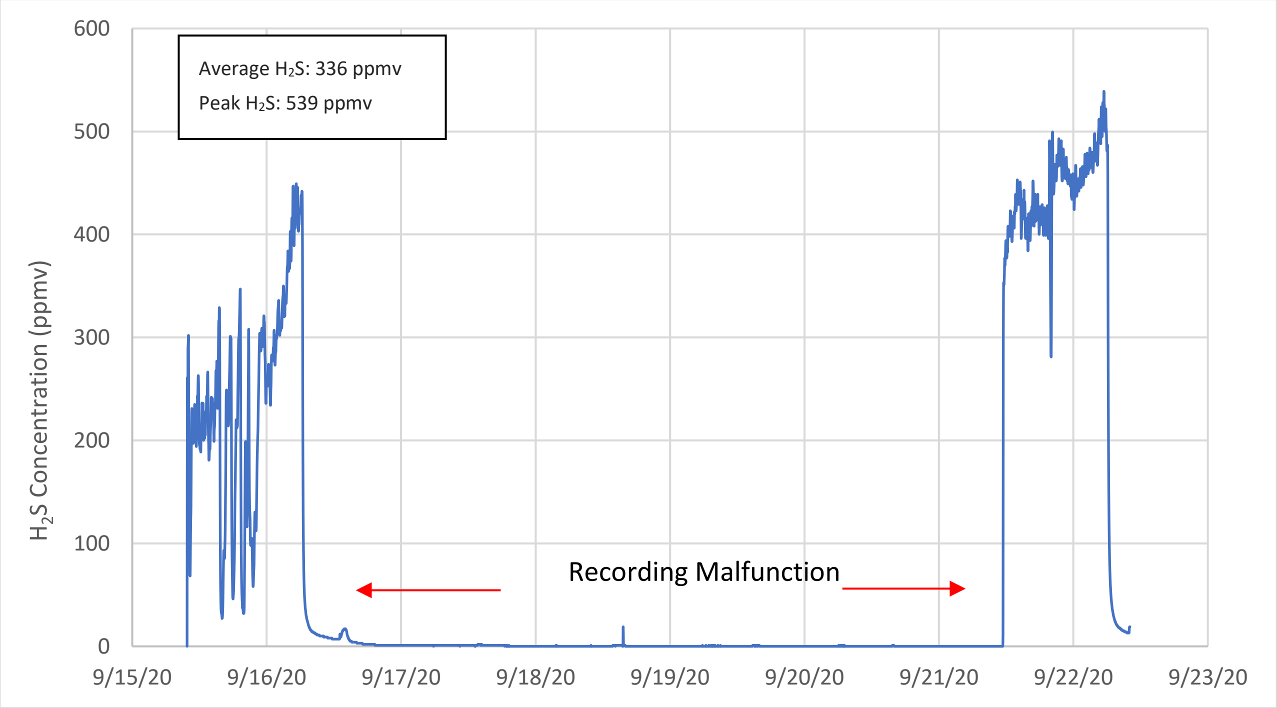


Figure 4-2. Lemay WWTF blended sludge well Acrulog H_2S monitoring plot

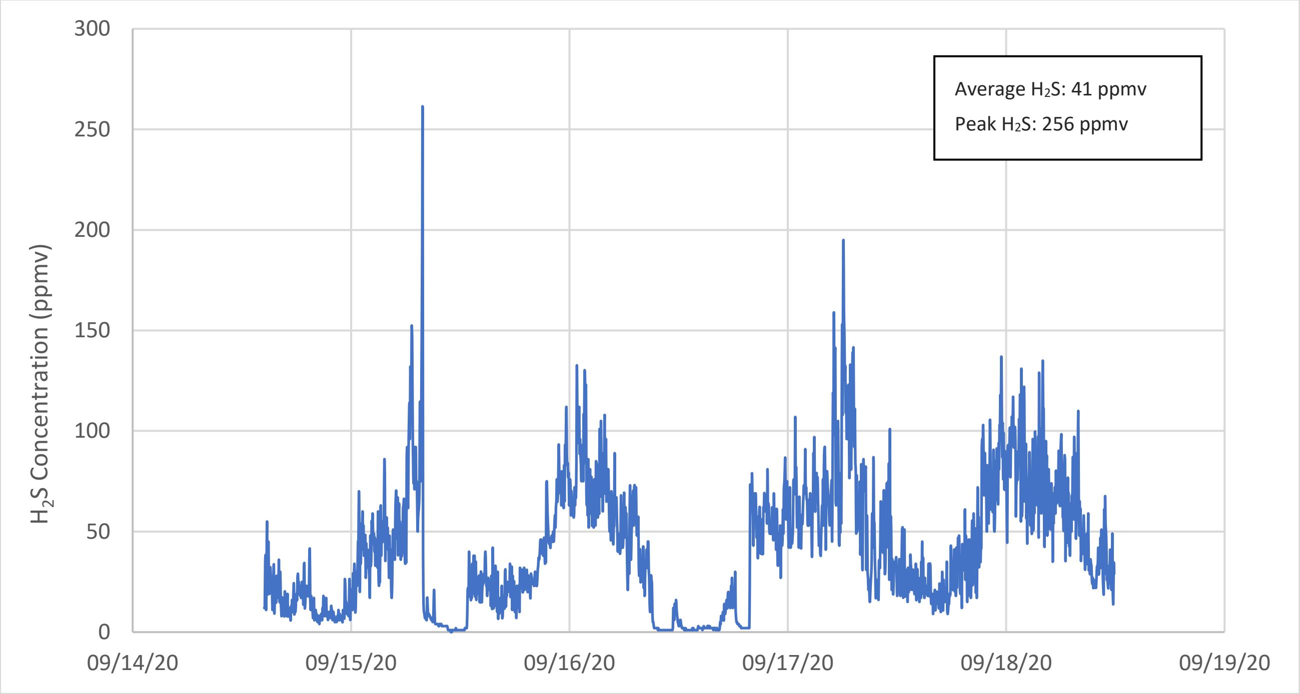


Figure 4-3. Bissell Point WWTF BFP Acrulog H_2S monitoring plot

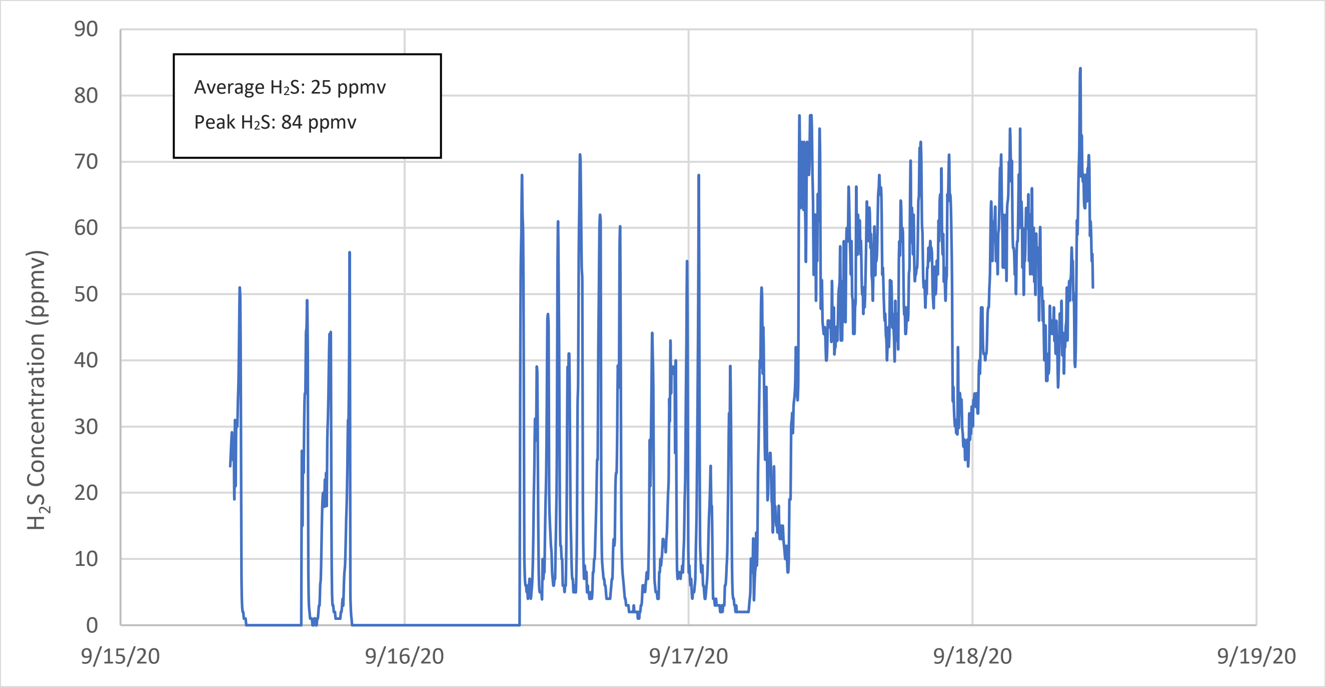


Figure 4-4. Lemay WWTF BFP Acrulog H_2S monitoring plot

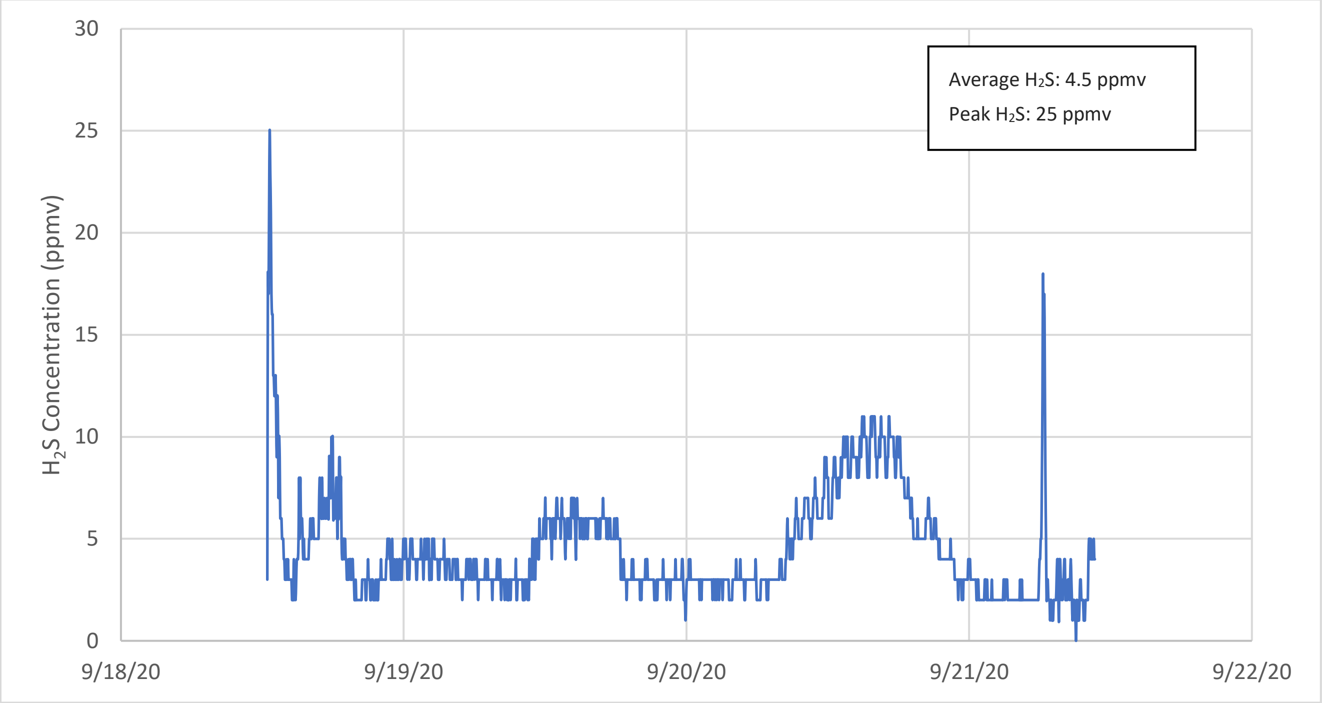


Figure 4-5. Bissell Point WWTF cake receiving bin Acrulog H_2S monitoring plot

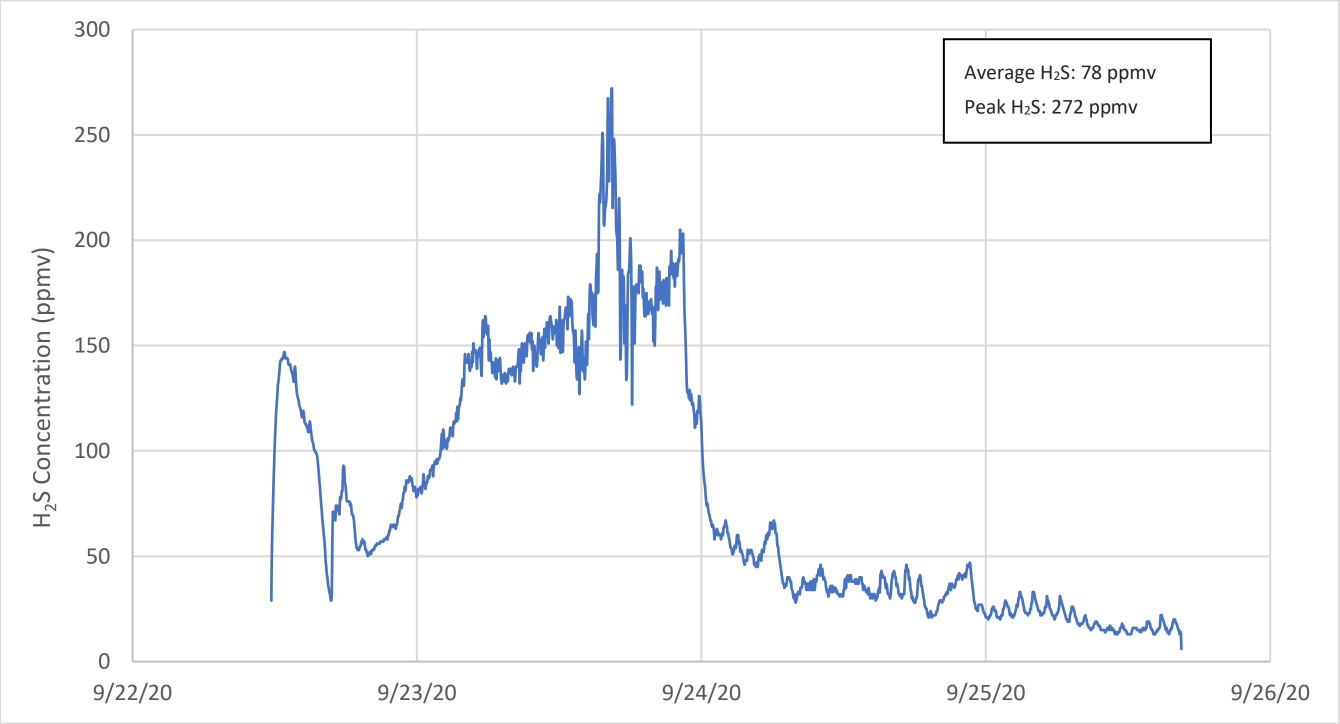


Figure 4-6. Lemay WWTF cake receiving bin Acrulog H_2S monitoring plot

4.2 ADDITIONAL COLLECTED H_2S DATA

As noted in Section 3, Acrulogs could not be installed at the odor control system at Lemay WWTF due to a lack of electrical power supply. MSD records daily minimum, maximum, and average H_2S concentrations from the odor control influent and these were provided to BC for the period from 12/31/18 through 9/1/20. A graph of the daily maximum and averages is shown in Figure 4-7.

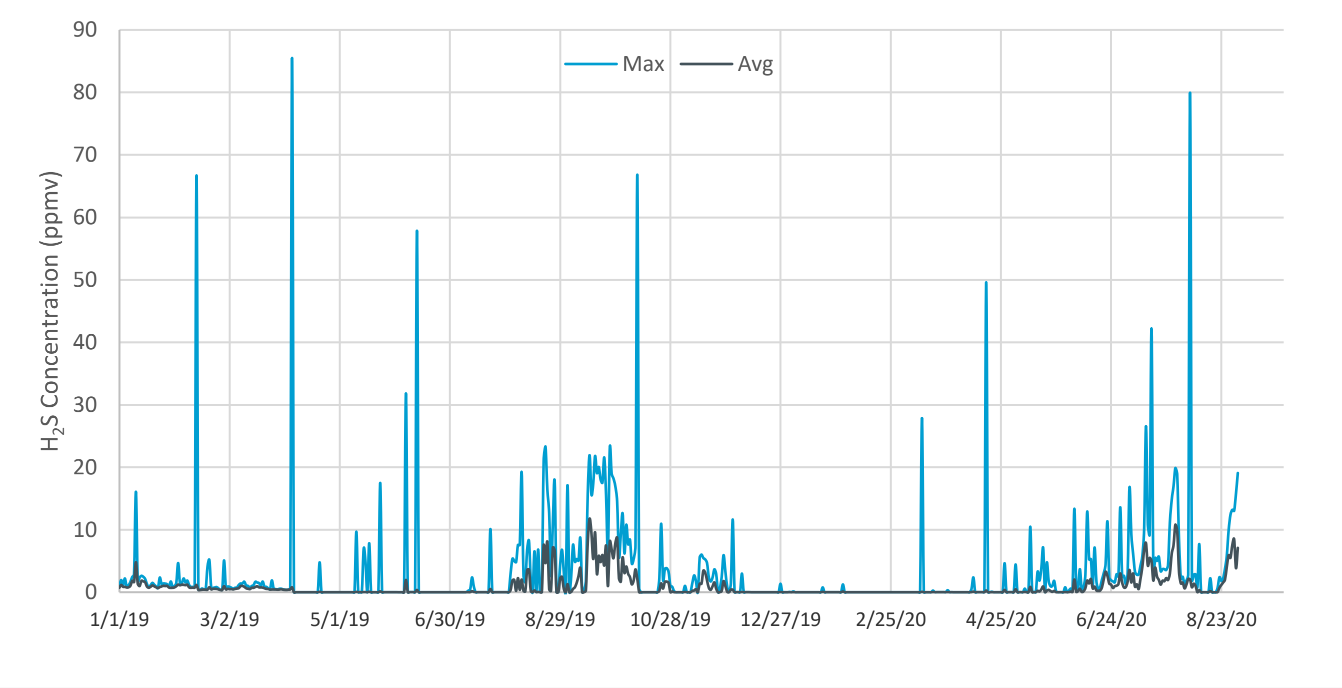


Figure 4-7. H_2S monitoring plot for the Lemay WWTF carbon adsorption odor control inlet

Provided by MSD using SCADA output

The plot shows daily H_2S concentration averages and maximums. The overall average and maximum measured H_2S concentrations for this period were 1 ppmv and 86 ppmv, respectively. While these values will not be used directly in determining odor loadings for the new Lemay WWTF odor control system because the sources and emissions will be different in the new facility, they are useful as a basis for comparison.

4.3 ODOR PANEL LABORATORY RESULTS

The results of the odor panel analyses are listed in Table 4.2. Complete odor panel testing laboratory reports are provided in Attachment A. The results shown in the table are presented in units of dilutions-to-threshold (D/T), where the numerical value represents the number of times the sample must be diluted with carbon-filtered "odorless" air to render the air barely detectable by the average human nose. Therefore, the Lemay WWTF blended sludge well odor measurement of 470,000 D/T indicates the odor panel found that the sample would need to be diluted 470,000 times for the odor in the sample to be barely detectable. All listed odor units in the table are very high, including the Lemay WWTF belt filter press odor, which exceeded the maximum measurable D/T by the laboratory, even after the sample was diluted at a 10:1 ratio in the field.

Table 4.2. Odor Panel Testing Results

Sample	Sampling Date	Facility	Sampling Location	Odor (D/T)
1	9/14/20	Bissell Point WWTF	Blended sludge well	140,000
2	9/14/20	Bissell Point WWTF	BFP surface above sludge	110,000
3	9/14/20	Bissell Point WWTF	Cake receiving bin	39,000
4	9/14/20	Bissell Point WWTF	Scum concentrator	12,000
5	9/15/20	Lemay WWTF	Blended sludge well	470,000
6	9/15/20	Lemay WWTF	BFP surface above sludge	> 600,000
7	9/15/20	Lemay WWTF	Cake receiving bin	380,000
8	9/15/20	Lemay WWTF	Odor control carbon adsorber inlet	14,000
9	9/15/20	Lemay WWTF	Odor control carbon adsorber outlet	2,600

Observations from the odor panel results include the following:

- The odor panel measured very high odors at the Lemay and Bissell Point WWTF dewatering sampling locations, especially at the blended sludge well, BFP surface, and cake receiving bin, which all contain similar sludge and cake material.
- The blended sludge tank at Lemay WWTF is aerated, which may be contributing to H_2S stripping and volatilization of other odorous organic and nitrogen-containing compounds, such as ammonia. This is a process that will be applied in the new dewatering facilities, at both WWTFs, as well; therefore, the calculated odor loadings will use these high values.
- High odors were also measured at Bissell Point WWTF, though not at the same level as Lemay WWTF. This was not consistent with the Acrulog H_2S measurements, where Bissell Point WWTF concentrations were mostly higher. This indicates that non-H_2S compounds contribute more to the total odor profile at Lemay WWTF (those these compounds are also likely to be prevalent in the Bissell Point WWTF foul air streams as well. Based on the recorded odor concentrations, the selected odor control technology (or technologies) will have to remove both H_2S and non-H_2S compounds that contribute to odor, such as organic sulfides, to meet fence line odor limits

4.4 REDUCED SULFUR COMPOUNDS LABORATORY RESULTS

Concentrations of 20 RSCs commonly found in wastewater treatment facilities were measured by ALS Environmental for all sampling locations that were also analyzed by the odor panel. The laboratory analysis method used was ASTM D5504. Results are presented in Table 4-3. Complete RSC testing laboratory reports are provided in Attachment A.

Of the 20 RSCs analyzed, the 5 included in Table 4-3 were the ones that were measured either above the method reporting limit (MRL) or in high enough concentrations that their presence was determined to contribute significantly to the total odor of the sample. The organic sulfides measured in the laboratory testing that were present in significant concentrations included carbonyl sulfide (CS), methyl mercaptan (MM), dimethyl sulfide (DMS), carbon disulfide (CDS), and dimethyl disulfide (DMDS). For each of these compounds, the human detection threshold concentration is noted in the table. The human detection threshold is defined as the concentration below which it is estimated that the average nose cannot detect that compound. These threshold concentrations are based on data in the Water Environment Federation (WEF) Manual of Practice (MOP) No. 25 (2004).

While the ASTM D5504 protocol does include H_2S concentration measurements, the better means of understanding H_2S concentrations in the locations is the Acrulog data (discussed in Section 4.1). That data is preferred for the corresponding sampling locations, as it provides average and peak H_2S concentrations for continuous measurements over a period of multiple days up to approximately 1 week.

Table 4.3. Organic Sulfide Laboratory Analysis Results

Sample	Facility	Sampling Location	Organic Sulfide Concentration (ppmv)				
			CS [a]	MM [b]	DMS [c]	CDS [d]	DMDS [e]
1	Bissell Point WWTF	Blended sludge well	0.80	17.0	2.20	ND	ND
2	Bissell Point WWTF	BFP surface above sludge	0.13	2.10	0.48	ND	ND
3	Bissell Point WWTF	Cake receiving bin	0.78	3.10	0.18	ND	ND
4	Bissell Point WWTF	Scum Concentrator	ND	0.06	ND	ND	ND
5	Lemay WWTF	Blended sludge well	ND	3.20	0.10	ND	ND
6	Lemay WWTF	BFP surface above sludge	ND	0.70	ND	ND	ND
7	Lemay WWTF	Cake receiving bin	0.62	12.0	0.71	0.07	6.50
8	Lemay WWTF	Odor control carbon inlet	0.0082	0.068	ND	ND	ND
9	Lemay WWTF	Odor control carbon outlet	0.0140	0.018	0.0064	0.0037	0.0063

[a] *Carbonyl sulfide (odor threshold = 0.00057 ppmv, WEF MOP 25, 2004).*

[b] *Methyl mercaptan (odor threshold = 0.00011 ppmv WEF MOP 25, 2004).*

[c] *Dimethyl sulfide (odor threshold = 0.0001 ppmv WEF MOP 25, 2004).*

[d] *Carbon disulfide (odor threshold = 0.0078 ppmv WEF MOP 25, 2004).*

[e] *Dimethyl disulfide (odor threshold = 0.00019 ppmv WEF MOP 25, 2004).*

Highlighted cells in Table 4.3 indicate the measured organic sulfide concentrations that were more than 100 times the human detection threshold for that compound (which are noted in the table footnotes). A value of 100 was selected to indicate that the concentration is significant because a 100:1 dilution factor is often used by BC as a compound concentration that results at a plant fence line following a treated air stream being emitted by a well-designed stack. This indicates that air streams containing compound concentrations greater than 100 times the respective human detection threshold would need some degree of odor control.

Based on this threshold, the critical organic sulfides that need to be controlled in the odor control systems that are designed as part of the FBI project include carbonyl sulfide, methyl mercaptan, and dimethyl sulfide. These compounds are all commonly present organic sulfides in wastewater facilities; each are generally described as having a character of rotting vegetables.

Attachment A: Laboratory Analysis Results

St. Croix Sensory, Inc.

Odor Evaluation Report

Report Number: 2025902

Project Name: STL, MSD, FBI Project

Samples Collected: 9/14/20
Samples Received: 9/15/20
Samples Evaluated: 9/15/20

Report Prepared For: **Brown and Caldwell**
One Tech Drive, Ste 310
Andover, MA 01810-2435

Report Prepared By: **St. Croix Sensory, Inc.**
1150 Stillwater Boulevard North
Stillwater, MN 55082 U.S.A
1-800-879-9231
stcroix@fivesenses.com

Data Release Authorization:
Michelle Harty
Michelle Harty
Laboratory Manager

Reviewed and Approved:
Charles M McGinley
Charles M. McGinley, P.E.
Technical Director

St. Croix Sensory is ISO/IEC 17025:2005 Accredited

Perry Johnson Laboratory Accreditation, Inc.
Certificate No.: L18-374

Accreditation No.: 81047
Initial Accreditation Date: 19 May 2014

Odor Evaluation Report

Client: Brown and Caldwell
Project Name: STL, MSD, FBI Project
Report Number: 2025902
Samples Evaluated: 9/15/20

#	Field No.	Sample Description	DT	RT	I	HT	DR	Comments
1	1	Cake Bin - Bissell	3,900	2,100	- - -	- - -	- - -	
2	2	BFP - Bissell	11,000	5,500	- - -	- - -	- - -	
3	3	Scum - Bissell	1,200	650	- - -	- - -	- - -	
4	4	Sludge Well - Bissell	14,000	8,500	- - -	- - -	- - -	

Odor Detection Threshold Testing (Evaluations) conducted in compliance with and under all conditions specified or required by ASTM E679 and EN13725 unless noted in report “Comments” column. The Client Chain of Custody (COC) attached to the Odor Evaluation Report provides information that may include sampling location(s), methods, and/or environmental conditions during sampling. Client, designated agents, and/or reviewers provide interpretation of results based on sampling conditions.

DT - Detection Threshold as determined by ASTM E679 and EN13725. The Practical Detection Limit (PDL) of DT is 12, based on the nominal lowest dilution presentation ratio of 8. Result is dimensionless dilution ratio at which half the assessors detect the diluted air as different from the blank air. Odor Units (OU) or Odor Units per cubic meters (OU/m3) are commonly used as pseudo-units.

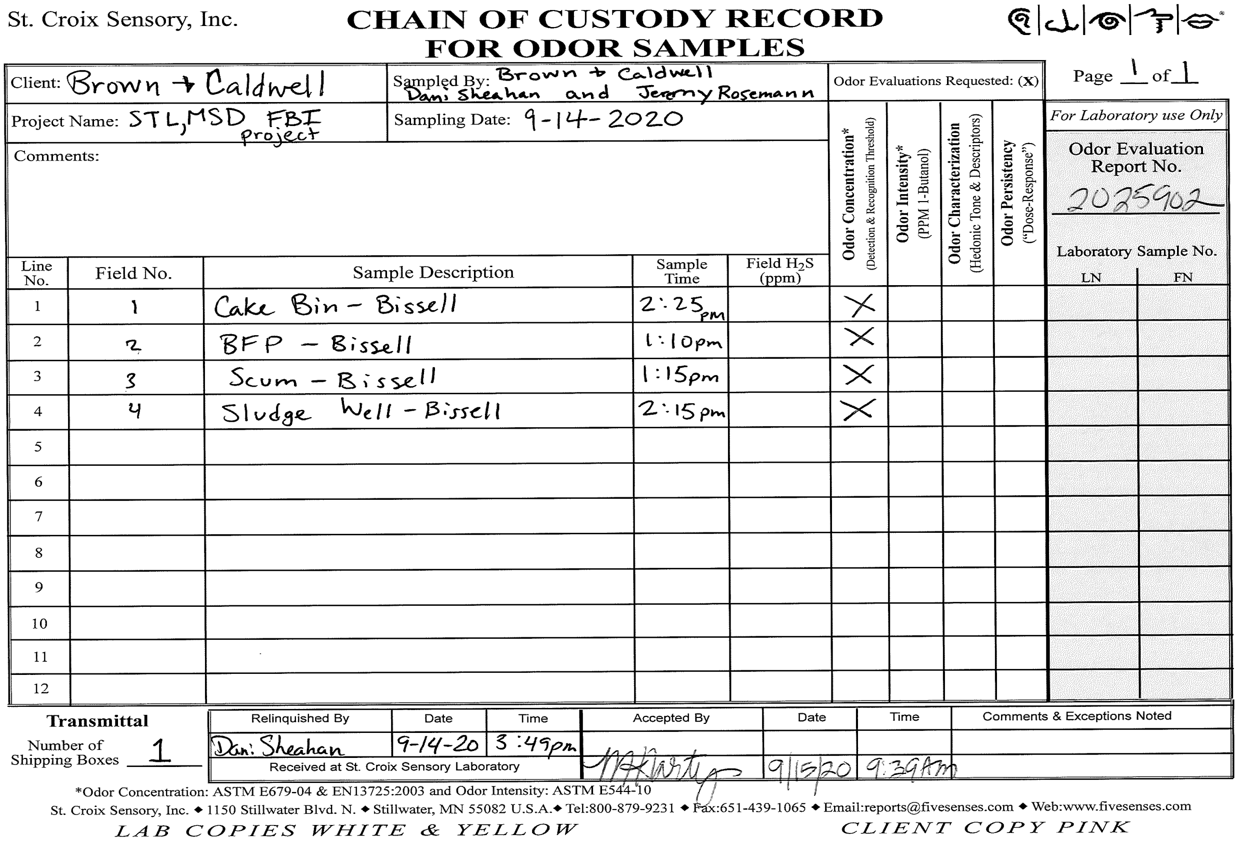
RT - Recognition Threshold as determined by ASTM E679 and EN13725. Result is dimensionless dilution ratio at which half the assessors recognize a character in the diluted odorous air. Odor Units (OU) or Odor Units per cubic meter (OU/m3) are commonly used pseudo-units.

I - Perceived odor intensity as determined by ASTM E544. Intensity is expressed as average reported scale value on 10pt n-butanol in water static scale.

HT – Hedonic Tone value. Average rating of assessors’ opinion of odor pleasantness on scale of -10 (most unpleasant) to +10 (most pleasant).

DR – the slope of the dose-response relationship of odor intensity with dilution (persistency of odor).

Attachments



St. Croix Sensory, Inc.

CHAIN OF CUSTODY RECORD FOR ODOR SAMPLES

Page 1 of 1

Client: Brown + Caldwell

Sampled By: Brown + Caldwell Dani Sheahan and Jeremy Rosemann

Project Name: STL,MSD FBI project

Sampling Date: 9-14-2020

Comments:

For Laboratory use Only

Odor Evaluation Report No. 2025902

Odor Evaluations Requested: (X)

Line No.	Field No.	Sample Description	Sample Time	Field H_2S (ppm)	Odor Concentration* (Detection & Recognition Threshold)	Odor Intensity* (PPM 1-Butanol)	Odor Characterization (Hedonic Tone & Descriptors)	Odor Persistency ("Dose-Response")	Laboratory Sample No. LN	Laboratory Sample No. FN
1	1	Cake Bin - Bissell	2:25 pm		X					
2	2	BFP - Bissell	1:10pm		X					
3	3	Scum - Bissell	1:15pm		X					
4	4	Sludge Well - Bissell	2:15 pm		X					
5										
6										
7										
8										
9										
10										
11										
12										

Transmittal

Number of Shipping Boxes 1

Relinquished By	Date	Time	Accepted By	Date	Time	Comments & Exceptions Noted
Dani Sheahan	9-14-20	3:49pm				
Received at St. Croix Sensory Laboratory				9/15/20	9:39Am	

*Odor Concentration: ASTM E679-04 & EN13725:2003 and Odor Intensity: ASTM E544-10

St. Croix Sensory, Inc. ◆ 1150 Stillwater Blvd. N. ◆ Stillwater, MN 55082 U.S.A.◆ Tel:800-879-9231 ◆ Fax:651-439-1065 ◆ Email:reports@fivesenses.com ◆ Web:www.fivesenses.com

LAB COPIES WHITE & YELLOW *CLIENT COPY PINK*

St. Croix Sensory, Inc.

Odor Evaluation Report

Report Number: 2026002

Project Name: MSD FBI Project

Samples Collected: 9/15/20
Samples Received: 9/16/20
Samples Evaluated: 9/16/20

Report Prepared For: **Brown and Caldwell**
One Tech Drive, Ste. 310
Andover, MA 01810-2435

Report Prepared By: **St. Croix Sensory, Inc.**
1150 Stillwater Boulevard North
Stillwater, MN 55082 U.S.A
1-800-879-9231
stcroix@fivesenses.com

Data Release Authorization:
Michelle Harty
Michelle Harty
Laboratory Manager

Reviewed and Approved:
Charles M McGinley
Charles M. McGinley, P.E.
Technical Director

St. Croix Sensory is ISO/IEC 17025:2005 Accredited

Perry Johnson Laboratory Accreditation, Inc.
Certificate No.: L18-374

Accreditation No.: 81047
Initial Accreditation Date: 19 May 2014

Odor Evaluation Report

St. Croix Sensory, Inc.

Client: Brown and Caldwell

Report Number: 2026002

Project Name: MSD FBI Project

Samples Evaluated: 9/16/20

#	Field No.	Sample Description	DT	RT	I	HT	DR	Comments
1	1	Cake Bins - Lemay	38,000	21,000	- - -	- - -	- - -	
2	2	Sludge Well - Lemay	47,000	31,000	- - -	- - -	- - -	
3	3	BFP - Lemay	>60,000	>60,000	- - -	- - -	- - -	
4	4	Filter In - Lemay	14,000	6,900	- - -	-2.9	- - -	
5	5	Filter Out - Lemay	2,600	1,400	- - -	-1.5	- - -	

Odor Detection Threshold Testing (Evaluations) conducted in compliance with and under all conditions specified or required by ASTM E679 and EN13725 unless noted in report "Comments" column. The Client Chain of Custody (COC) attached to the Odor Evaluation Report provides information that may include sampling location(s), methods, and/or environmental conditions during sampling. Client, designated agents, and/or reviewers provide interpretation of results based on sampling conditions.

DT - Detection Threshold as determined by ASTM E679 and EN13725. The Practical Detection Limit (PDL) of DT is 12, based on the nominal lowest dilution presentation ratio of 8. Result is dimensionless dilution ratio at which half the assessors detect the diluted air as different from the blank air. Odor Units (OU) or Odor Units per cubic meters (OU/m3) are commonly used as pseudo-units.

RT - Recognition Threshold as determined by ASTM E679 and EN13725. Result is dimensionless dilution ratio at which half the assessors recognize a character in the diluted odorous air. Odor Units (OU) or Odor Units per cubic meter (OU/m3) are commonly used pseudo-units.

I - Perceived odor intensity as determined by ASTM E544. Intensity is expressed as average reported scale value on 10pt n-butanol in water static scale.

HT – Hedonic Tone value. Average rating of assessors' opinion of odor pleasantness on scale of -10 (most unpleasant) to +10 (most pleasant).

DR – the slope of the dose-response relationship of odor intensity with dilution (persistency of odor).

St. Croix Sensory, Inc.

Report Number:	2026002
Client:	Brown and Caldwell
Project Name:	MSD FBI Project
Samples Evaluated:	9/16/2020

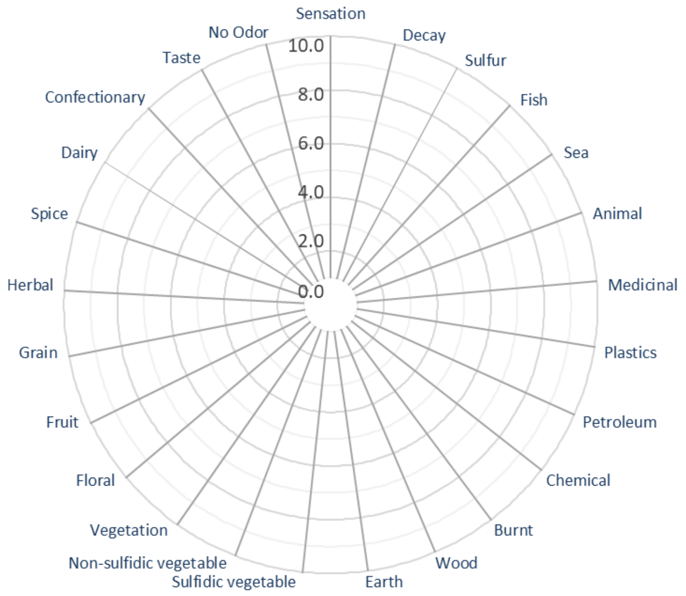
Field No: 1

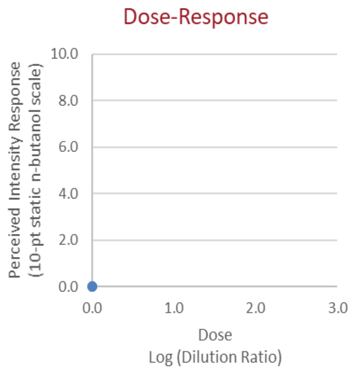
Description: Cake Bins - Lemay

DT: 38,000
RT: 21,000
I: - - -
HT: - - -
DR: - - -

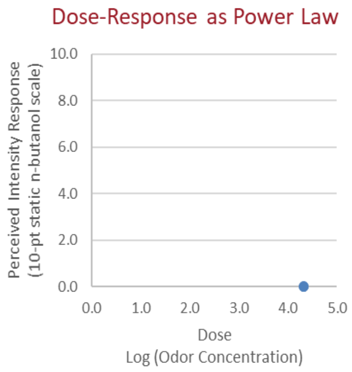
Comments:

Odor Descriptors





Log I = n Log C + Log k



Log I = n' Log (RT/C) + Log k'

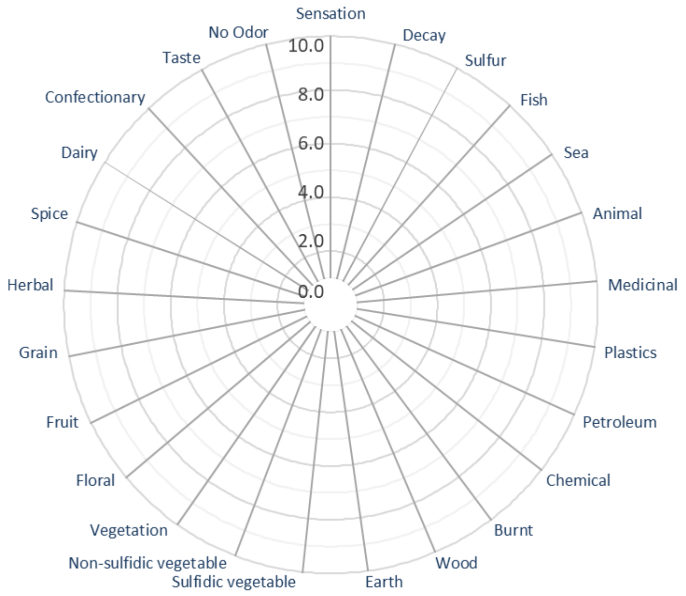
DT - Detection Threshold as determined by ASTM E679 and EN13725.
RT - Recognition Threshold as determined by ASTM E679 and EN13725.
I - Perceived odor intensity as determined by ASTM E544.
HT – Hedonic Tone value (pleasantness rating).
DR – The slope of the dose-response (dilution–intensity) relationship.
C – Dilution ratio of the odor sample presentation.
n, k, n′, and k′ – computed constants for the specific odor sample.

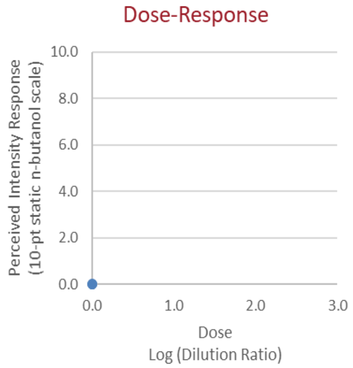
Field No: 2
Description: Sludge Well - Lemay

DT: 47,000
RT: 31,000
I: - - -
HT: - - -
DR: - - -

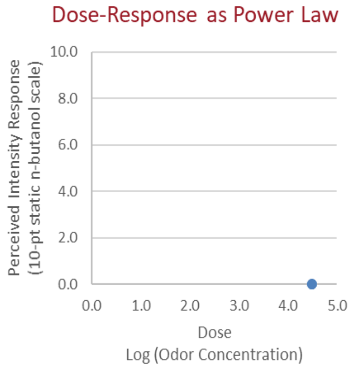
Comments:

Odor Descriptors





Log I = n Log C + Log k



Log I = n' Log (RT/C) + Log k'

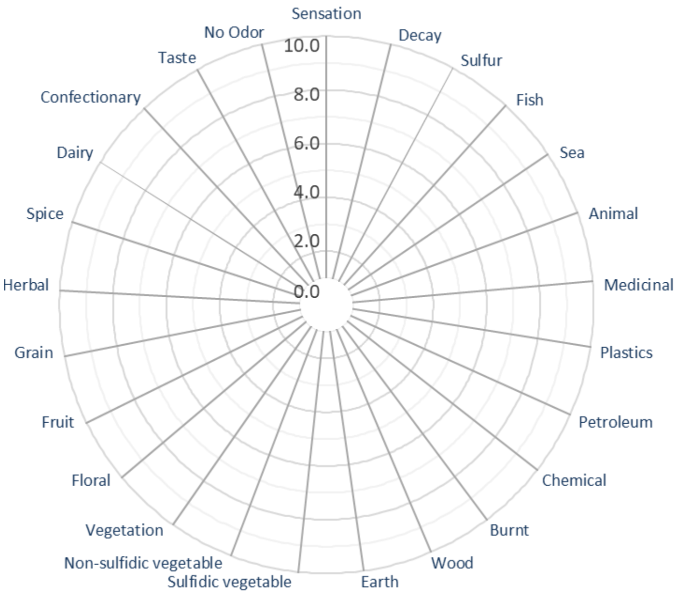
DT - Detection Threshold as determined by ASTM E679 and EN13725.
RT - Recognition Threshold as determined by ASTM E679 and EN13725.
I - Perceived odor intensity as determined by ASTM E544.
HT – Hedonic Tone value (pleasantness rating).
DR – The slope of the dose-response (dilution–intensity) relationship.
C – Dilution ratio of the odor sample presentation.
n, k, n′, and k′ – computed constants for the specific odor sample.

Field No: 3
Description: BFP - Lemay

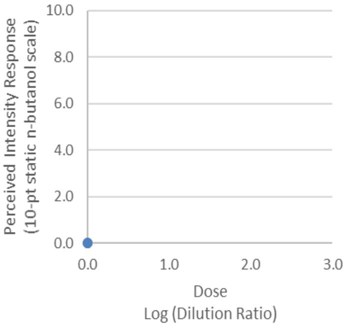
DT: >60,000
RT: >60,000
I: - - -
HT: - - -
DR: - - -

Comments:

Odor Descriptors

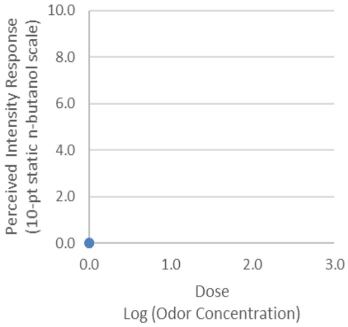


Dose-Response



Log I = n Log C + Log k

Dose-Response as Power Law



Log I = n' Log (RT/C) + Log k'

DT - Detection Threshold as determined by ASTM E679 and EN13725.
RT - Recognition Threshold as determined by ASTM E679 and EN13725.
I - Perceived odor intensity as determined by ASTM E544.
HT – Hedonic Tone value (pleasantness rating).
DR – The slope of the dose-response (dilution–intensity) relationship.
C – Dilution ratio of the odor sample presentation.
n, k, n′, and k′ – computed constants for the specific odor sample.

St. Croix Sensory, Inc.

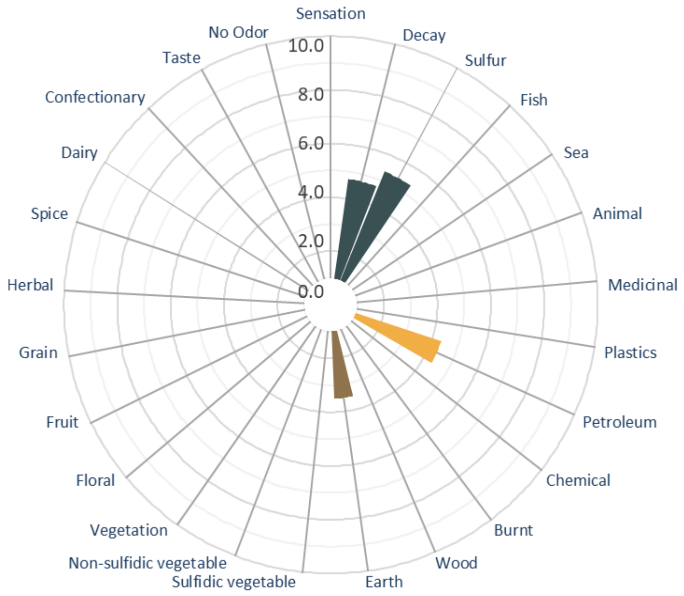
Report Number: 2026002
Client: Brown and Caldwell
Project Name: MSD FBI Project
Samples Evaluated: 9/16/2020

Field No: 4
Description: Filter In - Lemay

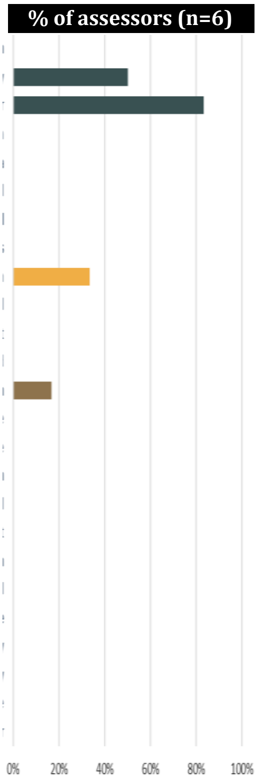
DT: 14,000
RT: 6,900
I: - - -
HT: -2.9
DR: - - -

Comments:

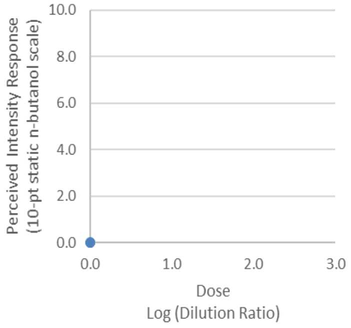
Odor Descriptors



Strength	Descriptor
	Sensation
4.7	Decay
5.4	Sulfur
	Fish
	Sea
	Animal
	Medicinal
	Plastics
4.4	Petroleum
	Chemical
	Burnt
	Wood
3.5	Earth
	Sulfidic vegetable
	Non-sulfidic vegetable
	Vegetation
	Floral
	Fruit
	Grain
	Herbal
	Spice
	Dairy
	Confectionary
	Taste
	No Odor

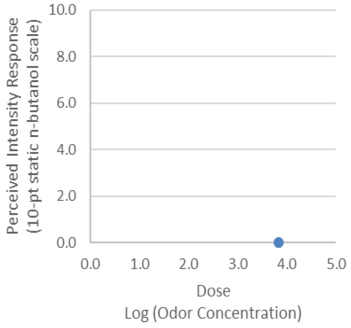


Dose-Response



Log I = n Log C + Log k

Dose-Response as Power Law



Log I = n' Log (RT/C) + Log k'

DT - Detection Threshold as determined by ASTM E679 and EN13725.
RT - Recognition Threshold as determined by ASTM E679 and EN13725.
I - Perceived odor intensity as determined by ASTM E544.
HT – Hedonic Tone value (pleasantness rating).
DR – The slope of the dose-response (dilution–intensity) relationship.
C – Dilution ratio of the odor sample presentation.
n, k, n′, and k′ – computed constants for the specific odor sample.

St. Croix Sensory, Inc.

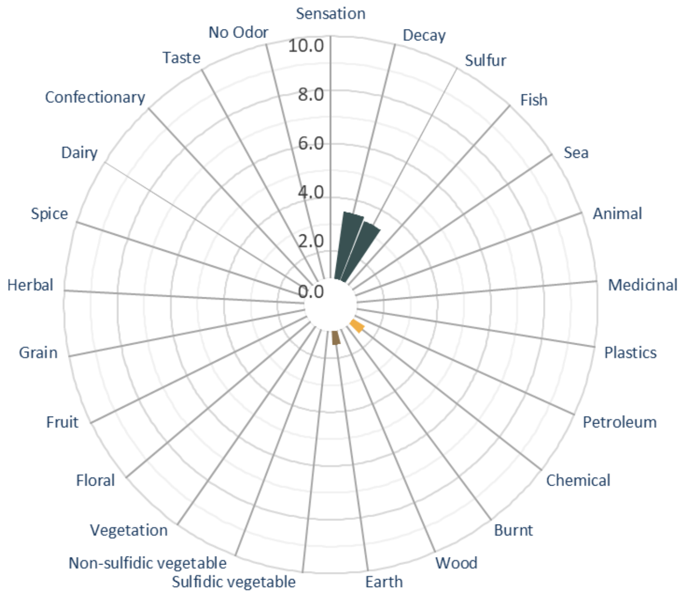
Report Number: 2026002
Client: Brown and Caldwell
Project Name: MSD FBI Project
Samples Evaluated: 9/16/2020

Field No: 5
Description: **Filter Out - Lemay**

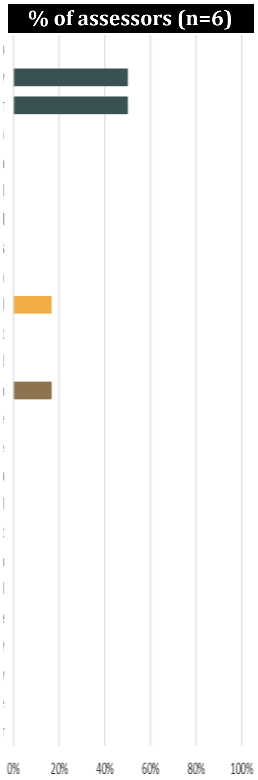
DT: **2,600**
RT: **1,400**
I: **- - -**
HT: **-1.5**
DR: **- - -**

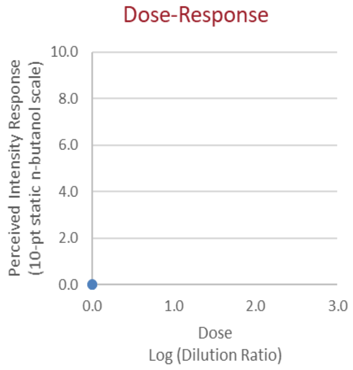
Comments:

Odor Descriptors

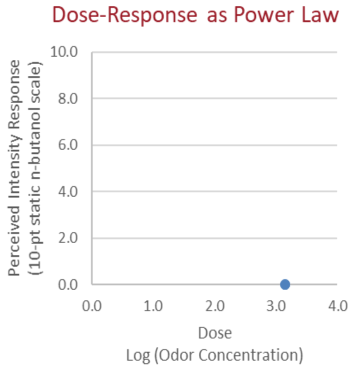


Strength	Descriptor
	Sensation
3.5	Decay
3.4	Sulfur
	Fish
	Sea
	Animal
	Medicinal
	Plastics
	Petroleum
1.4	Chemical
	Burnt
	Wood
0.2	Earth
	Sulfidic vegetable
	Non-sulfidic vegetable
	Vegetation
	Floral
	Fruit
	Grain
	Herbal
	Spice
	Dairy
	Confectionary
	Taste
	No Odor





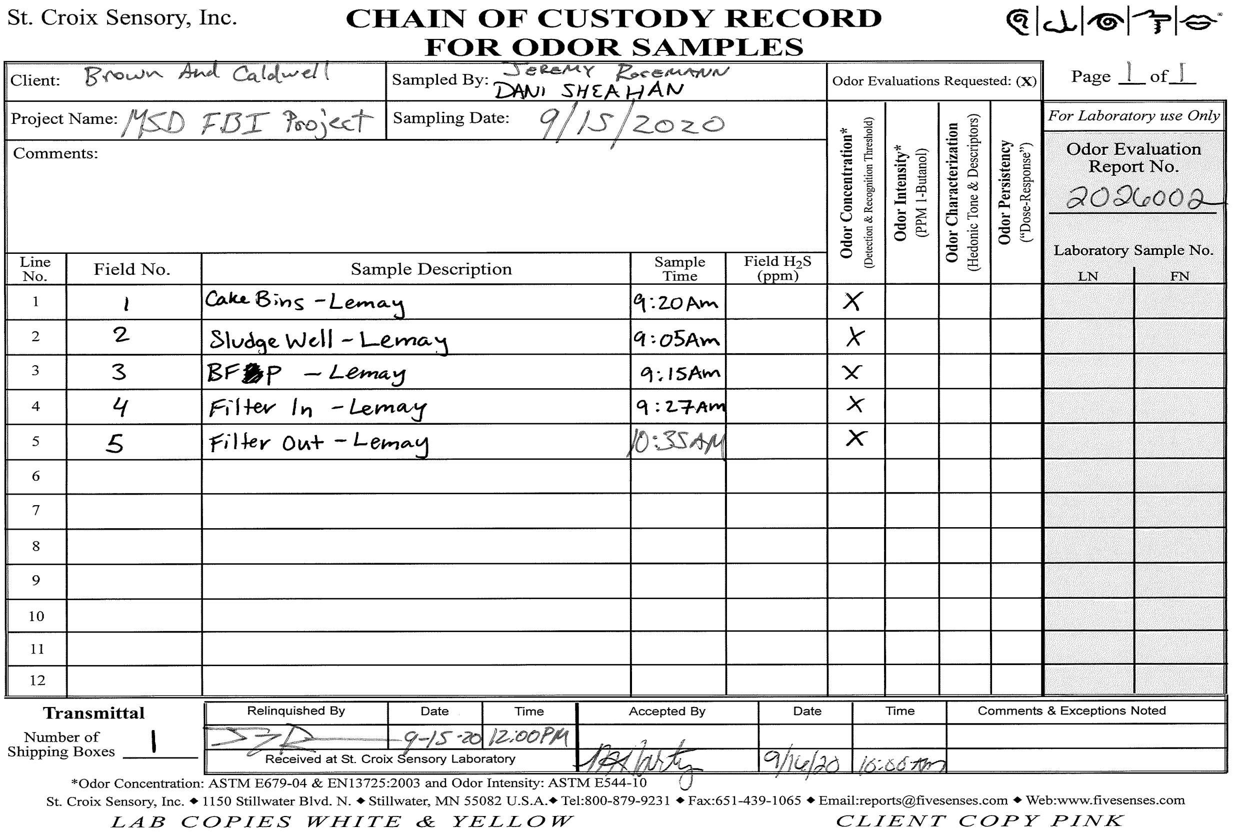
Log I = n Log C + Log k



Log I = n' Log (RT/C) + Log k'

DT - Detection Threshold as determined by ASTM E679 and EN13725.
RT - Recognition Threshold as determined by ASTM E679 and EN13725.
I - Perceived odor intensity as determined by ASTM E544.
HT – Hedonic Tone value (pleasantness rating).
DR – The slope of the dose-response (dilution–intensity) relationship.
C – Dilution ratio of the odor sample presentation.
n, k, n′, and k′ – computed constants for the specific odor sample.

Attachments



St. Croix Sensory, Inc.

CHAIN OF CUSTODY RECORD FOR ODOR SAMPLES

Page 1 of 1

Client: Brown And Caldwell

Sampled By: Jeremy Rosemann
Dani Sheahan

Project Name: MSD FBI Project

Sampling Date: 9/15/2020

Comments:

Odor Evaluations Requested: (X)

For Laboratory use Only

Odor Evaluation Report No. 2026002

Line No.	Field No.	Sample Description	Sample Time	Field H_2S (ppm)	Odor Concentration* (Detection & Recognition Threshold)	Odor Intensity* (PPM 1-Butanol)	Odor Characterization (Hedonic Tone & Descriptors)	Odor Persistency ("Dose-Response")	Laboratory Sample No. LN	Laboratory Sample No. FN
1	1	Cake Bins - Lemay	9:20Am		X					
2	2	Sludge Well - Lemay	9:05Am		X					
3	3	BFP - Lemay	9:15Am		X					
4	4	Filter In - Lemay	9:27Am		X					
5	5	Filter Out - Lemay	10:35AM		X					
6										
7										
8										
9										
10										
11										
12										

Transmittal

Number of Shipping Boxes 1

Relinquished By	Date	Time	Accepted By	Date	Time	Comments & Exceptions Noted
	9-15-20	12:00PM				
Received at St. Croix Sensory Laboratory				9/16/20	10:00Am	

*Odor Concentration: ASTM E679-04 & EN13725:2003 and Odor Intensity: ASTM E544-10

St. Croix Sensory, Inc. ◆ 1150 Stillwater Blvd. N. ◆ Stillwater, MN 55082 U.S.A.◆ Tel:800-879-9231 ◆ Fax:651-439-1065 ◆ Email:reports@fivesenses.com ◆ Web:www.fivesenses.com

LAB COPIES WHITE & YELLOW *CLIENT COPY PINK*

2655 Park Center Dr., Suite A
Simi Valley, CA 93065
T: +1 805 526 7161
www.alsglobal.com

LABORATORY REPORT

September 22, 2020

Carol Zuerndorfer
Brown and Caldwell
7733 Forsyth Blvd. 11th Floor, Suite 1100
Van Clayton, MO 63105

RE: STL MSD FBI PROJECT / 154697

Dear Carol:

Enclosed are the results of the samples submitted to our laboratory on September 15, 2020. For your reference, these analyses have been assigned our service request number P2005110.

All analyses were performed according to our laboratory's NELAP and DoD-ELAP-approved quality assurance program. The test results meet requirements of the current NELAP and DoD-ELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP and DoD-ELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. Results are intended to be considered in their entirety and apply only to the samples analyzed and reported herein.

If you have any questions, please call me at (805) 526-7161.

Respectfully submitted,

ALS | Environmental

Sue Anderson

By Sue Anderson at 3:14 pm, Sep 22, 2020

Sue Anderson
Project Manager

Client: Brown and Caldwell
Project: STL MSD FBI PROJECT / 154697
Service Request No: P2005110

CASE NARRATIVE

The samples were received intact under chain of custody on September 15, 2020 and were stored in accordance with the analytical method requirements. Please refer to the sample acceptance check form for additional information. The results reported herein are applicable only to the condition of the samples at the time of sample receipt.

Sulfur & Total Reduced Sulfur as Hydrogen Sulfide Analysis

The samples were analyzed for twenty sulfur compounds and total reduced sulfur as hydrogen sulfide (TRS as H_2S) per ASTM D 5504-12 using a gas chromatograph equipped with a sulfur chemiluminescence detector (SCD). All compounds with the exception of hydrogen sulfide and carbonyl sulfide are quantitated against the initial calibration curve for methyl mercaptan. The TRS as H_2S results were determined by obtaining the total response for all chromatographic peaks and quantitating the value against the initial calibration curve for hydrogen sulfide thus generating a result specified as "Total Reduced Sulfur as Hydrogen Sulfide". This method is included on the laboratory's NELAP scope of accreditation, however it is not part of the DoD-ELAP accreditation.

The analyses of samples BFP – Bissell (P2005110-002), Scum – Bissell (P2005110-003) and Sludge Well – Bissell (P2005110-004) were performed past the holding time. The results have been flagged accordingly.

The results of analyses are given in the attached laboratory report. All results are intended to be considered in their entirety, and ALS Environmental (ALS) is not responsible for utilization of less than the complete report.

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T: +1 805 526 7161
www.alsglobal.com

ALS Environmental – Simi Valley

CERTIFICATIONS, ACCREDITATIONS, AND REGISTRATIONS

Agency	Web Site	Number
Alaska DEC	http://dec.alaska.gov/eh/lab.aspx	17-019
Arizona DHS	http://www.azdhs.gov/preparedness/state-laboratory/lab-licensure-certification/index.php#laboratory-licensure-home	AZ0694
Florida DOH (NELAP)	http://www.floridahealth.gov/licensing-and-regulation/environmental-laboratories/index.html	E871020
Louisiana DEQ (NELAP)	http://www.deq.louisiana.gov/page/la-lab-accreditation	05071
Maine DHHS	http://www.maine.gov/dhhs/mecdc/environmental-health/dwp/professionals/labCert.shtml	2018027
Minnesota DOH (NELAP)	http://www.health.state.mn.us/accreditation	1776326
New Jersey DEP (NELAP)	http://www.nj.gov/dep/enforcement/oqa.html	CA009
New York DOH (NELAP)	http://www.wadsworth.org/labcert/elap/elap.html	11221
Oregon PHD (NELAP)	http://www.oregon.gov/oha/ph/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	4068-007
Pennsylvania DEP	http://www.dep.pa.gov/Business/OtherPrograms/Labs/Pages/Laboratory-Accreditation-Program.aspx	68-03307 (Registration)
PJLA (DoD ELAP)	http://www.pjlabs.com/search-accredited-labs	65818 (Testing)
Texas CEQ (NELAP)	http://www.tceq.texas.gov/agency/qa/env_lab_accreditation.html	T104704413-19-10
Utah DOH (NELAP)	http://health.utah.gov/lab/lab_cert_env	CA016272019-10
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C946

Analyses were performed according to our laboratory's NELAP and DoD-ELAP approved quality assurance program. A complete listing of specific NELAP and DoD-ELAP certified analytes can be found in the certifications section at www.alsglobal.com, or at the accreditation body's website.

Each of the certifications listed above have an explicit Scope of Accreditation that applies to specific matrices/methods/analytes; therefore, please contact the laboratory for information corresponding to a particular certification.

ALS ENVIRONMENTAL

DETAIL SUMMARY REPORT

Client: Brown and Caldwell

Service Request: P2005110

Project ID: STL MSD FBI PROJECT / 154697

Date Received: 9/15/2020

Time Received: 10:15

Client Sample ID	Lab Code	Matrix	Date Collected	Time Collected	ASTM D 5504-12 - Sulfur Bag
Cake Bin - Bissell	P2005110-001	Air	9/14/2020	14:25	X
BFP - Bissell	P2005110-002	Air	9/14/2020	13:10	X
Scum - Bissell	P2005110-003	Air	9/14/2020	13:15	X
Sludge Well - Bissell	P2005110-004	Air	9/14/2020	14:15	X

Air - Chain of Custody Record & Analytical Service Request

Page 1 of 1

2655 Park Center Drive, Suite A
Simi Valley, California 93065
Phone (805) 526-7161

Requested Turnaround Time in Business Days (Surcharges) please circle
[✓ 1 Day (100%)] 2 Day (75%) 3 Day (50%) 4 Day (35%) 5 Day (25%) 10 Day-Standard

ALS Project No. P2005110

ALS Contact:

Company Name & Address (Reporting Information): Brown and Caldwell
7733 Forsyth Blvd.
Clayton, MO 63105

Project Name: STL MSD FBI Project

Project Number: 154697

Project Manager: Dave Yates

P.O. # / Billing Information: 154697

Phone: 314-660-3211

Fax:

Email Address for Result Reporting: CZUERNDORFER@BRWNCALD.COM

Sampler (Print & Sign): DANI SHEAHAN Danielle Sheahan
SERGUY ROSEMAN

Client Sample ID	Laboratory ID Number	Date Collected	Time Collected	Canister ID (Bar code # - AC, SC, etc.)	Flow Controller ID (Bar code # - FC #)	Canister Start Pressure "Hg	Canister End Pressure "Hg/psig	Sample Volume	**Analysis Method** ASTM D5504 reduced sulfurs		Comments e.g. Actual Preservative or specific instructions
Cake Bin-Bissell		9-14-20	2:25pm					1L	X		
BFP-Bissell		9-14-20	1:10pm					1L	X		
Scun-Bissell		9-14-20	1:15pm					1L	X		
Sludge Well-Bissell		9-14-20	2:15pm					1L	X		

Report Tier Levels - please select
Tier I - Results (Default if not specified) X
Tier II (Results + QC Summaries) ____
Tier III (Results + QC & Calibration Summaries) ____
Tier IV (Data Validation Package) 10% Surcharge ____

EDD required Yes / No
Type: ____________ Units: ____________

Chain of Custody Seal: (Circle)
INTACT BROKEN ABSENT

Project Requirements (MRLs, QAPP)

Relinquished by: (Signature)	Date:	Time:	Received by: (Signature)	Date:	Time:
Danielle Sheahan	9-14-20	3:35pm		9/15/20	915

Cooler / Blank Temperature ____ °C

ALS Environmental
Sample Acceptance Check Form

Client: Brown and Caldwell Work order: P2005110
Project: STL MSD FBI PROJECT / 154697
Sample(s) received on: 9/15/20 Date opened: 9/15/20 by: DENISE.POSADA

Note: This form is used for all samples received by ALS. The use of this form for custody seals is strictly meant to indicate presence/absence and not as an indication of compliance or nonconformity. Thermal preservation and pH will only be evaluated either at the request of the client and/or as required by the method/SOP.

		Yes	**No**	**N/A**
1	Were **sample containers** properly marked with client sample ID?	☒	☐	☐
2	Did **sample containers** arrive in good condition?	☒	☐	☐
3	Were **chain-of-custody** papers used and filled out?	☒	☐	☐
4	Did **sample container labels** and/or tags agree with custody papers?	☒	☐	☐
5	Was **sample volume** received adequate for analysis?	☒	☐	☐
6	Are samples within specified holding times?	☒	☐	☐
7	Was proper **temperature** (thermal preservation) of cooler at receipt adhered to?	☐	☐	☒
8	Were **custody seals** on outside of cooler/Box/Container?	☐	☒	☐
	Location of seal(s)? ______ Sealing Lid?	☐	☐	☒
	Were signature and date included?	☐	☐	☒
	Were seals intact?	☐	☐	☒
9	Do containers have appropriate **preservation**, according to method/SOP or Client specified information?	☐	☐	☒
	Is there a client indication that the submitted samples are **pH** preserved?	☐	☐	☒
	Were **VOA vials** checked for presence/absence of air bubbles?	☐	☐	☒
	Does the client/method/SOP require that the analyst check the sample pH and if necessary alter it?	☐	☐	☒
10	**Tubes:** Are the tubes capped and intact?	☐	☐	☒
11	**Badges:** Are the badges properly capped and intact?	☐	☐	☒
	Are dual bed badges separated and individually capped and intact?	☐	☐	☒

Lab Sample ID	Container Description	Required pH *	Received pH	Adjusted pH	VOA Headspace (Presence/Absence)	Receipt / Preservation Comments
P2005110-001.01	1 L Zefon Bag					
P2005110-002.01	1 L Zefon Bag					
P2005110-003.01	1 L Zefon Bag					
P2005110-004.01	1 L Zefon Bag					

Explain any discrepancies: (include lab sample ID numbers):

RSK - MEEPP, HCL (pH<2); RSK - CO2, (pH 5-8); Sulfur (pH>4)

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Cake Bin - Bissell**	ALS Project ID:	P2005110
Client Project ID:	**STL MSD FBI PROJECT / 154697**	ALS Sample ID:	P2005110-001

Test Code:	ASTM D 5504-12	Date Collected:	9/14/20
Instrument ID:	Agilent 6890A/GC13/SCD	Time Collected:	14:25
Analyst:	Gilbert Gutierrez	Date Received:	9/15/20
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/15/20
Test Notes:		Time Analyzed:	13:04
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result** µg/m³	MRL µg/m³	**Result ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**1,100**	7.0	**820**	5.0	
463-58-1	Carbonyl Sulfide	**190**	12	**78**	5.0	
74-93-1	Methyl Mercaptan	**610**	9.8	**310**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	**47**	13	**18**	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	**61**	9.6	**16**	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: **Brown and Caldwell**
Client Sample ID: **BFP - Bissell**
Client Project ID: **STL MSD FBI PROJECT / 154697**

ALS Project ID: P2005110
ALS Sample ID: P2005110-002

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag
Test Notes: **H1**

Date Collected: 9/14/20
Time Collected: 13:10
Date Received: 9/15/20
Date Analyzed: 9/15/20
Time Analyzed: 13:24
Volume(s) Analyzed: 1.0 ml(s)

CAS #	**Compound**	**Result** **µg/m³**	MRL µg/m³	**Result** **ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**14,000**	7.0	**10,000**	5.0	
463-58-1	Carbonyl Sulfide	**33**	12	**13**	5.0	
74-93-1	Methyl Mercaptan	**410**	9.8	**210**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	**120**	13	**48**	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H1 = Sample analysis performed past holding time. See case narrative.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Scum - Bissell**	ALS Project ID:	P2005110
Client Project ID:	**STL MSD FBI PROJECT / 154697**	ALS Sample ID:	P2005110-003

Test Code:	ASTM D 5504-12	Date Collected:	9/14/20
Instrument ID:	Agilent 6890A/GC13/SCD	Time Collected:	13:15
Analyst:	Gilbert Gutierrez	Date Received:	9/15/20
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/15/20
Test Notes:	**H1**	Time Analyzed:	13:44
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result µg/m³**	MRL µg/m³	**Result ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**270**	7.0	**190**	5.0	
463-58-1	Carbonyl Sulfide	ND	12	ND	5.0	
74-93-1	Methyl Mercaptan	**12**	9.8	**6.0**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	ND	13	ND	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H1 = Sample analysis performed past holding time. See case narrative.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: **Brown and Caldwell**
Client Sample ID: **Sludge Well - Bissell**
Client Project ID: **STL MSD FBI PROJECT / 154697**

ALS Project ID: P2005110
ALS Sample ID: P2005110-004

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag
Test Notes: **H1**

Date Collected: 9/14/20
Time Collected: 14:15
Date Received: 9/15/20
Date Analyzed: 9/15/20
Time Analyzed: 14:27
Volume(s) Analyzed: 0.50 ml(s)

CAS #	**Compound**	**Result** **µg/m³**	MRL µg/m³	**Result** **ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**120,000**	14	**84,000**	10	
463-58-1	Carbonyl Sulfide	**200**	25	**80**	10	
74-93-1	Methyl Mercaptan	**3,300**	20	**1,700**	10	
75-08-1	Ethyl Mercaptan	ND	25	ND	10	
75-18-3	Dimethyl Sulfide	**550**	25	**220**	10	
75-15-0	Carbon Disulfide	ND	16	ND	5.0	
75-33-2	Isopropyl Mercaptan	ND	31	ND	10	
75-66-1	tert-Butyl Mercaptan	ND	37	ND	10	
107-03-9	n-Propyl Mercaptan	ND	31	ND	10	
624-89-5	Ethyl Methyl Sulfide	ND	31	ND	10	
110-02-1	Thiophene	ND	34	ND	10	
513-44-0	Isobutyl Mercaptan	ND	37	ND	10	
352-93-2	Diethyl Sulfide	ND	37	ND	10	
109-79-5	n-Butyl Mercaptan	ND	37	ND	10	
624-92-0	Dimethyl Disulfide	ND	19	ND	5.0	
616-44-4	3-Methylthiophene	ND	40	ND	10	
110-01-0	Tetrahydrothiophene	ND	36	ND	10	
638-02-8	2,5-Dimethylthiophene	ND	46	ND	10	
872-55-9	2-Ethylthiophene	ND	46	ND	10	
110-81-6	Diethyl Disulfide	ND	25	ND	5.0	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H1 = Sample analysis performed past holding time. See case narrative.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: **Brown and Caldwell**
Client Project ID: **STL MSD FBI PROJECT / 154697**
ALS Project ID: P2005110

Total Reduced Sulfur as Hydrogen Sulfide

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag(s)
Test Notes:

Date(s) Collected: 9/14/20
Date Received: 9/15/20
Date Analyzed: 9/15/20

Client Sample ID	ALS Sample ID	Injection Volume ml(s)	Time Analyzed	**Result µg/m³**	MRL µg/m³	**Result ppbV**	MRL ppbV	Data Qualifier
Cake Bin - Bissell	P2005110-001	1.0	13:04	**1,700**	7.0	**1,200**	5.0	
BFP - Bissell	P2005110-002	1.0	13:24	**15,000**	7.0	**11,000**	5.0	**H1**
Scum - Bissell	P2005110-003	1.0	13:44	**280**	7.0	**200**	5.0	**H1**
Sludge Well - Bissell	P2005110-004	0.50	14:27	**120,000**	14	**86,000**	10	**H1**
Method Blank	P200915-MB	1.0	06:56	ND	7.0	ND	5.0	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H1 = Sample analysis performed past holding time. See case narrative.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Method Blank**	ALS Project ID:	P2005110
Client Project ID:	**STL MSD FBI PROJECT / 154697**	ALS Sample ID:	P200915-MB

Test Code:	ASTM D 5504-12	Date Collected:	NA
Instrument ID:	Agilent 6890A/GC13/SCD	Time Collected:	NA
Analyst:	Gilbert Gutierrez	Date Received:	NA
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/15/20
Test Notes:		Time Analyzed:	06:56
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result µg/m³**	MRL µg/m³	**Result ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	ND	7.0	ND	5.0	
463-58-1	Carbonyl Sulfide	ND	12	ND	5.0	
74-93-1	Methyl Mercaptan	ND	9.8	ND	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	ND	13	ND	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY
Page 1 of 1

Client: **Brown and Caldwell**
Client Sample ID: **Lab Control Sample**
Client Project ID: **STL MSD FBI PROJECT / 154697**

ALS Project ID: P2005110
ALS Sample ID: P200915-LCS

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 9/15/20
Volume(s) Analyzed: NA ml(s)

CAS #	**Compound**	Spike Amount ppbV	**Result ppbV**	**% Recovery**	ALS Acceptance Limits	Data Qualifier
7783-06-4	Hydrogen Sulfide	989	**944**	**95**	72-122	
463-58-1	Carbonyl Sulfide	1,050	**1,080**	**103**	72-121	
74-93-1	Methyl Mercaptan	1,050	**1,100**	**105**	74-127	

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LABORATORY REPORT

September 23, 2020

Carol Zuerndorfer
Brown and Caldwell
7733 Forsyth Blvd. 11th Floor, Suite 1100
Van Clayton, MO 63105

RE: STL MSD FBI / 154697

Dear Carol:

Enclosed are the results of the samples submitted to our laboratory on September 16, 2020. For your reference, these analyses have been assigned our service request number P2005133.

All analyses were performed according to our laboratory's NELAP and DoD-ELAP-approved quality assurance program. The test results meet requirements of the current NELAP and DoD-ELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP and DoD-ELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. Results are intended to be considered in their entirety and apply only to the samples analyzed and reported herein.

If you have any questions, please call me at (805) 526-7161.

Respectfully submitted,

ALS | Environmental

Sue Anderson

By Sue Anderson at 1:25 pm, Sep 23, 2020

Sue Anderson
Project Manager

2655 Park Center Dr., Suite A
Simi Valley, CA 93065
T: +1 805 526 7161
www.alsglobal.com

Client: Brown and Caldwell
Project: STL MSD FBI / 154697

Service Request No: P2005133

CASE NARRATIVE

The samples were received intact under chain of custody on September 16, 2020 and were stored in accordance with the analytical method requirements. All samples except Filter Out – Lemay (P2005133-005) were received past the recommended holding time. The analysis was performed as soon as possible after receipt by the laboratory. The data is flagged to indicate the holding time exceedances. Please refer to the sample acceptance check form for additional information. The results reported herein are applicable only to the condition of the samples at the time of sample receipt.

Sulfur Analysis

The samples were analyzed for twenty sulfur compounds per ASTM D 5504-12 using a gas chromatograph equipped with a sulfur chemiluminescence detector (SCD). All compounds with the exception of hydrogen sulfide and carbonyl sulfide are quantitated against the initial calibration curve for methyl mercaptan. This method is included on the laboratory's NELAP scope of accreditation, however it is not part of the DoD-ELAP accreditation.

The results of analyses are given in the attached laboratory report. All results are intended to be considered in their entirety, and ALS Environmental (ALS) is not responsible for utilization of less than the complete report.

Use of ALS Environmental (ALS)'s Name. Client shall not use ALS's name or trademark in any marketing or reporting materials, press releases or in any other manner ("Materials") whatsoever and shall not attribute to ALS any test result, tolerance or specification derived from ALS's data ("Attribution") without ALS's prior written consent, which may be withheld by ALS for any reason in its sole discretion. To request ALS's consent, Client shall provide copies of the proposed Materials or Attribution and describe in writing Client's proposed use of such Materials or Attribution. If ALS has not provided written approval of the Materials or Attribution within ten (10) days of receipt from Client, Client's request to use ALS's name or trademark in any Materials or Attribution shall be deemed denied. ALS may, in its discretion, reasonably charge Client for its time in reviewing Materials or Attribution requests. Client acknowledges and agrees that the unauthorized use of ALS's name or trademark may cause ALS to incur irreparable harm for which the recovery of money damages will be inadequate. Accordingly, Client acknowledges and agrees that a violation shall justify preliminary injunctive relief. For questions contact the laboratory.

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ALS Environmental – Simi Valley

CERTIFICATIONS, ACCREDITATIONS, AND REGISTRATIONS

Agency	Web Site	Number
Alaska DEC	http://dec.alaska.gov/eh/lab.aspx	17-019
Arizona DHS	http://www.azdhs.gov/preparedness/state-laboratory/lab-licensure-certification/index.php#laboratory-licensure-home	AZ0694
Florida DOH (NELAP)	http://www.floridahealth.gov/licensing-and-regulation/environmental-laboratories/index.html	E871020
Louisiana DEQ (NELAP)	http://www.deq.louisiana.gov/page/la-lab-accreditation	05071
Maine DHHS	http://www.maine.gov/dhhs/mecdc/environmental-health/dwp/professionals/labCert.shtml	2018027
Minnesota DOH (NELAP)	http://www.health.state.mn.us/accreditation	1776326
New Jersey DEP (NELAP)	http://www.nj.gov/dep/enforcement/oqa.html	CA009
New York DOH (NELAP)	http://www.wadsworth.org/labcert/elap/elap.html	11221
Oregon PHD (NELAP)	http://www.oregon.gov/oha/ph/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	4068-007
Pennsylvania DEP	http://www.dep.pa.gov/Business/OtherPrograms/Labs/Pages/Laboratory-Accreditation-Program.aspx	68-03307 (Registration)
PJLA (DoD ELAP)	http://www.pjlabs.com/search-accredited-labs	65818 (Testing)
Texas CEQ (NELAP)	http://www.tceq.texas.gov/agency/qa/env_lab_accreditation.html	T104704413-19-10
Utah DOH (NELAP)	http://health.utah.gov/lab/lab_cert_env	CA016272019-10
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C946

Analyses were performed according to our laboratory's NELAP and DoD-ELAP approved quality assurance program. A complete listing of specific NELAP and DoD-ELAP certified analytes can be found in the certifications section at www.alsglobal.com, or at the accreditation body's website.

Each of the certifications listed above have an explicit Scope of Accreditation that applies to specific matrices/methods/analytes; therefore, please contact the laboratory for information corresponding to a particular certification.

ALS ENVIRONMENTAL

DETAIL SUMMARY REPORT

Client: Brown and Caldwell

Service Request: P2005133

Project ID: STL MSD FBI / 154697

Date Received: 9/16/2020

Time Received: 10:10

Client Sample ID	Lab Code	Matrix	Date Collected	Time Collected	ASTM D 5504-12 - Sulfur Bag
Cake Bins - Lemay	P2005133-001	Air	9/15/2020	09:20	X
Sludge Well - Lemay	P2005133-002	Air	9/15/2020	09:05	X
BFP - Lemay	P2005133-003	Air	9/15/2020	09:15	X
Filter In - Lemay	P2005133-004	Air	9/15/2020	09:27	X
Filter Out - Lemay	P2005133-005	Air	9/15/2020	10:35	X

Air - Chain of Custody Record & Analytical Service Request

Page 1 of 1

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Simi Valley, California 93065
Phone (805) 526-7161

Requested Turnaround Time in Business Days (Surcharges) please circle
[✓ 1 Day (100%)] 2 Day (75%) 3 Day (50%) 4 Day (35%) 5 Day (25%) 10 Day-Standard

ALS Project No. P2005133

ALS Contact:

Company Name & Address (Reporting Information)
Brown and Caldwell
7733 Forsyth Blvd.
Clayton, MO 63105

Project Name: STL MSD FBI

Project Number: 154697

Project Manager: DAVE YATES

P.O. # / Billing Information: 154697

Phone: 314-660-3211

Fax:

Email Address for Result Reporting: CZUERNDORFER@BRWNCALD.COM

Sampler (Print & Sign): DANI SHEAHAN JEREMY ROSEMANN

Analysis Method

Client Sample ID	Laboratory ID Number	Date Collected	Time Collected	Canister ID (Bar code # - AC, SC, etc.)	Flow Controller ID (Bar code # - FC #)	Canister Start Pressure "Hg	Canister End Pressure "Hg/psig	Sample Volume	ASTM D5504 reduced sulfurs		Comments e.g. Actual Preservative or specific instructions
Cake Bins-Lemay		9-15-2020	9:20AM					1L	X		
Sludge Well-Lemay		9-15-2020	9:05Am					1L	X		
BFP-Lemay		9-15-2020	9:15Am					1L	X		
Filter In-Lemay		9-15-2020	9:27Am					1L	X		
Filter Out-Lemay		9-15-2020	10:35AM					1L	X		

Report Tier Levels - please select
Tier I - Results (Default if not specified) X
Tier II (Results + QC Summaries) ____
Tier III (Results + QC & Calibration Summaries) ____
Tier IV (Data Validation Package) 10% Surcharge ____

EDD required Yes / No
Type: ________ Units: ________

Chain of Custody Seal: (Circle)
INTACT BROKEN ABSENT

Project Requirements (MRLs, QAPP)

Relinquished by: (Signature)	Date: 9-15-20	Time: 1:35 PM	Received by: (Signature)	Date: 9/16/20	Time: 1010
Relinquished by: (Signature)	Date:	Time:	Received by: (Signature)	Date:	Time:

Cooler / Blank Temperature ____ °C

ALS Environmental
Sample Acceptance Check Form

Client: Brown and Caldwell   Work order: P2005133

Project: STL MSD FBI / 154697

Sample(s) received on: 9/16/2020   Date opened: 9/16/2020   by: DENISE.POSADA

Note: This form is used for all samples received by ALS. The use of this form for custody seals is strictly meant to indicate presence/absence and not as an indication of compliance or nonconformity. Thermal preservation and pH will only be evaluated either at the request of the client and/or as required by the method/SOP.

		Yes	**No**	**N/A**
1	Were **sample containers** properly marked with client sample ID?	☒	☐	☐
2	Did **sample containers** arrive in good condition?	☒	☐	☐
3	Were **chain-of-custody** papers used and filled out?	☒	☐	☐
4	Did **sample container labels** and/or tags agree with custody papers?	☒	☐	☐
5	Was **sample volume** received adequate for analysis?	☒	☐	☐
6	Are samples within specified holding times?	☐	☒	☐
7	Was proper **temperature** (thermal preservation) of cooler at receipt adhered to?	☐	☐	☒
8	Were **custody seals** on outside of cooler/Box/Container?	☐	☒	☐
	Location of seal(s)? ____________ Sealing Lid?	☐	☐	☒
	Were signature and date included?	☐	☐	☒
	Were seals intact?	☐	☐	☒
9	Do containers have appropriate **preservation**, according to method/SOP or Client specified information?	☐	☐	☒
	Is there a client indication that the submitted samples are **pH** preserved?	☐	☐	☒
	Were **VOA vials** checked for presence/absence of air bubbles?	☐	☐	☒
	Does the client/method/SOP require that the analyst check the sample pH and if necessary alter it?	☐	☐	☒
10	**Tubes:** Are the tubes capped and intact?	☐	☐	☒
11	**Badges:** Are the badges properly capped and intact?	☐	☐	☒
	Are dual bed badges separated and individually capped and intact?	☐	☐	☒

Lab Sample ID	Container Description	Required pH *	Received pH	Adjusted pH	VOA Headspace (Presence/Absence)	Receipt / Preservation Comments
P2005133-001.01	1 L Zefon Bag					
P2005133-002.01	1 L Zefon Bag					
P2005133-003.01	1 L Zefon Bag					
P2005133-004.01	1 L Zefon Bag					
P2005133-005.01	1 L Zefon Bag					

Explain any discrepancies: (include lab sample ID numbers):

All samples except -005 received past hold time.

RSK - MEEPP, HCL (pH<2); RSK - CO2, (pH 5-8); Sulfur (pH>4)

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: **Brown and Caldwell**
Client Sample ID: **Cake Bins - Lemay**
Client Project ID: **STL MSD FBI / 154697**

ALS Project ID: P2005133
ALS Sample ID: P2005133-001

Test Code: ASTM D 5504-12
Instrument ID: Agilent 7890A/GC22/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag
Test Notes: **H3**

Date Collected: 9/15/20
Time Collected: 09:20
Date Received: 9/16/20
Date Analyzed: 9/16/20
Time Analyzed: 10:52
Volume(s) Analyzed: 1.0 ml(s)

CAS #	**Compound**	**Result** **µg/m³**	MRL µg/m³	**Result** **ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**4,600**	7.0	**3,300**	5.0	
463-58-1	Carbonyl Sulfide	**150**	12	**62**	5.0	
74-93-1	Methyl Mercaptan	**2,300**	9.8	**1,200**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	**180**	13	**71**	5.0	
75-15-0	Carbon Disulfide	**21**	7.8	**6.6**	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	**2,500**	9.6	**650**	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H3 = Sample was received and analyzed past holding time.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Sludge Well - Lemay**	ALS Project ID:	P2005133
Client Project ID:	**STL MSD FBI / 154697**	ALS Sample ID:	P2005133-002

Test Code:	ASTM D 5504-12	Date Collected:	9/15/20
Instrument ID:	Agilent 7890A/GC22/SCD	Time Collected:	09:05
Analyst:	Gilbert Gutierrez	Date Received:	9/16/20
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/16/20
Test Notes:	**H3**	Time Analyzed:	11:09
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result** **µg/m³**	MRL µg/m³	**Result** **ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**33,000**	7.0	**24,000**	5.0	
463-58-1	Carbonyl Sulfide	ND	12	ND	5.0	
74-93-1	Methyl Mercaptan	**640**	9.8	**320**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	**26**	13	**10**	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H3 = Sample was received and analyzed past holding time.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**BFP - Lemay**	ALS Project ID:	P2005133
Client Project ID:	**STL MSD FBI / 154697**	ALS Sample ID:	P2005133-003

Test Code:	ASTM D 5504-12	Date Collected:	9/15/20
Instrument ID:	Agilent 7890A/GC22/SCD	Time Collected:	09:15
Analyst:	Gilbert Gutierrez	Date Received:	9/16/20
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/16/20
Test Notes:	**H3**	Time Analyzed:	11:28
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result** **µg/m³**	MRL µg/m³	**Result** **ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**11,000**	7.0	**7,600**	5.0	
463-58-1	Carbonyl Sulfide	ND	12	ND	5.0	
74-93-1	Methyl Mercaptan	**140**	9.8	**70**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	ND	13	ND	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

H3 = Sample was received and analyzed past holding time.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Filter In - Lemay**	ALS Project ID:	P2005133
Client Project ID:	**STL MSD FBI / 154697**	ALS Sample ID:	P2005133-004

Test Code:	ASTM D 5504-12	Date Collected:	9/15/20
Instrument ID:	Agilent 7890A/GC22/SCD	Time Collected:	09:27
Analyst:	Gilbert Gutierrez	Date Received:	9/16/20
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/16/20
Test Notes:	**H3**	Time Analyzed:	11:48
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result** µg/m³	MRL µg/m³	**Result** ppbV	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**6,900**	7.0	**5,000**	5.0	
463-58-1	Carbonyl Sulfide	**20**	12	**8.2**	5.0	
74-93-1	Methyl Mercaptan	**130**	9.8	**68**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	ND	13	ND	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H3 = Sample was received and analyzed past holding time.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Filter Out - Lemay**	ALS Project ID:	P2005133
Client Project ID:	**STL MSD FBI / 154697**	ALS Sample ID:	P2005133-005

Test Code:	ASTM D 5504-12	Date Collected:	9/15/20
Instrument ID:	Agilent 7890A/GC22/SCD	Time Collected:	10:35
Analyst:	Gilbert Gutierrez	Date Received:	9/16/20
Sample Type:	1 L Zefon Bag	Date Analyzed:	9/16/20
Test Notes:		Time Analyzed:	10:35
		Volume(s) Analyzed:	1.0 ml(s)

CAS #	**Compound**	**Result µg/m³**	MRL µg/m³	**Result ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	**220**	7.0	**160**	5.0	
463-58-1	Carbonyl Sulfide	**35**	12	**14**	5.0	
74-93-1	Methyl Mercaptan	**35**	9.8	**18**	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	**16**	13	**6.4**	5.0	
75-15-0	Carbon Disulfide	**12**	7.8	**3.7**	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	**24**	9.6	**6.3**	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

Client: **Brown and Caldwell**
Client Project ID: **STL MSD FBI / 154697**
ALS Project ID: P2005133

Total Reduced Sulfur as Hydrogen Sulfide

Test Code: ASTM D 5504-12
Instrument ID: Agilent 7890A/GC22/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag(s)
Test Notes:

Date(s) Collected: 9/15/20
Date Received: 9/16/20
Date Analyzed: 9/16/20

Client Sample ID	ALS Sample ID	Injection Volume ml(s)	Time Analyzed	**Result µg/m³**	MRL µg/m³	**Result ppbV**	MRL ppbV	Data Qualifier
Cake Bins - Lemay	P2005133-001	1.0	10:52	**7,600**	7.0	**5,400**	5.0	**H3**
Sludge Well - Lemay	P2005133-002	1.0	11:09	**34,000**	7.0	**24,000**	5.0	**H3**
BFP - Lemay	P2005133-003	1.0	11:28	**11,000**	7.0	**7,700**	5.0	**H3**
Filter In - Lemay	P2005133-004	1.0	11:48	**7,100**	7.0	**5,100**	5.0	**H3**
Filter Out - Lemay	P2005133-005	1.0	10:35	**300**	7.0	**220**	5.0	
Method Blank	P200916-MB	1.0	07:41	ND	7.0	ND	5.0	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
H3 = Sample was received and analyzed past holding time.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: **Brown and Caldwell**
Client Sample ID: **Method Blank**
Client Project ID: **STL MSD FBI / 154697**

ALS Project ID: P2005133
ALS Sample ID: P200916-MB

Test Code: ASTM D 5504-12
Instrument ID: Agilent 7890A/GC22/SCD
Analyst: Gilbert Gutierrez
Sample Type: 1 L Zefon Bag
Test Notes:

Date Collected: NA
Time Collected: NA
Date Received: NA
Date Analyzed: 9/16/20
Time Analyzed: 07:41
Volume(s) Analyzed: 1.0 ml(s)

CAS #	**Compound**	**Result** **µg/m³**	MRL µg/m³	**Result** **ppbV**	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	ND	7.0	ND	5.0	
463-58-1	Carbonyl Sulfide	ND	12	ND	5.0	
74-93-1	Methyl Mercaptan	ND	9.8	ND	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	ND	13	ND	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 1 of 1

Client:	**Brown and Caldwell**		
Client Sample ID:	**Lab Control Sample**	ALS Project ID:	P2005133
Client Project ID:	**STL MSD FBI / 154697**	ALS Sample ID:	P200916-LCS

Test Code:	ASTM D 5504-12	Date Collected:	NA
Instrument ID:	Agilent 7890A/GC22/SCD	Date Received:	NA
Analyst:	Gilbert Gutierrez	Date Analyzed:	9/16/20
Sample Type:	1 L Zefon Bag	Volume(s) Analyzed:	NA ml(s)
Test Notes:			

CAS #	**Compound**	Spike Amount ppbV	**Result ppbV**	**% Recovery**	ALS Acceptance Limits	Data Qualifier
7783-06-4	Hydrogen Sulfide	989	**1,190**	**120**	72-122	
463-58-1	Carbonyl Sulfide	1,050	**1,160**	**110**	72-121	
74-93-1	Methyl Mercaptan	1,050	**977**	**93**	74-127	

FINAL

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum 07:

Truck Receiving Stations

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

16 NOVEMBER 2020

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Introduction

The purpose of this technical memorandum (TM) is to present considerations for the sizing and selection of dewatered sludge (cake) receiving facilities associated with the Metropolitan St. Louis Sewer District (MSD) Bissell Point Wastewater Treatment Facility (WWTF) and Lemay WWTF Fluidized Bed Incinerators (FBI) Project.

This TM includes a review of existing receiving facilities at Bissell Point WWTF, as well as options for future cake receiving at both facilities. For each option, preliminary design criteria are presented herein, including:

- Required system components.
- Number and size of each component.
- Integration with future FBI systems.
- Integration with existing facilities (where applicable).

This memorandum also includes sections covering:

- Background and overview of existing cake receiving facilities
- Future cake receiving projections.
- Cake receiving options, including planning level cost estimates.
- Other considerations.

Background & Existing Receiving Facilities

In 1996, a cake receiving station was installed adjacent to the Bissell Point WWTF Solids Handling Building. This receiving station allows for cake from other WWTFs to be trucked to Bissell Point WWTF for disposal via incineration within existing multiple hearth incinerators (MHIs). A separate receiving station, which is not anticipated to be modified under this project, allows Bissell Point WWTF to also receive trucked septage, fats, oils and grease (FOG) from non-MSD sources. Note that Bissell Point WWTF is the only MSD facility which currently operates a cake receiving station.

The original intent of the Bissell Point cake receiving station was to allow other MSD facilities to direct solids off-site during contingency or emergency situations when those facilities were unable to adequately dispose of their sludge; however, in August 2015, MSD was advised that it would no longer by permitted to dispose of sludge from the Lower Meramec, Grand Glaize, and Fenton WWTFs at local municipal landfills due to odor concerns. As such, cake from these facilities is currently directed to Bissell Point WWTF on a more continuous basis.

Cake from other MSD facilities is currently received at Bissell Point Monday through Saturday, with up to five 24-cubic yard truckloads received per day. The existing cake receiving station is located along the west wall of the Solids Handling Building at the south end of the building. This facility was constructed in 1996 (Contract BP-14) and consists of a below grade steel receiving bin set in a concrete vault (approximately 20 feet deep) which shares common wall construction with the subgrade foundation of the adjacent building. The bin has hinged doors which are typically closed but can swing open to receive cake. During receiving, trucks back up to the receiving station and dump the cake into the subgrade bin, which consists of a 50-cubic yard live bottom hopper.

Figure 1 provides a picture of the existing cake receiving station with the hinged doors closed.

Figure 1. Bissell Point WWTF Existing Cake Receiving Station

From the cake receiving bin, cake is fed into a dual cylinder hydraulic piston pump via a twin-screw auger feeder. The cake is then pumped either to a biosolids storage well or to the belt filter press discharge conveyance system prior to incineration. Figure 2 provides a schematic of this existing arrangement.

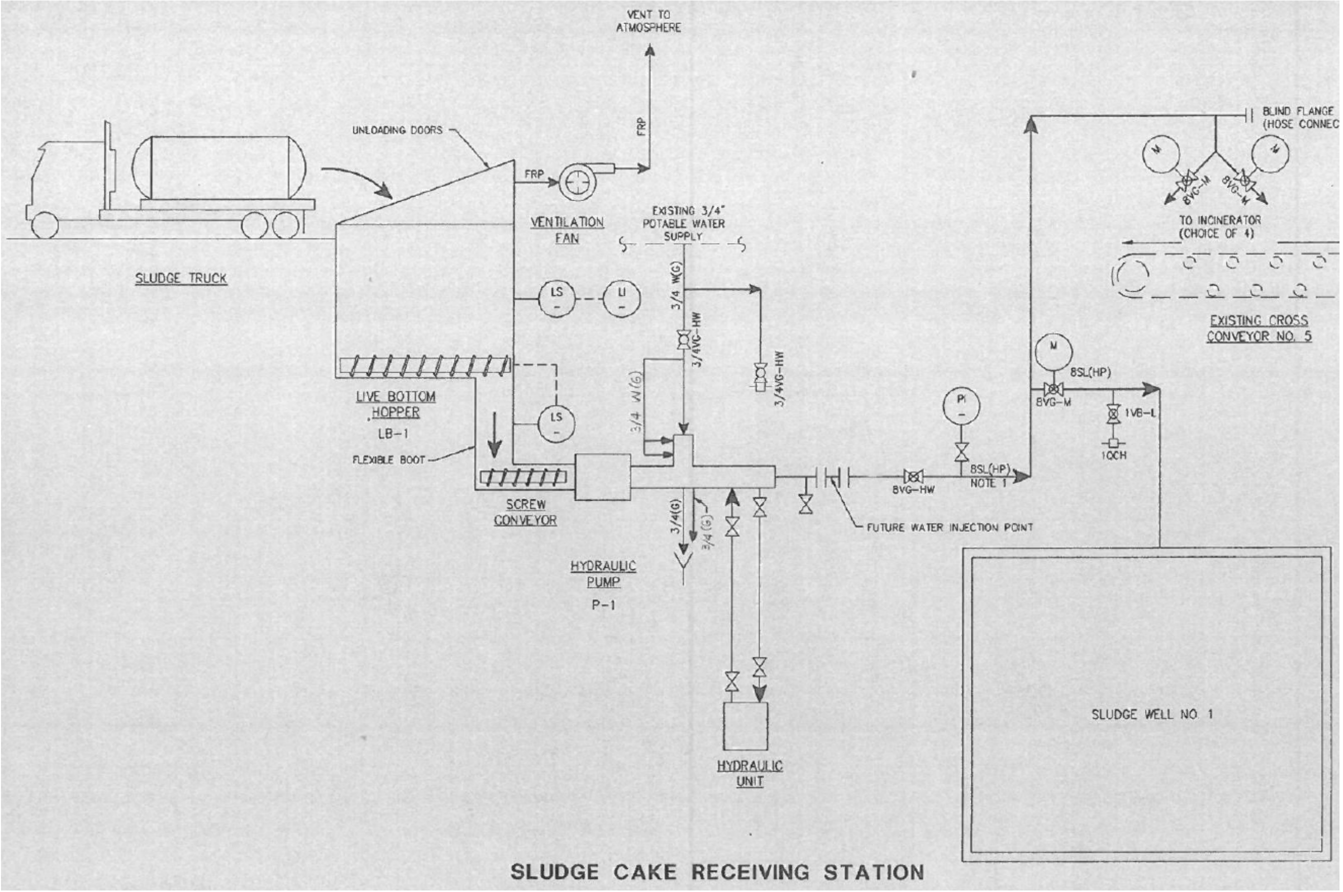

Figure 2. Schematic of Existing Bissell Point WWTF Cake Receiving Station

The existing cake receiving station equipment has been in operation for 22+ years and has been relied on more heavily in recent years. The system has no redundancy and the equipment is showing signs of significant wear and tear to the live bottom hopper, twin screw feeder, and piston pump. The hydraulic system has also recently experienced more frequent leaks, which is typical for this type and age of equipment. Currently, when any one of these items needs repair, the entire system must be taken out of service, resulting in the periodic inability to receive cake at Bissell Point WWTF.

Given these limitations, MSD is currently constructing a new fully-redundant truck receiving station under the Bissell Point WWTF Redundant Sludge Acceptance and Belt Filter Press Replacement (12828) Project. This truck receiving station is anticipated to become the primary truck receiving station upon its completion in early 2020, with the existing system to thereafter be utilized as backup. Similar to the existing cake receiving station, the new system will include a below grade receiving bin. This bin will be located in the approximate footprint of the former chemical storage location at the Solids Handling Building. The design includes the following features:

- 50-yard cake storage bin.
- Cake storage bin with a sliding frame-type bottom.
- Hydraulic actuated dual cylinder piston pump.
- Modular design.
- Major equipment items will be supplied by a single manufacturer.

Figure 3 provides a plan and section of the new cake receiving facilities currently under construction at Bissell Point WWTF.

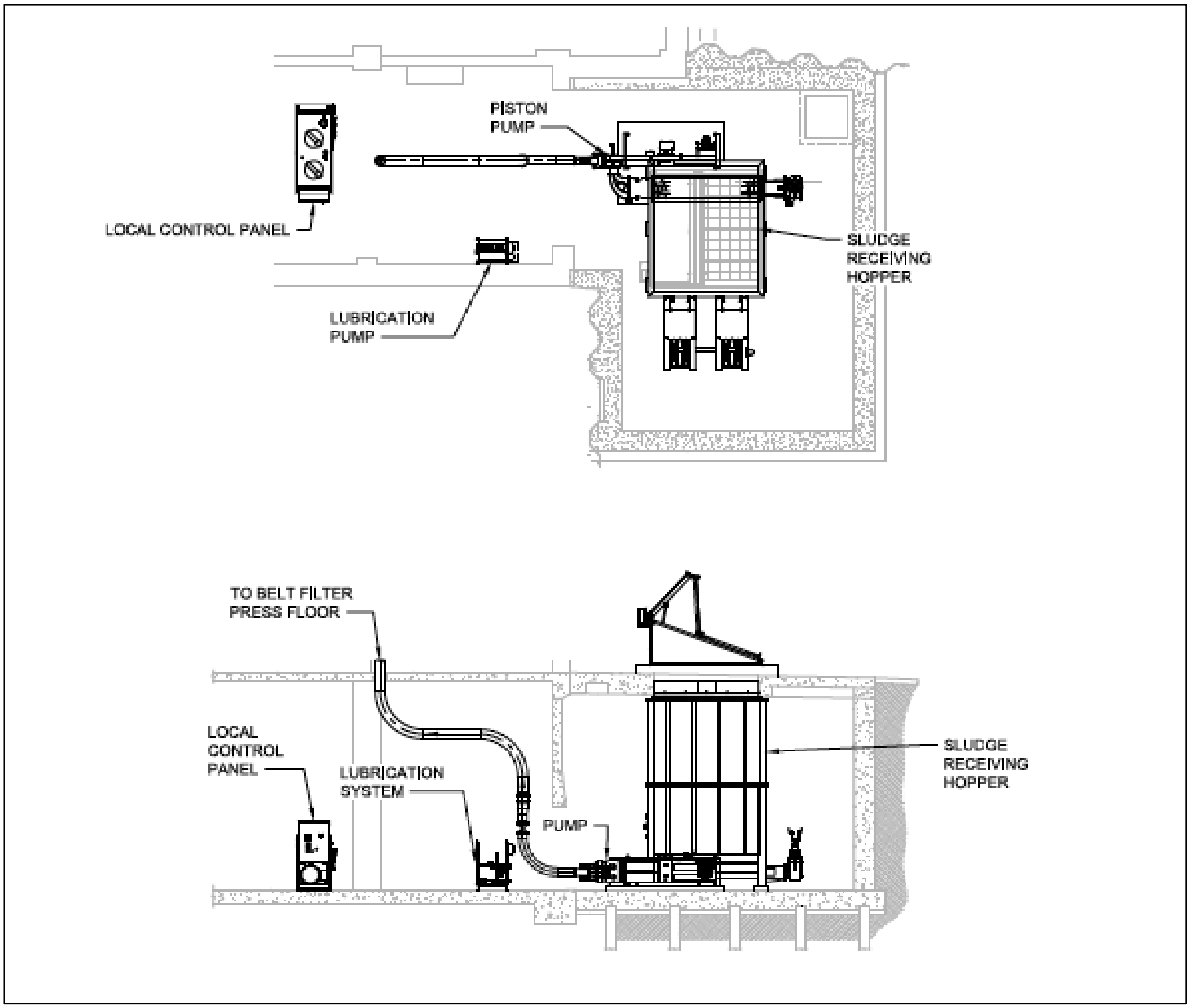

Figure 3. Planned Bissell Point WWTF Expanded Cake Receiving Facilities

Under the Bissell Point and Lemay WWTF FBI Project, MSD has concluded that cake receiving at both Bissell Point and Lemay is needed to provide additional flexibility for MSD’s district wide solids management.

Note that dual cake receiving stations at both Bissell Point and Lemay WWTFs will allow cake to be transferred between the facilities if solids processing capacity / capability becomes limited at either facility.

MSD is also currently considering whether trucking of cake to Bissell Point WWTF from the Lower Meramec, Grand Glaize, and Fenton WWTFs will be discontinued in the future. As an alternate, liquid sludge may be pumped from these facilities to the Lemay WWTF for dewatering and incineration. Note that TM-05 (previously submitted to MSD for review) evaluates alternatives and presents considerations for a Biosolids Transfer Pump Station at Lower Meramec WWTF, and a forcemain to convey liquid sludge to Lemay WWTF. Based on direction from MSD, alternatives presented herein assume that the force main alternative will be selected; however, should this direction change, new receiving stations at Bissell Point and Lemay WWTFs may also be required to receive cake from Lower Meramec, Grand Glaize, and Fenton WWTFs. This scenario would merit reconsideration of scoring and analyses for various options for Bissell and Lemay WWTFs cake receiving facilities as presented herein.

Projected Cake Transfer and Receiving Requirements

Cake receiving facilities are common for wastewater treatment facilities operating incineration systems. Such receiving facilities allow for outside cake to be utilized to supplement incinerator feed (thus reducing auxiliary fuel requirements) and also can provide an alternate cake disposal option for other WWTPs. As previously noted, the primary role of the planned Bissell and Lemay WWTF cake receiving facilities will be to allow cake to be transferred between Bissell and Lemay if future incineration capacity becomes limited at either facility.

In order to establish design criteria for the new cake receiving facilities, solids loading criteria and projections (previously presented to MSD under TM-09) are summarized in Table 1.

Table 1. Projected Solids Quantities for Bissell Point and Lemay WWTFs

Description	Bissell Point	Lemay
	[1]Total Solids, dtpd	[1,2]Total Solids, dtpd
Normal, AA	134.8	111.6
Normal, MM	168.1	122.9
Normal, PW	246.8	144.7
Flood Stage, MM	250.1	165.2
Flood Stage, PW	300.3	211.9

[1] Projections taken from TM-09: FBI Design Criteria.

[2] Lemay WWTF solids projections include cake from Lower Meramec, Grand Glaize, and Fention WWTFs.

It is currently anticipated that four new FBIs and three new FBIs will be installed at Bissell Point and Lemay WWTFs, respectively. Each of these units will be tentatively rated for a maximum cake throughput capacity of approximately 83 dry tons per day (dtpd). Normally, two or three FBIs will be in service at Bissell Point WWTF and two FBIs will be in service at Lemay WWTF, leaving at least one FBI out-of-service for planned maintenance at any given time. Should one additional FBI need to be taken out of service at either WWTF, this would require cake to be periodically hauled to the other WWTF for incineration. Considering projections for annual average, maximum month, and peak week solids throughput provided in Table 1, Table 2 provides estimates for how much cake would need to be hauled between WWTFs under each scenario. Note that projections were not provided for flood stage conditions, as neither WWTF is expected to have excess incineration capacity under these conditions.

Table 2. Required Cake Receiving Under AA, MM, and PW Conditions

Description	Bissell Point	Lemay
	Total Solids, dtpd	Total Solids, dtpd
[1]Capacity with 2 FBIs out of Service	166	83
[2]Cake Received from Other WWTF:		
- Normal, AA	28.6	0
- Normal, MM	39.9	2.1
- Normal, PW	61.7	80.8

[1] Assumes remaining online FBIs operating at 100% design capacity (83 dtpd each).

[2] Capacity with 2 FBIs out of service, less projected solids quantities provided under Table 1.

Table 2 shows that it is more likely that MSD will need to haul cake from Lemay to Bissell Point under both annual average and peak month conditions; however, under peak week conditions, a greater impact will be seen for hauling cake from Bissell Point to Lemay. Given capacity limitations of the planned Lemay WWTF incineration facilities, it is possible that Bissell Point cake would need to be landfilled unless enough notice is provided to allow Lemay to bring the third FBI online to handle Bissell Point cake.

Based on the projections established under Table 2, Table 3 provides an estimate of the number of trucks required to haul cake between Bissell Point and Lemay WWTFs.

Table 3. Estimated Cake Trucking Between Bissell Point and Lemay WWTFs

Description	Trucks To Bissell Point	Trucks To Lemay
Approximate Number of Trucks Required per Day:		
- Normal, AA	0	6
- Normal, MM	1	8
- Normal, PW	16	12

[1]Assumes maximum truck capacity of ~20 wet tons.

Cake Receiving Facility Considerations

The following sections provide a review of significant features associated with cake receiving for the new or modified facilities at Bissell Point and Lemay WWTFs. Note that the OA Team's recommendations regarding each feature are provided in each section.

ENCLOSED (INDOOR) VERSUS UN-ENCLOSED (OUTDOOR) RECEIVING FACILITY AND ODOR CONTROL

As previously described, truck unloading at Bissell Point WWTF currently occurs outdoors adjacent to the existing Solids Handling Building. The receiving bin is equipped with a hinged cover to help contain odors from the below grade receiving bin, and the bin itself is vented directly to atmosphere via a centrifugal fan. With this arrangement, odors generated during truck unloading are not contained. Note that other facilities operating cake receiving often find this problematic due to complaints from nearby private residences and / or businesses.

Figure 4. Example of Outdoor Cake Receiving Facility (Photo Provided by Schwing Bioset)

With outdoor unloading stations, equipment and personnel are exposed to the weather, and unloading must occur regardless of outdoor conditions. This can result in additional wear and operations and maintenance (O&M) considerations for equipment and personnel. Figure 4 provides another example of an outdoor cake receiving facility.

In order to address odor concerns associated with outdoor cake receiving facilities, it is more common for cake receiving stations to be enclosed within a building. Figures 5 and 6 provide examples of enclosed cake receiving facilities.

For such indoor installations, the building envelope is typically designed as a relatively simple enclosure with the main purpose of containing odors and protecting equipment; associated building mechanical costs (e.g. lighting, ventilation, etc.) are held to a minimum.

For many of the cake receiving options discussed herein, space to house new cake receiving facilities would be designed as an extension of the planned new FBI buildings, thus further reducing costs associated with this project element. Note that due to National Fire Protection Agency (NFPA) code classification requirements, the cake receiving space would need to be physically separated (via partition wall) from the incinerator area to reduce code classification and ventilation requirements for the entire facility; however, odorous air from the cake receiving facility could be tied back into the overall odor control system, with odorous air fed to the incinerators or to dedicated odor control scrubbers.

Figure 5. Example of Indoor Cake Receiving Station at GEB WWTP

Based on the OA Team's experience at other facilities operating cake receiving stations, it is recommended that new cake receiving stations be enclosed within a building envelope. As such, options discussed herein assume that a simplistic building envelope is included for the new cake receiving facility.

Figure 6. Example of Truck Unloading for Indoor Cake Receiving Station at GEB WWTP

Above Grade versus Below Grade Cake Receiving Bins

The District previously considered below-grade or above-grade receiving bins, and ultimately decided on below-grade bins for the systems currently being constructed. The OA Team agrees with this recommendation as discussed below.

Below-grade receiving bins are very common for facilities operating cake receiving stations. This is arguably a more simplistic arrangement compared to an above-grade facility, given that it allows trucks to back in at-grade to unload cake, rather than needing to be elevated or lifted to allow cake to be dumped into an above-grade receiving bin.

The below-grade arrangement also allows for equipment to be fully enclosed and protected from weather without incorporating a large above-grade building footprint. Cake is also better contained, thus reducing fugitive odors.

One concern associated with a below-grade arrangement is access to equipment for O&M requirements; however, proper design of the facility can alleviate this concern. Figure 7 provides an example of below-grade cake receiving bins within a building, designed to provide maximum equipment access.

Figure 7. Below Grade Cake Receiving Bins Designed for Maximum O&M Access

(Photo Provided by Schwing Bioset)

Type of Receiving Bin

In the past, cake receiving facilities have often utilized multiple screw / auger type live bottom receiving bins. This design incorporates an inclined bin bottom which directs cake to a live-bottom floor comprised of multiple screw conveyors or augers in parallel. There are several drawbacks associated with this design, as summarized below:

- Live bottom augers / conveyors are difficult to access for O&M and require significant footprint / clearance on either side of bin for removal and replacement.
- Inclined design of bin can allow cake to “bridge” the augers, resulting in cake buildup within the bin, sometimes requiring corrective intervention from O&M personnel.
- Live bottom augers can overfeed downstream cake pump fill chambers, causing excessive wear on seals and bearings, resulting in frequent leaks.

Given these issues, it is recommended that screw / auger live bottom receiving bins not be considered further for new cake receiving at Bissell Point and Lemay WWTFs. Rather, the OA Team concurs with previous evaluation findings which recommend a more modern sliding frame or push floor style receiving bin.

As previously discussed, MSD is currently proceeding with the installation of a push floor style receiving bin to supplement existing receiving capacity at the Bissell Point WWTF. This style of receiving bin incorporates a rectangular receiving bin with two parallel, hydraulically driven rectangular frames along the bottom of the bin floor. These frames push cake along the bin floor to a pair of parallel extraction screws located below one end of the bottom of the bin, allowing the cake to be removed from the bin and fed to a downstream cake pump. Refer to Figure 8 for a representation of the push floor style receiving bin. Also note that Figure 4 previously presented shows a cake receiving facility utilizing a push floor style bin.

Sliding frame bins are similar to push floor bins with a few notable exceptions. These bins incorporate a cylindrical shaped bin with a single hydraulically driven frame at the bottom of the bin floor. The sliding frame moves cake to either one or two extraction screws located below the middle of the bin floor, depending on how many cake pumps are coupled to the receiving bin discharge. Refer to Figure 8 for a representation of the sliding frame style receiving bin.

As summarized below, it is the OA Team’s experience that sliding frame bins offer the following advantages compared to push floor style bins.

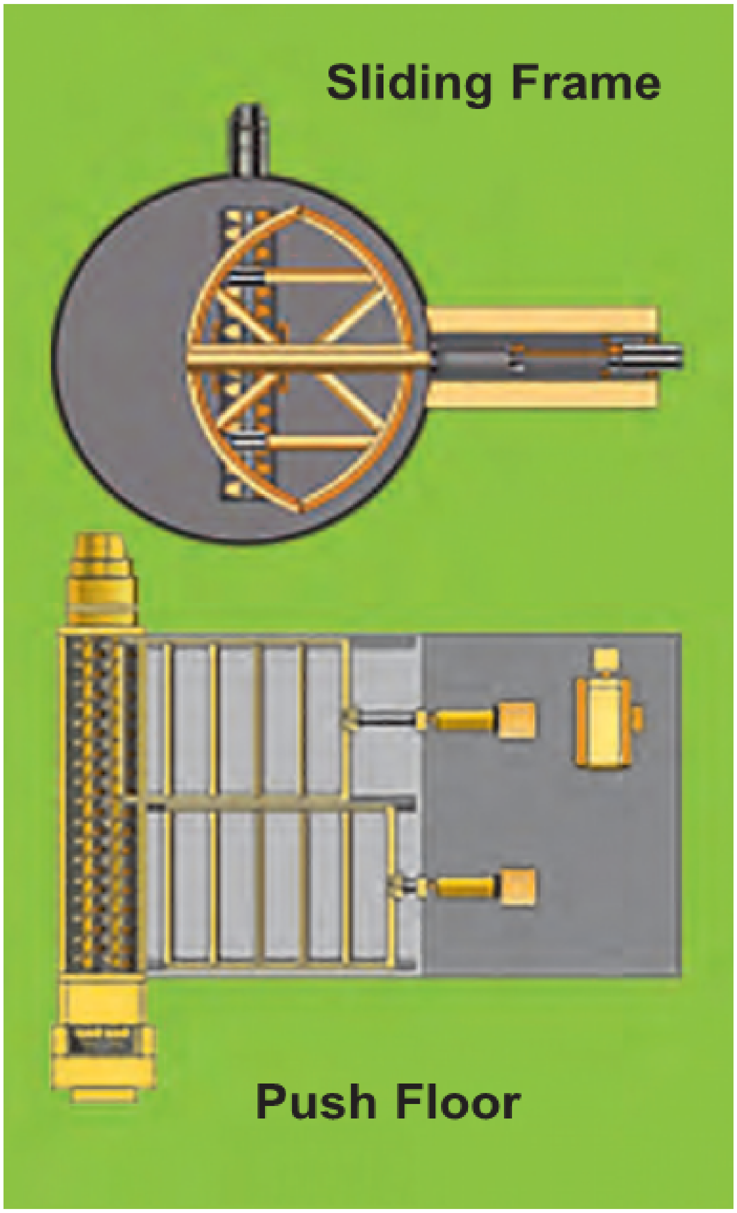

Figure 8. Sliding Frame versus Push Floor Style Cake Receiving Bins (Graphic Provided by Schwing Bioset)

- Sliding frame bins only utilize one hydraulically driven frame versus two for the push floor style bins. This reduces the size / complexity of the hydraulic system and associated hosing and connections (which can be prone to leaks).
- The cylindrical design of the sliding frame bins reduces the potential for cake accumulation and bridging within the bin. This can be a factor for the rectangular design of the push floor style bin.

Figure 9. Example of Sliding Frame Bin Downstream of Dewatering Centrifuges at NEORSD's Southerly

- The sliding frame design is more compact compared to the push floor style receiving bin. The design also more easily allows for two downstream cake pumps to be paired to the bin, versus the push floor bin which typically only uses one downstream cake pump.
- With the more compact design of sliding frame bins, this style is often used downstream of dewatering equipment to collect cake and provide a wide-spot in the system. This will likely be the recommended approach for dewatering systems associated with this project. As such, there may be some benefit for having similar equipment in differing process areas for O&M similarity. Figures 9 and 10 provide examples of sliding frame bins installed downstream of dewatering equipment.

Given the above advantages associated with sliding frame style receiving bins, the OA Team recommends that this style be considered for cake receiving options further discussed herein which do not make use of existing cake receiving equipment at Bissell Point WWTF.

Received Cake Transfer Technologies

Sludge cake is an exceptionally viscous fluid which can be difficult to move via many material handling technologies.

Figure 10. Dual-Piston Hydraulic Cake Pump Paired to a Sliding Frame Bin at MCES' Metro WWTP

As such, most newer facilities operating dewatering and incineration systems rely on high pressure pumps to convey cake. As such, two options are utilized for high pressure cake pumping, 1) multi-stage progressing cavity pumps, and 2) hydraulically driven piston pumps.

While multi-stage progressing cavity pumps can generate enough pressure to convey cake up to 200 ft; up to 6 - 9 stages are often required. This often results in pumps up to thirty feet long, thus requiring a considerable footprint. These pumps can also be difficult to access and disassemble for regular O&M.

Hydraulically driven piston pumps are more common for this application and are recommended by the OA Team for use with the planned new cake receiving facilities. This style of pump is more compact and can generate higher discharge pressures compared to progressing cavity pumps (allowing cake to be transferred further distances up to 400+ ft). Furthermore, this style of pump can be furnished as a packaged system with the cake receiving bins and operates on a similar hydraulic system utilized for the sliding frame bin components.

Refer to TM No. 15 for a detailed discussion on cake transfer equipment and the recommendation to use hydraulic piston pumps.

Summary of Recommended Cake Receiving Components

As discussed in the previous sections, the recommended cake receiving system components are summarized below.

- Indoor (enclosed) cake receiving facility to help control odor, protect equipment, and provide better O&M access.
- Cake receiving facility odor control integrated with overall facility odor control system. Odorous air can be fed to new FBIs (utilized as fluidizing air) or directed to dedicated odor control scrubbers.
- Below grade cake receiving bins designed with suitable O&M accessibility.
- Sliding frame style cake receiving bins for options which do not involve re-use of existing push-floor style bins at Bissell Point WWTF.
- Hydraulic piston pumps downstream of cake receiving bins to transfer cake to dewatered cake collection bins.

Cake Receiving Options

Based on the recommendation made in the previous sections, the OA Team has developed five cake receiving facility options for consideration by MSD. Each of these five options considers cake receiving at both Bissell Point and Lemay WWTFs, and two options consider the re-use of new cake receiving equipment currently being installed at Bissell Point.

The cake receiving options presented herein namely differ on how much receiving capacity and redundancy is provided to MSD during infrequent periods where incineration capacity becomes limited at either facility. As discussed further below, cost associated with options which consider the installation of multiple cake receiving bins at one facility or the other can be tied to MSD’s perceived acceptability of enterprise risk associated with these infrequent cake hauling events.

OPTION 1 – IMPROVE EXISTING (CURRENTLY UNDER CONSTRUCTION) 1-BAY CAKE RECEIVING FACILITY AT BISSELL POINT AND INSTALL NEW 1-BAY CAKE RECEIVING FACILITY AT LEMAY

Under this option, the new single bay receiving facility at Bissell Point WWTF would continue to be utilized to periodically receive cake trucked from Lemay WWTF. This option thus leverages MSD’s recent investment into new receiving equipment at Bissell WWTF.

Note that past evaluations and discussions have considered relocation of the equipment currently being installed (e.g. push floor receiving bin, bin cover, single hydraulic dual piston pump, and hydraulic power pack) to a new location adjacent to the planned future incinerator building; however, recent discussions with MSD has indicated that this approach is not preferable. As such, Option 1 assumes that the existing equipment will remain in its current location with improvements. These improvements would namely include construction of an above-grade building envelope and associated odor control and ventilation.

The improved cake receiving facility at Bissell Point WWTF would conservatively provide receiving capacity for one truck per hour, which exceeds the anticipated trucking requirements outlined in Table 3 and which also aligns well with the capacity of a single hydraulic driven dual piston pump. However, note that the push floor style receiving bin cannot be easily modified for a second pump, meaning that the ability to receive cake at Bissell Point would be contingent upon the availability of a single installed pump. Should this pump be out-of-service, cake from Lemay WWTF would need to be directed elsewhere (e.g. landfill).

Under this option, discharge piping from the single cake pump would be split (currently combined into a single pipeline) into two pipelines to the planned FBI building. Note that piston pumps are capable of pumping cake up to several hundred feet along high-pressure pipelines with lubrication water injection rings along the cake piping route to reduce pipeline friction losses. These injection rings would correspondingly require high-pressure lubrication water pump skids.

This option also includes the installation of a single bay cake receiving facility at Lemay WWTF. The Lemay receiving facility would likely be constructed immediately adjacent to the planned future FBI building to help realize cost savings associated with a consolidated building footprint. As previously discussed, the OA Team recommends that this facility include an indoor, below-grade sliding frame cake receiving bin, tied to two downstream hydraulic driven dual piston cake pumps. This would provide additional pumping redundancy to allow Bissell Point cake to continue to be directed to Lemay even if one pump is out of service.

Preliminary design criteria and functional requirements for the Option 1 cake receiving facilities are summarized in Table 4.

Table 4. Option 1 – Preliminary Design Criteria / Functional Requirements

Bissell Point WWTF	
Component	**Description / Functional Requirements**
[1]**Existing Cake Receiving Bin**	*Receive Lemay WWTF Cake*
Type	Hydraulically Driven Push Floor (Schwing Bioset)
Number	1
Size / Shape	Rectangular
Length, ft	20
Width, ft	10
Sidewall Depth, ft	12
Overall Height, ft	16
Capacity, cubic yard (cy)	50
[1]**Existing Twin Screw Extraction Conveyor**	*Transfer Cake from Receiving Bin to Cake Pump*
Type	Shafted Dual Screw Conveyor (Schwing Bioset)
Number	1
Diameter, in	13

Bissell Point WWTF

Component	Description / Functional Requirements
Length, ft	18
[1]Existing Received Cake Pump	*Transfer Cake to Incinerators*
Type	Schwing Bioset KSP-45 (to be confirmed) Hydraulically Driven Twin Cylinder Reciprocating Piston Pump
Number	1
Hydraulic Drive Motor, hp	125 (to be confirmed)
Hydraulic Drive Pressure, psi	2,585 (to be confirmed)
Discharge Type	Dual header (modified from existing single header)
Discharge Pressure, psi	400-900
Capacity @ 25 %TS	
Strokes per Minute	2-10
Gallons per Minute	24-120
Dry Tons per Day	27-134
New Received Cake Pipeline Lubrication System	*Injection Lubrication Water to Cake Piping to Reduce Friction Losses*
Type	*Positive Displacement Pump, Skid Mounted (Schwing Bioset)*
Number	*2 (to be confirmed)*
Capacity, gph	*72*
Discharge Pressure, psi	*1500*
Motor, hp	*3*

Lemay WWTF

Component	Description / Functional Requirements
New Cake Receiving Bin	*Receive Bissell Point WWTF Cake*
Type	Sliding Frame with Retractable Hatch
Number	1
Size / Shape	Cylindrical
Height, ft	18
Diameter, ft	12.5

Bissell Point WWTF	
Component	**Description / Functional Requirements**
Capacity, cy	80
Sliding Frame Hydraulic Drive Motor, hp	7.5
New Received Cake Pump	*Transfer Cake to Incinerators*
Type	Hydraulically Driven Twin Cylinder Reciprocating Piston Pump
Number	2
Hydraulic Drive Motor, hp	200
Hydraulic Drive Pressure, psi	2,585
Discharge Type	Dual header
Discharge Pressure, psi	400-900
Capacity @ 25 %TS	
Strokes per Minute	2-10
Gallons per Minute	24-120
Dry Tons per Day	27-134
New Received Cake Pipeline Lubrication System	*Injection Lubrication Water to Cake Piping to Reduce Friction Losses*
Type	*Positive Displacement Pump, Skid Mounted (Schwing Bioset)*
Number	*2*
Capacity, gph	*72*
Discharge Pressure, psi	*1500*
Motor, hp	*3*

[1] Assumes re-use of existing cake receiving equipment at Bissell Point WWTF.

OPTION 2 – EXPAND EXISTING (CURRENTLY UNDER CONSTRUCTION) 1-BAY CAKE RECEIVING FACILITY AT BISSELL POINT TO A 2-BAY FACILITY AND INSTALL NEW 1-BAY CAKE RECEIVING FACILITY AT LEMAY

Similar to Option 1, under Option 2 the new single bay receiving facility at Bissell Point WWTF would continue to be utilized to periodically receive cake trucked from Lemay WWTF; however, this option also includes the expansion of the facility to a two-bay receiving facility for greater operational flexibility and redundancy.

Option 2 assumes that the expanded cake receiving facility will be maintained in the location of the existing facility. As such, the foundation walls of the existing structure would be demolished, and the basement area expanded to house additional equipment. As previously discussed, a new above-grade building envelope and associated odor control and ventilation would also be constructed to house the expanded two bay cake receiving facility.

In order to match the existing equipment, a new rectangular push floor style cake receiving bin, extraction screw, and cake pump would be installed. This would allow the two cake receiving bins (one new and one existing) to operate as two separate receiving trains. This arrangement would greatly improve redundancy limitations discussed under Option 1.

Under this option, discharge piping from the two cake pumps would likely be consolidated into two pipelines to the planned FBI building. As previously noted, lubrication water injection rings and associated lubrication water pumps would be required along the cake piping to reduce pipeline friction losses.

This option also includes the installation of a single bay cake receiving facility at Lemay WWTF. This facility would be identical to that already discussed under Option 1.

Preliminary design criteria and functional requirements for the Option 2 cake receiving facilities are summarized in Table 5.

Table 5. Option 2 – Preliminary Design Criteria / Functional Requirements

Bissell Point WWTF	
Component	**Description / Functional Requirements**
[1]Cake Receiving Bin	*Receive Lemay WWTF Cake*
Type	Hydraulically Driven Push Floor (Schwing Bioset)
Number	2 (1 existing, 1 new)
Size / Shape	Rectangular
Length, ft	20
Width, ft	10
Sidewall Depth, ft	12
Overall Height, ft	16

Bissell Point WWTF	
Component	**Description / Functional Requirements**
Capacity, cubic yard (cy) each	50
[1]**Twin Screw Extraction Conveyor**	*Transfer Cake from Receiving Bin to Cake Pump*
Type	Shafted Dual Screw Conveyor (Schwing Bioset)
Number	2 (1 existing, 1 new)
Diameter, in	13
Length, ft	18
[1]**Existing Received Cake Pump**	*Transfer Cake to Incinerators*
Type	Schwing Bioset KSP-45 (to be confirmed) Hydraulically Driven Twin Cylinder Reciprocating Piston Pump
Number	2 (1 existing, 1 new)
Hydraulic Drive Motor, hp	125 (to be confirmed)
Hydraulic Drive Pressure, psi	2,585 (to be confirmed)
Discharge Type	Dual header
Discharge Pressure, psi	400-900
Capacity @ 25 %TS	
Strokes per Minute	2-10
Gallons per Minute	24-120
Dry Tons per Day	27-134
New Received Cake Pipeline Lubrication System	*Injection Lubrication Water to Cake Piping to Reduce Friction Losses*
Type	*Positive Displacement Pump, Skid Mounted (Schwing Bioset)*
Number	*2*
Capacity, gph	*72*
Discharge Pressure, psi	*1500*
Motor, hp	*3*
Lemay WWTF	
Component	**Description / Functional Requirements**
[2]*Refer to Table 4 for Lemay WWTP Receiving Facility Preliminary Description / Functional Requirements*	

[1] Assumes re-use of existing cake receiving equipment at Bissell Point WWTF.

[2] Preliminary description / functional requirements provided under Option 1 discussion and Table 4.

OPTION 3 – ADD NEW 1-BAY CAKE RECEIVING FACILITY AT BISSELL POINT AND LEMAY

This option assumes that new, identical one bay cake receiving facilities are constructed at Bissell Point and Lemay WWTFs. Existing cake receiving facilities at Bissell Point would be abandoned in place or retained with minimal modifications to serve as a back-up.

The new cake receiving facilities would likely be constructed immediately adjacent to the planned FBI buildings to help realize cost savings associated with consolidated building footprints. As previously discussed, the OA Team recommends that the facilities include an indoor, below grade sliding frame cake receiving bin, each tied to two downstream hydraulic driven dual piston cake pumps. Unlike the arrangement discussed for Bissell Point under Options 1 and 2, Option 3 provides greater receiving redundancy and pumping capacity without needing to construct a second receiving bin. With two cake pumps tied to each bin, the required level of service outlined in Tables 2 and 3 could be provided regardless if one pump must be taken offline for maintenance.

Preliminary design criteria and functional requirements for the Option 3 cake receiving facilities are summarized in Table 6.

Table 6. Option 3 – Preliminary Design Criteria / Functional Requirements

Typical for [1]Bissell Point and Lemay WWTFs	
Component	**Description / Functional Requirements**
New Cake Receiving Bin	*Receive Cake from Other WWTF*
Type	Sliding Frame with Retractable Hatch
Number	1
Size / Shape	Cylindrical
Height, ft	18
Diameter, ft	12.5
Capacity, cy	80
Sliding Frame Hydraulic Drive Motor, hp	7.5
New Received Cake Pump	*Transfer Cake to Incinerators*
Type	Hydraulically Driven Twin Cylinder Reciprocating Piston Pump
Number	2
Hydraulic Drive Motor, hp	200
Hydraulic Drive Pressure, psi	2,585
Discharge Type	Dual header
Discharge Pressure, psi	400-900

Typical for [1]Bissell Point and Lemay WWTFs	
Component	**Description / Functional Requirements**
Capacity @ 25 %TS	
Strokes per Minute	2-10
Gallons per Minute	24-120
Dry Tons per Day	27-134
New Received Cake Pipeline Lubrication System	*Injection Lubrication Water to Cake Piping to Reduce Friction Losses*
Type	*Positive Displacement Pump, Skid Mounted (Schwing Bioset)*
Number	*2*
Capacity, gph	*72*
Discharge Pressure, psi	*1500*
Motor, hp	*3*
[1]Assumes existing cake receiving facilities are abandoned in place or retained as back-up with minimal modifications.	

OPTION 4 – ADD NEW 2-BAY CAKE RECEIVING FACILITY AT BISSELL POINT AND NEW 1-BAY CAKE RECEIVING FACILITY LEMAY

This option is very similar to Option 3, except that it assumes that a new two bay cake receiving facility is installed at Bissell Point in lieu of a one bay facility. This expanded receiving capacity would allow for Bissell Point to receive additional cake from other MSD or non-MSD facilities in the future, possibly allowing for incineration capacity to be further utilized / maximized.

Preliminary design criteria and functional requirements for the Option 4 cake receiving facilities are summarized in Table 7.

Table 7. Option 4 – Preliminary Design Criteria / Functional Requirements

[1]Bissell Point WWTF	
Component	**Description / Functional Requirements**
New Cake Receiving Bin	*Receive Cake from Other WWTF*
Type	Sliding Frame with Retractable Hatch
Number	2
Size / Shape	Cylindrical

[1]**Bissell Point WWTF**	
Component	**Description / Functional Requirements**
Height, ft Diameter, ft	18 12.5
Capacity, cy	80
Sliding Frame Hydraulic Drive Motor, hp	7.5
New Received Cake Pump	*Transfer Cake to Incinerators*
Type	Hydraulically Driven Twin Cylinder Reciprocating Piston Pump
Number	1 (1 per receiving bin)
Hydraulic Drive Motor, hp	200
Hydraulic Drive Pressure, psi	2,585
Discharge Type	Dual header
Discharge Pressure, psi	400-900
Capacity @ 25 %TS	
Strokes per Minute	2-10
Gallons per Minute	24-120
Dry Tons per Day	27-134
New Received Cake Pipeline Lubrication System	*Injection Lubrication Water to Cake Piping to Reduce Friction Losses*
Type	*Positive Displacement Pump, Skid Mounted (Schwing Bioset)*
Number	*2*
Capacity, gph	*72*
Discharge Pressure, psi	*1500*
Motor, hp	*3*
Lemay WWTF	
Component	**Description / Functional Requirements**
[2]*Refer to Table 6 for Lemay WWTP Receiving Facility Preliminary Description / Functional Requirements*	

[1] Assumes existing Bissell Point WWTF cake receiving facilities are abandoned in place.

[2] Preliminary description / functional requirements provided under Option 3 discussion and Table 6.

OPTION 5 – ADD NEW 2-BAY CAKE RECEIVING FACILITY AT BISSELL POINT AND LEMAY

This option is very similar to Option 4, except that it assumes that a new two bay cake receiving facility is installed at both Bissell Point and Lemay in lieu of a one bay facility at Lemay. This expanded receiving capacity would allow for both Bissell Point and Lemay to receive additional cake from other MSD or non-MSD facilities in the future, possibly allowing for incineration capacity to be further utilized / maximized.

Preliminary design criteria and functional requirements for the Option 5 cake receiving facilities are summarized in Table 8.

Table 8. Option 5 – Preliminary Design Criteria / Functional Requirements

Typical for [1]Bissell Point and Lemay WWTFs	
Component	**Description / Functional Requirements**
New Cake Receiving Bin	*Receive Cake from Other WWTF*
Type	Sliding Frame with Retractable Hatch
Number	2
Size / Shape	Cylindrical
Height, ft	18
Diameter, ft	12.5
Capacity, cy	80
Sliding Frame Hydraulic Drive Motor, hp	7.5
New Received Cake Pump	*Transfer Cake to Incinerators*
Type	Hydraulically Driven Twin Cylinder Reciprocating Piston Pump
Number	1 (1 per receiving bin)
Hydraulic Drive Motor, hp	200
Hydraulic Drive Pressure, psi	2,585
Discharge Type	Dual header
Discharge Pressure, psi	400-900
Capacity @ 25 %TS	
Strokes per Minute	2-10
Gallons per Minute	24-120
Dry Tons per Day	27-134

Typical for [1]Bissell Point and Lemay WWTFs	
Component	**Description / Functional Requirements**
New Received Cake Pipeline Lubrication System	*Injection Lubrication Water to Cake Piping to Reduce Friction Losses*
Type	*Positive Displacement Pump, Skid Mounted (Schwing Bioset)*
Number	*2*
Capacity, gph	*72*
Discharge Pressure, psi	*1500*
Motor, hp	*3*
[1]Assumes existing Bissell Point WWTF cake receiving facilities are abandoned in place.	

Figure 11 provides an example conceptual design prepared by the OA Team for another client for an enclosed two-bay receiving facility. A similar concept would apply to two bay facilities discussed under Options 4 and 5.

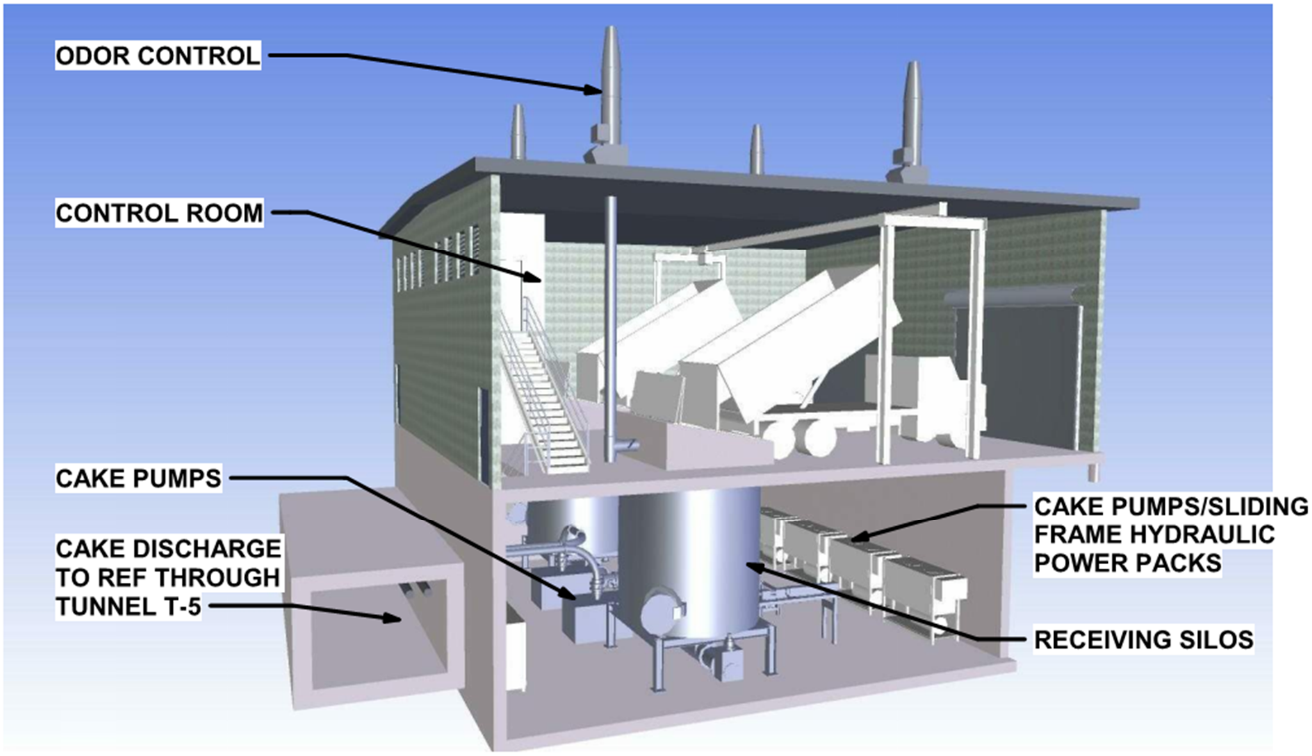

Figure 11. Example Conceptual Design of Enclosed Two Bay Receiving Facility

Cost and Non-Cost Comparison of Options

The OA Team evaluated each cake receiving option over cost and non-cost factors in order to establish a composite, readily comparable score for each option. As such, each category was initially assigned an equal 50% weighting to be divided across the options based on the ratio of scoring within the cost and non-cost categories. Note that further explanation is provided in subsequent sections, along with a subsequent sensitivity analysis. A summary of the initial allocation is shown in Table 9.

Table 9. Percentage of Allocation for Cost and Non-Cost Categories

Category	Allocated percentage (% of 100)
Cost	50%
Non-Cost	50%
Total	**100%**

PRELIMINARY OPINIONS OF PROBABLY CONSTRUCTION AND PROJECT COST

Table 10 provides planning level opinions of probable construction cost (OPCC) and opinions of probable project cost (OPPC) for each of the cake receiving options discussed herein.

Table 10. Preliminary OPCCs and OPPCs for Cake Receiving Options

Cost Item	Bissell WWTF Cake Receiving Options				
	Option 1	Option 2	Option 3	Option 4	Option 5
Demolition	$150,000	$300,000	$0	$0	$0
Site / Civil	$100,000	$300,000	$300,000	$522,000	$522,000
Building Envelope (with HVAC)	$1,100,000	$2,107,000	$1,100,000	$2,107,000	$2,107,000
Equipment Total	$195,000	$2,800,000	$2,800,000	$5,584,000	$5,584,000
Equipment	*$150,000*	*$2,100,000*	*$2,100,000*	*$4,300,000*	*$4,300,000*
Equipment Installation	*$45,000*	*$700,000*	*$700,000*	*$1,284,000*	*$1,284,000*
Cost Item	**Lemay WWTF Cake Receiving Options**				
	Option 1	**Option 2**	**Option 1**	**Option 4**	**Option 1**
Demolition	$0	$0	$0	$0	$0
Site / Civil	$300,000	$300,000	$300,000	$300,000	$522,000
Building Envelope (with HVAC)	$1,100,000	$1,100,000	$1,100,000	$1,100,000	$2,107,000
Equipment Total	$2,800,000	$2,800,000	$2,800,000	$2,800,000	$5,584,000

Cost Item	Bissell WWTF Cake Receiving Options				
	Option 1	Option 2	Option 3	Option 4	Option 5
Equipment	*$2,100,000*	*$2,100,000*	*$2,100,000*	*$2,100,000*	*$4,300,000*
Equipment Installation	*$700,000*	*$700,000*	*$700,000*	*$700,000*	*$1,284,000*
Subtotal "A"	**$5,745,000**	**$9,707,000**	**$8,400,000**	**$12,413,000**	**$16,423,000**
General Requirements (15%)	$862,000	$1,456,000	$1,260,000	$1,862,000	$2,464,000
Electrical (18%)	$1,034,000	$1,747,000	$1,512,000	$2,234,000	$2,957,000
Instrumentation and Controls (15%)	$689,000	$1,165,000	$1,008,000	$1,490,000	$1,971,000
Subtotal "B"	**$8,330,000**	**$14,075,000**	**$12,180,000**	**$17,999,000**	**$23,817,000**
Contingency (40%)	$3,332,100	$5,630,000	$4,872,000	$7,200,000	$9,527,000
Total OPCC	**$11,662,000**	**$19,705,000**	**$17,052,000**	**$25,198,000**	**$33,344,226**
Engineering, Legal, Administration (25%)	$2,916,000	$4,926,000	$4,263,000	$6,300,000	$8,336,000
Total OPPC	**$14,578,000**	**$24,632,000**	**$21,315,000**	**$31,498,000**	**$41,680,000**

Based on the total OPPCs for each cake receiving option, costs were compared as shown in Table 11. As previously noted, this comparison established a weighted percentage for each option based solely on cost.

Table 11. Overall Cost Scoring

Option	Overall Cost Score (Higher Score = Lower Cost)			
	Fraction of Total Cost	Inverse of Fraction	Fraction of Total Cost Inverse	Overall Cost Score (%)
	F = (NPV/Σ(NPVS))	(1/F)	F = (1/F)/ Σ(1/F)	F*50%
Option 1	0.11	9.17	1.46	16.19%
Option 2	0.18	5.43	0.87	9.58%
Option 3	0.16	6.27	1.00	11.07%
Option 4	0.24	4.24	0.68	7.49%
Option 5	0.31	3.21	0.51	5.66%
TOTAL:	**1**	**28.32**	**4.52**	**50.00%**

As would be expected, Option 1 received the highest score (16.19%) given that this option presented the lowest required project cost. On the other hand, Option 5 received the lowest score (5.66%) given that it presented the highest relative project cost.

NON-COST ANALYSES

Non-Economic Criteria and Scoring

Each option was also evaluated across the following seven, non-cost criteria based on its ability to achieve the criterion objective:

- **Reliability** – Resilient, dependable, and consistent service
- **Operability** – Ease of operation
- **Flexibility** – Manageable options offered during service interruption
- **Maintainability** – Long useful life with minimal and manageable maintenance
- **Adaptability** – Adaptable to potential future loadings
- **Sustainability** – Positive environmental impact and reduced carbon footprint
- **Constructability** – Construction methods minimize cost and schedule risk

Non-cost criteria were scored on a 1-5 scale, with a score of 1 meaning that the option is comparatively inferior or disadvantageous to meeting the criterion objective; a score of 3 meaning the option meets the criterion objective; and a score of 5 meaning the option is comparatively superior or advantageous to meeting the criterion objective. Table 12 further defines the non-economic criterion scoring.

Table 12. Non-Economic Scoring Definitions

Non-Economic Criteria	Score of 1	Score of 3	Score of 5
	INFERIOR/ DISADVANTAGEOUS	NEUTRAL/MEETS OBJECTIVE	Superior/ Advantageous
Reliability	Appreciable risk of system component failure and/or reduction in capacity	Moderate risk of system component failure and/or reduction in capacity	Low risk of system component failure and reduction in capacity
Operability	Complex system requiring frequent operations changes/decisions	Moderately complex system requiring periodic operations changes/decisions	Non-complex system requiring only occasional operations changes/decisions
Flexibility	Undesirable or unreliable standby operating modes available if primary mode is interrupted or unavailable	Acceptable standby operating modes available if primary mode is interrupted or unavailable	Reliable standby operating modes available if primary mode is interrupted or unavailable
Maintainability	Complex and/or frequent maintenance requirements over life of system equipment	Moderately complex and/or periodic maintenance requirements over life of system equipment	Non-complex and infrequent maintenance requirements over life of system equipment

Non-Economic Criteria	Score of 1	Score of 3	Score of 5
	INFERIOR/ DISADVANTAGEOUS	NEUTRAL/MEETS OBJECTIVE	Superior/ Advantageous
Adaptability	Requires significant system expansion to reliably support potential future solids loadings	Requires minimal system expansion to reliably support potential future solids loadings	Requires little to no change to system to reliably support potential future solids loadings
Sustainability	Negative environmental impact and/or appreciable increase in overall carbon footprint	Minimal environmental impact and/or unappreciable change in overall carbon footprint	Positive environmental impact and reduction in overall carbon footprint
Constructability	Requires complex, unproven and/or higher risk construction methods to implement	Requires moderately complex and/or moderate risk construction methods to implement	Uses non-complex, proven, and low risk construction methods to implement
Scores of 2 and 4 are intended to quantify moderate, but measurable differences between alternatives that are similar across the criterion.			

Each criterion was also weighted based upon its relative criticality and relevance to implementation, construction, and support of proposed operations associated with each option. Weights for each non-economic criterion were allocated as a percentage of 100, as shown in Table 13.

Table 13. Non-Economic Criteria Weightings

Non-Economic Criterion	Weight (%)
Reliability	20%
Operability	15%
Flexibility	15%
Maintainability	10%
Adaptability	10%
Sustainability	15%
Constructability	15%

The OA Team assigned non-cost scoring to each option, the results of which are presented in Table 14.

Table 14. Non-Cost Scoring

Criterion	Scoring					Description
	Option 1	Option 2	Option 3	Option 4	Option 5	
Reliability **(20%)**	2	3	3	4	5	[2] Option 1 will provide the least redundant pumping capacity with only one receiving bin tied to one pump at Bissell Point. [3] Option 2 will provide an extra receiving station at Bissell Point, minimizing the effect of an individual component failure on system capacity at the plant. This is similar to Option 3, which provides a single cake receiving bin with redundant pumping capacity at both WWTFs. [4] Option 4 will provide two new receiving bays at Bissell Point, providing additional system redundancy compared to Options 2 and 3. [5] Option 5 will provide two receiving stations at both Bissell Point and Lemay, minimizing the effect of any individual component failures on the overall system capacity.
Operability **(15%)**	3	3	4	4	4	[3] The solids handling equipment used in these systems can require frequent attention from operations, but the equipment should be familiar to district personnel. [4] Options 3, 4, and 5 will utilize newer equipment which is considered advantageous in terms of long term O&M.
Flexibility **(15%)**	2	4	3	4	5	[2] Option 1 will require Lemay cake to be directed to landfill if the single receiving bin becomes unavailable at Bissell Point. [3] Option 3 will provide all new equipment but will only provide a single receiving bay at each facility, thus providing somewhat limited flexibility. This option does however provide two pumps per bin, meaning that flexibility is offered if only one pumps goes offline. [4] Options 2 and 4 allow for complete receiving facility redundancy at Bissell Point; if one unloading station goes down, a second cake-receiving bin will be available. [5] Option 5 allows for complete cake-receiving facility redundancy at both Bissell Point and Lemay.

Criterion	Scoring					Description
	Option 1	Option 2	Option 3	Option 4	Option 5	
Maintainability **(10%)**	2	3	3	4	4	[2] For Option 1, the equipment will be similar to the other options, but the older facility will require more maintenance over the life of the equipment. [3] For Options 2 and 3, the equipment at the cake-receiving stations should only require periodic maintenance and should be familiar to MSD O&M staff. [4] For Option 4 and 5, the equipment at the cake-receiving stations should only require periodic maintenance and should be familiar to district operations staff. Additionally, all this equipment will be in new facilities that will be designed with major maintenance activities in mind.
Adaptability **(10%)**	2	4	4	4	5	[2] Option 1 will provide the least adaptability to receive future loads given use of the single, existing cake receiving bin. [4] Options 2 and 4 will each provide similar adaptability to receive future loads between the options, with one bin and two pumps for Option 3, and two bins and two pumps for Options 2 and 4. [5] Option 5 will have an additional receiving facility at both Bissell Point and Lemay.
Sustainability **(15%)**	2	4	4	4	5	[2] Option 1 presents the highest risk for needing to landfill cake, which is considered disadvantageous in terms of sustainability. [4] Options 2 through 4 present similar risk of needing to landfill cake, with similar redundancy in equipment between the options. [5] Option 5 presents the least likelihood that cake will need to be landfilled.

Criterion	Scoring					Description
	Option 1	Option 2	Option 3	Option 4	Option 5	
Constructability (15%)	3	2	4	3	3	[2] Under Option 2, expansion of the existing basement area will be the most challenging in terms of construction. [3] Option 1 is less challenging compared to Option 2, but also involves modifications to existing facilities. While Options 4 and 5 involve all new facilities, the footprint of these facilities will be larger to accommodate two receiving bins. [4] Option 3 includes all new receiving facilities with smaller footprints compared to Options 4 and 5.

The non-economic scores for each criterion were weighted using the allocations presented in **Error! Reference source not found.** 13 and totaled for an overall non-economic score for each option. This calculation is shown in Table 15.

Table 15. Overall Non-Cost Scoring

Option	Overall Non-Cost Score (Higher Score = Most Advantageous)			
	Total Non-Cost Weighted Score	Total Non-Cost Weighted Score	Fraction of Total Non-Cost Score	Overall Non-Cost Score (%)
	t = Σ[(CRITERION SCORE)*CRITERION WEIGHT)]	n = t/7 (7 Criteria)	N = n/Σ(n)	N*50%
Option 1	2.3	0.33	0.13	6.61%
Option 2	3.25	0.46	0.19	9.34%
Option 3	3.55	0.51	0.20	10.20%
Option 4	3.85	0.55	0.22	11.06%
Option 5	4.45	0.64	0.26	12.79%
TOTAL:	**N/A**	**2.49**	**1**	**50.00%**

As previously noted, non-cost scores were given an initial 50% weighting in this analysis which was distributed across the five options. A higher percentage score received by an option correlates to expected beneficial attributes of that option as compared to the other options. Options 4 and 5 received the highest non-cost scores (11.06% and 12.79%, respectively) and Option 1 received the lowest non-economic score (6.61%).

SUMMARY COMPARISON OF OPTIONS

Weighted scorings for each of the cost and non-cost evaluation categories, presented previously in Tables 11 and 15, are summarized in Table 16. Also presented in Table 16 is a summation of the scores across each category, resulting in an overall composite score which can be utilized to compare each option.

Table 16. Overall Scoring for Each Option at 50% Weighting for Cost and Non-Cost

Option	Results of Scoring at 50% Weighting for Cost and Non-Cost		
	Cost Score (%)	Non-Cost Score (%)	Total (%)
Option 1	16.19%	6.61%	22.80%
Option 2	9.58%	9.34%	18.92%
Option 3	11.07%	10.20%	21.27%
Option 4	7.49%	11.06%	18.56%
Option 5	5.66%	12.79%	18.45%
Total	*50%*	*50%*	*100%*

A graphical representation of the scoring presented in Table 16 is presented in Figure 12.

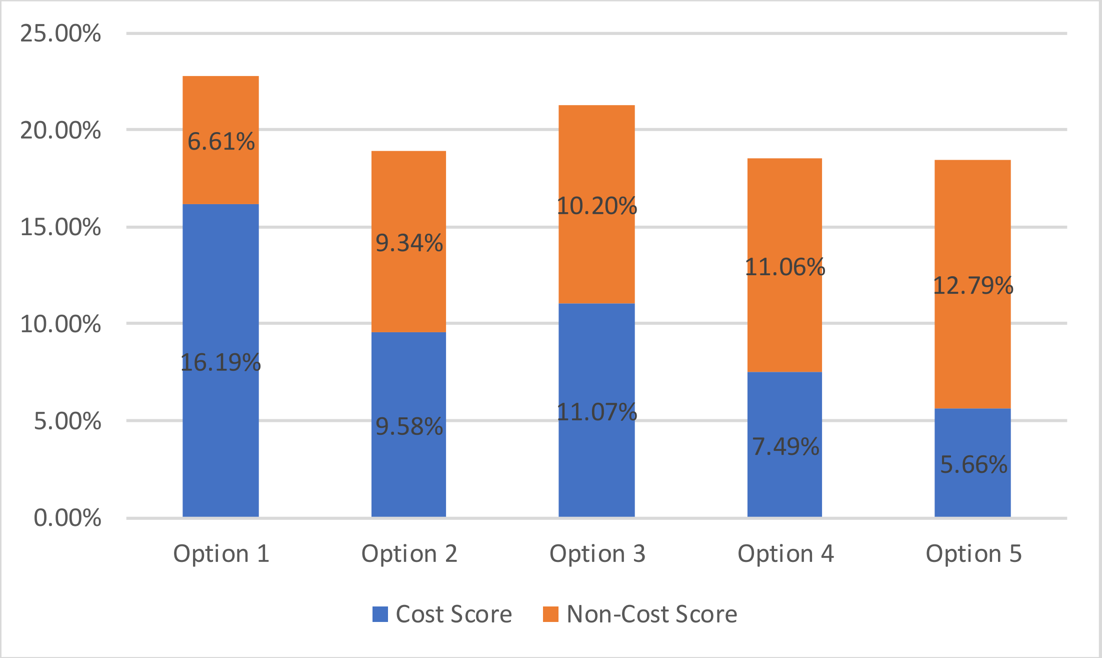

Figure 12. Overall Scoring for Each Option at 50% Weighting for Cost and Non-Cost

As shown in Table 16 and Figure 12, Option 1 received the most favorable scoring (22.80%) at a 50% cost and 50% non-cost factor weighting. Option 3 followed as a close second, with a score of 21.27%. This scoring is largely reflective of the significant cost advantage associated with Option 1, given that this option assumes re-use and only minimal modifications to the existing cake receiving facility at Bissell Point WWTF; however, the OA Team feels that this cake receiving option does not provide MSD with sufficient system redundancy required for long term, reliable operation. In other words, Option 1 likes poses an unacceptable enterprise risk to MSD's long-term solids management strategy.

Sensitivity Analysis

40% COST AND 60% NON-COST WEIGHTING

In order to address concerns noted above in association with Option 1, the OA Team performed a sensitivity analysis. This analysis looked at the breakpoint where changing cost and non-cost allocations (initially assigned equally at 50%) would result in another option receiving the highest evaluated score. As such, Table 17 provides the results for a 40% cost and 60% non-cost allocation.

Table 17. Overall Scoring for Each Option at 40% Cost and 60% Non-Cost Weighting

Option	Results of Scoring at 40% Cost and 60% Non-Cost Weighting		
	Cost Score (%)	Non-Cost Score (%)	Total (%)
Option 1	12.95%	7.93%	20.88%
Option 2	7.67%	11.21%	18.87%
Option 3	8.86%	12.24%	21.10%
Option 4	5.99%	13.28%	19.27%
Option 5	4.53%	15.34%	19.88%
Total	*40%*	*60%*	*100%*

A graphical representation of the scoring presented in Table 17 is presented in Figure 13.

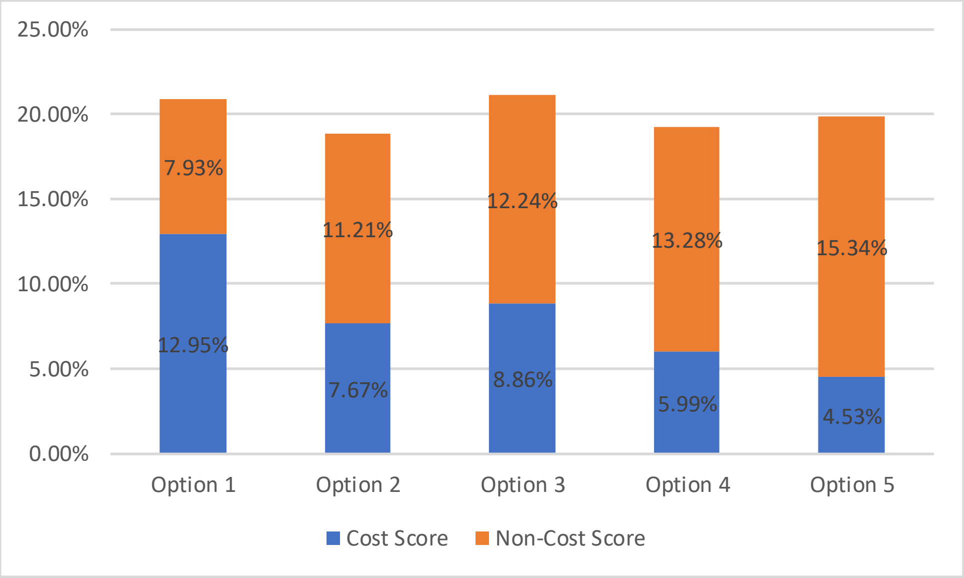

Figure 13. Overall Scoring for Each Option at 40% Cost and 60% Non-Cost Weighting

As shown in Table 17 and Figure 13, Option 3 received the most favorable scoring (21.10%) at a 40% cost and 60% non-cost factor weighting. Option 1 followed as a close second, with a score of 20.88%. This scoring represents additional consideration given to non-cost factors such as operability, flexibility, and constructability where Option 3 received relatively high scores. Note that this scoring adjustment (i.e. monetization of non-cost factors) reflects in MSD paying an equivalent ~$1.65M in extra capital cost to overcome negative non-cost impacts associated with Option 1.

30% COST AND 70% NON-COST WEIGHTING

The OA Team also performed an additional sensitivity analysis at a 30% cost and 70% non-cost allocation. Table 18 provides the results of this analysis.

Table 18. Overall Scoring for Each Option at 30% Cost and 70% Non-Cost Weighting

Option	Results of Scoring at 30% Cost and 70% Non-Cost Weighting		
	Cost Score (%)	Non-Cost Score (%)	Total (%)
Option 1	9.71%	9.25%	18.97%
Option 2	5.75%	13.07%	18.82%
Option 3	6.64%	14.28%	20.92%
Option 4	4.50%	15.49%	19.98%
Option 5	3.40%	17.90%	21.30%
Total	*30%*	*70%*	*100%*

A graphical representation of the scoring presented in Table 18 is presented in Figure 14.

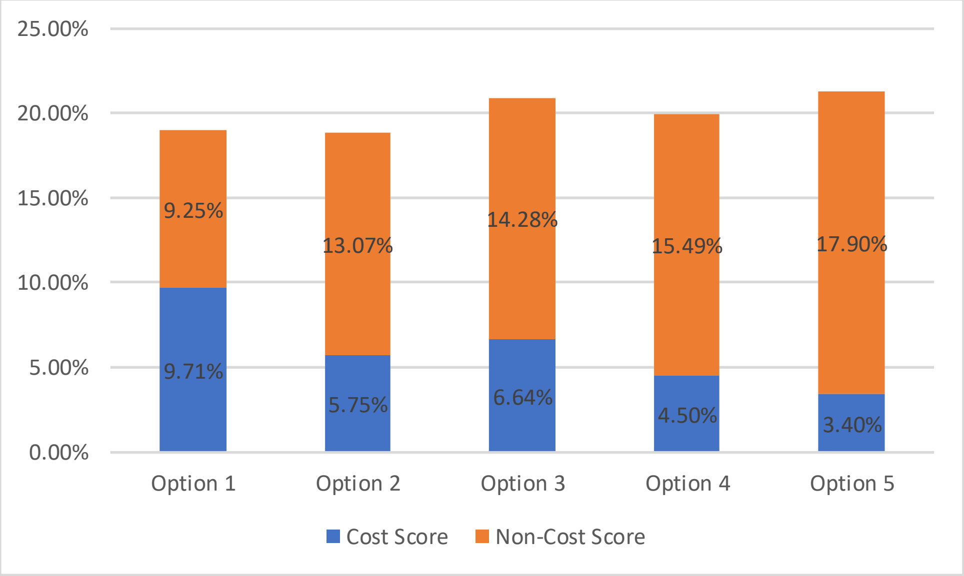

Figure 14. Overall Scoring for Each Option at 30% Cost and 70% Non-Cost Weighting

As shown in Table 17 and Figure 14, Option 5 received the most favorable scoring (21.30%) at a 30% cost and 70% non-cost factor weighting. Option 3 followed as a close second, with a score of 20.92%. This scoring represents additional consideration given to non-cost factors such as sustainability, flexibility, and adaptability where Option 5 received the highest non-cost scores. Note that this scoring adjustment (i.e. monetization of non-cost factors) reflects in MSD paying an equivalent ~$13.5M in extra capital cost for the non-cost benefits which Option 5 provides.

Recommendation

Based on the results of the evaluation presented herein, the OA Team recommends that Option 3 be selected for implementation.

In summary, this option provides cake receiving in excess of the required capacity during infrequent incineration outages at either the Bissell Point or Lemay WWTFs. Furthermore, this option balances capital cost requirements with important non-cost factors (such as operational redundancy and flexibility) in order to provide MSD the most cost effective means to reliably ensure cake receiving capacity at both facilities. In other words, this option provides redundancy similar to that offered by any of the two bay options considered in the analysis at a lower cost.

Lastly, note that Option 3 ranked in either first or second place for any of the three cost and non-cost analyses (and sensitivity analyses) outlined herein, and came in first place when considering an equivalent $1.65M in monetized non-cost impact compared to Option 1 (under the 40% cost and 60% non-cost sensitivity).

Note that MSD concurred with the Option 3 recommendation and asked that Option 3 be expanded to include space for a second cake receiving bin in the future if needed.

FINAL

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum No. 09: FBI Design Criteria

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

27 MAY 2021

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1.0 Purpose and Scope

The purpose of this memorandum is to establish the fluid bed incinerator (FBI) design criteria for both the Bissell Point and Lemay Wastewater Treatment Facilities (WWTFs), including:

- Number and size of FBI systems
- Solids loading and characteristic criteria
- Limits of the FBI system supplier's scope
- Required system components, including air pollution control equipment

This memorandum includes sections covering:

- A review of design solids quantities for current and future conditions
- A summary of solids physical characteristics and composition, including metals concentrations
- A review of industry system sizing approaches and FBI system supplier scopes for previous projects
- A summary of applicable pollution emission regulations, including the SSI MACT rules
- An evaluation and recommendation for the FBI system supplier's scope of supply
- A review of FBI system components and evaluation and recommendation for component alternatives
- Identification of suitable FBI system sizing alternatives for the Bissell Point and Lemay WWTFs, development of criteria for each alternative, and evaluation of economic and non-economic criteria in developing a recommended approach for each facility

2.0 Background

2.1 SOLIDS QUANTITIES

Solids quantities for the Bissell Point and Lemay WWTFs were developed as part of TM 4 Solids Quantities and Characteristics. Solids quantities were based on an evaluation of recent (2016 through 2019) solids data from the facilities and adjustments to account for:

- Reallocation of solids produced in the Grand Glaize, Fenton, and Lower Meramec WWTFs from the Bissell Point WWTF to the Lemay WWTF
- Implementation of chemical phosphorus (ChemP) nutrient removal in the future
- Additional solids that will captured and conveyed to WWTFs for treatment after future implementation of CSO improvements
- Process changes that will be implemented at the Lower Meramec WWTF

A summary of current design solids quantities for the Bissell Point WWTF is shown in Table 2-1.

Table 2-1 Bissell Point WWTF Current Design Solids Quantities

Description	PS, dtpd	WAS/TF*, dtpd	CSO Solids, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	90.8	22.2	0.8	113.8	50.8	-
Normal, MM	124.7	23.8	-	148.5	50.9	1.3
Normal, PW	191.5	23.6	-	215.1	37.5	1.9
Flood Stage, MM	189.0	36.0	2.5	227.5	35.4	2.0
Flood Stage, PW	248.1	30.7	3.0	281.8	30.5	2.5

*AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day; *represents all secondary solids produced at the facility.*

A summary of future design solids quantities for the Bissell Point WWTF is shown in Table 2-2.

Table 2-2 Bissell Point WWTF Future Design Solids Quantities

Description	PS[1], dtpd	WAS/TF*, dtpd	CSO Solids, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	111.8	22.2	0.8	134.8	42.9	-
Normal, MM	144.3	23.8	-	168.1	44.9	1.2
Normal, PW	223.2	23.6	-	246.8	32.6	1.8
Flood Stage, MM	211.6	36.0	2.5	250.1	32.2	1.9
Flood Stage, PW	266.6	30.7	3.0	300.3	28.7	2.2

[1] *Increased solids in the future are from chemical solids associated with ChemP nutrient removal.*

*AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day; *represents all secondary solids produced at the facility.*

A summary of current design solids quantities for the Lemay WWTF is shown in Table 2-3.

Table 2-3 Lemay WWTF Current Design Solids Quantities

Description	PS, dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Solids County Plants, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal Operation, AA	27.5	22.3	1.9	22.0	73.7	60.1	-
Normal Operation, MM	34.7	25.9	-	28.6	89.2	54.4	1.2
Normal Operation, PW	47.6	30.6	-	35.2	113.4	52.4	1.5
Flood Stage, MM	32.7	33.0	3.9	40.9	110.4	47.2	1.5
Flood Stage, PW	43.3	46.2	4.7	52.3	146.5	38.7	2.0

AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day.

A summary of future design solids quantities for the Lemay WWTF is shown in Table 2-4.

Table 2-4 Lemay WWTF Future Design Solids Quantities

Description	PS[1], dtpd	WAS/TF, dtpd	CSO Solids, dtpd	Solids County Plants, dtpd	Total Solids, dtpd	% Volatile Solids	Peaking Factor
Normal, AA	56.2	22.3	13.4	19.8	111.6	56.4	-
Normal, MM	71.3	25.9		25.7	122.9	49.9	1.1
Normal, PW	82.4	30.6	-	31.7	144.7	52.6	1.3
Flood Stage, MM	69.6	33	26.8	35.8	165.2	50.8	1.5
Flood Stage, PW	83.6	46.2	33.4	48.7	211.9	43.6	1.9

[1] *Increased solids in the future are from chemical solids associated with ChemP nutrient removal*

AA = Annual Average; MM = Max Month; PW = Peak Week; PS = Primary sludge; WAS = Waste activated sludge; TF = Trickling filter; dtpd = dry tons per day.

2.2 SOLIDS CHARACTERISTICS

2.2.1 Solids Physical Characteristics

Physical characteristics of the cake solids at the Bissell Point WWTF are shown in Table 2-5.

Table 2-5 Bissell Point WWTF Solids Physical Characteristics

Item	Cake %TS	PS Fraction, %	VS Fraction, %
Average	29.7	79.4	50.8
Range*	23.8 - 38.0	52.7 - 90.8	32.0 - 66.0
Average w/o Flood Stage	29.2	79.2	52.4
Range* w/o Flood Stage	23.5 - 37.4	51.8 - 90.7	34.0 - 66.7
Average Flood Stage	33.4	No Data	39.1
Range* Flood Stage	26.1 - 39.7	No Data	29.0 - 58.0

**5th to 95th Percentile; %TS = percent total solids, PS = Primary sludge; VS = Volatile solids.*

Physical characteristics of the cake solids at the Lemay WWTF are shown in Table 2-6.

Table 2-6 Lemay WWTF Solids Physical Characteristics

Item	Cake %TS	PS Fraction, %	VS Fraction, %
Average	28.9	53.7	60.1
Range*	23.9 - 36.2	18.3 - 76.7	42.0 - 75.0
Average w/o Flood Stage	28.6	54.9	61.6
Range* w/o Flood Stage	23.8 - 35.8	21.7 - 76.8	45.0 - 75.0
Average Flood Stage	30.8	45.2	51.1
Range* Flood Stage	25.3 - 37.8	7.6 - 75.2	37.0 - 72.0

**5th to 95th Percentile; %TS = percent total solids, PS = Primary sludge; VS = Volatile solids.*

2.2.2 Solids Composition

Dewatered cake metal concentrations for the years 2011, 2012, and 2013 at the Bissell Point WWTF are shown in Table 2-7.

Table 2-7 Bissell Point WWTF 2011 to 2013 Dewatered Cake Metal Concentrations (mg/kg)

	Range			Median		
	2011	2012	2013	2011	2012	2013
Arsenic	2.6 – 4.9	1.1 – 4.5	1.8 – 5.1	3.8	2.7	3.2
Beryllium	0.2 – 0.6	0.02 – 1.0	0.02 – 0.4	0.4	0.2	0.2
Cadmium	7.2 – 26.5	2.7 – 78.4	17.2 – 58.2	20.9	37.3	32.4
Chromium	70.7 – 120.2	40.0 – 160.0	63.7 – 176.7	94.6	107.4	92.5
Mercury	0.1 – 0.3	0.1 – 0.3	0.1 – 1.0	0.2	0.2	0.2
Nickel	42.0 – 124.3	24.5 – 113.9	34.1 – 94.9	56.6	84.7	48.5
Lead	57.1 – 105.4	39.5 – 112.8	37.3 – 101.1	65.8	62.5	64.6

Dewatered cake metal concentrations for the period of January 2016 through April 2019 at the Bissell Point WWTF are shown in Table 2-8.

Table 2-8 Bissell Point WWTF 2015 to 2018 Dewatered Cake Metal Concentrations (mg/kg)

	Range				Median			
	2016	2017	2018	2019*	2016	2017	2018	2019*
Arsenic	NA	0.35 – 6.75	3.5 – 7.8	NA	5.7	4.3	5.2	NA
Beryllium	0.03 - 5.3	5.2 - 5.5	5.2 - 5.5	5.1 - 5.3	2.5	5.3	5.3	5.2
Cadmium	6.6 - 26	0.21 - 50	1.6 - 34	4.7 - 19	16	14	19	13
Chromium	NA	4.8 - 122	20 - 125	NA	77	65	81	NA
Mercury	0.16 - 0.53	0.52 - 0.6	0.52 - 0.54	0.51 - 0.53	0.35	0.53	0.53	0.52
Nickel	NA	4.2 - 108	12 - 114	NA	57	48	69	NA

Lead	39 - 116	2.3 - 118	15 - 166	60 - 77	63	74	86	66

**Includes the months January through April; NA = Not available*

An ultimate analysis of the Bissell Point WWTF dewatered cake based on a February 26, 2014 report from Hazen Research Inc. is shown in Table 2-9. The WEF Manual of Practice (MOP) 30 Wastewater Incineration Systems recommends taking enough samples for ultimate analysis to understand seasonal variations.

Table 2-9 Bissell Point WWTF Ultimate Analysis

ELEMENT	%
Carbon	58.2
Hydrogen	7.9
Nitrogen	6.1
Sulfur	2.5
Oxygen	25.3
Total	100
Chlorine*	0.014

**Measured with the ultimate analysis sample, but not traditionally reported with ultimate analysis constituents*

Dewatered cake metal concentrations for the years 2011, 2012, and 2013 at the Lemay WWTF are shown in Table 2-10.

Table 2-10 Lemay WWTF 2011 to 2013 Dewatered Cake Metal Concentrations (mg/kg)

	RANGE			MEDIAN		
	2011	2012	2013	2011	2012	2013
Arsenic	1.0 – 3.0	0.9 – 3.6	0.4 – 3.7	2.7	1.5	1.9
Beryllium	0.2 – 0.4	0.012 – 1.0	0.029 – 0.9	0.4	0.2	0.1
Cadmium	0.01 – 2.8	0.61 – 31.5	0.7 – 5.7	0.9	2.0	1.4
Chromium	38.8 – 49.0	24.9 – 126.3	26.4 – 128.4	43.6	46.9	44.6
Mercury	0.18 – 0.4	0.22 – 0.6	0.16 – 1.2	0.3	0.3	0.3
Nickel	16.2 – 24.7	17.7 – 66.0	17.2 – 37.6	25.3	28.2	22.9
Lead	33.4 – 97.1	30.7 – 85.7	37.9 – 83.0	50.5	53.0	61.2

Dewatered cake metal concentrations for the period of January 2016 through April 2019 at the Lemay WWTF are shown in Table 2-11.

Table 2-11 Lemay WWTF 2015 to 2018 Dewatered Cake Metal Concentrations (mg/kg)

	Range				Median			
	2016	2017	2018	2019*	2016	2017	2018	2019*
Arsenic	3 - 6.7	0.35 - 6.5	3.1 - 9	4.2 - 10	4.0	3.7	4.9	7.6
Beryllium	0.03 - 5.4	5.2 - 5.4	5.2 - 5.4	5.2 - 5.5	2.6	5.3	5.3	5.3
Cadmium	0.03 - 2.8	0.24 - 18	1.6 - 14	1.5 - 2.3	2.0	3.2	3.1	2.0
Chromium	27 - 42	4.2 - 110	23 - 95	37 - 89	36	39	49	65
Mercury	0.14 - 0.66	0.52 - 1.1	0.52 - 0.71	0.52 - 0.55	0.41	0.64	0.55	0.53
Nickel	19 - 25	2 - 62	11 - 66	16 - 51	22	22	24	28
Lead	51 - 91	3 - 280	53 - 208	90 - 198	74	117	120	121

**Includes the months January through April*

An ultimate analysis of the Lemay WWTF dewatered cake based on a February 26, 2014 report from Hazen Research Inc. is shown in Table 2-11.

Table 2-12 Lemay WWTF Ultimate Analysis

ELEMENT	%
Carbon	54.1
Hydrogen	7.7
Nitrogen	4.2
Sulfur	1.1
Oxygen	32.9
Total	100
Chlorine*	0.015

** Measured with the ultimate analysis sample, but not traditionally reported with ultimate analysis constituents*

2.3 SIZING APPROACH - INDUSTRY REVIEW

The WEF Solids Process Design and Management (2012) reference book recommends that typically unit process sizing be based on an expected future maximum month sludge production. It also recommends that peak week production be considered as a check for adequate performance under extreme solids production.

It is common practice for smaller WWTFs with FBI systems to only have one incinerator unit, such as the WWTFs located in New Orleans, LA, Green Bay, WI, Independence, MO, and Mattabassett, CT. Disposal options used at these facilities when FBI units are out of service for planned maintenance or unplanned outages typically include untreated solids hauled to a landfill, lime stabilized material hauled to a landfill, or stabilized material land applied. However, for the five largest FBI facilities constructed in North America over the last 15 years, standby capacity has been provided to process solids during planned or unplanned outages. In general, these FBI facilities have been sized so that multiple units can process maximum month solids production with one additional standby unit (MM+1). A summary of sizing criteria for these WWTFs is shown in Table 2-13.

Table 2-13 Large FBI System Sizing Summary

CRITERIA	WASTEWATER TREATMENT FACILITY				
	METRO	GE BOOTH LAKEVIEW	DUFFIN CREEK	SOUTHERLY	MILL CREEK
Location	St. Paul, MN	Mississauga (Toronto) ON	Pickering (Toronto) ON	Cleveland, OH	Cincinnati, OH
Startup (Manufacturer)	2004-2005 (Hitachi Zosen)	2005-2010 (IDI Suez)	2014 (2 Units IDI Suez), 1982 (2 units Dorr Oliver)	2013 (IDI Suez)	2010 (IDI Suez)
Number of FBI Units	3	4	4	3	3
Capacity, each	120 dtpd	110 dtpd	110 dtpd	100 dtpd	100 dtpd
Sizing criteria	AA+1 or MM (w/o +1)	MM+1	MM+1	MM+1	MM+1
Current total avg. loading	240 dtpd	138 dtpd	160 dtpd	120 dtpd	120 dtpd
Outage/ emergency provisions	120 dtpd lime stabilization system, adding 4th FBI unit	Store solids in blend tank, primaries, and secondaries	Has not been required, but could store solids in clarifiers	Haul to landfill	Store sludge in holding tanks, temporary dewatering/ hauling

2.4 SSI MACT AND OTHER REGULATORY REQUIREMENTS

Emissions from new FBI systems are primarily regulated under 40 CFR 60, Subpart LLLL, for USEPA MACT 129 pollutants, while emissions of Beryllium are regulated under 40 CFR 503. Emission limits for new FBI systems are shown in Table 2-14.

Table 2-14 New FBI System Regulatory Emissions Limits

POLLUTANT	EMISSION LIMIT*
Oxides of nitrogen (NOx)	30 ppmvd
Carbon monoxide (CO)	27 ppmvd
Hydrochloric acid (HCl)	0.24 ppmvd
Sulfur dioxide (SO2)	5.3 ppmvd
Particulate matter (PM)	9.6 mg/dscm
PCDD/PCDF, TMB	0.013 ng/dscm
PCDD/PCDF, TEQ	0.0044 ng/dscm
Cadmium (Cd)	0.0011 mg/dscm

POLLUTANT	EMISSION LIMIT*
Lead (Pb)	0.00062 mg/dscm
Mercury (Hg)	0.001 mg/dscm
Beryllium (Be)	10 grams/24 hours
Fugitive emissions	5%

**MACT 129 concentrations are corrected to 7% O2*

2.5 EXISTING INCINERATOR POLLUTION EMISSION TEST RESULTS

2.5.1 Bissell Point and Lemay WWTF Existing Emission Test Results

Emissions test results for the existing multiple hearth incinerators at the Bissell Point and Lemay WWTFs from 2015 and 2016 compared with the MACT 129 emission limits for existing multiple hearth incinerators (Subpart MMMM) and new FBI systems (Subpart LLLL) are shown in Table 2-15.

Table 2-15 Bissell Point and Lemay WWTF Existing Multiple Hearth Incinerator Emission Test Results

POLLUTANT	BP NO. 2	BP NO. 3	BP NO. 4	LM NO. 2	LM NO. 3	EXIST MHI MACT REGS	NEW FBI MACT REGS
Date	Mar 2016	Nov 2015	Nov 2015	Mar 2016	Nov 2015		
NOx, ppmvd	191.4	142	148.2	159.1	158.6	220	30
CO, ppmvd	2,557	2,626	607.7	2,443	2,332	3800	27
HCl, ppmvd	0.15	0.12	0.17	<0.14	0.15	1.2	0.24
SO_2 ppmvd	10.2	1.3	1.0	3.2	1.8	26	5.3
PM ppmvd	10.77	6.06	7.85	24.53	15.42	80	9.6
PCDD/PCDF, TMB, ng/dscm	2.37	0.216 TEF**	0.032 TEF**	0.84	1.38	5 or 0.32 TEF**	0.013
PCDD/PCDF, TEQ, ng/dscm	NA	NA	NA	NA	NA	NA	0.0044
Cd, mg/dscm	0.072	0.024	0.017	0.0043	0.0052	0.095	0.0011
Pb, mg/dscm	0.098	0.032	0.004	0.065	0.037	0.3	0.00062
Hg, mg/dscm	0.078	0.09	0.037	0.069	0.096	0.28	0.001
Be, 10 g/24 hrs***	<0.12	<0.022	<0.048	<0.082	<0.09	10	10
Fugitive emission	0%	0%	0%	0%	0%	5%	5%

**MACT 129 concentrations are corrected to 7% O2; **Reported as toxic equivalency factor (TEF); ***40 CFR 61 limits; BP No. 2 = Bissell Point MHI No. 2; LM No. 2 = Lemay MHI No. 2, etc.*

As shown in Table 2-15, the existing MHIs at Bissell Point and Lemay WWTFs are all within the MACT 129 and 40 CFR 503 emission limits for “existing MHI” classification and only within these emission limits for “new FBI” classification for HCl and Beryllium.

2.5.2 FBI Facility Pollution Control Systems and Emission Test Results

Table 2-16 shows the type of pollution control equipment installed and recent emission test results, indicated as a percentage of the SSI MACT limits for a new FBI classification, at the same large FBI facilities as presented in Table 2-13. Because these facilities were constructed before implementation of the SSI MACT regulations, the “new” facility emission limits do not apply to these facilities. If these facilities had needed to meet such regulations, different design criteria or technologies would have been used. However, the information is provided only as background regarding a preliminary consideration of the effectiveness of different technologies relative to the new standards.

Table 2-16 FBI Facility Pollution Control Systems and Emission Test Results

CRITERIA	WASTEWATER TREATMENT FACILITY					
	METRO	LAKEVIEW	DUFFIN CREEK		SOUTHERLY	MILL CREEK
Control for PM, Pb, Cd	FF, MVS, WESP	MVS	MVS		MVS	MVS
Control for HCl, SO2	MVS, caustic	MVS	MVS		MVS, caustic, SPC	MVS, SPC
Control for NOx	Bed temp, MVS	Bed temp, MVS	Bed temp, MVS		Bed temp, MVS	Bed temp, MVS
Control for Hg	PAC	GAC	GAC (will be replaced with SPC)		SPC	SPC
Test as % of MACT* For New FBIs			**w/GAC**	**w/o GAC**		
PM, %	18		41	5	10	7
HCl, %	35	370	185	140	39	13
SO2, %	56				107	21
CO, %	23				13	7
NOx, %	36				66	75
Hg (Method 29), %	18		18	910	3,320	930
Pb, %	43				83	138
Cd, %	7				17	6
PCDD/PCDF, TEQ, %	0.2	50	23	23	13	3

MVS = Multiple venturi scrubber, FF = Fabric filter, WESP = Wet electrostatic precipitator,
PAC = Powdered activated carbon injection, GAC = Granular activated carbon,

*SPC = Sorbent polymer composite, *For comparison only. These facilities are subject to MACT "existing FBI" classification limits.*

3.0 FBI System Scope

3.1 INDUSTRY REVIEW

Overall FBI systems consist of combustion systems, reactors, blowers, heat exchangers, pollution control equipment, exhaust gas fans and ductwork, stacks, instrumentation and control systems, and electrical components. In the North American biosolids incinerator market the standard approach has been for a single supplier to design and supply the bulk of these components, to ensure that 1) the equipment and controls support the basic combustion process, 2) interconnected components are fully coordinated and compatible with each other, and 3) there is a single source of responsibility for overall system performance.

TM-08 *Fluidized Bed Incinerators – Equipment Procurement Alternatives* reviewed the scopes of nine of the most recent incinerator projects in North America and all were procured with a single system supplier providing the major components of the incinerator system, as noted below:

- Furnish components, including
    - Reactor vessels
    - Fluidizing air blowers
    - Fuel combustion systems
    - Heat transfer equipment, including primary heat exchangers, and secondary heat exchangers where selected
    - Induced draft fans where required
    - Exhaust gas ductwork
    - Pollutions control systems, all including multiple venturi scrubbers; and where selected mercury removal systems, chemical feed systems, WESPs, fabric filters, and NOx control systems
    - Instrumentation and control systems, including process instruments, PLCs, programming, and HMIs
    - Auxiliary systems, including purge blowers and water booster systems for reactor sprays and scrubbers
- Design, including
    - Design of all systems furnished
    - Structural and heat loads
    - Power and utility requirements
    - Process and instrumentation diagrams (P&IDs)
- Services, including
    - Installation of reactors, and reactor and duct refractory
    - Installation supervision
    - Testing and commissioning
    - O&M manuals and training

Compared to the typical items included in a system supplier's scope identified above, some of the projects had an expanded scope that included additional components to satisfy a unique configuration or client preference. Components include:

- Furnish systems, including
  - Wet ash slurry tank and pumps
  - Compressed air system
  - Fuel oil system
  - Waste heat steam boiler
  - Steam turbines or steam driven fluidizing air blowers
  - Steam system including condensate, deaerator, and water treatment
  - Thermal oil heat recovery system, including cake feed indirect dryer
  - Chemical storage tanks
  - Sand storage and conveyance
  - Exhaust stacks
  - Platforms
  - Continuous emissions monitoring system (CEMS)
  - Motor control centers (MCCs)
- Design, including
  - Platforms
  - Piping
  - Control block descriptions
  - Electrical, including one-lines, conduit, wiring, wiring schematics, and MCC, local control panel (LCP), and redundant power unit (RPU) drawings

3.2 RECOMMENDED SCOPE

It is advantageous to include components in the supplier's scope that have complicated interfaces between the component and rest of the incinerator system. The more extensive the interface, the more design and operational coordination that will be required between the component and overall system supplier; this also presents a greater risk of misunderstanding of design requirements or last-minute modification issues. There are also advantages to including in the supplier's scope components that have direct impact on incinerator operation with interactive operational and safety control functions, such as natural gas or fuel oil supply and burner systems. It is important that the control of these items be part of the FBI control system to reduce/prevent miscommunication that may result in safety/code compliance and/or operation & maintenance issues.

On the other hand, for components that have simple, well-defined interfaces with the overall FBI system, it can be advantageous to not include these in the system supplier's scope; as this promotes increased competition by allowing multiple vendors and reduces the number of firms adding markups to a component. There can also be a benefit to having the general construction contractor supply items where there is a desire to standardize on the type and manufacturer of similar equipment at the facility, such as MCCs.

Based on the criteria identified above, it is recommended that all the components identified as typically provided by the system supplier based on the industry scope review in Section 3.1 be included in the FBI scope of supply. It is also recommended that the following components (if selected to be included in the District's FBI design configuration) be included in the systems supplier's scope:

- Furnish systems, including
  - Wet ash slurry tank and pumps
  - Fuel oil system
  - Waste heat steam boiler
  - Thermal oil heat recovery system, including cake feed indirect dryer
  - Chemical storage tanks
  - Platforms
  - CEMS
- Design, including
  - Coordination of platform locations
  - Control block descriptions
  - Electrical, including one-lines, conduit, wiring, and wiring schematics

4.0 FBI System Selection

FBI systems come in many configurations and components based on 1) unique project objectives, such as whether better reliability and lower costs for energy recovery are more important, 2) differing site specific conditions, such as pollutant concentrations in the sludge, and 3) owner and supplier preferences. This section evaluates alternatives for major FBI system considerations.

4.1 FBI SYSTEM OVERVIEW

Figure 4-1 shows typical components that may comprise an overall FBI system.

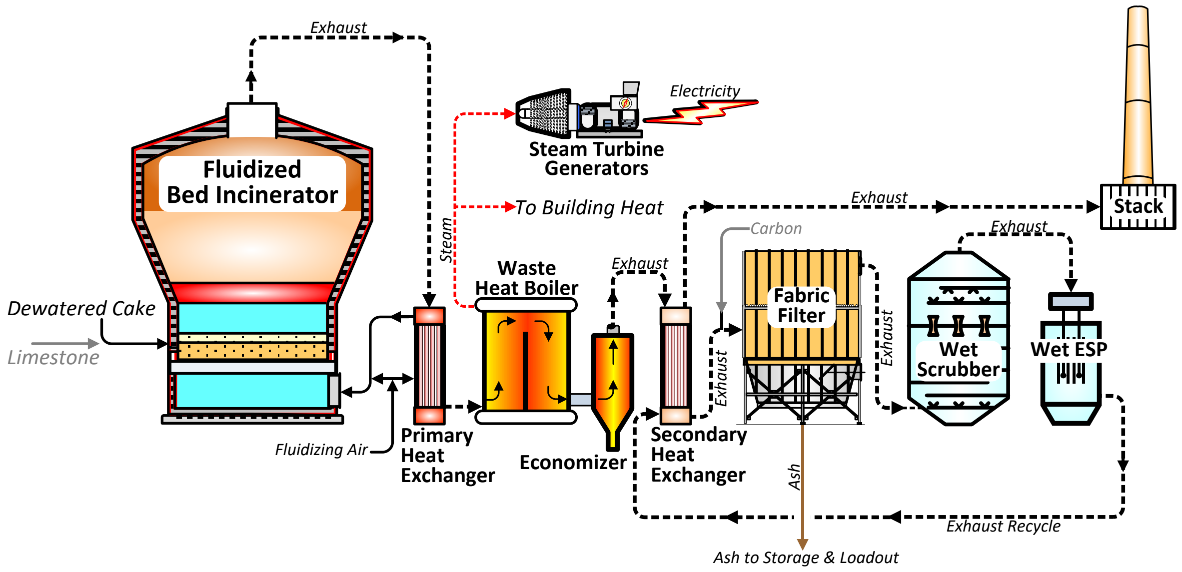

Figure 4-1 FBI System Process Flow Schematic

Major FBI system process components consist of:

- Fluid bed reactor: The fluid bed reactor is the combustion component of the FBI system. Air enters a sand bed from a lower wind box, fluidizing the bed in which sludge is fed under high temperatures, thermally oxidizing the volatile part of the sludge. Exhaust gases from the process rise to an overbed space where additional time at elevated temperatures (around 1500^{o}F) completes the combustion process of any unburned material. Air is supplied to the wind box by a fluidizing air blower. With a hot wind box design, the fluidizing air is heated in a primary heat exchanger. The reactor vessel is refractory lined because of the high combustion temperature. The fluid bed creates good conditions for thermal oxidation of wastewater sludge providing solids dispersion and good contact with heat and oxygen.
- Primary heat exchanger: A shell and tube type primary heat exchanger is used to preheat fluidizing air to reduce or eliminate auxiliary fuel use. Uncleaned exhaust gas from the reactor at a temperature of approximately 1500^{o}F passes through the tube side to preheat the fluidizing air to approximately 1200^{o}F that passes through the shell side. The shell of the heat exchanger is refractory lined. The primary heat exchangers operate in severe service conditions, with extreme temperatures and dirty exhaust gas containing ash and acid gases. Due to the challenging conditions some units have experienced failure of the tube/tube sheet connections in as little as

five years, although typical service life is longer (generally 10 to 15 years). Some recent installations have eliminated these units by using a thermal dryer to reduce the moisture content of the incinerator sludge feed. Use of a primary heat exchanger or thermal dryer is evaluated in Section 4.2.1.

- Thermal dryers: An emerging trend is to provide thermal dryers upstream of the incinerators to reduce moisture content, providing a higher volatile solids concentration of the wet feed, which can allow for autogenous combustion without the need for a primary heat exchanger. While most installations have been overseas, Suez incorporated this approach for their Green Bay facility. While thermal dryers can eliminate the need to use primary heat exchangers to achieve autogenous combustion, these systems add complexity to the overall processing system, with the addition of a major system including a sludge dryer, heat recovery heat exchanger, thermal oil or steam system (with associated instrumentation/control), and electric components. Use of a thermal dryer or primary heat exchanger is evaluated in Section 4.2.1.
- Secondary heat exchanger: A secondary heat exchanger is used to heat exhaust gas to condition the gas upstream of a granular activated carbon (GAC) unit or to provide plume suppression at the stack. Uncleaned exhaust gas at a temperature of approximately 1000°F passes through the tube side to heat cleaned exhaust gas that passes through the shell side. The shell of the heat exchanger is refractory lined. Similar to primary heat exchangers, secondary heat exchangers are subject to severe service conditions and can experience similar long-term wear and tear maintenance issues. However, since these units operate at lower temperatures, service life is typically longer than for primary heat exchangers.
- Fabric filter: For FBI systems that have dry ash systems, fabric filters are provided to remove ash, particulate, metals, and other pollutants, and can be used with powdered activated carbon (PAC) injection to remove mercury. Ash from a fabric filter is dry. The exhaust gas temperature must be reduced upstream of the fabric filter, which can be done with a waste heat boiler or other conditioning equipment. Fabric filters are in a housing with ash hopper, collector, and outlet plenum sections. Fabric filters are very effective at removing particulate and other contaminants. However, these systems require a large footprint and vertical space, along with being subject to corrosion from acid gas condensation and air infiltration. Use of a fabric filter is evaluated in Section 4.2.3.
- Wet scrubber: Multiple fixed venturi wet scrubbers are provided to remove pollutants from the exhaust gas, including particulate matter (PM), metals (lead, cadmium, and beryllium), and acid gases (SO_2 and HCl). Ash from a scrubber forms a slurry with the scrubber water. These units are provided with 1) a quench section to reduce the temperature and create saturated conditions, 2) a cooling section consisting of trays or a packed tower to condense out moisture, and 3) multiple fixed venturis to remove fine particulate, acid gases, and other pollutants. Other wet scrubbing technologies are available but have limited experience in FBI systems processing biosolids. Envirocare is the predominant wet scrubber supplier for biosolids FBI systems and has options for installing WESP or sorbent polymer composite (SPC) mercury removal sections on the top of the scrubber, eliminating the need for separate vessels if this optional equipment is needed. Caustic feed systems have been provided at some facilities to enhance removal of acid gases (HCl and SO_2) and meet regulatory limits for drain water pH from scrubbers. Use of a caustic feed system is evaluated in Section 4.2.6.
- Wet electrostatic precipitator (WESP): For most recent FBI systems, WESPs have been provided downstream of wet scrubbers to remove additional particulate and metals (lead and cadmium) to assure compliance with stringent SSI MACT regulations. High voltage electrodes impart a charge on pollutants for removal in collection tubes. WESP units require an upstream demister to

remove water particles. Under some conditions it may be possible to meet new FBI classification MACT metal pollutant emission limits with only a wet scrubber or fabric filter; however, if required to guarantee compliance with the standard, suppliers in the past have typically also provided WESPs. Use of a WESP is evaluated in Section 4.2.2.

- Mercury removal systems: Three types of mercury removal systems have been used for FBI systems. Mercury removal systems are evaluated in more detail in Section 4.2.5.
  - Granular activated carbon (GAC), used for wet ash systems. A GAC system consists of fixed bed granular activated layers, with upstream gas conditioning (demisting and dew point control) and startup heater skid. The system may also include high efficiency filters. In addition to mercury removal, a GAC system is designed to remove dioxins and furans.
  - Powdered activated carbon (PAC) injection, used for dry ash systems. This system consists of PAC injection upstream of a filter. In addition to mercury removal, this system is also designed to remove dioxins and furans.
  - Sorbent polymer composite (SPC). This system consists of vessels containing SPC media. This system also removes SO_2.
- Selective non-catalytic reduction (SNCR) NOx control systems: Temperature and excess air control should be used to minimize NOx formation, but even with the best operating controls additional control technology is sometimes required to meet new FBI classification MACT NOx emission limits. SNCR systems use injection of urea or aqua ammonia directly into the freeboard area of the reactor to reduce NOx (NO and NO_2) into nitrogen gas and water vapor. SNCR systems include injection lances, distribution panels, chemical feed systems, and chemical storage tanks. Urea-NOx removal efficiencies are lower than for ammonia, but chemical handling and safety are less critical. Published reports indicate that urea may increase nitrous oxide (N_2O) emissions. Ammonia slip should be monitored to avoid equipment corrosion, ash disposal issues, and ammonia emissions. Use of a SNCR system is evaluated in Section 4.2.4.
- Waste heat recovery systems: Waste heat recovery systems can provide substantial amounts of energy for use at treatment facilities, reducing costs and non-renewable energy usage. For systems with electricity generation, often enough power can be produced to operate the FBI system with excess power available for other uses. However, waste heat recovery can add significant capital costs and operating and maintenance effort in addition to reducing overall system reliability. Waste heat boilers in FBI service are subject to erosion and tube leaks due to abrasive ash in the exhaust gas stream. These issues can be partially addressed by sizing the unit to limit exhaust gas velocity and by providing abrasion resistant materials in high wear areas. Heat recovery systems for use of heat external to the FBI process will be covered in a subsequent technical memorandum.
- Exhaust stack: Exhaust stacks are furnished for FBI systems to ensure adequate dispersion of combustion gases and pollutants. Continued use of existing stacks versus installation of new stacks is evaluated in Section 4.2.7.

4.2 FBI COMPONENT ALTERNATIVES

4.2.1 Process Heat Recovery

Both a primary heat exchanger and an upstream sludge feed dryer system can be used to recover heat from the incinerator exhaust gas and reduce or eliminate the amount of supplemental fuel needed for combusting the dewatered solids. For the purpose of comparison, two alternatives developed for FBI sizing and summarized in following sections, were used to perform concept level estimates of operating conditions and costs of primary heat exchanger or sludge feed dryer configurations. The alternatives used were Alternative BPA2 (3 units for MM+1) for Bissell Point WWTF and Alternative LA2 (2 units for MM+1) for Lemay WWTF, which are described in detail in Sections 5 and 6, respectively. Operating conditions were evaluated for future annual average, since the facilities will operate under these conditions for most of their service life.

4.2.1.1 Primary Heat Exchanger

A primary heat exchanger system consists of:

- Refractory lined shell and tube heat exchanger, in which heat is recovered from the incinerator exhaust gas at 1500°F passing through the tube side, and transferred to the fluidizing air, passing through the shell side, heating the fluidizing air to around 1200°F
- Bypass damper and ductwork, to allow some of the fluidizing air to bypass the heat exchanger and reduce the temperature of the fluidizing air sent to the reactor
- Hot wind box on the bottom of the reactor, refractory lined to withstand high design temperatures (~1200°F)

Preheating the fluidizing air can provide substantial heat for the combustion process. A primary heat exchanger is estimated to provide 26 percent of the overall heat required for combustion at the Bissell Point WWTF and 27 percent at the Lemay WWTF. Additional information on heat recovery is shown in Table 4-1 in the evaluation section.

Primary heat exchangers have been used for decades with biosolids FBI systems. Of the nine recent FBI facilities in North America, eight of them used a primary heat exchanger as part of their design. Operation of a primary heat exchanger is simple, with the bypass damper in clean fluidizing air service being the only moving part. As identified in previous sections, the operating conditions of the heat exchanger itself are severe and premature component failure can be an issue. Material selection can partially address these issues.

4.2.1.2 Upstream Sludge Feed Dryer

An upstream sludge feed dryer system consists of the following components:

- Sludge dryer, which could be a disc, paddle, or fluid bed type
- Partially dried cake conveyance equipment, typically piston pump
- Heat recovery boiler (steam), which can consist of superheaters, evaporators, economizers, and steam drum, or shell and tube heat exchanger (thermal oil), which can consist of a refractory lined vessel. Both systems are typically designed to recover heat from the 1500°F exhaust gas and transfer it to a heating medium operating from 400°F (thermal oil) to 600°F (steam).
- For a thermal oil system, components would include an expansion tank, pump, oil cooler, and potentially an emergency drain system with receiving tank
- For a steam system, components would include condensers, condensate pumps, feed water treatment package, condensate storage tank, condensate transfer pumps, deaerators, heat exchangers, boiler feed pumps, booster pumps and cooling water pumps.
- For both thermal oil and steam systems, components would include associated process piping, instrumentation, control, and electric equipment

Pre-drying the incinerator feed can significantly reduce the amount of heat required to combust biosolids. However, this can be limited by how dry the feed material can be before it can no longer be reliably pumped. Typical practice is to avoid the plastic phase of biosolids, which can occur between 40 and 60 percent solids, when the material becomes sticky, viscosity increases, and the energy needed to handle the biosolids cake increases substantially. For cake that has low volatile material and high solids, the ability to substantially reduce the heat requirement can be limited if the solids content is not allowed to go above 40 percent. For example, if the feed cake is dried to 40 percent for the Lemay example case, auxiliary fuel use would be around twice that associated with a configuration using a primary heat exchanger. Additional information on the impact of drying on energy use is shown in Table 4-1.

Upstream feed sludge dryers have been used since the 1990's in Europe (Hamburg 1998), but only recently in North America (Green Bay 2018). At Hamburg a disc dryer using steam dries post-digestion (64 %VS) sludge feed to 42 percent solids before conveyance to fluid bed boilers. Operation is reported to be relatively trouble free. At Green Bay a disc dryer using thermal oil dries post-digestion (65 %VS) to 38 percent solids upstream of an FBI. The thermal oil system serves multiple heat uses at the facility in addition to the dryer though there were reported startup issues related to the complexity of the system.

Thermal oil systems can have the risk of the thermal fluid, a combustible liquid, leaking into the exhaust gas ductwork, which operates at temperatures up to 1550°F. Steam systems also have associated safety risks, which can require a certified boiler operator to be on site, depending on local regulations.

4.2.1.3 Primary Heat Exchanger/Feed Dryer Evaluation

Table 4-1 shows a comparison of estimated energy requirements for primary heat exchanger (hot wind box) and pre-drying (cold wind box) configurations.

Table 4-1 Primary Heat Exchanger and Dryer Energy Requirement Summary

DESCRIPTION	%TS	TOTAL HEAT NEEDED, MMBTUH*	PHE HEAT RECOVERY, MMBTUH	AUXILIARY FUEL, MMBTUH	NG USE, SCFH	ANNUAL NG COST, $
Bissell Hot Wind Box	29.7	44.3	11.5	8.3	12,356	487,074
Bissell Cold Wind Box	**40**	35.6	NA	11.2	16,708	658,629
Bissell Cold Wind Box	**45**	32.8	NA	8.4	12,569	495,470
Bissell Cold Wind Box	**50**	30.6	NA	6.2	9,258	364,950
Lemay Hot Wind Box	28.9	41.0	11.2	3.2	4,797	189,098
Lemay Cold Wind Box	**40**	33.1	NA	6.5	9,634	379,772
Lemay Cold Wind Box	**47**	30.0	NA	3.4	5,031	198,322
Lemay Cold Wind Box	**50**	28.9	NA	2.3	3,453	136,117

** MMBTUH = Million British Thermal Units per hour; PHE = Primary Heat Exchanger; NG = Natural Gas; SCFH = Standard Cubic Feet Per Hour of gas flow.*

Table 4-2 shows a planning level opinion of probable construction costs for one FBI treatment train for the primary heat exchanger and upstream sludge feed dryer alternatives.

Table 4-2 Primary Heat Exchanger and Dryer Planning Level Costs

PRIMARY HEAT EXCHANGER		SLUDGE FEED DRYER	
Item	Cost	Item	Cost
General Requirement	$150,000	General Requirement	$460,000
Primary Heat Exchanger	$650,000	Thermal Dryer	$1,000,000
Ductwork	$300,000	Heat Recovery Heat Exchanger	$500,000
Hot Windbox Refractory	$40,000	Thermal Fluid Pump & Cooler	$100,000
Installation	$200,000	Dryer Condenser and Compressor	$130,000
I&C (7%)	$70,000	Ductwork	$500,000
Subtotal	$1,410,000	Piston Pump	$500,000
Construction Contingency (35%)	$490,000	Thermal Fluid Tanks	$50,000
Engineering & Legal (20%)	$380,000	Process Piping	$260,000
Total	**$2,280,000**	Equipment Installation	$350,000
		I&C (7%)	$190,000
		Electrical (8%)	$220,000
		Subtotal	$4,260,000
		Construction Contingency (35%)	$1,490,000
		Engineering & Legal (20%)	$1,150,000
		Total	**$6,900,000**

The sludge feed dryer alternative is approximately $4.5 million more in capital cost than the primary heat exchanger alternative. With the potential for seven FBI trains, this is a potential difference of over $30 million in capital cost for the overall project. Table 4-3 lists the advantages and disadvantages of each alternative.

Table 4-3 Primary Heat Exchanger and Dryer Alternative Summary

	PRIMARY HEAT EXCHANGER	UPSTREAM SLUDGE FEED DRYER
Advantages	• Substantially less capital cost • Simpler system • More experience • Less auxiliary fuel at proven feed solids percentages (<43%TS)	• Potential for autogenous operation (but at unproven %TS)
Disadvantages	• Limited to no potential for autogenous operation	• More expensive • Complex system, more maintenance, and challenges with pumping higher TS% • Increased safety issues

Because the primary heat exchanger is simpler to operate, requires less auxiliary fuel at proven sludge feed % TS, and requires significantly less capital investment than the upstream sludge feed dryer, a primary heat exchanger is recommended.

4.2.1.4 Secondary Heat Exchanger

Many FBI facilities built within the last 20 years have been provided with secondary heat exchangers to provide suppression of condensation plumes from the discharge stack. Without any heating of the exhaust gas under most temperature conditions, moisture from the exhaust gas, which is at or near saturated conditions, will condense a short distance from the stack exit and create a visible white plume. Secondary heat exchangers have typically been designed to heat exhaust gases to 250°F, around 150°F above a typical gas dew point temperature of 100°F, which has proved effective in eliminating condensate plumes for most weather conditions.

With secondary heat exchanger operation, uncleaned exhaust gas at a temperature of approximately 1000°F would pass through the tube side to heat cleaned exhaust gas that passes through the shell side. The shell of the heat exchanger would be refractory lined. Secondary heat exchangers are subject to severe service conditions of temperature and ash abrasion and can experience long-term wear and tear maintenance issues. Service life can be around 10 to 15 years, but in some cases have been shorter where corrosion or thermal cycling are issues. Maintenance typically includes periodically repairing tubes at the inlet, tube/tubesheet welds, refractory, and in some cases addressing shell corrosion.

A conceptual level opinion of probable construction cost for one secondary heat exchanger, associated ductwork and dampers is approximately $900,000. The costs for seven secondary heat exchangers at both facilities would be $6.3 million.

There will be some plume suppression even if a secondary heat exchanger is not provided, but a condensation plume would be expected under cold winter conditions. A granular activated carbon (GAC) system, as will be installed for this project, requires a conditioning heat exchanger upstream of the GAC bed, to raise the sensible temperature at least 35°F above the dew point temperature, typically around 100°F at the wet scrubber exit. The ID fan downstream of the GAC system will add heat from compression and raise the sensible another 25ºF to 35ºF. At the stack the exhaust gas will be 60ºF to 70ºF above the dewpoint. Under most weather conditions, this elevated temperature (160ºF to 170ºF) should provide suppression of a condensate plume. However, during the winter under cold conditions, a white condensate plume will be visible. It is difficult to predict under exactly which temperature, humidity and wind conditions a plume will be visible.

With the FBI system and required air pollution control there will not be a yellowish color or haze from the stack. Table 1 summarizes the advantages and disadvantages of providing or not providing a secondary heat exchanger.

Table 4-4 Secondary Heat Exchanger Option Comparison

ALTERNATIVE	ADVANTAGES	DISADVANTAGES
Secondary heat exchanger	• Provides consistent plume suppression	• Has significant capital costs • Requires operational and maintenance effort • Periodic replacement cost
No secondary heat exchanger	• No initial capital cost • No associated operational and maintenance effort • No periodic replacement cost	• In cold weather will have a visible plume, which depending on the surroundings can be a public relations issue

Project approach alternatives include:

- Specify that space is reserved for secondary heat exchanger equipment and ductwork in the facility layout for future installation
- Include secondary heat exchanger equipment and ductwork as a bid alternative in the Design Builder Proposal
- Include secondary heat exchanger equipment and ductwork in the project as a regular scope item

The secondary heat exchanger would provide benefits for a limited period of time, would not reduce pollution emissions and would have significant costs. For these reasons, the project team decided to reserve space for a secondary heat exchanger equipment and ductwork for possible future installation but to not require as part of the regular project scope or as a bid alternative.

4.2.2 WESP

WESPs remove particulate matter (PM), including fine particulates, and metals, including cadmium, lead, and beryllium, from exhaust gases. Within the unit, high voltage (around 50 kV) ionizing electrodes impart a charge on pollutant particulates which are collected on parallel grounded plates. The collector plates are intermittently washed with water and the collected particulates/particles are drained from the bottom of the vessel. WESPs are particularly effective in removing fine particles and have typically been included downstream of multiple venturi scrubbers to “polish” exhaust emissions. Exhaust gases must be cooled and saturated prior to entering the vessel. An upstream demister is required to remove water particles, which can suppress operating voltage. Heavy particulate loading may cause particulate accumulation and limit exhaust gas flow through the unit. Figure 4-2 shows a typical WESP system.

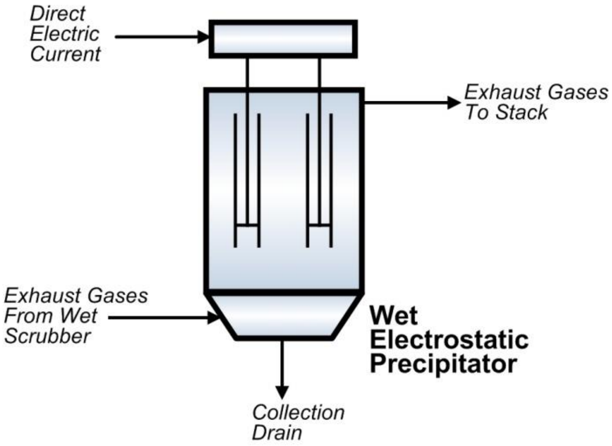

Figure 4-2 **WESP Schematic**

The three most recent FBI systems procured in the United States, which are subject to new FBI classification MACT limits (Subpart LLLL), all included WESPs in their scope of supply. One of those facilities, the Atherton WWTF (Little Blue Valley Sewer District) in Independence, Missouri, had installed a new FBI system with a multiple fixed venturi scrubber, but not a WESP, during the period when the SSI MACT regulations were still being finalized. On startup, emission testing performed in September 2014 identified that the system was not compliant for mercury or NOx emissions. Lead emissions were at 80 percent of the new limit. Because metal emissions are impacted by metal concentrations in the feed sludge, the need for a WESP to control lead emissions was evaluated to determine if the technology should be included in the planned advanced emission control project to ensure overall compliance with the new standards. Important criteria for the evaluation included:

- Historical cake lead levels typically which ranged from 15 to 50 mg/kg, with spikes to 130 mg/kg. Observed levels after September 2014 ranged from 15 to 35 mg/kg.
- Removal efficiency based on the emission testing was 98.98%, at a relatively high pressure drop across the venturi section of the scrubber of 35 inches water column.
- Based on the removal efficiency of 98.98%, at some of the recent higher cake lead concentration levels (15 to 35 mg/kg), it was calculated that the emissions would not be compliant with the new limits. With a .02% reduction in removal efficiency, at 98.96%, it was calculated that for all the recent lead cake concentration levels the emissions would not be compliant.

Based on the evaluation it was recommended that a WESP be provided to ensure compliance for lead emissions at the facility.

Important criteria for consideration of the need for WESP technology at the Bissell Point and Lemay WWTFs include:

- Emission test results for lead with multiple fixed venturi scrubbers for initial testing at Bissell Point WWTF ranged from 0.004 to 0.098 mg/dscm and at Lemay WWTF from 0.037 to 0.065 mg/dscm. All these readings are substantially above the SSI MACT limit of 0.00062 mg/dscm for a new FBI classification.
- At the Bissell Point WWTF the median cake lead concentrations ranged from 63 to 86 mg/kg for 2016 to 2018 and at the Lemay WWTF concentrations ranged from 74 to 120 mg/kg for the same time period. These levels are above the levels at the Atherton WWTF.

Based on recent project experience at other plants and high cake lead concentration levels and lack of compliance with the new emission limits at the MSD facilities, a WESP would be recommended if a multiple venturi scrubber were the only other particulate removal device. As reviewed subsequently in this memorandum, a granular activated carbon (GAC) system with filters is recommended for mercury removal. The filters upstream of the GAC vessel are primarily provided to prevent fouling in the carbon media bed, which is done to assure mercury removal performance, extend bed service life, and protect from fires. During review of technical information related to the GAC system supplied by APC, the vendor indicated that they would guarantee meeting the regulatory limits for particulate, cadmium, and lead with the high efficiency particulate arrestance (HEPA) filter supplied with GAC system. Since the WESP and HEPA filters would perform the same function to remove these pollutants and the HEPA filters would be supplied to protect the GAC system regardless of whether a WESP was provided, elimination of the WESPs was evaluated.

Issues that were evaluated:

- Would the HEPA filters provide adequate performance to assure compliance with the emission levels? – Wet scrubbers often can achieve compliance by themselves based on loading conditions. Envirocare, one of the suppliers of a multiple fixed venturi type wet scrubber, has stated their units will remove 98% of 0.5 micron and larger particulate. By definition a HEPA filter is designed to remove 99.97% of 0.3 micron and larger particulate, which results in over 50 times less particulate emissions at this size than a wet scrubber. APC also provided data showing compliance with emission limits using only their fine particulate removal filters, with less removal efficiency (95% of 0.3 micron and larger) than a HEPA filter.
- Would an Incinerator System Supplier be willing to guarantee the overall pollution emission performance based on this approach? We reviewed with Suez, a supplier who has provided pollution control equipment designed to meet the SSI MACT standards for "new" FBIs, if they could guarantee emissions without a WESP based on a HEPA filter. They indicated they would provided that: 1) The GAC system supplier would guarantee performance for the sub-system, 2) there was test data for compliance without WESP operation, and 3) The performance of the upstream wet scrubber was specified, so that there were delineation for which vendor was responsible for what level of particulate removal, with clear definition of what was going to the GAC HEPA filter. With respect to these items:
  - 1) APC confirmed they would guarantee compliance.
  - 2) APC shared test data with a less efficient filter showing compliance.
  - 3) A requirement has been added to the fluid bed incinerator spec identifying that the wet scrubber must meet SSI MACT MMMM requirements (removal efficiency for an "existing FBI"), which the wet scrubber vendor has indicated is achievable and APC has indicated is suitable for their equipment.

A conceptual opinion of probable construction cost (OPCC) for each WESP is $830,000. For all seven units at both facilities the conceptual OPCC is over $5,600,000.

The principle reasons for not requiring the WESPS is to eliminate unnecessary systems that would need to be operated and maintained and make the overall FBI system more complex. Since the HEPA filters will provide the same function as the WESP for particulate and metal removal, performance for removal of these pollutants will be guaranteed, and elimination of the WESPs achieves significant cost savings, WESPs are not recommended for this project.

4.2.3 Fabric Filter

Similar to WESPs and multiple venturi scrubbers, fabric filters remove PM, including fine particulates, and metals from exhaust gases. This technology can also be used in conjunction with upstream powdered activated carbon injection to provide mercury removal, which is covered in more detail in Section 4.2.5. Fabric filters would be used when it is desired to have a dry ash collection system. Fabric filters of the size needed for FBI service would consist of multiple modules, each including fabric bags, cages, tube sheets, pulse-jet cleaning system, hoppers, inlet/outlet ductwork, hopper heaters and vibrators. Ash from the hopper bottoms would typically discharge to a pneumatic transporter for conveyance to storage. A fabric filter would not replace a multiple venturi scrubber, since the scrubber is still needed to condense out moisture and remove acid gases.

Compared with other particulate and metal removal equipment, fabric filters require a large volume of building space for installation. For the Metro WWTF (St. Paul, MN), a fabric filter sized to process 40,000 acfm (actual cubic feet per minute) at 350ºF has dimensions of 11 feet wide by 37 feet long by 50 feet high. Fabric filters require regular maintenance for the bags, as torn bags will compromise performance and fabric surfaces can foul. Corrosion is also an issue for fabric filters, particularly for the lower parts of the hopper section where (due to limited gas flow and a high surface area to volume ratio) temperatures can drop below the acid gas dewpoint of the exhaust gas. This can be mitigated with stainless steel construction, but that also has an increased cost. Because of their configuration with a large cover perimeter seal length, it is difficult to prevent infiltration of air into the units, causing localized cooling which will accelerate corrosion and increase the amount of exhaust gas that must be treated and conveyed through downstream equipment.

The Metro WWTF fabric filter of carbon steel construction had a conceptual opinion of probable uninstalled equipment cost of $1,800,000. Because of the disadvantages associated with a fabric filter and the fact that a multiple venturi scrubber with similar pollution control efficiency will be installed whether a fabric filter is provided, a fabric filter is only recommended if a dry ash system is desired or powdered activated carbon mercury removal system is selected.

If a dry ash system is desired, a cyclone separator may offer advantages compared with a fabric filter; including smaller space requirements, no need for gas conditioning, and less maintenance as there are no fabric filter bags. The project team decided to not include a dry ash system as part of the present project, but to leave space for a dry ash system in case in the future there are stronger drivers for beneficial reuse of ash.

4.2.4 NOx Control

Nitrogen oxides (NOx) are formed during incineration through two processes, fuel NOx, and to a lesser amount, thermal NOx. Fuel NOx is created when the nitrogen portion of the cake solids or auxiliary fuel is oxidized during combustion. Only a small portion of the nitrogen in the solids is oxidized. Higher temperatures and oxygen concentrations create more fuel NOx. Thermal NOx is formed when nitrogen and oxygen in combustion air combine at high temperatures. The amount of thermal NOx created increases significantly at temperatures above 2000ºF. NOx control is more difficult with cake solids that have a high volatile content (above 75% VS) and high solids concentrations, which will create high bed temperatures. Plant process and incinerator operational controls are used to limit bed temperatures and limit oxygen content, including:

- Solids concentrations: Reduce cake solids concentrations when volatile content is high, by reducing polymer dosage, or torque (when centrifuges are used).

- Volatile solids content: Mix high volatile material (such as primary scum and FOG) completely with sludge cake to create uniform volatile solids feed and avoid periods with high volatile feed or only feeding high volatile materials to one area of the bed.
- Primary heat exchanger bypass: Reduce bed temperatures during high volatile solids conditions by bypassing some of the fluidizing air around the primary heat exchanger; resulting in a lower combustion air temperature to the wind box.
- Additional cool air supply: If the maximum amount of air possible is being bypassed around the primary heat exchanger and bed temperatures are still too high, provide additional cooling air through the preheat burner air fan or overfire/overbed air fed directly to the reactor without any preheating.
- Oxygen concentration: Limit excess air to between 3 and 8% in the reactor. This is achieved by maintaining a minimum amount of volatile solids feed to the incinerator, since there is limited ability to turn down the fluidizing air flow.

SNCR systems for NOx control have been provided at biosolids FBI facilities when plant process and operational controls do not adequately control NOx or for new facilities where there is no operating history as assurance that the new stringent limits can be met. SNCR systems use urea or aqua ammonia to reduce NOx (NO and NO_2) into nitrogen gas and water vapor. The optimum chemical reaction temperatures for ammonia and urea range from 1550 to 1900°F. Lances are used to inject these chemicals directly into the freeboard area of the reactor. SNCR systems include injection lances, distribution panels, chemical feed systems, and chemical storage tanks.

New FBI facilities at Green Bay, WI, Cromwell, CT, and Independence, MO, are required to meet the MACT NOx limits for new FBI classification (30 ppmvd) and their experience is summarized as follows:

- Green Bay, WI: Digested solids with design solids criteria of 65% VS and 38% TS (pre-dried). A SNCR system was provided to inject urea or ammonia into the freeboard area. There was concern that the higher solids content would create higher bed temperatures. After startup it was found that process controls are adequate to limit NOx and ammonia is no longer used. NOx during emission testing was 12 ppmvd. Operational control procedures used include: 1) keep bed temperatures between 1250°F and 1400°F, 2) keep reactor O_2 levels between 3% and 8%, 3) minimize fuel oil use, 4) maintain steady state, and 5) adjust feed rate as needed. CEMS monitoring of NOx was eliminated.
- Cromwell, CT: Cake with design solids criteria of 85% VS and 25% TS. A SNCR system was provided to inject ammonia into the freeboard area. Similar to Green Bay, operational controls have proved sufficient to control NOx and ammonia is no longer used. Operational control procedures which have been made part of the air permit requirements (all on a 12-hour block average) consist of: 1) keeping bed temperature < 1445°F, 2) maintaining O_2 in reactor exhaust < 8.5%, and 3) maintaining 0.9 dt/hr minimum sludge feed. NOx during emission testing was 15.4 ppmvd. Also similar to Green Bay, the CEMS monitoring of NOx was eliminated.
- Independence, MO: Cake with design solids criteria of 65 to 85% VS and 22 to 30% TS. After rain events the facility can experience a “hot sludge” with high VS, up to 87%, along with TS above 26%, during which time NOx readings have gone as high as 280 ppmvd. The facility implemented operational procedures to control bed temperature, which were able to control NOx emissions to the new limits during periods of normal VS content but could not meet the limits during periods of high VS. Operational controls included increasing bypass flow around the primary heat exchanger and use of cooling air from the preheat burner fan and overfire air. Because of

centrifuge control issues, the facility is not able to easily lower the %TS of the cake produced. Pilot testing of an SNCR system was performed which established that this technology could achieve the regulatory limit of 30 ppmvd if the baseline concentration did not exceed 140 ppmvd. An SNCR system was installed in 2019 based on that control efficiency and has been effective in meeting the regulatory limit. The facility elected to use a CEMS to verify compliance as they did not want operations to be constrained by an upper bed/freeboard temperature limit.

A review of recent NOx emission results of the Metro, Southerly, and Mill Creek WWTFs (Table 2-16) shows that each of these facilities, while held only to existing FBI classifications limits, still complied with the new NOx limits; and none are operating a SNCR system.

In general, it appears that at most facilities under typical operating conditions, a SNCR system is not needed to comply with the new NOx limits. An important exception to this is the Atherton WWTF (Independence, MO) which periodically has a "hot sludge" and continuous CEMS monitoring of NOx.

The volatile content at the Bissell Point and Lemay WWTFs is relatively low, averaging 50.8% and 60.1%, respectively. The upper 95 percentile of VS at the Bissell Point and Lemay WWTFs is 66.0% and 75%, respectively. Under most conditions the low volatile content of the solids at these facilities would indicate that operational controls should be sufficient for compliance. The facilities currently meeting new SSI MACT regulations through operational controls have limits on maximum O2 content (8% and 8.5%). The oxygen limit prevents extreme solids feed turndown in order to maintain oxygen in the reactor below prescribed limits, since with fewer solids to combust there will be more unburned oxygen. However, 8% oxygen content represents a 60% turndown for feed solids, which is below the manufacturer recommended limit of 70% turndown. So if a maximum oxygen content is included as a permit requirement, it shouldn't have a significant impact on operations.

Based on costs for the Atherton WWTF's SNCR system, and adjusting for the size, scope, and schedule of this project, a conceptual level opinion of cost for an SNCR system is $6.4 million. Two alternatives were reviewed with respect to SNCR system approach: 1) Include the SNCR system in the project scope, or 2) Leave space in the facility for an SNCR system, but only install if testing determines it is needed.

4.2.4.1 SNCR in Scope

Under this alternative, SNCR systems would be included in the FBI system scope for each of the processing trains and installed with the improvements. The FBI system supplier would be required to guarantee NOx emissions.

Advantages:

- Simplest contract approach, which keeps sole responsibility for passing all the pollution emission limits with the FBI system supplier.

Disadvantages:

- Based on other facility experience, there is a good chance that District will pay a significant cost (more than $5 million) for something that will be decommissioned after its first use.

4.2.4.2 SNCR as an Alternative Bid Item

Under this alternative, an alternative bid item for the SNCR system, with a fixed price and schedule, would be included in the Design Build proposal for future installation of a system if testing demonstrates that one is needed. Design provisions would be provided that facilitate relatively fast incorporation of an SNCR system into the facility, including:

- Leave space and foundations in the facility for the SNCR system and associated tank.
- Install ports for SNCR lances in the FBI reactor shell.
- Provide suitable electrical and I&C infrastructure.

As part of this approach it should be reviewed with MDNR the technical basis for why a SNCR system is unlikely to be needed and establish agreement that if in the scenario that compliance testing did not demonstrate compliance, that the District would have a year to install and test an SNCR system.

Advantages:

- Provides substantial cost savings and avoids the likely scenario of installing a system only to have it decommissioned.

Disadvantages:

- If a test were to fail and regulatory issues become a significant problem, then MSD staff will be in the position of explaining why the supplier wasn't required to guarantee performance for this pollutant.

To reduce time for installation, a requirement could be included to provide shop drawings during the construction phase, which would reduce the time the time for installation if needed. A total of 25 weeks is estimated for installation A total of 15 weeks is estimated for shop drawings.

NOx emission compliance must be demonstrated with a NOx CEMS or by compliance testing, with subsequent operating limits (maximum bed temperatures) to ensure operating conditions are representative of test conditions that demonstrated compliance. Most facilities have elected to not install or have removed NOx CEMS systems. This avoids the difficulty of maintaining NOx limits during all periods, such as startup, shutdown, and high volatile sludge periods, when NOx control is difficult. It would be less risky to demonstrate compliance under controlled compliance test conditions. If an SNCR system is not to be installed, not installing a NOx CEMS, and demonstrating compliance through emissions testing is recommended.

4.2.4.3 SNCR Recommendation

If agreement with MDNR can be obtained, it is recommended to pursue installation of a SNCR as an alternative bid item, as this has the potential to save significant costs at a reasonable risk based on other facility experience.

4.2.5 Mercury Control

Unlike most metals which typically drop out of the process with the ash, and which are removed in wet scrubbers or other particulate removal technology, mercury can exist in the following three forms following incineration:

- Particulate Mercury: Mercury entrained with the ash and bound to particulate matter. This fraction of the total mercury is removed in wet scrubbers. A very small portion of the total mercury is in this form.

- Elemental Mercury: Elemental mercury in the solids volatilized by combustion. As the gaseous elemental mercury is cooled through the remaining processes, it may react with other components of the flue gas to form oxidized gaseous mercury. In most wastewater treatment plants, only a fraction of the elemental mercury is oxidized. The unoxidized elemental mercury is not removed in wet scrubbers and will be emitted with the exhaust if not removed by enhanced treatment.
- Oxidized Gaseous Mercury: Elemental mercury which is oxidized by exhaust gas components such as halogens (chlorine, fluorine, and bromine); oxides of sulfur such as sulfur dioxide (SO_2) and sulfur trioxide (SO_3); and nitrogen such as nitrogen dioxide (NO_2). This form of mercury is soluble in water and can be partially removed in wet scrubbers.

Although some of the oxidized mercury can be captured by wet scrubbers, this form of mercury removal is inefficient and since it only affects a fraction of the overall mercury in the exhaust gas. As such, this method is generally not sufficient to meet regulatory requirements. Analysis of data at multiple facilities shows that scrubber mercury removal is typically 10 to 25% of the mercury in the exhaust gas.

The SSI MACT mercury emission limit is 0.001 mg/dscm for new FBI units. At the Lemay WWTF, based on ten test results from 2015 to 2018 after installation of multiple venturi scrubbers, mercury emissions ranged from 0.0312 to 0.096 mg/dscm, with an average value of 0.073 mg/dscm. At the Bissell Point WWTF, based on seven test results from 2015 to 2017 after installation of multiple venturi scrubbers, mercury emissions ranged from 0.028 to 0.09 mg/dscm, with an average value of 0.052 mg/dscm. All the test results are above the new limit and the upper levels require removal efficiencies downstream of the wet scrubber of around 99 percent.

Proven technologies used for mercury removal include:

- Fixed bed granular activated carbon (GAC) adsorber systems: Used at plants with wet ash systems (Bissell Point and Lemay WWTFs currently use wet ash systems). For fixed bed carbon media filters, mercury is adsorbed directly from the exhaust gas stream onto the carbon. GAC is arranged in a fixed bed and requires periodic replacement. The temperature of the gas must be above the dew point to prevent condensation on the bed which impacts removal efficiency and can cause heating. This system is located at the end of the emissions control train after a secondary heat exchanger. Spent GAC is typically disposed of in a hazardous waste landfill. Two major suppliers are considered for this application; Carbon Process & Plant Engineering (CPPE) and Air Pollution Control Technology (APC).
- Sorbent polymer composite (SPC) media vessels: The fixed sorbent polishing media technology is relatively new to the market and has recently been installed in several SSI facilities needing to meet regulatory requirements for "existing" units. This technology uses a proprietary media bed composed of sorbent polymer composites which can capture both ionized and elemental mercury. The SPC modules are tolerant of water saturated gas and do not require a demister or a reheat step. The SPC removal efficiency is a function of media bed depth. Initially systems were sized for a maximum of 70% removal, but recent systems have been designed for up to 95% removal. SPC media technology is currently being marketed by Envirocare International. The supplier was contacted regarding the ability of SPC to meet the project emission requirements. They indicated that they have not been able to consistently meet 99% removal efficiency, which they identified would be needed to meet the limits for *new* units (given the mercury loadings). They also indicated that the technology is not suitable for efficiencies greater than 95%, and that they are not currently in a position to recommend the technology for new FBI classification limits. The technology has significant advantages compared with GAC, including less equipment

and fire risks, and it is recommended to maintain contact with the vendor during design in case technology development causes a change in their position.

- Powdered activated carbon (PAC) injection systems: Used in plants with dry ash systems, this system includes continuous injection of PAC and requires a fabric filter for ash and spent PAC collection. A carbon layer forms on the surface of the filter bags adsorbing the mercury from the exhaust gases. The resulting ash, carbon, and mercury are collected in the fabric filter as dry components for disposal. Conditioning of the gas upstream of the fabric filter is needed. Several suppliers are available including Babcock-Wilcox and IAC. Because of the disadvantages associated with a fabric filter, this system would only be used if a dry ash system was selected.

For the reasons identified above, PAC and SPC systems have not been further evaluated for this project. A fixed bed GAC adsorber system is the only system considered further and includes the following major components:

- Demister (CPPE) or Coalescer/Demister (APC): Prevents large water droplet carry over to downstream equipment.
- Heat Exchanger: Re-heats exhaust gases to above dew point to prevent condensation and media blockage in adsorber vessel.
- HEPA Filters: Removes particulates upstream of GAC adsorber. HEPA filters are required for APC only.
- Adsorber: Holds GAC media used to adsorb mercury from exhaust gases. GAC media is typically “impregnated” with sulphur which enhances chemisorption capabilities of the carbon. The media is installed in multiple layers, with each layer having a removal efficiency based on its depth. Overall removal efficiency is achieved by providing enough layers with the required depths. Most of the mercury is adsorbed in the first layer. When adsorption capacity is mainly used up in the first layer, it will need to be replaced without the need to initially replace downstream layers.
- Startup Heater: Used to heat the GAC media before introduction of exhaust gas to prevent condensation on cold media.

Figure 4-3 illustrates the major components of a GAC system and their location with respect to the wet scrubber and WESP.

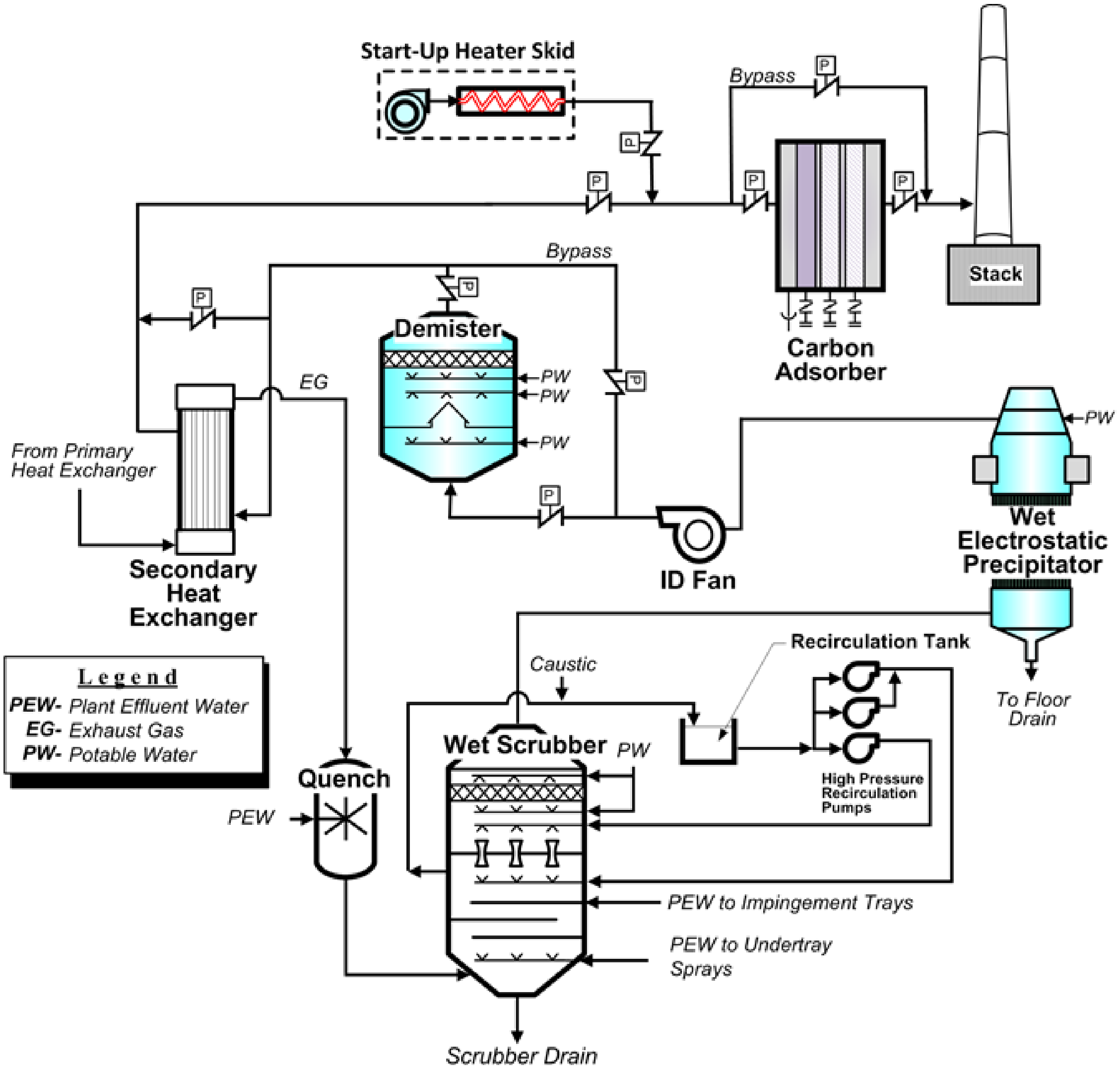

Figure 4-3 GAC Mercury Removal System Schematic

In addition to mercury, the GAC scrubber will also adsorb dioxins and furans. Typically, high temperature operation by the incinerator process followed by rapid quench of the exhaust gases is sufficient to destroy dioxins and furans. Incinerator systems with long exhaust trains with slow cooling unit processes (e.g., waste heat boilers, etc.) may experience dioxin and furan re-formation. To measure the performance of the GAC bed over time, periodic media/carbon grab samples will be required. Samples will be analyzed based on sulfur availability to determine remaining life of the media bed on an annual or bi-annual basis.

CPPE and APC are the only two manufacturers identified with experience supplying GAC systems in North America for removal of mercury from biosolids incinerator exhaust. CPPE has more experience with eight facilities in operation, with the longest operating experience being 14 years, while APC has six facilities in operation, with the longest operating experience being 3 years.

Granular activated carbon is a combustible material generally susceptible to fires; which have occurred in the units at several biosolids incinerator facilities. Damage causing the GAC units to be out of service for over a month has occurred at the Cromwell, CT (Mattabassett District WPCF, August 2016), Jamestown, NC (High Point Eastside WWTP, August 2016), and Green Bay, WI (Green Bay WWTP, November 2019) facilities (all CPPE installations). After the first reports of fires Black & Veatch did a survey of existing GAC facilities in the Spring of 2017. All but two of the CPPE facilities reported issues with temperature excursions, and the two facilities that did not were recently commissioned with limited operating experience. Several of the facilities had not had recent issues with temperature excursions. Causes of temperature excursions include:

- Moisture adsorption on carbon surface: Moisture adsorption on the surface is an exothermic process, particularly an issue on startup with the initial exposure to moisture and during offline conditions (if exposed to moisture without convective cooling). Mitigation is to lower temperature during startup and isolate then unit while offline.
- Hydrocarbon deposits on the bed: This can allow combustion of the hydrocarbons, which can be mitigated by ensuring proper fuel and solids combustion, including sufficient oxygen at all times.
- Buildup of ammonium sulfate or particulate on the bed: This can cause plugging, poor distribution of exhaust gas, and localized areas of poor convective cooling. Mitigation includes good particulate and acid gas control.
- Failure of interlocks and improper response to high temperature: If dampers don’t provide isolation or fans are operated at the wrong time, this can provide oxygen and moisture to promote fires. Mitigation includes robust commissioning and training.

Since the 2016 incidents, CPPE has provided temperature and carbon monoxide monitoring to detect unsafe conditions, along with a deluge system to automatically provide protection. The Green Bay incident, which is under investigation, occurred after implementation of these safety upgrades.

APC has not had reported temperature excursions in their facilities to date, which is primarily attributed to the following items that are inherent to the APC technology:

- HEPA high efficiency particulate filtration protects from hydrocarbons, particulate fouling, gas maldistribution, and poor localized convective cooling.
- Superior carbon media with a higher quality resistance to fires and a higher self-ignition temperature.
- Horizontal carbon beds that don’t promote accumulation of fines at the bottom of vertical beds.
- Proprietary systems to prevent buildup in the bed and exothermic mitigation systems for startup and standby modes.

Because of the repeated fires in the CPPE system and the inherently safer APC technology, Black & Veatch recommended sole-sourcing APC for the GAC system and MSD concurred.

4.2.6 Acid Gas Control

Sulfur dioxide (SO_2) and hydrochloric acid (HCl) are acid gases in the exhaust that are produced from sulfur and chlorides contained in the cake feed and are regulated under SSI MACT. Because both SO_2 and HCl are water soluble, wet scrubbers are a good removal technology and often are efficient enough to meet the MACT regulations. For solids with a high sulfur content or facilities with low scrubber water pH, the removal achieved by wet scrubbers without caustic addition may not be enough to meet emission limits. Liquid caustic (sodium hydroxide) addition, dry lime addition, or use of SPC modules have been used to further reduce acid gases, with liquid caustic the predominant approach to achieve compliance. Liquid sodium hydroxide (NaOH) is typically added in the wet scrubber where water can be re-circulated. Sodium sulfate (Na_2SO_4) and sodium chloride are created as reaction by-products which are removed with the scrubber drainage.

As identified in the mercury control section, SPC is an emerging technology for mercury removal, and also removes SO_2 as part of the treatment process. Although, the manufacturer is not recommending use of this technology for compliance with MACT 129 regulations for new FBI classification, its use for SO_2 removal was reviewed with them as to whether it could be a practical alternative compared with use of liquid caustic. The manufacturer indicated that they typically do not find the modules cost effective when used solely for the purpose of SO_2 removal. Preliminary sizing indicated that for each FBI train 63 SPC modules would be required in a stand-alone vessel with an approximate equipment cost of $850,000 for each unit.

The Metro WWTF initially used dry lime ($CaOH_2$) addition to remove acid gases. Lime addition is performed by injecting the dry chemical directly into the reactor overbed or exhaust duct work to react with the acid gases. Calcium sulfate ($CaSO_4$) and calcium chloride (CaCl) are created as reaction by-products and can be collected by a fabric filter or electrostatic precipitator. Exhaust gas inlet temperature may be limited by fabric filter bag requirements, which would require upstream conditioning of the gas. Dry chemical injection would also require blowers for injection and high temperature injection lances. It should be noted that the Metro WWTF has replaced dry lime injection with caustic addition at their wet scrubber. Because of the disadvantages identified with a fabric filter, use of caustic feed to a wet scrubber is recommended if additional acid gas control is needed.

Newer scrubber systems use a recirculation arrangement where the multiple venturi drain pH is controlled to a range of 6 to 8. The re-circulated treated venturi drain water is injected back to the system by the scrubber venturi pumps. A blow down from the recirculation tank is provided to remove the neutralized acids during continuous operation. Figure 4-4 illustrates a typical scrubber recirculation system with caustic injection. Chemical bulk storage and handling will require a separate room and equipment with compatible construction materials.

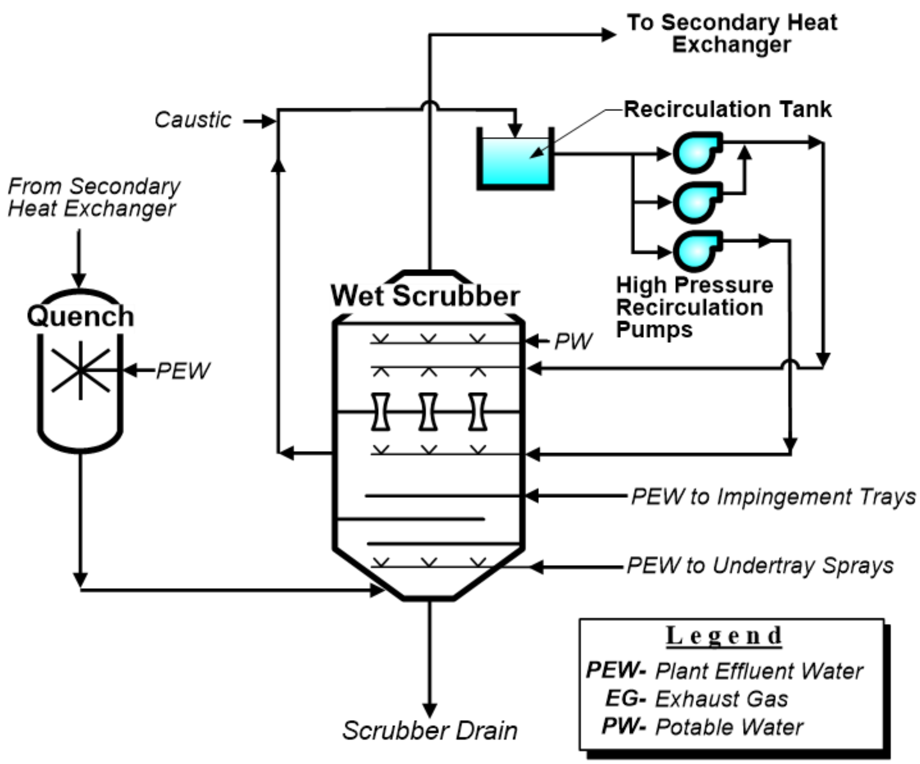

Figure 4-4 **Caustic (Sodium Hydroxide) Feed System Schematic**

The three most recent FBI facilities subject to new FBI classification MACT regulations (Independence, MO, Cromwell, CT, and Green Bay, WI) were provided with caustic systems and use them to control the scrubber drain pH. Information from a survey of FBI facilities related to acid gas emissions is shown in Table 4-5 (including percent sulfur of cake volatiles where available) with select SO_2 emission test results (for comparison with the limit of 5.3 ppmvd).

Table 4-5 **Acid Gas Emission Facility Survey**

FACILITY	SULFUR	CAUSTIC	SO_2 TEST, PPMVD	COMMENTS
Independence, MO	1.7%	Yes	3.5 / 1.2	• pH control range: 6 to 7 • Some scaling issues at higher pH • Test at lowest dosage that achieves compliance • Scrubber water pH: 6.8 - 7.6, Avg 7.2; Hardness (CaCO3): 64 – 201 mg/l, Avg 138 mg/l
Green Bay, WI	--	Yes	0.1	• pH control range: 5.5 to 6.5
Cromwell, CT	--	Yes	0.15	• pH control range: 6 to 7
St. Paul, MN	1.2%	Yes	3.0	• pH control range: 5.5 to 6.5 • Scaling issues • Test at lowest dosage that achieves compliance
Cleveland, OH	1.4%	Yes	8.1 / 5.9 / 8.6	• pH control range: 6 to 7 • Tote system feeds upper tray section

FACILITY	SULFUR	CAUSTIC	SO_2 TEST, PPMVD	COMMENTS
				• Avoid running due to scaling, tune scrubber operation before testing
Cincinnati, OH	2.5%	Removed	0.6 / 1.1 / 1.7	• Initially failed emission limit due to low water flow, installed caustic system • Improved water supply and achieve compliance without using caustic

All the facilities required to meet new FBI classification limits feed caustic. St. Paul, MN also feeds caustic and meets new FBI classification limits. Cleveland usually does not feed caustic and is above the new FBI classification limits. Cincinnati is an outlier, in that they do not feed caustic, but their emissions are under the new FBI classification limits, with an apparently high sulfur content.

For comparison, similar information is provided for the Bissell Point and Lemay WWTF's in Table 4-6, showing multiple test results.

Table 4-6 Bissell Point and Lemay WWTFs Acid Gas Emission Data

FACILITY	SULFUR	CAUSTIC	SO_2 TEST, PPMVD	COMMENTS
Bissell Point	2.5%	No	10.2 / 1.3 / 1.0 / 21.6 / 0.9 / 0.7 / 7.2 / 4.0	• Effluent pH: 6.3 – 8.9, typical 6.9 – 7.7 • Effluent alkalinity: 157 - 177 • Effluent total hardness: 276 – 364
Lemay	1.1%	No	3.2 / 1.8 / 1.9 / 19.1 / 3.6 / 2.7 / 3.2 / 1.9 / 1.8 / 1.7	• Effluent pH: 6.4 – 7.8, typical 6.6 – 7.3 • Effluent alkalinity: 122 - 153 • Effluent total hardness: 232 – 268

Testing results from the Bissell Point WWTF indicate that three of the SO_2 concentrations would have been above the new emission limits, while only one of the test results from the Lemay WWTF exceeded the new limit. Although the new venturi scrubbers are demonstrating compliance most of the time without caustic addition, the new limits have been exceeded at both plants. Because general industry experience has been that caustic is used to meet the new FBI classification SO_2 limits (in addition to the multiple venturi scrubbers installed at the Bissell Point and Lemay WWTFs not being able to reliably meet those limits under varying conditions), it is recommended that a caustic system be included in the scope of supply for the new FBI project.

4.2.7 Exhaust Stack

At both the Bissell Point and Lemay WWTFs the potential to continue using the existing exhaust stacks rather than provide new stacks for the FBIs was evaluated. The practicality of this is dependent on the specific location of the new facilities in relation to the existing stacks. From an engineering standpoint it is best to have the stacks close to the incinerator equipment to minimize condensation, corrosion, and pressure drop issues. The cost of new exhaust stacks will be less than the cost of ductwork, supports, foundation, and excavation work to convey exhaust gas from the new FBI facilities to the existing stacks, unless the new facilities are located close to the existing stacks.

For the Bissell Point WWTF the new FBI system will be located over 800 feet from the existing stack. It would be more expensive to route the exhaust from the new FBI facilities to the existing stack and would have the operational and maintenance disadvantages identified above compared with new stacks. For this reason, reusing the existing stack at the Bissell Point WWTF is not recommended.

For the Lemay WWTF the new FBI system will be relatively close to the existing stack. To date preliminary design has been based on providing new stacks for each FBI train to ensure suitable velocity at the stack exit for dispersion. During 25% design, potential reuse of the existing stack will be evaluated for considerations of the existing stack condition and the ability of the existing stack to provide suitable dispersion.

5.0 Bissell Point FBI Sizing

The following three FBI sizing alternatives (Alt) for the Bissell Point WWTF were evaluated based on solids production of 250 dtpd for future maximum month (MM), 135 dtpd for future annual average (AA), and 114 dtpd for current AA:

- Alt 1 (BPA1) – 2 units sized for future MM, with one additional unit (3 units at 125 dtpd, 250 dtpd firm capacity, 375 dtpd installed capacity). This alternative was selected to reflect typical sizing criteria of multiple units to meet MM conditions and one standby unit, with the fewest units possible (three).
- Alt 2 (BPA2) – 3 units sized for future MM, with one additional unit (4 units at 83 dtpd, 250 dtpd firm capacity, 334 dtpd installed capacity). This alternative was selected to reflect typical sizing criteria of multiple units to meet MM conditions and one standby unit, with more, smaller units than under Alt 1 BPA1.
- Alt 3 (BPA3) – 2 units sized for future MM (2 units at 125 dtpd, 125 dtpd firm capacity, 250 dtpd installed capacity). This alternative was selected to evaluate an alternative sized to meet MM conditions without a standby unit.

All the alternatives are based on FBI trains consisting of the components recommended in Sections 3 and 4.

Units were sized to provide sufficient combustion and fluidizing air, adequate volume for heat release and adequate retention time in the freeboard area to provide substantially complete combustion. The standard sizing basis for the quantity of combustion air is to provide enough oxygen to fully react with the volatile combustible components (carbon, hydrogen, and sulfur) with 40 percent excess air to ensure enough contact for complete combustion.

Fluidizing air is determined based on providing adequate air to fluidize the sand bed without entraining an excessive amount of sand in the exhaust gas (typically a velocity of 3 feet per second). Because of the need to maintain the bed velocity within acceptable limits, the fluidizing air can only be adjusted plus or minus 10 percent from the design basis. Under large turndown solids loading conditions, FBI systems lose substantial energy efficiency, since fluidizing air cannot be turned down proportionally with the solids feed rate, and there are less volatiles from the sludge to heat the air to combustion temperatures. Ideally, solids loading turndown should generally be held to 70 percent of design capacity or greater with operation between 80 and 90 percent described as the "sweet spot" of efficient and effective operation.

FBI units have a maximum capacity of 10 percent more than the nominal capacity based on the additional fluidizing air that can be provided. The units also have more capacity at lower volatile solids concentrations (i.e., typically occurring during flood or high river conditions) because of heat release limits for a given size. Each reactor will be rated for a specific heat release limit corresponding to the unit's volume. Because inert material in the feed solids will not create heat during combustion, each reactor can process a higher dry solids feed rate when the material has a low volatile content.

5.1 BISSELL POINT ALTERNATIVE 1 (BPA1) – 2 UNITS FOR MM + 1

5.1.1 BPA1 Description

Under BPA1 two units would be sized to meet future MM conditions with an additional standby unit to process solids above MM production and provide capacity when units are out of service for maintenance. Design criteria for the FBI units for BPA1 are listed in Table 5-1.

Table 5-1 BPA1 FBI Unit Design Criteria

DESCRIPTION	VALUE
Number of units	3
Nominal design capacity, each	125 dtpd
Firm nominal capacity	250 dtpd
Installed nominal capacity	375 dtpd
Bed outside diameter	19.4 feet
Design fluidizing air	14,177 scfm
Minimum fluidizing air	12,759 scfm
Max flood capacity (33.4 %TS, 32.2 %VS), each	138 dtpd
Max normal capacity (29.7 %TS, 50.8 %VS), each	113 dtpd

5.1.2 BPA1 Operating Evaluation

The firm and installed FBI capacity of each alternative FBI configuration was evaluated with respect to current and future design solids loadings for the facility. The evaluation included a review of what percentage of the time FBI units would be operating in desirable and undesirable ranges with respect to individual units. Figure 5-1 shows FBI system capacity under normal and flood operating conditions with respect to current design solids production rates. Figure 5-2 shows FBI system capacity under normal and flood operating conditions with respect to future design solids production rates.

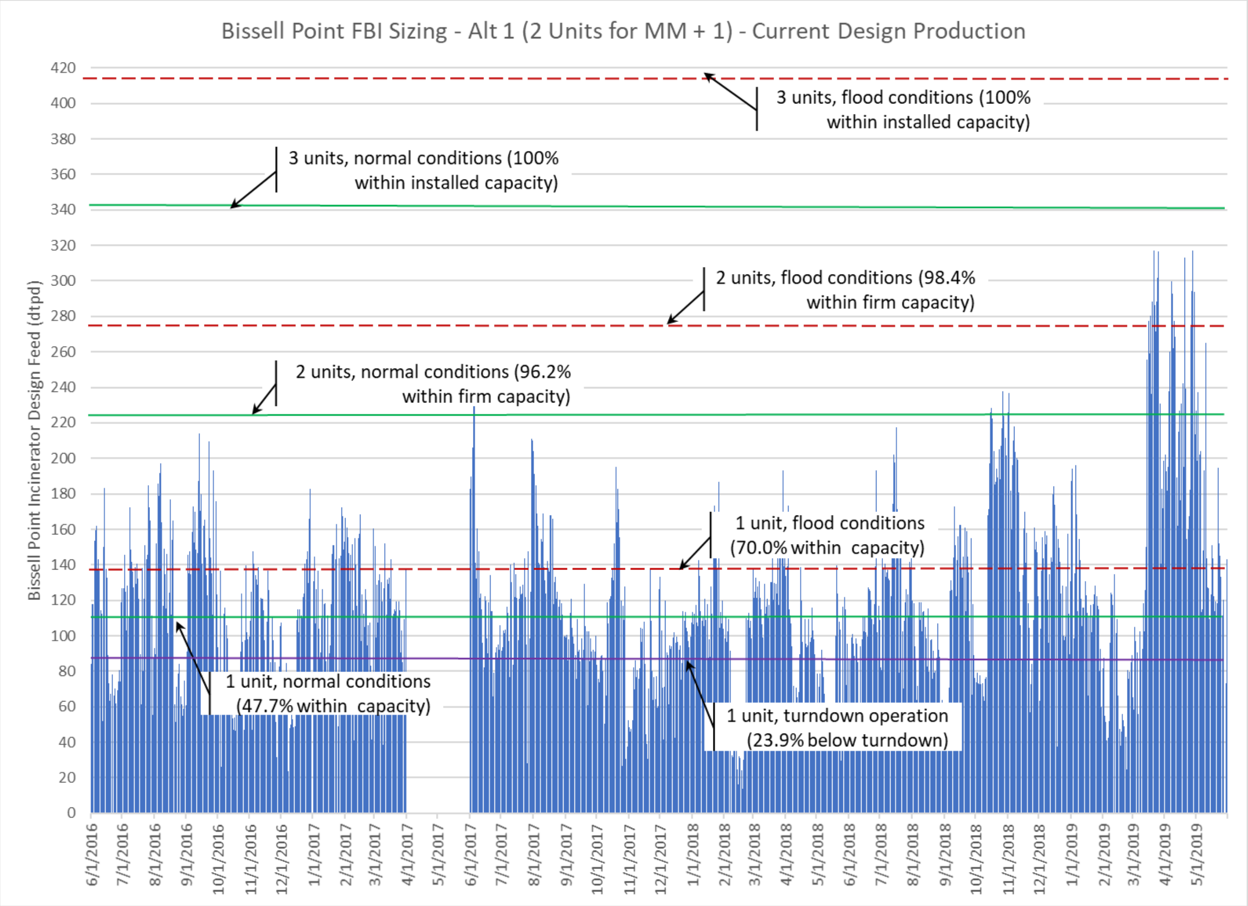

Figure 5-1 **BPA1 - Current Solids Loading Profile and FBI System Capacity**

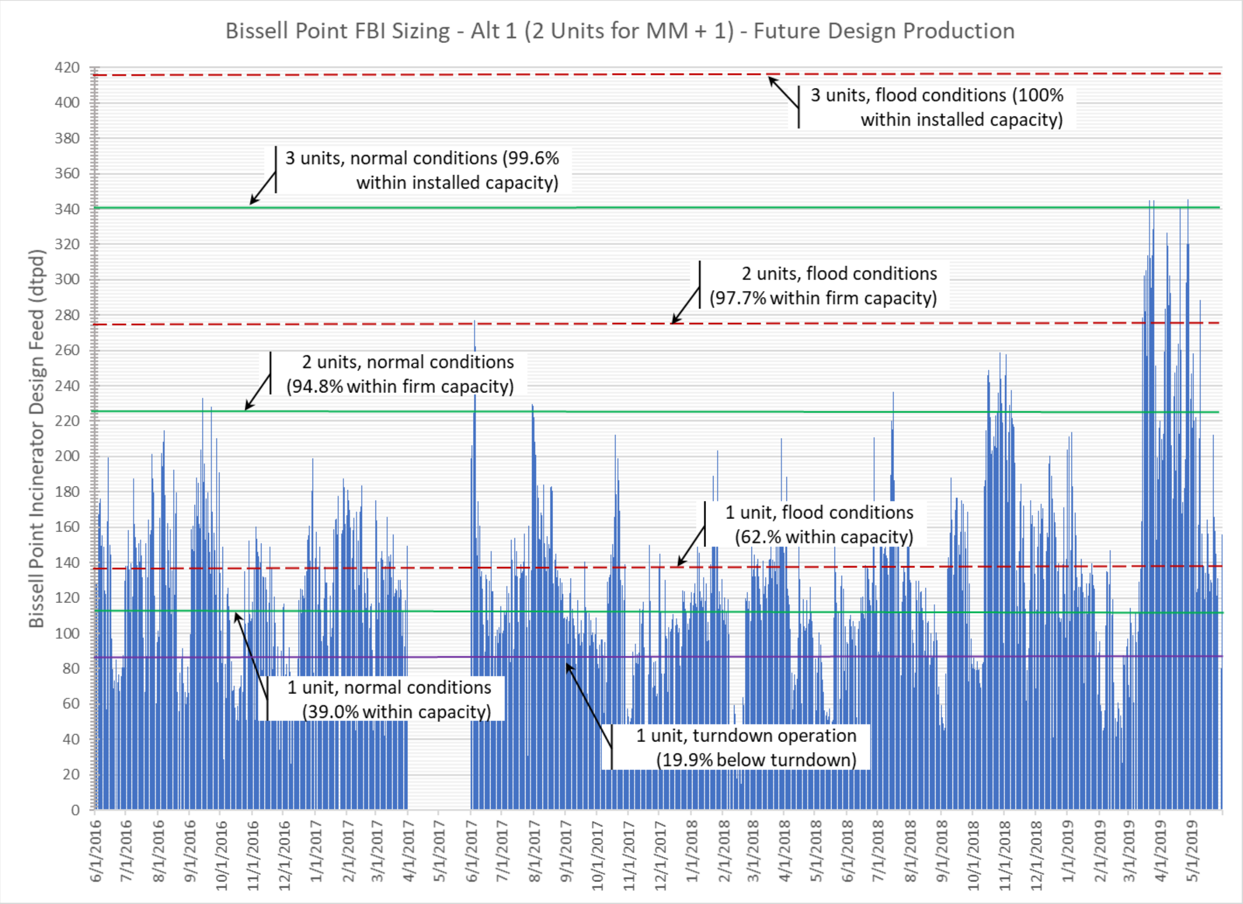

Figure 5-2 BPA1 - Future Solids Loading Profile and FBI System Capacity

Under BPA1, a single FBI unit would be operating below the recommended turndown range 23.9% of the time for current design solids loadings and that percentage increases to 47.7% for the higher future solids loading conditions. Some of the low solids conditions could be addressed by reducing solids inventory in primary clarifiers or turning a unit off and on, although thermal cycling of FBI system components will reduce equipment service life. The percentage of time the FBI units are predicted to need to operate below their recommended turndown limit under this alternative is high. Under this alternative the percentage of time that the solids loadings exceed firm capacity is 1.6% and 2.3% for current and future design loadings, respectively, and under no conditions is the installed capacity exceeded.

An evaluation of percentage of time FBI units would operate in various turndown amounts under this and other Bissell Point alternatives is included in the Non-Economic Considerations Section 5.5 and shown in Figure 5-7. Table 5-2 shows a summary of operating conditions for future MM, future AA, and current AA design conditions.

Table 5-2 BPA1 Operating Condition Summary

DESCRIPTION	FUTURE MM	FUTURE AA	CURRENT AA
Total solids load, dtpd	250	135	114
# operating /capacity each, dtpd	2 / 125	2 / 67.5	2 / 57
Turndown, % each	100	54	46
Auxiliary heat required each, MMBtuh	17.0	11.8	8.5
Auxiliary heat required total, MMBtuh	34.0	23.6	17.0
Auxiliary ng required each, cfh	25,300	17,600	12,600
Auxiliary ng required total, cfh	50,600	35,200	25,200
Power required each, kW	1,090	872	872
Power required total, kW	2,180	1,744	1,744

Evaluating peak loading conditions when firm capacity is exceeded provides information on the impact and frequency of those periods and what options are available to accommodate excess solids. A consideration in that evaluation is estimating the frequency and duration of "annual" maintenance and major rehabilitation projects to determine the likelihood installed units can treat excess solids. Based on a review of other facilities, a 6-week outage period for each unit every 12 to 16 months should be anticipated for periodic maintenance, including inspection of equipment, scheduled maintenance, and minor repairs. With three units under this alternative, it is anticipated that one of the three installed units would be out of service 18 weeks per year, or around 1/3 of the time. As identified, under this alternative firm capacity is exceeded between 1.6% to 2.3% of the time, or around 8 days per year. During that time potential options to process solids include:

- *Treat solids in the standby unit if available*. The standby unit should be available around two-thirds of the time. Scheduling maintenance during periods of historically low solids loadings will increase the likelihood that solids loads will not exceed the nominal capacity of the FBI units (with one out of service), but that risk will not be eliminated entirely due to volatility of weather patterns and events.
- *Allow solids inventory in primary clarifiers to increase*. At an average concentration of 5.7% solids each foot of blanket depth has 47.5 dry tons of solids for each primary clarifier, with 380 dry tons of solids per foot for all 8 clarifiers. For future conditions, peak day flows exceed firm capacity by around 60 dry tons, which is the equivalent of 2 inches of blanket depth. Plant staff have noted that during peak flows it can be hard to retain solids in the clarifiers.
- *Dewater solids for other disposal or later processing*. Solids dewatering will be sized to provide more firm capacity than FBI units. The additional capacity could be used to dewater additional solids which could potentially be hauled to landfill, the Lemay WWTF, or stored on site for processing when surplus capacity is resumed at the FBI facility.
- *Landfilling*. Currently landfilling of solids has been discontinued by MSD due to landfills refusing to receive biosolids because of their odors. The practicality of landfilling on an emergency basis (if a standby FBI was not available and solids inventory could not be increased in the primaries) and the quality of "flood" cake should be reviewed.
- *Transfer to Lemay WWTF*. Both Bissell Point and Lemay WWTFs are to have cake receiving facilities, which could be used to receive cake from the other facility on an emergency basis.

MSD's planning document *"Solids Handling Technical Memorandum - Fluidized Bed Incinerators"* identified that hauling should be kept to a minimum but also noted the "potential to coordinate combined capacity of the facilities for emergency backup versus otherwise maintaining redundant, excess capacity at a standalone facility" should be considered. No permit issues were identified in the TM with this practice, but this should be further reviewed.

- *Storing cake on site*. Cake storage could be provided on site to store excess dewatered solids until surplus capacity became available in the FBI facility. Note that odor issues may be prevalent with this option and would likely only be considered under extreme conditions.

Major rehabilitation of FBI facilities can occur every 15 to 20 years. During that period options for temporary alternative processes (such as lime stabilization) can be considered to treat excess solids (i.e., solids exceeding the capacity of the units in operation).

5.2 BISSELL POINT ALTERNATIVE 2 (BPA2) – 3 UNITS FOR MM + 1

5.2.1 BPA2 Description

Under BPA2 three units would be sized to meet future MM conditions with an additional standby unit to process solids above MM production and provide capacity when units are out of service for maintenance. Design criteria for the FBI units for BPA2 are listed in Table 5-3.

Table 5-3 BPA2 FBI Unit Design Criteria

DESCRIPTION	VALUE
Number of units	4
Nominal design capacity, each	83 dtpd
Firm nominal capacity	250 dtpd
Installed nominal capacity	334 dtpd
Bed outside diameter	15.7 feet
Design fluidizing air	9,743 scfm
Minimum fluidizing air	8,769 scfm
Max flood capacity (33.4 %TS, 32.2 %VS), each	92 dtpd
Max normal capacity (29.7 %TS, 50.8 %VS), each	75 dtpd

5.2.2 BPA2 Operating Evaluation

Figure 5-3 shows FBI system capacity under normal and flood operating conditions with respect to current design solids production rates. Figure 5-4 shows FBI system capacity under normal and flood operating conditions with respect to future design solids production rates.

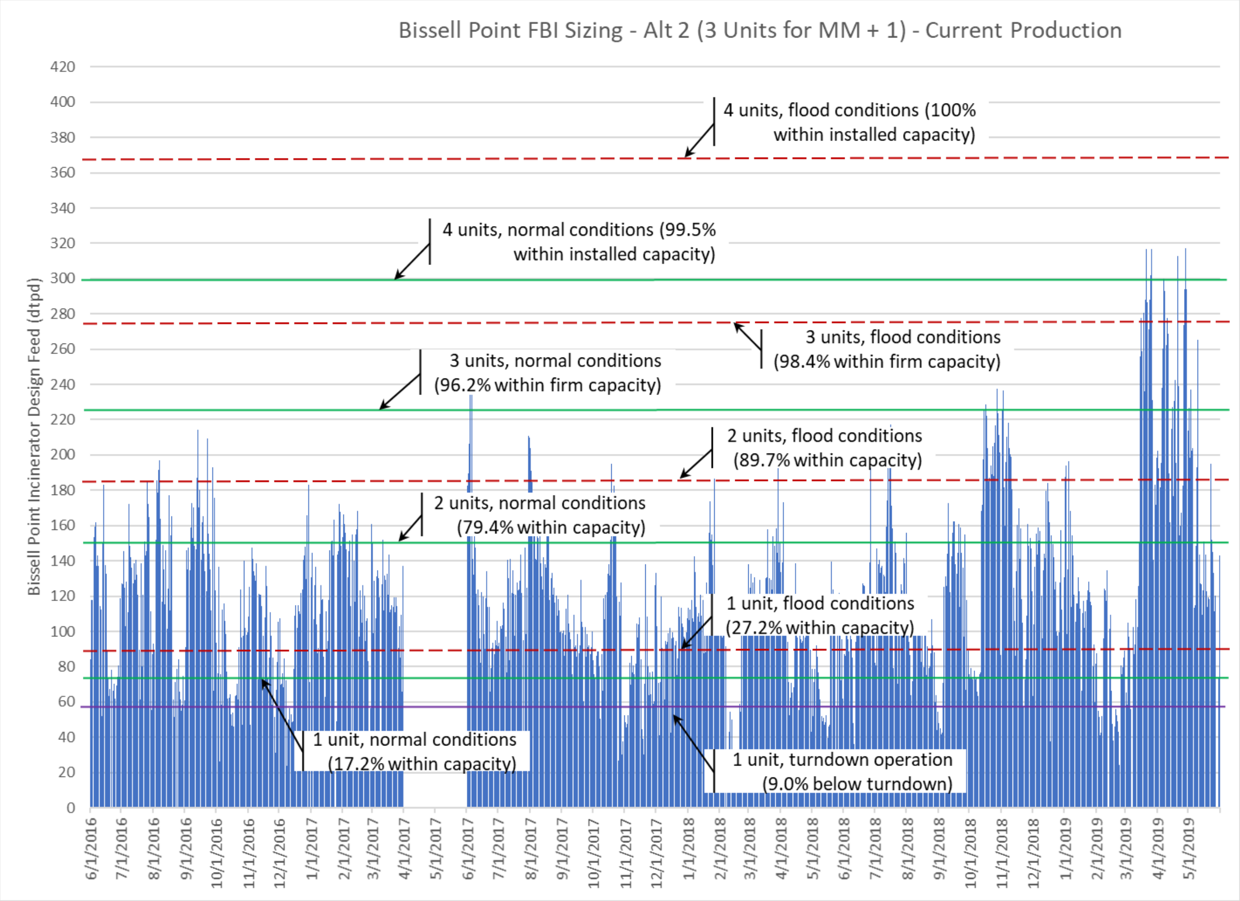

Figure 5-3 **BPA2 Current Solids Loading Profile and FBI System Capacity**

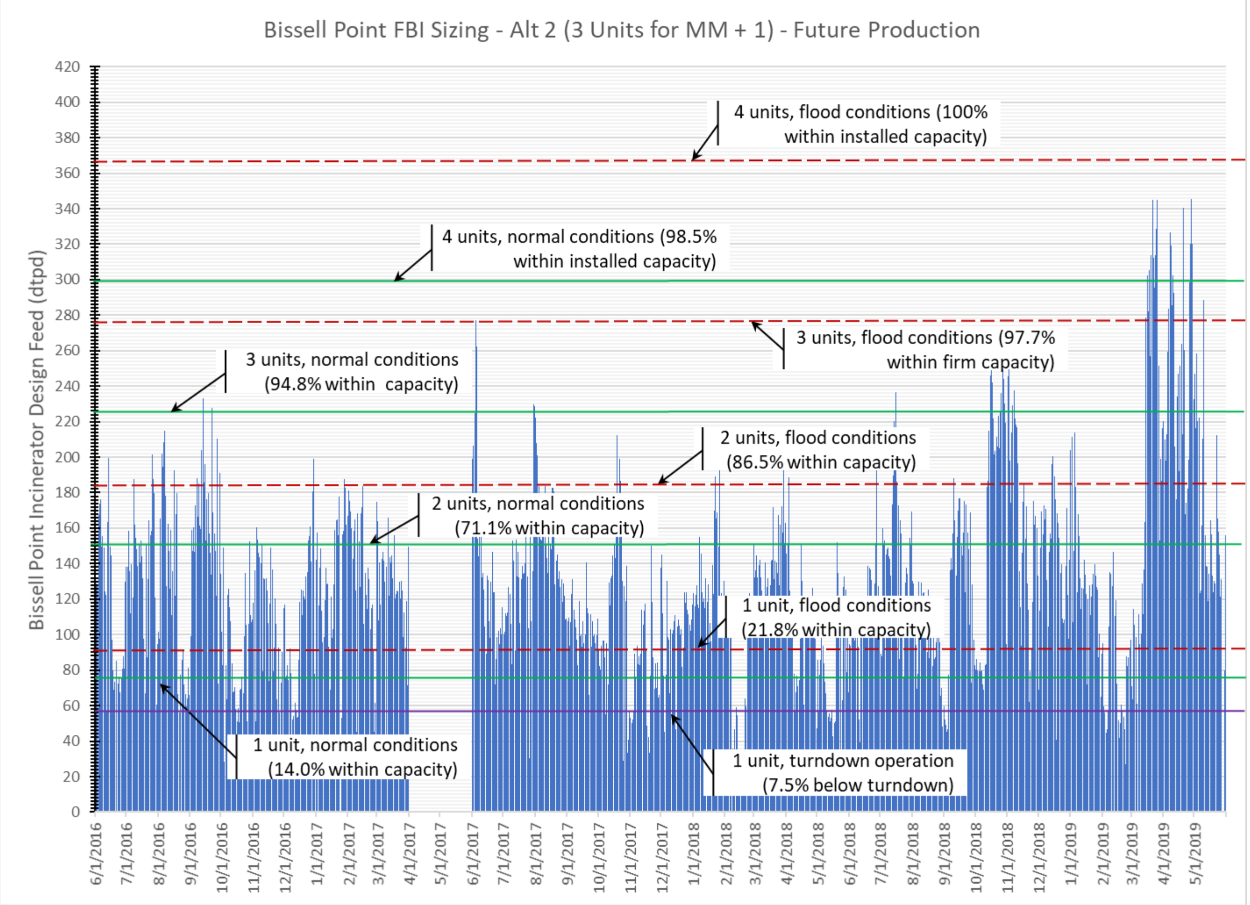

Figure 5-4 BPA2 Future Solids Loading Profile and FBI System Capacity

Under Alt BPA2, a single FBI unit would be operating below the recommended turndown range 9.0% of the time for current design solids loadings and 7.5% for the higher future solids loading conditions. The percentage of time the FBI units are predicted to need to operate below their recommended turndown limit under this alternative is significantly lower than under Alt BPA1. Under this alternative the percentage of time that the solids loadings exceed firm capacity is 1.6% and 2.3% for current and future design loadings, respectively, and under no conditions is the installed capacity exceeded.

An evaluation of percentage of time FBI units would operate in various turndown amounts under this and other Bissell Point alternatives is included in the Non-Economic Considerations Section 5.5 and shown in Figure 5-7. Table 5-4 shows a summary of operating conditions for future MM, future AA, and current AA design conditions.

Table 5-4 BPA2 Operating Condition Summary

DESCRIPTION	FUTURE MM	FUTURE AA	CURRENT AA
Total solids load, dtpd	250	135	114
# operating /capacity each, dtpd	3 / 83.4	2 / 67.5	2 / 57
Turndown, % each	100	81	68
Auxiliary heat required each, MMBtuh	11.9	8.3	5.0
Auxiliary heat required total, MMBtuh	35.7	16.6	10.0
Auxiliary ng required each, cfh	17,800	12,400	7,400
Auxiliary ng required total, cfh	53,400	24,800	14,800
Power required each, kW	728	589	582
Power required total, kW	2,184	1,178	1,164

Based on a 6-week outage period for each unit every 12 months and four units under this alternative, it is anticipated that one of the four installed units would be out of service 24 weeks per year, or around 45% of the time. As identified, under this alternative firm capacity is exceeded between 1.6% to 2.3% of the time, or around 8 days per year. During that time potential options to process solids in excess of firm capacity are the same as under BPA1.

5.3 BISSELL POINT ALTERNATIVE 3 (BPA3) – 2 UNITS FOR MM

5.3.1 BPA3 Description

Under BPA3 two units would be sized to meet future MM conditions with no additional standby unit. Design criteria for the FBI units for BPA1 are listed in Table 5-5. The FBI units are sized the same as for BPA1, but there is one less unit overall, with no standby unit.

Table 5-5 BPA1 FBI Unit Design Criteria

DESCRIPTION	VALUE
Number of units	2
Nominal design capacity, each	125 dtpd
Firm nominal capacity	125 dtpd
Installed nominal capacity	250 dtpd
Bed outside diameter	19.4 feet
Design fluidizing air	14,177 scfm
Minimum fluidizing air	12,759 scfm
Max flood capacity (33.4 %TS, 32.2 %VS), each	138 dtpd
Max normal capacity (29.7 %TS, 50.8 %VS), each	113 dtpd

5.3.2 BPA3 Operating Evaluation

Figure 5-5 shows FBI system capacity under normal and flood operating conditions with respect to current design solids production rates. Figure 5-6 shows FBI system capacity under normal and flood operating conditions with respect to future design solids production rates.

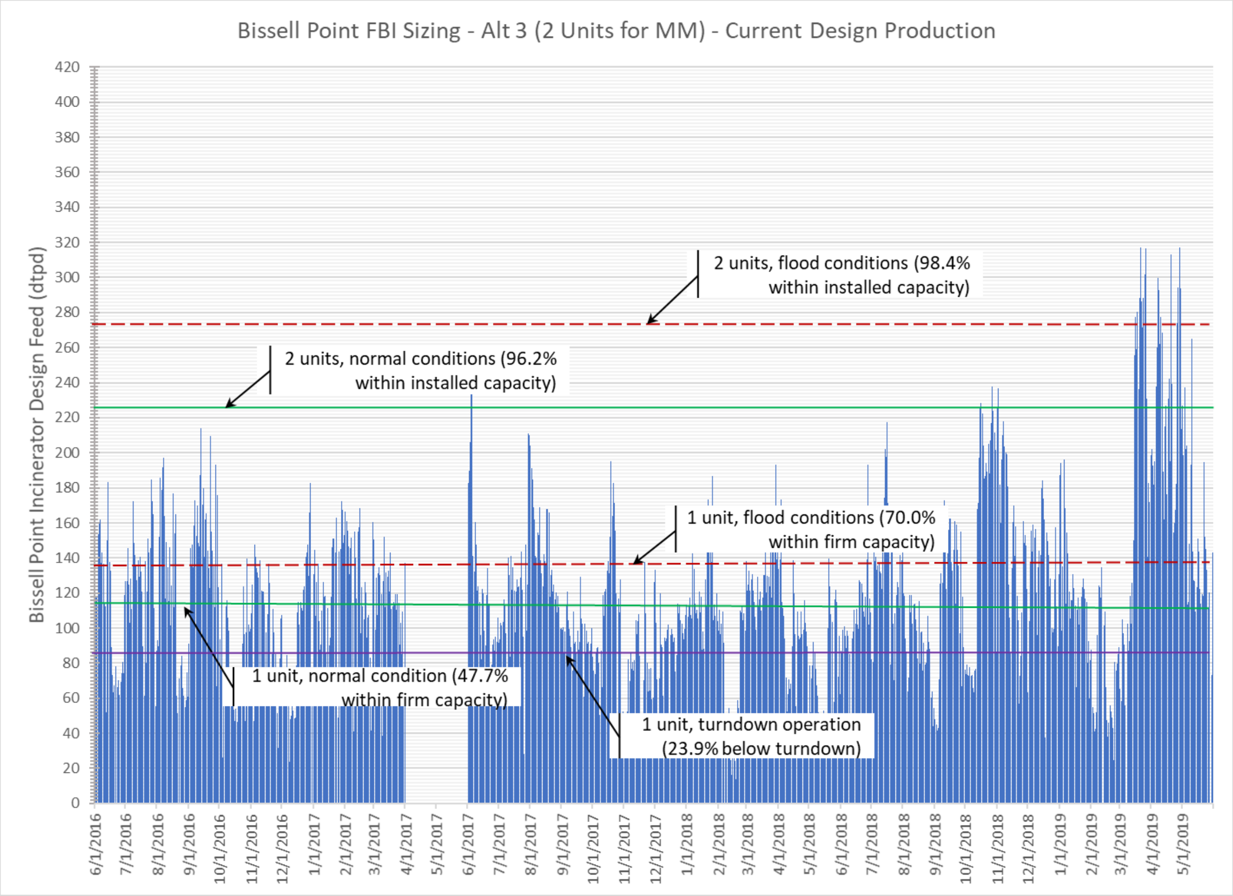

Figure 5-5 BPA3 Current Solids Loading Profile and FBI System Capacity

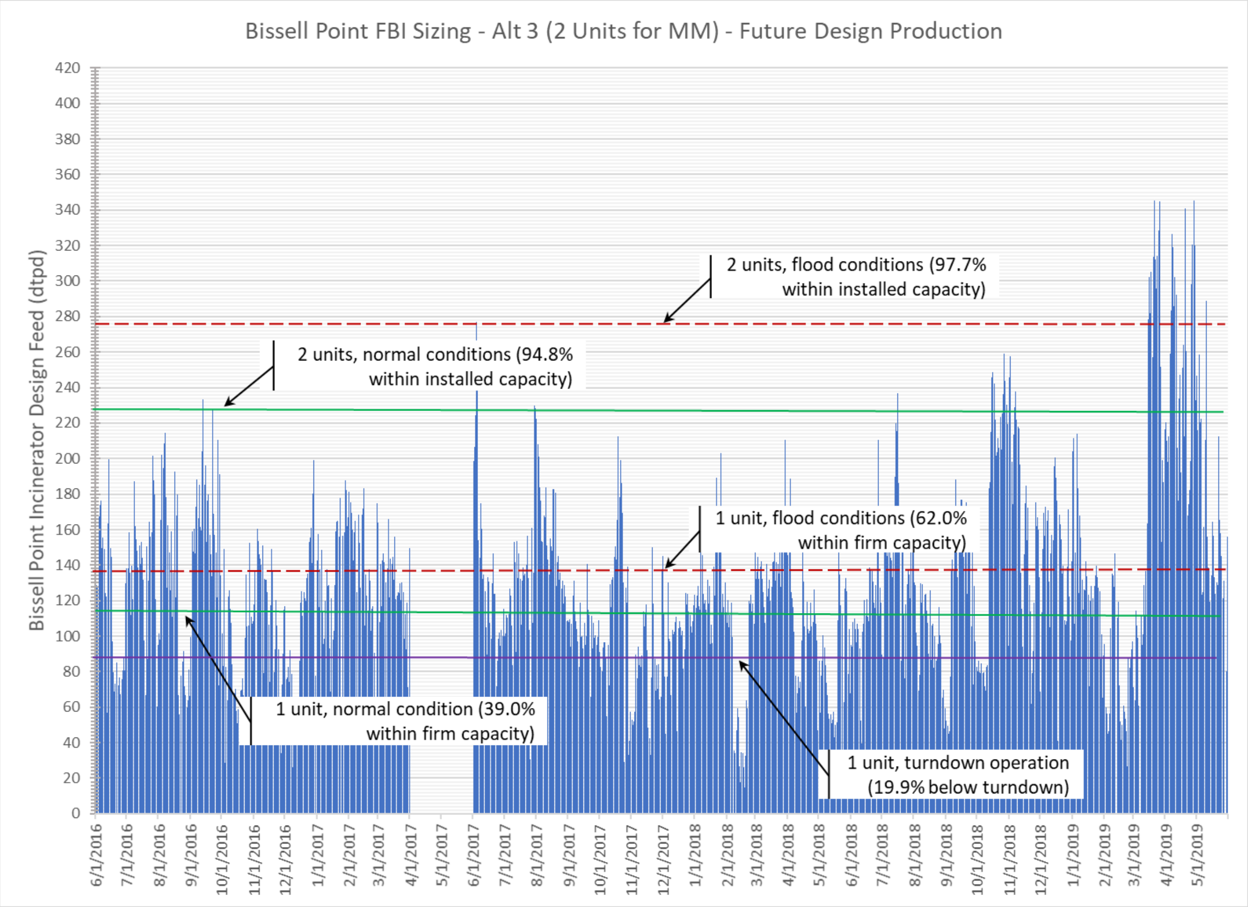

Figure 5-6 BPA3 Future Solids Loading Profile and FBI System Capacity

As with BPA1, under BPA3 a single FBI unit would be operating below the recommended turndown range 23.9% of the time for current design solids loadings and that percentage decreases to 19.9% for the higher future solids loading conditions. Under this alternative the percentage of time that the solids loadings exceed firm capacity is 30% and 38% for current and future design loadings, respectively. The solids loadings exceed installed capacity 1.6% and 2.3% for current and future design loadings, respectively. With two units, based on a 6-week outage period for each unit, for 12 weeks, or around 25% of the time, one of the units would not be available. With such a high percentage of the time that firm capacity is exceeded it is anticipated that alternative methods to process solids would need to be used frequently. Operating conditions would be the same as for BPA1 and are the same as shown in Table 5-2 for that alternative.

5.4 ALTERNATIVE COSTS

5.4.1 Capital Costs

A planning level opinion of probable construction costs (OPCC) and probable project cost (OPPC) are shown in Table 5-6 for the alternatives. The OPCC includes:

- Construction contingency (30% for non-FBI items, 20% for FBI equipment)
- General requirements (10%)
- Contractor fee (12%)

- Insurance and bond (1.7%)

Table 5-6 Bissell Point Alternative OPCC & OPPC

ALTERNATIVE	BPA1	BPA2	BPA3
Building	$8,821,000	$7,480,000	$6,300,000
FBI System Equipment	$143,380,000	$143,420,000	$96,830,000
FBI System Installation	$2,230,000	$2,970,000	$1,490,000
Process Piping	$13,000,000	$17,340,000	$8,670,000
Process Ductwork	$520,000	$690,000	$340,000
Electrical	$13,430,000	$13,730,000	$9,090,000
I&C	$4,480,000	$4,580,000	$3,030,000
Construction Costs	$185,861,000	$190,210,000	$125,750,000
Engineering and Legal	$37,170,000	$38,040,000	$25,150,000
Project Cost	$223,031,000	$228,250,000	$150,900,000

Alt 1 (BPA1) – 2 units sized for future MM, with one additional unit; Alt 2 (BPA2) – 3 units sized for future MM, with one additional unit; Alt 3 (BPA3) – 2 units sized for future MM

5.4.2 Operating Costs

For the purpose of comparing costs, annual operating costs that will have a significant difference between alternatives were modeled consisting of fuel, electrical, and maintenance costs for both future AA (FAA) and current AA (CAA) conditions. Table 5-7 shows these costs for the alternatives. Operating costs are based on:

- 24 hour per day, 7 days per week operation
- Natural gas cost of $4.50 per cubic foot
- Electricity cost of $0.077 per kW-hr
- Annual maintenance cost based on 2% of equipment cost

Table 5-7 Bissell Point Alternative Annual Differential Operating Costs

ALT	BPA1 FAA	BPA1 CAA	BPA2 FAA	BPA2 CAA	BPA3 FAA	BPA3 CAA
NG Fuel	$1,390,000	$990,000	$980,000	$580,000	$1,390,000	$990,000
Electrical	$1,180,000	$1,180,000	$790,000	$790,000	$1,180,000	$1,180,000
Maintenance	$2,870,000	$2,870,000	$2,870,000	$2,870,000	$1,940,000	$1,940,000
Total	$5,440,000	$5,040,000	$4,640,000	$4,240,000	$4,510,000	$4,110,000

Alt 1 (BPA1) – 2 units sized for future MM, with one additional unit; Alt 2 (BPA2) – 3 units sized for future MM, with one additional unit; Alt 3 (BPA3) – 2 units sized for future MM

5.4.3 Present Worth Costs

Present worth costs for each alternative are shown in Table 5-8. Total present worth costs are based on:

- Evaluation period: 20 years
- Interest rate: 4%
- Escalation rate: 2.5%
- Current conditions modeled for years 0 to 10, future conditions modeled for years 11 to 20

Table 5-8 Bissell Point Alternative Present Worth Costs

ALT	BPA1	BPA2	BPA3
O&M PW	$89,710,315	$75,975,140	$73,743,174
OPCC	$223,031,000	$228,250,000	$150,900,000
Total	$312,741,315	$304,225,140	$224,643,174

Alt 1 (BPA1) – 2 units sized for future MM, with one additional unit; Alt 2 (BPA2) – 3 units sized for future MM, with one additional unit; Alt 3 (BPA3) – 2 units sized for future MM

5.5 NON-ECONOMIC CONSIDERATIONS

A key factor in evaluating the performance of an alternative is the percentage of time that the FBI units will be operating in a desirable range of the unit's capacity, and what percentage of the time units are operating near the ends of the recommended operating range (or below the turndown limit). When operating near the turndown range of a unit, fuel and electricity use is appreciably more inefficient; operation below the turndown range is not recommended due to notably inefficient operation and high oxygen content in the combustion zone impacting the ability to meet NOx emission limits. When enough solids are not available to run at or above the turndown limit, solids will need to be inventoried until a sufficient amount is available to operate at the limit for a reasonable period. This will add operational complexity and cause additional thermal cycling of equipment which reduces service life.

Figure 5-7 shows an operating profile comparison between alternatives BPA1 and BPA2. BPA3's profile is essentially the same as BPA1's profile and is not shown for clarity.

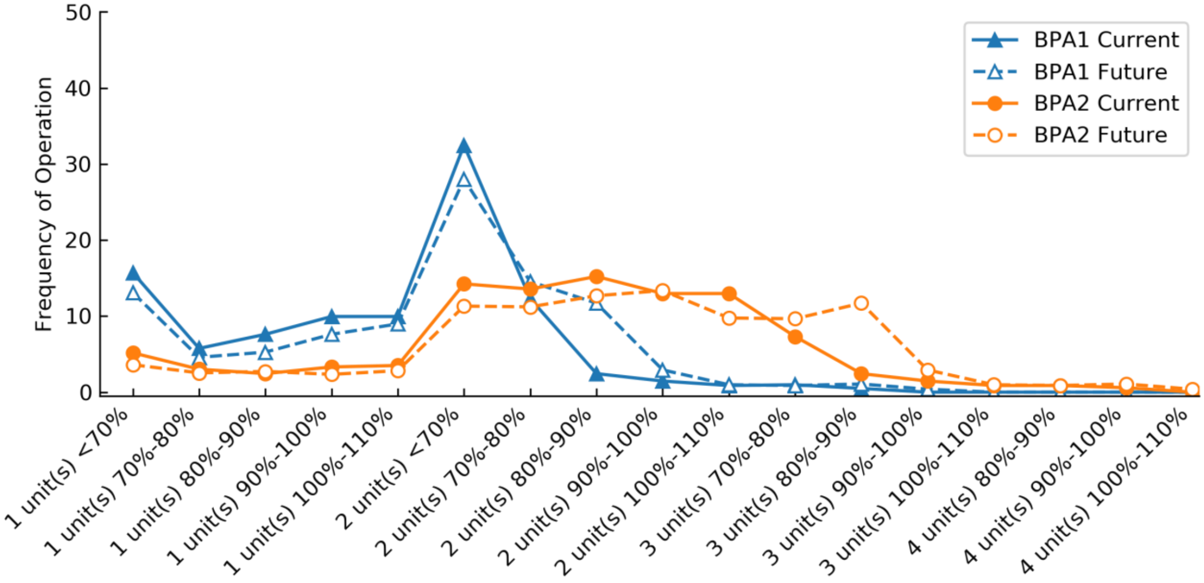

Figure 5-7 Bissell Point Alternative Operating Profile Comparison

As shown in the figure, BPA2 has a significantly better operating profile than BPA1. For future conditions BPA2 has units operating below turndown 14.9% of the time compared with 41.1% of the time for BPA1. For future conditions, BPA2 units operate for 31.1% of the time between 80% and 100%, while BPA1 units operate 27.5% of the time in that range. The extreme loadings caused by flooding make it difficult to size units with capacity to process those high solids loading rates while at the same time operating in optimum capacity ranges under normal conditions. BPA2 does a better job of accommodating the solids range than does BPA1.

Another advantage to having more smaller units is that a single failure of a unit causes less of an overall reduction in treatment capacity. On the other hand, a disadvantage to more units is that there are more systems to operate and maintain.

Consideration was given to providing units of different sizes, some sized for normal operation and some for flood conditions. This would result in near continuous use of the normal units and infrequent use of the flood units, in turn causing unequal wear and more frequent cycling of the large units.

5.6 EVALUATION AND RECOMMENDATION

BPA3, with two operating units and no standby unit has a significantly lower overall project cost. However, with firm capacity not able to meet solids loading rates 38% of the time for future conditions, this alternative does not satisfy an essential requirement of the project to reliably process solids from treatment.

The project costs for BPA1 and BPA2 are relatively close to each other. BPA2 has a significantly better operating profile which will provide substantial benefits to plant operation and energy efficiency and is thus the recommended alternative.

6.0 Lemay FBI Sizing

FBI alternatives (Alt) for the Lemay WWTF were evaluated based on solids production of 165 dtpd for future maximum month (MM), 112 dtpd for future annual average (AA), 110 dtpd for current MM, and 74 dtpd for current AA. Three alternatives were evaluated of different size and number for the Lemay WWTF as follows:

- Alt 1 (LA1) – 2 units each sized for future AA, with no additional unit (2 units at 112 dtpd, 112 dtpd firm capacity, 224 dtpd installed capacity). This alternative was selected to provide one unit able to meet typical conditions with an additional unit to provide capacity to treat solids above this load, with the intent to evaluate whether a configuration with only two units could provide acceptable performance.
- Alt 2 (LA2) – 2 units sized for future MM, with one additional unit (3 units at 83 dtpd, 165 dtpd firm capacity, 249 dtpd installed capacity). This alternative was selected to reflect typical sizing criteria of multiple units to meet MM conditions and one standby unit, with the fewest units possible (three).
- Alt 3 (LA3) – 2 units initially installed sized for future MM (2 units at 83 dtpd, 83 dtpd firm capacity, 165 dtpd installed capacity). Before future loading conditions occur, under this alternative an additional unit would be installed, resulting in 165 dtpd firm capacity and 249 dtpd installed capacity. Solids loadings are projected to increase significantly when CSO and chemical phosphorus removal improvements are implemented. This alternative was selected to evaluate whether an alternative sized to meet MM conditions with a standby unit, as configured under LA3, would provide acceptable performance while delaying investment in the third FBI unit.

6.1 LEMAY ALTERNATIVE 1 (LA1) – 2 UNITS FOR AA

6.1.1 LA1 Description

Under LA1 two units would be sized to meet future AA conditions with no additional standby unit. Design criteria for the FBI units for LA1 are listed in Table 6-1.

Table 6-1 LA1 FBI Unit Design Criteria

DESCRIPTION	VALUE
Number of units	2
Nominal design capacity, each	112 dtpd
Firm nominal capacity	112 dtpd
Installed nominal capacity	224 dtpd
Bed outside diameter	19.4 feet
Design fluidizing air	13,474 scfm
Minimum fluidizing air	12,127 scfm
Max flood capacity (30.8 %TS, 50.8 %VS), each	123 dtpd
Max normal capacity (28.9 %TS, 60.1 %VS), each	113 dtpd

6.1.2 LA1 Operating Evaluation

Figure 6-1 shows FBI system capacity under normal and flood operating conditions with respect to current design solids production rates. Figure 6-2 shows FBI system capacity under normal and flood operating conditions with respect to future design solids production rates.

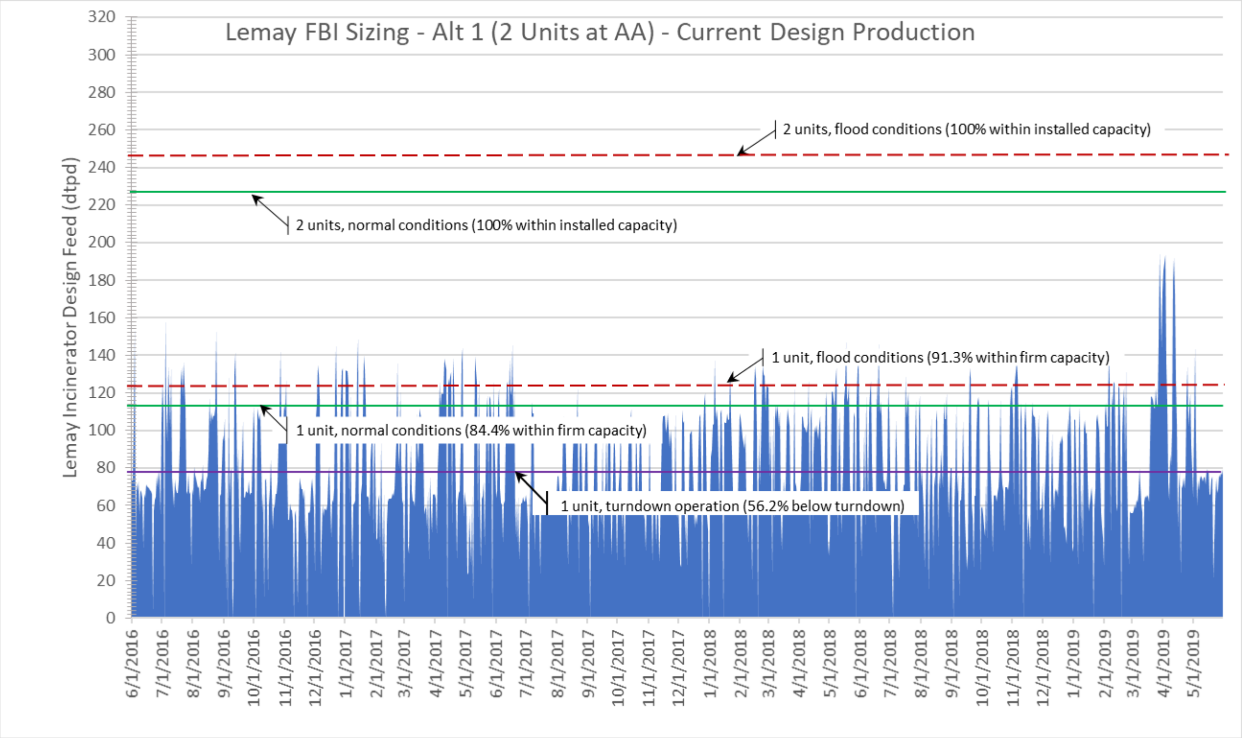

Figure 6-1 **LA1 Current Solids Loading Profile and FBI System Capacity**

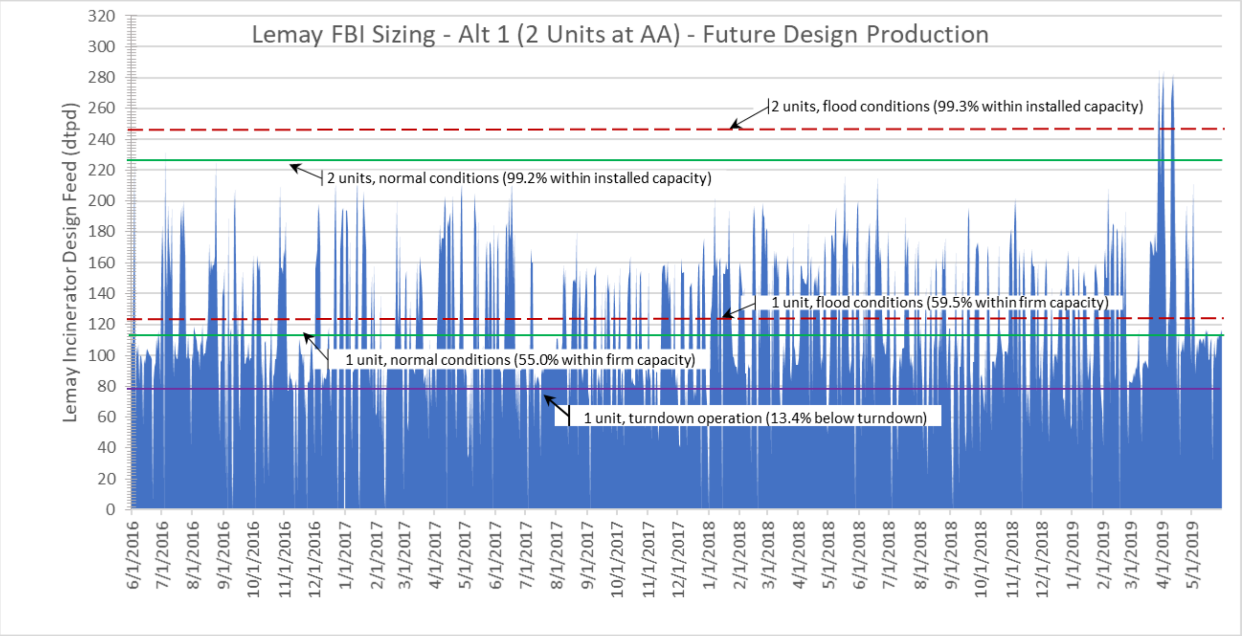

Figure 6-2 **LA1 Future Solids Loading Profile and FBI System Capacity**

Under LA1, a single FBI unit would be operating below the recommended turndown range 56% of the time for current design solids loadings and 13% for the higher future solids loading conditions. For the current conditions, this is a relatively large percentage of time operating below the turndown limit (thus requiring a cycle operation). Under this alternative the percentage of time that the solids loadings exceed firm capacity is 8.7% and 40.5% for current and future design loadings, respectively, and the installed capacity would be exceeded 0.7% of the time for future design loadings.

An evaluation of percentage of time FBI units would operate in various turndown amounts under this and other Lemay alternatives is included in the Non-Economic Considerations Section 6.5 and shown in Figure 6-7. Table 6-2 shows a summary of operating conditions for future MM, future AA, and current AA design conditions.

Table 6-2 LA1 Operating Condition Summary

DESCRIPTION	FUTURE MM	FUTURE AA	CURRENT AA
Total solids load, dtpd	165	112	74
# operating /capacity each, dtpd	2 / 82.5	1 / 112	1 / 74
Turndown, % each	74	100	66
Auxiliary heat required each, MMBtuh	6.0	6.1	2.1
Auxiliary heat required total, MMBtuh	12.0	6.1	2.1
Auxiliary ng required each, cfh	9,000	9,100	3,200
Auxiliary ng required total, cfh	18,000	9,100	3,200
Power required each, kW	782	978	782
Power required total, kW	1,564	978	782

The current AA condition would require substantially less fuel use than the future AA, partly due to the higher volatile content in the solids, reflecting no ChemP treatment. When evaluating nutrient removal options in the future, the impact on fuel use in the incinerators should be an important consideration.

Based on a 6-week outage period for each unit every 12 months and two units under this alternative, it is anticipated that one of the two installed units would be out of service 12 weeks per year, or around 25% of the time. As identified, under this alternative firm capacity is exceeded between 8.7% to 40.5% of the time. With such a high percentage of the time that firm capacity is exceeded for future conditions it is anticipated that alternative methods to process solids would need to be used frequently. During that time potential options to process solids in excess of firm capacity are the same as identified in the Bissell Point Alternatives Section.

6.2 LEMAY ALTERNATIVE 2 (LA2) – 2 UNITS FOR MM + 1

6.2.1 LA2 Description

Under LA2 two units would be sized to meet future MM conditions with an additional standby unit to process solids above MM production and provide capacity when units are out of service for maintenance. Design criteria for the FBI units for LA2 are listed in Table 6-3.

Table 6-3 LA2 FBI Unit Design Criteria

DESCRIPTION	VALUE
Number of units	3
Nominal design capacity, each	83 dtpd
Firm nominal capacity	165 dtpd
Installed nominal capacity	249 dtpd
Bed outside diameter	17.6 feet
Design fluidizing air	9,948 scfm
Minimum fluidizing air	8,953 scfm
Max flood capacity (30.8 %TS, 50.8 %VS), each	91 dtpd
Max normal capacity (28.9 %TS, 60.1 %VS), each	83 dtpd

6.2.2 LA2 Operating Evaluation

Figure 6-3 shows FBI system capacity under normal and flood operating conditions with respect to current design solids production rates. Figure 6-4 shows FBI system capacity under normal and flood operating conditions with respect to future design solids production rates.

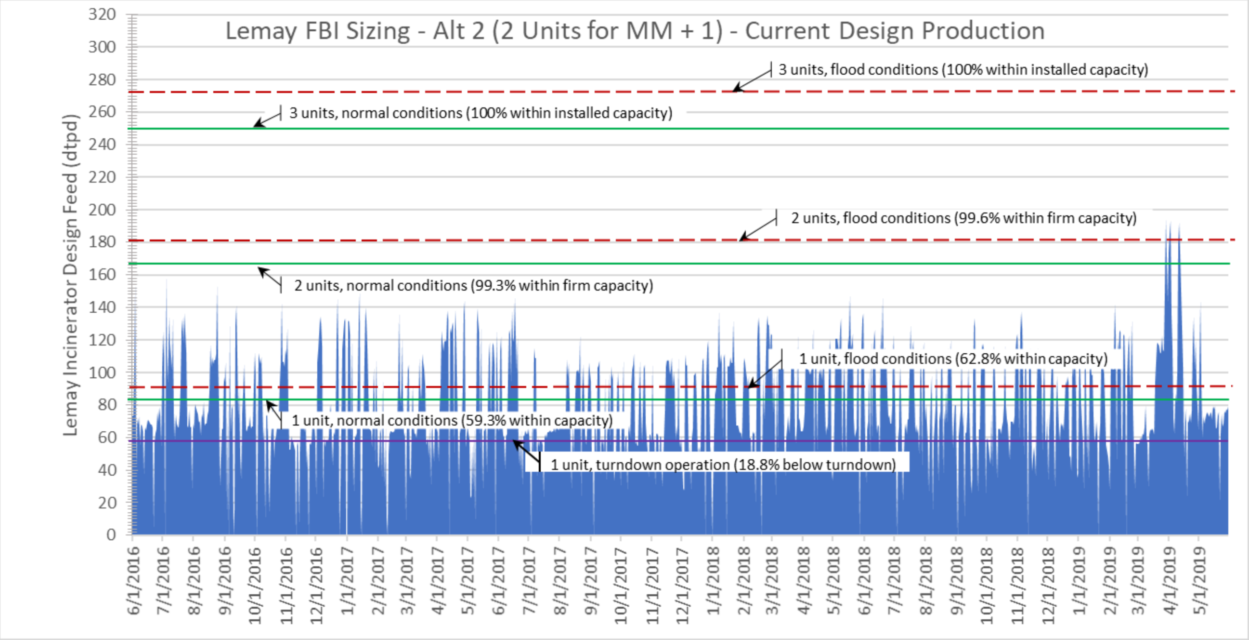

Figure 6-3 LA2 Current Solids Loading Profile and FBI System Capacity

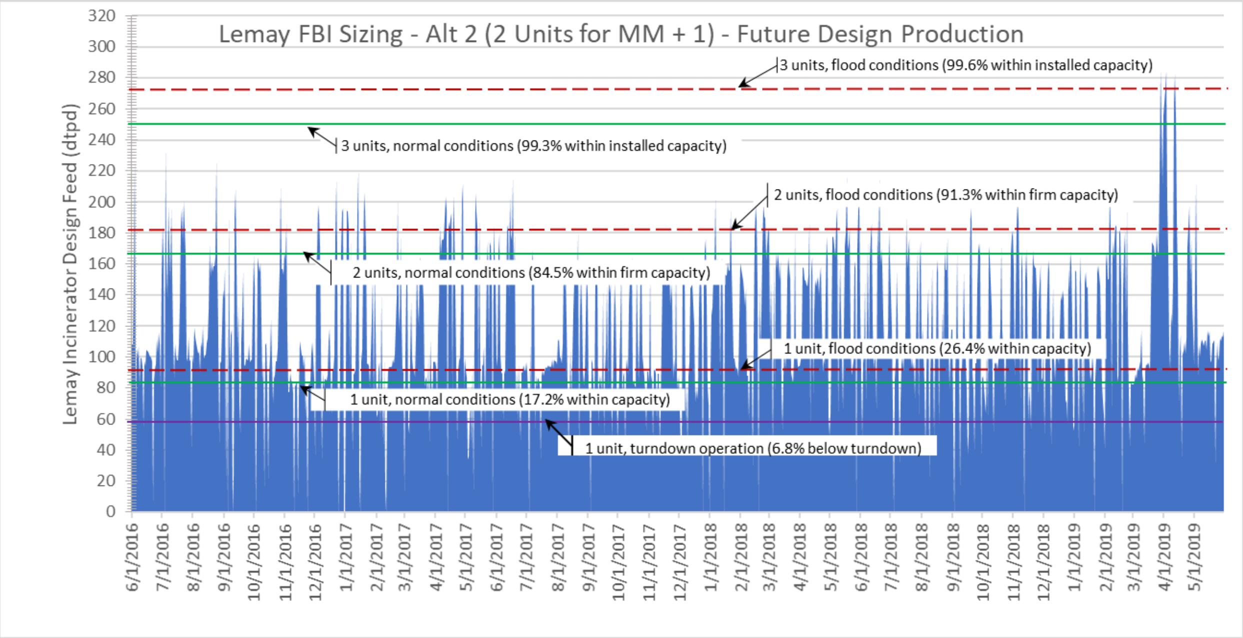

Figure 6-4 **LA2 Future Solids Loading Profile and FBI System Capacity**

Under LA2, a single FBI unit would be operating below the recommended turndown range 18.8% of the time for current design solids loadings and 6.8% for the higher future solids loading conditions. Under this alternative the percentage of time that the solids loadings exceed firm capacity is 0.4% and 8.7% for current and future design loadings, respectively, and the installed capacity is exceeded 0.4% of the time for the future design loadings.

An evaluation of percentage of time FBI units would operate in various turndown amounts under this and other Lemay alternatives is included in the Non-Economic Considerations Section 6.5 and shown in Figure 6-7. Table 6-4 shows a summary of operating conditions for future MM, future AA, and current AA design conditions.

Table 6-4 **LA2 Operating Condition Summary**

DESCRIPTION	FUTURE MM	FUTURE AA	CURRENT AA
Total solids load, dtpd	165	112	74
# operating /capacity each, dtpd	2 / 82.5	2 / 56	1 / 74
Turndown, % each	100	68	90
Auxiliary heat required each, MMBtuh	4.0	3.2	2.8
Auxiliary heat required total, MMBtuh	8.0	6.4	2.8
Auxiliary ng required each, cfh	6,000	4,800	4,200
Auxiliary ng required total, cfh	12,000	9,600	4,200
Power required each, kW	720	576	646
Power required total, kW	1,440	1,152	646

Based on a 6-week outage period for each unit every 12 months and three units under this alternative, it is anticipated that one of the three installed units would be out of service 18 weeks per year, or around 35% of the time. As identified, under this alternative firm capacity is exceeded between 0.4% to 8.7% of the time.

6.3 LEMAY ALTERNATIVE 3 (LA3) – INITIAL 2 UNITS FOR MM

6.3.1 LA3 Description

Under LA3 initially two units would be sized to meet MM conditions. Before future loading conditions occur, an additional unit would be installed. Design criteria for the FBI units for LA3 are listed in Table 6-3. For comparison purposes with the initial values, current MM is 110 dtpd and current AA is 74 dtpd. Sizing of the units is the same as for LA2, the difference between the alternatives being when the third unit is installed.

Table 6-5 LA3 FBI Unit Design Criteria

DESCRIPTION	INITIAL	FUTURE
Number of units	2	3
Nominal design capacity, each	83 dtpd	83 dtpd
Firm nominal capacity	83 dtpd	165 dtpd
Installed nominal capacity	165 dtpd	249 dtpd
Bed outside diameter	17.6	17.6 feet
Design fluidizing air	9,948 scfm	9,948 scfm
Minimum fluidizing air	8,953 scfm	8,953 scfm
Max flood capacity (30.8 %TS, 50.8 %VS), each	91 dtpd	91 dtpd
Max normal capacity (28.9 %TS, 60.1 %VS), each	83 dtpd	83 dtpd

6.3.2 LA3 Operating Evaluation

Figure 6-5 shows FBI system capacity under normal and flood operating conditions with respect to current design solids production rates. Figure 6-6 shows FBI system capacity under normal and flood operating conditions with respect to future design solids production rates.

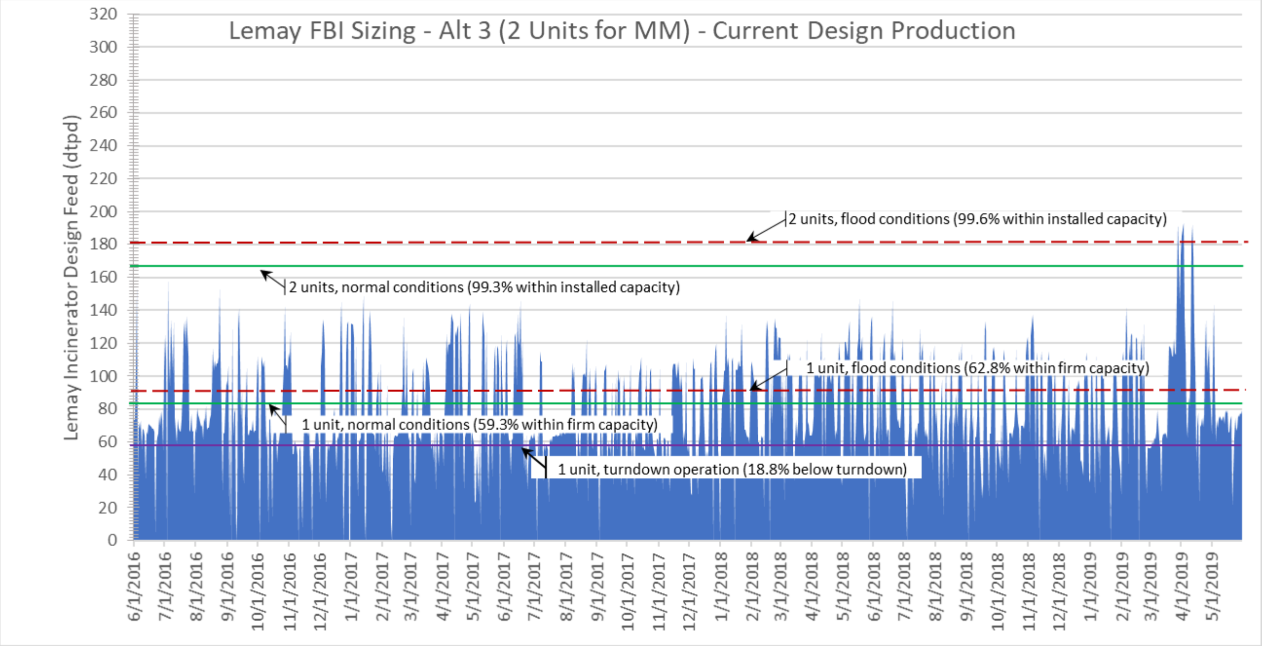

Figure 6-5 LA3 Current Solids Loading Profile and FBI System Capacity

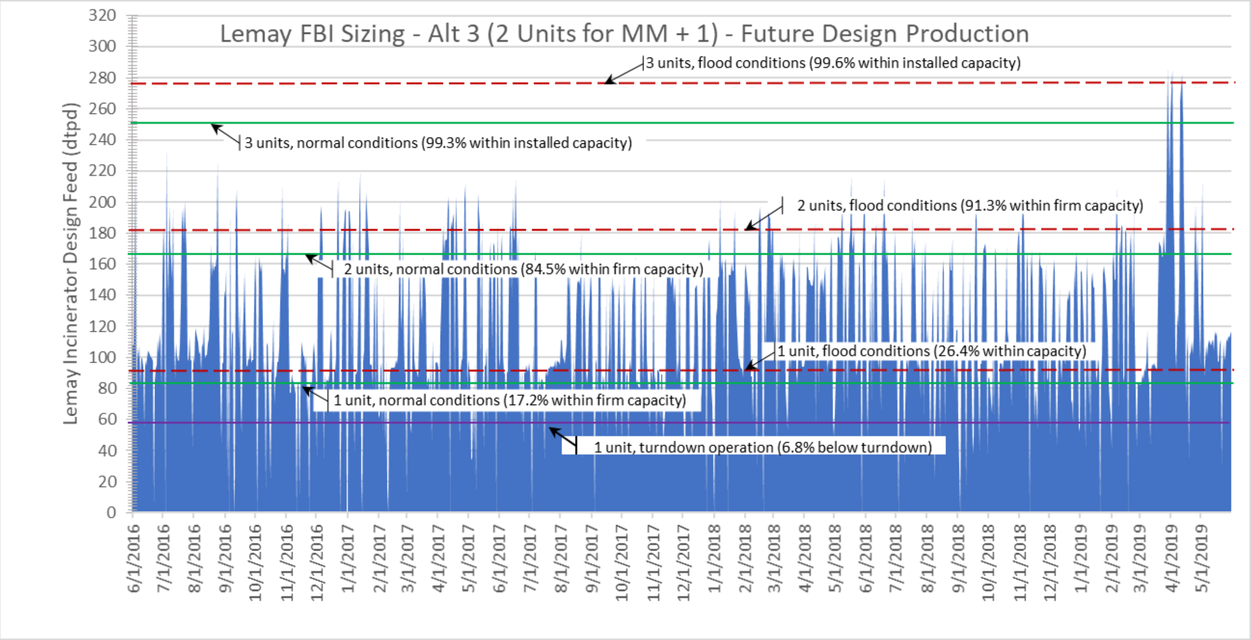

Figure 6-6 LA3 Future Solids Loading Profile and FBI System Capacity

As with LA2, under Alt LA3, a single FBI unit would be operating below the recommended turndown range 18.8% of the time for current design solids loadings and that percentage decreases 6.8% for the higher future solids loading conditions. Under this alternative the percentage of time that the solids loadings exceed firm capacity is 37.2% and 8.7% for current and future design loadings, respectively, and the solids loadings exceed installed capacity 0.4% and 0.4% for current and future design loadings, respectively. For current conditions, with two units before the third unit is installed, based on a 6-week outage period for each unit, for 12 weeks, or around 25% of the time, one of the units would not be available. With such a high percentage of the time that firm capacity is exceeded for current conditions it is anticipated that alternative methods to process solids would need to be used frequently. Operating conditions would be the same as for LA2 and are the same as shown in Table 5-4 for that alternative.

6.4 ALTERNATIVE COSTS

6.4.1 Capital Costs

A planning level opinion of probable construction costs (OPCC) and project cost (OPPC) are shown in Table 6-6 for the alternatives. The allowances used are the same as for the Bissell Point WWTF evaluation.

Table 6-6 Lemay Alternative OPCC & OPPC

ALTERNATIVE	LA1	LA2	LA3
Building	$6,300,000	$7,720,000	$7,720,000
FBI System Equipment	$111,700,000	$108,050,000	$111,720,000
FBI System Installation	$1,490,000	$2,230,000	$1,490,000
Process Piping	$8,660,000	$13,000,000	$8,660,000
Process Ductwork	$340,000	$520,000	$340,000
Electrical	$10,290,000	$10,500,000	$10,390,000
I&C	$3,430,000	$3,500,000	$3,460,000
Construction Costs	$142,210,000	$145,520,000	$143,780,000
Engineering and Legal	$28,440,000	$29,100,000	$28,760,000
Project Cost	$170,650,000	$174,620,000	$172,540,000

Alt 1 (LA1) – 2 units each sized for future AA, with no additional unit; Alt 2 (LA2) – 2 units sized for future MM, with one additional unit; Alt 3 (LA3) – 2 units initially installed sized for future MM

6.4.2 Operating Costs

Annual operating costs were developed for of fuel, electrical, and maintenance costs for both future AA (FAA) and current AA (CAA) conditions. Table 6-7 shows these costs for the alternatives. Operating costs are based on the same criteria as the Bissell Point Section.

Table 6-7 Lemay Alternative Annual Differential Operating Costs

ALT	LA1 FAA	LA1 CAA	LA2 FAA	LA2 CAA	LA3 FAA	LA3 CAA
NG Fuel	$360,000	$130,000	$380,000	$170,000	$380,000	$170,000
Electrical	$660,000	$530,000	$780,000	$440,000	$780,000	$440,000
Maintenance	$2,230,000	$2,230,000	$2,160,000	$2,160,000	$2,230,000	$2,230,000
Total	$3,250,000	$2,890,000	$3,320,000	$2,770,000	$3,390,000	$2,840,000

Alt 1 (LA1) – 2 units each sized for future AA, with no additional unit; Alt 2 (LA2) – 2 units sized for future MM, with one additional unit; Alt 3 (LA3) – 2 units initially installed sized for future MM; CAA = Current annual average; FAA = Future annual average.

6.4.3 Present Worth Costs

Present worth costs for each alternative are shown in Table 6-8. Total present worth costs are based on the same criteria outlined in the Bissell Point Section. For the LA3 OPCC costs, one third of the costs were calculated based on construction of the third unit in the 11th year.

Table 6-8 Lemay Alternative Present Worth Costs

ALT	LA1	LA2	LA3
O&M PW	$52,479,160	$51,928,770	$53,130,597
OPCC	$170,650,000	$174,620,000	$164,585,906
Total	$223,129,160	$226,548,770	$217,716,503

Alt 1 (LA1) – 2 units each sized for future AA, with no additional unit; Alt 2 (LA2) – 2 units sized for future MM, with one additional unit; Alt 3 (LA3) – 2 units initially installed sized for future MM

6.5 NON-ECONOMIC CONSIDERATIONS

Figure 6-7 shows an operating profile comparison between alternatives LA1 and LA2. LA3's profile is essentially the same as LA2's profile and is not shown for clarity.

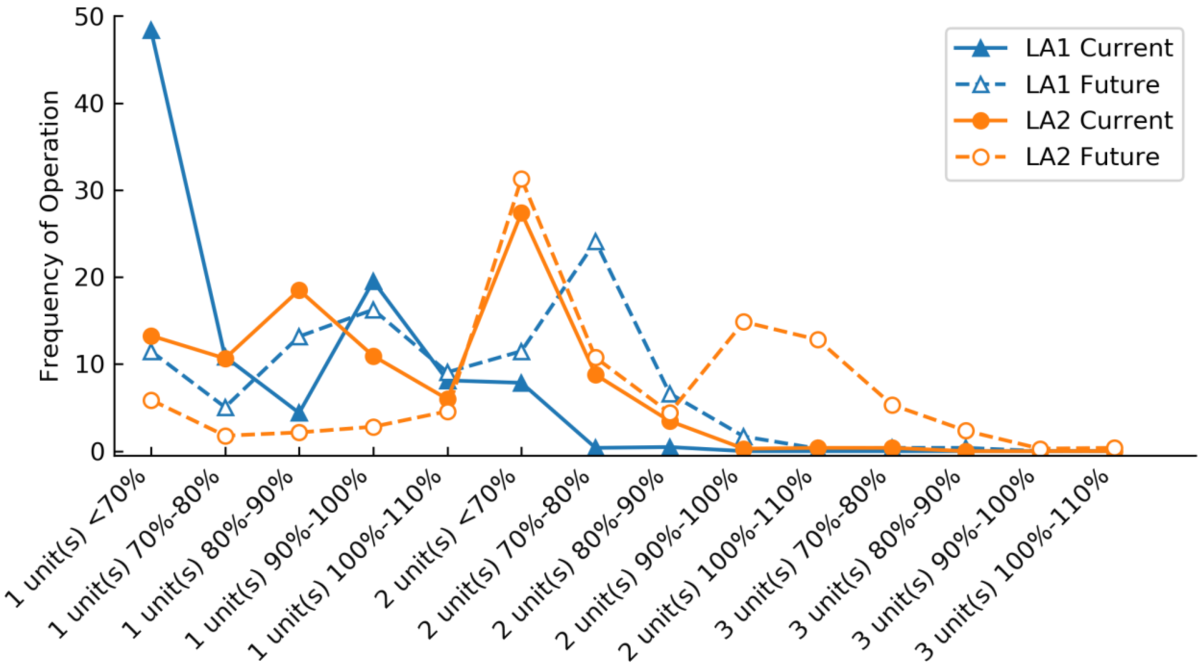

Figure 6-7 Lemay Alternative Operating Profile Comparison

For current conditions, LA1 has units operating below turndown 56.3% of the time compared with 40.7% for LA2. For future conditions LA1 has units operating below turndown 23% of the time compared with 37.2% of the time for LA2. For future conditions, LA1 units operate for 37.8% of the time between 80% and 100%, while LA2 units operate 24.2% of the time in that range. Neither alternative demonstrates a notably better operating profile. Whereas large flood loads made it difficult to size units for Bissell Point, the large increase in solids between current and future conditions make it difficult to size units for Lemay.

6.6 EVALUATION AND RECOMMENDATION

Because LA3 with firm capacity is not able to meet solids loading rates 37% of the time for current conditions, this alternative does not satisfy an essential requirement of the project to reliably process solids from treatment. Delaying the installation of the third unit under this alternative does not provide any significant cost benefit either.

The costs between LA1 and LA2 are relatively similar, and neither has an operating profile that is significantly better than the other. However, LA1 would be operating below the recommended turndown range 56% of the time for current design loadings, which is a large percentage of the time to require units to cycle on and off. LA1 also would exceed firm capacity 40.5% of the time for future design loadings. Because of these issues with LA1, LA2 is the recommended alternative.

FINAL

BISSELL POINT & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum No. 10: Ash Handling System

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

16 NOVEMBER 2020

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1.0 Introduction and Overview

The purpose of this technical memorandum (TM) is to discuss considerations for the sizing and selection of residual ash handling equipment and systems associated with the Metropolitan St. Louis Sewer District (MSD) Bissell Point & Lemay WWTF Fluidized Bed Incinerators (FBI) Project.

This memorandum includes a review of existing ash system processes, as well as options for future ash handling at each facility. Note that both wet and dry ash handling options are considered. For each option, preliminary design criteria are presented herein, including:

- Required system components.
- Number and size of each component.
- Integration with future FBI systems.
- Integration with existing facilities (where applicable).

This memorandum also includes sections covering:

- Overview of existing ash handling and disposal at Bissell Point and Lemay WWTFs.
- Current and future ash loading projections.
- Dry and wet ash system options, including planning level cost estimates.
- Other considerations.

Note that TM No. 9 – FBI Design Criteria further discusses design criteria for individual components of the planned FBI systems. As such, selected system components of the upstream FBIs will need to be coordinated with the final composition of the ash handling facilities. Pending confirmation of these items, initial recommendations included in Section 10 for the ash handling facilities will be finalized.

2.0 Existing Ash Handling Facilities

The following sections provide an overview of existing ash handling facilities and disposal methods at the Bissell Point and Lemay WWTFs. Further discussion pertaining to re-use or repurposing of components of the existing ash handling facilities is provided under subsequent sections of this TM.

2.0 BISSELL POINT WWTF

The Bissell Point WWTF currently maintains four (4) operational multiple hearth incinerators (MHIs), each with a rated solids processing capacity of approximately 60 dry tons per day (dtpd). These MHIs and associated system components and equipment were primarily constructed under Contracts PA-09 (1964) and PA-16 (1965).

Each MHI is constructed of eleven cylindrical, stacked hearths. Dewatered sludge (cake) is fed to the MHI via high pressure hydraulic piston pumps. The cake is then moved via rabble arms located interior to each of the MHI hearths and falls by gravity through openings in each hearth's floor. The cake is combusted as it moved down through the hearths via use of gas fired burners situated at various locations about the MHI's sidewall (shell).

Air is also fed to the MHI's burners and hearths in order to provide ample excess air to safely ensure complete combustion of the cake. During the cake combustion process, a residual ash is produced. The majority of this ash is retained with the MHI and is further dried and cooled as it passes through the MHI's lower hearths.

Resultant dry ash is normally discharged from each MHI's bottom-most hearth (Hearth No. 11) by gravity to an ash hopper located underside each MHI. The ash is then transferred from the ash hopper via screw conveyor to ash sluice (mixing) tanks located adjacent to the MHIs.

During combustion, a fraction of the resultant ash is exhausted from the MHI as particulate entrained within the MHI flue gas. In the case of the Bissell Point WWTF MHI's, this fraction of the ash is captured within downstream air pollution control wet scrubber systems, which remove particulate, metals, and acid gasses from the MHI flue gasses prior to exhausting to atmosphere.

Drain water from each of the MHI's wet scrubbers is also directed to the ash sluice tanks. Within these tanks, dry ash from the MHIs is blended with the wet scrubber drain water to produce an ash slurry. The resultant ash slurry is then pumped to onsite ash storage lagoons.

Bissell Point WWTF currently operates two ash storage lagoons, each with a rectangular footprint of approximately 270 feet (ft) by 600 ft and an operating depth ranging from about 15.5 ft to 19.5 ft. These lagoons were originally constructed in the 1870's to serve as drinking water reservoirs. The exterior tank walls are constructed of limestone masonry, while the tank floor is constructed of 6-inch-thick unreinforced concrete overlaid with a 4-inch thick course of paving bricks. The lagoons were renovated in 1964 to remove original covers and to install at-grade access walkways and entrance ramps for heavy equipment.

Ash slurry is typically directed to one lagoon at a time via use of three existing above ground ash slurry lines. This approach leaves the other lagoon available for cleaning, repairs, or as standby. The slurry is fed to the in-service lagoon on the western-most edge of the structure. As the slurry flows eastwards through the lagoon, ash and particulate settle out to the lagoon floor, resulting in a "clean" supernatant. Each lagoon is equipped with a drain and decanting structure located at the eastern-most edge of the structure. During normal lagoon operation, adjustable height drain inlet pipes are used to allow the supernatant to be returned to the WWTF liquid stream for treatment.

Each of the ash storage lagoons has a usable storage volume of approximately 75,000 cubic yards of ash. Once this usable storage volume has been exhausted, the lagoon is brought offline (ash slurry is directed to the standby lagoon) and the lagoon is decanted via use of the underdrain. Once the lagoon is drained, ash and particulate collected on the lagoon floor are dredged via use of heavy equipment and transferred to trucks for conveyance to and disposal at St. Louis MSD's Prospect Hill Landfill.

Under Contract PA-49A (1977), the MHI ash system was modified to allow dry ash to be transferred directly from each MHI to a storage and loadout silo for more continuous truck loadout. Under this operation, dry ash is pulled via vacuum through an ash filter receiver (fabric filter) located at the top of an ash storage silo housed in a standalone building adjacent to the MHI building. The filter receiver separates the ash and particulate from the conveyance air and discharges the particulate to the storage silo below. The resultant clean air is then further scrubbed prior to re-introduction to the MHI flue gas stream. From the ash storage silo, ash is discharged by gravity to an ash conditioning screw conveyor. This conveyor injects and mixes water with the ash in order to reduce fugitive ash emissions prior to and during discharge to a truck below. The resultant conditioned ash is then hauled to St. Louis MSD's Prospect Hill Landfill.

Note that normal operation of the Bissell Point WWTF MHIs is to direct ash slurry to the onsite storage lagoons. The dry ash storage and offload system can be utilized on an as-needed contingency basis.

Section 5 provides a discussion regarding the existing condition and considerations for possible re-use of the Bissell Point WWTF ash lagoons for the future ash handling system.

2.1 LEMAY WWTF

The Lemay WWTF currently maintains three (3) operational MHIs, each with a rated solids processing capacity of approximately 60 dtpd. These MHIs and associated system components were primarily constructed under Contracts PA-09 (1964) and PA-13 (1964).

Similar to the arrangement of the Bissell Point WWTF MHIs, each MHI is constructed of eleven cylindrical, stacked hearths. Operationally, the Lemay WWTF MHIs are very similar to the Bissell Point WWTF MHIs, with one exception being that cake is fed to the MHIs via belt conveyors which discharge to inlet ports located at the top of each MHI. Once the cake is within the MHI hearths, the combustion process is identical to that already summarized above.

Unlike the Bissel MHIs, the Lemay MHI's are equipped with downstream waste heat recovery system (steam boilers). A majority of the particulate and ash entrained within the MHI's flue gas is dropped out in the boiler tubes. This portion of the ash is then conveyed and re-combined with the MHI's discharge dry ash.

Dry ash from the MHI and waste heat recovery systems is conveyed via screw conveyor to ash slurry hoppers located below the MHIs. The slurry hoppers blend the MHI dry ash with the drain water received from each the MHI's wet scrubber systems to create an ash slurry. The resultant ash slurry is then pumped to offsite ash storage lagoons via use of two existing buried ash slurry lines, with one line dedicated to each upstream ash slurry hopper. This arrangement offers MSD with limited operational redundancy should one line need to be taken offline for maintenance.

Lemay WWTF currently utilizes two offsite ash storage lagoons. Each lagoon is clay lined and has a usable capacity of approximately 40,000 cubic yards of ash. Ash slurry is typically directed to one lagoon at a time, leaving the other lagoon available for cleaning, repairs, or as standby. The slurry is fed to the in-service lagoon on the western-most edge. As the slurry flow eastwards through the lagoon, ash and particulate settle out to the lagoon floor, resulting in a "clean" supernatant. Each lagoon is equipped with a drain at the eastern-most edge of the structure. During normal lagoon operation, the drain is used to allow the supernatant to be returned to the WWTF liquid stream for treatment.

Similar to the approach at Bissell Point WWTF, once the usable storage volume of the in-service lagoon has been exhausted, the lagoon is brought offline (ash slurry is directed to the standby lagoon) and the lagoon is decanted via use of an underdrain. Once the lagoon is drained, ash and particulate collected on the lagoon floor is dredged by use of heavy equipment and transferred to trucks for conveyance to and disposal at St. Louis MSD's Prospect Hill Landfill.

Unlike Bissell Point WWTF, Lemay WWTF does not have the ability to direct dry ash to loadout on a contingency basis. As such, normal operation is to direct ash slurry to the offsite storage lagoons.

Section 5 provides a discussion regarding the existing condition and considerations for possible re-use of the Lemay WWTF ash lagoons for the future ash handling system.

3.0 Current and Future Ash Loading Projections

Estimates for ash production at the Bissell Point and Lemay WWTFs can be closely linked to current and future projected solids quantities established under TM No. 4 – Solids Processing Data Assessment and further discussed under TM No. 9 – FBI Design Criteria.

In summary, ash production can be correlated with the non-volatile (inert) fraction of the solids fed to the incinerators. This inert fraction is the component of the solids which is non-combustible, and which will directly correlate with the amount of particulate and ash produced as a byproduct of combustion.

For the purposes of selecting air pollution control equipment and to determine sizing associated with the ash handling systems, future estimated flood stage maximum month (MM) solids production will be utilized as the basis for design. Consideration has also been given to the installed FBI capacity to account for processing of stored solids in excess of future MM conditions. Note that this approach is consistent with the sizing criteria discussed under TM No. 9.

The following tables provide estimated current and future ash production at the Bissell Point and Lemay WWTFs. Note that each value for estimated ash production (current and future) assumes 100% capture of particulate within the incinerator air pollution control systems (i.e. wet scrubbers). Black & Veatch (B&V) considers this to be a reasonable assumption, considering that newer style wet scrubber systems offer 99%+ particulate removal efficiencies.

3.0 BISSELL POINT WWTF

Table 3-1 provides Bissell Point WWTF's current solids loading and volatile solids content, with a resultant estimate for ash production.

Table 3-1. Bissell Point WWTF Current Design Solids and Ash Quantities

Description	Total Solids, dtpd	% Volatile Solids	Estimated Ash Production, dtpd
Normal, AA	113.8	50.8	56.0
Normal, MM	148.5	50.9	72.9
Normal, PW	215.1	37.5	134.4
Flood Stage, MM	227.5	35.4	147.0
Flood Stage, PW	281.8	30.5	195.9

AA = Annual Average; MM = Max Month; PW = Peak Week; dtpd = dry tons per day.

Historical ash production quantities reported within MSD's Solids Handling TM No. 9: Fluidized Bed Incinerators (MSD, June 2018) were reviewed for comparison purposes. This memorandum reported an average of 23,605 cubic yards of ash produced at Bissell Point WWTF per year between years 2010-2017. This equates to approximately 55 dry tons of ash hauled to landfill per day. As such, it appears that ash production estimates summarized within Table 3-1 are generally consistent for average conditions.

Table 3-2 provides Bissell Point WWTF's projected future solids loading and volatile solids content, with a resultant estimate for ash production.

Table 3-2. Bissell Point WWTF Future Design Solids and Ash Quantities

Description	Total Solids, dtpd	% Volatile Solids	Estimated Ash Production, dtpd
Normal, AA	134.8	42.9	77.0
Normal, MM	168.1	44.9	92.6
Normal, PW	246.8	32.6	166.3
Flood Stage, MM	250.1	32.2	169.6
Flood Stage, PW	300.3	28.7	214.1
AA = Annual Average; MM = Max Month; PW = Peak Week; dtpd = dry tons per day.			

As noted above, flood stage MM will be utilized as the basis of design for sizing ash system components discussed under Section 4.

3.1 LEMAY WWTF

Table 3-3 provides Lemay WWTF's current solids loading and volatile solids content, with a resultant estimate for ash production.

Table 3-3. Lemay WWTF Current Design Solids and Ash Quantities

Description	Total Solids, dtpd	% Volatile Solids	Estimated Ash Production, dtpd
Normal Operation, AA	73.7	60.1	29.4
Normal Operation, MM	89.2	54.4	40.6
Normal Operation, PW	113.4	52.4	54.0
Flood Stage, MM	110.4	47.2	58.3
Flood Stage, PW	146.5	38.7	89.8
AA = Annual Average; MM = Max Month; PW = Peak Week; dtpd = dry tons per day.			

Historical ash production quantities reported within MSD's Solids Handling TM No. 9: Fluidized Bed Incinerators (MSD, June 2018) were reviewed for comparison purposes. This memorandum reported an average of 25,868 cubic yards of ash produced at Lemay WWTF per year between years 2010-2017. This equates to approximately 60 dry tons of ash hauled to landfill per day. When comparing against Table 3-3, this value is considerably higher than either the average or peak conditions during normal operation.

It should be noted that MSD's reported ash hauling data for Bissell Point and Lemay WWTF's appears to show more ash hauled from Lemay annually compared to Bissell Point. This does not appear to correlate with the higher quantities and lower volatile content for solids processed at Bissell Point WWTF. OA team members have noted the possibility that historically stabilized ash within the Lemay WWTF's ash lagoons may have been hauled to landfill over this period; however, no firm explanation is apparent at this time.

Table 3-4 provides Lemay WWTF's projected future solids loading and volatile solids content, with a resultant estimate for ash production.

Table 3-4. Lemay WWTF Future Design Solids Quantities

Description	Total Solids, dtpd	% Volatile Solids	Estimated Ash Production, dtpd
Normal, AA	111.6	56.4	48.7
Normal, MM	122.9	49.9	61.6
Normal, PW	144.7	52.6	68.6
Flood Stage, MM	165.2	50.8	81.3
Flood Stage, PW	211.9	43.6	119.5

AA = Annual Average; MM = Max Month; PW = Peak Week; dtpd = dry tons per day.

As noted above, flood stage MM will be utilized as the basis of design for sizing ash system components.

In reviewing the above data, relatively low solids volatile content (%VS) was noted for both the Bissell Point and Lemay WWTFs. For the future FBI installations, combustion will occur in the sand bed (fluidized bed) and within the reactor's lower freeboard. Unlike MHIs, where the resultant ash is contained within the incinerator's hearths, ash produced within FBIs is almost entirely expelled from the reactor as air-entrained particulate. There are some exceptions, with the most notable being that solids associated with wet-weather events (i.e. silt and mud) generally consist of large and heavy particles. During large wet weather events where a significant fraction of the solids fed to the reactor are non-volatile, it is possible that sand bed levels could rise gradually over time. Over longer periods of time and repeated high river levels, the sand bed level has the potential to become problematic for FBI operation, as this level is interlocked with the sludge feed to an FBI. Should the sludge feed need to be cut off, the incinerator could be operated with auxiliary fuel only for a period to allow for the accumulated grit to be broken into smaller particles and expelled within the flue gas.

4.0 Dry and Wet Ash Handling System Options

4.1 OVERVIEW OF ASH HANDLING SYSTEMS

Dry ash systems are fairly common for facilities operating MHIs. This is generally due to the design of MHIs, where the majority of the ash is contained within the MHI hearths rather than being expelled within the incinerator's flue gasses.

The relatively small fraction of particulate contained within the MHI flue gas can be removed in either a dry or wet form. For facilities wishing to operate dry ash systems, a dry cyclonic scrubber or fabric filter can be utilized, although dry cyclonic scrubbers are far more common for MHI installations. For facilities operating wet ash systems (such as the Bissell Point and Lemay WWTFs) the remaining particulate can instead be removed in the MHI's air pollution control wet scrubber systems. For the handling of the dry ash from the base of MHI, equipment is required to convey the dry ash, slurry it, and convey the resultant ash slurry (as is currently performed at Bissell Point and Lemay WWTFs)

Unlike MHI facilities, FBI facilities more commonly utilize a wet ash system. This is generally due to the design of FBIs, where the majority of the ash is exhausted from the reactor as particulate entrained within the flue gas. This particulate can be removed from the flue gas by a fabric filter (baghouse) as dry ash or much more commonly as an ash slurry by a wet scrubber system. Refer to Section 4.2 for further discussion.

The following sections describe wet ash and dry ash system options available for the new FBI systems to be installed at Bissell Point and Lemay WWTFs.

4.2 OPTION 1 – WET ASH SYSTEM

As previously noted, wet ash systems are more prevalent for facilities operating FBIs. This is the case for newer FBI installations in Cincinnati, Cleveland, Green Bay, and Toronto (among others).

In the case of the Bissell Point and Lemay WWTF's, the presence of existing ash lagoons makes a wet ash system more favorable as finding space for lagoons often becomes a limiting factor for retrofit installations. In some cases, the inability to find suitable locations for lagoons has single handedly resulted in a dry ash handling system.

With installation of any of the FBI system components discussed under TM No. 9, a wet ash system could be achieved; however, additional equipment may be required in association with some potential FBI system components. As such, two options for wet ash systems have been developed: one without any dry ash system components (Option 1A), and one with dry ash system components to handle dry ash captured in waste heat boilers and/or fabric filters. (Option 1B). Refer to TM No. 9 for additional discussion of these potential FBI system components.

4.2.1 Option 1A – Wet Ash System for FBI System Without Dry Ash Components

4.2.1.1 Option 1A – Description

In general, newer style impingement and multiple venturi style wet scrubber systems are vastly improved compared to older style scrubbers. Wet scrubber manufacturers such as EnviroCare and Hitachi provide standard performance guarantees for removal efficiencies of 99%+ for particulate matter (PM). As a result, utilizing a wet scrubber as the primary means of PM control is a straightforward and cost-effective approach, especially considering that a wet scrubber system will be needed for the control of metals and acid gasses (sulfur dioxide and hydrochloric acid) regardless of the ash handling approach. Refer to TM No. 9 for further discussion.

If a wet ash system is selected for the planned FBI installations, and no upstream FBI system components are installed which require dry ash handling (e.g. waste heat recovery or fabric filter), then the wet ash system would be relatively non-complex as the system would only need to handle the ash slurry produced within the wet scrubber system itself.

Figure 4-1 provides a typical schematic of this layout, where particulate removed within the scrubber and downstream wet electrostatic precipitator (WESP) is slurried within the wet scrubber.

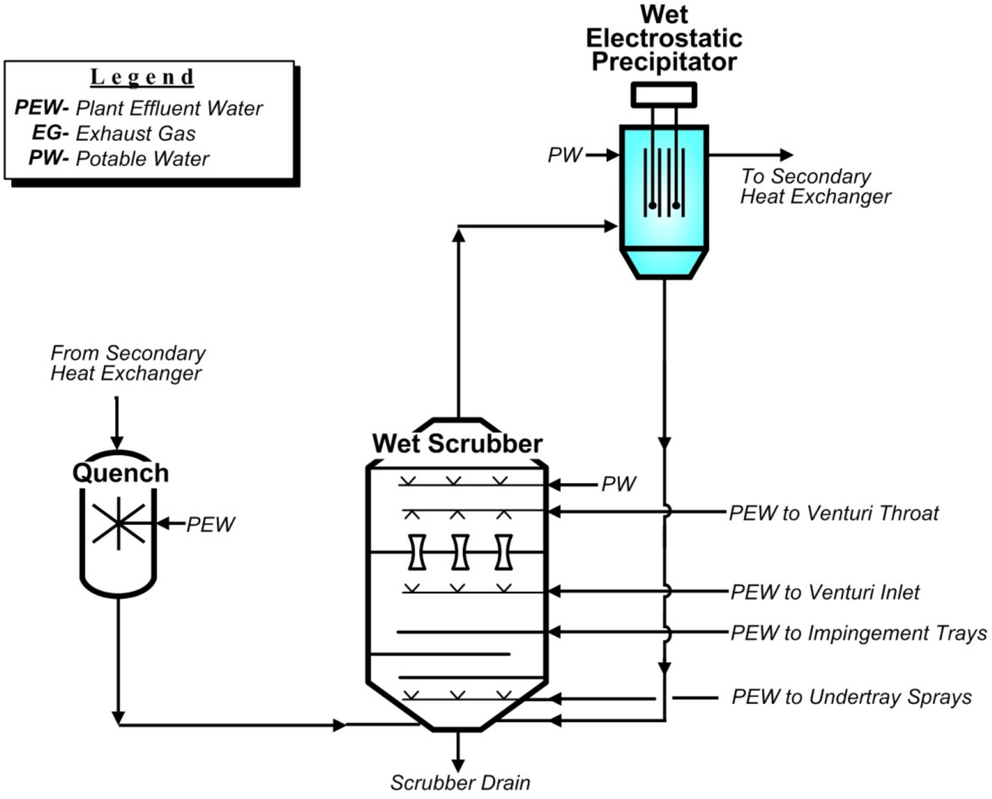

Figure 4-1. Wet Scrubber and WESP System Schematic

Under this approach, the wet scrubber sump would likely be sized to provide several minutes of scrubber drain water (ash slurry) retention time. This could negate the need to install a separate ash slurry tank at the discharge of the scrubber system, which would be beneficial both from a cost and space/footprint standpoint.

Figure 4-2 provides an example layout of a wet scrubber system designed to provide retention time within the scrubber sump. This layout is representative of an EnviroCare wet scrubber system; however, other wet scrubber system manufacturers offer similar arrangements.

Ash slurry pumps could be installed directly downstream of each wet scrubber system, coupled to the wet scrubber sump drain outlet. These pumps are typically equipped with variable speed drives (VFDs) and operate to maintain level within the wet scrubber sump, which would be monitored by pressure type level instrumentation.

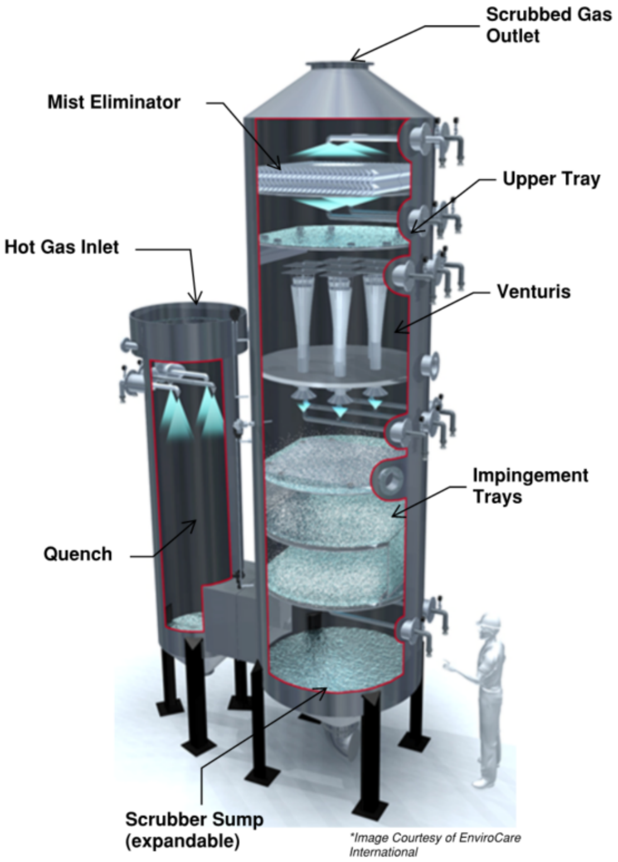

Figure 4-2. Example Impingement/Venturi Wet Scrubber Layout with Enlarged Sump

Figure 4-3 shows an example installation of ash slurry pumps installed directly downstream of a wet scrubber system. For this example, two pumps are installed in a duty-standby arrangement for each wet scrubber. In lieu of this arrangement, it would also be feasible to install a common drain header from multiple wet scrubber systems and direct to a common area with fewer pumps.

Figure 4-3. Example Installation of Ash Slurry Pumps Installed Directly to Wet Scrubber Drain Outlet

Under Option 1A, ash slurry pumps would continue to direct the slurry to ash lagoons. Given the abrasivity of the slurry, it is recommended to install redundant pipelines with crossover capability to allow for conveyance to each lagoon. With this arrangement, should a pipeline need to be taken out of service for cleaning or repair, upstream FBI systems or system components could remain online.

With the approach of installing pumps coupled directly to the wet scrubber drain outlet, only a few minutes of ash slurry retention time is provided within the wet scrubber sump. This is beneficial from the standpoint that the slurry entrained particulate (ash) will not have sufficient time to settle out; however, it could become problematic should there be an issue with the pumps. As such, with this type of arrangement, an overflow line would be provided. The most economical approach would be to allow this overflow line to drain by gravity to another process drain system, such as a centrate sidestream or sanitary sewer back to the WWTF liquid stream for treatment..

Table 4-1 provides preliminary descriptions, design criteria, and functional requirements associated with equipment anticipated under Option 1A.

Table 4-1. Option 1A - Preliminary Design Criteria / Functional Requirements

COMPONENT	DESCRIPTION / FUNCTIONAL REQUIREMENTS
Wet Scrubber Sump	*Wet Scrubber Manufactured with Enlarged Sump* *(Refer to TM No. 9 for Additional Description)*
Anticipated Scrubber / WESP Drain Flow (gpm)	1,500
Sump Capacity (gallons)	7,500
Ash Slurry Pumps	*Pumping of Ash Slurry*
Type	Centrifugal, abrasion resistant lined
Number	1 duty/1 standby per wet scrubber
Motor Size (hp)	75 (to be confirmed)
Drive Type	Variable Speed
Capacity at max speed (gpm)	1,600
Discharge Head @ 1,600 gpm (ft)	115 (to be confirmed)
Ash Slurry Piping	*Transfer of Ash Slurry to Ash Lagoons*
Type	High Density Polyethylene (HDPE) (to be confirmed)
Number	3 (one per lagoon with one standby)
Distance (feet)	To be determined based on selected FBI building location
Diameter (inch)	10
Ash Lagoons	*Existing Ash Storage Lagoons – Repurposed for New FBI Systems*
Type - Bissell Point WWTF - Lemay WWTF	 Rectangular, concrete and brick lined Rectangular, clay/ liner with rock lining
Capacity (cy) - Bissell Point WWTF - Lemay WWTF	 75,000 40,000

4.2.2 Option 1B – Wet Ash System for FBI System with Dry Ash Components

If a wet ash system is selected for the planned FBI installations, and upstream FBI system components are installed which require dry ash handling (e.g. waste heat recovery or fabric filter), additional ash handling equipment would be required.

Under this FBI system arrangement, the ash handling systems would need to incorporate components designed to convey ash in a dry form prior to producing an ash slurry; these components would be similar to the existing MHI ash handling systems at the Bissell Point and Lemay WWTFs (refer to Section 2).

A waste heat recovery system (boiler) would be installed upstream of wet scrubbers (and other air pollution control devices). As the hot exhaust gas from the through the boiler's internal tubes, particulate drops out and accumulates at the bottom of the boiler vessel where it must then be periodically removed.

Figure 4-4 shows one example of a waste heat boiler ash discharge approach. In this example, multiple discharge points are tied to a single boiler ash discharge screw conveyor, which in turn feeds a pneumatic conveyance system.

Figure 4-4. Example Boiler Ash Discharge Approach

Under this type of arrangement, the dry boiler ash would need to be conveyed to an ash slurry tank for mixing with the wet scrubber drain water. As such, an enlarged wet scrubber sump would not be required as discussed under Section 4.2.1 with the scrubber drain water directed instead to the common ash slurry tank. Given the distances that the dry ash would need to be conveyed in a facility of this size with multiple FBIs, it is likely that a dense phase pneumatic conveyance system would be utilized in lieu of screw conveyors. As such, the dry ash would likely be batch transported within pneumatic conveyance pots located near the dry ash discharge location(s). Pneumatic ash conveyance piping would be installed to discharge the dry ash directly into the common ash slurry tank.

Figure 4-5 provides an example schematic of this type of arrangement.

Once discharged to the ash slurry tank, the dry ash would then be mixed with the wet scrubber drain water. This could be a pumped system or some type of stationary mechanical mixer (e.g. submersible or vertical mixer). Note that continuous mixing would also be required in order to ensure that particulate does not settle out within the ash slurry tanks.

The combined ash slurry from the wet scrubbers and waste heat recovery equipment would be directed to lagoons via larger ash slurry pumps similar to those discussed under Section 4.2.1. Redundant pipelines with crossover capability would also be provided similar to Option 1A to allow for conveyance to each lagoon.

Figure 4-6 shows an example of larger ash slurry pumps installed adjacent two common ash slurry tanks. These tanks mix a pneumatically conveyed dry ash from waste heat boilers boilers and ash slurry from the wet scrubber drain.

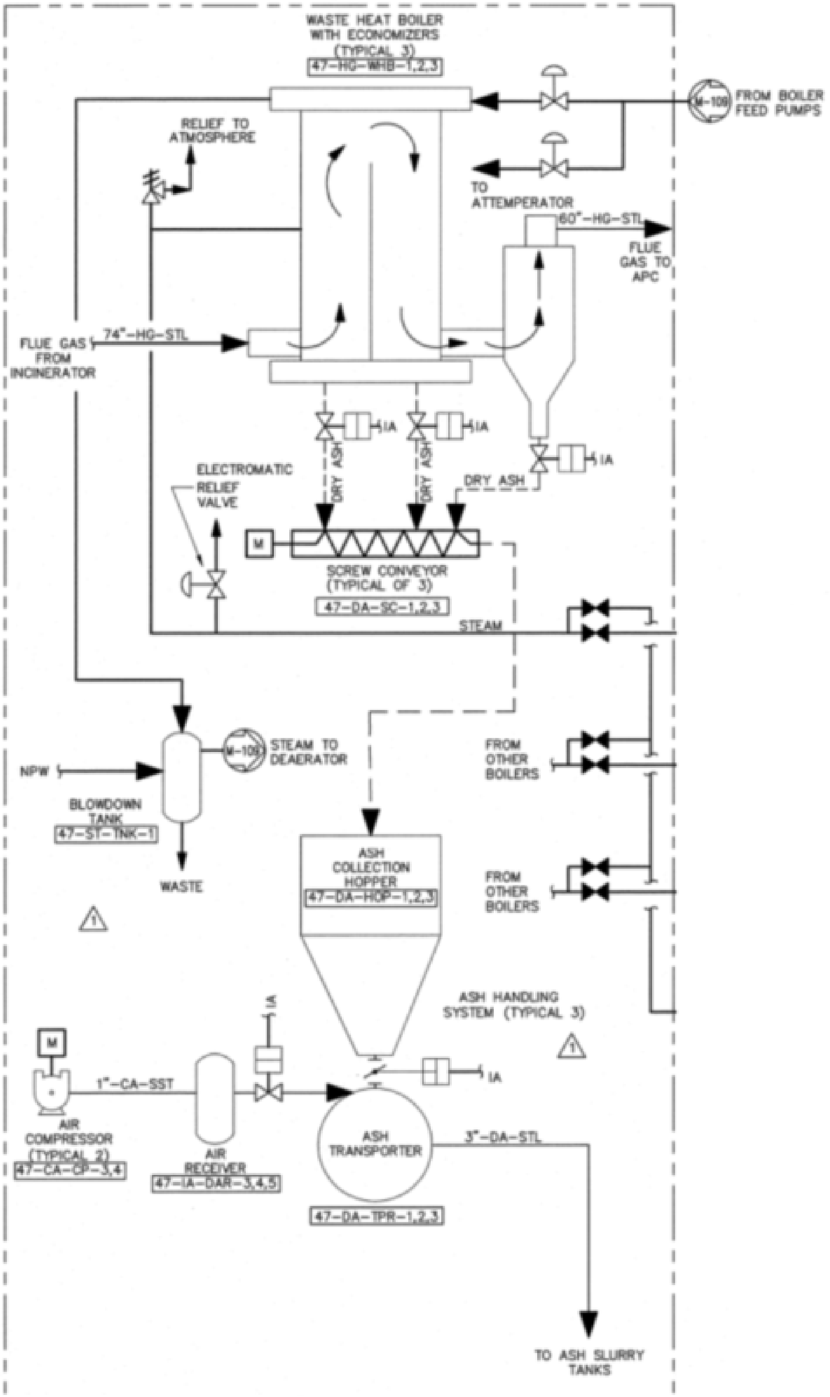

Figure 4-5. Example Integration of Boiler Ash Discharge to an Ash Slurry Tank

Figure 4-6. Example Installation of Ash Slurry Pumps Downstream of Ash Slurry Tanks

Note that the above discussion focuses on waste heat boiler dry ash handling. Further explanation of the fabric filter system is provided under Section 4.3; however, under Option 1B, should a fabric filter be installed in lieu of (or in addition to) a waste heat recovery system, fabric filter dry ash would be handled in the same manner as previously discussed.

Table 4-2 provides preliminary descriptions, design criteria, and functional requirements associated with equipment anticipated under Option 1B.

Table 4-2. Option 1B - Preliminary Design Criteria / Functional Requirements

COMPONENT	DESCRIPTION / FUNCTIONAL REQUIREMENTS
Dry Ash Discharge from Waste Heat Boiler or Fabric Filter	*Dry Ash Discharge from FBI System Components*
Type	Dense Phase Pneumatic Conveyance with Pneumatic Transfer Pots
Number	One per Dry Ash Discharge Location
Capacity (dry tons per hour) - Bissell Point WWTF - Lemay WWTF	 7 (divided by number of duty FBI trains; refer to TM No. 9) 3.5 (divided by number of duty FBI trains; refer to TM No. 9)
Dry Ash Conveyance Piping	*Conveyance of Dry Ash to Ash Slurry Tanks*
Type	Ceramic Lined with Long Radius / Abrasion Resistant Fittings
Number	2 per Pneumatic Transporter (one to each ash slurry tank)
Diameter (inch)	4 (to be confirmed)
Wet Scrubber Drain Piping	*Ash Slurry Conveyance from Wet Scrubbers to Ash Slurry Tanks*
Type	High Density Polyethylene (HDPE) (to be confirmed)
Number	One per Wet Scrubber
Diameter (inch)	10 (to be confirmed)
Ash Slurry Tanks	
Type	Formed Concrete with Sloped Bottoms
Number	2
Capacity (gallons)	40,000 each (to be confirmed)
Ash Slurry Pump Mixing System	*Mixing of Ash Slurry Tanks*
Type	Pumps, Centrifugal
Number	2 (one per ash slurry tank)
Capacity (gpm)	750
Discharge Head (ft)	70 (to be confirmed)
Ash Slurry Pumps	*Pumping of Ash Slurry*
Type	Centrifugal, abrasion resistant lined
Number	2 (one per ash slurry tank with crossover capability)
Motor Size (hp)	125 (to be confirmed)
Drive Type	Variable Speed
Capacity at max speed (gpm)	1,600 per duty FBI train (refer to TM No. 9)

COMPONENT	DESCRIPTION / FUNCTIONAL REQUIREMENTS
Discharge Head @ 1,600 gpm (ft)	115 (to be confirmed)
Ash Slurry Piping	*Transfer of Ash Slurry to Ash Lagoons*
Type	High Density Polyethylene (HDPE) (to be confirmed)
Number	3 (one per lagoon with one standby)
Distance (feet)	To be determined based on FBI building location
Diameter (inch)	10
Ash Lagoons	*Existing Ash Storage Lagoons – Repurposed for New FBI Systems*
Type - Bissell Point WWTF - Lemay WWTF	 Rectangular, brick lined Rectangular, clay/ liner with rock lining
Capacity (cy) - Bissell Point WWTF - Lemay WWTF	 75,000 40,000

4.3 OPTION 2 – DRY ASH SYSTEM

There are limited FBI installations with dry ash systems. One example is the Minneapolis / St. Paul Metro WWTP which use a dry ash system to handle dry ash from both waste heat recovery systems and fabric filters.

One possible operational advantage associated with dry ash systems includes the ability to more continuously offload ash to trucks. This offload approach would be in lieu of annual or biennial ash dredging and disposal required for ash lagoons. This type of approach could be advantageous if the ash needs to be directed for beneficial re-use on a more regular basis versus periodically following dredging. Beneficial re-use options include using ash as a soil amendment or additive (refer to Section 8 for additional discussion). However, if the dry ash system is utilized to capture mercury (see discussion below) it is unlikely that the resultant metals content of the ash would allow the material to be beneficially reused in certain applications. Note also that more consistent offload of ash would require more frequent truck traffic to and from the WWTF, which could pose a logistics and traffic concern.

In order to incorporate a dry ash system for the Bissell Point and Lemay WWTF FBI systems, an effective means of particulate control would need to be installed upstream of the wet scrubbers to keep the majority of the ash and particulate in a dry form. As discussed under TM No. 9, this could be achieved by a fabric filter (baghouse) or dry cyclone scrubber. Unlike with a dry cyclone, powder activated carbon (PAC) could be injected upstream of the fabric filter for mercury (Hg) control. Note that this technology is capable of meeting air pollutant emissions standards for mercury for new FBI installations. As such, if a dry ash system is selected, then it is likely that PAC would be recommended in lieu of other mercury removal technologies, namely granular activated carbon (GAC). Refer to TM No. 9 for additional discussion regarding these technologies.

Fabric filters also offer significantly higher particulate removal efficiency compared to dry cyclones, resulting in less particulate entrained in the downstream wet scrubber drain water. With a dry ash system, the wet scrubber drain water would likely be returned to the WWTF liquid stream directly for treatment in lieu of flowing through an ash lagoon. However, should metals contained with the wet scrubber drain water become a compliance concern for the liquid stream treatment process, it is possible that sidestream treatment (e.g. chemical precipitation) would be required. As such, a dry ash system should be designed to remove as much particulate upstream of the wet scrubber system as possible.

The dry cyclone option may be beneficial compared to a fabric filter when considering initial capital cost and building footprint requirements. This option would be considerably less expense compared to a fabric filter and would be easier to fit within a limited space; however, costs associated with potentially needing to perform sidestream treatment of the downstream wet scrubber drain water may outweigh the potential cost benefits. Furthermore, dry cyclones are not suitable for PAC injection, which would dictate the need for downstream GAC absorbers to be installed for mercury removal; refer to TM No. 9 for further discussion. Cost associated with this additional equipment would likely outweigh savings associated with the dry cyclone.

Figure 4-7 provides an example schematic of a dry ash system incorporating a fabric filter. As shown, PAC is injected to the flue gas stream to bind mercury, and particulate is captured downstream in the fabric filter itself. Refer to TM No. 9 for additional discussion of this technology.

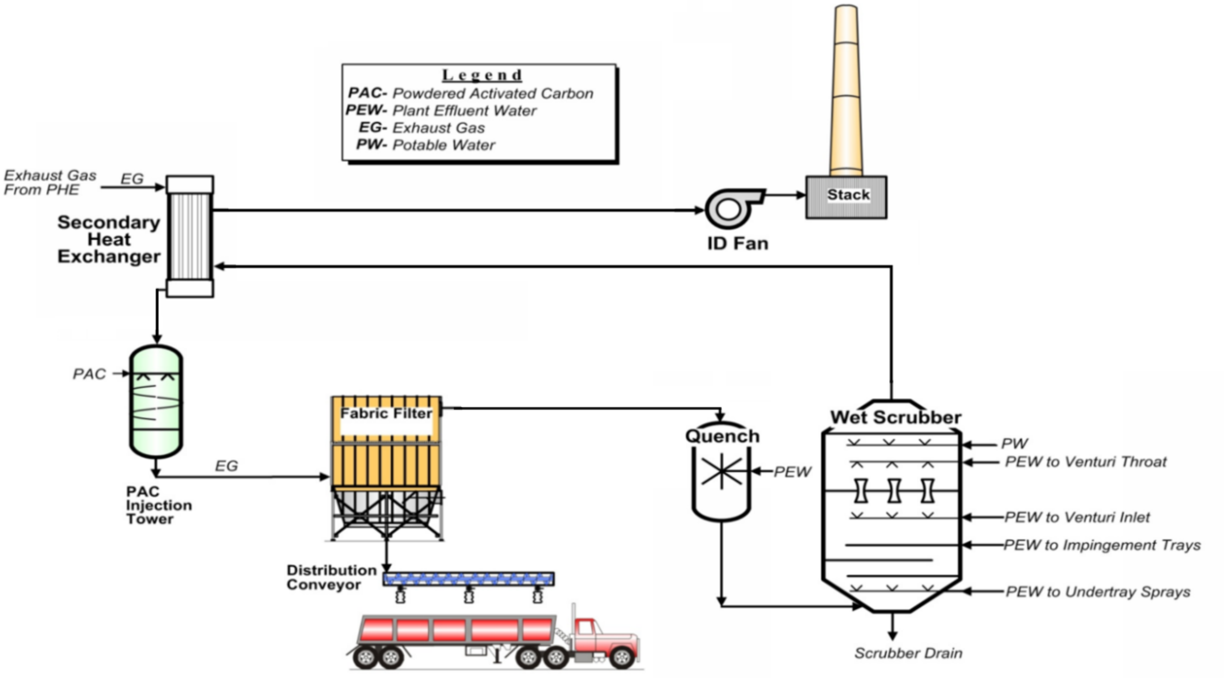

Figure 4-7. Example Schematic of Dry Ash System Incorporating a Fabric filter

Under this arrangement, dry ash would need to be conveyed to an ash storage and offload facility exterior to the incinerator building. As discussed previously, given the distances that the dry ash would need to travel in a facility of this size with multiple FBIs, it is likely that a dense phase pneumatic conveyance system would be utilized in lieu of screw conveyors. As such, the dry ash would likely be batch transported within pneumatic conveyance pots located near the boiler and/or fabric filter ash discharge location(s). Pneumatic ash conveyance piping would be installed to discharge the dry ash directly to a storage silo prior to offload.

Figure 4-8 provides an example of a pneumatic conveyance system installed downstream of a fabric filter ash discharge.

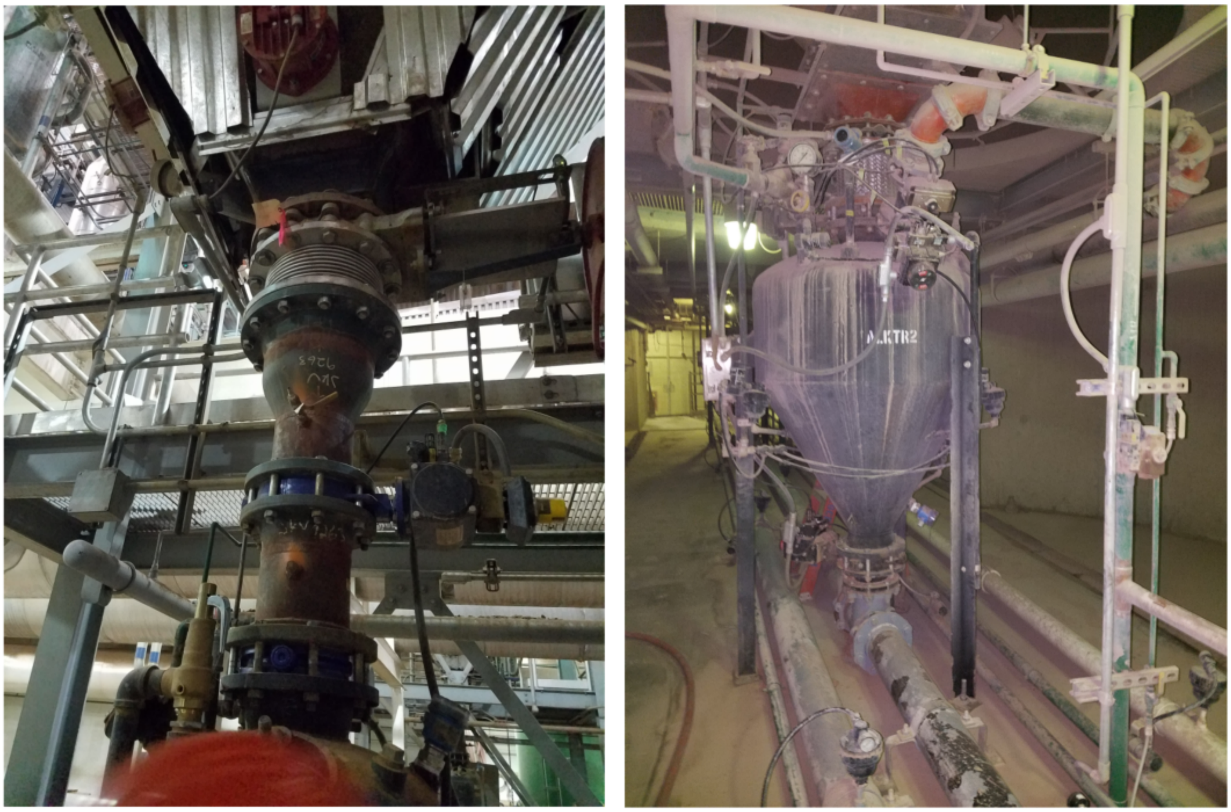

Figure 4-8. Example of Fabric filter Ash Discharge and Dense Phase Pneumatic Conveyance System

Figure 4-9 provides an example overall schematic of a dry ash handling system for waste heat recovery (boiler) and fabric filter ash discharge to a loadout facility.

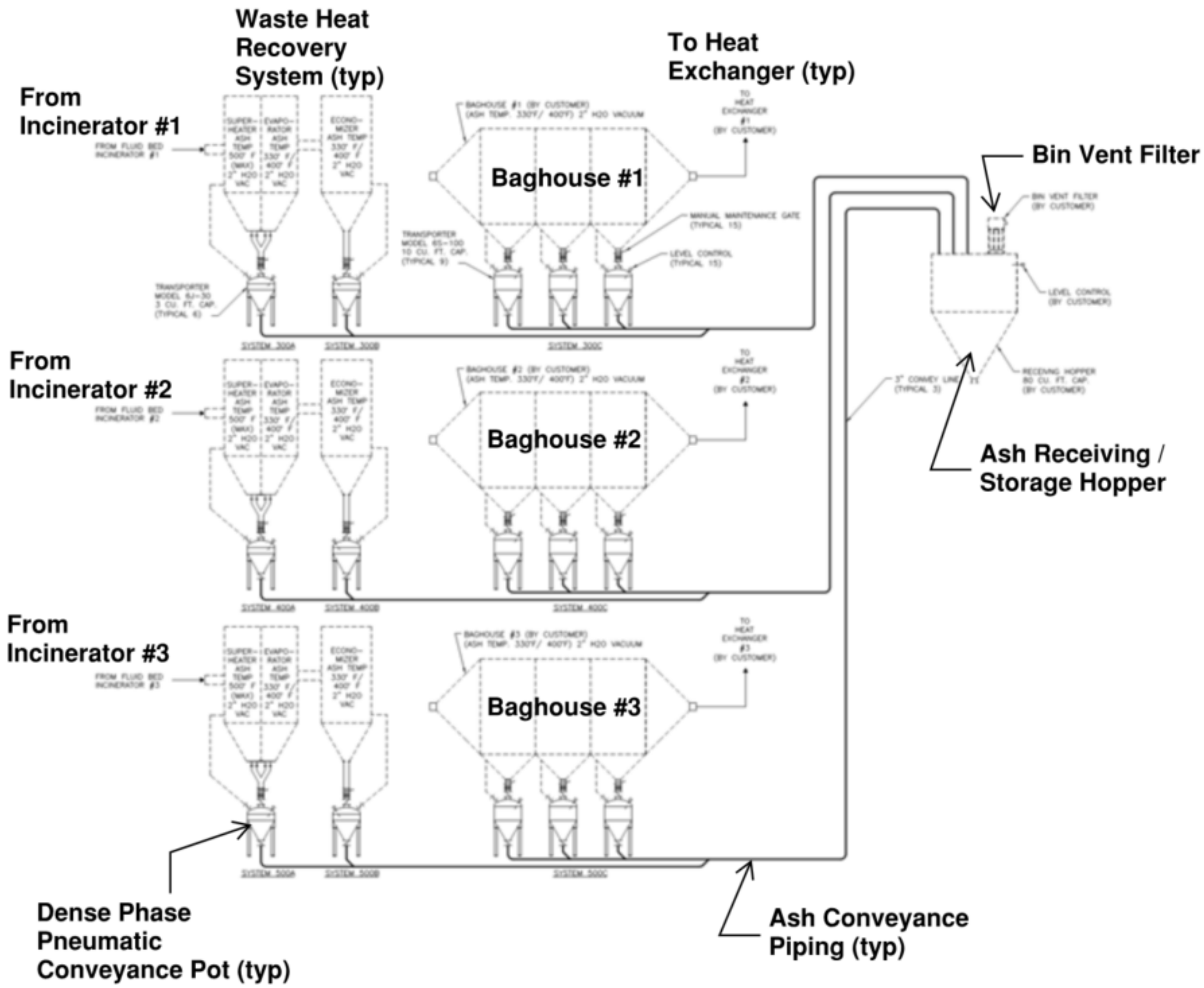

Figure 4-9. Example Boiler and Fabric filter Dry Ash Conveyance Schematic to Loadout

Prior to discharge of the dry ash to truck, ash conditioning would be required in order to minimize fugitive ash emissions within/from the ash loadout facility. Ash conditioning would likely consist of a conditioning screw conveyor with water injection, similar to the existing contingency ash offload facility at Bissell Point WWTF. Refer to Section 7 for additional discussion regarding regulatory considerations.

Figures 4-10 and 4-11 provide examples for conditioned ash loadout facilities. Note that Figure 4-10 shows an outdoor facility where dry ash is stored within a live bottom silo interior to the building. In this arrangement, dry ash is pulled out of the interior silos and conditioned with a conditioning screw conveyor (obscured in photo). Figure 4-11 shows an indoor facility where ash is stored and conditioned in one location.

Figure 4-10. Example Dry Ash Loadout Facility (Outdoor)

Figure 4-11. Example Dry Ash Loadout Facility (Indoor)

Table 4-3 provides preliminary descriptions, design criteria, and functional requirements associated with equipment anticipated under Option 2.

Table 4-3. Option 2 - Preliminary Design Criteria / Functional Requirements

COMPONENT	DESCRIPTION / FUNCTIONAL REQUIREMENTS
Dry Ash Discharge from Waste Heat Boiler or Fabric filter	*Dry Ash Discharge from FBI System Components*
Type	Dense Phase Pneumatic Conveyance with Pneumatic Transfer Pots
Number	One per Dry Ash Discharge Location
Capacity (dry tons per hour) - Bissell Point WWTF - Lemay WWTF	 7 (divided by number of duty FBI trains; refer to TM No. 9) 3.5 (divided by number of duty FBI trains; refer to TM No. 9)
Dry Ash Conveyance Piping	*Conveyance of Dry Ash to Ash Slurry Tanks*
Type	Ceramic Lined with Long Radius / Abrasion Resistant Fittings
Number	2 per Pneumatic Transporter (one to each dry ash storage silo)
Diameter (inch)	4 (to be confirmed)
Dry Ash Storage Silos	*Storage of Dry Ash Prior to Loadout*
Type	Cylindrical Silo
Number - Bissell Point WWTF - Lemay WWTF	 5 3
Diameter (ft)	16
Height (ft)	30
Capacity (total cu ft)	30,000
Dry Ash Storage (maximum time between loadouts) Bissell Point WWTF - Normal MM - Flood Stage MM Lemay WWTF - Normal MM - Flood Stage MM	 - 1 week - 3-4 days - 9 days - 4-5 days
Dry Ash Conditioning Conveyors	*Inject and Mix Water to Condition Dry Ash*
Type	Pugmill (twin screw conveyor)
Number	5 (one per storage silo)
[1,2]Capacity (cu ft ash / hr)	700
[2]Conditioning water (gpm)	20

COMPONENT	DESCRIPTION / FUNCTIONAL REQUIREMENTS
Conditioned Ash Loadout Conveyors	*Loadout Conditioned Ash to Truck*
Type	Shaftless Screw Conveyor
Number	2 (duty standby)
[2]Capacity (cu ft conditioned ash / hr)	860
Conditioned Ash Discharge Chutes	*Direct Conditioned Ash Uniformly Throughout Loadout Truck*
Type	Knife Gate Valves with Downstream Retractable Discharge Chutes
Number	8 (4 per loadout conveyor)
[1]Assumes loadout of ash to 20 wet ton capacity truck in 1 hour. [2]Assumes ash is conditioned to ~40% moisture content.	

4.4 OPTION 3 – COMBINED WET ASH AND DRY ASH SYSTEMS

MSD has expressed some interest in retaining the flexibility to operate both a dry ash and a wet ash handling system in the future. The OA Team understands that the main driver is to maintain current use of existing ash lagoons while retaining the ability to offload dry ash on a more continuous basis, should MSD identify an opportunity for ash beneficial re-use on a more continuous basis. This would be somewhat similar to the current ash handling approach at Bissell Point WWTF; refer to Section 2.

In order to achieve this level of flexibility, most of the wet ash and dry ash handling facilities described under Options 1 and 2 would be required. This would have significant implications from a capital cost, operations cost, maintainability, and space/footprint requirements standpoint.

Considering these challenges, one alternate approach would be the installation of removable ducting segments to allow for the future installation of dry ash collection and handling equipment (i.e. fabric filter or cyclone separator). This approach would allow MSD to identify and evaluate options for more continuous ash beneficial reuse without committing as significant of an investment to additional equipment under this initial project. Should MSD identify an attractive beneficial reuse option in the future, dry ash handling facilities similar to those discussed under Section 4.3 could then be installed.

Refer to Table 4-2 and 4-3 for wet ash and dry ash handling equipment which would ultimately be required under this alternative.

Note that preliminary estimates of cost presented under Section 9 for Option 3 assumes that space is allocated for future dry ash handling equipment in lieu of installing this equipment under the initial project.

5.0 Existing Ash Lagoons

Under either of the wet ash handling options discussed herein, it is anticipated that MSD's existing Bissell Point and Lemay WWTF ash lagoons will be reused. Refer to Section 2 for a description of the existing lagoons.

Previous evaluations and reports have identified various issues with the existing ash lagoons. These issues are summarized below:

September 2009 Condition Assessment Report

- Lemay WWTF Ash Lagoons:
    - Approximately 2 miles of existing ash slurry transfer lines are in poor condition (two lines, each approximately 1 mile in length).
    - No redundancy for existing ash slurry transfer lines; should one line need to be taken offline, all upstream components must also be taken offline.
    - Lagoons have occasional discharge violations due to overfilling.

December 2014 Bissell Point Ash Tank Floor Replacement Study

- Bissell Point WWTF Ash Lagoons:
    - During high river stages, liquid levels rise in the ash storage lagoons, suggesting infiltration and exfiltration of river water and ash slurry, respectively.
    - Extensive damage to existing concrete and brick lagoon floor.
    - Theorized that groundwater-induced buoyancy forces (hydrostatic pressure) have caused floor damage.

The following sections provide a discussion regarding suggested improvements for the future use of ash lagoons at Lemay and Bissell Point WWTFs.

5.1 FUTURE USE OF LEMAY WWTF ASH LAGOONS

The September 2009 Condition Assessment Report suggested that MSD could consider relocation of the existing Lemay WWTF ash lagoons to the nearby Defense Mapping site; however, it is now anticipated that the majority of this area is accounted for as part of other planned future MSD projects. As such, with no other potential locations currently identified for replacement lagoons, it is anticipated that the current lagoons will continue in-service.

In order to address the issues identified under the 2009 Condition Assessment, the following improvements are suggested:

- Replace existing ash slurry transfer pipelines as discussed under Section 4.2.
- Provide additional level monitoring of lagoons to help ensure that overfilling can be prevented in the future.

Preliminary estimates of costs associated with these suggested improvements are included under Section 9.

5.2 FUTURE USE OF BISSELL POINT WWTF ASH LAGOONS

The December 2014 evaluation of the existing Bissell Point WWTF ash lagoons identified three potential alternatives for fixing the issues previously identified. These include:

- Alternative 1: Install a new underdrain system and new concrete floors.
  - This alternative involves removing the existing lagoon floors and installation of underdrains systems below the existing floor elevation. The underdrain system would collect and convey groundwater from below the slab via use of a new pump station.
  - Upon installation of the underdrain system, new lagoon floors would be installed at the same elevation as existing in order to retain the capacity of the existing ash lagoons.
  - The preliminary opinion of probable construction cost (OPCC) for this alternative is approximately $10M, as escalated from the OPCC presented in the December 2014 report.
- Alternative 2: Install underdrain system and new concrete floors above existing floors.
  - This alternative is very similar to the previous alternative, with the exception that the new floor would be installed over the existing concrete floors of the ash lagoons (existing brick lining would be demolished). This alternative would save some cost associated with the demolition and removal of the existing concrete floors.
  - The preliminary OPCC for this alternative is approximately $8.2M, as escalated from the OPCC presented in the December 2014 report.
- Alternative 3: Implement operational changes and perform selective floor repairs
  - This alternative suggests that buoyancy forces during rising river stages be offset by pumping additional plant effluent water to the lagoons periodically. As such, the alternative would include a large plant effluent pump station.
  - Furthermore, selective repairs to the existing lagoon floors would be made in an attempt to address exfiltration. For the purposes of cost estimating, it was originally assumed that 25% of the existing lagoon floor would need repairs.
  - The preliminary OPCC for this alternative is approximately $3.5M, as escalated from the OPCC presented in the December 2014 report.

The December 2014 evaluation stopped short of making a final recommendation as to the repairs which should be made to each of the existing Bissell Point WWTF ash lagoons; however, the evaluation did offer recommendations regarding further investigatory work to be conducted to help better inform the decision-making process. These included:

- Conduct inspection of the tank floor when drained to further investigate the cause of the floor deterioration. The inspection should also identify areas of repair to provide a more accurate estimate of floor removal and repairs.
- Conduct an investigation of the soil conditions and groundwater conductivity. A minimum of four borings should be collected in each basin. Several borings should be located around the basins with piezometers installed to measure ground water level.

- Review operations impact if plant effluent water is pumped into the basins to offset buoyancy forces.

Further discussion with MSD will be needed to determine the exact scope of existing ash lagoon improvements to be included under the project; however, preliminary estimates of costs included under Section 9 for these repairs assume the most conservative estimated cost (i.e. Alternative 1).

7.0 Regulatory Considerations

As discussed under TM No. 9, emissions from new FBI systems are primarily regulated under 40 Code of Federal Regulation (CFR) Part 60, Subpart LLLL, for USEPA Maximum Achievable Control Technology (MACT) 129 pollutants.

Requirements for the monitoring and control of fugitive ash emissions are also specified under this rule. In summary, if fugitive ash emissions are observed for greater than 5% of the duration of required annual air pollutant emissions compliance testing, this could result in the facility's failure to meet compliance. While the OA Team has not heard of any facility failing a compliance test due to fugitive ash emissions, numerous installations have made precautionary efforts to reduce such emissions in both ash handling facilities as well as incineration processes in general.

Note that dry ash handling facilities are more prone to developing issues with fugitive ash emissions. For instance, the abrasivity of dry ash often results in the wear and failure of pneumatic conveyance piping. If a dry ash handling option is selected, precautions will need to be taken to proactively identify and correct areas which may be prone to wear or failure.

8.0 Ash Disposal Considerations

MSD's Solids Handling Technical Memorandum: Fluidized Bed Incinerators (MSD, June 2018) includes a brief discussion regarding the viability of the existing MSD Prospect Hill Landfill for the continued disposal of ash. Based on the ash quantities referenced in Section 3, it is expected that planned improvements to the existing landfill will provide approximately 15 years of remaining capacity.

Beyond this 15-year window, another means of ash disposal will need to be identified by MSD. This section provides a brief discussion of the OA Team's experience with other clients.

8.1 ALTERNATE LANDFILL SITES

Other municipalities have developed contracts with local municipal landfill companies to receive both dry ash and ash lagoon dredged ash on a continuous, annual, or biennial basis. Often, these contracts include pre-requisites regarding the water content and hazardous materials (i.e. metals) content of the ash.

Due to the trucking and tipping fees associated with alternate landfill sites, this option may not be attractive from a cost standpoint; however, it should be considered as a back-up should other beneficial re-use alternatives fail to materialize.

8.2 ASH BENEFICIAL RE-USE

Facilities are increasingly pursuing drivers for "green" alternatives, which have extended to finding alternate solutions for disposing of residual ash via beneficial reuse.

To this end, other clients have successfully pursued contracts for beneficial re-use of their ash as a soil additive or soil amendment. One facility (which operates a wet ash system with ash lagoons) currently has a contract in place with a third party which specifically dictates that ash dredged annually from its lagoons cannot be directed to municipal landfill and must be utilized for beneficial reuse. Such an arrangement puts the onus on the contract holder to determine the end-use or reuse of the ash.

In Europe (specifically Germany) regulations have been passed to require nutrient recovery from incinerator residual ash (which is exceedingly high in phosphorous content); however, this is not currently being performed on a large scale in North America. Regardless, the nutrient content and physical characteristics of the ash make it an attractive product for addition to commercial soil products and also as fill material.

Note that other facilities have investigated use of ash as a concrete amendment; however, the OA Team is not aware of any facilities regularly reusing their ash in this capacity.

It is anticipated that these beneficial reuse options may be available to MSD regardless of the preferred ash handling process, as discussed herein. As such, these options will be further investigated with MSD as this project progresses.

9.0 Preliminary OPCCs and OPPCs

This section provides planning level opinions of probable construction cost (OPCC) and opinions of probable project cost (OPPC) for each of the ash handling options discussed under Sections 4 and 5.

Note that each OPCC includes:

- Construction contingency (30%)
- General requirements (10%)
- Contractor fee (12%)
- Insurance and bond (1.7%)

Table 9-1. Planning Level OPCCs and OPPCs for Bissell Point WWTF Ash Handling

ALTERNATIVE	BISSELL POINT WWTF ASH HANDLING OPTIONS			
	OPTION 1A WET ASH	OPTION 1B WET FBI / DRY ASH	OPTION 2 DRY ASH	[12]OPTION 3 COMBINATION WET / DRY
Enlarged Wet Scrubber Sump	[1]$75,000	$0	$0	$0
Removeable Duct Segments	$0	$0	$0	[2]$390,000
Ash Slurry Pumps / Wet Scrubber Drain Pumps	[3]$780,000	[4]$520,000	[3]$780,000	[4]$520,000
Ash Slurry / Wet Scrubber Drain Piping (in building)	[5]$30,000	[6]$98,000	[5]$30,000	[6]$98,000
Ash Slurry Tanks and Pumped Mixing Systems	$0	[7]$390,000	$0	[7]$390,000
Ash Slurry / Wet Scrubber Drain Piping (outside building)	[8]$312,000	[8]$312,000	[8]$195,000	[8]$312,000
Ash Lagoon Improvements	[9]$10,000,000	[9]$10,000,000	$0	[9]$10,000,000
Fabric filter	$0	$0	[10]$2,340,000	$0
Building Footprint to House Fabric filter	$0	$0	[11]$1,200,000	[11]$1,200,000
Dry Ash Pneumatic Conveyance	$0	$1,950,000	$1,950,000	$0
Dry Ash Storage and Offload Building	$0	$0	$1,300,000	$0
Dry Ash Storage and Offload Equipment	$0	$0	$7,800,000	$0
Subtotal:	***$11,197,000***	***$13,270,000***	***$15,595,000***	***$12,910,000***

ALTERNATIVE	BISSELL POINT WWTF ASH HANDLING OPTIONS			
	OPTION 1A WET ASH	OPTION 1B WET FBI / DRY ASH	OPTION 2 DRY ASH	[12]OPTION 3 COMBINATION WET / DRY
General Requirements (10%)	$1,120,000	$1,327,000	$1,560,000	$1,291,000
Electrical and I&C (15% of equipment only)	$130,000	$378,000	$1,886,000	$333,000
Contractor OH&P (12%)	$1,494,000	$1,797,000	$2,285,000	$1,745,000
Insurance and Bonding (1.7%)	$237,000	$286,000	$363,000	$277,000
Subtotal: Estimated Construction Cost:	***$13,941,000***	***$16,772,000***	***$21,326,000***	***$16,279,000***
Contingency (30%)	$4,183,000	$5,032,000	$6,398,000	$4,884,000
Engineering and Legal (20%)	$3,625,000	$4,361,000	$5,545,000	$4,233,000
Total OPCC:	***$21,749,000***	***$26,165,000***	***$33,269,000***	***$25,396,000***

[1] Assumes 3 wet scrubbers, each with an enlarged scrubber sump. Cost includes wet scrubber manufacturer's estimated design and material costs.

[2] Removable high temperature, refractory lined duct sections to allow for installation of future dry ash handling equipment (i.e. fabric filter or dry cyclone).

[3] Assumes 4 ash slurry / wet scrubber drain pumps, one per wet scrubber system plus one standby. Pumps tied to common wet scrubber drain piping header. For Option 2, these pumps would be scrubber drain pumps only, and would direct flow to WWTF liquid stream for treatment.

[4] Assumes 2 ash slurry / wet scrubber drain pumps, one per ash slurry tank.

[5] Ash slurry / wet scrubber drain piping within building. From wet scrubbers to pumps, to exterior wall prior to tie-in to outside buried piping.

[6] Ash slurry / wet scrubber drain piping within building. From wet scrubbers to ash slurry tanks.

[7] Two formed concrete, sloped bottom tanks. One ash slurry recirculation pump and associated piping per tank.

[8] For Options 1 and 3, assumes three new buried ash slurry lines from new incineration building to existing onsite ash lagoons. For Option 2, assumes three new buried wet scrubber drain lines to tie-in to existing return to WWTF influent.

[9] Based upon December 2014 evaluation, with costs escalated to $2020. Refer to Section 5 for additional discussion.

[10] Based upon TM No. 9 uninstalled fabric filter cost of $1.8M with 30% installation costs.

[11] Additional building footprint required to house fabric filters. Costs are in addition to building costs presented under TM No. 9. Assumes that building would be sized to accommodate future fabric filters under Option 3.

[12] Under Option 3, should MSD wish to compare the cost of installation of dry ash system components under the current project, add Option 2 costs for Fabric Filter, Dry Ash Pneumatic Conveyance, and Dry Ash Storage and Offload Building and Equipment.

Table 9-2. Planning Level OPCCs and OPPCs for Lemay WWTF Ash Handling

ALTERNATIVE	LEMAY WWTF ASH HANDLING OPTIONS			
	OPTION 1A WET ASH	OPTION 1B WET FBI/ DRY ASH	OPTION 2 DRY ASH	[13]OPTION 3 COMBINATION WET / DRY
Enlarged Wet Scrubber Sump	[1]$75,000	$0	$0	$0
Removeable Duct Segments	$0	$0	$0	[2]$390,000
Ash Slurry Pumps	[3]$780,000	[4]$520,000	[3]$780,000	[4]$520,000
Ash Slurry / Wet Scrubber Drain Piping (in building)	[5]$30,000	[6]$98,000	[5]$30,000	[6]$98,000
Ash Slurry Tanks and Pumped Mixing Systems	$0	[7]$390,000	$0	[7]$390,000
Ash Slurry / Wet Scrubber Drain Piping (outside building)	[8]$2,400,000	[8]$2,400,000	[8]$163,000	[8]$2,400,000
Ash Lagoon Improvements	[9]$150,000	[9]$150,000	$0	[9]$150,000
Fabric filter	$0	$0	[10]$1,568,000	$0
Building Footprint to House Fabric filter	$0	$0	[11]$804,000	[11]$1,200,000
Dry Ash Pneumatic Conveyance	$0	$1,950,000	$1,307,000	$0
Dry Ash Storage and Offload Building	$0	$0	$1,000,000	$0
Dry Ash Storage and Offload Equipment	$0	$0	$5,850,000	$0
Subtotal:	***$3,435,000***	***$5,508,000***	***$11,501,000***	***$5,148,000***
General Requirements (10%)	$344,000	$551,000	$1,151,000	$515,000
Electrical and I&C (15% of equipment only)	$476,000	$724,000	$1,390,000	$679,000
Contractor OH&P (12%)	$511,000	$814,000	$1,686,000	$762,000
Insurance and Bonding (1.7%)	$82,000	$130,000	$268,000	$121,000
Subtotal: Estimated Construction Cost:	***$4,766,000***	***$7,597,000***	***$15,728,000***	***$7,104,000***
Contingency (30%)	$1,430,000	$2,280,000	$4,719,000	$2,132,000
Engineering and Legal (20%)	$1,240,000	$1,976,000	$4,090,000	$1,848,000

ALTERNATIVE	LEMAY WWTF ASH HANDLING OPTIONS			
	OPTION 1A WET ASH	OPTION 1B WET FBI/ DRY ASH	OPTION 2 DRY ASH	[13]OPTION 3 COMBINATION WET / DRY
Total OPCC:	***$7,436,000***	***$11,853,000***	***$24,537,000***	***$11,084,000***

[1] Assumes 3 wet scrubbers, each with an enlarged scrubber sump. Cost includes wet scrubber manufacturer's estimated design and material costs.

[2] Removable high temperature, refractory lined duct sections to allow for installation of future dry ash handling equipment (i.e. fabric filter or dry cyclone).

[3] Assumes 4 ash slurry / wet scrubber drain pumps, one per wet scrubber system plus one standby. Pumps tied to common wet scrubber drain piping header.

[4] Assumes 2 ash slurry / wet scrubber drain pumps, one per ash slurry tank.

[5] Ash slurry / wet scrubber drain piping within building. From wet scrubbers to pumps, to exterior wall prior to tie-in to outside buried piping.

[6] Ash slurry / wet scrubber drain piping within building. From wet scrubbers to ash slurry tanks.

[7] Two formed concrete, sloped bottom tanks. One ash slurry recirculation pump and associated piping per tank.

[8] For Options 1 and 3, assumes three new buried ash slurry lines from new incineration building to existing offsite ash lagoons. For Option 2, assumes three new buried wet scrubber drain lines to tie-in to existing return to WWTF influent.

[9] Assumes miscellaneous improvements to existing ash lagoons, including level monitoring instrumentation. Refer to Section 5 for additional discussion.

[10] Based upon TM No. 9 uninstalled fabric filter cost of $1.8M with 30% installation costs.

[11] Additional building footprint required to house fabric filters. Costs are in addition to building costs presented under TM No. 9. Assumes that building would be sized to accommodate future fabric filters under Option 3.

[12] Wet scrubber system water flows will be similar for Bissell Point and Lemay WWTF incinerators. This results in similar sizing and cost for ash slurry pumps / wet scrubber drain pumps.

[13] Under Option 3, should MSD wish to compare the cost of installation of dry ash system components under the current project, add Option 2 costs for Fabric Filter, Dry Ash Pneumatic Conveyance, and Dry Ash Storage and Offload Building and Equipment.

10.0 Summary and Preliminary Recommendations

Table 10-1 provides a summary comparison of the ash handling options evaluated herein.

Table 10-1. Summary Comparison of Ash Handling Options

	OPTION 1A WET ASH	OPTION 1B WET FBI/DRY ASH	OPTION 2 DRY ASH	OPTION 3 COMBINATION WET / DRY
	Complexity			
PROS	▪ Least complex system, requiring minimal amount of ash handling equipment.		▪ No need to upgrade or maintain existing ash lagoons.	▪ Buildout under current project not significantly more complex compared to Options 1A and 1B.
CONS	▪ Requires upgrades and ongoing maintenance of existing ash lagoons.	▪ Compared to Option 1A Requires additional dry ash handling equipment, ash slurry tanks, and mixing system. ▪ Requires upgrades and ongoing maintenance of existing ash lagoons.	▪ Requires significant dry ash handling equipment, including conveyance, piping, and standalone ash storage, conditioning, and loadout facility.	▪ Would require initial construction of ash slurry tanks and pump mixing system to support future buildout. ▪ With future dry ash systems installed, this options would be the most complex system with both wet and dry ash handling facilities. ▪ Requires upgrades and ongoing maintenance of existing ash lagoons.
	Flexibility			
PROS	▪ Provides additional system flexibility/ redundancy compared to existing wet ash handling systems. ▪ Provides significant ash storage capacity in lagoons, providing MSD with flexibility for scheduling offload and disposal.	▪ Provides additional system flexibility/ redundancy compared to existing wet ash handling systems. ▪ Provides significant ash storage capacity in lagoons, providing MSD with flexibility for scheduling offload and disposal.	▪ Does not rely on existing ash lagoons. ▪ Would allow for more continuous loadout.	▪ Provides MSD with options for future dry ash handling systems. ▪ With future dry ash systems installed, this option provides the most system flexibility, allowing for operation of both dry and wet ash systems.

	OPTION 1A WET ASH	OPTION 1B WET FBI/DRY ASH	OPTION 2 DRY ASH	OPTION 3 COMBINATION WET / DRY
CONS	▪ Relies exclusively on wet ash handling and existing lagoons. ▪ Does not easily allow for more continuous ash loadout.	▪ Relies exclusively on wet ash handling and existing lagoons. ▪ Does not easily allow for more continuous ash loadout.	▪ Would rely upon standalone ash storage and loadout facility for near-continuous operation. If storage or loadout capacity becomes limited, MSD will have few options for ash handling. ▪ Would also rely on multiple offload trucks per week to handle ash.	▪ Would require future buildout to provide additional flexibility compared to other options.
	Reliability			
PROS	▪ Least complex system, with minimal equipment failure points. ▪ Redundant ash slurry pipelines provide greater operational reliability compared to existing.	▪ Redundant ash slurry pipelines provide greater operational reliability compared to existing.		▪ System would offer multiple alternate approaches for ash handling / disposal upon future buildout.
CONS	▪ Ash slurry piping may wear and will require ongoing maintenance / periodic replacement.	▪ Introduces dry ash handling equipment, which is known to be prone to failures due to the abrasivity of ash.	▪ Introduces dry ash handling equipment, which is known to be prone to failures due to the abrasivity of ash.	▪ System would be very complex with numerous equipment failure points. ▪ Does not provide any additional flexibility upon initial buildout compared to other options.
	Regulatory			
PROS	▪ Limited to no opportunity for fugitive ash emissions associated with ash handling system.		▪ Does not rely on existing ash lagoons, which have some regulatory concerns (see Options 1A and 1B).	

	OPTION 1A WET ASH	OPTION 1B WET FBI/DRY ASH	OPTION 2 DRY ASH	OPTION 3 COMBINATION WET / DRY
CONS	▪ Relies on use of existing ash lagoons, which appear to have infiltration / exfiltration issues (at Bissell Point WWTF) and periodic overflow events (at Lemay WWTF). Requires upgrades to remedy regulatory concerns.	▪ Compared to Option 1A, higher risk of fugitive ash emissions. ▪ Relies on use of existing ash lagoons, which appear to have infiltration / exfiltration issues (at Bissell Point WWTF) and periodic overflow events (at Lemay WWTF). Requires upgrades to remedy regulatory concerns.	▪ Significant risk / likelihood of fugitive ash emissions associated with dry ash handling equipment.	▪ Relies on use of existing ash lagoons, which appear to have infiltration / exfiltration issues (at Bissell Point WWTF) and periodic overflow events (at Lemay WWTF). Requires upgrades to remedy regulatory concerns. ▪ Significant risk / likelihood of fugitive ash emissions associated with dry ash handling equipment under future buildout.
	Cost			
PROS	▪ Lowest capital cost.		▪ Does not require cost associated with upgrades to existing lagoons.	▪ Relatively low initial cost compared to Option 2. ▪ Provides opportunities for future buildout.
CONS	▪ Requires significant cost for upgrades of Bissell Point WWTF ash lagoon upgrades.	▪ Additional cost associated with installation and O&M of dry ash handling system components. ▪ Requires significant cost for upgrades of Bissell Point WWTF ash lagoon upgrades.	▪ Highest cost across all options at both WWTF's due to fabric filters, additional building footprint, and dry ash conveyance, storage, conditioning, and loadout facilities.	▪ Future buildout would incur significant additional future cost to MSD.

Based on the evaluation performed herein, it is preliminarily recommended that Option 1A or 1B be selected considering cost and non-cost evaluation factors.

Should MSD choose to install FBI systems which do not necessitate dry ash handling (i.e. waste heat recovery systems or fabric filter) then Option 1A would present the lowest cost (even with the required Bissell Point WWTF ash lagoon upgrades), least complex, and arguably easiest to operate and maintain ash handling system. Should MSD choose to install a waste heat recovery system, dry ash handling components could be incorporated into the overall wet ash system with minimal additional cost or complexity under Option 1B.

It is anticipated that all major “cons” associated with wet ash handling systems could be addressed with relative ease. Concerns associated with the long-term operation of the existing ash lagoons (particularly for Bissell Point WWTF) can largely be remedied by implementation of the previously identified lagoon improvements; refer to Section 5. Furthermore, future ash disposal and beneficial re-use options appear to be available to MSD regardless of whether an annual or biennial ash loadout approach is adopted, compared to a more continuous loadout approach with a dry ash system; refer to Section 8.

As mentioned herein and further discussed under TM No. 9, options for air emission controls equipment (particularly for mercury control) pose the most outstanding questions regarding the need to transition to an ash handling system with dry ash handling components. Should MSD choose PAC technology for mercury control in lieu of GAC for non-cost considerations (operational or other) then this may merit re-consideration of an ash handling system incorporating dry ash loadout. While the mercury removed will be bound with the activated carbon, it is possible that degradation in the carbon within the lagoons could re-release resolubilized mercury to the WWTF liquid stream, requiring additional side stream treatment (e.g. chemical precipitation). It is also possible that combining the mercury laden activated carbon with the remainder of the incinerator residual ash could reduce MSD’s future options for beneficial reuse.

FINAL

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum No. 11: Energy Recovery

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

11 JUNE 2021

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1.0 Purpose and Scope

Waste heat recovery systems from fluidized bed incinerator (FBI) exhaust gas can provide substantial amounts of energy for use at treatment facilities, reducing power costs and non-renewable energy usage. For systems with electricity generation, often enough power can be produced to operate the FBI system with excess power available for other uses. However, waste heat recovery can also add significant capital costs as well as operating and maintenance effort.

The purpose of this memorandum is to evaluate whether it is beneficial to include energy recovery from the FBI systems for building heat or electricity generation in the Bissell Point and Lemay Wastewater Treatment Facilities (WWTFs) Fluidized Bed Incinerators project. This memorandum includes sections covering:

- A review of past energy recovery evaluations
- A summary of the design basis for heat recovery
- Building Heat Replacement (Lemay)
    - For evaluation of supplying building heat from energy recovery of FBI exhaust gas at the Lemay WWTF: a review of the existing heating system, identification of suitable heating alternatives, development of criteria for alternatives, and evaluation of economic and non-economic criteria
- Electricity Production (Bissell Point and Lemay)
    - For evaluation of electricity production from energy recovery of FBI exhaust gas at the Lemay and Bissell Point WWTFs: identification of suitable power generation alternatives, development of criteria, and evaluation of economic and non-economic criteria
- Steam Production (Bissell Point)
    - For evaluation of sale of steam from energy recovery of FBI exhaust gas at the Bissell Point WWTF: identification of suitable alternative, development of criteria, and evaluation of the alternative

2.0 Lemay WWTF

2.1 BACKGROUND

2.1.1 FBI Sizing and Loading Criteria

Design solids quantities for current and future conditions were developed as part of *TM 04 Solids Quantities and Characteristics*. For the Lemay WWTF solids production is projected at 165 dry tons per day (dtpd) for future maximum month (MM), 112 dtpd for future annual average (AA), 110 dtpd for current MM, and 74 dtpd for current AA. The size and quantities of FBI units were selected as part of *TM 09 FBI Design Criteria*. For the Lemay WWTF the alternative selected consisted of 2 units sized to meet future MM, with one additional standby unit (i.e. three total units) to process solids above MM production and provide capacity when units are out of service for maintenance. Design criteria for the FBI units are listed in Table 2-1.

Table 2-1 Lemay FBI Design Criteria

DESCRIPTION	VALUE
Number of units	3
Nominal design capacity, each	83 dtpd
Firm nominal capacity	165 dtpd
Installed nominal capacity	249 dtpd
Bed outside diameter	17.6 feet
Design fluidizing air	9,948 scfm
Max flood capacity (30.8% TS, 50.8% VS), each	91 dtpd
Max normal capacity (28.9% TS, 60.1% VS), each	83 dtpd
Nominal normal design capacity (28.9% TS, 60.1% VS), each	75 dtpd

dtpd = dry tons per day, scfm = standard cubic feet per minute, TS = total solids, VS = volatile solids

2.1.2 Ameren Energy Incentives

If steam turbine-generators were installed as part of the new FBI facilities, they would qualify for the Ameren Missouri Business Energy Efficiency Program “BizSavers.” This equipment would fall under their Custom Incentives portion of the program for commercial and industrial customers. These custom incentive payments are calculated based on annual energy savings of the proposed equipment. The steam turbine-generators would most likely fall under the “miscellaneous” category which has an incentive rate of $0.07 per kW-hr saved. Based on the maximum energy production calculated for electricity generation alternatives, the Lemay WWTF could be eligible for up to $400,000 and the Bissell Point WWTF for up to $500,000 in incentives. The “BizSavers” team from Ameren would need to be involved in the design stage, and all applications would need to be submitted before any equipment is purchased or installed. During this process, they would verify the energy production estimates and also determine the energy demand reduction potential on their end. Based on this, they would determine the value of their incentive offer, and all incentives greater than $15,000 would also require an additional pre-installation inspection to complete the process. Although these incentives would help to reduce energy recovery costs and thus make it more financially attractive, at the scale that the District would be considering, these incentives would in fact have minimal impact to the overall economic evaluation (as described in the following sections of this technical memorandum).

2.1.3 Past Evaluations

Energy recovery assessments have been completed in the past. As part of the Solids Handling Master Plan (SMP) finalized in 2010, power generating energy recovery alternatives were developed for both the existing multiple hearth incinerators option and for new FBIs option. The alternative for new FBIs is of most interest for the current project and was based on recovering heat from the FBI exhaust gas to produce high pressure superheated steam for power generation. The energy recovery system as evaluated in *Phase II TM 2 – Lemay WWTP Solids Processing Alternatives Evaluation* consisted of:

- Waste heat boilers (WHBs)
- Ash pneumatic conveyance
- Condensing steam turbine-generator
- Steam system including condenser, condensate pumps, cooling heat exchanger, condensate storage tank, deaerator, and WHB feed pumps
- Packaged water treatment system for boiler water make up.

Design criteria for major energy recovery system components is shown in Table 2-2.

Table 2-2 SMP (2010) TM2 Lemay Energy Recovery Alternative Design Criteria

DESCRIPTION	CRITERIA
Waste Heat Boilers	
Number	2
Type	Water tube
Design flue gas flow	65,000 pph
Steam pressure	400 psia
Steam temperature	600°F (superheated)
Steam flow[1], (less parasitic loads, i.e. deaerator)	11,250 pph
WHB Fly Ash Transport System	
Type	Pneumatic
Steam Turbine Generator	
Number	1
Type	Condensing to 4" Hg
Steam pressure	400 psia
Steam temperature	600°F (superheated)
Design steam flow	12,900 pph

DESCRIPTION	CRITERIA
Alternator type	Synchronous
Power output	0.8 MW
Steam Surface Condenser	
Number	1
Type	Water cooled
Cooling Water Heat Exchangers	
Number	2 (1 duty, 1 standby)
Condensate Handling System	
Condensate storage tank number	1
Condensate storage tank capacity	750 gallons
Deaerator number	1
Deaerator condensate flow rate	12,900 pph
Deaerator steam use	1,000 pph
WHB feed pump number	2 (1 duty, 1 standby)
Packaged Water Treatment System	
Number	2 (1 duty, 1 standby)
Treated water flow	10 gpm

pph = pounds per hour, [1]Steam produced at annual average conditions

Life cycle costs were developed as part of the evaluation and a summary is shown in Table 2-3.

Table 2-3 SMP (2010) TM2 Lemay Opinions of Costs, Savings, and Life Cycle Costs

ALTERNATIVE	L-3 FBI + CFG[1]	L-3-A FBI + POWER[2]
Capital Costs[3]	$121,211,000	$24,233,000
Salvage Value	($2,622,000)	($494,000)
Annual O&M Costs	$4,913,000	$565,000
Annual Revenue	($0)	($182,000)
Present Worth Costs		
Capital	$121,211,000	$24,233,000
Salvage	($988,000)	($186,000)
O&M	$61,229,000	$7,041,000
Revenue	($0)	($2,268,000)
Total Present Worth Costs	$181,452,000	$28,810,000

[1]Alternative L-3 FBI + CFG - new FBI units with centrifuge dewatering technology

[2] *Alternative L-3-A FBI + POWER – differential additional costs of electricity production from steam to base costs (Alt L-3 FBI + CFG) for new FBI units with centrifuge dewatering technology*

[3] *Costs provided are in 2010 dollars*

As shown by the present worth analysis, annual costs to operate the waste energy recovery facility were greater than the revenue generated, and the capital investment did not have a payback period.

As part of the same project, a triple bottom line evaluation, considering economic, social, and environmental criteria was performed in *Phase II TM 10 Triple Bottom Line Evaluation*. The overall weighted total score for the alternative of new FBI units with centrifuge dewatering without energy recovery (L-3 FBI + CFG) was 34.60, while the score for the alternative with energy recovery (L-3-A FBI + STG) was 30.80, indicating that the alternative without energy recovery scored higher when both economic and non-economic factors were considered.

2.2 BUILDING HEATING

2.2.1 Existing Steam System

The existing steam system (commissioned in 1968) consists of four waste heat boilers, located in the Incinerator and Filter Building (that recover energy from the exhaust gas of multiple hearth incinerators), and two natural gas fired auxiliary boilers (located in the Maintenance Building). The steam supply system provides steam to multiple uses in several buildings as follows:

- Incinerator and Filter Building: Air handling unit (AHU) heating coils, boiler feedwater heat exchangers, and fly ash nozzles
- Maintenance Building: Water heater, AHU humidifier, chillers, and heating water heat exchangers
- West and East Trash Buildings: AHU coils
- Biofilter
- Blower and Thickener Building: Water heater, AHU humidifiers, chillers, and heating water heat exchangers
- Primary Control Building: Duct mounted humidifier and duct mounted reheat coil

Condensate from the multiple buildings, except the Biofilter and Primary Control Building, is returned to a condensate surge tank located in the Maintenance Building. Condensate pumps convey the condensate to the deaerator from which boiler feed pumps convey it to the boilers. A schematic of the existing steam heating system is shown in Figure 2-1.

In 2007 the steam system was modified, which included removal and addition of heating coils and other HVAC equipment. Based on steam production records there was a significant reduction in steam use after the modification project. Plant staff have indicated that the waste heat boilers are in poor condition, with only two of the four units currently in operation. Otherwise it is thought that much of the rest of the steam system is in suitable condition, including the piping and heating coils.

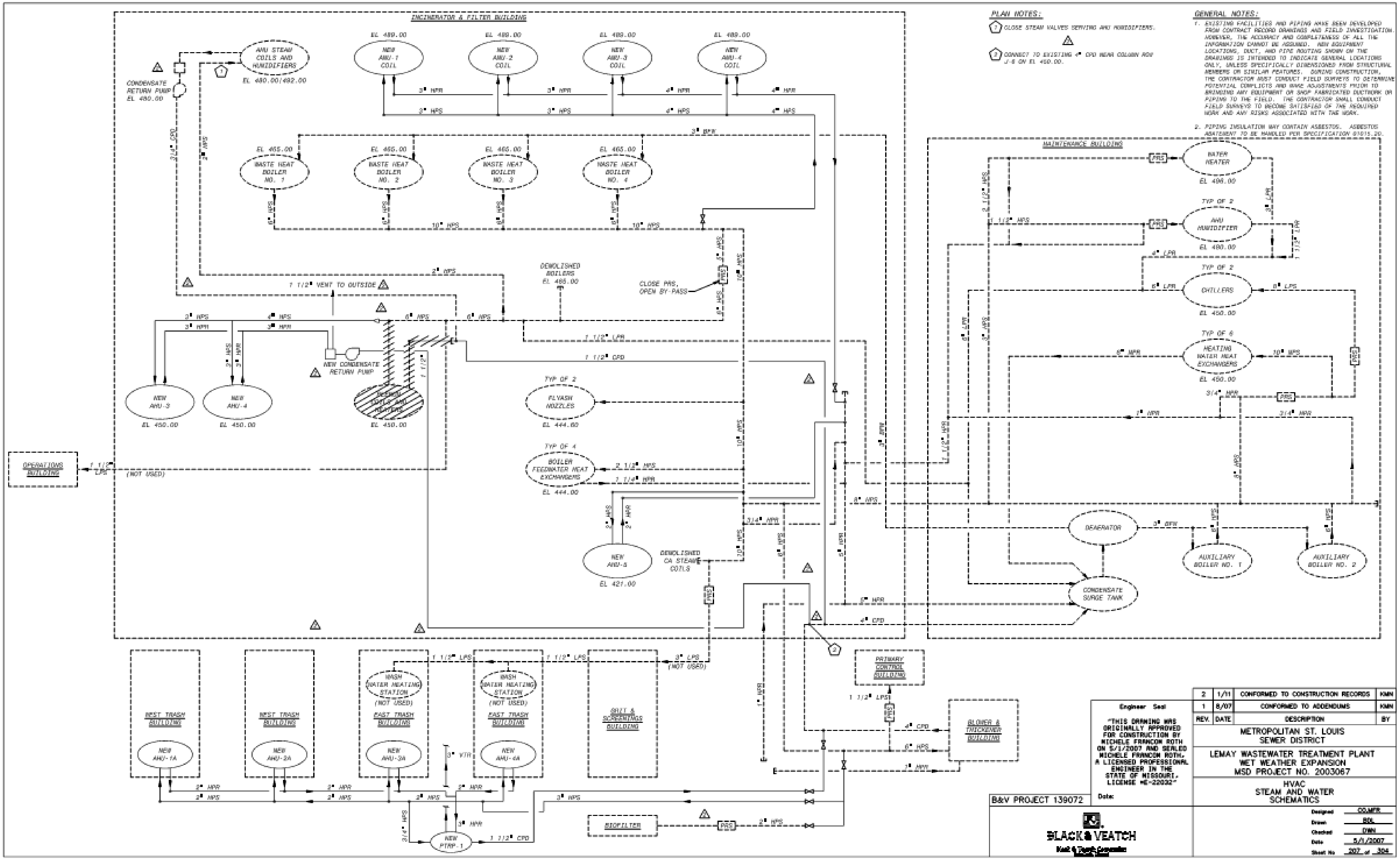
With proper maintenance, steam and condensate piping can have a long service life, in excess of 50 years. Steam boilers, tanks and deaerators, have a more limited typical service life of 15 to 20 years, but can last 2 to 3 times longer than that with good maintenance and periodic replacement of deteriorated components. Steam alternatives were evaluated based on replacing the major equipment components, the boilers, condensate surge tank, deaerator, and associated pumps, but utilizing the existing steam and condensate piping. If a steam heating alternative is selected it is recommended that the steam and condensate systems be inspected to determine the specific condition of the system components, including ultrasonically testing the piping and comparing the current performance of major equipment with original specifications.

Steam production data from the years 2016, 2017, and 2018 were analyzed to determine average and design steam use. Design criteria of the existing steam system is listed in Table 2-4.

Table 2-4 Existing Steam System Design Criteria

DESCRIPTION	CRITERIA
Historic Steam Production	
Average annual production	117,305,000 pounds
Average daily / hourly production	322,000 ppd / 13,416 pph
Average waste heat steam % of total	60%
Design daily / hourly production (97.5% of days)	537,250 ppd / 22,385 pph
Design Steam Production (85% usage factor)	26,500 pph
Waste Heat Boilers	
Number	4 (one per MHI, only 2 operating)
Make / model	International Boiler Works / IVH-9_15
Exhaust gas inlet temperature	1400°F
Exhaust gas outlet temperature	500°F
Exhaust gas flow	52,363 pph
Design steam pressure	200 psig
Operating steam pressure	125 psig
Steam temperature	353°F
Steam flow	15,000 pph
Auxiliary Boilers	
Number	2
Make / model	Superior Boiler Works / 300-HP APACHE
Type	Scotch Marine
Steam pressure	150 psig
Steam flow	10,350 pph
Gas input	12.6 MMBtuh

pph = pounds per hour, ppd = pounds per day, MMBtuh = million BTUs per hour



PLAN NOTES:

① CLOSE STEAM VALVES SERVING AHU HUMIDIFIERS.

② CONNECT TO EXISTING 4" CPD NEAR COLUMN ROW J-6 ON EL 450.00.

GENERAL NOTES:

1. EXISTING FACILITIES AND PIPING HAVE BEEN DEVELOPED FROM CONTRACT RECORD DRAWINGS AND FIELD INVESTIGATION. HOWEVER, THE ACCURACY AND COMPLETENESS OF ALL THE INFORMATION CANNOT BE ASSURED. NEW EQUIPMENT LOCATIONS, DUCT, AND PIPE ROUTING SHOWN ON THE DRAWINGS IS INTENDED TO INDICATE GENERAL LOCATIONS ONLY, UNLESS SPECIFICALLY DIMENSIONED FROM STRUCTURAL MEMBERS OR SIMILAR FEATURES. DURING CONSTRUCTION, THE CONTRACTOR MUST CONDUCT FIELD SURVEYS TO DETERMINE POTENTIAL CONFLICTS AND MAKE ADJUSTMENTS PRIOR TO BRINGING ANY EQUIPMENT OR SHOP FABRICATED DUCTWORK OR PIPING TO THE FIELD. THE CONTRACTOR SHALL CONDUCT FIELD SURVEYS TO BECOME SATISFIED OF THE REQUIRED WORK AND ANY RISKS ASSOCIATED WITH THE WORK.
2. PIPING INSULATION MAY CONTAIN ASBESTOS. ASBESTOS ABATEMENT TO BE HANDLED PER SPECIFICATION 01015.20.

REV.	DATE	DESCRIPTION	BY
2	1/11	CONFORMED TO CONSTRUCTION RECORDS	KMN
1	8/07	CONFORMED TO ADDENDUMS	KMN

Engineer Seal

"THIS DRAWING WAS ORIGINALLY APPROVED FOR CONSTRUCTION BY MICHELE FRANCOM ROTH ON 5/1/2007 AND SEALED MICHELE FRANCOM ROTH, A LICENSED PROFESSIONAL ENGINEER IN THE STATE OF MISSOURI, LICENSE #E-22032"

Date:

B&V PROJECT 139072

METROPOLITAN ST. LOUIS
SEWER DISTRICT

LEMAY WASTEWATER TREATMENT PLANT
WET WEATHER EXPANSION
MSD PROJECT NO. 2003067

HVAC
STEAM AND WATER
SCHEMATICS

BLACK & VEATCH

Designed CO,MFR
Drawn BDL
Checked DWN
Date 5/1/2007
Sheet No 207 of 304

Figure 2-1 Existing Steam Heating System

2.2.2 Building Heating Alternatives

Three building heating alternatives were evaluated:

- **Alternative 1 – Steam Heating – FBI Waste Heat Boilers (A1 ST-WHB)**
  - Provide new WHBs with the new FBI system, natural gas fired auxiliary (steam) boilers, new steam and condensate piping between the new FBI Building and the existing Maintenance Building and reuse the balance of the existing steam system
- **Alternative 2 – Steam Heating – Natural Gas Boilers (A2 ST-NGB)**
  - Provide new natural gas fired boilers in the Maintenance Building and reuse the balance of the existing steam system. No new WHBs will be provided for the new FBI system.
- **Alternative 3 Direct Fired Natural Gas Heating (A3 NG-SYS)**
  - Abandon the existing steam system and provide new natural gas fired heating equipment at each facility supplied by the existing steam system.

2.2.2.1 Alternative 1 ST-WHB, Steam Heating – FBI Waste Heat Boilers

Under this alternative, new WHBs would be provided with the new FBI system, new auxiliary boilers would replace the existing boilers, and much of the existing steam heating system would continue to be used. Two WHBs and ductwork would be provided so that any of the three FBI systems when operating could feed a WHB or bypass the boilers. Major components of this alternative would include:

- WHBs to capture heat from the FBI exhaust gas and produce saturated steam
- Refractory lined ductwork and dampers for FBI exhaust gas conveyance and bypass duct
- Steam and condensate piping between the new FBI Building and existing Maintenance Building
- New natural gas fired auxiliary boilers located in the Maintenance Building to supply steam when the WHB supply is insufficient or the equipment is out of service, new condensate surge tank and deaerator. Each auxiliary boiler is sized to provide full heating load.
- Reuse of the balance of existing steam and condensate piping, steam heating equipment, and other miscellaneous items using steam

The existing Maintenance Building would have to be evaluated to confirm the location of the existing auxiliary boilers has sufficient space and combustion air supply for the new auxiliary boilers. Design criteria for system components under this alternative are shown in Table 2-5.

Table 2-5 A1 ST-WHB, Steam Heating – FBI WHB Design Criteria

DESCRIPTION	CRITERIA
Waste Heat Boilers	
Number	2
Type	Water tube
Exhaust gas inlet temperature	950°F
Exhaust gas outlet temperature	450°F
Exhaust gas flow, each	68,000 pph

DESCRIPTION	CRITERIA
Design steam pressure	200 psig
Operating steam pressure	125 psig
Steam temperature	353^{o}F (Saturated)
Steam flow, each	9,500 pph
Auxiliary Boilers	
Number	2 (1 duty, 1 standby)
Type	Scotch Marine
Steam pressure	125 psig
Steam flow, each	26,500 pph
Gas input, each	33.5 MMBtuh

pph = pounds per hour, MMBtuh = million Btus per hour

2.2.2.2 Alternative 2 ST-NGB, Steam Heating – NG Boilers

Under this alternative, new natural gas fired boilers would replace the existing auxiliary boilers, and much of the existing steam heating system would continue to be used. Major components of this alternative would include:

- New natural gas fired boilers located in the Maintenance Building to supply steam, new condensate surge tank, deaerator, and associated pumps
- Reuse of the balance of existing steam and condensate piping, steam heating equipment, and other miscellaneous items using steam

The existing Maintenance building would have to be evaluated to confirm the location of the existing auxiliary boilers has sufficient space and combustion air supply. Design criteria for system components under this alternative are shown in Table 2-6.

Table 2-6 A2 ST-NGB, Steam Heating – NG Boilers Design Criteria

DESCRIPTION	CRITERIA
Natural Gas Fired Boilers	
Number	2 (1 duty, 1 standby)
Type	Scotch Marine
Steam pressure	125 psig
Steam temperature	353^{o}F (saturated)
Steam flow	26,500 pph
Gas input	33.5 MMBtuh

pph = pounds per hour, MMBtuh = million Btus per hour

2.2.2.3 Alternative 3 NG-SYS, Direct Fired NG Heating

Under this alternative, new natural gas fired heating equipment would be provided at each facility supplied by the existing steam system; with the existing system either abandoned or demolished. Major components of this alternative would include:

- New natural gas fired AHUs to replace each existing AHU that has a steam coil in the Incinerator and Filter Building and the Blower and Thickener Building
- New gas distribution piping to new gas fired equipment
- Replacement of miscellaneous equipment currently using steam, including the heating water heat exchangers (replaced with natural gas fired hot water boilers), steam chillers (replaced with electrical chillers), AHU humidifier, and water heater, with new electric or natural gas fired equipment serving the same purpose. Equipment, such as hot water coil AHUs in the Maintenance and Blower and Thickener Buildings, that use hot water from the steam/hot water heat exchangers, would be reused with hot water supplied by the new hot water boilers.

Design criteria for major system components under this alternative are shown in Table 2-7.

Table 2-7 A3 NG-SYS, Direct Fired NG Heating Design Criteria

DESCRIPTION	CRITERIA
General	
Total design energy used by HVAC equipment being replaced	61.7 MMBtuh
AHUs in Incinerator & Filter Building and Trash Buildings	
Number and location	Same as existing
Type	Direct fired ng
Capacity	Same as existing
Heating Water Boilers (HWBs)	
Maintenance Bldg HWBs number	2 (1 duty, 1 standby)
Maintenance Bldg HWBs output, each	26.8 MMBtuh
Maintenance Bldg HWBs heating water supply temperature	200°F
Blower & Thickener Bldg number	2 (1 duty, 1 standby)
Blower & Thickener Bldg output, each	14.5 MMBtuh
Blower & Thickener Bldg heating water supply temperature	200°F
Maintenance Building Chillers	
Number	2 (1 duty, 1 standby)
Capacity, each	300 tons

pph = pounds per hour, MMBtuh = million BTUs per hour

2.2.3 Costs

2.2.3.1 Opinion of Probable Project Costs

A planning level opinion of probable project cost (OPPC) is shown in Table 2-8 for the alternatives. The OPPC includes:

- Construction contingency (35%)
- Contractor costs 23.7%
  - General requirements (10%)
  - Contractor fee (12%)
  - Insurance and bond (1.7%)

Table 2-8 Lemay Building Heating Alternatives OPPC

ALTERNATIVE	A1 ST-WHB	A2 ST-NGB	A3 NG-SYS
WHB Building	$1,755,000	NA	NA
WHBs	$3,000,000	NA	NA
WHB ductwork	$1,594,000	NA	NA
Yard steam piping	$200,000	$100,000	NA
WHB fly ash transport system	$643,000	NA	NA
Aux/NG boilers	$750,000	$750,000	NA
Condensate tank/deaerator	$641,000	$641,000	NA
Equipment installation	$755,000	$209,000	$578,000
NG AHUs	NA	NA	$1,456,000
Yard/building NG piping	NA	NA	$40,000
Miscellaneous equipment	NA	NA	$1,434,000
Electrical	$463,000	$128,000	$231,000
I&C	$405,000	$112,000	$202,000
Contractor costs	$2,419,000	$460,000	$934,000
Construction contingency	$4,419,000	$840,000	$1,706,000
Engineering and legal	$3,409,000	$648,000	$1,316,000
Project cost	$20,453,000	$3,888,000	$7,897,000

Alt 1 (ST-WHB) – Steam heating with new WHBs and Aux boilers; Alt 2 (ST-NGB) – Steam heating with new NG boilers; Alt 3 (NG-SYS) – New NG fired heating equipment, NA = Not applicable

2.2.3.2 Operating Costs

For the purpose of comparing costs, annual operating costs that would have a significant difference between alternatives were modeled consisting of fuel and maintenance costs. Table 2-9 shows these costs for the alternatives. Operating costs are based on:

- 24 hour per day, 7 days per week operation
- Natural gas cost of $4.50 per 1,000 cubic foot
- Annual process equipment maintenance cost based on 2% of equipment cost
- Annual HVAC equipment maintenance cost based on 0.5% of equipment cost
- Maintenance cost calculations were based on a capital cost of $4 million for new HVAC systems for the purpose of applying maintenance allowances. For the steam alternatives, the process equipment maintenance allowance was used for one half ($2 million) of the HVAC costs, based on steam components, such as the piping and traps, being reflective of process equipment for maintenance level of effort, rather than HVAC equipment.

Table 2-9 Lemay Building Heating Alternatives Annual Differential Operating Costs

ALT	A1 ST-WHB	A2 ST-NGB	A3 NG-SYS
NG Fuel	$198,000	$660,000	$594,000
Maintenance and labor	$377,000	$155,000	$20,000
Total	$575,000	$815,000	$614,000

Alt 1 (ST-WHB) – Steam heating with new WHBs and Aux boilers; Alt 2 (ST-NGB) – Steam heating with new NG boilers; Alt 3 (NG-SYS) – New NG fired heating equipment

2.2.3.3 Present Worth Costs

Present worth costs for each alternative are shown in Table 2-10. Total present worth costs are based on:

- Evaluation period: 20 year
- Interest rate: 4%
- Escalation rate: 2.5%

Table 2-10 Lemay Building Heating Alternatives Present Worth Costs

ALT	A1 ST-WHB	A2 ST-NGB	A3 NG-SYS
O&M PW	$9,908,000	$14,037,000	$10,577,000
OPCC	$20,453,000	$3,888,000	$7,897,000
Total	$30,361,000	$17,925,000	$18,474,000

Alt 1 (ST-WHB) – Steam heating with new WHBs and Aux boilers; Alt 2 (ST-NGB) – Steam heating with new NG boilers; Alt 3 (NG-SYS) – New NG fired heating equipment

2.2.4 Non-Economic Criteria

Table 2-11 has a summary of advantages and disadvantages for each building heating alternative.

Table 2-11 Lemay Building Heating Alternatives Present Worth Costs

	A1 ST-WHB	A2 ST-NGB	A3 NG-SYS
Advantages	• Recovers waste energy to reduce fossil fuel use and cost	• Lowest capital costs • Effectively utilizes existing assets	• Simple system to operate • Lowest O&M costs

Disadvantages	• Substantially more capital cost not justified by annual savings • Adds operational complexity to FBI system	• More maintenance effort than NG system	• Greater capital costs than new ng steam boiler alternative

Alt 1 (ST-WHB) – Steam heating with new WHBs and Aux boilers; Alt 2 (ST-NGB) – Steam heating with new NG boilers; Alt 3 (NG-SYS) – New NG fired heating equipment

2.2.5 Evaluation and Recommendation

The WHB alternative has substantial capital cost that isn't justified by the limited annual cost savings. Additionally, operating the WHBs will add complexity to the FBI trains, which will already have many advanced air pollution equipment process components to operate in conjunction with the combustion reactor. For these reasons, the WHB steam building heating alternative is not recommended.

The building heating alternatives were based on the same building use and HVAC requirements as the existing buildings as determining future use and HVAC requirements is outside the scope of this technical memorandum. Future use for these buildings may significantly change their HVAC requirements. The natural gas fired equipment alternative has lower operating and maintenance effort with higher capital costs, while the natural gas fired boiler steam building heating alternative has lower capital costs, but greater operating and maintenance costs and effort. The present worth cost difference of these alternatives is within the margin of error for the estimates. Given that the future use for these buildings may impact the relative merits of these alternatives, it is recommended that the type of future heating system be reevaluated when the future use of the buildings is determined. As such, Alternative A-2 would be the preferred alternative based on capital costs alone until such time as the future use of the building is defined. If the future use of the building results in no change to the current HVAC requirements; then Alternative A-2 and A-3 are essentially economically equivalent, and A-3 would be preferable from a non-economic standpoint.

Subsequent to primary development of this technical memorandum the decision was made to demolish the existing Maintenance Building, construct the new FBI facility in the location of that building, and to repurpose the Grit and Screening Building as a new Maintenance Building. A decentralized approach was selected for the heating system in order to:

- Reduce the risk of multi-building heating failure due to relying on a single centralized system dependent on aged steam system components
- Provide new, more efficient natural gas fired systems for new facilities
- Continue use existing steam equipment in select areas to maximize existing infrastructure with remaining service life.

A summary of the decentralized system consists of:

- A natural gas fired heating system for the Solids Processing Facility
- A steam heating system for the new Maintenance Building (repurposed Grit and Screening Building), if practical, which would also supply the Trash Buildings and the Primary Control Building
- A steam heating system for the Blower and Thickener Building, which would also supply the Biofilter

- A natural gas fired heating system for the Administration Building.

2.3 ELECTRICITY GENERATION

2.3.1 Electricity Generation Facility

In order to determine if it would be beneficial to include energy recovery with electricity generation for the new FBI facility at the Lemay WWTF an alternative was developed based on recovering energy from the FBI exhaust gas and producing steam from the energy to power a steam turbine generator. The energy recovery system for electricity power generation would be similar to the system previously evaluated as part of the Solids Master Plan. Two WHBs and ductwork would be provided so that any of the FBI systems when operating could feed a WHB or bypass the boilers. The energy recovery system would consist of:

- Waste heat boilers (WHB), with super heaters, evaporators, and economizers, to capture heat from the FBI exhaust gas and produce superheated steam
- Refractory lined ductwork and dampers for FBI exhaust gas conveyance and bypass duct
- Pneumatic conveyance system to transport ash from the WHB hoppers to the ash system, including transporter and air compressors
- Condensing steam turbine-generator to convert steam to electrical power
- Steam condenser to condense steam on the discharge of the turbine and condensate pumps to convey condensate to condensate storage tank
- Cooling heat exchanger to transfer heat from the closed water circuit providing cooling to the condenser to plant effluent
- Condensate system consisting of condensate storage tank, deaerator, and WHB feed pumps
- Packaged water treatment system to treat potable water for boiler water make up, including filters, carbon filters, water softeners, reverse osmosis, demineralizers, demineralized water storage tank and make up water pumps
- Building area to house the energy recovery system.

Design criteria for major energy recovery system components is shown in Table 2-12.

Table 2-12 Lemay Electricity Generation Design Criteria

DESCRIPTION	CRITERIA
Waste Heat Boiler	
Number	2
Type	Water tube, vertical
Flue gas inlet	950ºF
Flue gas outlet	446ºF
Design flue gas flow	73,000 pph
Steam pressure	450 psig
Steam temperature	600ºF (superheated)
Steam flow, nominal capacity, each	8,850 pph

DESCRIPTION	CRITERIA
Steam flow, max rating, each	12,000 pph
Steam flow, each (less parasitic loads, i.e. deaerator)	10,800 pph
WHB Fly Ash Transport System	
Type	Pneumatic
Number of transporters	2
Number of compressors	2
Steam Turbine Generator	
Number	1
Turbine type	Horizontal, multi-stage, condensing, impulse
Steam pressure	400 psig
Steam temperature	600°F (superheated)
Maximum design steam flow	23,000 pph
Nominal steam flow with 1 WHB	10,800 pph
Nominal steam flow with 2 WHB	21,600 pph
Alternator type	Synchronous
Alternator speed	1,800
Power output with 1 WHB	716 kW
Power output with 2 WHB	1,697 kW
Output voltage	4,160 V
Steam Surface Condenser	
Number	1
Type	Water cooled
Condensate pump number	2 (1 duty, 1 standby)
Condensate pump capacity	48 gpm, each
Cooling Water Heat Exchangers	
Number	2 (1 duty, 1 standby)
Cooling fluid (effluent) flow	2,550 gpm
Cooled fluid (recirculated potable water) flow	2,180 gpm
Condensate Handling System	
Condensate storage tank number	1
Condensate storage tank capacity	1,850 gallons
Deaerator number	1
Deaerator capacity, min	10 minutes

DESCRIPTION	CRITERIA
Deaerator condensate flow rate	24,000 pph
Deaerator steam use	1,000 - 2000 pph
WHB feed water pump number	3 (2 duty, 1 standby)
WHB feed water pump flow	27 gpm, each
WHB feed water pump approximate head	1,200 ft
Packaged Water Treatment System	
Number	2 (1 duty, 1 standby)
Treated water flow	11 gpm
Make up water tank capacity	1,900 gallons

2.3.2 Costs

2.3.2.1 Opinion of Probable Project Costs

A planning level opinion of probable project cost (OPPC) are shown in Table 2-13 for the Lemay WWTF Electricity Generation Alternative. The allowances used are the same as for the Lemay WWTF Building Heating evaluation.

Table 2-13 Lemay Electricity Production Alternative OPPC

DESCRIPTION	COST
WHB Building	$2,205,000
WHBs	$4,390,000
WHB fly ash transport system	$643,000
Steam turbine generator	$1,472,000
Steam condenser	$378,000
Cooling water heat exchangers	$311,000
Condensate handling system	$641,000
Packaged water treatment system	$151,000
Equipment installation	$1,175,000
Process Piping	$2,024,000
Process Ductwork	$1,594,000
Electrical (8%)	$733,000
I&C (7%)	$641,000
Contractor costs (23.7%)	$3,877,000
Construction Contingency (35%)	$7,082,000

DESCRIPTION	COST
Engineering and Legal (20%)	$5,463,000
Project Costs	$32,780,000

2.3.2.2 Operating Costs

Annual operating costs were developed for electrical, labor and maintenance costs for both future AA (FAA) and current AA (CAA) conditions. Table 2-14 shows these costs for the alternatives. Operating costs are based on:

- 24 hour per day, 7 days per week operation
- Electricity cost of $0.068 per kW-hr
- Labor costs of $24/hour
- Annual maintenance cost based on 2% of equipment cost and 0.5% of building capital cost

Table 2-14 Lemay Electricity Generation Annual Differential Operating Costs

ITEM	CAA	FAA
Electrical Savings	($268,000)	($403,000)
Maintenance	$165,000	$165,000
Labor	$235,000	$235,000
Total	$132,000	($2,000)

2.3.2.3 Present Worth Costs

Present worth costs for the Lemay Electricity Generation alternative are shown in Table 2-15. Total present worth costs are based on:

- Evaluation period: 20 years
- Interest rate: 4%
- Escalation rate: 2.5%
- Current conditions modeled for years 0 to 10, future conditions modeled for years 11 to 20

Table 2-15 Lemay Electricity Generation Alternative Present Worth Costs

ITEM	COST
O&M PW	$1,186,000
OPCC	$32,780,000
Ameren Incentive	($400,000)
Total	$33,566,000

2.3.3 Non-Economic Criteria

Table 2-16 has a summary of advantages and disadvantages for the Lemay Electrical Generation alternative.

Table 2-16 Lemay Electricity Generation Advantages and Disadvantage

ITEM	SUMMARY
Advantages	• Recovers waste energy to create renewable energy and reduce electricity costs
Disadvantages	• Substantially more capital cost not justified by annual savings • Adds operational complexity to FBI system

2.3.4 Evaluation and Recommendation

The Lemay Electricity Generation alternative has substantial capital cost that isn't justified by the annual cost savings and operating the WHBs will add complexity to the FBI trains, which will already have many advanced air pollution equipment process components to operate in conjunction with the combustion reactor. These results are similar to the previous electricity generation evaluation done for the Solids Master Plan work. For these reasons, the Lemay Electricity Generation alternative is not recommended.

To accommodate the option for adding energy recovery in the future, it is recommended that the system is configured such that take-off duct is included for re-routing of waste heat to a future adjacent building; which would house a waste heat boiler, steam turbine, and steam system (condenser, de-aerators, pumps, water treatment system, etc.). With such a configuration, additional costs are not necessary at this time while still configuring the system to allow for the implementation of future energy recovery systems.

3.0 Bissell Point WWTF

3.1 BACKGROUND

3.1.1 FBI Sizing and Loading Criteria

Design solids quantities for current and future conditions were developed as part of *TM 04 Solids Quantities and Characteristics*. For the Bissell Point WWTF solids production is projected at 250 dtpd for future MM, 135 dtpd for future AA, 114 dtpd for current AA. The size and quantities of FBI units were selected as part of *TM 09 FBI Design Criteria*. For the Bissell Point WWTF the alternative was selected that consisted of 3 units sized to meet future MM, with one additional standby unit to process solids above MM production and provide capacity when units are out of service for maintenance. Design criteria for the FBI units are listed in Table 3-1.

Table 3-1 Bissell Point FBI Design Criteria

DESCRIPTION	VALUE
Number of units	4
Nominal design capacity, each	83 dtpd
Firm nominal capacity	250 dtpd
Installed nominal capacity	334 dtpd
Bed outside diameter	15.7 feet
Design fluidizing air	9,743 scfm
Max flood capacity (33.4 %TS, 32.2 %VS), each	92 dtpd
Nominal normal capacity (29.7 %TS, 50.8 %VS), each	68 dtpd

dtpd = dry tons per day, scfm = standard cubic feet per minute, TS = total solids, VS = volatile solids

3.1.2 Past Evaluations

Energy recovery assessments have been completed in the past. As part of the Solids Handling Master Plan (SMP), steam energy recovery alternatives were developed for both the existing multiple hearth incinerators option and new FBIs option. The alternatives for new FBIs are of most interest for the current project and were based on recovering heat from the FBI exhaust gas to produce either medium pressure steam for sale to Trigen or high pressure superheated steam for on-site power generation, as identified in the *Phase II TM 1 – Bissell Point WWTP Solids Processing Alternatives Evaluation*. The medium pressure steam for sale to Trigen alternative, identified as Alternative B-2-A in TM1, consisted of:

- Waste heat boilers (WHBs)
- Ash pneumatic conveyance
- Packaged water treatment system for boiler water.

The packaged water treatment system was designed for a once-through use steam system with no condensate return from Trigen. Design criteria for major energy recovery system components of the medium pressure steam for sale alternative is shown in Table 3-2.

Table 3-2 SMP (2010) TM1 Bissell Point Sale of Medium Pressure Steam Alternative Design Criteria

DESCRIPTION	CRITERIA
Waste Heat Boilers	
Number	2 (one per FBI)
Type	Water tube
Design flue gas flow	68,250 pph
Steam pressure	180 psia
Steam temperature	373ºF (saturated)
Steam flow (less parasitic loads, i.e. deaerator)	15,100 pph
WHB Fly Ash Transport System	
Type	Pneumatic
Packaged Water Treatment System	
Number	2 (1 duty, 1 standby)
Treated water flow	50 gpm

pph = pounds per hour

The high pressure superheated steam for on-site power generation alternative, identified as Alternative B-2-B consisted of:

- Waste heat boilers (WHBs)
- Ash pneumatic conveyance
- Condensing steam turbine-generator
- Steam system including condenser, condensate pumps, cooling heat exchanger, condensate storage tank, deaerator, and WHB feed pumps
- Packaged water treatment system for boiler water make up.

Design criteria for major energy recovery system components of the high pressure steam for on-site power generation is shown in Table 3-3.

Table 3-3 SMP (2010) TM1 Bissell Point Power Generation Alternative Design Criteria

DESCRIPTION	CRITERIA
Waste Heat Boilers	
Number	2 (one per FBI)
Type	Water tube
Design flue gas flow	68,250 pph
Steam pressure	400 psia
Steam temperature	600ºF (superheated)
Steam flow	11,800 pph[1]

DESCRIPTION	CRITERIA
WHB Fly Ash Transport System	
Type	Pneumatic
Steam Turbine Generator	
Number	1
Type	Condensing to 4” Hg
Steam pressure	400 psia
Steam temperature	600°F (superheated)
Design steam flow	16,400 pph[2]
Alternator type	Synchronous
Power output	1.0 MW
Steam Surface Condenser	
Number	1
Type	Water cooled
Cooling Water Heat Exchangers	
Number	2 (1 duty, 1 standby)
Condensate Handling System	
Condensate storage tank number	1
Condensate storage tank capacity	900 gallons
Deaerator number	1
Deaerator condensate flow rate	16,400 pph
Deaerator steam use	1,000 to 2,000 pph
WHB feed pump number	2 (1 duty, 1 standby)
Packaged Water Treatment System	
Number	2 (1 duty, 1 standby)
Treated water flow	15 gpm

pph = pounds per hour

[1] *Less parasitic loads, i.e. deaerator, etc.*

[2] *Steam turbine sized for steam rate prior to parasitic load deduction*

Life cycle costs were developed as part of the evaluation and a summary is shown in Table 3-4.

Table 3-4 SMP (2010) TM1 Bissell Point Opinions of Costs, Savings, and Life Cycle Costs

ALTERNATIVE	B-2 FBI + CFG[1]	B-2-A FBI + STEAM[2]	B-2-B FBI + POWER[3]
Capital Costs	$175,732,000	$15,559,000	$29,003,000
Salvage Value	($4,556,000)	($1,861,000)	($494,000)
Annual O&M Costs	$7,860,000	$383,000	$691,000
Annual Revenue	($0)	($855,000)	($806,000)
Present Worth Costs			
Capital	$175,732,000	$15,559,000	$29,003,000
Salvage	($1,717,000)	($701,000)	($186,000)
O&M	$97,947,000	$4,773,000	$8,611,000
Revenue	($0)	($10,655,000)	($10,971,000)
Total Present Worth Costs	$271,962,000	$8,976,000	$26,457,000

[1] *Alternative B-2 FBI + CFG - new FBI units with centrifuge dewatering technology*

[2] *Alternative B-2-A FBI + STEAM – differential additional costs of steam production for sale to base costs of new FBI units with centrifuge dewatering technology*

[3] *B-2-B FBI + POWER - differential additional costs of electricity production from steam to base costs of new FBI units with centrifuge dewatering technology*

As shown by the analysis both energy recovery alternatives had a positive overall present worth cost meaning that overall costs were greater than benefits for the review period and there was not a positive payback on investment.

As part of the same project, a triple bottom line evaluation, considering economic, social, and environmental criteria was performed in *Phase II TM 10 Triple Bottom Line Evaluation*. The overall weighted total score for the alternative of new FBI units with centrifuge dewatering without energy recovery (B-2 FBI + CFG) was 39.70, the score for the alternative with steam for sale energy recovery (B-2-A FBI + ST) was 36.25, and the score for the alternative with steam for power generation energy recovery was 36.55, indicating that the alternative without energy recovery scored higher when both economic and non-economic factors were evaluated.

3.2 ELECTRICITY PRODUCTION

3.2.1 Electricity Generation Facility

In order to determine if it would be beneficial to include energy recovery with electricity generation for the new FBI facility at the Bissell WWTF an alternative was developed based on recovering energy from the FBI exhaust gas and producing steam from the energy to power a steam turbine generator. The energy recovery system for electricity power generation would be similar to the system previously evaluated as part of the Solids Master Plan. Two WHBs and ductwork would be provided so that any of the four FBI systems when operating could feed a WHB or bypass the boilers. The energy recovery system would consist of the same components as the Lemay WWTF Electricity Generation Alternative.

Because the FBI reactors for both Lemay and Bissell Point WWTFs have a nominal 83 dtpd capacity, the sizing criteria for two waste heat boilers and associated steam system would be the same for the Bissell Point WWTF Electricity Generation alternative as for the Lemay WWTF Electricity Generation alternative. Design criteria for major energy recovery system components is shown in Table 2-12: Lemay Electricity Generation Design Criteria.

3.2.2 Costs

3.2.2.1 Opinion of Probable Project Costs

Because the FBI reactors and energy recovery system for both Lemay and Bissell Point WWTFs had the same sizing the OPPC was the same for the Bissell Point WWTF Electricity Generation alternative as for the Lemay WWTF Electricity Generation alternative. A planning level OPPC for the energy recovery system at both WWTFs are shown in Table 2-13: Lemay Electricity Production Alternative OPPC. The total project costs for the energy recovery system was $32,780,000.

3.2.2.2 Operating Costs

Annual operating costs were developed for electrical, labor and maintenance costs for both future AA (FAA) and current AA (CAA) conditions. Although the energy recovery system for the Bissell Point WWTF was sized similarly to the Lemay WWTF, the solids production rates are different, and the operating costs will be different based on the plant specific production rates. Table 3-5 shows these costs for the alternatives. Operating costs are based on:

- 24 hour per day, 7 days per week operation
- Electricity cost of $0.068 per kW-hr
- Labor costs of $24/hour
- Annual maintenance cost based on 2% of equipment cost and 0.5% of building capital cost

Table 3-5 Bissell Point Electricity Generation Annual Differential Operating Costs

ITEM	CAA	FAA
Electrical Savings	($454,000)	($533,000)
Maintenance	$165,000	$165,000
Labor	$235,000	$235,000
Total	($54,000)	($132,000)

3.2.2.3 Present Worth Costs

Present worth costs for the Bissell Point Electricity Generation alternative are shown in Table 3-5. Total present worth costs are based on:

- Evaluation period: 20 years
- Interest rate: 4%
- Escalation rate: 2.5%
- Current conditions modeled for years 0 to 10, future conditions modeled for years 11 to 20

Table 3-6 Bissell Point Electricity Generation Alternative Present Worth Costs

ITEM	COST
O&M PW	($1,576,000)
OPCC	$32,780,000
Ameren incentive	($500,000)
Total	$30,704,000

3.2.3 Non-Economic Criteria

Table 3-7 has a summary of advantages and disadvantages for the Bissell Point Electrical Generation alternative.

Table 3-7 Bissell Electricity Generation Advantages and Disadvantage

ITEM	SUMMARY
Advantages	• Recovers waste energy to create renewable energy and reduce electricity costs
Disadvantages	• Substantially more capital cost not justified by annual savings • Adds operational complexity to FBI system

3.2.4 Evaluation and Recommendation

Similar to the Lemay Electricity Generation alternative, the Bissell Point Electricity Generation alternative has substantial capital cost that isn't justified by the annual cost savings and operating the WHBs will add complexity to the FBI trains, which will already have many advanced air pollution equipment process components to operate in conjunction with the combustion reactor. These results are similar to the previous electricity generation evaluation done for the Solids Master Plan work. For these reasons, the Bissell Point Electricity Generation alternative is not recommended.

3.3 SALE OF STEAM TO PROCTOR & GAMBLE

3.3.1 Steam Generation Facility

An alternative was developed to evaluate the sale of steam generated at the Bissell Point WWTF to the Proctor & Gamble (P&G) plant located nearby based on recovering energy from the FBI exhaust gas and producing steam to convey for off-site use. The energy recovery system would consist of:

- WHBs to capture heat from the FBI exhaust gas and produce saturated steam
- Refractory lined ductwork and dampers for FBI exhaust gas conveyance and bypass duct
- Pneumatic conveyance system to transport ash from the WHB hoppers to the ash system, including transporter and air compressors

- Steam piping between the new FBI Building and P&G plant, based on above grade piping with yard supports and foundations
- Deaerator and WHB feed pumps
- Packaged water treatment system to treat potable water for boiler water
- Building area to house the energy recovery system

Design criteria for major energy recovery system components is shown in Table 3-8.

Table 3-8 Bissell Point Sale of Steam Design Criteria

DESCRIPTION	CRITERIA
Waste Heat Boiler	
Number	2
Type	Water tube
Flue gas inlet	950°F
Flue gas outlet	450°F
Design flue gas flow	73,000 pph
Design steam pressure	200 psig
Operating steam pressure	125 psig
Steam temperature	353°F (saturated)
Steam flow, each	9,500 pph
WHB Fly Ash Transport System	
Type	Pneumatic
Number of transporters	2
Number of compressors	2
Deaerator and WHB Pumps	
Deaerator number	1
Deaerator capacity, min	10 minutes
Deaerator condensate flow rate	0 pph
Deaerator steam use	1,000 - 2000 pph
WHB feed water pump number	3 (2 duty, 1 standby)
WHB feed water pump flow	27 gpm, each
WHB feed water pump approximate head	1,200 ft
Packaged Water Treatment System	
Number	2 (1 duty, 1 standby)
Treated water flow	50 gpm

3.3.2 Costs

3.3.2.1 Opinion of Probable Project Costs

A planning level OPPC is shown in Table 3-9 for the Bissell Point WWTF Sale of Steam Alternative. The allowances used are the same as for the Lemay WWTF Building Heating evaluation.

Table 3-9 Bissell Sale of Steam Alternative OPPC

DESCRIPTION	COST
WHB Building	$1,755,000
WHBs	$3,000,000
WHB fly ash transport system	$643,000
Steam conveyance piping	$546,000
Deaerator and WHB pumps	$641,000
Packaged water treatment system	$300,000
Equipment installation	$688,000
Process Piping	$200,000
Process Ductwork	$1,594,000
Electrical (8%)	$422,000
I&C (7%)	$369,000
Contractor costs (23.7%)	$2,407,000
Construction Contingency (35%)	$4,398,000
Engineering and Legal (20%)	$3,393,000
Project Costs	$20,356,000

3.3.2.2 Operating Costs

Annual operating costs were developed for electrical, labor and maintenance costs for both future AA (FAA) and current AA (CAA) conditions. Table 3-10 shows these costs for the conditions. Operating costs are based on:

- 24 hour per day, 7 days per week operation
- Natural gas cost of $4.50 per million Btu
- Revenue based on 80% of the cost to P&G of producing steam with natural gas in their steam system
- Labor costs of $24/hour
- Annual maintenance cost based on 2% of equipment cost and 0.5% of building capital cost

Table 3-10 Bissell Point Sale of Steam Annual Differential Operating Costs

ITEM	CAA	FAA
Revenue from P&G	($531,000)	($623,000)
Maintenance	$98,000	$98,000
Labor	$235,000	$235,000
Total	($198,000)	($290,000)

3.3.2.3 Present Worth Costs

Present worth costs for the Bissell Point Sale of Steam alternative are shown in Table 3-11. Total present worth costs are based on:

- Evaluation period: 20 years
- Interest rate: 4%
- Escalation rate: 2.5%
- Current conditions modeled for years 0 to 10, future conditions modeled for years 11 to 20

Table 3-11 Bissell Point Sale of Steam Alternative Present Worth Costs

ITEM	COST
O&M PW	$5,739,000
Steam Sale	($9,967,000)
OPCC	$20,356,000
Total	$16,128,000

3.3.3 Non-Economic Criteria

Table 3-12 has a summary of advantages and disadvantages for the Bissell Point Sale of Steam alternative.

Table 3-12 Bissell Point Sale of Steam Alternative Advantages and Disadvantage

ITEM	SUMMARY
Advantages	• Recovers waste energy to create renewable energy and provide revenue from steam sales
Disadvantages	• Substantially more capital cost not justified by annual savings • Adds operational complexity to FBI system

3.3.4 Evaluation and Recommendation

The Bissell Point Sale of Steam alternative has substantial capital cost that isn't justified by the annual cost savings and operating the WHBs will add complexity to the FBI trains. These results are similar to other energy recovery evaluations in this TM. For these reasons, the Bissell Point Sale of Steam alternative is not recommended.

To accommodate the option for adding energy recovery in the future, it is recommended that the system is configured such that take-off duct is included for re-routing of waste heat to a future adjacent building; which would house a waste heat boiler, steam turbine, and steam system (condenser, de-aerators, pumps, water treatment system, etc.). With such a configuration, additional costs are not necessary at this time while still configuring the system to allow for the implementation of future energy recovery systems.

FINAL

BISSELL & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum 15:

Cake Conveyance

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

13 NOVEMBER 2020

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Introduction

The purpose of this technical memorandum (TM) is to discuss considerations for the sizing and selection of dewatered sludge (cake) conveyance technologies associated with the Metropolitan St. Louis Sewer District (MSD) Bissell Point Wastewater Treatment Facility (WWTF) and Lemay WWTF Fluidized Bed Incinerators (FBI) Project.

Solids Production and Conveyance

Cake conveyance will be required to transport cake from each facility's dewatering and receiving facilities to the new FBIs. As such, each of the cake conveyance alternatives reviewed herein must be capable of handling projected solids production at Bissell Point and Lemay WWTFs; refer to Table 1.

Table 1. Current and Projected Bissell Point and Lemay Cake Production

Description	Bissell Point	Lemay
	[1]Total Solids, dtpd	[1,2]Total Solids, dtpd
Normal, AA	134.8	111.6
Normal, MM	168.1	122.9
Normal, PW	246.8	144.7
Flood Stage, MM	250.1	165.2
Flood Stage, PW	300.3	211.9

[1]Projections taken from TM-09: FBI Design Criteria.

[2]Lemay WWTF solids projections include cake from Lower Meramec, Grand Glaize, and Fenton WWTFs.

In addition, conveyance may be required to direct cake to offload during periods where incineration capacity is not sufficient to process all cake onsite. As such, projected cake receiving quantities are provided under Table 2.

Table 2. Projected Cake Receiving at Bissell Point and Lemay WWTFs

Description	Bissell Point (Cake from Lemay)	Lemay (Cake from Bissell Point)
	[1]Total Solids, dtpd	[1]Total Solids, dtpd
[2]Cake Received from Other WWTF:		
- Normal, AA	28.6	0
- Normal, MM	39.9	2.1
- Normal, PW	61.7	80.8

[1]Assumes remaining online FBIs operating at 100% design capacity (83 dtpd each).

[2]Capacity with 2 FBIs out of service, less projected solids quantities provided under Table 1.

Cake Conveyance Alternatives

Several alternatives for cake conveyance were developed in discussion with MSD. Note that it is assumed that the same cake conveyance technology(ies) will be utilized at both Bissell Point and Lemay WWTFs. As such, alternatives presented herein are considered representative for both facilities.

Table 3 presents a summary of alternatives considered in this evaluation.

Table 3. Cake Conveyance Alternatives

CAKE CONVEYANCE FROM DEWATERING OR RECEIVING	CAKE CONVEYANCE INTO FBI		
	OPTION A HYDRAULIC PISTON PUMP	OPTION B PROGRESSING CAVITY PUMP	OPTION C TWIN-SCREW CONVEYOR
ALTERNATIVE 1 BELT CONVEYORS	Alternative 1A	Alternative 1B	Alternative 1C
ALTERNATIVE 2 SCREW CONVEYORS	Alternative 2A	Alternative 2B	Alternative 2C
ALTERNATIVE 3 PROGRESSING CAVITY PUMPS	N/A	Alternative 3	N/A
ALTERNATIVE 4 HYDRAULIC PISTON PUMPS	Alternative 4	N/A	N/A

Note that each alternative presented in Table 3 is comprised of two components. The first component (located in the left-hand column of Table 3) is cake conveyance from dewatering or receiving. Four alternatives are considered for this component: Belt Conveyors, Screw Conveyors, Progressive Cavity Pumps, and Hydraulic Piston Pumps.

Note that the first component addresses how cake will be conveyed from dewatering or receiving but does not necessarily address how cake will be fed into the FBI. This is because feeding cake into an FBI's fluidized sand bed requires a conveyance method which is suitable for a high temperature, pressurized application. This is notable given that this type of service cannot be achieved by belt conveyors nor screw conveyors. As such, alternatives which consider belt conveyors or screw conveyors would also require a separate downstream cake conveyance component which is suitable to feed cake into the FBIs.

The second component of each alternative (located on the top-most row of Table 3) is cake conveyance into the FBI itself. For this second component, three options are considered: Hydraulic Piston Pumps, Progressing Cavity Pumps, and Twin-Screw Conveyors.

Considering each of the cake conveyance options noted above, eight resultant alternatives were developed and are presented in Table 3. For clarity, a summary description of each of these alternatives is also provided below. Note that detailed discussions for each cake conveyance technology are provided thereafter.

ALTERNATIVES 1A, 1B, AND 1C

Under these alternatives, dewatered and received cake would be transferred via a series of belt conveyors to a hopper adjacent to each FBI. Cake collected in this hopper would then be transferred to either a hydraulic piston pump (Alternative 1A), a progressing cavity pump (Alternative 1B), or a twin-screw conveyor (Alternative 1C) in order to feed the cake into each FBI.

Under these alternatives, it is likely that numerous flat and inclined belt conveyors, diverter gates, slide gates, chutes, and other appurtenances would be required to appropriately direct cake from dewatering and receiving to each of the FBIs. In addition, a dedicated hopper adjacent to each FBI would be required in order to provide a “wide-spot” in the system by which to provide a consistent feed to the downstream progressing cavity pumps, hydraulic piston pumps, or twin-screw conveyors and thereafter into the FBI.

ALTERNATIVES 2A, 2B, AND 2C

Under these alternatives, dewatered and received cake would be transferred via a series of screw conveyors to a hopper adjacent to each FBI. Cake collected in this hopper would then be transferred to either a hydraulic piston pump (Alternative 2A), a progressing cavity pump (Alternative 2B), or a twin-screw conveyor (Alternative 2C).

Under these alternatives, it is likely that numerous flat and inclined screw conveyors, discharge chutes, control gates, and other appurtenances would be required to appropriately direct cake from dewatering and receiving to each of the FBIs. Similar to Alternatives 1A through 1C, a dedicated hopper adjacent to each FBI would be required in order to provide a “wide-spot” in the system by which to provide a consistent feed to the downstream progressing cavity pumps, hydraulic piston pumps, or twin-screw conveyors and thereafter into the FBI.

ALTERNATIVE 3

Under this alternative, dewatered and received cake would be transferred via progressing cavity pumps through a series of enclosed, high pressure cake pipelines directly into each FBI. As such, under this arrangement no separate cake hoppers would be required adjacent to the FBIs.

ALTERNATIVE 4

Under this alternative, dewatered and received cake would be transferred via hydraulic piston pumps through a series of enclosed, high pressure pipelines directly into each FBI. Similar to Alternative 3, under this arrangement no separate cake hoppers would be required adjacent to the FBIs.

Discussion of Cake Conveyance Technologies

BELT CONVEYORS

As previously noted, Alternatives 1A, 1B, and 1C consist of a series of belt conveyors to transfer cake from dewatering and receiving to the FBIs.

Belt conveyors, which are currently used for cake transfer within the existing Bissel Point and Lemay WWTF multiple hearth incinerator (MHI) facilities, are available in flat (up to 20 - 30% incline) and cleated (>30% incline) arrangements. Note that while cleated belts offer a greater degree of incline for conveying cake, many facilities prefer flat belts given the additional housekeeping and maintenance problems associated with the cleated style. In addition, the conveyors themselves can be equipped in troughed arrangements or with sidewalls to help prevent spilling.

When compared to screw conveyors of the same capacity (discussed further below), flat belt conveyors provide a higher conveyance capacity for moving cake from point-to-point based on the same footprint size. These advantages aside, because belt conveyors are an “open” type technology, they are often associated with housekeeping/cleaning issues (e.g. sludge cake falling off the conveyor). In addition, belt conveyors require regular attention due to belt wear, periodic cleaning, and preventative repair/maintenance of constantly moving parts and pieces along the conveyance pathway.

Given the “open” arrangement of belt conveyors, additional safety precautions are required such as fencing, pull cords, emergency stops, and other appurtenances which can make accessing and maintenance of equipment components more difficult. This is an important consideration, given that barriers often result in inadequate maintenance / attention to various equipment components. Note that other facilities have experienced significant problems with maintenance of belt conveyor systems, including several which have broken belts (taking entire incinerator trains offline until repairs can be completed) and fires caused by missing or stuck belt rollers.

For large facilities such as Bissell Point and Lemay WWTFs, belt conveyors and associated diverter gates, discharge chutes, slide gates, cleaning systems (such as spray bars, drain troughs, and curbs), support and access systems (structural framing, stairs, ladders, and access platforms) are a complex system requiring significant footprint and other building considerations.

Figure 1 provides two example photos of another facility which utilizes a complex network of belt conveyors to transfer cake from dewatering to incinerators.

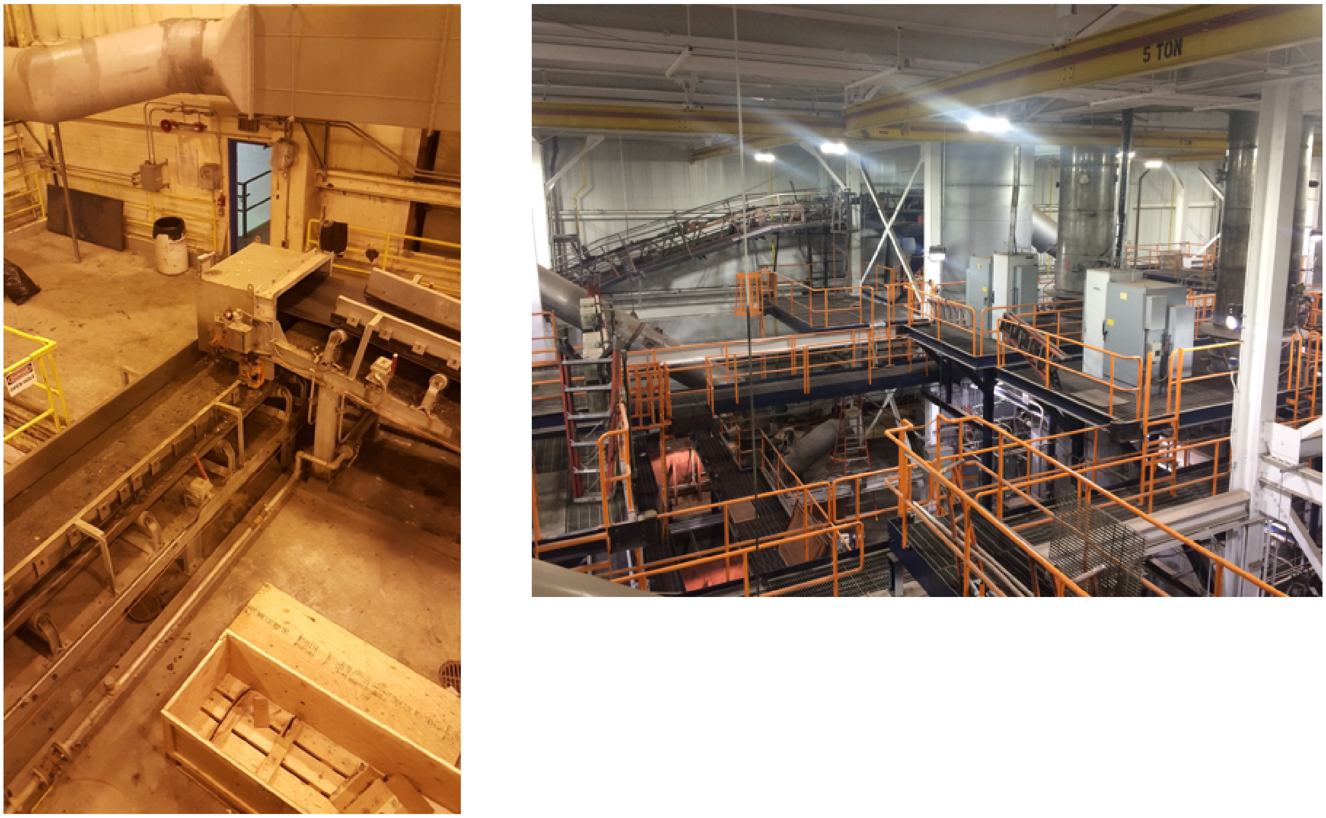


Figure 1. Extensive Belt Conveyor Network to Convey Cake from Dewatering to MHIs

SCREW CONVEYORS

As previously noted, Alternatives 2A, 2B, and 2C consist of a series of screw conveyors to transfer cake from dewatering and receiving to the FBIs.

Compared to belt conveyors, screw conveyors offer the advantage of a closed system for sludge cake conveyance. The screw conveyors generally consist of an external trough and a rotating internal screw, available in a shafted or shaftless arrangement. However, whether shaftless or shafted, screw conveyors provide a significantly lower capacity (running 1/3 to 1/2 full) when compared to other conveyance technologies such as belt conveyors of the same general footprint. Furthermore, longer runs of shafted screw conveyors require intermediate bearings for screw conveyor support which are difficult to access for maintenance.

Shaftless screw conveyors require liners which need periodic replacement, thus requiring significant access space to remove the internal screw. In general, screw conveyors are considered a less viable approach for sludge cake conveyance over longer distances when compared to the other technologies included under this evaluation. While a good solution for shorter distances, this technology is likely infeasible for the long runs needed to traverse the planned dewatering and incineration complexes.

Figure 2 provides an example of a typical shafted screw conveyor.

Figure 2. Example of Typical Shafted Screw Conveyor

PROGRESSING CAVITY PUMPS

As previously noted, Alternatives 1B, 2B, and 3 consist of progressing cavity pumps to transfer cake from dewatering and receiving to the FBIs and to feed cake into the FBIs.

Progressing cavity sludge cake pumps are considered advantageous in terms of offering a closed system for sludge cake conveyance and when compared to other sludge cake pumping systems on cost (i.e. versus hydraulic piston pumps discussed below).

This type of pump is also considered to be capable of handling dewatered sludge cake up to 25-30% solids concentration but has an approximate pressure discharge limitation of 400 psi which can only be achieved with large, multi-stage (6-9 stage) pump arrangements. With this large number of stages, the cost of a progressing cavity pump becomes comparable to a hydraulic piston pump.

Given the above, based on a normal sludge cake pressure loss of approximately 2 psi per foot of pipe, progressing cavity pumps can be expected to reliably transfer sludge cake no more than 200 ft. Given the extended distances and elevation changes required to convey sludge cake from the planned dewatering to incineration or to offload, this may be a considerable limiting factor.

Another limiting factor with progressing cavity pumps can be excessive maintenance and downtime. Other facilities which have operated progressing cavity pumps have required extensive piping modifications to reduce pressures (and to allow the pumps to operate as intended); some facilities have even replaced their progressing cavity pumps with hydraulic piston pumps given that they can deliver more than twice the discharge pressure.

Figure 3 provides an example of a typical multi stage progressing cavity pump for cake conveyance.

Figure 3. Example of Multi-Stage Progressing Cavity Pumps for Dewatered Sludge Cake

HYDRAULIC PISTON PUMPS

As previously noted, Alternatives 1A, 2A, and 4 consist of hydraulic piston pumps to transfer cake from dewatering and receiving to the FBIs and to feed cake into the FBIs.

When compared to progressing cavity pumps, hydraulically driven piston pumps offer increased pumping capacity for sludge cakes up to 35% solids concentrations at longer distances up to 400+ ft. This doubling of distance, when compared to progressing cavity pumps, is linked directly to the 900 - 1000 psi of pressure that can be generated at the discharge of the pump and a normal cake pressure loss of 2 psi per foot of pipe.

It is important to note that hydraulic piston pumps are commonly used at WWTPs to consistently convey sludge cake to incinerators over long distances, including those facilities visited by MSD staff as part of this project. These facilities include the Mill Creek WWTP in Cincinnati, Southerly WWTP in Cleveland, and G.E. Booth WWTP in Toronto.

Hydraulic piston pumps are also quickly and easily accommodating of varying capacity requirements, as the cake conveyance rate of the pump is simply dictated by the frequency of piston strokes. For example, the Schwing KSP-65 model pump, shown in Figure 4 below, can convey cake at a wide range of rates from less than 25 dtpd and up to 150+ dtpd.

Disadvantages associated with hydraulic piston pumps are primarily attributed to relatively higher cost and the notable preventative maintenance required for pump and hydraulic components, depending on the rate and frequency of use.

One other benefit of hydraulic piston pumps is that they can be furnished as a packaged system with associated cake collection or receiving bins and hydraulic systems. Figure 4 provides an example of a packaged dewatered cake receiving bin coupled with hydraulic piston pump and hydraulic system.

Figure 4. Example of Packaged Cake Collection Bin and Hydraulic Piston Pump

TWIN SCREW FEEDERS

Twin screw feeders are typically utilized to pack material (including cake) into pump fill chambers and would be used for this purpose for the progressing cavity pump or hydraulic piston pump alternatives previously discussed.

Twin screw feeders have also infrequently been used in the past to inject cake into the fluidized sand bed of FBIs, given that the dual screw of the screw feeder is capable of building enough pressure at the feeder outlet to convey cake into the bed. It should be noted that these have only been used for high solids (~40% TS) and that these do have associated safety risks (one system sustained fire damage during operation).

Modern FBI designs do not incorporate twin screw feeders, and FBI system suppliers have indicated that they will not consider this technology as part of their design.

Drawbacks include requirements for several large, elevated fill chambers installed at each cake feed port of the FBI, as well as exposure of twin-screw components to high temperatures. These systems are also maintenance intensive and would require significant footprint adjacent to each FBI to provide enough space for regular operations and maintenance activities.

Figure 5 provides an example of a typical twin-screw feeder. Note that the Owner's Representative (OR) team was unable to find a photo representative of a twin-screw feeder conveying cake into an FBI.

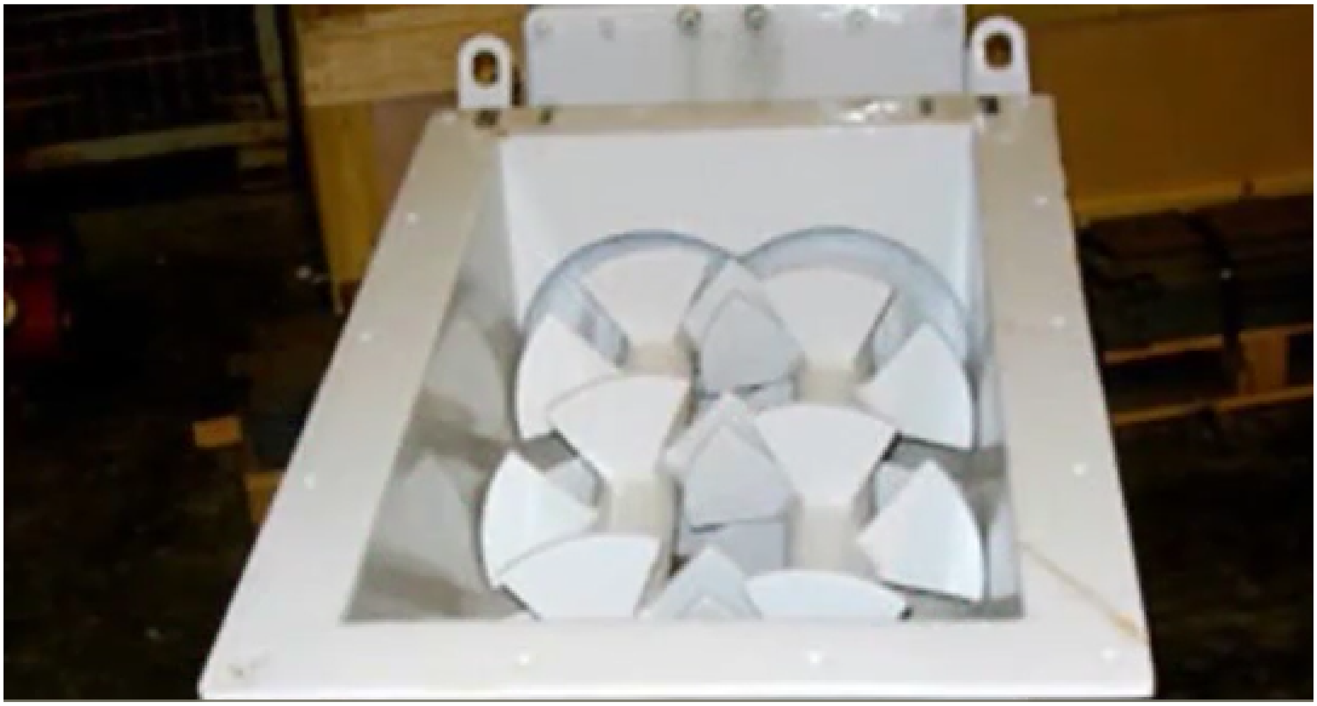


Figure 5. Example of Twin-Screw Feeder

Cost and Non-Cost Comparison of Alternatives

The OR team evaluated each cake conveyance alternative over cost and non-cost factors in order to establish a composite, comparable score for each alternative. As such, each category (cost and non-cost) was initially assigned an equal 50% weighting to be divided across the alternatives based on the ratio of scoring within the cost and non-cost categories. Note that further explanation is provided in subsequent sections. A summary of the initial allocation is shown in Table 4.

Table 4. Percentage of Allocation for Cost and Non-Cost Categories

Category	Allocated percentage (% of 100)
Cost	50%
Non-Cost	50%
Total	**100%**

COST COMPARISON OF ALTERNATIVES

Table 5 provides the cost categories over which each alternative was compared, including capital, operations, and maintenance costs.

For this evaluation, cost criteria were scored on a 1-5 scale, with a score of 1 meaning that the alternative represents a higher cost; a score of 3 meaning the alternative has an average cost; and a score of 5 meaning the alternative has a lower cost. Table 5 further defines the cost scoring criteria.

Table 5. Cost Scoring Definitions

ECONOMIC CRITERIA	SCORE OF 1	SCORE OF 3	SCORE OF 5
	HIGHEST COST	AVERAGE COST	LOWEST COST
Capital Cost	Highest relative equipment cost	Average relative equipment cost	Lowest relative equipment cost
Operation Cost	Highest relative power required	Average relative power required	Lowest relative power required
Maintenance Cost	Highest relative equipment maintenance cost	Average relative equipment maintenance cost	Lowest relative equipment maintenance cost

Results of the cost scoring for each alternative are presented in Table 6. Note that explanation regarding how the scoring was assigned is provided under the “description column” of Table 6.

Table 6. Cost Scoring of Alternatives

Criterion	Option	Scoring				Description
		ALT 1	ALT 2	ALT 3	ALT 4	
Capital[1]	A	2	2		4	[2] Alt 1A/B and Alt 2A/B - \$5,000/ft [3] Alt 1C and Alt 2C - \$4,000/ft. [4] Alt 3 and Alt 4 - \$3,000/ft
	B	2	2	4		
	C	3	3			
Operation[2]	A	2	2		4	[2] Alt 1A/B and Alt 2A/B – 350 HP [3] Alt 1C and Alt 2C – 250 HP [4] Alt 3 and Alt 4 – 200 HP
	B	2	2	4		
	C	3	3			
Maintenance	A	2	2		4	[2] Alt 1A/B and Alt 2A/B – Maintenance of multiple conveyors and pumps [3] Alt 1C and Alt 2C – Maintenance of multiple conveyors [4] Alt 3 and Alt 4 – Maintenance of pumps
	B	2	2	4		
	C	3	3			

[1] Costs are comparative and do not include all costs associated with cake conveyance. Comparative costs are for each cake conveyance train from dewatering to an FBI, assuming an average conveyance run of 200 ft.

[2] Power requirements are comparative and do not include all power associated with cake conveyance. Power requirements are for each cake conveyance train from dewatering to an FBI, assuming an average conveyance run of 200 ft.

Based on the cost scoring for each cost criterion presented in Table 6, a total cost score was summed for each alternative. The total cost scores were then divided by the total number of points assigned to all alternatives in order to establish a relative percentage score for each alternative. Each alternative's percentage score was then multiplied by the weighting factor of 50% presented in Table 4. Refer to Table 7.

Table 7. Results of Cost Scoring for Each Alternative

Alternative	Total Cost Score	Percentage of Total	Weighted Percentage
Alternative 1A	6	9.1%	4.6%
Alternative 1B	6	9.1%	4.6%
Alternative 1C	9	13.6%	6.8%
Alternative 2A	6	9.1%	4.6%
Alternative 2B	6	9.1%	4.6%
Alternative 2C	9	13.6%	6.8%
Alternative 3	12	18.2%	9.1%
Alternative 4	12	18.2%	9.1%
Total	*66*	*100%*	*50%*

As shown in Tables 6 and 7, Alternatives 3 and 4 received the highest relative cost scoring based on advantages associated with capital, operations, and maintenance of fewer equipment items and types of equipment required under these alternatives.

NON-COST COMPARISON OF ALTERNATIVES

Each option was also evaluated across the following five non-cost criteria based on its ability to achieve the criterion objective:

- **Reliability** – Resilient, dependable, and consistent service
- **Operability** – Ease of operation
- **Flexibility** – Manageable options offered during service interruption
- **Maintainability** – Long useful life with minimal and manageable maintenance
- **Constructability** – Construction methods minimize cost and schedule risk

Non-cost criteria were scored on a 1-5 scale, with a score of 1 meaning that the alternative is comparatively inferior or disadvantageous to meeting the criterion objective; a score of 3 meaning the alternative meets the criterion objective; and a score of 5 meaning the alternative is comparatively superior or advantageous to meeting the criterion objective. Table 8 further defines the non-cost criterion scoring.

Table 8. Non-Cost Criteria Scoring Definitions

Non-Economic Criteria	Score of 1	Score of 3	Score of 5
	Inferior/ Disadvantageous	Neutral/Meets Objective	Superior/ Advantageous
Reliability	Appreciable risk of system component failure and/or reduction in capacity	Moderate risk of system component failure and/or reduction in capacity	Low risk of system component failure and reduction in capacity
Operability	Complex system requiring frequent operations changes/decisions	Moderately complex system requiring periodic operations changes/decisions	Non-complex system requiring only occasional operations changes/decisions
Flexibility	Undesirable or unreliable standby operating modes available if primary mode is interrupted or unavailable	Acceptable standby operating modes available if primary mode is interrupted or unavailable	Reliable standby operating modes available if primary mode is interrupted or unavailable
Maintainability	Complex and/or frequent maintenance requirements over life of system equipment	Moderately complex and/or periodic maintenance requirements over life of system equipment	Non-complex and infrequent maintenance requirements over life of system equipment
Constructability	Requires complex, unproven and/or higher risk construction methods to implement	Requires moderately complex and/or moderate risk construction methods to implement	Uses non-complex, proven, and low risk construction methods to implement
Scores of 2 and 4 are intended to quantify moderate, but measurable differences between alternatives that are similar across the criterion.			

The OR team assigned non-cost scoring to each alternative, the results of which are presented in Table 9. Note that explanation regarding how the scoring was assigned is provided under the "description" column of Table 9.

Table 9. Non-Cost Scoring of Alternatives

Criterion	Option	Scoring				Description
		ALT 1	ALT 2	ALT 3	ALT 4	
Reliability	A	2	2		5	[2] Alt 1A/B and Alt 2A/B consist of a series of belt or screw conveyors. Failure of any sections between dewatering and incineration will take at least one FBI train offline. [1] Alt 1C and Alt 2C also rely on a twin-screw conveyor to direct cake into the FBI. This feed technology has been rarely used for FBIs given the challenges with maintaining a safe and reliable seal between the conveyor and 1400°F FBI bed gasses. [3] Alt 3 provides greater reliability of conveyance than a series of belt or screw conveyors as the cake is conveyed from dewatering into the FBI within a pipe and with no transitions between equipment sections or types. [5] Alt 4 also conveys the cake from dewatering into the FBI within a pipe and with no transitions. Hydraulic piston pumps can deliver higher pressures than progressing cavity pumps and thus present a lower risk of being shut off on overpressure.
	B	2	2	3		
	C	1	1			
Operability	A	2	2		5	[2] Alt 1A/B and Alt 2A/B consist of a series of belt or screw conveyors to transport cake from dewatering to incineration. This series of multiple conveyor sections and transition points introduces significant complexity to the system with multiple moving parts that need to be monitored and controlled. [1] Alt 1C and Alt 2C also introduce the operational complexity of a twin-screw conveyor to direct cake into the FBI. This feed technology has been rarely used for FBIs given the challenges with maintaining a safe and reliable seal between the conveyor and 1400°F FBI bed gasses. [4] Alt 3 introduces significantly less complexity than a series of belt or screw conveyors as the cake is conveyed from dewatering into the FBI within a pipe and with no transitions between equipment sections or types. Operation is limited to the pump itself and motorized valve positions to establish flow path to the selected FBI. [5] Alt 4 also conveys the cake from dewatering into the FBI within a pipe and with no transitions. Hydraulic piston pumps offer greater ease of operation as they can deliver higher pressures than progressing cavity pumps.
	B	2	2	4		
	C	1	1			

Criterion	Option	Scoring				Description
		ALT 1	ALT 2	ALT 3	ALT 4	
Flexibility	A	2	2		5	[2] Alt 1A/B/C and Alt 2A/B/C consist of a series of belt or screw conveyors to transport cake from dewatering to incineration. Failure of any sections between dewatering and incineration will take at least one FBI train offline as it is likely impractical to have a backup conveyor for each conveyor section from dewatering to three or four FBIs. [4] Alt 3 offers significantly greater flexibility than belt or screw conveyors as multiple flow paths can be provided to potentially direct cake from any dewatered cake collection bin to any FBI by changing the motorized valve positions. [5] Alt 4 offers the same flow path flexibility as Alt 3; however, with the additional pressures that hydraulic piston pumps can deliver, there is a greater likelihood that all flow paths will be available, including from the furthest cake collection bin to the furthest FBI.
	B	2	2	4		
	C	2	2			
Maintainability	A	2	3		3	[2] Alt 1A/B/C consists of a series of belt conveyors to transport cake from dewatering to incineration. This series of multiple conveyor sections and transition points introduces numerous moving parts that need to be maintained. Given the open nature of the belt conveyor system, additional maintenance will be needed for housekeeping due to spills and leaks along the length of the conveyor runs. [3] Alt 2A/B/C consists of a series of screw conveyors to transport cake from dewatering to incineration. This series of multiple conveyor sections and transition points also introduces numerous moving parts that need to be maintained; screw conveyors are an enclosed system with leaks and spills typically limited to transition points between conveyor sections. [4] Alt 3 presents significantly less points of maintenance than a series of belt or screw conveyors, as the moving parts of the system are limited to the progressing cavity pump. Maintenance on a progressing cavity pump can be significant at times when rotors and stators require adjustment or replacement. [3] Alt 4 also presents less points of maintenance than a series of belt or screw conveyors; however, maintenance on a hydraulic piston pump can also be significant, such as when the poppet valve assemblies require adjustment or replacement. There is also maintenance required on the hydraulic power pack.
	B	2	3	4		
	C	2	3			

Criterion	Option	Scoring				Description
		ALT 1	ALT 2	ALT 3	ALT 4	
Constructability	A	2	2		4	[2] Alt 1A/B/C and Alt 2A/B/C consist of a series of belt or screw conveyors to transport cake from dewatering to incineration. This arrangement introduces the complexity of installing multiple sections of conveyors and access platforms and stairs to ensure the entire length of conveyance can be safely operated and maintained. [4] Alt 3 and Alt 4 introduce significantly less complexity than a series of belt or screw conveyors, as the pumps will be accessible from the floor and the piping can be routed overhead without the need to install a series of access platforms or stairs.
	B	2	2	4		
	C	2	2			

Based on the non-cost scoring for each cost criterion presented in Table 9, a total non-cost score was summed for each alternative. The total non-cost scores were then divided by the total number of points assigned to all alternatives in order to establish a relative percentage score for each alternative. Each alternative's percentage score was then multiplied by the weighting factor of 50% presented in Table 4. Refer to Table 10.

Table 10. Results of Non-Cost Scoring for Each Alternative

Alternative	Total Non-Cost Score	Percentage of Total	Weighted Percentage
Alternative 1A	10	10%	5%
Alternative 1B	10	10%	5%
Alternative 1C	8	8%	4%
Alternative 2A	11	11%	5.5%
Alternative 2B	11	11%	5.5%
Alternative 2C	9	9%	4.5%
Alternative 3	19	19%	9.5%
Alternative 4	22	22%	11%
Total	*66*	*100%*	*50%*

As shown in Tables 9 and 10, Alternative 4 received the highest relative non-cost scoring based on advantages associated with various non-cost criteria.

SUMMARY COMPARISON OF ALTERNATIVES

Weighted scorings for each of the cost and non-cost evaluation categories, presented previously in Tables 7 and 10, are summarized in Table 11. Also presented in Table 11 is a summation of the scores across each category, resulting in an overall composite score which can be utilized to compare each alternative.

Table 11. Summary Comparison of Alternatives

Alternative	Total Weighted Cost Score	Total Weighted Non-Cost Score	Total Score
Alternative 1A	4.6%	5%	9.6%
Alternative 1B	4.6%	5%	9.6%
Alternative 1C	6.8%	4%	10.8%
Alternative 2A	4.6%	5.5%	10.1%
Alternative 2B	4.6%	5.5%	10.1%
Alternative 2C	6.8%	4.5%	11.3%
Alternative 3	9.1%	9.5%	18.6%
Alternative 4	9.1%	11%	20.1%
Total	*50%*	*50%*	*100%*

A graphical representation of the scoring presented in Table 11 is presented in Figure 6.

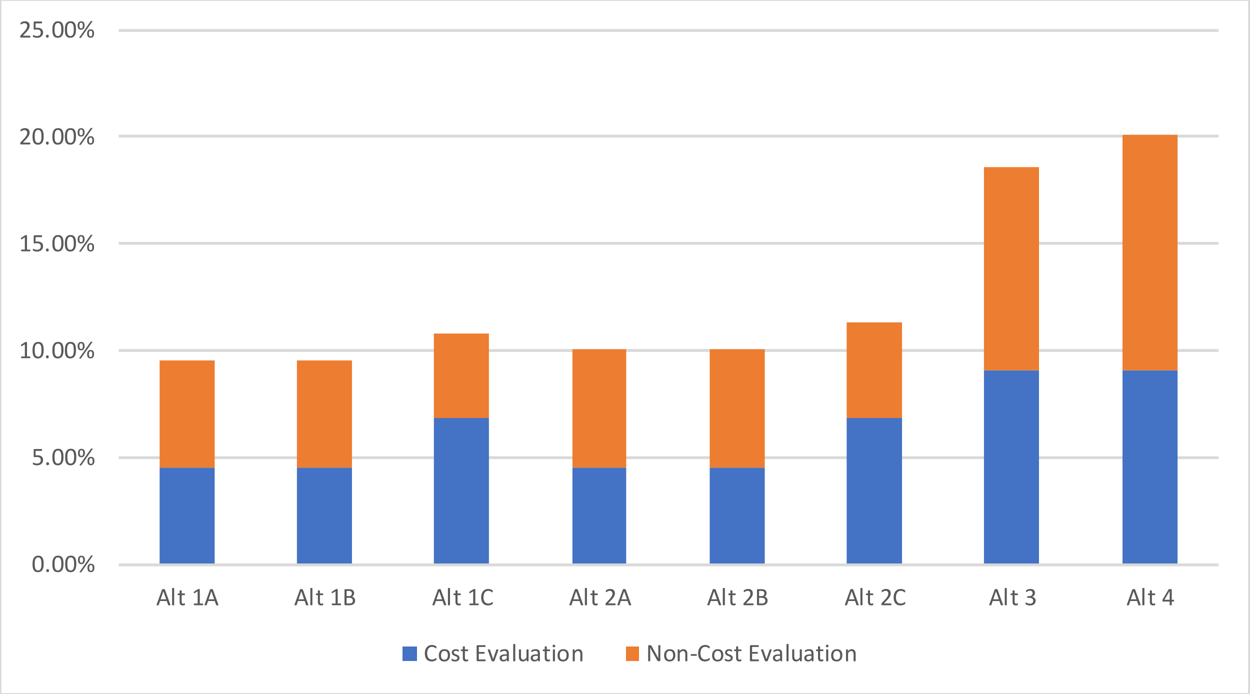


Figure 6. Summary Comparison of Alternatives

Recommendation

Based on the results of the evaluation presented herein, the OR team recommends that Alternative 4 be selected for implementation. In summary, this alternative is expected to provide the lowest life cycle cost relative to other alternatives, while also providing significant non-cost benefits. It should also be noted that ultimate site selection and process equipment configuration could alter the scoring for Alternative 3; if such a configuration results in longer pipe runs than are feasible.

FINAL

BISSELL POINT & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum 17: Abandon and Demolition Alternatives

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

28 JULY 2020

Table of Contents

List of Abbreviations

BC	Brown and Caldwell
BFP	Belt Filter Presses
BV	Black & Veatch
DB	Design Build
FBI	Fluid Bed Incinerator
MHI	Multiple Hearth Incinerator
TM	Technical Memorandum
WWTF	Wastewater Treatment Facility

1.0 Introduction

This Technical Memorandum (TM-17) addresses (at a conceptual level) potential demolition and abandonment options for the Bissell Point WWTF and Lemay WWTF facilities that may warrant consideration upon completion of the fluidized bed incineration (FBI) project.

The Bissell Point facility includes the following that are either currently abandoned or could be following the construction of new FBI facilities:

- Solids Handling Building
    - This houses the dewatering and incineration facilities, and includes:
        - 6 multiple hearth incinerators (MHIs)
        - 15 belt filter presses
        - Machine shop
        - Emission stack and ash storage silo
- Maintenance Center and Thickening Facility
    - Thickening Area
        - This houses maintenance as well as office (lab, lockers, offices, breakroom) facilities on the lower floor, and also includes:
            - 12 gravity belt thickeners (abandoned-in-place)
    - Maintenance Area
        - This area includes the majority of Bissell's maintenance shop floorspace.
- Administration Building
    - This building houses the management offices for the facility.
- Sludge Storage Tanks
    - Two circular storage tanks (abandoned-in-place) are located adjacent to the Solids Handling Facilities.

The Lemay facility similarly includes the following that are either currently abandoned or would be following the construction of new FBI facilities:

- Incineration and Filter Building
    - This building houses all of the incineration and dewatering facilities, as well as office, storage, electrical, and control rooms. This building includes:
        - 6 belt filter presses
        - 4 MHI's
        - Emission stack
- Administration Building
    - This building houses management offices as well as conference and meeting room space.
- Maintenance Building
    - This building serves as the space for all maintenance and shop floorspace.

- Grit and Screenings Building
    - This building has been abandoned-in-place with the exception of an electric room which serves the UV disinfection facilities.
- Service Building
    - This building currently serves as storage space for the facility; otherwise, it is essentially abandoned.

The new FBI project will require a new building for dewatering and incineration equipment and the existing equipment and structures used for each facility's current solids handling systems will no longer be needed. This TM identifies equipment and structures that will of necessity be abandoned, and also those that may of practicality need to be abandoned with the completion of the FBI project.

2.0 Existing Systems to be Abandoned

2.1 BISSELL POINT WWTF

The Solids Handling Building contains the dewatering equipment and incinerators for the Bissell Point WWTF. The building is connected to the Maintenance Center and Thickening Facilities, which includes the Administration Building, the Gravity Thickening Building, and the Maintenance Building. Adjacent to these structures are the two sludge storage tanks. Each of the buildings can be seen in Figure 2-1 below.

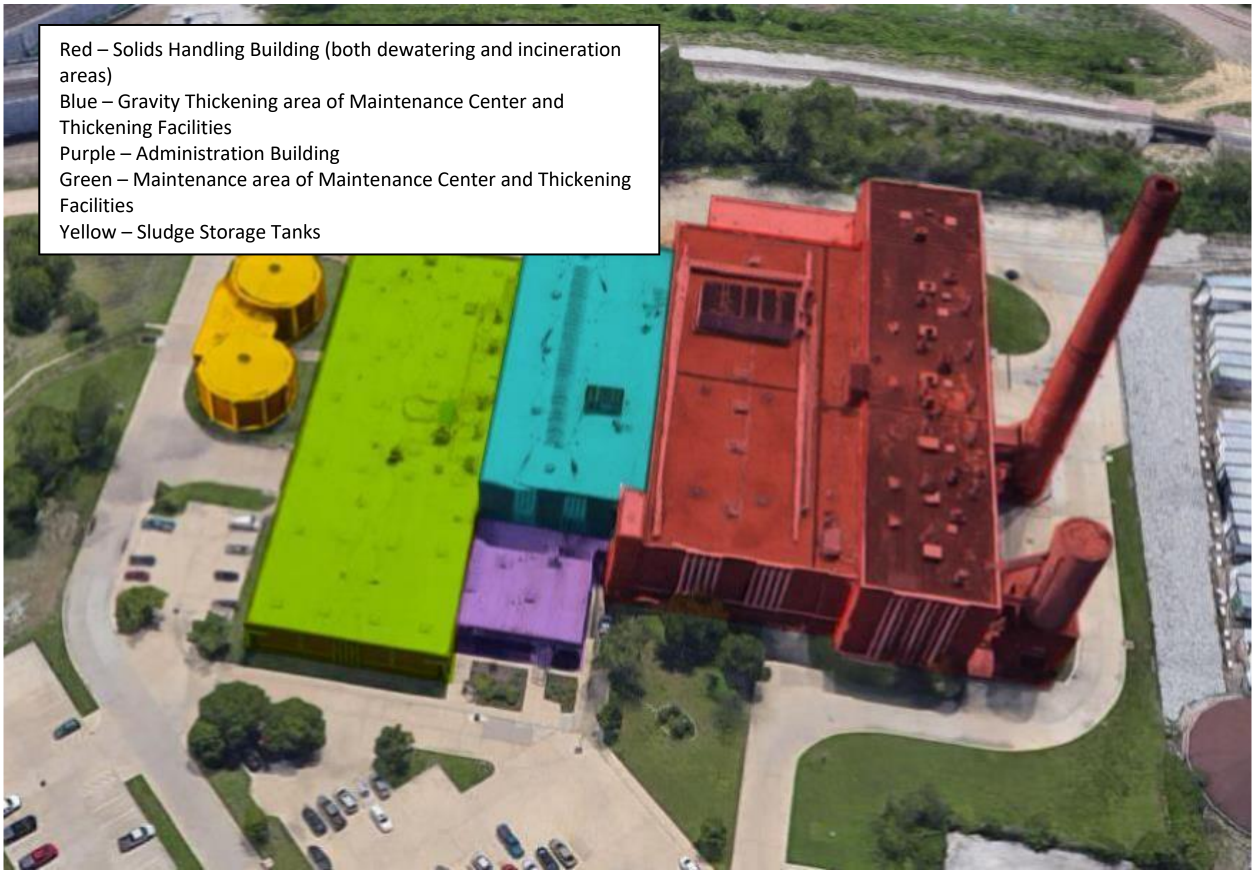


Figure 2-1 Bissell Point WWTF Buildings Layout

2.1.1 Solids Handling Building

The Solids Handling Building, as described here, is comprised of the dewatering area, the incineration area, and the machine shop located on the southside of the dewatering area.

2.1.1.1 Dewatering Area

The dewatering area is a three-story structure (with basement) located between the incineration area of the Solids Handling Building and the Gravity Thickening Building. The area contains the belt filter presses and associated pumps, two lime storage bins, a vacuum filter storage room, two polymer mixing tanks, two sludge wet wells, and four polymer storage tanks. Some of these items are no longer is service.

All equipment in this area will be abandoned as part of the FBI project including the existing sludge wet wells, which will be replaced by a new blended sludge well in the new dewatering building.

There is a tunnel access point on the eastern side of the basement that will need to remain in service.

2.1.1.2 Incineration Area

The incineration area is a three-story structure (with basement) and contains the six multiple hearth incinerators (MHIs) as well as the adjacent emission stack and the ash storage silo (out of service) . The emission stack, ash storage silo, and all equipment in this building will no longer be in service with the completion of the FBI construction and commissioning.

The boiler room is located within the incineration area and will not be part of the future facility. The boiler feeds heat to the overall facility; as such, a new heating source will be required for the existing locker rooms of the Maintenance Center and Thickening Facility and Administration Building if the Solids Handling Building were to be demolished.

2.1.1.3 Machine Shop

The machine shop is a single-story structure located adjacent to the south end of the Solids Handling Building. The shop area houses stop logs, air compressors for the plant, polymer pumps and loading. Also, the main gas meter is located just outside of the shop area.

The stop logs and compressors will need to be relocated if the shop area is demolished; polymer systems can be demolished; the gas meter will need to remain in service and must be protected or relocated during demo activities.

2.1.2 Maintenance Center and Thickening Facilities

The Maintenance Center and Thickening Facilities Building contains three smaller areas: The Administration Building, the maintenance area, and the gravity thickening area. It is anticipated that the maintenance area and the gravity thickening area will remain active spaces, but the Administration Building could be moved to the new FBI building.

2.1.2.1 Administration Building

The Administration Building is a single-story structure housing several offices, a conference room, restroom, and storage. The building can remain in service following completion of the FBI construction but could be considered for demolition if administration is moved into the new FBI building.

2.1.2.2 Maintenance Area

The maintenance area is a single-story structure that serves as the plant storage and maintenance facility. The area is an active area and will remain in service throughout construction and remain operable following completion of the FBI project, therefore there is no plan for demolition of the area at this time.

2.1.2.3 Gravity Thickening Area

The gravity thickening area is a three-story structure located between the Solids Handling Building and maintenance area. The building houses the 12 out-of-service gravity belt thickeners, two scum concentrators, electrical rooms, and storage rooms.

The gravity belt thickeners can be removed as part of this project. The existing scum concentrators will be abandoned with the commissioning of the new dewatering facility. The remainder of the building’s rooms and equipment should remain as active spaces.

2.1.2.4 Sludge Storage Tanks

The two circular sludge storage tanks have largely gone unused since being constructed and should be considered for demolition.

2.2 LEMAY WWTF

The Incineration and Filter (I&F) Building contains the dewatering equipment and incinerators for Lemay. The building is connected to the Maintenance Building and is adjacent to the Administration Building; as shown in Figure 2-2 below.

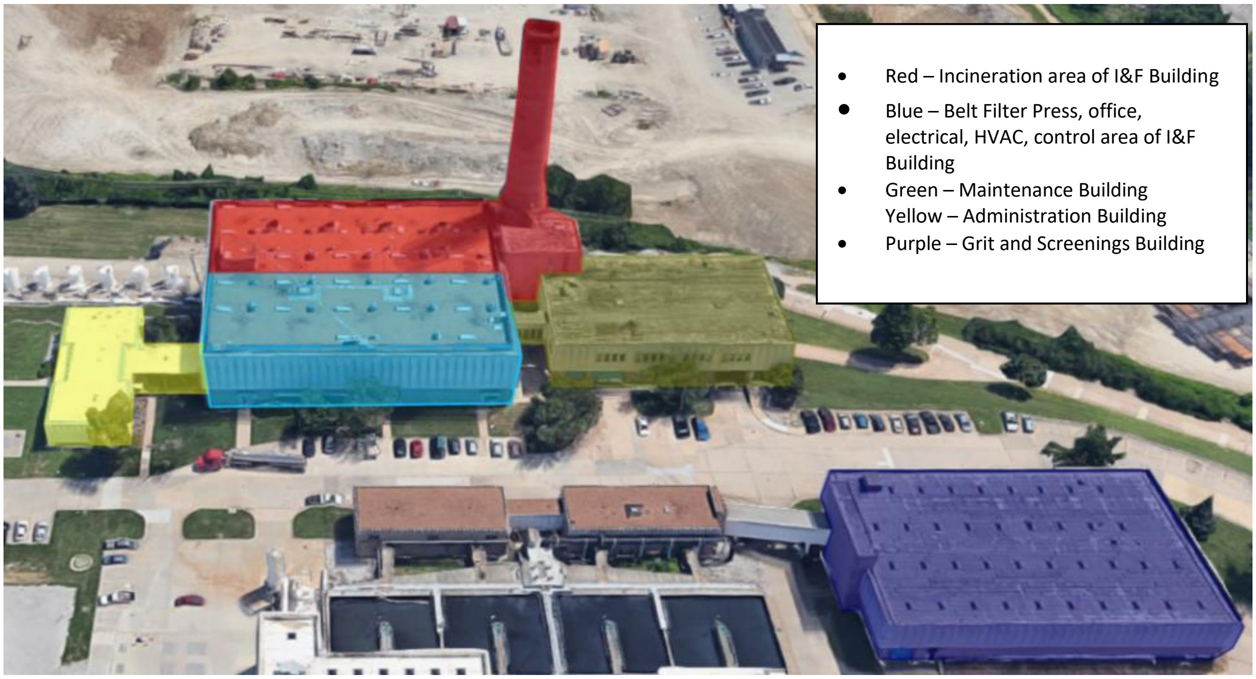


Figure 2-2 Lemay WWTF Buildings Layout

2.2.1 Incineration and Filter Building

The Incineration and Filter (I&F) Building includes the following functional areas:

2.2.1.1 Incineration Area

The incineration area is a four-story structure (with basement) and contains the four MHIs as well as the adjacent emission stack and polymer tanks. The emission stack and all equipment in this area will no longer be in service as part of the FBI construction.

The boiler room is located within the incineration area and will not be part of the future facility. The boiler feeds heat to much of the overall Lemay facility so a new heating source will be required for many of the existing buildings across the Lemay WWTF facility.

2.2.1.2 Belt Filter Press Area

The belt filter press area is a three-story structure adjacent to the incineration area and contains belt filter press dewatering equipment for the co-thickened sludge. All process equipment in this building will no longer be in service upon the completion of the new FBI process.

However, the main floor (El. 465') of the belt filter press area contains the Main Control Room for the plant and will need to be relocated if the building were to be demolished. The main Floor also contains the building ventilation system. If the building were to remain active at the completion of the new FBI construction, the ventilation room must remain active. All other equipment in this building will not be required going forward after the new FBIs are in service and can be demolished.

2.2.2 Maintenance Building

The Maintenance Building is a five-story structure directly south of the Incinerator and Filter Building. This building contains; Steam condensate room which delivers steam power to the plant, maintenance room and storage, I&E shop, "hotel" type equipment, warehousing and loading docks, multiple drive-in garages, two air handling systems, general office spaces, locker rooms, and a lunch area. The majority of this building can remain active upon completion of the new FBI system.

The plant staff has indicated that the maintenance shop area has inadequate overhead clearance, and discontinuous spaces. A more open concept would be beneficial to the needs of the staff if this building were to be demolished.

2.2.3 Administration Building

The Administration Building is a one-story structure that contains mostly office spaces and an abandoned laboratory. The staff has indicated that the west side of the building is no longer required and can be demolished.

Adjacent to the Administration Building are six odor control units for the belt filter press floor if the I&F Building that will no longer be needed after the completion of the dewatering system and can be demolished.

2.2.4 Grit and Screening Building

The Grit and Screening Building is located directly west of the Maintenance Building and is effectively abandoned-in-place. Only a portion of the electrical room is still active and will need to be relocated to a different site if the decision is made to demolish this structure.

3.0 Preliminary Assessment of Abandoned Facilities

3.1 DEMOLITION AND RE-PURPOSING

With the completion of new FBI facilities, the District will have abandoned floor space and buildings that would either be demolished, re-purposed, or abandoned-in-place. Previous evaluations have confirmed that re-purposing buildings to house portions of the FBI facilities is not recommended; and more evaluation would need to be completed to determine if there are other re-purpose uses for an abandoned facility. Unfortunately, because wastewater treatment buildings are constructed for unique purposes, re-purposing for other uses generally presents challenges that make this impractical. Additionally, if the re-purposing also includes major structural renovations, code issues could impact the level of upgrade needed and render the option too costly to consider. Often, the ultimate decision is made to either abandon-in-place and absorb the utility, nuisance, insurance, safety, and security issues; or to demolish the buildings entirely.

There could be a number of approaches considered from Design Build teams. The OR team’s experience with solids handling building demolition (see photos below from the Cincinnati Mill Creek plant demolition project) consists primarily of a demolition contractor essentially demolishing existing multiple hearth incinerator (MHI) facilities with a heavy-duty high-reach excavator. The owner in that case salvaged all of the equipment that they wanted to re-use and everything left remaining was torn down and disposed of by the contractor. The contractor was able to offset some of the demolition costs by salvaging scrap metal from this demolition.

Figures 3-1 and 3-2: Demolition of MHI facilities at the Cincinnati Mill Creek Wastewater Facility.

3.2 BISSELL POINT WWTF

The majority of equipment within the Solids Handling Building is at or beyond useful life and can be considered for abandoning-in-place or sold as scrap. This includes the 15 belt filter presses, 6 MHIs, and all related equipment and appurtenances associated with those processes.

A number of improvements were made to the facility in 1994 including new HVAC, plumbing, electrical, and I&C components. Most of this equipment can be abandoned-in-place and/or demolished as discussed below.

A Schwing cake pump that is currently being installed (along with piping) for a new cake receiving bin could be repurposed to another MSD facility.

As previously noted, the Thickening and Maintenance Center will remain in place. However, consideration may be given to removing the out-of-service gravity belt thickeners in this area.

3.3 LEMAY WWTF

Upon consultation with the plant staff it has been decided that nearly all of the I&F Building will no longer be active following the construction of the new Fluidized Bed Incinerators (FBI’s), and much of the equipment and facilities can be considered for abandoning-in-place or sold as scrap (if applicable). The Maintenance Building will continue to be active and should be undisturbed during construction (unless this area is selected for the construction of the FBI facilities). With the completion of a new FBI system and building, approximately 5% of the I&F Building will continue in service on a floor-space area basis. However, it should be noted that this 5% area is a critically functional area of the plant and contains the main control room for the entire plant (referred to as “The Fishbowl”).

Only 5% of the Grit and Screen Building is currently in service (for the electrical room) with portions of the remaining area used for grit dumpster storage.

4.0 Alternative Evaluation

4.1 BISSELL POINT WWTF

MSD has stated the Maintenance Center and Thickening Facilities Building should remain active, so no demolition is anticipated for either of these structures. Consideration may be given to removing the out-of-service gravity belt thickeners.

4.1.1 Abandon-In-Place

Construction of the new FBI Facility will mean a significant portion of the Solids Handling Building will no longer be in service. The lowest capital-cost solution is to abandon all existing dewatering and incineration equipment in-place and/or allow the DB team to sell off as scrap.

4.1.2 Partial Demolition

One option for the existing facilities is partial demolition, which would remove all facilities no longer required while leaving other portions of the buildings in place.

4.1.2.1 Solids Handling Building Only

This would entail demolishing the entire Solids Handling Building (shown in red in Figure 4-1 below) while leaving the Maintenance Center and Thickening Facilities and the Administration Building and sludge storage tanks in-place.

The retired chimney stack and ash storage silo will each likely require disassembly via large crane and an experienced crew and is likely to be higher cost activity.

If the decision is made to demolish the incineration area of the Solids Handling Building, it is recommended that dewatering area would also be demolished at the same time, or that the entire facility be abandoned-in-place. The two areas are contiguous to one building and it would not be practical to demolish only a portion of this building and re-construct exterior walls and support systems for the portion left in place.

The Solids Handling Building was constructed as a separate structure from the Maintenance Center and Thickening Buildings and so could theoretically be demolished without having to develop an extensive reconstruction plan for the exterior walls. Access points between the two building systems would need to be addressed and bricked over.

Costs associated with structural support during deconstruction, retrofitting, and material salvaging/reuse are expected to compare closely with demolition costs for the entire building, with the added benefit of providing cleared and useful space for the property.

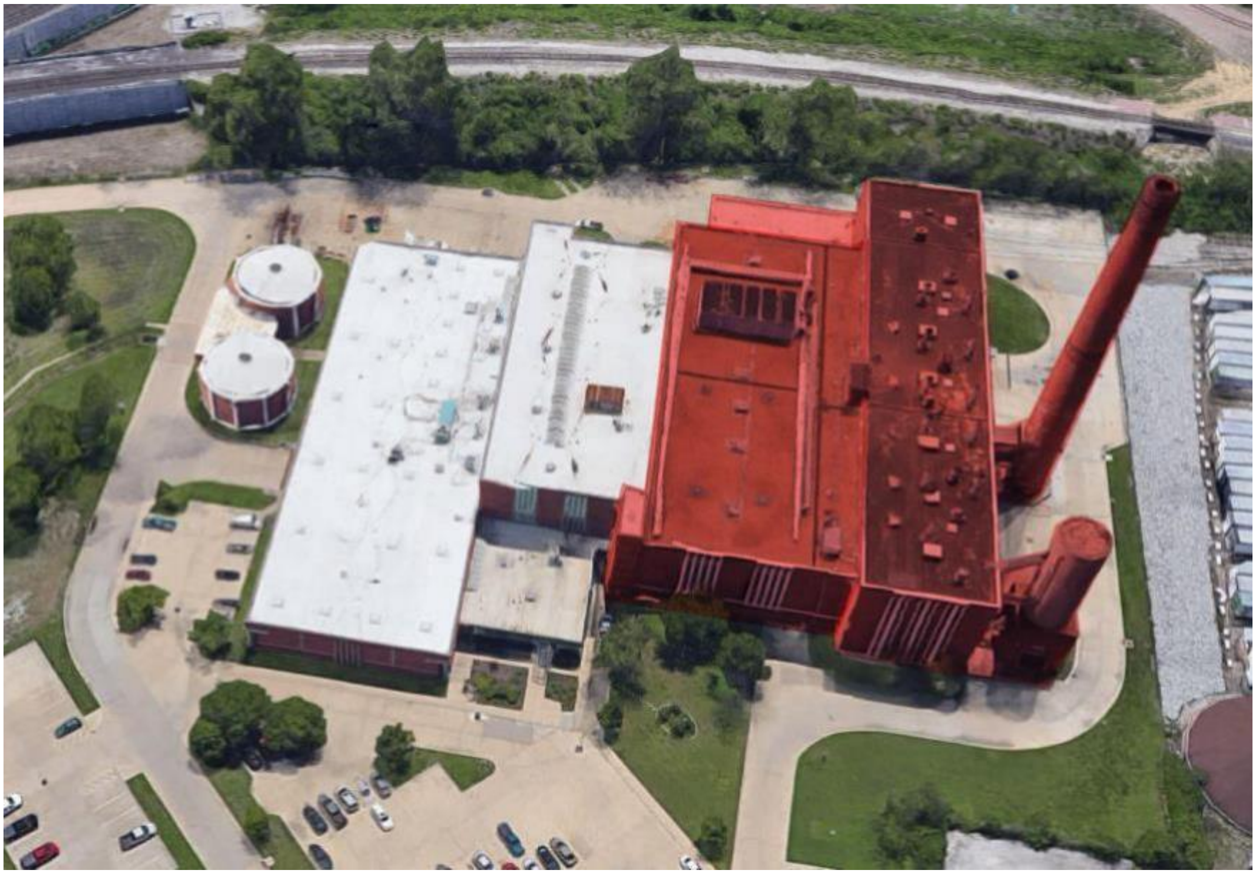


Figure 4-1 Alternative Evaluation - Solids Handling Building

4.1.2.2 Solids Handling Building and Storage Tanks

This would entail demolishing the Solids Handling Building and abandoned sludge storage tanks (both shown in red in Figure 4-2 below) while leaving the Maintenance Center and Thickening Facilities Building and Administration Buildings in place and active.

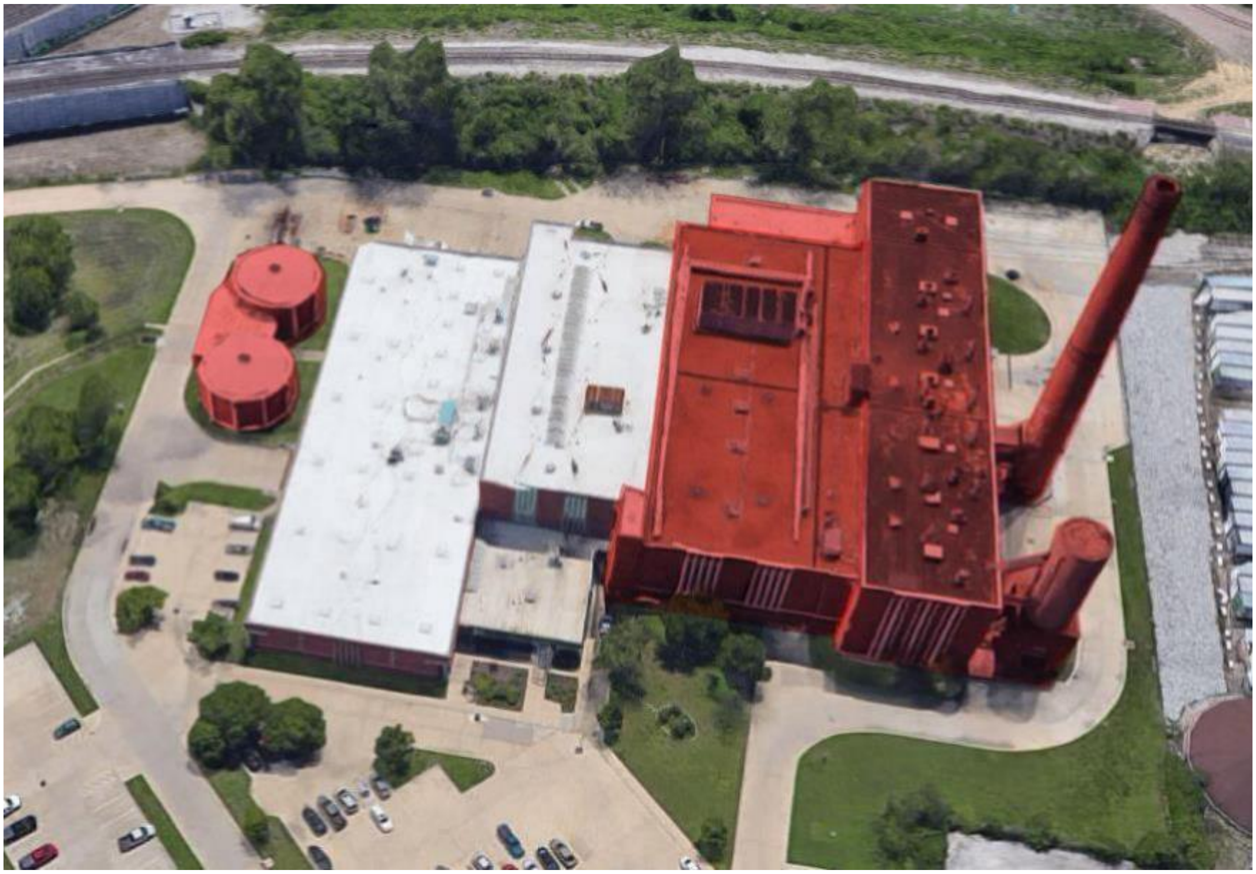


Figure 4-2 Alternative Evaluation - Solids Handling Building and Storage Tanks

4.1.3 Comprehensive Demolition

A full demolition of all facilities to be abandoned would require that the administration area and all employee areas such as locker rooms, lunch area, and general storage be moved to the new FBI building and a new storage and maintenance facility be constructed. All existing facilities on the current site would be demolished at grade.

4.2 LEMAY WWTF

4.2.1 Abandon-In-Place

Construction of the new FBI Facility will mean a significant portion of the I&F Building will no longer be active. The lowest capital cost solution would be to abandon all existing dewatering and incineration equipment in place and/or allow the DB team to sell off as scrap.

The Grit and Screenings Building has already been abandoned-in-place and equipment that remains in this building could also be sold off as scrap materials.

The Maintenance Building and Administration Building are both areas that could remain active after construction of new FBI facilities. If they were to be abandoned or demolished, new facilities that serve the functions of these areas would need to be constructed (either in the new FBI facilities or as part of a re-purposed plan within those buildings).

4.2.2 Partial Demolition

Consideration could be given to partial demolition, which would remove all facilities no longer required while leaving other portions of the buildings in place. However, this may not be practical from a cost and risk perspective, as discussed below.

4.2.2.1 Incinerator Area Only

This would entail demolishing the entire incinerator area of the I&F Building (shown in red in Figure 4-14 below) while leaving the belt filter press area of the building as well as the Maintenance Building and Administration Building in place. Because this building is constructed as one contiguous building, partial demolition of the building and would require the reconstruction of an exterior wall. Additionally, the dewatering area on the fourth floor of the building sits above areas that would remain in service, and it would not be practical to demolish the dewatering area without demolishing the entire building. However, if a partial demolition were to be implemented, it would be possible to remove the dewatering equipment as part of incinerator demolition.

The retired chimney stack will likely require disassembly via large crane and an experienced crew and is likely to be higher cost activity.

Figure 4-3 Alternative Evaluation – Incinerator Area

4.2.2.2 Incinerator and Filter Building

This would involve demolishing the entire I&F Building (shown in red in Figure 4-24 below) while leaving the Maintenance Building and Administration Building in place and operational. This option would necessitate that the all of the Main Floor office, storage, electrical, and control rooms would need to be included as new facilities under the FBI project and would need to remain functional until the FBI system were on-line and fully operational.

Figure 4-4 Alternative Evaluation – Incinerator and Filter Building

4.2.2.3 Incinerator and Filter Building and Administration Building

This would entail demolishing the I&F Building and Administration Building (shown in red in **Error! Reference source not found.**5 below) while leaving only the Maintenance Building in place and operational. Functionally it is the same as the previous option other than the Administrative Building has been included in the demolition plan.

Figure 4-5 Alternative Evaluation – Incinerator and Filter Building and Administration Building

4.2.3 Comprehensive Demolition

A full demolition of all facilities to be abandoned would require that the function of the Administration Building as well as the main floor of the belt filter press area of the I&F Building be moved to the new FBI building and a new storage and maintenance facility also be constructed. All existing facilities on the current site would be demolished at grade.

5.0 Economic and Non-Economic Evaluation

5.1 ECONOMIC FACTORS

5.1.1 Economic Factors – Bissell Point

Abandonment of the existing facilities will essentially require very little capital cost to the District but will require some maintenance cost moving forward in terms of electricity, as well as heating and cooling. More investigation should be made during the 15% design into developing a maintenance cost based on historical MSD records.

Three demolition alternatives were provided in prior sections and cost estimates prepared for each. Based on current factors, the estimates for demolition are as follows (*Note: The range for this cost estimate is +50%/-30%*):

Table 5-1: Bissell Point - Demolition Costs

Building / Area	Demolition Cost Estimate	+50%	-30%
Solids Handling Building	$7,600,000	$11,400,000	$5,320,000
Sludge Tanks	$973,000	$1,460,000	$681,000
Stack	$344,000	$516,000	$241,000

5.1.2 Economic Factors – Lemay

Three demolition alternatives were provided in prior sections and cost estimates prepared for each. Based on current factors, the estimates for demolition are as follows:

Table 5-2: Lemay - Demolition Costs

Structure	Final Demo Cost Estimate	+50%	-30%
I&F Building	$3,033,000	$4,550,000	$2,123,000
Incineration Bldg	*$1,423,000*	*$2,135,000*	*$996,000*
Filter Bldg	*$1,610,000*	*$2,415,000*	*$1,127,000*
Administration Building	$228,000	$342,000	$160,000
Maintenance Building	$1,709,000	$2,564,000	$1,196,000
Grit & Screen Building	$1,933,000	$2,900,000	$1,353,000
Stack	$344,000	$516,000	$241,000
Service Building	$465,000	$698,000	$326,000

Notes:

- Partial Demolition - Incineration Area-Only:
  - Consideration may be given to partial demolition of the incinerator portion of the I&F Building; but this would require the construction of a new exterior wall and connection to existing structural elements. That cost has not been factored in this estimate.
  - Code Issues: The partial demolition of the I&F Building would also likely necessitate that

the remaining building be brought up to current code requirements, particularly for ACA and seismic design. A more extensive evaluation would need to be conducted to determine the cost impact for this.

- **For the reasons stated above, partial demolition is not considered a viable option for the I&F Building.**

5.1.3 Annual Maintenance Cost Criteria

Maintenance costs for unoccupied or abandoned buildings can be difficult to quantify, can vary considerably from one building to another, and are often very site-specific. In general, however these are real costs that are absorbed in maintaining an abandoned building, unless the building is literally abandoned from the perspective of having all utilities disconnected, being locked and boarded for security and safety, and requiring no regular operations or maintenance attention. For the District's facilities, this is not the case. If buildings are to be abandoned at the Bissell Point and Lemay facilities, they are likely going to require some level of maintenance and activity with them as they will be contiguous to areas that will remain active. As such, it is expected that they will have a cost associated with their upkeep and maintenance. Utility costs have been estimated for the potential demolition / abandoned areas in the tables below. Note that these costs do not include labor for any type of maintenance, security, or safety activity that could be required for them.

Table 5-3: Bissell Point - Abandoned Area Maintenance Costs

Building / Area	Floors	Space (sq.ft.)	Annual Cost Per Year**	Present Worth Cost of Utilities**
Solids Handling Building	5	165,590	$166,000	$2,260,000

The utility cost estimate for Lemay is included in the table below.

Table 5-4: Lemay - Abandoned Area Maintenance Costs

Building / Area	Floors	Space (sq.ft.)	Annual Cost Per Year**	Present Worth Cost Per Year**
Incinerator and Filter Building	4	92,130	$92,000	$1,250,000
Administration Building	1	5,836	$6,000	$80,000
Maintenance Building*	6	49,560	$50,000	$680,000
Grit and Screen Building	5	47,883	$48,000	$650,000
Service Building	1	9,393	$9,000	$120,000

**Maintenance Area is not scheduled for abandonment, but this building is included in analysis since one site option would utilize this space.*

***Present Worth Parameters for Tables 5-3 and 5-4.*

Interest Rate (%)	*4%*
Time Period (Years)	*20*
Cost Per Year Per Sq.Ft.	*$1*

Estimates above have not included any major repair improvements that may be required over the years, such as roofing or brick tuckpointing, since it is assumed MSD would not do those high level repairs.

5.1.4 Cost Summary for Maintenance and Demolition

A summary of the present worth cost of maintaining abandoned areas and buildings versus the cost for demolishing them is provided in the following tables for each facility.

Table 5-5: Bissell Point - Utility Costs Versus Demolition Costs

Building / Area	Present Worth Cost of Utilities	Demolition Costs
Solids Handling Building	$2,260,000	$7,600,000
Sludge Tanks	N/A	$915,000
Stack	N/A	$244,000

The following considerations should be weighed in assessing demolition and abandonment options with respect to the costs quantified above:

- Demolition costs are going to be very design-build-team specific with costs that could vary significantly from one team to another.
- The Solids Handling Building may very well have a maintenance cost associated with it that warrants strong consideration of demolition; based on the assumptions outlined in this technical memorandum.
- There are not utility costs assumed for the emission stacks or the sludge storage tanks, but these systems may very well have labor and upkeep costs associated with them that would need to be factored into the overall cost assessment.
- Costs do not include hazardous material (asbestos, lead paint, etc.) removal.

The cost summary for Lemay is included in the table below.

Table 5-6: Lemay - Utility Costs Versus Demolition Costs

Building / Area	Present Worth Cost of Utilities	Demolition Costs
I&F Building	$1,250,000	$3,033,000
Administration Building	$80,000	$228,000
Maintenance Building*	$680,000	$1,709,000
Grit & Screen Building	$650,000	$1,933,000
Stack	N/A	$344,000
Service Building	$120,000	$465,000

**Maintenance Area is not scheduled for abandonment, but this building is included in analysis since one site option would utilize this space.*

The following considerations should be weighed in assessing demolition and abandonment options with respect to the costs quantified above:

- Demolishing only the incinerator portion of the I&F Building is not considered practical but is shown for comparative purposes. The cost for this option would need to include a detailed plan for re-constructing an exterior wall and designing a retrofitted building that was functional with the portion that remained. Those costs and efforts would include inherent risk for unforeseen conditions that could escalate re-construction costs significantly and are therefore not recommended.

- The I&F Building includes functional areas (offices, control rooms, etc.) for the entire plant, and would need to be relocated if this building were to be demolished**. However, it is estimated that less than 5% of this building would remain active (on a floor space basis) once the new FBI facilities go on-line**.
- The Grit and Screen Building provides the most opportunity from an economic perspective to locate the new FBI facilities, as the cost for maintaining this building is not considerably less than the cost for demolishing it.
- The Service Building offers the lowest cost demolition option for Lemay with respect to siting options, with a present worth maintenance cost that is just below the demolition cost and is currently a building that is being used for storage only.
- The Maintenance Building provides an opportunistic location for the new FBI facilities from the perspective of coordinating with existing utilities. The present worth maintenance cost of this building is just under the demolition cost for it. However, this site would require that a new maintenance facility be constructed in its place.

5.2 NON-ECONOMIC FACTORS

There are several non-economic factors that should be evaluated when considering which structures will be abandoned or demolished. These include:

- Desire of Operations staff to eliminate abandoned buildings on site.
- Potential for re-use (such as storage or shop areas) of any structures identified to be abandoned.
- The potential for hazardous materials exists at both the Bissell and Lemay facilities. It is believed at this time that hazardous materials exist in the different areas of each facility, but more investigation should be performed during the 15% design to confirm this.
- The complexity of relocating systems that are non-process equipment but still relevant to the operation of the facility. These include main control rooms, administration areas, employee areas, power feeds, and (at Lemay) equipment associated with the existing steam heating system.
- The potential value from leaving options available for the Design-Build team to develop.

5.2.1 Site Selection Factors (Lemay-only)

While an identified site for the Bissell Point facility has been selected that would allow new facilities to be constructed relatively independent of existing buildings and structures, the Lemay facility on the other hand is constrained somewhat and site selection options considered there will also impact demolition considerations. Currently, there are four primary locations that have been identified at Lemay, as shown in the figure below. The early conceptual footprints for the FBI facilities indicate a building size of approximately 150 feet by 250 feet in dimensions. These are summarized, along with notes on the constraints of each, as follows:

- **Option 1:** Would generally require the demolition of the Grit and Screening Building. This option could be pushed farther away from the G&S Building but would likely require taking at least a part of this space, which in turn would require partial demolition, and since partial demolition is not considered practical for this building, this option would basically dictate the demolition of the entire building.

- **Option 2:** Would be constructed in an open area that would not require demolition, but it would take up a site that has been previously allocated for future nutrient removal options. Even so, the team believes that this option could be implemented without compromising future nutrient removal options.
- **Option 3:** Would require the demolition and rebuilding of Maintenance facilities.
- **Option 4/4a:** Would either require the demolition of the Service Building or could be pushed towards the river, but there would be very little space for drive access between the FBI facilities and the Service Building, and the FBI facilities would encroach to the outer edges of the property.

Figure 4-7 Lemay Siting Options (Footprint area for FBI Facilities is 150 ft. x 250 ft.)

As seen above, all of the options for Lemay include the necessity for demolition (rather than the option of demolition) or has some constraint to it that should be considered. The only viable option that does not necessarily have either these conditions or constraints is Option 4a, but even this option limits accessibility to the building and could present future operational and logistical challenges.

6.0 Recommendations

The full scope of demolition and abandonment at the Bissell Point and Lemay facilities should be evaluated in further detail during the 15% Design. This should include site visits by each engineering discipline (structural, HVAC, process, etc.) to fully identify and document all equipment that can be abandoned as part of the new FBI project.

6.1 BISSELL POINT WWTF

For purposes of this report, it is recommended that the Solids Handling Building be demolished as part of the FBI project, along with the emission stack, storage silo, and sludge holding tank.

It is further recommended that the D-B contractor be responsible for the removal of all equipment within the buildings identified for demolition. Prior to D-B contracting, MSD should identify and move all equipment that can be repurposed at Bissell or other facilities.

It is not recommended that the Gravity Thickening and Maintenance Center or the Administration buildings be demolished, but it would be prudent to consider removal of the out-of-service gravity belt thickeners as part of any demolition project. This may require creating an opening in the roof and removing these units with a crane. If this option is warranted from the District's perspective, additional consideration should be given during the 15% design phase.

6.2 LEMAY WWTF

Demolition options for Lemay are going to be site-selection-specific and will have a capital cost as well as life-cycle impact. From a pre-design-only perspective that is independent of any other considerations and constraints, the OR team would recommend Option 1 and the demolition of the Grit and Screen Building. This option would require the relocation of the electric room for the UV system, and relocation of some underground utilities, but it would also locate the FBI facilities in close proximity to the existing solids handling systems and would eliminate at least one abandoned building.

Other options however are just as valid, depending on the District's preferences for demolition of abandoned spaces, capital costs, and site accessibility.

7.0 Conclusions

7.1 BISSELL POINT WWTF

After discussion with MSD, items to be demolished are; 1) the Solids Handling Building, 2) the emissions stack and ash storage silo, and 3) the two sludge storage tanks. The Gravity Thickening and Maintenance Center Building and Administration Building will remain.

7.2 LEMAY WWTF

After discussion with MSD, items to be demolished are; 1) the Incinerator and Filter Building, 2) the emissions stack, 3) the odor control units adjacent to the Administration Building, and 4) the Maintenance Building. The location of the new FBI facilities will be the former site of the Maintenance Building. Selective demolition within the interior only of the Grit and Screening Building will allow that building to be converted to a new maintenance facility (refer to the supplement included with this TM 17). The Administration Building and Service Building will remain.

FINAL

BISSELL POINT & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum 17: Abandon and Demolition Alternatives

Supplement: Lemay G&S Building / Maintenance Building Considerations

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

24 July 2020

Table of Contents

Attachment

1.0 Introduction

This document serves as a supplement to Technical Memorandum (TM-17), and specifically addresses follow-up issues and evaluations related to site selection for the Lemay facility, and in particular the potential use of the Grit and Screenings (G&S) Building as either a re-purposed maintenance facility, or as the location for the proposed FBI facilities.

Based on the direction provided by the District in Management Meeting No. 11 on June 23, 2020, these two potential sites (shown in the figure below) were to be evaluated further, with demolition recommendations as follows:

- If Option 1 is chosen:
    - Demolish stack, G&S Building, Service Building, Administration Building, and I&F Building; relocate the Electrical Room for the UV system to another location on the plant site.
- If Option 3 is chosen:
    - Demolish stack, I&F Building, Administration Building, Maintenance Facility, and re-purpose the G&S Building for maintenance.

Figure 1: Two final locations recommended for the FBI facilities at Lemay.

Demolition costs for the Lemay facilities were summarized in TM-17 and are presented below (Note: Table numbers are the same as they are in the main body of TM-17 for ease of reference):

Table 5-2: Lemay - Demolition Costs

Structure	Final Demo Cost Estimate	+50%	-30%
I&F Building	$3,033,000	$4,550,000	$2,123,000
Administration Building	$228,000	$342,000	$160,000
Maintenance Building	$1,709,000	$2,564,000	$1,196,000
Grit & Screen Building	$1,933,000	$2,900,000	$1,353,000
Stack	$344,000	$516,000	$241,000
Service Building	$465,000	$698,000	$326,000

Estimated costs for maintaining abandoned buildings should demolition not be included in this project are summarized below.

Table 5-4: Lemay - Abandoned Area Maintenance Costs

Building / Area	Floors	Space (sq.ft.)	Annual Cost Per Year**	Present Worth Cost Per Year**
Incinerator and Filter Building	4	92,130	$92,000	$1,250,000
Administration Building	1	5,836	$6,000	$80,000
Maintenance Building*	6	49,560	$50,000	$680,000
Grit and Screen Building	5	47,883	$48,000	$650,000
Service Building	1	9,393	$9,000	$120,000

**Maintenance Area is not scheduled for abandonment, but this building is included in analysis since one site option would utilize this space.*

***Present Worth Parameters for Tables 5-3 and 5-4.*

Interest Rate (%)	*4%*
Time Period (Years)	*20*
Cost Per Year Per Sq.Ft.	*$1*

Conversion of Grit and Screen Building to a Maintenance Facility

Under Option 3, the new FBI facilities would be constructed in the location of the existing Maintenance Building, and the Grit and Screenings (G&S) Building would be re-purposed to be new Maintenance Facilities. The G&S building would be converted by removing the existing equipment, and then constructing a new floor across the grade-level opening. The existing grade level facilities would be retrofitted to account for the following maintenance facility space needs:

- Maintenance Area: 6,000 square feet (sf)
- Locker room: 1,200 sf

- Women's locker rooms: 1,200 sf
- Training room: 1,200 sf
- Lunch room: 1,200 sf

These modifications are broadly described in the figure below.

Grit and Screen Building – Grade Level View Inside

Remove all equipment. Extend floor across opening at the grade level elevation (but leave a smaller opening with a hatch to be able to drop items to bottom level in the future). Don't extend floor across the mezzanine level – just leave open. Basement becomes storage. Mezzanine may accommodate boilers, storage or other functions.

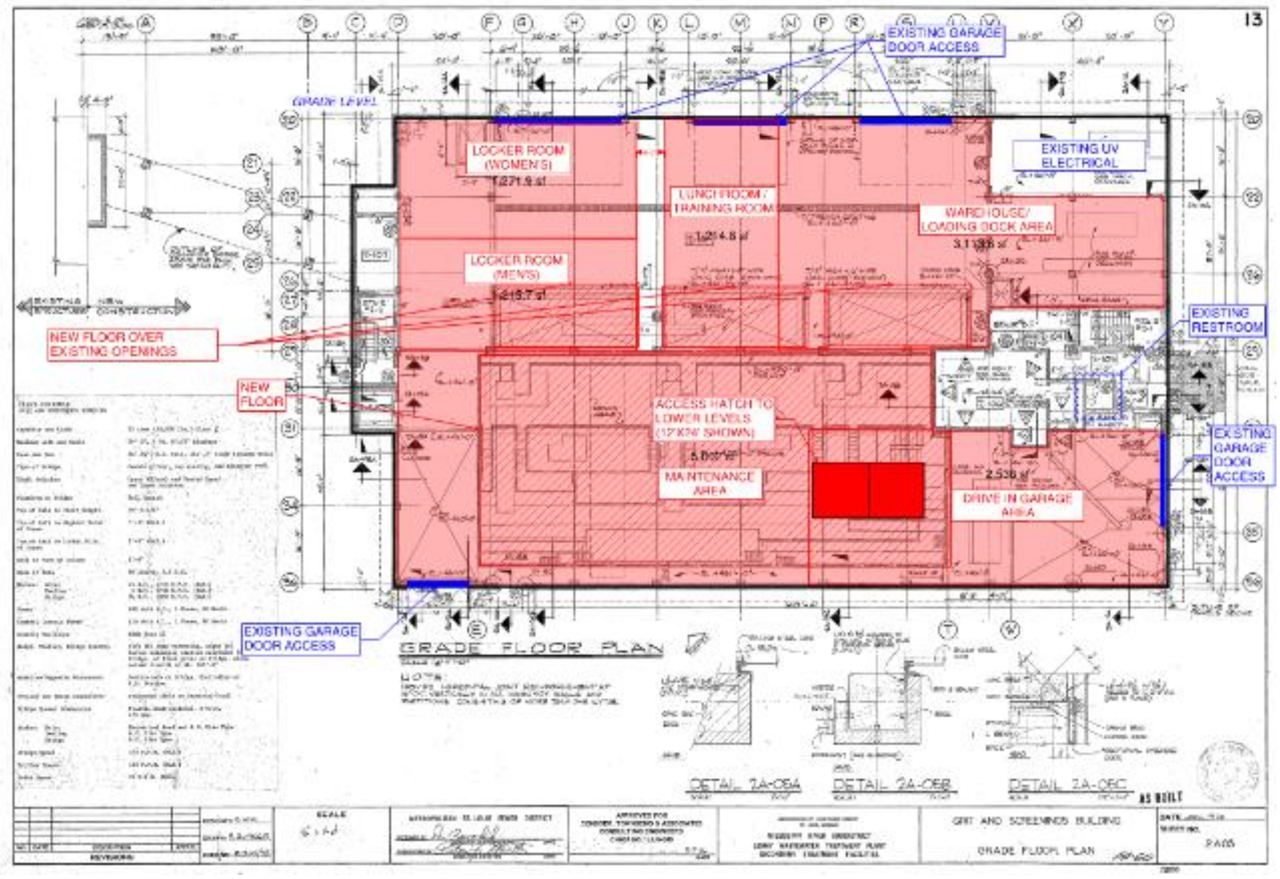
The scope of work for building retrofits can be highly volatile and do entail higher level risks with respect to unforeseen circumstances and conditions. The G&S Building was evaluated in TM-12 from a high-level perspective for re-purposing as part of the FBI process; particularly for housing the dewatering systems. Generally, the G&S Building was considered to be in good shape with some general improvements recommended based on its overall age and condition. These improvement recommendations included:

- New Roof
- New Skylights
- Topping slabs and aesthetic cracking repaired in concrete
- New Intake Louvers, Supply Air Fans, and Associated Ductwork
- New Exhaust Fans, Roof Hood, Associated Ductwork
- New Heating Water Coils and Filters
- New Sump Pumps

TM-12 concluded that the required upgrades to the building should not prohibit the reuse of the building. Overall, the building is in decent condition and decades of usefulness remain. The cost of a new building would far outweigh the cost of the needed repairs.

A preliminary floorplan was developed for this evaluation, in which the space requirements outlined above were allocated on the grade-level portion of the Grit and Screenings Building, as shown on the figure below. This layout allocates these space needs around the only active portion of the existing building: the UV system electrical room. This option would allow that space to continue serving the same function without having to relocate it to another location at the plant.

Additionally, storage areas in the existing Maintenance Building would be either relocated to the mezzanine or basement area of the Grit and Screen Building or could be located to the existing Service Building.



The figure above provides the following, relocated facilities at grade level with preliminary designated surface areas:

- Men’s and women’s locker rooms: 1,200 +/- sf
- Lunchroom/Training Room: 1,200 +/s sf
- Warehouse/Loading Dock: 3,000 +/- sf
- Maintenance Area: 5,000 +/- sf
- Drive in Garage Area: 2,500 +/- sf

Other ancillary facilities have been relocated to the second floor and lower levels

A high-level preliminary architectural review was conducted to assess potential code issues for converting the G&S building, and the following items were noted for further consideration:

- The proposed new use for the Grit & Screenings (G&S) Bldg. would change to mixed occupancy with the occupancy codes of B (for the office spaces), F-1 (for the maintenance areas), and S-1 (for the combustible storage area).
- A physical barrier will be required from the B occupancy to the F1 and S occupancies.
- For each occupancy area two points of egress will be required from that space. The existing stairwells can be used, but proper corridors are required to get to those stairwells.
- The existing stairwells are not to code regarding treads and risers. However, since the building will stay as an MSD owned/controlled building and will not become a public building, the code officials likely would not require the stairs to be modified, but the railings will likely be required to upgrade to compliance.
- All new locker rooms and restroom facilities will need to be ADA compliant.
- The existing elevator will need to be upgraded to be ADA compliant.
- Sprinkler systems will be required. The Grade Floor may not require sprinklers. The other floors will. The cost for sprinklers is approx. $10/square foot.
- The existing roof is in poor shape and will need to be repaired replaced. All roof insulation should be replaced. It is recommended that the insulation be increased to R30.
- The existing skylights will likely need to be replaced.
- A more thorough review of the proposed layout will be required for including proper entrance and exits for each space, existing stairwells, and including corridors to get to existing exits.
- All doors and hardware should be replaced.
- The aluminum windows should be replaced.
- All new floors will be supported by a new framing system.
- The building should be tested for lead paint and asbestos.
- A completely new HVAC system will be needed.
- Damaged exterior metal panels will need to be fixed.

A high-level structural review, included as an attachment to this TM, was conducted to assess potential issues for converting the G&S building as shown in the Figure above, and the following items were noted:

- Foundations bear on rock at elevation 440 and the lower basement bears directly on rock with rock anchors to resist buoyant forces and it is likely that the foundations and vertical columns have adequate reserve capacity for dead loads proposed.
- It is likely that horizontal elements, such as beams and purlins, do not have adequate reserve capacity for new floor framing systems and vertical loads will likely need to be transferred directly to the columns.
- Modifications to lower floors will likely not have any impact on seismic loads applied to the building.
- Infill on the second level would induce additional seismic loads to the building superstructure and would require further seismic analysis to verify lateral capacity of the structural system.
- Concrete beams and columns on the second floor do not have reinforcing steel size and spacing to

meet the current code requirements for a concrete frame.

- If the precast wall panels are analyzed as shear walls, their connectivity would need to be enhanced, and the fact that they are outboard of the column grid means that the overturning forces inherent to a shear wall cannot be resisted by a cantilevered slab.
- It is likely the second floor to roof lateral resisting elements do not have adequate capacity and a new lateral resisting system from the second floor to the roof would be needed.

Based on the preliminary structural review, it is recommended that the existing load carrying capacity of structural elements will need to be identified including the capacities of columns and foundations. The lateral load analysis if the second-floor infill is proposed will be more difficult and will likely require an enhanced seismic load resisting system design and construction.

The overall economic evaluation on a net present worth basis is included below for these two alternatives. It is assumed that existing equipment would be relocated to the re-purposed facilities.

Lemay - Utility Costs Versus Demolition Costs

Building / Area	**Present Worth Cost of Maintaining Abandoned Building**	**Demolition Costs**	**Net Present Worth Cost of Demolition**
I&F Building	$1,250,000	$3,033,000	$1,783,000
Administration Building	$80,000	$228,000	$148,000
Maintenance Building	$680,000	$1,709,000	$1,029,000
Grit & Screen Building	$650,000	$1,933,000	$1,283,000
Stack	N/A	$344,000	$344,000
Service Building	$120,000	$465,000	$345,000
Relocate UV Electrical Room to Another Location			$750,000
Conversion of G&S Building to Maintenance Facility		Includes 30% Contingency	$3,800,000
Option 1 Net Present Worth Cost Demolish stack, G&S Building, Service Building, Administration Building and I&F Building; relocate UV Electrical Room			**$4,653,000**
Option 3 Net Present Worth Cost Demolish stack, I&F Building, Administration Building, Maintenance Facility, and re-purpose the G&S Building for maintenance.			**$7,104,000**
Difference in Net Present Worth Cost			**$2,451,000**

Assumptions:

- Costs for re-purposing the G&S Building assume that the building will not require major structural or code-related modifications.
- Existing maintenance facility equipment would be relocated to the new G&S Building and would not require new equipment as part of this project.

For the purposes of this assessment, it is assumed that re-purposing of the G&S Building will be undertaken with a focus on minimizing renovation requirements as much as possible; rather than attempt to duplicate the existing maintenance facility areas into this building. As such, the maintenance area allocated for the G&S Building has a smaller footprint than the existing maintenance facility. However, operations staff have indicated the space allocated in the G&S Building is adequate for their needs. Renovation costs may be increased or decreased based on the final level of development and/or code-level requirements. For example, the cost estimate includes a budget for equipment demolition that operations staff have indicated may be completed internally before the FBI project is undertaken. This would decrease the cost estimate. On the other hand, the cost estimate does not include a new roof for the building. This would increase the cost estimate.

There are non-cost considerations for Option 3 that may be considered as well, including:

- Option 3 re-purposes the Grit and Screen building for more efficient maintenance functions.
- Provides opportunity for improving locker room facilities (as well as providing adequate space for women’s facilities) within the re-purposed building facilities.
- Allows continued use of UV electric room facilities.
- Location of new FBI facilities in the location of the current Maintenance Building provides some topographical advantages for multi-level system and provides space for future expansion (if needed) where the current I&F building is located.
- Maintains tunnel access for the new FBI facilities.
- Re-use of an existing 15-ton crane and hoist.
- Better functionality of the entire plant system under this option with respect to deliveries and normal traffic flow inside plant site.
- Utilization of existing space for new boilers rather than allocating additional space for them in the new FBI facilities.
- Demolition needs to be completed with either option; bur this option provides more of an opportunity for re-purposing a building for more efficient operations functions rather than deferring to a future cost.

Non-cost disadvantages for Option 3 include:

- Construction would need to be staged to complete conversion of the G&S Building into a new Maintenance Facility before demolition of the existing Maintenance Building could begin. This could potentially add some time to the overall schedule for completion.
    - Note: This issue could be addressed by the DB team by completing this portion of the project while construction of the FBI systems at Bissell Point were initiated. Generally, it has been assumed that commencement of construction at the two sites would be staggered by six months or so.

2.0 Recommendations

The District directed the OR team to develop recommendations for demolition and site selection based on the best alternatives for the FBI project, while providing options (where warranted) that the District may consider. From the perspective of the FBI facilities, there are advantages to constructing the facilities at the existing Maintenance Building location. There are topographical advantages that promote a better layout of the facilities vertically and will provide a better flow of traffic into this facility for loading and unloading activities. Additionally, there is some risk with deep excavation and proximity to existing facilities that would need to be addressed in constructing the FBI facilities at the G&S Building location. Although each of these issues could in fact be mitigated, they do present issues that would need to be addressed and would carry some form of risk.

Lastly, from the perspective that the existing maintenance facilities are not meeting the needs of operations staff, and thus assuming that there will be a future expenditure to address this issue, this project offers an opportunity-cost to re-purpose a building and complete such an upgrade at a lower cost than what would likely be incurred later, where a new maintenance facility in a completely new building may be on the order of $10-20M, depending on final size and configuration.

For these reasons, the OR recommendation is for the District to implement Option 3 and upgrade the G&S Building to house the maintenance facilities, and construct FBI facilities where the existing Maintenance Building currently resides.

ATTACHMENT

Grit and Screenings Building Repurposing

Existing Building

The existing building is a concrete framed structure with precast roof double tees and precast wall panels from the second floor to roof. The west section of the building has a deep open basement with a bridge crane over this space, which was utilized for process equipment. The building bears on bedrock.

Proposed Infill Floors

The proposed repurposing includes infill floors at the second floor, grade level, and basement level. These floors have varying occupancy and loads, as well as durability requirements.

Infill Floor Construction

The floor construction for the second floor can consist of steel framing, metal deck and concrete topping, as the proposed occupancy is for locker rooms and office space. The floor at grade level should consist of cast in place concrete which is a better performing system for vehicles, chemical exposure, and washdown capability. The storage floor at elevation 437 is presumed to be utilized for light storage (125 psf) and can consist of steel framing, metal deck and concrete topping.

Operational status of the existing bridge crane will facilitate construction of the infill floors over the deep basement areas.

Foundations and Vertical Capacity

According to the existing structural documentation, the foundations bear on rock at elevation 440, approximately 21’ below existing grade. The lower basement finished floor elevation is as low as 416, bears directly on rock, and has rock anchors to resist buoyant uplift forces. It is likely that the rock and the foundations have adequate reserve capacity for the additionally proposed dead loads from the infill floors. It is also likely that the concrete column elements have adequate reserve capacity for the proposed floors. However, it is likely that the horizontal elements, such as beams and purlins, do not have adequate reserve capacity and any new floor framing system will need to transfer all vertical loads directly to the columns.

Seismic Concerns

The construction of floors below grade has very little impact on the seismic loads applied to the building, as the soil and the building vibrate together below grade. A significant infill floor area at the second level would induce additional seismic loads to the building superstructure and would require a seismic analysis of the existing building to verify the lateral capacity of the structural system.

The concrete walls from the second floor to grade level would likely have adequate lateral capacity to resist the applied seismic loads. The concrete beams and columns above the second floor do not have reinforcing steel size and spacing that would meet the current code requirements for a concrete frame. If the precast wall panels are analyzed as shear walls, their connectivity would need to be enhanced, and the fact that they are outboard of the column grid means that the overturning forces inherent to a shear wall cannot be resisted by a cantilevered slab.

It is likely that the second floor to roof lateral resisting elements do not have adequate capacity and a new lateral resisting system from the second floor to roof would be needed.

The concern with utilizing the precast concrete components for lateral load resistance is their connection to the cast in place concrete frame. The precast concrete roof and precast concrete panels have a limited shear capacity due to connectivity between individual units.

Required Analysis and Design

The existing load carrying capacities of structural elements will need to be identified. This includes the capacities of columns and foundations for the vertical loads. The lateral load analysis if a second-floor infill is proposed is significantly more difficult to analyze and will most likely require an enhanced seismic load resisting system design and construction.

Overview and Conclusions

The proposed infill floors below grade have no impact on the lateral loads of the building and can be constructed with framing systems that bear directly onto the existing columns while utilizing the existing bridge crane to facilitate construction. The existing columns and foundation systems most likely have adequate reserve capacity but will require analysis and verification.

The proposed infill floor at the second floor will cause an increase in seismic loads into the building, requiring an analysis, and most likely, a seismic upgrade to the existing lateral load resisting system.

BISSELL POINT & LEMAY WWTF FLUIDIZED BED INCINERATORS (12565)

Technical Memorandum 18:

Dewatered Sludge Truck Loading

B&V PROJECT NO. 401975

PREPARED FOR

Metropolitan St. Louis Sewer District

27 OCTOBER 2020

Technical Memorandum 18

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Prepared for: Metropolitan St. Louis Sewer District

Project Title: Bissell Point & Lemay WWTF Fluidized Bed Incinerators

BC Project No.: 153644

Technical Memorandum No. 18

Subject: Dewatered Sludge Truck Loading

Date: October 27, 2020

To: Bently Green, PE, Black & Veatch Project Manager

From: Dave Yates, PE, Brown and Caldwell Project Manager

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Table of Contents

List of Abbreviations

BC	Brown and Caldwell
BFP	Belt Filter Presses
BNR	Biological Nutrient Removal
BV	Black & Veatch
dt	Dry Ton
gpd	Gallons Per Day
gpm	Gallons Per Minute
MHI	Multiple Hearth Incinerators
ppd	Pounds Per Day
TM	Technical Memorandum
TS	Total Solids
VS	Volatile Solids
WAS	Waste Activated Sludge
WWTF	Wastewater Treatment Facility

1.0 Introduction

This technical memorandum addresses dewatered sludge truck loading at the Bissell Point WWTF and Lemay WWTF dewatering and incineration facilities. Dewatered sludge truck loading is recommended to provide flexibility in the event the production of dewatered sludge exceeds the capacity of incineration equipment. The capability to divert a portion of the dewatered sludge from incinerator feed to truck loading allows for the dewatered sludge to be hauled to the other incinerator facility or another disposal location. Each plant will be provided with a dewatered sludge receiving station, which is addressed in a separate TM. The objective of this technical memorandum (TM 18) is to document the selected dewatered sludge truck loading facility conceptual approach.

2.0 Dewatered Sludge Truck Loading

2.1 GENERAL ASSUMPTIONS

The following general assumptions are made for both Bissell Point and Lemay:

- Utilization of the truck loading facilities will be a rare occurrence in the event that incineration feed capacity is exceeded. Primary disposal of dewatered sludge will be to onsite incineration.
- Truck hauling will be available 24 hours per day and 7 days per week during a truck hauling event.
- Preferred disposal of hauled dewatered sludge is at the other plant (Bissell Point or Lemay) incineration facility. In the event that the other plant incineration is experiencing a peak loading event and does not have spare capacity at that time, a suitable alternative disposal option would be required to receive hauled dewatered sludge.

2.2 TRUCK LOADING CONCEPTUAL DESCRIPTION

Pumping of dewatered sludge to incineration is recommended in a separate technical memorandum. Dewatered sludge pump discharge piping and valving would be provided to allow for diversion of a portion of the dewatered sludge from incinerator feed directly to truck loading. No storage or equalization bin will be provided for dewatered sludge truck loading. The truck loading facilities should be located adjacent to the new dewatering facilities to minimize the required distance for dewatered sludge pumping. A flexible rubber sleeve will be provided on the end of the dewatered sludge discharge pipes to avoid damage from or to trucks and to minimize spillage of dewatered sludge.

Figure 2-1. St. Petersburg, FL Truck Loading Facility

Truck travel path through the plant and loading areas will be designed to accommodate the District's designated truck/trailer size. In order to evenly load the trailers, multiple drop points will be provided along the length of the trailer. Each drop point will be provided with an actuated valve to control the discharge of dewatered sludge. The need for multiple truck loading bays or future additional truck loading bays can be evaluated to determine if they are required to meet design truck loading rates.

Since Bissell Point WWTF is located in an industrial area odors are less of a concern for truck loading. Depending on what time of year a truck loading event is anticipated to occur, an open-air truck loading facility may be considered at Bissell Point. At a minimum, provision of a canopy structure is required to divert precipitation from the truck loading area.

There is some concern about the dewatered cake freezing during the winter months after learning about a few other Midwest facilities who have open-air truck loading and have had challenges in the winter. Please reference the following examples:

- A private client in Kansas City has had difficulty using their open-air loading station in the winter when the product in the process equipment and the truck freezes. They later put a cover over the outdoor station with space heaters to avoid issues with freezing.
- Little Blue Valley Sewer District, outside Kansas City, has temporary dewatered sludge lime stabilization capability and they try to schedule truck loading in the spring or fall to coincide with a land application season. They conduct truck loading outdoors because of the infrequent nature. In March of one year, their first load froze in the truck and the trailer had to be placed in the headworks screenings building to warm up enough for the product to thaw and be disposed of in the field.
- Metropolitan Council Environmental Services (MCES) in St. Paul, MN installed three fluidized bed incinerators in 2004, and they included an enclosed truck loading bay even though they have a substantial amount of space from neighbors. They originally were going to haul off a fraction of the dewatered sludge production as lime stabilized product for land application, but now they only load trucks for landfill disposal in emergencies. The enclosed truck loading bay protects against odor and freezing temperatures in the winter.

Although freezing of dewatered sludge in trailers during a truck loadout event is a concern, the rare requirement to load trucks in the event that incinerator capacity is exceeded would likely occur during the spring or summer months when conditions that might freeze a truck load of dewatered sludge are less common. . A review of historical records, as seen in TM-04, shows the peak solids production related to flood events exceeding the incinerator capacity, will likely occur during the spring or summer months.

Lemay WWTF is adjacent to a residential area so foul air collection and odor control treatment will be required for the truck loading facility. The Lemay truck loading facility will be enclosed and provided with roll-up doors to facilitate truck access. Ventilation and foul air withdrawal will be active during truck loading and will be designed to avoid hazardous area classification due to the presence of dewatered sludge or concentrated scum (if directed to truck loading).

2.3 ADDITIONAL TRUCK LOADING CONSIDERATIONS

Due to the anticipated infrequency of truck loading, a limited amount of truck loading automation is envisioned. Truck loading controls may be provided adjacent to the truck loading area and on an elevated platform to permit viewing of the truck trailer interior during loading. A truck scale is not envisioned for these truck loading facilities due to the anticipated infrequent use. However, if hauling is contracted, then a ticketing system or some type of tracking system should be considered to facilitate payments to the hauling contractor depending on the terms of the hauling contract. With a 24/7 truck loading schedule requiring around the clock hauling, there will may be a premium payment to contracted truck haulers.

A concrete slab will be provided sloping to a heavy-duty trench drain directed back to the plant treatment process to facilitate washdown of any dewatered sludge spilled during loading. Concrete pavement should also be provided at the entrance and exit to truck loading bays where frequent truck starting and stopping may deteriorate asphalt pavement. Adequate lighting should be provided to accommodate around the clock truck loading. Access to restroom facilities for truck drivers may also be considered during layout of the dewatering building.

Primary and secondary scum are currently concentrated and then conveyed to the blended sludge dewatering feed well. The capability to convey concentrated scum to truck loading can be evaluated as an option.

Lastly, peak solids loading during high river levels is likely to cause a situation in which solids production at both Bissell Point WWTF and Lemay WWTF may exceed incineration capacity. This would remove the option to accept dewatered sludge hauled from one plant to the other. An alternative disposal outlet for dewatered sludge would be required and should be developed for this rare and short term condition. Local landfills currently do not accept dewatered sludge in the St. Louis metropolitan area, but it may be possible for the District to haul dewatered sludge to a landfill on a limited basis during rare events. This contingency plan should be explored to confirm viability.

3.0 Conclusion

This technical memorandum documents the selected truck loading facility concepts and provides additional considerations that might be incorporated into the truck loading facilities. The truck loading facility conceptual approach will be further developed in the Conceptual Design Report.

Limitations

This document was prepared solely for Black and Veatch in accordance with professional standards at the time the services were performed and in accordance with the contract between Black and Veatch and Brown and Caldwell dated May 16, 2019. This document is governed by the specific scope of work authorized by Black and Veatch; 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 Black and Veatch and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Addendum No. 1

Conceptual Design Report

Bissell & Lemay WWTF Fluidized Bed Incinerators

Project No. 12565

December 3, 2021

Re: Wet Electrostatic Precipitators (WESPs)

The Conceptual Design Report (CDR) and associated Technical Memorandums reflect the state of conceptual design at the time that this document was finalized in July 2021. The conceptual design continues to evolve, and changes will be noted by addenda up until the time that the Design-Build Request for Proposal is released.

This addendum to the CDR is reflects the current inclusion of wet electrostatic precipitators (WESPs) in the air pollution control equipment for the fluid bed incinerator system (FBIS).

WESPs remove particulate matter (PM), including fine particulates, and metals, including cadmium, lead, and beryllium, from the FBIS exhaust gases and have typically been included in FBIS when facilities are subject to new FBI classification MACT limits (Subpart LLLL). Related to metal and particulate removal, the preselected mercury removal granular activated carbon (GAC) system supplier, APC, provides high efficiency particulate arrestance (HEPA) filters as a component of their system, primarily to prevent fouling in the carbon media bed. The filters will perform a similar role as a WESP in removing PM and metals.

At the time the CDR was finalized, APC had initially indicated that they would be able to guarantee meeting the regulatory limits for particulate, cadmium, and lead with the HEPA filters. Subsequently, APC reviewed test data that indicated a portion of lead emissions were associated with the vapor phase of lead which the HEPA filters would not remove. As a result, they have indicated that they will not be able to guarantee meeting the MACT limits (Subpart LLLL) for lead emissions. WESP suppliers have been able to guarantee the MACT limits for lead with use of this equipment, and as a result, WESPs have been added to the requirements for the FBIS air pollution control equipment.