Solids Handling Facilities Plan

11th Addition to the Nine Springs WWTP

Prepared for the

Madison Metropolitan Sewerage District
Madison, Wisconsin

January 2010

Applied Technologies
Engineers - Architects

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CHAPTER 1
EXECUTIVE SUMMARY

The Madison Metropolitan Sewerage District (MMSD) owns and operates the Nine Springs Wastewater Treatment Plant (NSWWTP), a 50 million gallon per day (mgd) advanced wastewater treatment plant (WWTP). Wastewater generated within the District's 178-square mile service area is collected and treated at the NSWWTP, which discharges highly treated effluent to Badfish and Badger Mill Creeks. Treated biosolids from the NSWWTP are recycled to agricultural land through MMSD's successful Metrogro program.

The District modified the solids handling system at the NSWWTP in the last major construction project at the plant, the 10th Addition. An advanced anaerobic digestion process was implemented (temperature-phased anaerobic digestion) to provide a Class A biosolids product. A variety of technical and operational issues arose that prevented the District from achieving the intended goals for the advanced digestion process. Thus, the District authorized this Solids Handling Facilities Plan (11th Addition Facilities Plan) to evaluate solids handling system alternatives for the NSWWTP over a 20-year period (2010 through 2030) with the primary goal to provide the District with a detailed "roadmap" to achieve a reliable, cost-effective, sustainable process yielding a Class A biosolids end product.

Under current waste loadings the NSWWTP solids handling system processes approximately 100,000 lbs/day of waste primary and secondary solids, yielding the liquid Class B biosolids product for the Metrogro program. The District is currently transporting and applying about 40 million gallons of Metrogro on area farm land annually. Plant loading projections out to the year 2030 predict that the solids handling system loadings will increase to more than 150,000 lbs/day, a 50% increase above existing loadings.

An evaluation of the existing solids handling system was performed and it was determined that the digestion system should revert to mesophilic mode with Class B biosolids. This is an interim mode of operation until the issues that arose with the 10th Addition Class A biosolids system can be addressed through this facilities plan and resulting 11th Addition construction.

An overview screening of Class A biosolids technologies led to a "first tier" evaluation of six different anaerobic digestion alternatives. An ensuing "second tier" evaluation provided a more detailed analysis of the following:

- Conventional mesophilic digestion with thermal pretreatment
- Multi-stage acid phase digestion
- Acid phase digestion with thermal post treatment

Sizing, design criteria, and preliminary site layouts were developed for each of the alternatives. Evaluation criteria included consideration of sludge thickening, digester heating, digester mixing, digester foaming, Class A biosolids production, struvite mitigation, and full scale process experience. Economic (present worth) and non-economic comparisons of the alternatives were prepared. From the second tier evaluations, the technology recommended for implementation in the 11th Addition to the NSWWTP is multi-stage acid phase digestion.

The recommended plan, converting the existing anaerobic digestion system to multi-stage acid phase digestion (mesophilic acid phase, thermophilic gas phase), is proposed to achieve the District's goals for Class A biosolids via a site specific Class A permit. The plan includes the addition of the following major facilities:

- WAS Thickening Facilities
- Acid Digesters
- Thermophilic Digester No. 8
- Struvite Harvesting
- Digester Heating / Mixing Modifications
- Related Plant Improvements

The estimated capital cost for the recommended plan is $45,000,000. The new construction is estimated to result in a net addition of $160,000 to the plant's annual O&M budget. It is anticipated that implementation of struvite recovery will result in O&M savings due to fertilizer revenue and reduction in iron chemical costs.

The most likely source of funds for this project is a low interest loan from the DNR's Clean

Water Fund. The current interest rate for eligible projects is 2.910% (60% of market rate). Assuming that the project is 90% eligible for the reduced interest loan rate and an 18-year payment schedule, the annual debt service costs will be approximately $3.33 million.

A preliminary sewer user charge analysis was performed as part of this Facilities Plan. Residential customers pay for MMSD-provided services and sewer service provided by their local community. The current (year 2010) typical residential annual charge is estimated to be $245, including both MMSD and local community charges. In year 2014 when the debt service costs for the project are fully incorporated into customer bills, the typical residential annual charge will be $302. Without the project, the year 2014 residential annual charge would be reduced by $18 to $284. The impact of the project on residential rates is therefore on the order of a 6.5% increase.

The steps and anticipated schedule for implementing the recommended plant upgrade are outlined below:

Conduct Public Hearing	February 2010
Submit Facilities Plan to DNR	February 2010
DNR Approval of Facilities Plan	March 2010
Begin Design	January 2010
Submit Plans and Specifications to the DNR	December 2010
DNR Approval of Plans and Specifications	February 2011
Bidding	February 2011
Award of Contract	March 2011
Submit Clean Water Fund Application	March 2011
Begin Construction	April 2011
Substantial Completion/Startup of Facilities	October 2013
Complete Construction	December 2013

CHAPTER 2
INTRODUCTION

This report presents the conclusions and recommendations of the Solids Handling Facilities Plan for the Madison Metropolitan Sewerage District (MMSD), Madison, Wisconsin. MMSD is a municipal corporation that provides wastewater collection and treatment services to 43 municipal customers in its service area, encompassing approximately 178 square miles and serving a current population of about 330,000 people. MMSD owns 95 miles of interceptor sewers, 29 miles of force mains, 15 miles of effluent force mains, and 17 regional pumping stations. All wastewater collected from the service area is treated at MMSD's Nine Springs Wastewater Treatment Facilities (NSWWTP). The NSWWTP is a 50 mgd plant employing biological nutrient removal to meet effluent discharge standards for ammonia and phosphorus. Treated biosolids (residuals from wastewater treatment) are recycled to agricultural lands through MMSD's Metrogro program, a successful enterprise for the last 30 years.

In the 10th Addition to the Nine Springs WWTP (NSWWTP) the Madison Metropolitan Sewerage District (MMSD) converted its conventional mesophilic anaerobic digestion system to an advanced temperature phased anaerobic digestion (TPAD) process. Since startup in 2006, the TPAD facilities have not been able to achieve the District's goal of a Class A biosolids product. A number of issues have prevented the system from performing as originally intended, primarily related to process heating and stability. MMSD modified the process train to include an acid phase digester prior to the thermophilic and mesophilic phases to alleviate some of the process issues. While partially successful, the acid phase modification did not result in adequate process stability and production of Class A biosolids..

In 2008 MMSD initiated the preparation of a Solids Handling Facilities Plan. The primary goal of the Plan is to provide the District with a detailed roadmap to achieve a reliable, cost-effective, sustainable process yielding a Class A biosolids product. In addition to advanced anaerobic digestion, the Solids Handling Facilities Plan encompasses several related aspects of the existing digestion system.

The facilities planning process is required by the Wisconsin DNR and U.S. EPA prior to construction, expansion, or modification of the wastewater treatment plant. The planning process is a systematic economic, technical, and environmental evaluation of alternatives for wastewater treatment and disposal. The recommended wastewater treatment alternative must meet the required effluent limitations and be cost-effective. The facilities planning procedure assures the public and all levels of government that decisions regarding the facilities are soundly made and consider all relevant factors.

PROJECT BACKGROUND

The 10th Addition to the NSWWTP encompassed eight years of testing, planning, design, construction, and start-up activities. One of the primary aspects of the 10th Addition was the conversion of the solids handling system to an advanced anaerobic digestion process (temperature phased anaerobic digestion, or TPAD), with the goal of producing a Class A biosolids product. The TPAD process at NSWWTP was designed to operate in a batch-feed, two-stage configuration, with a thermophilic first stage followed by a mesophilic second stage. Three thermophilic digesters were to run in sequential batch feed / digest / drawdown modes, with each mode lasting 12 hours. The 12-hour digestion time at 135 °F would meet the regulatory requirements for producing Class A biosolids. Substantial modifications to the existing anaerobic digestion facilities included new Digester No. 7, gas mixing systems, sludge recirculation and transfer pumping, boilers, and heat exchangers.

The 10th Addition facilities have not achieved the original objectives for a Class A biosolids product after two years of start-up and testing. A series of operational issues have arisen, generally described as follows:

- Process instability resulting in digester foaming
- Heat transfer inhibition leading to inadequate digester heating

The District made process modifications in an effort to address these difficulties, incorporating an acid-phase digester prior to the thermophilic stage in an attempt to reduce grease build-up in heat exchange equipment. The District also made a series of modifications to address related issues:

- Progressing cavity pumps replaced centrifugal sludge transfer pumps to eliminate gas binding.
- Higher ferric chloride doses were employed to mitigate struvite formation downstream of the thermophilic digesters. The iron dosing rate must be balanced against the potential to form vivianite in the secondary heat exchangers.
- Glass-lined piping was installed to replace struvite-laden sludge lines in the Solids Tunnel.

- A grinder was installed in the raw sludge line to reduce ragging in the heat exchangers.
- A gas treatment system was added to remove impurities and moisture in the biogas.

The 10^{th} Addition digestion system was operated in the modified acid-thermo-meso mode of operation, with all sludge being fed through Digester No. 7 as the acid phase digester. Due to some of the materials handling limitations, the system did not achieve a Class A status, and process instability was problematic. The District eventually converted the anaerobic digestion system back to a stable mesophilic operation, which is the current mode of operation. The mesophilic operation is intended to be an interim mode until the Solids Handling Facilities Plan project, with resultant construction can be completed.

PURPOSE AND SCOPE

A Facilities Plan develops the most cost-effective and environmentally sound plan for wastewater management to abate existing sources of pollution, provide adequate treatment capacity for future growth in the planning area, and meet area wide water quality standards and water management goals issued by the DNR. The most current planning guidelines and regulations distributed by the U.S. EPA and DNR were used to prepare this report.

The scope of work for this Solids Handling Facilities Plan included the following activities:

1. Review existing data and facilities by visiting the facilities with District personnel, and obtaining copies of operating data and reports. The data will include: influent and effluent data as well as biosolids data for a minimum of three years. The data will also include appropriate previous reports.

2. Analyze the performance of the existing anaerobic digestion system, and individual unit operations within. Review existing facilities to identify items that will need modification, upgrading or replacement.

3. Review previous memos addressing modes of operation for the existing facilities. Identify methods to optimize operation of the existing facilities using acid phased digestion. Determine a preliminary list of operating procedure modifications and minor facility enhancements that could improve digester operations during the interim period before the planned facilities are constructed and operational. Complete a workshop with the District staff to present preliminary findings and

brainstorm additional ideas to optimize the existing facilities and develop a consensus on an action plan during the interim period. Prepare a brief memo summarizing of the interim program action plan.

4. Since this is a Solids Handling Facilities Plan, an infiltration/inflow (I/I) analysis will not be included.

5. Utilize 10 year and 20 year population and flow / loading projections provided by the District.

6. Correspondence with the Wisconsin Department of Natural Resources related to developing effluent limits will not be required since this is a Solids Handling Facilities Plan.

7. Select, develop and investigate viable wastewater management alternatives that address the needs of the District. Conduct a brainstorming meeting with the District to obtain input and to screen the alternatives.

8. Make arrangements for visits to plants with District staff to view process arrangements / equipment that are being evaluated during the project if requested.

9. Prepare technical memoranda to provide input for the project-specific issues and as a means of intermediate communication with the District. The technical memoranda will be included as an Appendix to the Facilities Plan. Technical memoranda are anticipated for the following topics:

- Review / screening of Class A biosolids technologies
- Plant loading and biosolids production projections for 10 and 20 years
- Anaerobic digestion modeling
- Implementation of Acid Phase Digestion
- Regulatory approval of Class A protocol
- Solids Thickening
- Biogas utilization
- Heat transfer / temperature control
- Digester mixing evaluation
- Phosphorus removal for struvite control / mitigation of scale formation

- Grease Receiving and Digestion
- Digester foaming mitigation
- Mesophilic anaerobic digestion with Class A sidestream treatment
- Plant site development

10. Prepare a mid-course review presentation to discuss the project with the District, DNR, and other interested agencies.

11. Prepare sizing and layouts for the viable alternatives. Identify potential arrangements on the present treatment plant site.

12. Prepare a cost-effectiveness analysis and a non-monetary evaluation of the viable alternatives. Estimate capital costs and operations and maintenance costs for the viable alternatives. Evaluate non-monetary advantages and disadvantages of the viable alternatives. Recommend a preferred alternative to the District.

13. Prepare an implementation plan and schedule for the selected alternative. The District will estimate the impact of the selected plan on the District's sewer user charge system.

14. Prepare a draft facilities plan report and submit 5 copies to the District for review.

15. Assist the District in conducting a public hearing on the draft facilities plan.

16. Finalize the facilities plan incorporating comments from the District, and submit 10 copies of the final facilities plan to the District and DNR. Provide electronic versions of the final facilities plan in WORD and PDF formats. Review any DNR comments and prepare a response and provide information as required to obtain DNR approval of the facilities plan.

PROJECT DOCUMENTATION

The Solids Handling Facilities Planning effort has been documented through a series of technical memoranda and workshops that are included Appendices attached to this report.

PLANNING AREA AND STUDY PERIOD

The planning area for the Facilities Plan is the same as the 2030 Sewer Service Area, shown in Figure 2-1. The planning area encompasses approximately 219 square miles.

In accordance with state and federal criteria, the planning period for the Facilities Plan will be 20 years. Therefore, the planning period encompasses the years 2010 through 2030.

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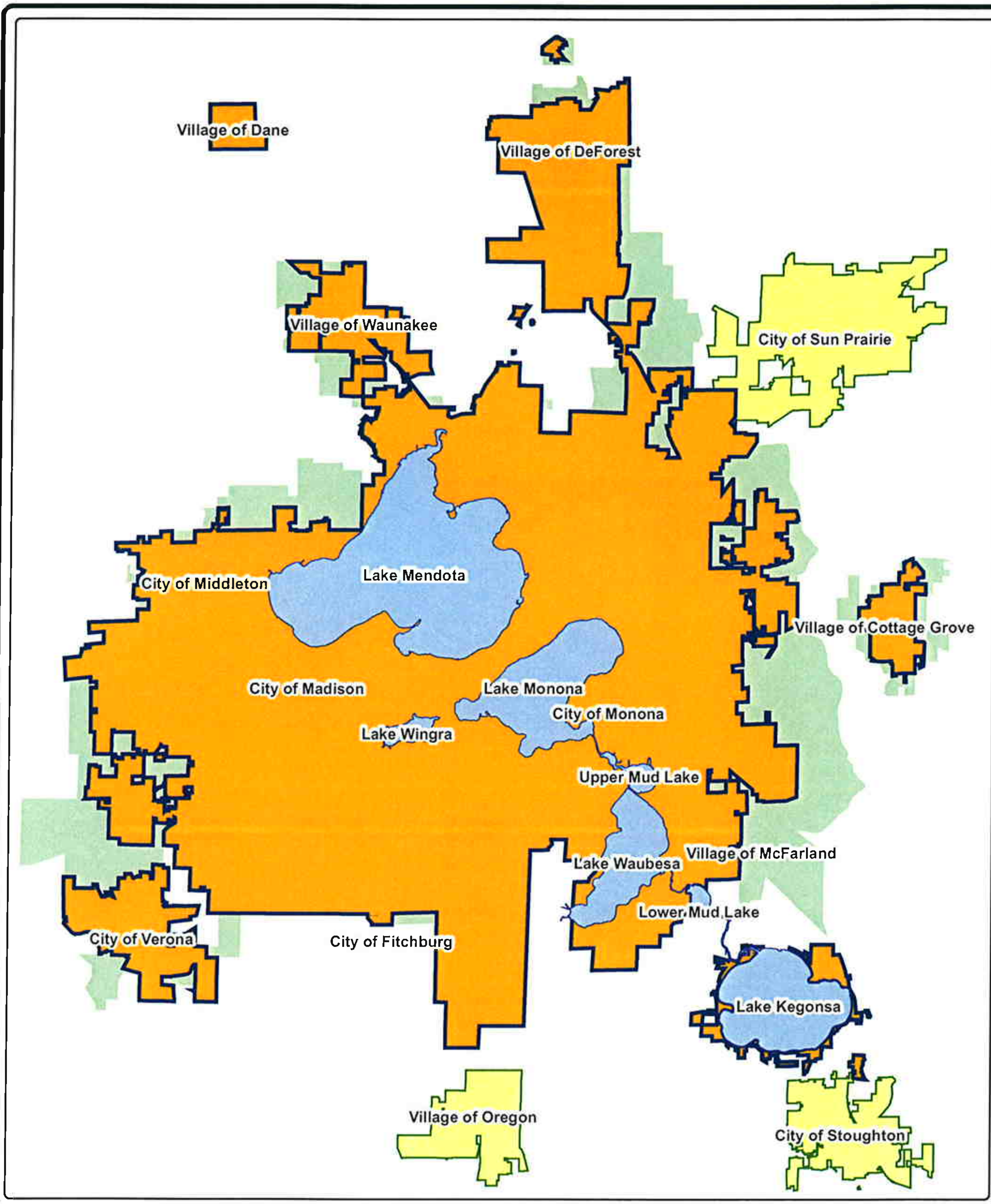

Present District Boundary
Potential 2030 Boundary
Outside District

POTENTIAL 2030
MMSD SERVICE AREA

MADISON METROPOLITAN SEWERAGE DISTRICT
2008

FIGURE 2-1

CHAPTER 3
EFFLUENT LIMITATIONS

Effluent limitations are based on the water use objectives and water quality standards that are developed to achieve the desired results. In Wisconsin, these objectives and standards are established by federal, State, and regional agencies and are administered through the Wisconsin Pollutant Discharge Elimination System (WPDES). Under this system, the DNR issues WPDES permits to each discharger in the State, setting forth the effluent limitations that must be met. Land application of biosolids is covered by WPDES due to the potential contamination of nearby bodies of water.

This chapter briefly reviews federal and State water use objectives and water quality standards as they relate to solids treatment at the NSWWTP, and the current and proposed WPDES permits and related effluent limitations.

BIOSOLID USE OBJECTIVES AND QUALITY STANDARDS

Recognizing the need for a nationwide approach to water quality, the U.S. Congress, through the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), declared its objective to restore and maintain the chemical, physical and biological integrity of the nation's waters. Congress also required the establishment of water quality standards for all waters consistent with the applicable requirements of the Act.

The Wisconsin Legislature, through Chapter 283 of the Wisconsin Statutes, requires that any disposal of sludge from a wastewater treatment plant be done under a valid WPDES permit. Chapter NR 204 of the Wisconsin Administrative Code defines the monitoring and disposal requirements of sewage sludge. MMSD currently land applies biosolids from the NSWWTP under the regulations outlined in NR 204.07.

NR 204 defines exceptional quality sludge as sludge that meets the Class A pathogen requirements, high quality pollutant limitations, and has undergone at least one pre-application process to reduce the likelihood of pathogen transmittal. Because exceptional quality sludge is not considered to be a health or environmental hazard, it is exempt from many disposal requirements.

DISCHARGE PERMIT REQUIREMENTS

Public Law 92-500 requires a National Pollutant Discharge Elimination System (NPDES) permit for any point source discharge of pollutants into the nation's navigable waters. Chapter 283 of the Wisconsin Statutes authorizes the DNR to "establish, administer and maintain a state pollutant discharge elimination system." This permit system, known as WPDES, conforms to the objectives and requirements of Public Law 92-500. The State of Wisconsin has expanded the permit system beyond the navigable waters concept by applying it to all of the State's receiving waters. Due to the possibility of the State's waters being contaminated by land applied sludge, biosolids disposal is also covered under WPDES.

On April 1, 2004, the Madison Metropolitan Sewerage District was granted WPDES Permit No. WI-0024597-07-0 with provisions to land-apply biosolids that meet Class B requirements. This permit expired on March 31, 2009. The DNR issued a proposed permit in 2009 that is subject to review prior to reissuance. A copy of this proposed permit is contained in the Appendix.

Table 3-1 shows the biosolids pollutant limits for Exceptional Quality sludge and Class B sludge listed in the proposed discharge permit. Table 3-2 shows the pathogen control requirements for Class A and Class B sludge and Table 3-3 provides a listing of vector attraction reduction options for anaerobic processes, both tables derived from lists in the proposed discharge permit.

Table 3-1
Biosolids Pollutant Limitations
Nine Springs WWTP (1)

Biosolids Parameter	Limit
Arsenic, Dry Weight	
High Quality	41 mg/kg
Ceiling	75 mg/kg
Cadmium, Dry Weight	
High Quality	39 mg/kg
Ceiling	85 mg/kg
Copper, Dry Weight	
High Quality	1,500 mg/kg
Ceiling	4,300 mg/kg
Lead, Dry Weight	
High Quality	300 mg/kg
Ceiling	840 mg/kg
Mercury, Dry Weight	
High Quality	17 mg/kg
Ceiling	57 mg/kg
Molybdenum, Dry Weight	
Ceiling	75 mg/kg
Nickel, Dry Weight	
High Quality	420 mg/kg
Ceiling	420 mg/kg
Selenium, Dry Weight	
High Quality	100 mg/kg
Ceiling	100 mg/kg
Zinc, Dry Weight	
High Quality	2,800 mg/kg
Ceiling	7,500 mg/kg

(1) See discharge permit for sample type and frequency

Table 3-2
Biosolids Pathogen Control Options
Nine Springs WWTP

Sludge Type	Biosolids Parameter	Limit
Class A	Fecal Coliform	1,000 MPN[1]/g TS
	or	
	Salmonella	3 MPN/4 g TS
	and (1) of the following processes:	
	Temp/Time based on % Solids Composting Alkaline Treatment Heat Treatment Beta Ray Irradiation Pasteurization Prior and Post Tests for Enteric Virus/Viable Helminth Ova Heat Drying Thermophilic Aerobic Digestion Gamma Ray Irradiation PFRP[2] Equivalent Process	
Class B	Fecal Coliform	2,000,000 MPN/g TS
	Or (1) of the following processes	
	Aerobic Digestion Anaerobic Digestion Alkaline Stabilization Air Drying Composting PSRP[3] Equivalent Process	

[1] Most Probable Number
[2] Process to Further Reduce Pathogens
[3] Processes to Significantly Reduce Pathogens

Table 3-3 Vector Attraction Reduction Options Nine Springs WWTP – Anaerobic Processes		
Option	**Limit**	**Limit Application**
Volatile solids reduction	≥ 38%	Across process
Anaerobic bench-scale test	< 17% VS reduction	On anaerobic digested sludge
pH adjustment	> 12 S.U. for 2 hours and > 11.5 for addnl. 22 hours	During the process
Drying with primary solids	> 90% TS	When applied or bagged
Injection	-	When applied
Incorporation	-	Within 6 hours of application
Equivalent Process	Approved by WDNR	Varies with process

CHAPTER 4
CURRENT SITUATION

This chapter presents a summary of the current wasteloads received at the NSWWTP and a review of the operating performance of the NSWWTP solids handling system.

WASTEWATER FLOWS AND LOADINGS

A thorough evaluation of historical plant loadings at the NSWWTP was prepared for the District's 50-year Master Plan. The information in this report was developed to be in agreement with the Master Plan. Technical Memorandum No. 1: *Basis of Design* (TM-01) contains an analysis of existing plant loadings to provide a design basis for solids projections. Wastewater influent data taken from the Master Plan for the years 2003 through 2007 are summarized in Table 4-1.

Table 4-1
NSWWTP Loadings
Annual Plant Influent Loadings

Year	Flow (mgd)	BOD_5		TSS		TKN		Total -P	
		(mg/L)	(lbs/day)	(mg/L)	(lbs/day)	(mg/L)	(lbs/day)	(mg/L)	(lbs/day)
2003	38.56	243	78,115	261	83,769	35.2	11,342	6.49	2,087
2004	41.93	231	80,860	251	86,915	33.9	11,915	6.21	2,186
2005	39.37	245	81,648	243	80,197	37.5	12,439	6.39	2,132
2006	41.22	245	83,722	229	78,214	38.2	13,185	6.29	2,165
2007	43.00	240	84,396	212	75,592	36.4	12,955	5.95	2,125

The NSWWTP is a biological nutrient removal plant, utilizing a variation of the University of Cape Town (UCT) process to achieve nitrogen and phosphorus removal. The plant has been performing extremely well in terms of meeting discharge permit effluent limits. Table 4-2 provides a summary of the plant effluent quality.

Table 4-2 NSWWTP Performance Summary Effluent Quality						
Year	**Badfish Creek Effluent Flow (mgd)**	**Badger Mill Creek Effluent Flow (mgd)**	**BOD (mg/L)**	**TSS (mg/L)**	**Ammonia (mg/L)**	**Total P (mg/L)**
2003	36.85	2.99	3	5	0.28	0.29
2004	40.22	2.78	3	5	0.22	0.44
2005	37.47	3.11	4	5	0.27	0.39
2006	38.63	3.08	4	5	0.21	0.42
2007	41.68	3.24	4	4	0.12	0.39

SLUDGE PRODUCTION

Current sludge production at the NSWWTP, estimated from current loadings on the plant, is summarized in Table 4-3. These estimates serve as the basis for projecting future sludge production to be used as the solids handling system design basis.

Table 4-3 NSWWTP Solids System Current Sludge Production Estimates[1]		
Process Parameter	**Average**	**Maximum Month**
Plant Influent		
Flow, mgd	42.9	54.8
TSS loading, ppd	75,700	90,800
BOD loading, ppd	85,100	102,100
N loading, ppd	12,900	15,500
P loading, ppd	2,100	2,300
Primary Sludge		
Total solids, ppd	60,800	73,000
Waste Activated Sludge		
Total solids, ppd	49,700	59,600
Thickened Sludge (digester feed)		
Total solids, ppd	106,300	127,600
Volatile solids, ppd	80,800	97,000
(1) From Table 1.3, TM-01		

For more than thirty years the District has recycled biosolids to agricultural land through its Metrogro program, in which liquid sludge is hauled from NSWWTP for land application of Class B biosolids. Table 4-4 provides a summary of Metrogro operations.

Table 4-4 NSWWTP Metrogro Summary Class B Biosolids Land Application						
Year	**Total Volume Recycled (million gal)**	**Dry Solids Recycled (tons)**	**Land Area Applied (acres)**	**Total Program Cost ($1000)**	**Liquid Cost ($/1000 gal)**	**Dry Solids Cost ($/dry ton)**
2003	40.0	8,827	5,285	$1,359	$33.91	$154
2004	38.4	8,397	4,923	$1,440	$37.48	$171
2005	34.0	7,086	4,376	$1,238	$36.39	$175
2006	35.9	7,185	4,431	$1,301	$36.23	$181
2007	38.2	7,380	4,758	$1,335	$35.13	$181

SOLIDS HANDLING SYSTEM PERFORMANCE

The existing solids handling system at the NSWWTP is depicted in Figure 4-1. In the 10th Addition to the NSWWTP, MMSD converted its conventional mesophilic anaerobic digestion system to an advanced temperature phased anaerobic digestion (TPAD) process. The 10th Addition to the NSWWTP encompassed eight years of testing, planning, design, construction, and start-up activities. One of the primary aspects of the 10th Addition was the conversion of the solids handling system to an advanced anaerobic digestion process (TPAD), with the goal of producing a Class A biosolids product. The TPAD process at NSWWTP was designed to operate in a batch-feed, two-stage configuration, with a thermophilic first stage followed by a mesophilic second stage. Three thermophilic digesters were to run in sequential batch feed / digest / drawdown modes, with each mode lasting 12 hours. The 12-hour digestion time at 135 °F would meet the regulatory requirements for producing Class A biosolids. Substantial modifications to the existing anaerobic digestion facilities included new Digester No. 7, gas mixing systems, sludge recirculation and transfer pumping, boilers, and heat exchangers.

The 10th Addition facilities have not achieved the original objectives for a Class A biosolids product after two years of start-up and testing. A series of operational issues have arisen, generally described as follows:

- Process instability resulting in digester foaming
- Heat transfer inhibition leading to inadequate digester heating

The District made process modifications in an effort to address these difficulties, incorporating an acid-phase digester prior to the thermophilic stage. The District also made a series of modifications to address related issues:

- Progressing cavity pumps replaced centrifugal sludge transfer pumps to eliminate gas binding.
- Higher ferric chloride doses were employed to mitigate struvite formation downstream of the thermophilic digesters. The iron dosing rate must be balanced against the potential to form vivianite in the secondary heat exchangers.
- Glass-lined piping was installed to replace struvite-laden sludge lines in the Solids Tunnel.
- A grinder was installed in the raw sludge line to reduce ragging in the heat exchangers.
- A gas treatment system was added to remove impurities in the biogas.

The 10th Addition digestion system operated in the modified acid-thermo-meso mode of operation, with all sludge being fed through Digester No. 7 as the acid phase digester (as shown on Figure 4-1). Due to some of the materials handling limitations and the configuration of Digester No. 7, the system did not operate in a manner to achieve a Class A status, and process instability continued to be problematic. The system performance was erratic and the maintenance was extremely labor intensive. In the summer of 2008 the District began process modifications to convert the solids handling system back to a mesophilic mode. Reverting back to mesophilic operations was completed in the fall of 2008, with the Metrogro program continuing with Class B biosolids. This mode of operation is familiar to the plant staff and the process has been stable. This is intended to be an interim operation until the Solids Handling Facilities Plan and resultant construction (11th Addition to the NSWWTP) can be completed.

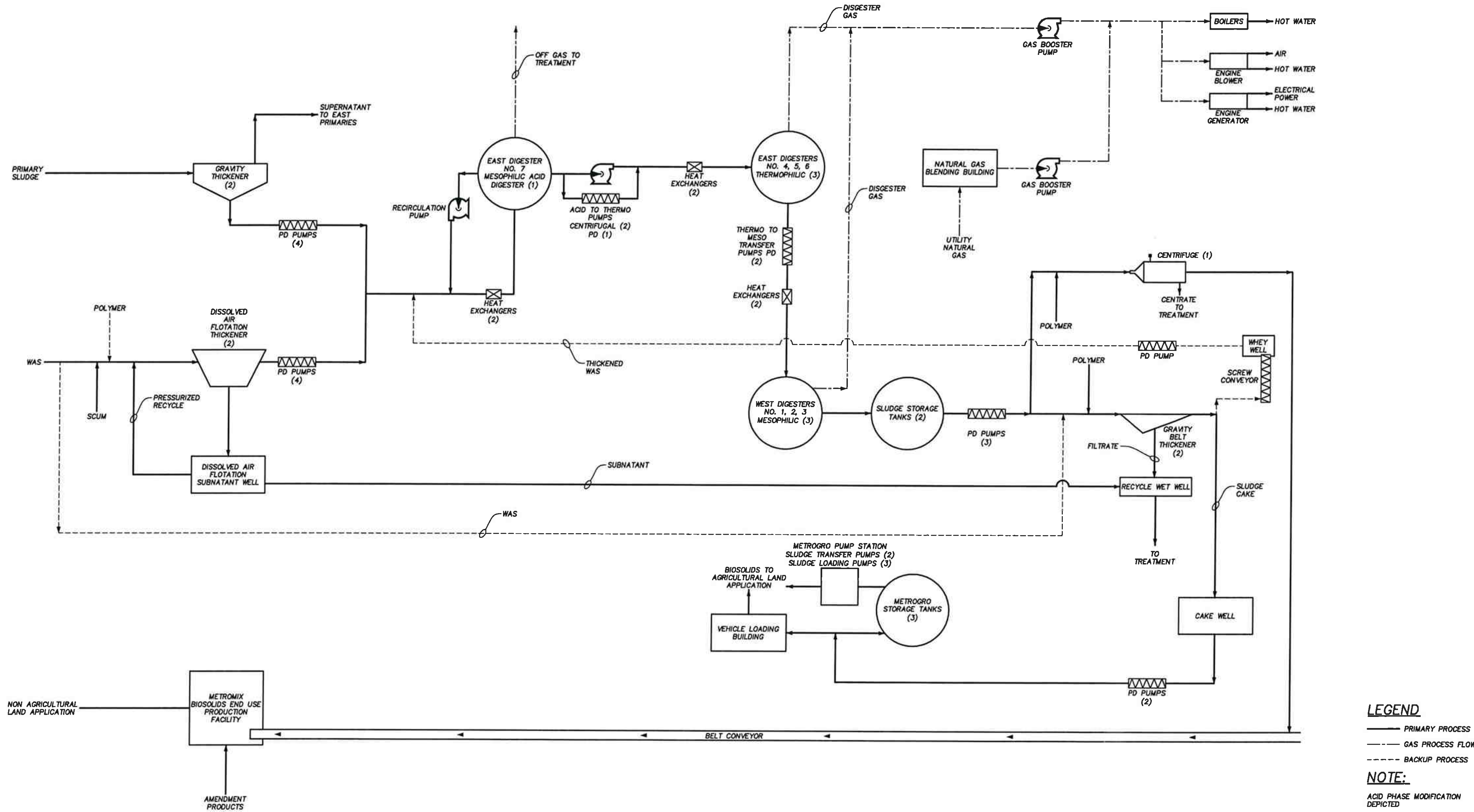

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FIGURE 4-1
SOLIDS PROCESS SCHEMATIC
Madison Metropolitan Sewage District

CHAPTER 5
PROJECTED WASTEWATER FLOWS AND LOADINGS

This chapter contains information on wasteload and sludge production projections for the planning area. As presented in Chapter 2, the planning period is 20 years, encompassing the years 2010 through 2030. Wasteload and sludge production projections are used to evaluate the existing facilities at the NSWWTP and develop future treatment alternatives for the solids handling facilities at the plant.

WASTELOAD PROJECTIONS

Population and wasteload projections for NSWWTP were prepared in the District's 50-year Master Plan. The projections included residential, commercial, and industrial loadings, as well as estimated hauled wastes. These projections have been incorporated into this report.

TM-01 contains an analysis of year 2030 projected plant loadings, including a comparison of projections made in the Master Plan, the 10^{th} Addition project, and a process model using operational data from 2005 – 2007. Updated peaking factors, flows and loadings from the Master Plan were used to establish design criteria. Table 5-1 presents a summary of the 2030 projected influent flows and wasteloads.

Table 5-1
Nine Springs WWTP
2030 Projected Influent Flows and Loading(1)

Parameter	Units	Annual Average	Maximum Month
Flow	(mgd)	53.8	67.2
BOD_5	(lbs/day)	122,100	146,500
TSS	(lbs/day)	117,800	141,400
TKN	(lbs/day)	19,800	23,800
Total-P	(lbs/day)	2,900	3,200

(1) From Table 1.3, TM-01

SLUDGE PRODUCTION

In TM-01 the sludge production for the year 2030 was estimated using a process model calibrated for the NSWWTP. The more conservative values from the Master Plan were used for the design criteria. Table 5-2 shows estimated values for sludge production for the Nine Springs WWTP in the year 2030. These values form the basis for design for subsequent evaluation of solids handling alternatives.

Table 5-2
Nine Springs WWTP
2030 Projected Sludge Production[1]

Parameter	Units	Annual Average	Maximum Month
Primary Sludge			
Total Solids	(lbs/day)	88,400	105,600
Waste Activated Sludge			
Total Solids	(lbs/day)	72,200	85,400
Thickened Sludge			
Total Solids	(lbs/day)	154,500	183,800
Volatile Solids	(lbs/day)	117,400	139,700

(1) From Table 1.3, TM-01

CHAPTER 6

EXISTING FACILITIES EVALUATION AND ALTERNATIVE ANALYSIS

This chapter presents an evaluation of the existing solids handling facilities and unit processes at MMSD's NSWWTP. The capacities of the facilities are compared to the current flows and loadings and projected year 2030 design flows and loadings. Deficiencies and shortfalls are identified, and alternatives for upgrading or expanding the existing facilities are then identified and evaluated.

GENERAL DESCRIPTION

The NSWWTP is an advanced wastewater treatment plant that treats wastewater generated within the MMSD Service Area limits and discharges treated effluent to the Badfish Creek and Badger Mill Creek. The plant was last upgraded in the 10th Addition to the NSWWTP in 2006. The NSWWTP is a biological nutrient removal (BNR) plant, utilizing a variation of the University of Capetown (UCT) process to achieve ammonia and phosphorus reduction. The plant produces a very high quality effluent, with BOD/TSS less than 5 mg/L, ammonia less than 0.3 mg/L, and total P less than 0.4 mg/L.

The NSWWTP liquid treatment processes include preliminary treatment (screening and grit removal), primary treatment, secondary treatment (BNR activated sludge), final clarifiers, UV effluent disinfection, and effluent pumping. Primary sludge collected from the primary clarifiers is gravity thickened and fed to the anaerobic digestion system. Waste activated sludge from secondary treatment is thickened by dissolved air flotation prior to being fed to the anaerobic digesters. Figure 6-1 provides a process flow schematic of the solids handling system, while Figure 6-2 shows a site plan of the existing solids facilities at the NSWWTP.

Existing Anaerobic Digestion Facilities

The NSWWTP solids handling facilities have seven (7) anaerobic digesters and two (2) sludge storage tanks. Table 6-1 presents a summary of the anaerobic digesters and sludge storage tank characteristics. Digesters No. 1, 2, 3, and 7 were designed for mesophilic operation. Digesters No. 4, 5, and 6 were designed for thermophilic operation. Under acid-phase operation, Digester No. 7 was operated as the acid digester. Under the current interim operation, all digesters are being operated in a parallel mesophilic mode.

Table 6-1 Nine Springs WWTP *Existing Anaerobic Digesters*				
	East Complex Digesters (1)	**East Complex Digesters (2)**	**West Complex Digesters (3)**	**Sludge Storage Tanks**
Number of Units	3	1	3	2
Diameter, ft	80	80	75	70
Side Water Depth, ft	26.4	26.4	15.4	12
Cone Depth, ft	1.67	6.67	11.8	12
Unit Volume, gal	1,014,000	1,076,000	639,000	450,000

Notes:
(1) Digesters No. 4, 5, and 6
(2) Digester No. 7
(3) Digesters No. 1, 2, and 3

The digester feed consists of thickened primary sludge and waste activated sludge (WAS). Primary sludge and waste activated sludge are thickened using gravity thickening (GT) and dissolved air flotation thickening (DAFT), respectively. The DAFT units also receive primary and secondary scum. Digested sludge is thickened using two (2) gravity belt thickeners (GBT). One of these units also serves as backup for WAS thickening when a DAFT unit is out of service. The thickened digested sludge (Metrogro) is stored in three (3) 160-ft diameter tanks with a combined capacity of 19.4 MG. Table 6-2 presents a summary of the GT and DAFT characteristics and the performance during the period of May 2007 to December 2007.

Table 6-2 Nine Springs WWTP *Existing Sludge Thickening Units*		
	Gravity Thickeners	**DAFT**
Number of Units	2	2
Diameter, ft	55	55
Total Surface Area, sqf	4,752	4,752
Solids Loading, ppd	60,800 (1)	49,700 (2)
Solids Capture Efficiency, %	98.3	93.8
Thickened Sludge Solids, %	5.0	4.2

Notes:
(1) Primary sludge based on historical plant TSS loadings
(2) Waste activated sludge

UNIT PROCESS EVALUATION AND ALTERNATIVE ANALYSIS

The solids handling system at the NSWWTP underwent significant modifications in the 10th Addition project to convert from conventional mesophilic anaerobic digestion to an advanced digestion process (TPAD). The ultimate goal of the process is to produce a Class A biosolids product. Startup of the new process began in 2006. Problems arose almost immediately, and over the next two years numerous efforts were unsuccessful in achieving a stable Class A biosolids system. During the initial startup of TPAD in February 2006, heat exchanger fouling limited raw sludge heating so that thermophilic temperatures could not be attained. The District converted to a three phase (acid-thermo-meso) system in September 2006. The subsequent digestion operations are described as follows:

Time Period	Process arrangement	Description
Feb – Sept /2006	TPAD (thermo-meso)	System startup as designed; could not reach design temps due to heat exchanger fouling
Sept – Nov /2006	3-phase (acid-thermo-meso)	Acid digester foaming issues
Dec /2006 – Apr /2007	TPAD (thermo-meso)	Interim mode w/ acid digester out of service
Apr – Dec /2007	3-phase (acid-thermo-meso)	Acid digester foaming issues
Dec /2007 – Feb /2008	TPAD (thermo-meso)	Interim mode w/ acid digester out of service
Feb – July /2008	3-phase (acid-thermo-meso)	Acid digester foaming issues

Over the course of the 10th Addition startup activities, numerous operational issues arose, including the following:

- Fouling of raw sludge heat exchangers (coating with grease)
- Rags plugging raw sludge heat exchangers
- Sludge flow through raw sludge heat exchangers below design due to high headlosses
- Gas binding of centrifugal sludge transfer pumps

- Struvite accumulation in the thermo to meso step down system
- Vivianite scale formation in the 2nd stage heat exchangers
- Foaming of the acid digester
- High contaminant levels in the biogas, damaging the engine generators
- Significant odor associated with the acid digester

The District made numerous modifications and additions to address most of the problems identified in the 10th Addition startup. The District has successfully continued operation of its Metrogro program throughout this period. The District remains committed to the goal of producing a Class A biosolids product through the stable operation of a suitable process at the NSWWTP. The District initiated planning through the Solids Handling Facilities Plan to identify the best path to achieving its ultimate goals.

After July 2008, the digestion system was converted back to single stage conventional mesophilic digestion. This mode of operation, discussed in Workshop No. 2, is intended to be an interim mode of operation until the problems that arose in the 10th Addition can be addressed. Operating in a mesophilic mode reduces or eliminates the issues encountered with thermophilic operation.

Screening of Sludge Stabilization Alternatives

The Solids Handling Facilities Plan was initiated at a kickoff meeting in June 2008 (Workshop No. 1), in which an initial review of plant loadings over 2007 – 2008 was presented, as well as an evaluation of the performance of the post – 10th Addition solids handling system. A general anaerobic digestion process comparison was presented, summarized in Table 6-3.

An overview of Class A sludge stabilization technologies, along with an evaluation of their suitability to meet the District's long term biosolids management goals and objectives was summarized in TM-02: *Sludge Stabilization Alternatives Evaluation.* The initial screening was based on the following criteria:

- Ability to produce Class A biosolids.
- Economic feasibility.
- Proven technology with successful full-scale installations in biosolids facilities at municipal WWTPs of equivalent size and complexity as the Nine Springs WWTP.

- Consistent with the Nine Springs WWTP digestion facility and the MMSD land application programs (Metrogro and Metromix).
- Consistent with local environmental conditions.

A total of 24 stabilization technology options were considered in the preliminary screening. Three alternatives were selected for detailed technical an economic evaluation:

- Cambi thermal hydrolysis process (THP) followed by conventional anaerobic digestion
- Acid-phase digestion with a mesophilic-thermophilic-mesophilic configuration
- Temperature phased anaerobic digestion (TPAD)

Table 6-3

Anaerobic Digestion Process Comparison

Digestion Process	SRT per Tank @ Max Month (days)	Total SRT @ Max Month (days)	Operating Temperature	VS Loading @ Max Month (days)	Pathogen Level Produced
Conventional Digestion	15	15	mesophilic	0.18	Class B
Staged Digestion	15/5	20	mesophilic	0.18	Class B
Two-Phase Digestion	2/12	14	mesophilic	1.5-2.5	Class B
Temperature-Phase Digestion	5/10	15	thermophilic / mesophilic	0.3	Class A
Two-Phase Digestion	2/12	14	mesophilic / thermophilc	1.5 – 2.5	Class A

Detailed Evaluations of Sludge Stabilization Alternatives

Detailed evaluations of sludge stabilization alternatives were performed through a series of draft technical memoranda, summarized in TM-03: *Anaerobic Digestion Process Evaluation* and TM-03A: *Anaerobic Digestion Process Evaluation II*, as well as Workshops Nos. 3 and 4. TM-03 provides documentation of process evaluation prior to Workshop No. 4 (first tier), while subsequent evaluations are in TM-03A (second tier).

First Tier Process Evaluations

The list of technologies in the first tier of evaluations derived from initial screening in TM-02 was expanded to include the option of conventional mesophilic digestion followed by thermal post treatment for 25% of the biosolids production. Thermal post treatment technologies considered were:

- Cambi THP
- Heat Drying
- En-vessel Pasteurization
- Batch Thermophilic

The candidate technologies in the first tier evaluations were subjected to detailed economic and non-economic evaluations. The process criteria employed are summarized in Table 6-4. For each of the technologies, process flow diagrams were developed for current and 2030 loadings, as well as site location schematics. Evaluation criteria included

- Sludge thickening requirements
- Digester foaming mitigation
- Class A biosolids production
- Full scale installation experience

Table 6-4 **Recommended Design Criteria for Anaerobic Digestion Processes**		
Digestion Process	**Design Criteria**	**Controlling Criteria**
Acid-Phase Digestion		
Acid Digester (mesophilic)	VSLR 1 to 2.5 lbs VS/cfd	Maximum Month with one unit out of service
	HRT 1.5 to 3 days	Maximum Month with all units in service and annual average with one unit out of service
Methane Digester (thermophilic)	HRT ≥ 12 days	Maximum Month with all units in service and annual average with largest unit out of service
Methane Digester (mesophilic)	HRT ≥ 2 days	Maximum Month with all units in service and annual average with largest unit out of service
TPAD		
Thermophilic Digester	VSLR < 0.30 lbs VS/cf/day HRT ≥ 5 days	Maximum Month with all units in service and annual average with largest unit out of service
Mesophilic Digester	HRT ≥ 10 days	Maximum Month with all units in service and annual average with largest unit out of service
Conventional with Cambi THP		
Conventional Digester (1)	VSLR < 0.37 lbs VS/cfd (2) HRT ≥ 15 days	Maximum Month with all units in service and annual average with largest unit out of service
Conventional with Thermal Post-Treatment		
Conventional Digester	VSLR < 0.13 lbs VS/cfd	Annual average with all units in service
	VSLR < 0.18 lbs VS/cfd HRT ≥ 20 days (3)	Maximum Month with all units in service and annual average with largest unit out of service
Batch Thermal Tank	Holding Time ≥ 1 day (4)	Maximum Month with all units in service

Table 6-4 Recommended Design Criteria for Anaerobic Digestion Processes		
Digestion Process	**Design Criteria**	**Controlling Criteria**

Notes:

(1) Conventional digesters downstream of a Cambi THP system.

(2) Based on information provided by Cambi. Assumes a total solids concentration in the thermally hydrolyzed sludge of 10 percent with a volatile fraction of 80 percent.

(3) Based on operation experience at the Nine Springs WWTP

(4) Based on operating temperature of 131 deg F.

An economic evaluation, based on a 20-year present worth analysis, is summarized in Table 6-5. The non-economic comparison of alternatives in the first tier is presented in Table 6-6. From the first tier evaluations (TM-03 and Workshop No. 4), three candidate technologies were selected for further consideration in the second tier evaluations.

Table 6-5
Economic Comparison of Digestion Alternatives
First Tier Process Evaluation

Anaerobic Digestion Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Acid-Phase Digestion	$9,967,000	$21,267,000	$18,913,000	$50,147,000
TPAD (Thermo-Meso)	$9,631,000	$18,329,000	$18,913,000	$46,873,000
Conventional Digestion with Cambi THP	$23,108,000	$30,912,000	$17,933,000	$71,953,000
Conventional Digestion with Heat Drying	$29,133,000	$25,562,000	$18,428,000	$73,123,000
Conventional Digestion with En-Vessel Pasteurization	$17,380,000	$23,385,000	$21,938,000	$62,703,000
Conventional Digestion with Batch Thermal Tanks	$19,349,000	$24,450,000	$20,961,000	$64,760,000

Table 6-6 Non-Economic Comparison of Digestion Alternatives First Tier Process Evaluation		
Alternative	**Advantages**	**Disadvantages**
Acid-Phase Digestion	• Production of Class A Biosolids • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Improved biogas quality in methane digesters • Decreased non-filamentous foaming potential • Gradual temperature increase • Enhanced digestion of fats, oil, and grease	• Does not meet time-temperature Class A requirement • Requires extensive monitoring to obtain site-specific Class A permit • Requires pretreatment to remove *Microthrix* • Site constraint issues (requires two new 0.38 MG acid digesters and a 1.08 MG methane digester) • Requires separate gas system for acid digesters due to high sulfur levels and low BTU content in acid-phase digester gas • Requires improvements to sludge thickening system • Odor issues during cleaning of acid digester equipment for maintenance
TPAD	• Production of Class A Biosolids • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Existing facility designed for TPAD • Only requires improvements to sludge thickening system for 2030 conditions	• Does not meet time-temperature Class A requirement • Requires extensive monitoring to obtain site-specific Class A permit • Requires pretreatment to remove *Microthrix* • Higher potential for non-filamentous foaming than acid phase digestion • Prone to excessive struvite formation during thermophilic to mesophilic heat recovery • Requires preheating of raw sludge • Site constraint issues (requires two new 1.08 MG digesters) • Most of the gas produced in the thermophilic stage (poorer quality than the mesophilic stage)

Table 6-6
Non-Economic Comparison of Digestion Alternatives
First Tier Process Evaluation

Alternative	Advantages	Disadvantages
Conventional Digestion with Cambi THP	• Production of Class A Biosolids • Meets time-temperature Class A requirement • High volatile solids reduction • Successful full-scale installations in Europe • Destruction of *Microthrix* • Lower digester tankage requirements, when compared to acid-phase digestion and TPAD • Lower capacity requirements for dewatering and hauling	• Energy use/costs may increase • No full-scale installations in the US • New high solids thickening facility is required • Dark-colored side stream • Side stream treatment for nutrient removal may be required • Odor control
Conventional Digestion with Heat Drying	• Production of Class A Biosolids for 25% of the sludge flow (Metromix) • Process listed as a PFRP • Successful full-scale installations in the U.S. • Lower struvite scaling potential • Lower polymer usage than TPAD and acid phase digestion	• Requires pre-treatment to remove *Microthrix* and other foam-causing organisms • Lower volatile solids destruction and thickening/dewatering than other alternatives • Energy use/costs may increase • Site constraint issues (requires two new 1.08 MG conventional digester) • Production of Class B Biosolids for 75% of solids production • Increases Carbon Footprint by 28,500 tons per year @ 2030 flows
Conventional Digestion with En-Vessel Pasteurization	• Production of Class A Biosolids for 25% of sludge flow • Process listed as PRFP • Successful full-scale installations in the U.S. • Lower struvite scaling potential • Lower polymer usage than TPAD and acid phase digestion	• Requires pre-treatment to remove *Microthrix* and other foam-causing organisms. • Lower volatile solids destruction and thickening/dewatering than other alternatives. • Energy use/costs may increase • Site constraint issues (requires four new 1.08 MG conventional digester) • Costs associated with chemical addition and additional solids production • Production of Class B Biosolids for 75%

Table 6-6 Non-Economic Comparison of Digestion Alternatives First Tier Process Evaluation		
Alternative	**Advantages**	**Disadvantages**
		of solids production
Conventional Digestion with Batch Thermophilic Tanks	• Production of Class A Biosolids for 25% of sludge flow • Meets time-temperature Class A requirements • Lower struvite scaling potential • Lower polymer usage than TPAD and acid phase digestion	• Requires pre-treatment to remove *Microthrix* and other foam-causing organisms. • Lower volatile solids destruction and thickening/dewatering than other alternatives • Energy use/costs may increase • Site constraint issues (requires two new 1.08 MG conventional digester) • Site Constraint Issues (requires three 2-day batch tanks) • Production of Class B Biosolids for 75% of solids production

Second Tier Process Evaluations

The three process technologies that were selected for further study from tier 1 (TM-03 and Workshop No. 4) were:

- Conventional mesophilic digestion with Cambi THP pretreatment
- Multi-stage acid phase digestion (meso-thermo-thermo)
- Acid phase digestion with thermal post treatment

The candidate technologies in the second tier evaluations were subjected to detailed economic and non-economic evaluations, summarized in TM-03A. The process criteria applied to the second tier evaluations are presented in Table 6-7. For each of the technologies, process flow diagrams were developed for current and 2030 loadings, as well as site location schematics. Evaluation criteria included information developed in other technical memoranda:

- Sludge thickening requirements (TM-08)
- Digester heating requirements (TM-04)

- Digester mixing requirements (TM-04)
- Digester foaming mitigation (TM-05)
- Class A biosolids production
- Struvite mitigation (TM-06)
- Full scale installation experience

An economic evaluation, based on a 20-year present worth analysis, is summarized in Table 6-8. The non-economic comparison of alternatives in the second tier is presented in Table 6-9. From the second tier evaluations (TM-03A), the technology recommended for implementation at the NSWWTP is multi-stage acid phase digestion, with the noted advantages:

- This alternative has the lowest lifecycle costs of the three digestion alternatives examined.
- This alternative has a considerably lower capital cost than conventional digestion with Cambi THP and acid-phase digestion with thermal treatment.
- This alternative should have less operation and maintenance complexity than the other alternatives.
- This alternative can be modified to operate as acid-phase digestion with thermal treatment if future regulations eliminate Alternative 3 of the 503 regulations or if monitoring and testing become unfeasible.

Figures 6-3 and 6-4 illustrate the process schematic and preliminary site layout, respectively, for the selected alternative, multi-stage acid phase digestion.

Table 6-7 Recommended Design Criteria for Anaerobic Digestion Processes Second Tier Process Evaluation		
Digestion Process	**Design Criteria**	**Controlling Criteria**
Multi-Stage Acid-Phase		
Acid Digester (mesophilic)	VSLR 1 to 2.5 lbs VS/cfd	Maximum Month with one unit out of service
	HRT 1.5 to 3 days	Maximum Month with all units in service and annual average with one unit out of service
Methane Digester (first-stage thermophilic)	HRT $\geq$ 12 days	Maximum Month with all units in service and annual average with largest unit out of service
Methane Digester (second-stage thermophilic)	HRT $\geq$ 3 days	Maximum Month with all units in service and annual average with largest unit out of service
Methane Digester (mesophilic)	HRT $\geq$ 2 days	Maximum Month with all units in service and annual average with largest unit out of service
Acid-Phase with Thermal Post-Treatment		
Acid Digester (mesophilic)	VSLR 1 to 2.5 lbs VS/cfd	Maximum Month with one unit out of service
	HRT 1.5 to 3 days	Maximum Month with all units in service and annual average with one unit out of service
Methane Digester (mesophilic)	HRT $\geq$ 13 days	Maximum Month with all units in service and annual average with largest unit out of service
Thermal Treatment Tank	Holding Time $\geq$ 1 day (1)	Maximum Month with all units in service
Conventional with Cambi THP		
Conventional Digester (2)	VSLR < 0.37 lbs VS/cfd (3) HRT $\geq$ 15 days	Maximum Month with all units in service and annual average with largest unit out of service

Notes:

(5) Based on operating temperature of 131 deg F.

(6) Conventional digesters downstream of a Cambi THP system.

(7) Based on information provided by Cambi. Assumes a total solids concentration in the thermally hydrolyzed sludge of 10 percent with a volatile fraction of 80 percent.

Table 6-8 Economic Comparison of Digestion Alternatives Second Tier Process Evaluation				
Anaerobic Digestion Process Alternative	**Present Worth Capital Cost**	**Present Worth O&M Cost Excluding Hauling**	**Present Worth Solids Hauling Cost**	**Total Present Worth Cost**
Multi-Stage Acid-Phase Digestion	$19,365,000	$40,404,000	$22,036,000	$81,805,000
Acid-Phase Digestion with Thermal Treatment	$21,281,000	$41,092,000	$22,036,000	$84,409,000
Conventional Digestion with Cambi THP	$26,186,000	$42,500,000	$20,895,000	$89,581,000

Table 6-9 Non-Economic Comparison of Digestion Alternatives Second Tier Process Evaluation		
Digestion Alternative	**Advantages**	**Disadvantages**
Multi-Stage Acid-Phase Digestion	• Potential for production of Class A Biosolids • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Improved biogas quality in methane digesters • Decreased non-filamentous foaming potential • Gradual temperature increase • Enhanced digestion of fats, oil, and grease (FOG)	• Does not meet time-temperature Class A requirement • Requires extensive monitoring and testing to obtain site-specific Class A permit • Requires foam mitigation improvements to prevent *Microthrix* foaming problems • Site constraint issues (requires two new 0.4 MG acid digesters and a 1.08 MG methane digester) • Requires separate gas system for acid digesters due to high H_2S levels and low CH_4 content in acid digester gas • Requires new sludge thickening facility • Odor issues during cleaning of acid digester equipment for maintenance and other activities that result in acid sludge exposure to the atmosphere • Odors in digested sludge thickening facilities during summer conditions
Acid-Phase Digestion with Thermal Treatment	• Production of Class A Biosolids • Meets Time-Temperature Class A Requirement • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Improved biogas quality in methane digesters • Decreased non-filamentous foaming potential • Gradual temperature increase • Enhanced digestion of FOG	• Requires foam mitigation improvements to prevent *Microthrix* foaming problems • Site constraint issues (requires two new 0.4 MG acid digesters and a 1.08 MG methane digester) • Requires separate gas system for acid digesters due to high H_2S levels and low CH_4 content in acid digester gas • Requires new sludge thickening facility • Odor issues during cleaning of acid digester equipment for maintenance and other activities that result in acid sludge exposure to the atmosphere • Odors in digested sludge thickening facilities during summer conditions.

Table 6-9 Non-Economic Comparison of Digestion Alternatives Second Tier Process Evaluation		
Digestion Alternative	**Advantages**	**Disadvantages**
Conventional Digestion with Cambi THP	• Production of Class A Biosolids • Meets time-temperature Class A requirement • High volatile solids reduction • Successful full-scale installations in Europe • Destruction of *Microthrix* • Foam mitigation improvements are not required • Lower digester tankage requirements, when compared to acid-phase digestion • Lower capacity requirements for dewatering and hauling	• Energy use/costs may increase • No full-scale installations in the US • New high solids thickening facility is required • Dark-colored side stream • Side stream treatment for nutrient removal may be required • Odor control

Related Unit Process Evaluations

A series of technical memoranda were prepared to evaluate unit processes related to the sludge stabilization process selection described in TM-3A. These unit process evaluations are described in this section.

Digester Mixing

Digester mixing provisions were analyzed in TM-04: *Anaerobic Digestion Ancillary Systems Evaluation.* The existing west complex digesters are equipped with mechanical draft tube mixers, while the east complex digesters have confined gas mixers (see Table 6-10). Difficulties with short circuiting and severe foaming arose during the startup of the 10th Addition facilities. Four digester mixing technologies were examined as candidates to address the mixing system issues:

- Draft tube mixers
- Pump mixing
- Plunger mixing

- Gas mixing

The alternatives were subjected to a technical screening that eliminated gas mixing technologies. Mixing system alternatives were derived for the east complex digesters and proposed acid digesters, as shown in Table 6-11. No changes are recommended for the west digester draft tube mixers. An economic comparison of alternatives is presented in Table 6-12. Based on an economic and non-economic comparison, the installation of either pump or plunger mixing systems is recommended for the proposed Acid Digesters Nos. 1 and 2. The installation of draft tubes or plunger mixing systems is recommended for the proposed Digester No. 8. Based on increased foaming potential, inefficient scum reincorporation, excessive grit deposition, and short-circuiting, the replacement of the existing gas mixing systems in Digesters No. 4-7 with either draft tube or plunger mixing systems is recommended.

Table 6-10
Nine Springs WWTP
Existing Digester Mixing Systems

	East Complex Digesters (1)	East Complex Digesters (2)	West Complex Digesters (3)	Sludge Storage Tanks
Type	Confined Gas	Confined Gas	Internal Draft Tubes	Unmixed
Units per Digester	7	7	2	-
Mixing Energy, hp/1000 cf (4)	0.30	0.28	0.23	-
Turnover Rate, min (5)	34	<34 (6)	32	-

Notes:
(1) Digesters No. 4, 5, and 6.
(2) Digester No. 7.
(3) Digesters No. 1, 2, and 3.
(4) Typical Design Criteria is 0.2 to 0.3 hp per 1000 cf.
(5) Typical Design Criteria is 20 to 30 min
(6) Due to compressor modifications

Table 6-11 Recommended Mixing System Design Criteria			
	Methane Digesters No. 4 - No. 6	**Methane Digesters (No. 7 and No. 8)**	**Acid Digesters (No. 1 and No. 2)**
Alternative 1			
Type	Draft Tube Mixing	Draft Tube Mixing	Pump Mixing
Number of Units per Tank	4	4	2
Energy, hp (total)	40	40	25
Energy Input, hp/1000 cf	0.30	0.28	0.33
Total Flow, gpm	39,200	39,200	2,800 (1)
Turnover Rate, min	26	27	198
Alternative 2			
Type	Plunger Mixing	Plunger Mixing	Plunger Mixing
Number of Units per Tank	1	1	1
Energy, hp (total)	10	10	7.5

Notes:

(1) Digester heating system provides 1,400 gpm.

Table 6-12 Mixing Alternatives Economic Comparison			
	Draft Tube Mixers (1)	**Pump Mixing (2)**	**Plunger Mixing (3)**
Acid Digester			
PW Capital Cost	N/A	\$605,000	\$732,000
PW O&M Cost	N/A	\$391,000	\$331,000
Total PW Cost	N/A	\$996,000	\$1,063,000
Methane Digester			
PW Capital Cost	\$3,302,000	N/A	\$1,933,000
PW O&M Cost	\$1,421,000	N/A	\$660,000
Total PW Cost	\$4,723,000	N/A	\$2,593,000

Notes:

(1) Includes four 10 hp roof mounted mixers per digester (Digesters Nos. 4, 5, 6, 7, &8).

(2) Includes two 25 hp chopper centrifugal pumps (Acid Digesters Nos. 1 & 2).

(3) Includes one LM mixer per digester: 7.5 hp for each acid digester (Acid Digesters Nos. 1 & 2) and 10 hp for each methane digester (Digesters Nos. 4, 5, 6, 7, &8).

Digester Heating

Digester heating provisions were analyzed in TM-04. The existing digester sludge heating system at the NSWWTP consists of seven spiral heat exchangers (HEX 1-7) and five tube-and-shell heat exchangers (HEX 8-12). Each spiral heat exchanger and associated sludge circulation pump is normally dedicated to a single digester. The tube-and-shell heat exchangers are used for heat recovery (HEX 8 and 9) and raw sludge preheating (HEX 10). The MMSD Staff reported leaks and ragging problems in the raw sludge preheating unit (HEX 10) and struvite/vivianite scaling in a heat recovery unit (HEX 8). Table 6-13 shows the heating capacity for the existing heat exchanger units.

Table 6-13
Nine Springs WWTP
Existing Digester Heating System

	Digester 7	Digesters 4-6	Digesters 1-3	Raw Sludge
ID	HEX 7	HEX 4-6	HEX 1-3	HEX 8-12
Type	Spiral	Spiral	Spiral	Tube and Shell
Units	1	3	3	3/2
Unit Capacity, MMBTU/hr (1)	1.65 (2)	1.65 (2)	1.53	5.4/ 6.1

Notes:
(1) Heating capacity for mesophilic operation
(2) Thermophilic operation heating capacity of 0.5 MMBTU/hr

Currently, heat is supplied to the anaerobic digesters from two engine generators and an engine blower. With all units operating at a 1,500 kW load, approximately 6.0 MMBTU/hr of heating energy is recovered from the three engines. Six hot water boilers can provide a total plant heat supply of 33.3 MMBTU/hr. The hot water generated by the engines and boilers is used to provide anaerobic process heat as well as satisfying building heating / cooling via a plant-wide hot water circulation system. To accommodate acid-phase digestion, the existing heating facilities must meet the total heat requirements with one large boiler unit in standby at all time. The NSWWTP has sufficient heating capacity and redundancy to meet the design criteria at 2030 maximum month loadings.

The sludge heating requirements for the proposed acid phase digestion system were estimated for 2030 maximum month conditions, summarized in Table 6-14. The existing heat exchangers for Digesters No. 4, 5, 6 and 7 have adequate capacity to operate at mesophilic temperatures in acid-phase digestion mode at max month 2030 flows. The existing heat exchangers for Digesters Nos. 4-7 were not designed for thermophilic operation and consequently do not have sufficient capacity to meet the thermophilic heating demands. Under multi-phase acid-phase digestion, the use of the existing spiral heat exchangers with supplemental heating from the existing shell-and-tube heat exchangers (HEX 11 or HEX 12) is recommended.

For the acid-phase digestion with batch thermal treatment, the existing heat exchangers for Digesters No. 1, 2, and 3 have adequate capacity to heat thermophilic sludge (mesophilic-thermophilic operation) but do not have sufficient capacity to heat mesophilic sludge (mesophilic-mesophilic operation). If the methane digesters are operated at mesophilic temperatures, a new heating system is recommended for the batch thermal tanks (Digesters No. 1, 2, and 3).

Table 6-14
Estimated Heat Requirements for Acid Phase Digestion

	Target Temperature	Units	Summer Requirement, MMBTU/hr/Unit	Winter Requirement, MMBTU/hr/Unit
Raw Sludge	105 deg F	-	4.3	7.6
Acid Digester (1)	Mesophilic	2	0.74	0.76
Methane Digester (2,3)	Thermophilic	5	1.20	1.25
Methane Digester (4)	Thermophilic	3	Unheated	Unheated
Sludge Storage (5)	NA	2	Unheated	Unheated
Batch Thermal				
Methane Digester (2)	Mesophilic	5	0.09	0.13
Thermal Tank (4)	131 deg F	3	5.3	6.2
Sludge Storage (5)	NA	2	Unheated	Unheated

Notes:

(1) Proposed 0.4 MG Acid Digesters No. 1 and No. 2.

(2) Existing digesters No. 4 - No. 7 and Proposed digester No. 8.

(3) Will require supplemental heating from existing tube and shell heat exchangers

(4) Existing digesters No. 1 - No. 3.

(5) Existing sludge storage tanks No. 1 and No. 2.

Direct steam injection and water to sludge heat exchangers (spiral, shell-and-tube, and shell-and-tube with static mixers) were evaluated for the new acid digesters Nos. 1 and 2 and new thermophilic Digester No. 8. Table 6-15 presents the design criteria for the proposed digester heating systems and Table 6-16 provides present worth cost estimates. The use of an existing shell-and-tube heat exchanger (HEX 11 or HEX 12) to heat Digesters Nos. 4-7 during thermophilic operation is recommended. The installation of one new spiral heat exchanger is recommended for the proposed methane Digester No. 8. The installation of a new direct steam injection heating system is recommended for the proposed Acid Digesters No. 1 and No. 2. Under acid phase digestion with thermal treatment mode and mesophilic operation of Digesters No. 4 through No. 8, the installation of direct steam injectors to preheat the thermal tank feed is recommended.

Under both acid-phase digestion alternatives, the existing tube and shell heat exchangers (HEX 8 and HEX 9) could be used for heat recovery after the struvite scaling problems are solved (MMSD Staff reported struvite scaling in heat recovery exchanger during operation in the acid phase mode). Advantages of heat recovery include potential energy savings and lower polymer usage due to the cooling of the digested sludge prior to thickening. Disadvantages of heat recovery include low heat recovery efficiency due to poor heat transfer capacity in sludge and potential struvite/vivianite scaling in the heat exchangers due to sudden decreases in temperature.

Table 6-15 Preliminary Design Criteria - Digester Sludge Heating System		
Parameter	**Acid Digesters No. 1 and No. 2 (1)**	**Digester No. 8 (2)**
Heat Exchangers		
Total Units	2	1
Type	Direct Steam Injection	Spiral Heat Exchanger
Unit Capacity, MMBTU/hr	2 @ 6.80	1 @ 1.3 (3)
Sludge Recirculation Pumps		
Total Units	2	2
Units in service	1	1
Capacity per pump, gpm	150	300

Notes:
(1) New Acid Digesters No. 1 and 2.
(2) New Digester No. 8.
(3) Thermophilic operation

Table 6-16 Present Worth Cost of Direct Steam Injection		
	Multi-Phase Digestion (1)	**Acid Phase Digestion with Thermal Treatment (2)**
PW Capital Cost	$1,453,000	$2,045,000
PW O&M Cost	$6,841,000	$6,998,000
Total Present Worth Cost	$8,294,000	$9,043,000

Notes:
(1) Includes two direct steam injectors and two 10 MMBTU/hr steam boilers.
(2) Includes four direct steam injectors and two 14 MMBTU/hr steam boilers.

Digester Foaming

Digester foaming mitigation alternatives were analyzed in TM-05: *Foaming Mitigation Alternatives.* Severe digester foaming incidents occurred during operation of 10th Addition thermophilic digestion facilities. Based on the biological nutrient removal (BNR) operation at the NSWWTP, reported winter foaming events, and previous microscopic analyses, it is likely that the filamentous organisms are *Microthrix*, a slow-growing lipid-degrading filamentous bacterium that thrives under low dissolved oxygen (DO) conditions. While *Nocardia* foaming is prevalent in conventional activated sludge plants, *Microthrix* foaming is more prevalent in BNR plants. *Microthrix* filament population can predominate in aeration basins during cold weather months due to its ability to grow at low temperatures. The WAS fed to the digesters carries higher levels of filaments that lead to foaming in the digesters.

Operational changes in the anaerobic digesters are not expected to destroy *Microthrix* filaments because these organisms can survive for many months under anaerobic conditions and can grow at a wide range of pH levels. In fact, the Nine Springs WWTP has experienced digester foaming under different modes of operation, including temperature phased anaerobic digestion (TPAD), acid-phase digestion, and conventional digestion. Strategies to mitigate foaming at the Nine Springs WWTP include limiting *Microthrix* growth in the aeration basins, destroying the *Microthrix* cells prior to digestion, and modifying the digester mixing system.

Several approaches to limiting the growth of *Microthrix* in the aeration basins were considered, including lowering solids retention time, increasing dissolved oxygen concentration, and application of polyaluminum chloride (PAX-14). The use of any of these strategies would most likely result in a reduction in *Microthrix* in the aeration basins, but not an elimination of filaments.

Pretreatment of WAS to destroy *Microthrix* filaments prior to digestion was considered to be a more direct strategy for mitigating foaming in the digesters. Several technologies were included in a non-economic screening that resulted in the selection of the following for detailed consideration:

- Thermal hydrolyis
- Direct steam injection
- Electric-pulsing
- Crown sludge disintegration

Modifications to digester operations to mitigate foam were considered as well, including changing gas mixing to mechanical mixing, installing foam separators on the gas collection domes on top of the digesters, and application of anti-foaming chemicals. None of the digester operations measures would eliminate digester foaming, but they would reduce the impact of foaming on digester / gas system operations.

An economic comparison of foam mitigation alternatives is presented in Table 6-17. A noneconomic comparison of the foam mitigation approaches is presented in Table 6-18. The recommended approach to foam mitigation includes a combination of foam suppression methods, WAS heating via direct steam injection, and digester mixing changes.

Table 6-17
Economic Comparison of Foam Mitigation Alternatives

Foam Mitigation Process Alternative	Present Worth Capital Cost (1)	Present Worth O&M Cost (1)	Total Present Worth Cost (1)
Foam Suppression Methods (2)	$1,315,000	$714,000	$2,029,000
Thermal Hydrolysis (Cambi) (3)	$12,447,000	$12,102,000	$24,549,000
Direct Steam Injection (4)	$1,453,000	$6,841,000	$8,294,000
Electric-Pulsing (OpenCEL)	$14,726,000	$5,332,000	$20,058,000
Sludge Disintegration (Crown)	$5,478,000	$1,559,000	$7,037,000

Notes:

(1) Excludes costs common to all alternatives (i.e., thickening, digestion, biosolids hauling and disposal)

(2) Includes digester dome improvements for Digesters 1 through 8. Based on addition of Tramfloc 1147.

(3) Based on a two-reactor Cambi THP system. Includes cost of feed sludge thickening.

(4) Based on a Hydroheater system and two 400 HP steam generators (one duty and one standby).

Table 6-18
Foam Mitigation Alternatives Summary

Foam Mitigation Alternative	Limits *Microthrix* Growth	Destroys *Microthrix* Cells	Compatible with MMSD Operation	Increased Biogas Production	Successful Full-scale installations	Additional Operational Considerations
Low Solids Retention Time in Activated Sludge Process	X				NA	Not compatible with BNR process
Uniform Dissolved Oxygen Level in Aeration Basins	X		X		NA	Used during cold weather operation. Increases energy costs.
Control Lipid Loading to Activated Sludge Process	X		X	X	X	From direct grease addition to anaerobic digesters.
Addition of Sodium Hypochlorite	X	X			X	Used during foaming events. Impact on chloride permit.
Addition of Hydrogen Peroxide	X	X	X		X	Used during foaming events.
Addition of Polyaluminium Chloride (PAX-14)	X				X	Used during foaming events. Impact chloride permit.
Addition of Anti-foaming Chemicals to Digesters			X		X	Used during digester foaming events.
Thermal Hydrolysis		X	X	X	X	Energy intensive process.
Direct Steam Injection		?	X	X	X	Not proven for *Microthrix*. Energy intensive process
Pasteurization			X		X	Energy intensive process.
Electric-Pulsing		X	X	X	X	New technology with only one installation.
Crown Sludge Disintegration		X	X	X	X	Energy intensive process.
MicroSludge		X	X	X		Energy intensive process.
Ultrasonic Cavitation		X		X	X	Energy intensive process. Unsuccessful U.S. trials.

Sludge Thickening

Sludge thickening alternatives were analyzed in TM-08: *Sludge Thickening Systems Evaluation.* Implementation of an advanced digestion system will require higher solids concentrations than are currently achieved with the existing plant processes. Existing sludge thickening processes are described in Table 6-19. One of the gravity belt thickeners (GBT) serves as a backup WAS thickener.

Analysis of the existing sludge thickening systems showed the following:

- The existing primary sludge gravity thickeners are adequate for loadings to 2030
- The DAF thickeners cannot produce the required solids concentration for thickened WAS and should be replaced with new technology
- The digested sludge GBTs have sufficient capacity for 2030 with both units in service, but inadequate redundancy suggests that one GBT should be replaced initially due to its age and condition, and a third GBT should be installed in 2020 for the required redundancy.

Table 6-19
Nine Springs WWTP
Existing Sludge Thickening Units

	Gravity Thickeners	Dissolved Air Flotation (DAF) Thickeners	Gravity Belt Thickeners (GBT)
Service	Primary Sludge	WAS	Digested Sludge
Number of Units	2	2	2
Diameter, ft	55	55	NA
Total Surface Area, sf	4,752	4,752	NA
Belt Width, m	NA	NA	2
Hydraulic Capacity per Unit, gpm	990	1,540	250 (1)
Solids Capacity per Unit, lbs/hr	2,475	1,730	2,800 (1)
Solids Capture Efficiency, % (2)	98.3	92.0	97.4
Thickened Sludge Solids, % (2)	5.0	4.2	5.2

Notes:
(1) Capacity for digested sludge thickening
(2) Based on 2007-2008 operating data

Three technologies were evaluated for the new WAS thickening facilities. Tables 6-20 and 6-21 present the economic and non-economic comparisons, respectively. The costs include the required polymer system and sludge pumping equipment. Gravity belt or rotary drum thickeners are recommended for the new WAS thickening facilities.

Table 6-20
Economic Comparison of WAS Thickening Alternatives

	Gravity Belt Thickeners	Rotary Drum Thickeners	Centrifuges
Present Worth Capital Cost	$3,414,000	$3,994,000	$6,287,000
Present Worth O&M Cost	$4,831,000	$4,935,000	$4,428,000
Total Present Worth Cost for Alternative	$8,245,000	$8,929,000	$10,715,000

Struvite and Vivianite Scale Mitigation

Alternatives to address struvite and vivianite scale formation were analyzed in TM-06: *Struvite and Chemical Precipitation Evaluation.* The NSWWTP has a long history of experience with struvite scale formation in its solids handling system. The problems with struvite scale formation became much more pronounced while operating the 10th Addition TPAD system, which was plagued by vivianite formation as well.

The NSWWTP operates with an Enhanced Biological Phosphorus Removal (EBPR) process, where soluble phosphorus is removed from the bulk liquid and stored as intracellular polyphosphate in phosphorus accumulating organisms (PAOs). Waste activated sludge (WAS) from an EBPR process contains high phosphorus concentrations that are further increased after sludge thickening. Secondary phosphorus release occurs when the sludge is fed to an anaerobic digester. Formation of struvite is a common problem in anaerobic digesters and the downstream dewatering equipment. Struvite crystals create scaling in pipelines, walls, and process equipment, which results in reduced capacity as well as operation and maintenance problems.

Table 6-21 WAS Thickening Alternative Comparison		
	Advantages	**Disadvantages**
Gravity Belt Thickener	• MMSD Staff has experience with this technology • Lower energy consumption than centrifuges	• Requires more wash water than RDTs during operation and for cleaning • Normally operated during staffed hours only • High polymer consumption • Lower thickened solids concentration than other alternatives • Primary/secondary scum blinds the belt
Rotary Drum Thickener	• Lower energy consumption than centrifuges • Lower recycle water flows than GBTs. • Odor control easily installed because unit is completely enclosed. • Can handle primary sludge • Can be operated 24-hrs per day with remote monitoring.	• Primary/secondary scum cannot be fed to drum.
Centrifuge	• MMSD Staff has experience with this technology • Odor control easily installed because unit is completely enclosed. • Lower polymer consumption than other alternatives	• Higher energy consumption than other alternatives • Higher operation complexity than other alternatives • Higher polymer usage than other alternatives • Grit in primary sludge can result in abrasive damage to the equipment

The NSWWTP has experienced struvite scaling in draft tube mixers, heat exchangers, heat recirculation pumps, and sludge transfer lines. A considerable fraction of the phosphate removed in the EBPR process is recycled back to the EBPR system when gravity belt thickening (GBT) filtrate is recycled to the headworks. Sidestream treatment of the GBT filtrate is employed to reduce the phosphorus recycle. The sidestream treatment system is comprised of a ferric chloride storage and feed facility, located adjacent to the GBT Thickening Building. The system includes a 12,000-gallon storage tank and three feed pumps (5-280 gph ea.) that can dose three locations:

- GBT filtrate return to headworks
- Raw sludge feed to the digesters
- Digested sludge feed to the GBTs

Generally, the District employs treatment of GBT filtrate, feeding iron in a mole ratio of 1.5 times the P content in the filtrate. Historical records of ferric chloride consumption are shown in Table 6-22. Variability in the consumption of iron increased significantly after 10th Addition as attempts were made to deal with struvite and vivianite scaling that occurred with thermophilic digestion.

Table 6-22
Nine Springs WWTP
Historic Ferric Chloride Usage

Year	$FeCl_3$ Solution Feed, gpd	Daily Chemical Use, dry lbs $FeCl_3$/day	Daily Iron Consumption, lbs Fe/day
2006	403	1652	575
2007	303	1241	432
2008	786	3226	1122
2009	631	2588	900

Since struvite and vivianite are phosphate-containing precipitates, strategies to tie up the phosphate chemically were investigated. Table 6-23 a comparison of the various chemical addition options. The NSWWTP has been utilizing ferric chloride addition for sidestream treatment and struvite mitigation since the implementation of EBPR in the 9th Addition in 1996-97. Given the successful history at the NSWWTP, ferric chloride addition was chosen for further analysis for scale mitigation.

Iron salt addition was considered for three locations:

- Sludge pretreatment upstream of digestion
- Direct dosing of the digesters
- Sludge post treatment downstream of digestion.

Table 6-23
Preliminary Design Data for Chemical Addition

	Poly-Gone Lines	Ferric Chloride $FeCl_3$	Ferrous Chloride $FeCl_2$	Alum $Al_2(SO4)_3 \cdot 14H2O$	Lime $Ca(OH)_2$
Dosage Rate	1 gal PGL per 20,000 gal sludge	2.7 lbs Fe per lbs P	2.7 lbs Fe per lbs P	2.2 lbs Al per lbs P	1.5 x Total Alkalinity
Daily Usage, dry chemical ppd	-	10,000 (1,2)	7,800 (1,2)	30,800(1,2)	8,400 (3)
Daily Usage, gpd	15 (4)	2,400 (5)	2,900 (6)	5,700 (7)	-
Unit Price	$23.26/gal	$811/dry ton $FeCl_3$	$960/dry ton $FeCl_2$	$660/dry ton $Al_2(SO4)_3 \cdot 14H2O$	$260/dry ton $Ca(OH)_2$
Annual Cost	$131,200	$1,480,000	$1,367,000	$3,710,000	$398,600

Notes:
(1) Based on 2030 average annual total phosphorus loadings of 2,900 ppd to the NSWWTP.
(2) Assumes 44 percent of phosphorus loading to the digesters is in soluble form.
(3) Assumes a combined recycle stream average flow of 1.9 MG with an alkalinity of 350 mg/L.
(4) Based on 2030 average annual digester feed of 0.309 mgd to the anaerobic digesters.
(5) Based on ferric chloride solution strength of 37 percent, SG=1.35.
(6) Based on ferrous chloride solution strength of 25 percent, SG=1.28.
(7) Based on alum solution strength of 48.5 percent, SG=1.335.

Struvite harvesting was a different approach that was investigated as a scale mitigation measure. Struvite harvesting technologies use up-flow fluidized bed reactors to precipitate struvite pellets and extract phosphorus and ammonia from the liquid stream. The struvite pellets are collected and used as fertilizer. The process relies on the addition of magnesium and alkalinity to achieve phosphorus removal rates of up to 90% from the sidestream flows. Two scenarios that differed on the location of the struvite-harvesting reactor were evaluated. Table 6-24 presents the year 2030 design parameters. In the first scenario (Ostara System 1), the struvite-harvesting reactors receive dewatering filtrate downstream of digestion. In the second scenario (Ostara System 2), the struvite-harvesting reactors receive thickening and dewatering filtrate both upstream and downstream of digestion. Primary sludge and WAS are blended prior to thickening to promote secondary phosphorus release. The costs of chemical addition (magnesium and alkalinity) would be offset by the revenue from fertilizer sales. Significant positive effects of struvite harvesting would be a decrease in the phosphorus content of the Metrogro and Metromix products sent to land application and an increase in process stability due to scale mitigation in process equipment and piping. In addition, it is anticipated that the struvite harvesting process would result in a reduction of ferric chloride feed that is currently used at the plant for sidestream treatment.

Table 6-24 Design Data (2030) for the Ostara Struvite-Harvesting System (1)		
Parameter	**Upstream of Digestion (Ostara System 2)**	**Downstream of Digestion (Ostara System 1)**
Feed Flow Rate, gpd	1,250,000	264,000
Feed Ammonia Concentration, mg-N/L	224	1,057
Feed Ortho-Phosphate Concentration, mg-P/L	163	181
Treatment Capacity per Reactor, gpd	120,100	106,800
Proposed Number of Pearl 500 Reactors, units	11	3
Effluent Ortho-Phosphate, mg-P/L	21	17
Ortho-phosphate Removal Efficiency	87%	91%
Phosphorus Removed, ppd	1,481	361
Effluent Ammonia, mg-N/L	160	983
Ammonia Removal	29%	7%
Mass of Nitrogen Removed, ppf	670	163
Struvite Production Rate, tons/year	2,141	522
Building Footprint, sqf	12,900	4,500
Electricity Consumption, kWhr/day	3,273	777
Magnesium Chloride, tons/year	1,375-1,450	430-460

Note:
(1) Ostara Preliminary Proposal for Nutrient Recovery System at the NSWWTP, 4/23/2009

Economic and non-economic comparisons of the struvite mitigation alternatives are presented in Tables 6-25 and 6-26, respectively. The cost to install and own a phosphorus recovery (struvite harvesting) system is significant. The operating costs and removal rates are still not industry standard. There are two alternatives to provide a phosphorus recovery system at the NSWWTP. One is to establish a leasing agreement with a phosphorus recovery system supplier to provide a turnkey system with a 5-year contract and 5-year extension. The second would be to purchase the equipment outright and provide for strict performance guaranties in the form of deductions from a retainer to ensure process costs. The chemical costs of struvite harvesting are offset by fertilizer sales that are subject to market conditions. Potential savings from reduction in ferric chloride feed are not included in Table 6-25. Given that phosphorus is a finite resource derived from mining, the long-term outlook for phosphorus is that it will continue to grow in value. Future environmental regulations limiting the land application of phosphorus are anticipated, which would have a serious impact on the District's Metrogro program. The District intends to implement struvite harvesting as a long term sustainable practice to manage phosphorus.

Table 6-25
Economic Comparison of Struvite Mitigation Alternatives

Alternative	Present Worth Capital Cost	Present Worth O&M Cost	Total Present Worth Cost
Preventive maintenance of process piping and equipment (1)	-	$1,300,000	$1,300,000
Poly-Gone Lines (5)	$79,000	$1,786,000	$1,865,000
Iron Salt Addition Upstream of Digesters	$845,000	$17,962,000	$18,807,000
Iron Salt Addition to Digesters	$236,000	$17,651,000	$17,887,000
Struvite Harvesting Upstream of Digestion(2)	$19,923,000	$2,815,000(4)	$22,738,000
Struvite Harvesting Downstream of Digestion(3)	$9,021,000	$1,624,000(4)	$10,645,000

Notes:

(1) Based on information provided by the MMSD for costs related to pipe cleaning experience during 10th Addition TPAD operations.

(2) Based on Ostara proposal, System 2 costs

(3) Based on Ostara proposal, System 1 costs

(4) Includes credit for revenue share of fertilizer sales; excludes savings from reduction in ferric chloride feed

(5)The effectiveness of application of Poly-Gone lines is not known for struvite mitigation at the NSWWTP

Table 6-26 Struvite Mitigation Alternatives Summary							
Alternative	**Reduces P loading to main treatment**	**Mitigation of Digester Struvite**	**Low operational complexity**	**Reduction in P content of Metrgro**	**Phosphorus Recovery**	**Proven Technology**	**Additional Operational Considerations**
Poly-Gone Lines	X	X	X			X	Patented chemical. Unknown impact on effluent Total P.
Iron Salt Addition Upstream of Digestion	X	X	X			X	Impact on effluent chloride permit.
Iron Salt Addition to Digesters	X	X	X			X	Impact on effluent chloride permit. Vivianite formation. Hydrogen sulfide removal.
Struvite Harvesting Upstream of Digestion	X	X		X	X		Sensitive to wastewater chemical characteristics
Struvite Harvesting Downstream of Digestion	X			X	X		Sensitive to wastewater chemical characteristics

Grease Receiving Facility

The potential impact of grease addition to the operations at NSWWTP was evaluated in TM-07: *Grease Receiving Facility.* The MMSD has received septage and grease at the NSWWTP since 1986. Haulers truck septage and grease trap contents to the facility and discharge them to the screening influent channel at the headworks. Addition of septage and grease to the headworks has often caused maintenance and operational problems due to rapid blinding of the fine screens. The NSWWTP also receives high strength wastes, such as ice cream waste and digested animal tissues. These wastes are trucked to the facility, discharged to the whey wells, and pumped directly to the anaerobic digesters.

Grease collected from food service establishments is readily biodegradable. The direct addition of grease to the anaerobic digesters for co-digestion with primary sludge and WAS results in increased biogas production and increased volatile solids reduction (VSR). Reducing the amount of grease in the plant influent reduces the grease loading to the liquid treatment train and consequently results in less blinding of the fine screens at the headworks, less scum pumping volumes, decreased organic loadings to the secondary treatment, and less substrate availability for *Microthrix*. Adequate design and operation are critical to prevent clogging of the sludge piping, digester foaming, and the formation of a persistent scum layer.

Table 6-27 presents a summary of the hauling volumes and the composition of the high strength wastes hauled to the NSWWTP in 2008. Based on the reported grease trap waste characteristics, co-digestion of these materials in the NSWWTP digestion facility can provide high biochemical oxygen demand (BOD) loadings without considerably increasing the ammonia and phosphorus concentrations in the digesters. The ice cream and animal tissue wastes are currently received in the existing whey wells and fed directly to the digesters.

Table 6-27
Nine Springs WWTP
High Strength Waste Average Data

Parameter	Grease Trap Content (1)	Ice Cream Waste (2)	Animal Tissue Waste (3)
Hauling Frequency	4-5 days/week	1 day per week	1 day per month
Volume, gal per hauling day	2,000 (4)	3,500	6,000
TS, %	5.2	30.6	18.4
VS, %	NA	87.8	63.0
BOD, mg/L	32,200	135,900	88,200
TKN, mg/L	1,400	4,300	12,600
TP, mg/L	120	830	630

Notes:
(1) Based on 2008 average grease-hauling data.
(2) Based on 2002 Schoeps waste data.
(3) Based on 2004 Wisconsin Veterinary Diagnostic Laboratory waste data.
(4) Annual volume of 455,000 gallons averaged over 215 days.

An evaluation of digester capacity concluded that the anaerobic digesters have adequate capacity to receive all the grease trap waste that is currently hauled to the facility. Grease co-digestion can increase the digester gas production, reducing the dependence on outside sources of energy and helping to offset energy costs. Table 6-28 shows the estimated increase in digester gas production from the co-digestion of grease at the NSWWTP. The co-digestion of the grease currently hauled to the NSWWTP can result in a digester gas production increase of approximately 1%. The net increase may be lower because a fraction of the grease trap waste that is currently dumped at the headworks is collected as scum and added to the digesters. If additional high strength organic waste is added to the digesters, the anaerobic facility could generate up to 152,000 cubic feet per day of additional digester gas, which represents 13% of the projected 2030 digester gas production.

Table 6-28 Biogas Production Estimates		
Parameter	**Current Conditions (1)**	**2030 Conditions**
Digester Volatile Solids Loading, ppd	80,800	117,400 (2)
Volatile Solids Reduced, ppd	52,500	76,300 (3)
Digester Gas Production, cfd	763,800	1,106,000 (4)
Average Grease Trap Loading, ppd	540 (5)	9,900 (6)
Additional Volatile Solids Reduced, ppd (7)	410	7,600
Additional Digester Gas Production, cfd (8)	8,200	152,000

Notes:
(1) Based on NSWWTP process and operations data for the period of 05/2007 to 05/2008
(2) Based on the projected 2030 values presented in TM No. 1.
(3) Based on a volatile solids concentration of 76 percent and a volatile solids reduction of 65 percent.
(4) Based on the 2007-2008 average gas production to VSR ratio of 14.5 cubic feet of gas per pound reduced.
(5) Based on the 2008 annual grease hauling volume averaged over 365 days.
(6) Assumes grease loading at maximum capacity.
(7) Assumes a volatile solids concentration of 90 percent and a volatile solids reduction of 85 percent.
(8) Based on 20 cubic feet of digester gas per pound of volatile solids reduced.

Based on the grease-hauling frequency and volumes, the use of the existing 20,000-gallon whey wells is recommended due to adequate capacity and lower construction costs. The grease receiving system will include the following features:

- Truck unloading pump with grinder / screening
- Holding tank mixing
- Odor control
- Connection to heated digester recirculation
- Connection to acid phase digester feed

The total project costs for the conversion of the whey wells to a grease receiving station are estimated to be $450,000.

Biogas Utilization

The biogas utilization system at the NSWWTP was the subject of an evaluation summarized in TM-09: *Digester Gas Utilization.* The implementation of the proposed advanced digestion process will result in increased digester gas production. Maximizing the potential energy cost offsets requires that the capacity of the existing gas utilization facilities be evaluated.

Table 6-29 presents a summary of the gas and electricity usage at the NSWWTP, while Table 6-30 presents current and projected biogas production data. Digester gas is treated in a packaged plant system to remove moisture, siloxanes, and H_2S to prevent fouling of the cogeneration equipment. The gas treatment system includes iron sponge filters for H_2S removal, a gas chiller for moisture removal, and SAG system (patented media filters) for siloxanes removal. The packaged plant has a capacity of 800 cfm (1,152,000 cubic feet per day), which is adequate to treat the projected 2030 maximum month digester gas production.

Table 6-29 Nine Springs WWTP *Current Energy Consumption*			
	Average	**Maximum**	**Minimum**
Gas Usage (1)			
Hot Water Boiler Usage, MMBTU/month	4,400	7,000	1,700
Cogeneration Usage, MMBTU/month	4,900	8,200	2,600
Total Gas Requirements, MMBTU/month	9,300	12,300	7,100
Purchased Natural Gas, MMBTU/month	1,700	4,400	0
Electricity Demand			
Daily Purchased Electricity Demand, kWh (2)	61,000	89,500	38,500
Daily Cogeneration Output, kWh (1)	32,100	34,500	8,000
Total Daily Demand, kWh (1)	93,100	124,000	46,500
Purchased Electricity On-Peak Demand, kW (2)	3,300	4,300	2,600
Purchased Electricity Off-Peak Demand, kW (2)	3,400	4,100	2,800

Notes:

(1) Based on NSWWTP historic data during 2006-2007.

(2) Based on 50-Year Master Plan purchased electrical consumption during 2001-2007.

Table 6-30 Nine Springs WWTP *Digester Gas Production*		
	Current (1)	**2030 Projection**
Digester Solids Annual Average Loading, ppd	106,300	154,500 (2)
Volatile Solids Reduction, ppd	52,500	76,300 (3)
Digester Gas Production, cfd	763,800	1,106,700 (4)
Gas Production to VSR Ratio, cf/lbs	14.5	14.5
Energy Production, MMBTU/hr (5)	16.7	24.1

Note:

(1) Based on NSWWTP process and operations data for the period of 05/2007 to 05/2008.

(2) Based on 2030 projected values presented in TM No. 1.

(3) Based on 2007-2008 average volatile solids concentration of 76 percent in the digester feed and volatile solids reduction of 65 percent.

(4) Based on 2007-2008 gas production to VSR ratio

(5) Based on 524 BTU per cubic foot of digester gas.

Low-pressure gas storage provides a constant gas supply to the cogeneration facilities and maximizes energy production during peak utilization periods. Digester gas is stored during periods when production exceeds utilization, minimizing the amount of gas sent to the flares. During periods where digester gas production does not meet the minimum requirements of the cogeneration facility, stored gas can be used to continue operating at maximum levels. Gas storage at NSWWTP is provided inside two 70-ft diameter sludge storage tanks with gasholder covers and a combined storage capacity of 64,400 cubic feet (at 9.2 inches water column). The existing digester gas storage has adequate capacity for the projected 2030 gas production with approximately 84 minutes of storage, which is above the minimum recommended for cogeneration facilities (30 min). The gas holder covers were installed in the 1st Addition in 1934, so they have been in service for 75 years, well beyond their 50-year design life. These covers were rehabilitated in the 8th Addition, 17 years ago. Given their age and condition, it is recommended that replacement of the existing gas holders be considered.

Digester gas produced at the NSWWTP is currently used to fuel two (2) engine-driven generators, one (1) engine-driven blower, and six hot water boilers. The heat generated in the engines is recovered and used to maintain the digester temperatures. Surplus digester gas is burned in a candlestick flare. Table 6-31 presents a summary of the existing digester gas utilization facilities.

Table 6-31
Nine Springs WWTP
Existing Digester Gas Utilization Facilities

	Reciprocating Engines	Engine-Driven Blower	Hot Water Boilers
No. Units	2	1	6
Electrical Capacity per Unit, kW	475	550	-
Heating Capacity per Unit, MMBTU/hr	1.85	2.00	4.3, 6.8 (1)
Power Generation Efficiency, %	28	30	-
Maximum Gas Utilization (Combined), cfd (2,3)	527,600	247,300	1,402,000
Average Gas Utilization (Combined), cfd (2,4)	370,400	168,900	177,600

Notes:
(1) Three 4.3 MMBTU/hr units (Central Loop) and three 6.8 MMBTU/hr units (East Loop).
(2) Assumes 524 BTU per cubic foot of digester gas.
(3) Based on nominal electrical capacity.
(4) Based on NSWWTP 1992-2008 data.

A simplified evaluation of the existing cogeneration capacity and projected gas production is presented in Table 6-32. Based on the projected 2030 digester gas production, the digester and building heating requirements, and the capacity of the existing cogeneration units, the installation of additional cogeneration capacity is not recommended.

Table 6-32
Digester Gas Utilization

	Current Conditions		2030 Conditions	
	Winter	Summer	Winter	Summer
Digester Gas Production, MMBTU/hr	16.7 (1)	16.7 (1)	24.1 (1,2)	24.1 (1,2)
Heating Requirements, MMBTU/hr				
Digester Heating Requirements (3)	8.5 (4)	6.1 (4)	14.0 (2,4)	10.3 (2,4)
Building Heating Requirements (5)	7.1	2.3	9.1(6)	2.3
Total Heating Requirements	15.6	8.4	23.1	12.6
Engine-Driven Blower				
Digester Gas Usage, MMBTU/hr	3.5	3.5	4.4	4.4
Recovered Heat, MMBTU/hr (7)	1.2	1.2	1.5	1.5
Engine Generators (8)				
Available Gas, MMBTU/hr (9)	(1.2)	9.0	(1.9)	12.5
Recovered Heat, MMBTU/hr (7)	0	3.0	0	3.9

Note:
(1) Includes existing Digesters No. 1-6.
(2) Includes proposed Digester No. 8.
(3) Based on annual average solids loading.
(4) Includes existing Digesters No. 1-7.
(5) Based on 10th Addition Predesign Report
(6) Based on a heating demand of 2.0 MMBTU/hr for the proposed digester control and thickening buildings.
(7) Assumes 34 percent of the fuel energy is recovered as heat.
(8) Existing engine generators No. 1 and No. 2 with a total capacity of 11.5 MMBTU/hr
(9) Available gas for cogeneration = Gas produced - Heating requirements - Blower usage + Recovered heat

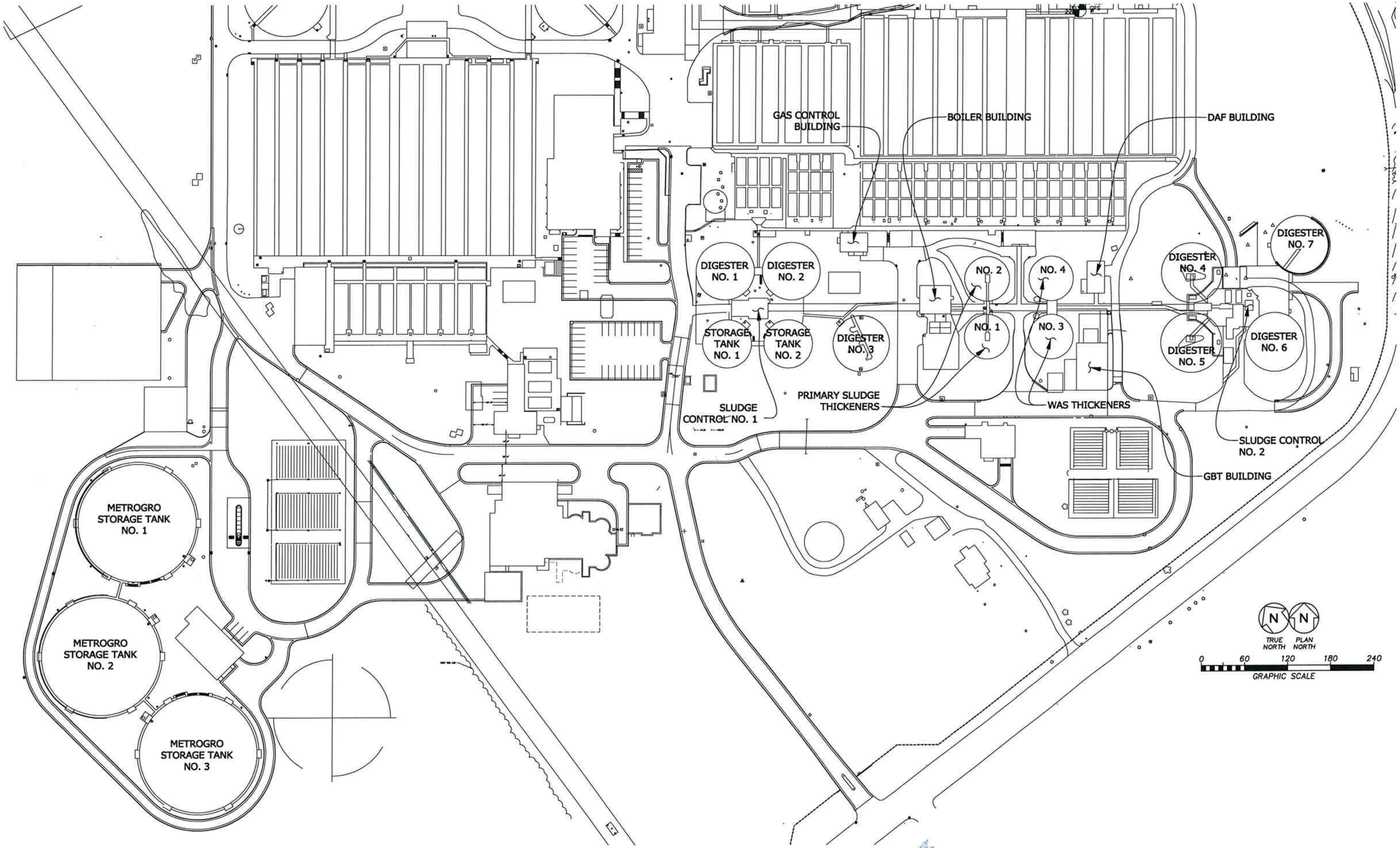

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FIGURE 6-2
NSWWTP SOLIDS HANDLING FACILITIES SITE PLAN
Madison Metropolitan Sewage District

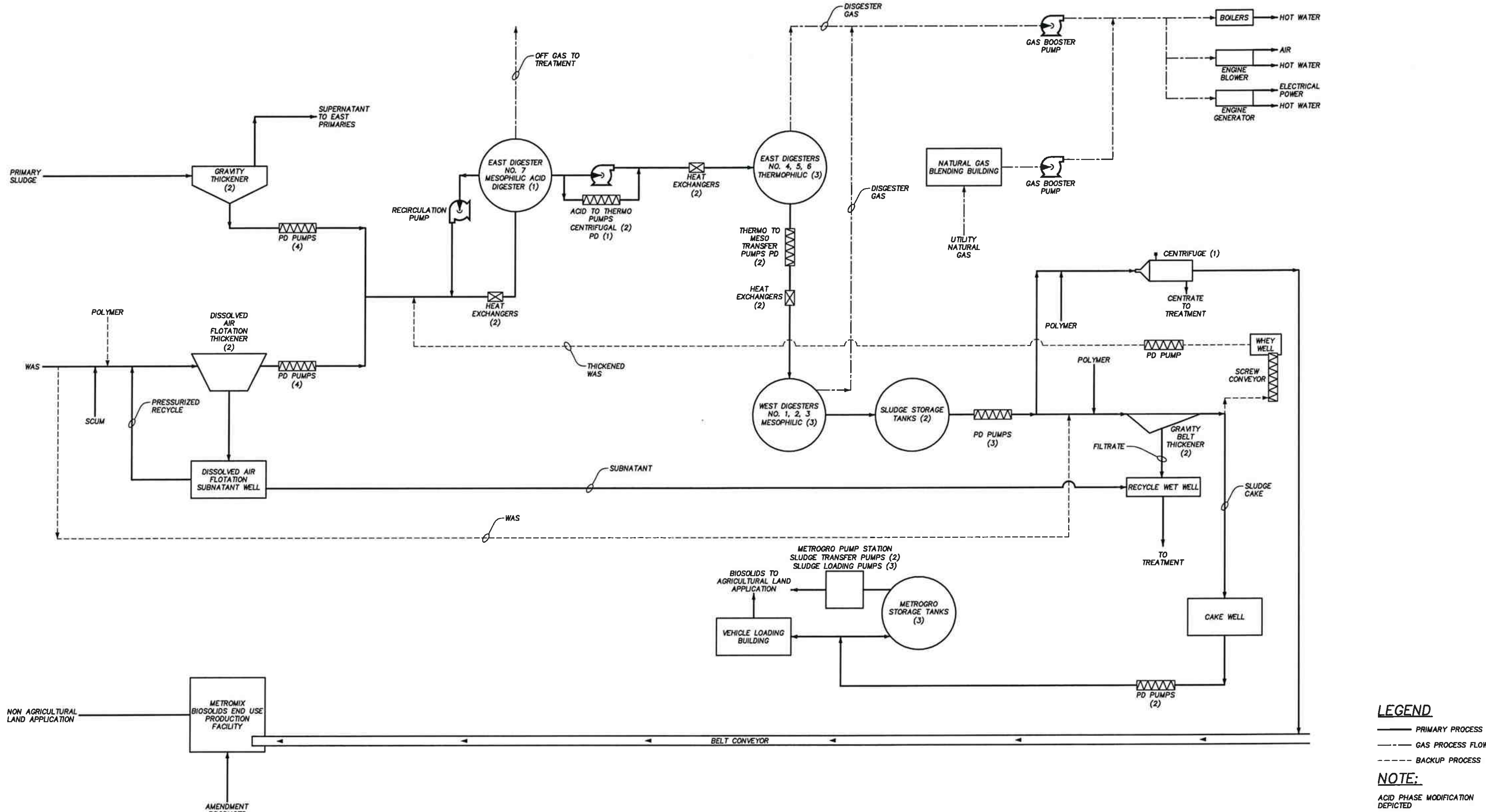

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FIGURE 6-1
SOLIDS PROCESS SCHEMATIC
Madison Metropolitan Sewage District

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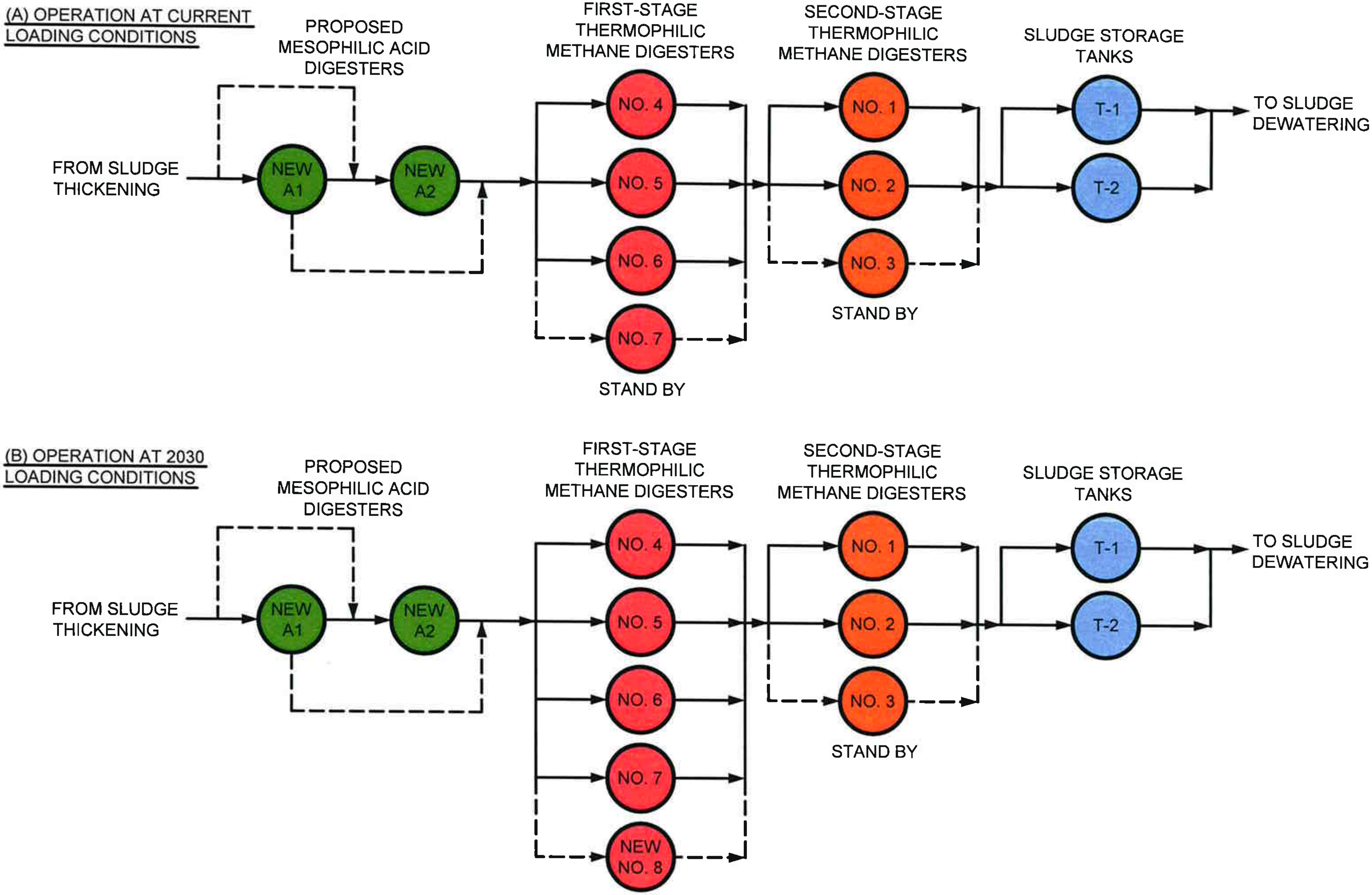

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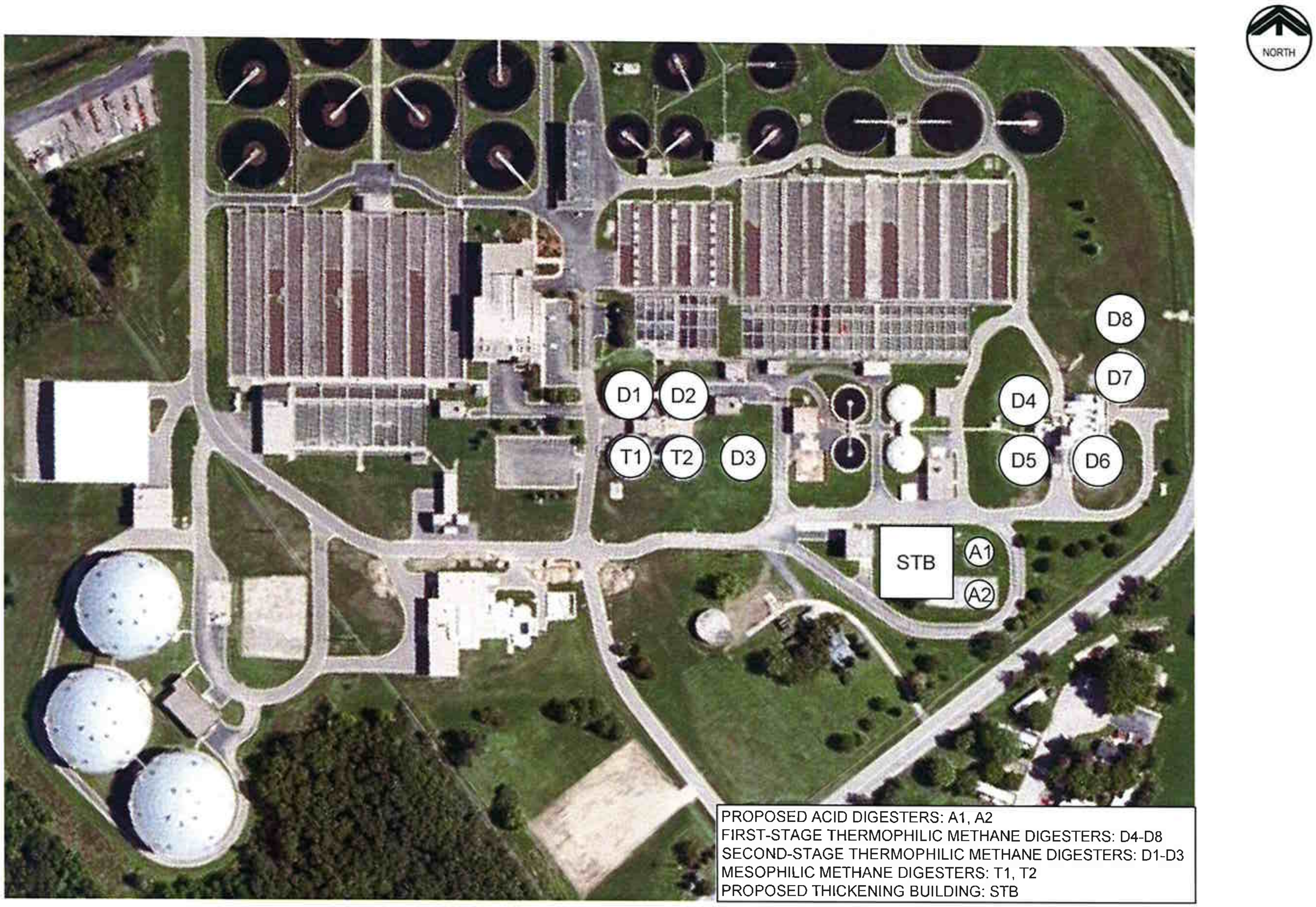
FIGURE 6-3
MULTI-STAGE ACID-PHASE DIGESTION
PROCESS SCHEMATIC
Madison Metropolitan Sewage District



PROPOSED ACID DIGESTERS: A1, A2
FIRST-STAGE THERMOPHILIC METHANE DIGESTERS: D4-D8
SECOND-STAGE THERMOPHILIC METHANE DIGESTERS: D1-D3
MESOPHILIC METHANE DIGESTERS: T1, T2
PROPOSED THICKENING BUILDING: STB

MULTI-STAGE ACID PHASE DIGESTION
PRELIMINARY LAYOUT

FIGURE 6-4

MADISON METROPOLITAN SEWAGE DISTRICT

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CHAPTER 7
RECOMMENDED PLAN AND IMPLEMENTATION

This chapter summarizes the recommendations in the preceding chapter to upgrade and expand the NSWWTP to accommodate solids handling system loadings over the next 20 years. This chapter also includes a resources impact summary, detailed project capital costs, funding availability, impacts on sewer user charge rates, and an implementation schedule.

RECOMMENDED PLAN

The recommended solids handling system plan for the NSWWTP is to convert the existing anaerobic digestion process to multi-stage acid phase digestion. This process is proposed to achieve the District's goals for Class A biosolids for its Metrogro and Metromix program via a site specific Class A permit. Figure 7-1 is a flow schematic of the recommended plan, and Figure 7-2 presents a site plan of the plant improvements. The recommended plan includes the current major plant improvements presented in Table 7-1.

These improvements will enable the District to achieve a reliable, cost-effective, sustainable process yielding a Class A biosolids product. The plan will also contribute to the long-term sustainability of the District's biosolids management plan with the proposed struvite harvesting process for the NSWWTP. The proposed construction of the solids handling system improvements will comprise the 11th Addition to the NSWWTP project.

The liquid treatment portion of the plant will continue to utilize the same EBPR activated sludge system, which includes single stage nitrification. The preliminary, primary, and secondary treatment systems will remain essentially unchanged. Effluent will continue to be disinfected with UV light. The treatment plant will continue to discharge highly treated effluent to the Badfish Creek and Badger Mill Creek outfalls.

Waste activated sludge (WAS) will be treated in a sludge blend tank designed to promote release of biologically stored phosphorus. Either primary sludge or recirculated acid sludge will serve as a volatile fatty acid source, causing a release of phosphorus when blended with the WAS. One of the existing DAF thickeners will be converted to a WAS blend tank.

Table 7-1
Nine Springs WWTP
Summary of Recommended Current Plant Improvements

Unit Process	No.	Size/Capacity	Status
WAS Thickening			
GBT (or equivalent RDT) units	3	2-meter belt width	New
New building	1	3000 sf	New
Polymer feed systems	4	15 lbs/hr	New
Thickened sludge pumps	4	120 gpm	New
Digested Sludge Thickening			
GBT unit	1	2-meter belt width	Replace existing
Acid Digesters			
Digester tanks	2	0.38 MG each	New
Mechanical mixing systems	2	Pumps or plunger mixing	New
Heating systems	2	Steam generators w/steam injectors	New
New building	1	1400 sf	New
Tunnel extension	1	200 lf	New
Off-gas flare system	1	Enclosed flare	New
Thermophilic Digester No. 8			
Digester tank	1	1.076 MG	New
Mechanical mixing systems	1	Draft tube or plunger mixing	New
Heating systems	1	Spiral heat exchanger	New
New building	1	1050 sf	New
Tunnel extension	1	200 lf	New
Foam separator dome	1		New
Digesters Nos. 4-7			
Mechanical mixing systems	4	Draft tube or plunger mixing	Replace existing
Foam separator domes	4	Retrofit on existing	New

Table 7-1
Nine Springs WWTP
Summary of Recommended Current Plant Improvements

Unit Process	No.	Size/Capacity	Status
Digesters Nos. 1-3			
Foam separator domes	3	Retrofit on existing	New
Ferric chloride system		Piping modifications	Add to existing
Foam Suppressant Feed			
Foam suppressant storage	1	10,000 FRP tank	New
Chemical Metering Pumps	2	Diaphragm	New
PAX Feed System	1	Modify existing chlorination system	Add to existing
Struvite Harvesting			
Ostara Process System	1	Struvite production 2141 tons/yr	New
New building	1	12900 sf	New
Tunnel extension	1	200 lf	New
DAF Thickener Modifications			
Blend tank conversion	1	Submersible mixers (2)	Retrofit
PSD tank conversion	1	Sludge collector	Retrofit
Grease Receiving Facility			
Whey well conversion	2	20,000 gal each	New

A new WAS thickening building will be constructed to house three new gravity belt thickeners to replace the existing DAF thickening for WAS. This will provide a thicker feed sludge to the acid phase digesters, which will provide the necessary volatile solids loading required by the acid digesters. The new thickening facility will include the associated polymer and sludge feed/transfer equipment. Filtrate from the thickening process will be diverted to the new struvite harvesting process.

Primary sludge will continue to be thickened in gravity thickeners. One of the existing DAF thickeners will be converted to a third primary sludge thickener to provide redundancy.

Two acid phase digesters will be constructed to pre-acidify thickened primary and waste activated sludges. The acid digester construction will include a new control building to house heating, mixing, and sludge transfer equipment. An enclosed flare will be provided to burn off-gas from the acid digesters. Thickened WAS will be pre-heated by direct steam injection.

Acidified sludge will be fed to the methane phase digesters, digesters Nos. 4 – 7 (existing) and No. 8 (new). The methane phase digesters will be operated at thermophilic conditions. New digester no. 8 will be constructed with a new control building to house heating and sludge transfer equipment, connected to the existing Sludge Control Building No. 2 via a tunnel. In Digesters Nos. 4 – 7 the gas mixing systems will be replaced with mechanical mixing to reduce foaming in the thermophilic digesters.

The existing digested sludge thickening facility will be upgraded by replacing the older of two gravity belt thickeners. Thickened digested sludge will continue to be pumped to the existing Metrogro Storage Tanks. The addition of a fourth Metrogro Storage Tank is anticipated at a future date, depending on the viability of Metromix production.

Sludge thickening filtrate from WAS and digested sludge thickening will be diverted to the new Struvite Harvesting Building that will house a proprietary system to recover phosphorus in the form of struvite. The struvite material will be shipped offsite and sold as a fertilizer. The net result of struvite harvesting will be a reduction in phosphorus levels in the digesters and in the biosolids products from the NSWWTP (Metrogro and Metromix).

Given the plant's size and age, District staff has identified a number of other items that will also require replacement and/or upgrading as part of the overall project. For example, the Biosolids End Use Facility does not possess sufficient capacity to process the sludge to be incorporated into Metromix product. The existing building will be expanded to accommodate the material handling equipment operations.

Some of the major items are listed below. Each of these modifications will need to be better defined during the preliminary design for the 11th Addition project. It is likely that additional items will be identified during the preliminary design phase of the project.

- Biosolids End Use Facility expansion
- Substations U3A, U3B, SB902 replacements
- Provision of a polyaluminum chloride (PAX) feed system for Microthrix control in the aeration basins
- Digester withdrawal valve repair (Digesters Nos. 4-7)
- Gas holder cover replacement for Storage Tanks Nos. 1 and 2
- Improvements to overflow hydraulics for west digester transfer to storage tanks
- Digester gas flow meter replacements
- Thermophilic sludge heat recovery / sludge cooling
- Lackeby heat exchanger repair
- Natural gas service metering revision
- Hot water system control valve replacement
- Dewatering centrifuge feed modifications
- Metrogro Loading Station modifications
- A fourth Metrogro Storage Tank
- Security system additions
- Operations Building electrical power system upgrades
- Existing control panel replacements

NO-ACTION ALTERNATIVE

The current NSWWTP operation is producing Class B biosolids via conventional mesophilic digestion. The goals established in 10th Addition for the production of Class A biosolids have not been achieved since the completion of the 10th Addition project.

The "No Action" alternative represents continued operation of the existing facilities with no additions to the facilities and no changes to present operation and maintenance procedures. This alternative recognizes the fact that the present facilities and staff are producing effluent that is generally in compliance with permit requirements.

However, the "No Action" alternative does not address the key issue of unmet goals for the District's long term biosolids reuse program. The effect of the "No Action" alternative would be that Class A biosolids production would not be achieved at the NSWWTP. This would not be an acceptable course of action for the District, so the "No Action" alternative was eliminated from further consideration.

RESOURCES IMPACT SUMMARY

The recommended plan will upgrade and increase the capacity of the existing solids handling system at the NSWWTP. It will have an overall positive impact on the surrounding environment including the agricultural land for recycled biosolds.

Water Quality

It is anticipated that the biosolids produced by the upgraded plant will consistently be of better quality than the current Class B biosolids production. It is expected that the land application of Class A biosolids will have a lower impact on the water quality within the watershed.

Soil erosion and sedimentation occurring during construction of the recommended plan should be minimal. The construction plans and specifications will contain provisions for the installation of erosion control measures to protect adjacent areas from run-off and siltation.

Air Quality

The recommended plan should not impact air quality, but the presence of acid sludge and thermophilic sludge will increase the potential for odors at the plant. Odor control / containment measures will be provided to counter the increased odor potential.

Plant staff may notice temporary dust from excavating equipment during construction. However, the construction specifications will require that fugitive dust control measures be implemented.

Historic and Archeological Sites

The proposed treatment plant expansion will take place on the existing plant site. This site has previously been disturbed during the numerous plant construction projects over the last 75 years. The proposed construction will be located in areas already developed or disturbed in prior construction projects (6th Addition, 8th Addition, and 10th Addition). These areas will not yield significant historic/archeological features.

Floodplains and Environmentally Significant Lands

The existing treatment plant facilities and proposed new facilities on the existing site are constructed outside of the floodplain. The entire existing plant site contains either treatment structures or open space. There are no environmentally significant lands where new facilities or structures are proposed to be constructed.

Public Health

The recommended plan will provide substantial benefits to public health. A higher quality biosolids product will reduce exposure to pathogens, lower phosphorus runoff, and provide increased opportunity for sustainable biosolids reuse.

PROJECT COST AND FUNDING

The estimated capital cost for the recommended plan is $41,200,000, as detailed in Table 7-2. The District estimates that the addition of upgrade/rehabilitation projects enumerated above will bring the project cost to $45,000,000. This capital cost, which includes construction, engineering, legal, and administrative costs, will be used for project financial planning. Table 7-2 also shows the anticipated impact of the new construction on the current plant O&M costs. The new construction is expected to result in a net annual addition of $160,000 in plant O&M costs. It is anticipated that implementation of struvite recovery will result in O&M savings due to fertilizer revenue and reduction in iron chemical costs at the plant.

TABLE 7-2 Nine Springs WWTP Summary of Total Project Costs		
Item	**Initial Cost**	**Estimated Additional O&M Costs (Initial)**
Waste Activated Sludge Thickening		$250,000
New thickeners	$675,000	
Polymer feed system	$150,000	
Sludge feed system	$ 67,500	
Sludge thickening building	$ 750,000	
Digested Sludge Thickening		-
New thickener	$225,000	
Acid Digesters		$150,000
Digester tanks	$1,520,000	
Digester covers	$220,000	
Digester mixers	$400,000	
Heating system	$730,000	
Control Building	$350,000	
Tunnel extension	$400,000	
Offgas flare	$300,000	
Accessories	$50,000	
Thermophilic Digester No. 8		$75,000
Digester tank	$2,152,000	
Digester covers	$300,000	
Digester mixers	$210,000	
Heating system	$113,000	
Control Building	$263,000	
Tunnel extension	$400,000	
Foam separator dome	$50,000	
Digesters Nos. 4 - 7		$35,000
Digester mixers	$840,000	
Foam separator domes	$200,000	
Digesters Nos. 1 - 3		-
Foam separator domes	$150,000	
Ferric Chloride System		($300,000)
Piping modifications	$125,000	
Foam Suppressant Feed System		$50,000
Tank, metering pumps	$300,000	
Struvite Harvesting System		($100,000)
Ostara System	$9,790,000	
New struvite harvesting building	$1,935,000	
Tunnel extension	$400,000	
DAF Thickener Modifications		-
Blend tank modifications	$250,000	
Primary sludge thickener conversion	$200,000	
Grease Receiving Station Modifications	$313,000	

TABLE 7-2 Nine Springs WWTP Summary of Total Project Costs		
Item	**Initial Cost**	**Estimated Additional O&M Costs (Initial)**
Subtotal	$23,829,000	$160,000
Site Work (8%)	$1,906,000	
Mechanical Process Piping (10%)	$2,383,000	
Instrumentation and Control (7%)	$1,668,000	
Electrical (8%)	$1,906,000	
Subtotal	$31,692,000	
Allowance for Undefined Design Details (25%) (1)	$5,319,000	
Total Construction Cost	$37,011,000	
Engineering, Legal, and Administrative (15%) (1)	$4,185,000	
Total Project Cost	$41,200,000	
Note: (1) Ostara struvite recovery allowance costs at 5%		

The most likely source of funds for this project is a low interest loan from the Clean Water Fund. The DNR Bureau of Environmental Loans administers the Clean Water Fund program that provides reduced interest rate loans for eligible wastewater projects. The current interest rate for eligible projects is 2.910% (60% of market rate). This interest rate changes with each State bond sale. Chapter NR 162 of the Wisconsin Administrative Code contains the rules for the Clean Water Fund program. Flows from industrial dischargers and reserve capacity at the treatment plant for flows beyond 10 years from the time of the project completion are not eligible for the low interest rate financing. The costs associated with facilities to treat these flows would be financed at the market interest rate.

The project capital cost is expected to be financed through a Clean Water Fund Loan. Assuming a total project cost of $45,000,000, a loan interest rate of 3.2% (based on a market rate of 5.0%, a parallel cost percentage of 90%, and a subsidized rate of 60% of the market rate), and 18 years of principal repayments the debt service costs for a CWF loan would be approximately $3,330,000 per year.

SEWER USER CHARGE IMPACTS

The impact of the plant expansion and upgrade on user charge rates is dependent upon the method chosen to allocate the annual revenue requirement for capital and annual operating costs over the various user categories. This will require a detailed user charge study.

The 2010 MMSD budget adopted in October 2009 included $15,548,587 in operating costs and $7,650,400 in debt service. The resulting service charge rates are shown in the following table:

2010 MMSD Service Charge Rates

Parameter	2010 Rate	
Volume	$440.36	per MG
CBOD	$0.12347	per pound
Suspended Solids	$0.18778	per pound
Nitrogen	$0.33234	per pound
Phosphorus	$2.06383	per pound
Equivalent Meters	$18.72	per year
Actual Customers	$9.93	per year

The estimated annual residential service charge for MMSD-provided services in 2010 is $122.

When debt service and operating costs for this project are fully incorporated into the 2014 budget, the residential service charge for MMSD provided services is estimated to be $154. Of the charges, about $18.00 would be attributable to this project. This estimate assumes a 0.5 % annual increase in loads, a 5% annual increase in base operating costs, and a 6.6% annual increase in debt service costs over the budgeted 2010 amounts. The estimate also includes annual operating cost increase of $160,000 because of this project as shown in Table 7-2.

Residential customers pay for MMSD provided services and sewer service provided by their local community. In 2010 the charge to a typical residential customer including both MMSD charges and local community charges is estimated to be $245. In 2014 when the debt service costs for the project are fully incorporated into customer bills, the typical residential service charge is estimated to be $302. Without this project the estimated service charge would be reduced by $18 to $284. The $18.00 increase is a 6.5% increase over the estimated charges without this project.

IMPLEMENTATION SCHEDULE

The steps and anticipated schedule for implementing the recommended plant are outlined below:

Conduct Public Hearing	February 2010
Submit Facilities Plan to DNR	February 2010
DNR Approval of Facilities Plan	March 2010
Begin Design	January 2010
Submit Plans and Specifications to the DNR	December 2010
DNR Approval of Plans and Specifications	February 2011
Bidding	February 2011
Award of Contract	March 2011
Submit Clean Water Fund Application	March 2011
Begin Construction	April 2011
Substantial Completion/Startup of Facilities	October 2013
Complete Construction	December 2013

PUBLIC PARTICIPATION

The District held a public hearing on Tuesday, February 16, 2010, to present the major findings and conclusions of the facilities plan and to solicit questions and comments from local officials and the general public. A 14-day comment period was provided prior to the hearing to allow for submission of written comments regarding the facilities plan, which the District made available at its office and on its web site. Documents related to the public hearing are included in the Appendix. No comments were received from the public prior to the hearing. There were no local officials or members of the general public in attendance at the public hearing.

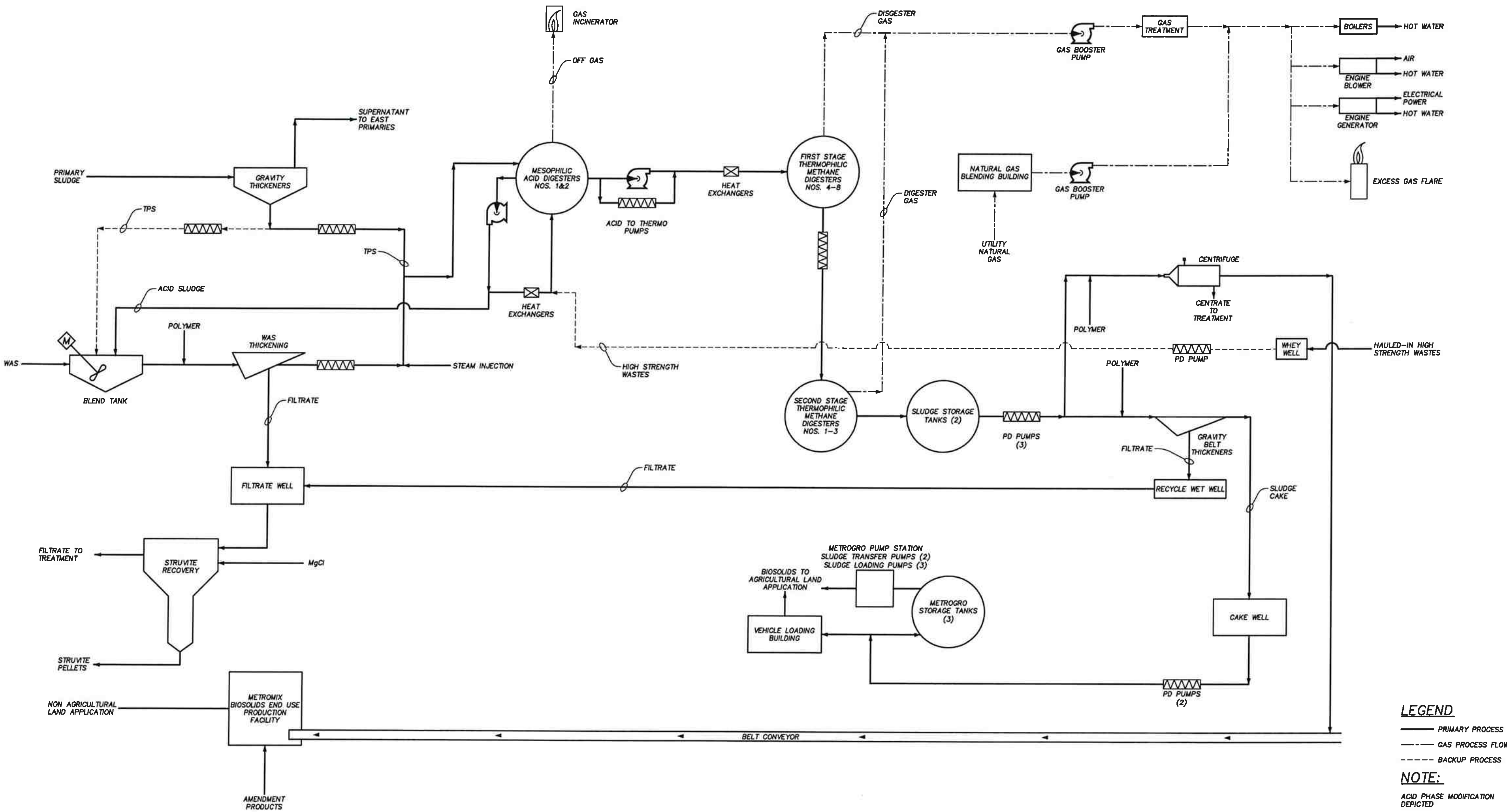

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FIGURE 7-1
SOLIDS PROCESS SCHEMATIC
Madison Metropolitan Sewage District

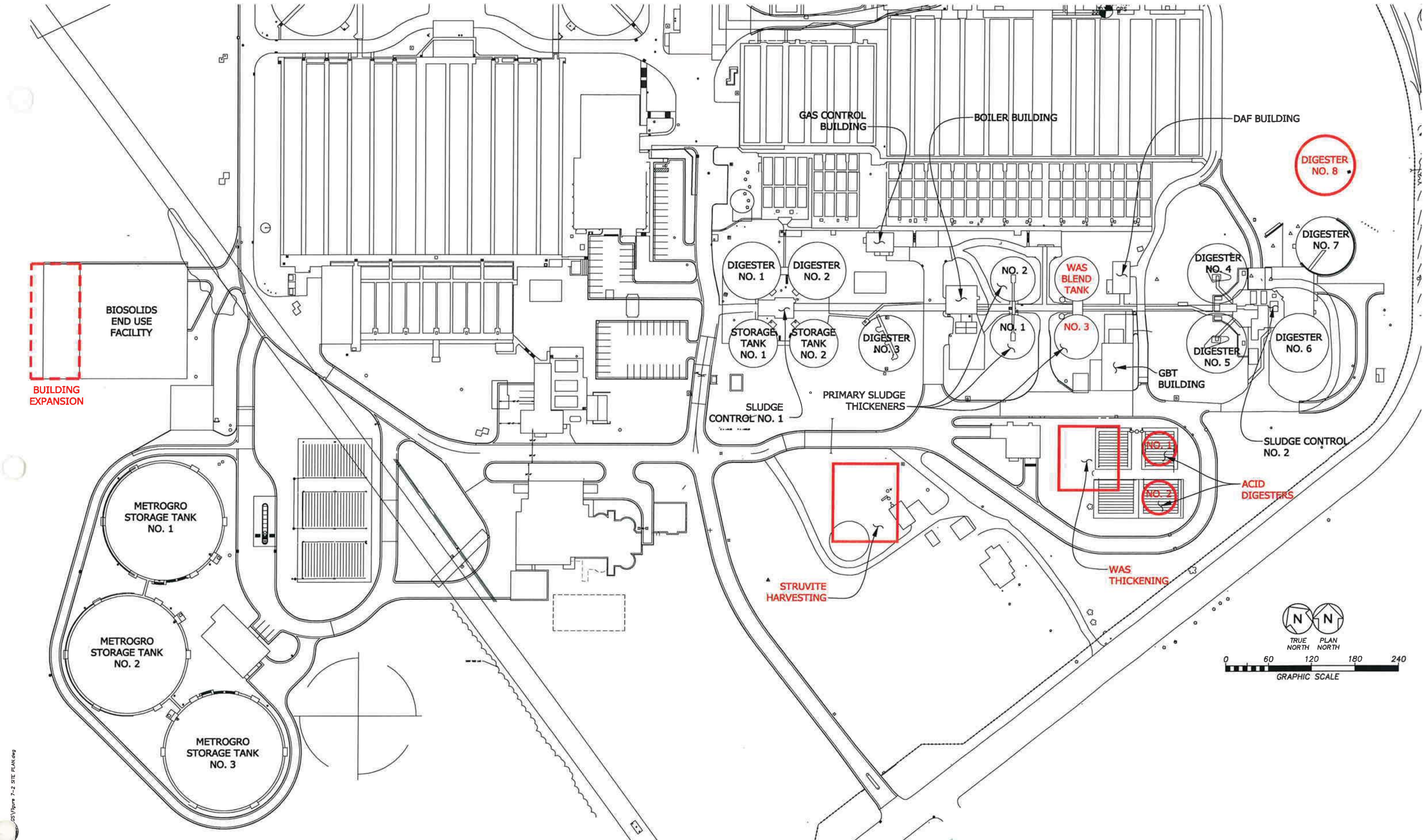

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FIGURE 7-2
NSWWTP SOLIDS HANDLING FACILITIES SITE PLAN
Madison Metropolitan Sewage District

APPENDIX A

WPDES Discharge Permit

WISCONSIN
DEPT. OF NATURAL RESOURCES

WPDES PERMIT

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

PERMIT TO DISCHARGE UNDER THE WISCONSIN POLLUTANT DISCHARGE ELIMINATION SYSTEM

MADISON METROPOLITAN SEWERAGE DISTRICT

is permitted, under the authority of Chapter 283, Wisconsin Statutes, to discharge from a facility located at

1610 Moorland Road, Madison,WI

to

BADFISH CREEK, FROM OUTFALL 001, AND GROUNDWATER OF THE YAHARA RIVER AND LAKE MONONA WATERSHED, FROM OUTFALL 008, BOTH IN THE LOWER ROCK RIVER BASIN AND TO BADGER MILL CREEK, FROM OUTFALL 005, INTHE SUGAR-PECATONICA RIVER BASIN, ALL IN DANE COUNTY

in accordance with the effluent limitations, monitoring requirements and other conditions set forth in this permit.

The permittee shall not discharge after the date of expiration. If the permittee wishes to continue to discharge after this expiration date an application shall be filed for reissuance of this permit, according to Chapter NR 200, Wis. Adm. Code, at least 180 days prior to the expiration date given below.

State of Wisconsin Department of Natural Resources
For the Secretary

By __________________________

Lloyd L. Eagan
South Central Regional Director

____

Date Permit Signed/Issued

PERMIT TERM: EFFECTIVE DATE - July 01, 2009 **EXPIRATION DATE - June 30, 2014**

TABLE OF CONTENTS

1 Influent Requirements

1.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
701	Influent to the wastewater treatment plant.

1.2 Monitoring Requirements

The permittee shall comply with the following monitoring requirements.

1.2.1 Sampling Point 701 - INFLUENT TO PLANT

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Continuous	Continuous	
BOD_5, Total		mg/L	Daily	24-Hr Flow Prop Comp	
Suspended Solids, Total		mg/L	Daily	24-Hr Flow Prop Comp	
Cadmium, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Chromium, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Copper, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Lead, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Nickel, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Zinc, Total Recoverable		µg/L	Monthly	24-Hr Flow Prop Comp	
Mercury, Total Recoverable		ng/L	Monthly	24-Hr Flow Prop Comp	

1.2.1.1 Total Metals Analyses

Measurements of total metals and total recoverable metals shall be considered as equivalent.

1.2.1.2 Sample Analysis

Samples shall be analyzed using a method which provides adequate sensitivity so that results can be quantified, unless not possible using the most sensitive approved method.

1.2.1.3 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results of samples and field blanks to the Department on Discharge Monitoring Reports.

2 In-Plant Requirements

2.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
111	In plant mercury monitoring - collect a mercury field blank at the Effluent Building using the Clean Hands/Dirty Hands sample collection procedure excerpted from EPA Method 1669.

2.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

2.2.1 Sampling Point 111 - In plant mercury monitoring

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Mercury, Total Recoverable		ng/L	Monthly	Blank	

2.2.1.1 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results of samples and field blanks to the Department on Discharge Monitoring Reports.

3 Surface Water Requirements

3.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
001	Disinfected effluent sample point at Effluent Building - Nine Springs Wastewater Treatment Plant; effluent discharged to Badfish Creek.
005	Same sample point as 001; effluent discharged to Badger Mill Creek.

3.2 Monitoring Requirements and Effluent Limitations

The permittee shall comply with the following monitoring requirements and limitations.

3.2.1 Sampling Point (Outfall) 001 - EFFL/BADFISH CREEK

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Continuous	Continuous	
BOD_5, Total	Monthly Avg	19 mg/L	Daily	24-Hr Comp	
BOD_5, Total	Weekly Avg	20 mg/L	Daily	24-Hr Comp	
Suspended Solids, Total	Monthly Avg	20 mg/L	Daily	24-Hr Comp	
Suspended Solids, Total	Weekly Avg	23 mg/L	Daily	24-Hr Comp	
Dissolved Oxygen	Daily Min	5.0 mg/L	Daily	Grab	
pH Field	Daily Max	9.0 su	Daily	Grab	
pH Field	Daily Min	6.0 su	Daily	Grab	
Phosphorus, Total	Monthly Avg	1.5 mg/L	Daily	24-Hr Comp	
Fecal Coliform	Geometric Mean	400 #/100 ml	2/Week	Grab	Limit applies April 15 - October 15.
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	4.4 mg/L	Daily	24-Hr Comp	Limit applies May - September.
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	1.8 mg/L	Daily	24-Hr Comp	Limit applies May - September.
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	4.1 mg/L	Daily	24-Hr Comp	Limit applies October - April.
Nitrogen, Ammonia (NH_3-N) Total	Daily Max	17 mg/L	Daily	24-Hr Comp	Limit applies year-round.
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	10 mg/L	Daily	24-Hr Comp	Limit applies October - April.
Acute WET		rTUa	Quarterly	24-Hr Comp	Sample during the quarters specified in section 3.2.1.5 .

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Chronic WET		rTU_c	Quarterly	24-Hr Comp	Sample during the quarters specified in section 3.2.1.5 .
Cadmium, Total Recoverable		µg/L	Monthly	24-Hr Comp	
Chromium, Total Recoverable		µg/L	Monthly	24-Hr Comp	
Copper, Total Recoverable		µg/L	Monthly	24-Hr Comp	
Lead, Total Recoverable		µg/L	Monthly	24-Hr Comp	
Nickel, Total Recoverable		µg/L	Monthly	24-Hr Comp	
Zinc, Total Recoverable		µg/L	Monthly	24-Hr Comp	
Mercury, Total Recoverable	Daily Max	5.7 ng/L	Monthly	Grab	
BOD_5, Total	Monthly Avg	7,923 lbs/day	Daily	Calculated	
BOD_5, Total	Weekly Avg	8,340 lbs/day	Daily	Calculated	
Suspended Solids, Total	Monthly Avg	8,340 lbs/day	Daily	Calculated	
Suspended Solids, Total	Weekly Avg	9,591 lbs/day	Daily	Calculated	
Chloride	Weekly Avg	481 mg/L	Weekly	24-Hr Comp	"This interim limit applies until 06/30/2014 when the target value of 430 mg/L becomes effective. (See section 6.2)
Chloride	Weekly Avg	200,000 lbs/day	Weekly	Calculated	

3.2.1.1 Total Metals Analyses

Measurements of total metals and total recoverable metals shall be considered as equivalent.

3.2.1.2 Sample Analysis

Samples shall be analyzed using a method which provides adequate sensitivity so that results can be quantified, unless not possible using the most sensitive approved method.

3.2.1.3 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results of samples and field blanks to the Department on Discharge Monitoring Reports.

3.2.1.4 Non-Wet Weather and Alternative Wet Weather Mass Limit

This parameter (chloride) has a mass limit based on weather conditions. The applicable non-wet weather mass limit is 200,000 pounds/day. The applicable wet weather mass limit is 260,000 pounds/day. Report the applicable mass limit on the Discharge Monitoring Report form in the variable limit column. See Standard Requirements for "Applicability of Alternative Wet Weather Mass Limitations" and "Appropriate Formulas for Effluent Calculations".

3.2.1.5 Whole Effluent Toxicity (WET) Testing

Primary Control Water: Control water shall be standard laboratory control water which has a hardness of +/- 10 % of the hardness of: 1) the Yahara River above the confluence with Badfish Creek. Different control water may be used if prior approval has been given by the Department.

Instream Waste Concentration (IWC): 93%

Dilution series: At least five effluent concentrations and dual controls must be included in each test.

- **Acute:** 100, 50, 25, 12.5, 6.25% and any additional selected by the permittee.
- **Chronic:** 100, 30, 10, 3, 1% (if the IWC $\leq$30%) or 100, 75, 50, 25, 12.5% (if the IWC >30%) and any additional selected by the permittee.

WET Testing Frequency: Tests are required during the following quarters.

- **Acute: Oct – Dec 2009, July – Sep 2010, Jan – Mar 2011, July – Sep 2012, April – June 2013**
- **Chronic: July – Sep 2009, Oct – Dec 2009, April – June 2010, July – Sep 2010,**
- **Jan – Mar 2011, Oct – Dec 2011, April – June 2012 , July – Sep 2012,**
- **Jan – Mar 2013, April – June 2013**

Reporting: The permittee shall report test results on the Discharge Monitoring Report form, and also complete the "Whole Effluent Toxicity Test Report Form" (Section 6, "*State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition*"), for each test. The original, complete, signed version of the Whole Effluent Toxicity Test Report Form shall be sent to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., P.O. Box 7921, Madison, WI 53707-7921, within 45 days of test completion. The original Discharge Monitoring Report (DMR) form and one copy shall be sent to the contact and location provided on the DMR by the required deadline.

Determination of Positive Results: An acute toxicity test shall be considered positive if the Toxic Unit - Acute (TU_a) is greater than 1.0 for either species. The TU_a shall be calculated as follows: If $LC_{50} \geq 100$, then $TU_a = 1.0$. If LC_{50} is < 100, then $TU_a = 100 \div LC_{50}$. A chronic toxicity test shall be considered positive if the Relative Toxic Unit - Chronic (rTU_c) is greater than 1.0 for either species. The rTU_c shall be calculated as follows: If $IC_{25} \geq IWC$, then $rTU_c = 1.0$. If $IC_{25} < IWC$, then $rTU_c = IWC \div IC_{25}$.

Additional Testing Requirements: Within 90 days of a test which showed positive results, the permittee shall submit the results of at least 2 retests to the Biomonitoring Coordinator on "Whole Effluent Toxicity Test Report Forms". The retests shall be completed using the same species and test methods specified for the original test (see the Standard Requirements section herein).

3.2.1.6 Chloride Variance – Implement Source Reduction Measures

This permit contains a variance to the water quality-based effluent limit (WQBEL) for chloride granted in accordance with s. NR 106.83(2), Wis. Adm. Code. As conditions of this variance the permittee shall (a) maintain effluent quality at or below the interim effluent limitation specified in the table above, (b) implement the chloride source reduction measures specified below, and (c) perform the actions listed in the compliance schedule. (See the Schedules of Compliance section herein.):

1. Identify sources of chloride to the sewer system.

2. Require significant industrial and commercial contributors to evaluate their chloride discharges and make recommendations for significantly reducing them, with the results of that evaluation being the basis for potential restrictions of chloride discharges.

3. Educate homeowners on the impact of chloride from residential softeners, discuss options available for increasing softener salt efficiency, and request voluntary reductions.

4. Recommend residential softener tune–ups on a voluntary basis.

5. Request voluntary support from local water softening businesses in the efforts described in subds. 2. and 3.

6. Educate licensed installers and self–installers of softeners on providing optional hard water for outside faucets for residences.

3.2.2 Sampling Point (Outfall) 005 - EFFL/BADGER MILL CREEK

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Continuous	Continuous	
BOD_5, Total	Weekly Avg	16 mg/L	Daily	24-Hr Comp	Limit applies November - April.
BOD_5, Total	Weekly Avg	7.0 mg/L	Daily	24-Hr Comp	Limit applies May - October.
Suspended Solids, Total	Monthly Avg	10 mg/L	Daily	24-Hr Comp	Limit applies May - October.
Suspended Solids, Total	Monthly Avg	16 mg/L	Daily	24-Hr Comp	Limit applies November - April.
Dissolved Oxygen	Daily Min	5.0 mg/L	Daily	Grab	
pH Field	Daily Max	9.0 su	Daily	Grab	
pH Field	Daily Min	6.0 su	Daily	Grab	
Phosphorus, Total	Monthly Avg	1.5 mg/L	Daily	24-Hr Comp	
Fecal Coliform	Geometric Mean	400 #/100 ml	2/Week	Grab	Limit applies May - September.
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	8.7 mg/L	Daily	24-Hr Comp	Limit applies October - April.
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	1.1 mg/L	Daily	24-Hr Comp	Limit applies May - September.
Nitrogen, Ammonia (NH_3-N) Total	Monthly Avg	3.8 mg/L	Daily	24-Hr Comp	Limit applies October - April.
Nitrogen, Ammonia (NH_3-N) Total	Daily Max	11 mg/L	Daily	24-Hr Comp	Limit applies year-round.
Nitrogen, Ammonia (NH_3-N) Total	Weekly Avg	2.6 mg/L	Daily	24-Hr Comp	Limit applies May - September.
Acute WET		rTUa	Quarterly	24-Hr Comp	Sample during the quarters specified in section 3.2.2.5 .

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Chronic WET		rTU_c	Quarterly	24-Hr Comp	Sample during the quarters specified in section 3.2.2.5 .
Chloride	Weekly Avg	481 mg/L	Daily	24-Hr Comp	This interim limit applies until 06/30/2014 when the target value of 430 mg/L becomes effective. (See section 6.2)
Chloride	Weekly Avg	14,000 lbs/day	Daily	24-Hr Comp	
Mercury, Total Recoverable	Daily Max	5.7 mg/L	Daily	Grab	

3.2.2.1 Total Metals Analyses

Measurements of total metals and total recoverable metals shall be considered as equivalent.

3.2.2.2 Sample Analysis

Samples shall be analyzed using a method which provides adequate sensitivity so that results can be quantified, unless not possible using the most sensitive approved method.

3.2.2.3 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results of samples and field blanks to the Department on Discharge Monitoring Reports.

3.2.2.4 Non-Wet Weather and Alternative Wet Weather Mass Limit

This parameter (chloride) has a mass limit based on weather conditions. The applicable non-wet weather mass limit is 14,000 pounds/day. The applicable wet weather mass limit is not applicable to this outfall because all effluent is pumped, with a maximum pump rate of 3.6 MGD. Report the applicable mass limit on the Discharge Monitoring Report form in the variable limit column. See Standard Requirements for "Applicability of Alternative Wet Weather Mass Limitations" and "Appropriate Formulas for Effluent Calculations".

3.2.2.5 Whole Effluent Toxicity (WET) Testing

Primary Control Water: the Sugar River above the confluence with Badger Mill Creek, for Outfall 005. Different control water may be used if prior approval has been given by the Department.

Instream Waste Concentration (IWC): 97%

Dilution series: At least five effluent concentrations and dual controls must be included in each test.

- **Acute:** 100, 50, 25, 12.5, 6.25% and any additional selected by the permittee.
- **Chronic:** 100, 30, 10, 3, 1% (if the IWC ≤30%) or 100, 75, 50, 25, 12.5% (if the IWC >30%) and any additional selected by the permittee.

WET Testing Frequency: Tests are required during the following quarters.

- **Acute: Oct – Dec 2009, July – Sep 2010, Jan – Mar 2011, July – Sep 2012, April – June 2013**
- **Chronic: July – Sep 2009, Oct – Dec 2009, April – June 2010, July – Sep 2010,**
- **Jan – Mar 2011, Oct – Dec 2011, April – June 2012 , July – Sep 2012,**
- **Jan – Mar 2013, April – June 2013**

Reporting: The permittee shall report test results on the Discharge Monitoring Report form, and also complete the "Whole Effluent Toxicity Test Report Form" (Section 6, "*State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition*"), for each test. The original, complete, signed version of the Whole Effluent Toxicity Test Report Form shall be sent to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., P.O. Box 7921, Madison, WI 53707-7921, within 45 days of test completion. The original Discharge Monitoring Report (DMR) form and one copy shall be sent to the contact and location provided on the DMR by the required deadline.

Determination of Positive Results: An acute toxicity test shall be considered positive if the Toxic Unit - Acute (TU_a) is greater than 1.0 for either species. The TU_a shall be calculated as follows: If $LC_{50} \geq 100$, then $TU_a = 1.0$. If LC_{50} is < 100, then $TU_a = 100 \div LC_{50}$. A chronic toxicity test shall be considered positive if the Relative Toxic Unit - Chronic (rTU_c) is greater than 1.0 for either species. The rTU_c shall be calculated as follows: If $IC_{25} \geq IWC$, then $rTU_c = 1.0$. If $IC_{25} < IWC$, then $rTU_c = IWC \div IC_{25}$.

Additional Testing Requirements: Within 90 days of a test which showed positive results, the permittee shall submit the results of at least 2 retests to the Biomonitoring Coordinator on "Whole Effluent Toxicity Test Report Forms". The retests shall be completed using the same species and test methods specified for the original test (see the Standard Requirements section herein).

3.2.2.6 Chloride Variance – Implement Source Reduction Measures

This permit contains a variance to the water quality-based effluent limit (WQBEL) for chloride granted in accordance with s. NR 106.83(2), Wis. Adm. Code. As conditions of this variance the permittee shall (a) maintain effluent quality at or below the interim effluent limitation specified in the table above, (b) implement the chloride source reduction measures specified for Outfall 001, and (c) perform the actions listed in the compliance schedule. (See the Schedules of Compliance section herein.):

4 Land Treatment Requirements

4.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, Waste Description/Sample Contents and Treatment Description (as applicable)**
008	Demonstration project - spray irrigation of final effluent on golf course.

4.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

4.2.1 Sampling Point (Outfall) 008 - Golf Course Spray Irrigation, Spray Irrigation

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		gal	Daily	Total Daily	
Hydraulic Application Rate	Monthly Avg	10,000 gal/ac/day	Monthly	Calculated	
BOD_5, Total	Monthly Avg	16 mg/L	Monthly	24-Hr Flow Prop Comp	
Suspended Solids, Total		mg/L	Monthly	24-Hr Flow Prop Comp	
pH Field		su	Monthly	Grab	
Nitrogen, Total Kjeldahl		mg/L	Monthly	24-Hr Flow Prop Comp	
Nitrogen, Ammonia (NH_3-N) Total		mg/L	Monthly	24-Hr Flow Prop Comp	
Nitrogen, Organic Total		mg/L	Monthly	Calculated	
Nitrogen, Nitrite + Nitrate Total		mg/L	Monthly	24-Hr Flow Prop Comp	
Nitrogen, Total		mg/L	Monthly	Calculated	
Chloride		mg/L	Monthly	24-Hr Flow Prop Comp	
Solids, Total Dissolved		mg/L	Monthly	24-Hr Flow Prop Comp	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Nitrogen, Max Applied On Any Zone		lbs/ac/yr	Annual	Total Annual	
Fecal Coliform	Geometric Mean	400 #/100 ml	2/Week	Grab	
Phosphorus, Total		mg/L	Daily	24-Hr Flow Prop Comp	

Daily Log – Monitoring Requirements and Limitations

All discharge and monitoring activity shall be documented on log sheets. Originals of the log sheets shall be kept by the permittee as described under "Records Retention" in the Standard Requirements section, and if requested, made available to the Department.

Parameters	**Limit**	**Units**	**Sample Frequency**	**Sample Type**
Zone or Location Being Sprayed	-	Number	Daily	Log
Acres Being Sprayed	-	Acres	Daily	Log
Start to End Time	-	Date, Hour	Daily	Log
Wastewater Loading Volume	-	Gallons	Daily	Log
Wastewater Loading Volume	-	Gallons/Acre	Daily	Calculated
Visual Observations	-	-	Daily	Log

Annual Report – Monitoring Requirements and Limitations

The Annual Report is due by January 31st of each year for the previous calendar year.

Parameters	**Limit**	**Units**	**Sample Frequency**	**Sample Type**
Total Volume Applied Per Zone	-	Gallons	Annual	Total Annual
Total Volume Applied Per Zone	-	Gallons/Acre	Annual	Total Annual
Total Nitrogen Applied per Zone	-	Pounds/Acre/Year	Annual	Calculated
Soil Analysis	-	-	Annual	Composite
Fertilizer Used	-	Pounds/Acre/Year	Annual	Total Annual

Note: Inches/load cycle = gallons/acre/load cycle divided by 27,154.

4.2.1.1 Monthly Avg Flow – LT Calculation

The monthly average discharge flow for Land Treatment systems is calculated by dividing the total wastewater volume discharged for the month by the total number of days in the month.

4.2.1.2 Spray Irrigation Site - Soil Analysis

The soil at each spray irrigation site shall be tested annually for nitrate-nitrogen, available phosphorus, available potassium and pH.

1.2.1.3 Additional Demonstration Irrigation Project Requirements

Demonstration irrigation projects may be conducted under the following conditions:

1. **Prior Approval Necessary for Equipment or Operational Changes**: The District shall provide written notice to the department in advance of substantive changes to equipment or operating procedures at this outfall. The written notice shall provide information on the proposed changes.
2. **Application of Effluent**: Effluent shall only be applied by direct irrigation and may not be applied during times of the day when the golf course is open for golfing or during times when wind conditions may be expected to cause significant drift.
3. **Irrigation Season**: Effluent may only be applied during the period of April 15th through October 15th.
4. **Irrigation Ponds**: Effluent storage in irrigation ponds shall only be done according to a department-approved management plan.
5. **Soil Samples:** A routine soil sample shall be collected from each spray field according to current UW Soils Dept. methods, and tested for the purpose of obtaining plant available nutrients and for making fertilizer and liming recommendations for the cover crop being grown.
6. **Golf Course Signage:** Adequate signage shall be placed in each area where effluent is used, advising the public that the test plot is being irrigated using non-potable treated effluent and that all golfers or other persons using the areas should practice good personal hygiene and hand washing before eating, drinking or smoking.

5 Land Application Requirements

In order for biosolids to be land applied it must at a minimum, meet all of the following criteria: the ceiling concentration limits for metals established in this permit; Class B pathogen requirements established in this permit; and one of the vector control requirements specified in this permit.

The permittee may publicly distribute biosolids if it meets the exceptional quality (EQ) criteria specified in s. NR 204.01(19). These criteria require EQ biosolids to meet the following: the high quality metal concentration limits; Class A process requirements for pathogens as well as either a fecal coliform limit of less than 1000 MPN/g TS or a *Salmonella* limit of less than 3 MPN/4g TS; and one of the process requirements for vector attraction reduction. If the biosolids do not meet the exceptional quality criteria specified in s. NR 204.03(19), the permitttee may not publicly distribute the biosolids, but the biosolids may be land applied if the minimum criteria specified in this section are met.

5.1 Sampling Point(s)

The discharge(s) shall be limited to land application of the waste type(s) designated for the listed sampling point(s) on Department approved land spreading sites or by hauling to another facility.

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
002	Anaerobically digested, gravity belt thickened liquid sludge. Monitoring shall apply only when this outfall is active.
009	Sequencing batch temperature phased anaerobically digested liquid sludge. Notify the Department when this outfall becomes active.
010	Sequencing batch temperature phased anaerobically digested, centrifuged cake sludge. Notify the Department when this outfall becomes active.

5.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

5.2.1 Sampling Points (Outfalls) 002, 009 and 010

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Solids, Total		Percent	1/ 2 Months	Composite	
Arsenic Dry Wt	High Quality	41 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Arsenic Dry Wt	Ceiling	75 mg/kg	1/ 2 Months	Composite	
Cadmium Dry Wt	High Quality	39 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Cadmium Dry Wt	Ceiling	85 mg/kg	1/ 2 Months	Composite	
Copper Dry Wt	High Quality	1,500 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Copper Dry Wt	Ceiling	4,300 mg/kg	1/ 2 Months	Composite	
Lead Dry Wt	High Quality	300 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Lead Dry Wt	Ceiling	840 mg/kg	1/ 2 Months	Composite	
Mercury Dry Wt	High Quality	17 mg/kg	1/ 2 Months	Composite	Sample 010 annually.

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Mercury Dry Wt	Ceiling	57 mg/kg	1/ 2 Months	Composite	
Molybdenum Dry Wt	Ceiling	75 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Nickel Dry Wt	High Quality	420 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Nickel Dry Wt	Ceiling	420 mg/kg	1/ 2 Months	Composite	
Selenium Dry Wt	Ceiling	100 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Selenium Dry Wt	High Quality	100 mg/kg	1/ 2 Months	Composite	
Zinc Dry Wt	High Quality	2,800 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Zinc Dry Wt	Ceiling	7,500 mg/kg	1/ 2 Months	Composite	Sample 010 annually.
Nitrogen, Total Kjeldahl		Percent	1/ 2 Months	Composite	Sample 010 annually.
Nitrogen, Ammonium (NH_4-N) Total		Percent	1/ 2 Months	Composite	Sample 010 annually.
Phosphorus, Total		Percent	1/ 2 Months	Composite	Sample 010 annually.
Potassium, Total Recoverable		Percent	1/ 2 Months	Composite	Sample 010 annually.
Municipal Sludge Priority Pollutant Scan			Once	Composite	As specified in ch. NR 215.03 (1-4), Wis. Adm. Code. Sample Outfall 002 only, in 2013.

Other Sludge Requirements	
Sludge Requirements	**Sample Frequency**
List 3 Requirements – Pathogen Control: The requirements in List 3 shall be met prior to land application of sludge.	**Sample 002 or 009 Bimonthly. Sample 010 Annually.**
List 4 Requirements – Vector Attraction Reduction: The vector attraction reduction shall be satisfied prior to, or at the time of land application as specified in List 4.	**Sample 002 or 009 Bimonthly. Sample 010 Annually.**

5.2.1.1 Exception to Bimonthly Sludge Sample Frequency

Where bimonthly sludge sampling is required, the requirement for the January – February period is hereby waived. To compensate, a sixth sample shall be collected and reported during any of the other bimonthly report periods.

5.2.1.2 List 2 Analysis

If the monitoring frequency for List 2 parameters is more frequent than "Annual" then the sludge may be analyzed for the List 2 parameters just prior to each land application season rather than at the more frequent interval specified.

5.2.1.3 Changes in Feed Sludge Characteristics

If a change in feed sludge characteristics, treatment process, or operational procedures occurs which may result in a significant shift in sludge characteristics, the permittee shall reanalyze the sludge for List 1, 2, 3 and 4 parameters each time such change occurs.

5.2.1.4 Multiple Sludge Sample Points (Outfalls)

If there are multiple sludge sample points (outfalls), but the sludges are not subject to different sludge treatment processes, then a separate List 2 analysis shall be conducted for each sludge type which is land applied, just prior to land application, and the application rate shall be calculated for each sludge type. In this case, List 1, 3, and 4 and PCBs need only be analyzed on a single sludge type, at the specified frequency. If there are multiple sludge sample points (outfalls), due to multiple treatment processes, List 1, 2, 3 and 4 and PCBs shall be analyzed for each sludge type at the specified frequency.

5.2.1.5 Sludge Which Exceeds the High Quality Limit

Cumulative pollutant loading records shall be kept for all bulk land application of sludge which does not meet the high quality limit for any parameter. This requirement applies for the entire calendar year in which any exceedance of Table 3 of s. NR 204.07(5)(c), is experienced. Such loading records shall be kept for all List 1 parameters for each site land applied in that calendar year. The formula to be used for calculating cumulative loading is as follows:

[(Pollutant concentration (mg/kg) x dry tons applied/ac) ÷ 500] + previous loading (lbs/acre) = cumulative lbs pollutant per acre

When a site reaches 90% of the allowable cumulative loading for any metal established in Table 2 of s. NR 204.07(5)(b), the Department shall be so notified through letter or in the comment section of the annual land application report (3400-55).

5.2.1.6 Sludge Analysis for PCBs

The permittee shall analyze the sludge for Total PCBs one time during **2013**. The results shall be reported as "PCB Total Dry Wt". Either congener-specific analysis or Aroclor analysis shall be used to determine the PCB concentration. The permittee may determine whether Aroclor or congener specific analysis is performed. Analyses shall be performed in accordance with Table EM in s. NR 219.04, Wis. Adm. Code and the conditions specified in Standard Requirements of this permit. PCB results shall be submitted by January 31, following the specified year of analysis.

5.2.1.7 Lists 1, 2, 3, and 4

List 1 **TOTAL SOLIDS AND METALS** See the Monitoring Requirements and Limitations table above for monitoring frequency and limitations for the List 1 parameters
Solids, Total (percent)
Arsenic, mg/kg (dry weight)
Cadmium, mg/kg (dry weight)
Copper, mg/kg (dry weight)
Lead, mg/kg (dry weight)
Mercury, mg/kg (dry weight)
Molybdenum, mg/kg (dry weight)
Nickel, mg/kg (dry weight)
Selenium, mg/kg (dry weight)
Zinc, mg/kg (dry weight)

List 2 **NUTRIENTS** See the Monitoring Requirements and Limitations table above for monitoring frequency for the List 2 parameters
Solids, Total (percent)
Nitrogen Total Kjeldahl (percent)
Nitrogen Ammonium (NH4-N) Total (percent)
Phosphorus Total as P (percent)
Phosphorus, Water Extractable (as percent of Total P)
Potassium Total Recoverable (percent)

List 3

PATHOGEN CONTROL FOR CLASS A SLUDGE

The permittee shall implement pathogen control as listed in List 3. The Department shall be notified of the pathogen control utilized and shall be notified when the permittee decides to utilize alternative pathogen control.

The following requirements shall be met prior to land application of sludge.

Parameter	Unit	Limit
Fecal Coliform*	MPN/g TS	1,000
OR		
Salmonella	MPN/4g TS	3
AND, ONE OF THE FOLLOWING PROCESS OPTIONS		
Temp/Time based on % Solids	Alkaline Treatment	
Prior test for Enteric Virus/Viable Helminth Ova	Post test for Enteric Virus/Viable Helminth Ova	
Composting	Heat Drying	
Heat Treatment	Thermophilic Aerobic Digestion	
Beta Ray Irradiation	Gamma Ray Irradiation	
Pasteurization	PFRP Equivalent Process	

* For Class A sludge, each sampling event shall satisfy the numerical standards specified above.

List 3

PATHOGEN CONTROL FOR CLASS B SLUDGE

The permittee shall implement pathogen control as listed in List 3. The Department shall be notified of the pathogen control utilized and shall be notified when the permittee decides to utilize alternative pathogen control.

The following requirements shall be met prior to land application of sludge.

Parameter	Unit	Limit
Fecal Coliform*	MPN/gTS or CFU/gTS	2,000,000
OR, ONE OF THE FOLLOWING PROCESS OPTIONS		
Aerobic Digestion	Air Drying	
Anaerobic Digestion	Composting	
Alkaline Stabilization	PSRP Equivalent Process	

* The Fecal Coliform limit shall be reported as the geometric mean of 7 discrete samples on a dry weight basis.

List 4 VECTOR ATTRACTION REDUCTION The permittee shall implement any one of the vector attraction reduction options specified in List 4. The Department shall be notified of the option utilized and shall be notified when the permittee decides to utilize an alternative option. One of the following shall be satisfied prior to, or at the time of land application as specified in List 4.		
Option	**Limit**	**Where/When it Shall be Met**
Volatile Solids Reduction	≥38%	Across the process
Specific Oxygen Uptake Rate	≤1.5 mg O_2/hr/g TS	On aerobic stabilized sludge
Anaerobic bench-scale test	<17 % VS reduction	On anaerobic digested sludge
Aerobic bench-scale test	<15 % VS reduction	On aerobic digested sludge
Aerobic Process	>14 days, Temp >40°C and Avg. Temp > 45°C	On composted sludge
pH adjustment	>12 S.U. (for 2 hours) and >11.5 (for an additional 22 hours)	During the process
Drying without primary solids	>75 % TS	When applied or bagged
Drying with primary solids	>90 % TS	When applied or bagged
Equivalent Process	Approved by the Department	Varies with process
Injection	-	When applied
Incorporation	-	Within 6 hours of application

5.2.1.8 Daily Land Application Log

Daily Land Application Log Discharge Monitoring Requirements and Limitations The permittee shall maintain a daily land application log for biosolids land applied each day when land application occurs. The following minimum records must be kept, in addition to all analytical results for the biosolids land applied. The log book records shall form the basis for the annual land application report requirements.		
Parameters	**Units**	**Sample Frequency**
DNR Site Number(s)	Number	Daily as used
Outfall number applied	Number	Daily as used
Acres applied	Acres	Daily as used
Amount applied	As appropriate * /day	Daily as used
Application rate per acre	unit */acre	Daily as used
Nitrogen applied per acre	lb/acre	Daily as used
Method of Application	Injection, Incorporation, or surface applied	Daily as used

*gallons, cubic yards, dry US Tons or dry Metric Tons

6 Schedules of Compliance

6.1 Mercury Pollutant Minimization Program

The permittee shall implement or continue a pollutant minimization program whenever, after the first 24 months of mercury monitoring, a mercury effluent limitation is necessary under the procedure in s. NR 106.145(2), Wis. Adm. Code.

Required Action	Date Due
Implement the Mercury Pollutant Minimization Program: The permittee shall implement the PMP as submitted or as amended by agreement of the permittee and the Department.	
Submit Annual Status Reports: The permittee shall submit to the Department an annual status report on the progress of the PMP as required by s. NR 106.145(7), Wis. Adm. Code. Submittal of each annual status report is required by March 31, annually. Note: If the permittee wishes to apply for an alternative mercury effluent limitation, that application is due with the application for permit reissuance by 6 months prior to permit expiration. The permittee should submit or reference the PMP plan as updated by the Annual Status Report or more recent developments as part of that application.	

6.2 Chloride Target Value

As a condition of the variance to the water quality based effluent limitation(s) for chloride granted in accordance with s. NR 106.83(2), Wis. Adm. Code, the permittee shall perform the following actions.

Required Action	Date Due
Annual Chloride Progress Report: Submit an annual progress report, that shall indicate which chloride source reduction measures have been implemented. The report shall also include a calculated annual mass discharge of chloride based on chloride sampling and flow data. After the first progress report is submitted, the permittee may submit a written request to the department to waive further annual progress reports. If after evaluating the progress of the source reduction measures, the department decides to accommodate the request, the department shall notify the permittee in writing that the subsequent annual reports are waived. The Final Chloride Report cannot be waived and shall be submitted by the Date Due. Note that the interim limitation of 481 mg/L remains enforceable until 6/30/2014, when the target value of 430 mg/L becomes effective. The first annual chloride progress report is to be submitted by the Date Due.	06/30/2010
Annual Chloride Progress Report #2: Submit a chloride progress report.	06/30/2011
Annual Chloride Progress Report #3: Submit a chloride progress report.	06/30/2012
Annual Chloride Progress Report #4: Submit a chloride progress report.	06/30/2013
Final Chloride Report: Submit a final report documenting the success in meeting the chloride target value of 430 mg/L, as well as the anticipated future reduction in chloride sources and chloride effluent concentrations. This report shall also include proposed target values and source reduction measures for negotiations with the department if the permittee intends to seek a renewed chloride variance per s. NR 106.83, Wis. Adm. Code, for the reissued permit. Note that the target value is the benchmark for evaluating the effectiveness of the chloride source reduction measures, but is not an enforceable limitation until the last day of this permit, 06/30/2014.	06/30/2014

7 Standard Requirements

NR 205, Wisconsin Administrative Code: The conditions in ss. NR 205.07(1) and NR 205.07(2), Wis. Adm. Code, are included by reference in this permit. The permittee shall comply with all of these requirements. Some of these requirements are outlined in the Standard Requirements section of this permit. Requirements not specifically outlined in the Standard Requirement section of this permit can be found in ss. NR 205.07(1) and NR 205.07(2).

7.1 Reporting and Monitoring Requirements

7.1.1 Monitoring Results

Monitoring results obtained during the previous month shall be summarized and reported on a Department Wastewater Discharge Monitoring Report. The report may require reporting of any or all of the information specified below under 'Recording of Results'. This report is to be returned to the Department no later than the date indicated on the form. When submitting a paper Discharge Monitoring Report form, the original and one copy of the Wastewater Discharge Monitoring Report Form shall be submitted to the return address printed on the form. A copy of the Wastewater Discharge Monitoring Report Form or an electronic file of the report shall be retained by the permittee.

All Wastewater Discharge Monitoring Reports submitted to the Department should be submitted using the electronic Discharge Monitoring Report system. Permittees who may be unable to submit Wastewater Discharge Monitoring Reports electronically may request approval to submit paper DMRs upon demonstration that electronic reporting is not feasible or practicable.

If the permittee monitors any pollutant more frequently than required by this permit, the results of such monitoring shall be included on the Wastewater Discharge Monitoring Report.

The permittee shall comply with all limits for each parameter regardless of monitoring frequency. For example, monthly, weekly, and/or daily limits shall be met even with monthly monitoring. The permittee may monitor more frequently than required for any parameter.

An Electronic Discharge Monitoring Report Certification sheet shall be signed and submitted with each electronic Discharge Monitoring Report submittal. This certification sheet, which is not part of the electronic report form, shall be signed by a principal executive officer, a ranking elected official or other duly authorized representative and shall be mailed to the Department at the time of submittal of the electronic Discharge Monitoring Report. The certification sheet certifies that the electronic report form is true, accurate and complete. Paper reports shall be signed by a principal executive officer, a ranking elected official, or other duly authorized representative.

7.1.2 Sampling and Testing Procedures

Sampling and laboratory testing procedures shall be performed in accordance with Chapters NR 218 and NR 219, Wis. Adm. Code and shall be performed by a laboratory certified or registered in accordance with the requirements of ch. NR 149, Wis. Adm. Code. Groundwater sample collection and analysis shall be performed in accordance with ch. NR 140, Wis. Adm. Code. The analytical methodologies used shall enable the laboratory to quantitate all substances for which monitoring is required at levels below the effluent limitation. If the required level cannot be met by any of the methods available in NR 219, Wis. Adm. Code, then the method with the lowest limit of detection shall be selected. Additional test procedures may be specified in this permit.

7.1.3 Pretreatment Sampling Requirements

Sampling for pretreatment parameters (cadmium, chromium, copper, lead, nickel, zinc, and mercury) shall be done during a day each month when industrial discharges are occurring at normal to maximum levels. The sampling of the influent and effluent for these parameters shall be coordinated. All 24 hour composite samples shall be flow proportional.

7.1.4 Recording of Results

The permittee shall maintain records which provide the following information for each effluent measurement or sample taken:

- the date, exact place, method and time of sampling or measurements;
- the individual who performed the sampling or measurements;
- the date the analysis was performed;
- the individual who performed the analysis;
- the analytical techniques or methods used; and
- the results of the analysis.

7.1.5 Reporting of Monitoring Results

The permittee shall use the following conventions when reporting effluent monitoring results:

- Pollutant concentrations less than the limit of detection shall be reported as < (less than) the value of the limit of detection. For example, if a substance is not detected at a detection limit of 0.1 mg/L, report the pollutant concentration as < 0.1 mg/L.

- Pollutant concentrations equal to or greater than the limit of detection, but less than the limit of quantitation, shall be reported and the limit of quantitation shall be specified.

- For the purposes of reporting a calculated result, average or a mass discharge value, the permittee may substitute a 0 (zero) for any pollutant concentration that is less than the limit of detection. However, if the effluent limitation is less than the limit of detection, the department may substitute a value other than zero for results less than the limit of detection, after considering the number of monitoring results that are greater than the limit of detection and if warranted when applying appropriate statistical techniques.

7.1.6 Compliance Maintenance Annual Reports

Compliance Maintenance Annual Reports (CMAR) shall be completed using information obtained over each calendar year regarding the wastewater conveyance and treatment system. The CMAR shall be submitted by the permittee in accordance with ch. NR 208, Wis. Adm. Code, by June 30, each year on an electronic report form provided by the Department.

In the case of a publicly owned treatment works, a resolution shall be passed by the governing body and submitted as part of the CMAR, verifying its review of the report and providing responses as required. Private owners of wastewater treatment works are not required to pass a resolution; but they must provide an Owner Statement and responses as required, as part of the CMAR submittal.

A separate CMAR certification document, that is not part of the electronic report form, shall be mailed to the Department at the time of electronic submittal of the CMAR. The CMAR certification shall be signed and submitted by an authorized representative of the permittee. The certification shall be submitted by mail. The certification shall verify the electronic report is complete, accurate and contains information from the owner's treatment works.

7.1.7 Records Retention

The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by the permit, and records of all data used to complete the application for the permit for a period of at least 3 years from the date of the sample, measurement, report or application. All pertinent sludge information, including permit application information and other documents specified in this permit or s. NR 204.06(9), Wis. Adm. Code shall be retained for a minimum of 5 years.

7.1.8 Other Information

Where the permittee becomes aware that it failed to submit any relevant facts in a permit application or submitted incorrect information in a permit application or in any report to the Department, it shall promptly submit such facts or correct information to the Department.

7.2 System Operating Requirements

7.2.1 Noncompliance Notification

- The permittee shall report the following types of noncompliance by a telephone call to the Department's regional office within 24 hours after becoming aware of the noncompliance:
  - any noncompliance which may endanger health or the environment;
  - any violation of an effluent limitation resulting from an unanticipated bypass;
  - any violation of an effluent limitation resulting from an upset; and
  - any violation of a maximum discharge limitation for any of the pollutants listed by the Department in the permit, either for effluent or sludge.

- A written report describing the noncompliance shall also be submitted to the Department's regional office within 5 days after the permittee becomes aware of the noncompliance. On a case-by-case basis, the Department may waive the requirement for submittal of a written report within 5 days and instruct the permittee to submit the written report with the next regularly scheduled monitoring report. In either case, the written report shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times; the steps taken or planned to reduce, eliminate and prevent reoccurrence of the noncompliance; and if the noncompliance has not been corrected, the length of time it is expected to continue.

NOTE: Section 292.11(2)(a), Wisconsin Statutes, requires any person who possesses or controls a hazardous substance or who causes the discharge of a hazardous substance to notify the Department of Natural Resources **immediately** of any discharge not authorized by the permit. The discharge of a hazardous substance that is not authorized by this permit or that violates this permit may be a hazardous substance spill. To report a hazardous substance spill, call DNR's 24-hour HOTLINE at **1-800-943-0003**

7.2.2 Flow Meters

Flow meters shall be calibrated annually, as per s. NR 218.06, Wis. Adm. Code.

7.2.3 Raw Grit and Screenings

All raw grit and screenings shall be disposed of at a properly licensed solid waste facility or picked up by a licensed waste hauler. If the facility or hauler are located in Wisconsin, then they shall be licensed under chs. NR 500-536, Wis. Adm. Code.

7.2.4 Sludge Management

All sludge management activities shall be conducted in compliance with ch. NR 204 "Domestic Sewage Sludge Management", Wis. Adm. Code.

7.2.5 Prohibited Wastes

Under no circumstances may the introduction of wastes prohibited by s. NR 211.10, Wis. Adm. Code, be allowed into the waste treatment system. Prohibited wastes include those:

- which create a fire or explosion hazard in the treatment work;
- which will cause corrosive structural damage to the treatment work;
- solid or viscous substances in amounts which cause obstructions to the flow in sewers or interference with the proper operation of the treatment work;
- wastewaters at a flow rate or pollutant loading which are excessive over relatively short time periods so as to cause a loss of treatment efficiency; and
- changes in discharge volume or composition from contributing industries which overload the treatment works or cause a loss of treatment efficiency.

7.2.6 Unscheduled Bypassing

Any unscheduled bypass or overflow of wastewater at the treatment works or from the collection system is prohibited, and the Department may take enforcement action against a permittee for such occurrences under s. 283.89, Wis. Stats., unless:

- The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
- There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and
- The permittee notified the Department as required in this Section.

Whenever there is an unscheduled bypass or overflow occurrence at the treatment works or from the collection system, the permittee shall notify the Department within 24 hours of initiation of the bypass or overflow occurrence by telephoning the wastewater staff in the regional office as soon as reasonably possible (FAX, email or voice mail, if staff are unavailable).

In addition, the permittee shall within 5 days of conclusion of the bypass or overflow occurrence report the following information to the Department in writing:

- Reason the bypass or overflow occurred, or explanation of other contributing circumstances that resulted in the overflow event. If the overflow or bypass is associated with wet weather, provide data on the amount and duration of the rainfall or snow melt for each separate event.
- Date the bypass or overflow occurred.
- Location where the bypass or overflow occurred.
- Duration of the bypass or overflow and estimated wastewater volume discharged.
- Steps taken or the proposed corrective action planned to prevent similar future occurrences.
- Any other information the permittee believes is relevant.

7.2.7 Scheduled Bypassing

Any construction or normal maintenance which results in a bypass of wastewater from a treatment system is prohibited unless authorized by the Department in writing. If the Department determines that there is significant public interest in the proposed action, the Department may schedule a public hearing or notice a proposal to approve the bypass. Each request shall specify the following minimum information:

- proposed date of bypass;
- estimated duration of the bypass;

- estimated volume of the bypass;
- alternatives to bypassing; and
- measures to mitigate environmental harm caused by the bypass.

7.2.8 Proper Operation and Maintenance

The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control which are installed or used by the permittee to achieve compliance with the conditions of this permit. The wastewater treatment facility shall be under the direct supervision of a state certified operator as required in s. NR 108.06(2), Wis. Adm. Code. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training as required in ch. NR 114, Wis. Adm. Code, and adequate laboratory and process controls, including appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems only when necessary to achieve compliance with the conditions of the permit.

7.3 Surface Water Requirements

7.3.1 Permittee-Determined Limit of Quantitation Incorporated into this Permit

For pollutants with water quality-based effluent limits below the Limit of Quantitation (LOQ) in this permit, the LOQ calculated by the permittee and reported on the Discharge Monitoring Reports (DMRs) is incorporated by reference into this permit. The LOQ shall be reported on the DMRs, shall be the lowest quantifiable level practicable, and shall be no greater than the minimum level (ML) specified in or approved under 40 CFR Part 136 for the pollutant at the time this permit was issued, unless this permit specifies a higher LOQ.

7.3.2 Appropriate Formulas for Effluent Calculations

The permittee shall use the following formulas for calculating effluent results to determine compliance with average limits and mass limits:

Weekly/Monthly average concentration = the sum of all daily results for that week/month, divided by the number of results during that time period.

Weekly Average Mass Discharge (lbs/day): Daily mass = daily concentration (mg/L) x daily flow (MGD) x 8.34, then average the daily mass values for the week.

Monthly Average Mass Discharge (lbs/day): Daily mass = daily concentration (mg/L) x daily flow (MGD) x 8.34, then average the daily mass values for the month.

7.3.3 Visible Foam or Floating Solids

There shall be no discharge of floating solids or visible foam in other than trace amounts.

7.3.4 Percent Removal

During any 30 consecutive days, the average effluent concentrations of BOD_5 and of total suspended solids shall not exceed 15% of the average influent concentrations, respectively. This requirement does not apply to removal of total suspended solids if the permittee operates a lagoon system and has received a variance for suspended solids granted under NR 210.07(2), Wis. Adm. Code.

7.3.5 Fecal Coliforms

The limit for fecal coliforms shall be expressed as a monthly geometric mean.

7.3.6 Seasonal Disinfection

Disinfection shall be provided from May 1 through September 30 of each year. Monitoring requirements and the limitation for fecal coliforms apply only during the period in which disinfection is required. Whenever chlorine is used for disinfection or other uses, the limitations and monitoring requirements for residual chlorine shall apply. A dechlorination process shall be in operation whenever chlorine is used.

7.3.7 Whole Effluent Toxicity (WET) Monitoring Requirements

In order to determine the potential impact of the discharge on aquatic organisms, static-renewal toxicity tests shall be performed on the effluent in accordance with the procedures specified in the *"State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition" (PUB-WT-797*, November 2004) as required by NR 219.04, Table A, Wis. Adm. Code). All of the WET tests required in this permit, including any required retests, shall be conducted on the *Ceriodaphnia dubia* and fathead minnow species. Receiving water samples shall not be collected from any point in contact with the permittee's mixing zone and every attempt shall be made to avoid contact with any other discharge's mixing zone.

7.3.8 Whole Effluent Toxicity (WET) Identification and Reduction

Within 60 days of a retest which showed positive results, the permittee shall submit a written report to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., PO Box 7921, Madison, WI 53707-7921, which details the following:

- A description of actions the permittee has taken or will take to remove toxicity and to prevent the recurrence of toxicity;
- A description of toxicity reduction evaluation (TRE) investigations that have been or will be done to identify potential sources of toxicity, including some or all of the following actions:
  - (a) Evaluate the performance of the treatment system to identify deficiencies contributing to effluent toxicity (e.g., operational problems, chemical additives, incomplete treatment)
  - (b) Identify the compound(s) causing toxicity
  - (c) Trace the compound(s) causing toxicity to their sources (e.g., industrial, commercial, domestic)
  - (d) Evaluate, select, and implement methods or technologies to control effluent toxicity (e.g., in-plant or pretreatment controls, source reduction or removal)
- Where corrective actions including a TRE have not been completed, an expeditious schedule under which corrective actions will be implemented;
- If no actions have been taken, the reason for not taking action.

The permittee may also request approval from the Department to postpone additional retests in order to investigate the source(s) of toxicity. Postponed retests must be completed after toxicity is believed to have been removed.

7.3.9 Whole Effluent Toxicity (WET) and Chloride Source Reduction Measures

Acute whole effluent toxicity testing requirements and acute whole effluent toxicity limitations may be held in abeyance by the department until chloride source reduction actions are completed, according to s. NR 106.89, Wis. Adm. Code, if either:

- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride exceeds 2,500 mg/L, or
- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride is less than 2,500 mg/L, but in excess of the calculated acute water quality-based effluent limitation, and additional data are submitted which demonstrate that chloride is the sole source of acute toxicity.

Chronic whole effluent toxicity testing requirements and chronic whole effluent toxicity limitations may be held in abeyance by the department until chloride source reduction actions are completed, according to s. NR 106.89, Wis. Adm. Code, if either:

- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride exceeds 2 times the calculated chronic water quality-based effluent limitation, or
- the permittee can demonstrate to the satisfaction of the department that the effluent concentration of chloride is less than 2 times the calculated chronic water quality-based effluent limitation, but in excess of the calculated chronic water quality-based effluent limitation, and additional data are submitted which demonstrate that chloride is the sole source of chronic toxicity.

Following the completion of chloride source reduction activities, the department shall evaluate the need for whole effluent toxicity monitoring and limitations.

7.4 Pretreatment Program Requirements

The permittee is required to operate an industrial pretreatment program as described in the program initially approved by the Department of Natural Resources including any subsequent program modifications approved by the Department, and including commitments to program implementation activities provided in the permittee's annual pretreatment program report, and that complies with the requirements set forth in 40 CFR Part 403 and ch. NR 211, Wis. Adm. Code. To ensure that the program is operated in accordance with these requirements, the following general conditions and requirements are hereby established:

7.4.1 Inventories

The permittee shall implement methods to maintain a current inventory of the general character and volume of wastewater that industrial users discharge to the treatment works and shall provide an updated industrial user listing annually and report any changes in the listing to the Department by March 31 of each year as part of the annual pretreatment program report required herein.

7.4.2 Regulation of Industrial Users

7.4.2.1 Limitations for Industrial Users:

The permittee shall develop, maintain, enforce and revise as necessary local limits to implement the general and specific prohibitions of the state and federal General Pretreatment Regulations.

7.4.2.2 Control Documents for Industrial Users (IUs)

The permittee shall control the discharge from each significant industrial user through individual discharge permits as required by s. NR 211.235, Wis. Adm. Code and in accordance with the approved pretreatment program procedures and the permittee's sewer use ordinance. The discharge permits shall be modified in a timely manner during the stated term of the discharge permits according to the sewer use ordinance as conditions warrant. The discharge permits shall include at a minimum the elements found in s. NR 211.235(1), Wis. Adm. Code and references to the approved pretreatment program procedures and the sewer use ordinance.

The permittee shall provide a copy of all newly issued, reissued, or modified discharge permits to the Department.

7.4.2.3 Review of Industrial User Reports, Inspections and Compliance Monitoring

The permittee shall require the submission of, receive, and review self-monitoring reports and other notices from industrial users in accordance with the approved pretreatment program procedures. The permittee shall randomly sample and analyze industrial user discharges and conduct surveillance activities to determine independent of information supplied by the industrial users, whether the industrial users are in compliance with pretreatment standards and requirements. The inspections and monitoring shall also be conducted to maintain accurate knowledge of local industrial processes, including changes in the discharge, pretreatment equipment operation, spill prevention control plans, slug control plans, and implementation of solvent management plans.

At least one time per year the permittee shall inspect and sample the discharge from each significant industrial user, or more frequently if so specified in the permittee's approved pretreatment program. At least once every 2 years the permittee shall evaluate whether each significant industrial user needs a slug control plan. If a slug control plan is needed, the plan shall contain at a minimum the elements specified in s. NR 211.235(4)(b), Wis. Adm. Code.

7.4.2.4 Enforcement and Industrial User Compliance Evaluation & Violation Reports

The permittee shall enforce the industrial pretreatment requirements including the industrial user discharge limitations of the permittee's sewer use ordinance. The permittee shall investigate instances of noncompliance by collecting and analyzing samples and collecting other information with sufficient care to produce evidence admissible in enforcement proceedings or in judicial actions. Investigation and response to instances of noncompliance shall be in accordance with the permittee's sewer use ordinance and approved Enforcement Response Plan.

The permittee shall make a semiannual report on forms provided or approved by the Department. The semiannual report shall include an analysis of industrial user significant noncompliance (i.e. the Industrial User Compliance Evaluation, also known as the SNC Analysis) as outlined in s.NR 211.23(1)(j), Wis. Adm. Code, and a summary of the permittee's response to all industrial noncompliance (i.e. the Industrial User Violation Report). The Industrial User Compliance Evaluation Report shall include monitoring results received from industrial users pursuant to s. NR 211.15(1)-(5), Wis. Adm. Code. The Industrial User Violation Report shall include copies of all notices of noncompliance, notices of violation and other enforcement correspondence sent by the permittee to industrial users, together with the industrial user's response. The Industrial User Compliance Evaluation and Violation Reports for the period January through June shall be provided to the Department by September 30 of each year and for the period July through December shall be provided to the Department by March 31 of the succeeding year, unless alternate submittal dates are approved.

7.4.2.5 Publication of Violations

The permittee shall publish a list of industrial users that have significantly violated the municipal sewer use ordinance during the calendar year, in the largest daily newspaper in the area by March 31 of the following year pursuant to s. NR 211.23(1)(j), Wis. Adm. Code. A copy of the newspaper publication shall be provided as part of the annual pretreatment report specified herein.

7.4.2.6 Multijurisdictional Agreements

The permittee shall establish agreements with all contributing jurisdictions as necessary to ensure compliance with pretreatment standards and requirements by all industrial users discharging to the permittee's wastewater treatment system. Any such agreement shall identify who will be responsible for maintaining the industrial user inventory, issuance of industrial user control mechanisms, inspections and sampling, pretreatment program implementation, and enforcement.

7.4.3 Annual Pretreatment Program Report

The permittee shall evaluate the pretreatment program, and submit the Pretreatment Program Report to the Department on forms provided or approved by the Department by March 31 annually, unless an alternate submittal date is approved. The report shall include a brief summary of the work performed during the preceding calendar year, including the numbers of discharge permits issued and in effect, pollution prevention activities, number of inspections and monitoring surveys conducted, budget and personnel assigned to the program, a general discussion of program progress in meeting the objectives of the permittee's pretreatment program together with summary comments and recommendations.

7.4.4 Pretreatment Program Modifications

- Future Modifications: The permittee shall within one year of any revisions to federal or state General Pretreatment Regulations submit an application to the Department in duplicate to modify and update its approved pretreatment program to incorporate such regulatory changes as applicable to the permittee. Additionally, the Department or the permittee may request an application for program modification at any time where necessary to improve program effectiveness based on program experience to date.

- Modifications Subject to Department Approval: The permittee shall submit all proposed pretreatment program modifications to the Department for determination of significance and opportunity for comment in accordance with the requirements and conditions of s. NR 211.27, Wis. Adm. Code. Any substantial proposed program modification shall be subject to Department public noticing and formal approval prior to implementation. A substantial program modification includes, but is not limited to, changes in enabling legal authority to administer and enforce pretreatment conditions and requirements; significant changes in program administrative or operational procedures; significant reductions in monitoring frequencies; significant reductions in program resources including personnel commitments, equipment, and funding levels; changes (including any relaxation) in the local limitations for substances enforced and applied to users of the sewerage treatment works; changes in treatment works sludge disposal or management practices which impact the pretreatment program; or program modifications which increase pollutant loadings to the treatment works. The Department shall use the procedures outlined in s. NR 211.30, Wis. Adm. Code for review and approval/denial of proposed pretreatment program modifications. The permittee shall comply with local public participation requirements when implementing the pretreatment program.

7.4.5 Program Resources

The permittee shall have sufficient resources and qualified personnel to carry out the pretreatment program responsibilities as listed in ss. NR 211.22 and NR 211.23, Wis. Adm. Code.

7.5 Land Treatment (Land Disposal) Requirements

7.5.1 Application of NR 140 to Substances Discharged

This permit does not authorize the permittee to discharge any substance in a concentration which would cause an applicable groundwater standard of ch. NR 140, Wis. Adm. Code, to be exceeded. The Department may seek a response under NR 140 if the permittee's discharge causes exceedance of an applicable groundwater standard for any substance, including substances not specifically limited or monitored under this permit

7.5.2 Appropriate Formulas for Nitrogen

Total Nitrogen = Total Kjeldahl Nitrogen (mg/L) + [NO_2 + NO_3] Nitrogen (mg/L)

Organic Nitrogen (mg/L) = Total Kjeldahl Nitrogen (mg/L) - Ammonia Nitrogen (mg/L)

7.5.3 Toxic or Hazardous Pollutants

The discharge of toxic or hazardous pollutants to land treatment systems is prohibited unless the applicant can demonstrate and the department determines that the discharge of such pollutants will be in such small quantities that no detrimental effect on groundwater or surface water will result pursuant to s. NR 206.07(2)(c), Wis. Adm. Code. The criteria used shall include but not be limited to the toxicity of the pollutant, capacity of the soil to remove the pollutant, degradability, usual or potential presence of the pollutant in the existing environment, method of application and all other relevant factors.

7.5.4 Industrial Waste - Pretreatment Requirements

Industrial waste discharges tributary to municipal land treatment systems shall be in compliance with the applicable pretreatment standards under ch. NR 211 Wis. Adm. Code pursuant to s. NR 206.07(2)(e), Wis. Adm. Code.

7.5.5 Overflow

Discharge to a land treatment system shall be limited so that the discharge and any precipitation which falls within the boundary of the disposal system during such discharge does not overflow the boundary of the system unless the WPDES permit authorizes collection and discharge of runoff to surface water pursuant to s. NR 206.07(2)(g), Wis. Adm. Code.

7.5.6 Management Plan Requirements

All land treatment systems shall be operated in accordance with an approved management plan. The management plan shall conform to the requirements of s. NR 110.25(3m), Wis. Adm. Code, per s. NR 206.07(2)(h), Wis. Adm. Code

7.5.7 Monthly Average Hydraulic Application Rate

Determine the monthly average hydraulic application rate (in gal/acre/day) for each outfall by calculating the total gallons of wastewater applied onto the site for the month, dividing that total by the number of wetted acres loaded during the month, and then dividing this resulting value by the number of days in the month. Enter this calculated monthly average value on the Discharge Monitoring Report form in the box for the last day of the month, in the "Hydraulic Application Rate" column.

7.5.8 Nitrogen Loading Requirements for Spray Irrigation

The annual total pounds of nitrogen applied to the irrigation acreage shall be restricted to the annual nitrogen needs of the cover crop as specified in the irrigation annual report table. The Department may approve an alternate nitrogen loading limit in the management plan, pursuant to s. NR 206.06, Wis. Adm. Code.

7.5.9 Runoff

Discharge shall be limited to prevent any runoff of effluent from the spray irrigation site. Wastewater may not be sprayed during any rainfall event that causes runoff from the site, pursuant to s. NR 206.08(2)(b)1,Wis. Adm. Code.

7.5.10 Ponding

The volume of discharge to a spray irrigation system shall be limited to prevent ponding, except for temporary conditions following rainfall events, pursuant to s. NR 206.08(2)(b)2, Wis. Adm. Code.

7.5.11 Frozen Ground

Spray irrigation onto frozen ground is prohibited, pursuant to s. NR 110.255(2)(a)2, Wis. Adm. Code.

7.5.12 Land Treatment Annual Report

Annual Land Treatment Reports are due by January 31st of each year for the previous calendar year.

7.6 Land Application Requirements

7.6.1 Sludge Management Program Standards And Requirements Based Upon Federally Promulgated Regulations

In the event that new federal sludge standards or regulations are promulgated, the permittee shall comply with the new sludge requirements by the dates established in the regulations, if required by federal law, even if the permit has not yet been modified to incorporate the new federal regulations.

7.6.2 General Sludge Management Information

The General Sludge Management Form 3400-48 shall be completed and submitted prior to any significant sludge management changes.

7.6.3 Sludge Samples

All sludge samples shall be collected at a point and in a manner which will yield sample results which are representative of the sludge being tested, and collected at the time which is appropriate for the specific test.

7.6.4 Land Application Characteristic Report

Each report shall consist of a Characteristic Form 3400-49 and Lab Report, unless approval for not submitting the lab reports has been given. Both reports shall be submitted by January 31 following each year of analysis.

The permittee shall use the following convention when reporting sludge monitoring results: Pollutant concentrations less than the limit of detection shall be reported as < (less than) the value of the limit of detection. For example, if a substance is not detected at a detection limit of 1.0 mg/kg, report the pollutant concentration as < 1.0 mg/kg .

All results shall be reported on a dry weight basis.

7.6.5 Calculation of Water Extractable Phosphorus

The permittee shall use the following formula to calculate and report Water Extractable Phosphorus:
Water Extractable Phosphorus (% of Total P) =
[Water Extractable Phosphorus (mg/kg, dry wt) ÷ Total Phosphorus (mg/kg, dry wt)] x 100

7.6.6 Monitoring and Calculating PCB Concentrations in Sludge

When sludge analysis for "PCB, Total Dry Wt" is required by this permit, the PCB concentration in the sludge shall be determined as follows.

Either congener-specific analysis or Aroclor analysis shall be used to determine the PCB concentration. The permittee may determine whether Aroclor or congener specific analysis is performed. Analyses shall be performed in accordance with the following provisions and Table EM in s. NR 219.04, Wis. Adm. Code.

- EPA Method 1668 may be used to test for all PCB congeners. If this method is employed, all PCB congeners shall be delineated. Non-detects shall be treated as zero. The values that are between the limit of detection and the limit of quantitation shall be used when calculating the total value of all congeners. All results shall be added together and the total PCB concentration by dry weight reported. **Note**: It is recognized that a number of the congeners will co-elute with others, so there will not be 209 results to sum.
- EPA Method 8082A shall be used for PCB-Aroclor analysis and may be used for congener specific analysis as well. If congener specific analysis is performed using Method 8082A, the list of congeners tested shall include at least congener numbers 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187, and 206 plus any other additional congeners which might be reasonably expected to occur in the particular sample. For either type of analysis, the sample shall be extracted using the Soxhlet extraction (EPA Method 3540C) (or the Soxhlet Dean-Stark modification) or the pressurized fluid extraction (EPA Method 3545A). If Aroclor analysis is performed using Method 8082A, clean up steps of the extract shall be performed as necessary to remove interference and to achieve as close to a limit of detection of 0.11 mg/kg as possible. Reporting protocol, consistent with s. NR 106.07(6)(e), should be as follows: If all Aroclors are less than the LOD, then the Total PCB Dry Wt result should be reported as less than the highest LOD. If a single Aroclor is detected then that is what should be reported for the Total PCB result. If multiple Aroclors are detected, they should be summed and reported as Total PCBs. If congener specific analysis is done using Method 8082A, clean up steps of the extract shall be performed as necessary to remove interference and to achieve as close to a limit of detection of 0.003 mg/kg as possible for each congener. If the aforementioned limits of detection cannot be achieved after using the appropriate clean up techniques, a reporting limit that is achievable for the Aroclors or each congener for the sample shall be determined. This reporting limit shall be reported and qualified indicating the presence of an interference. The lab conducting the analysis shall perform as many of the following methods as necessary to remove interference:

3620C – Florisil	3611B - Alumina
3640A - Gel Permeation	3660B - Sulfur Clean Up (using copper shot instead of powder)
3630C - Silica Gel	3665A - Sulfuric Acid Clean Up

7.6.7 Land Application Report

Land Application Report Form 3400-55 shall be submitted by January 31, following each year non-exceptional quality sludge is land applied. Non-exceptional quality sludge is defined in s. NR 204.07(4), Wis. Adm. Code.

7.6.8 Other Methods of Disposal or Distribution Report

The permittee shall submit Report Form 3400-52 by January 31, following each year sludge is hauled, landfilled, incinerated, or when exceptional quality sludge is distributed or land applied.

7.6.9 Approval to Land Apply

Bulk non-exceptional quality sludge as defined in s. NR 204.07(4), Wis. Adm. Code, may not be applied to land without a written approval letter or Form 3400-122 from the Department unless the Permittee has obtained permission from the Department to self approve sites in accordance with s. NR 204.06 (6), Wis. Adm. Code. Analysis of sludge characteristics is required prior to land application. Application on frozen or snow covered ground is restricted to the extent specified in s. NR 204.07(3) (l), Wis. Adm. Code.

7.6.10 Soil Analysis Requirements

Each site requested for approval for land application must have the soil tested prior to use. Each approved site used for land application must subsequently be soil tested such that there is at least one valid soil test in the four years prior to land application. All soil sampling and submittal of information to the testing laboratory shall be done in accordance with UW Extension Bulletin A-2100. The testing shall be done by the UW Soils Lab in Madison or Marshfield, WI or at a lab approved by UW. The test results including the crop recommendations shall be submitted to the DNR contact listed for this permit, as they are available. Application rates shall be determined based on the crop nitrogen recommendations and with consideration for other sources of nitrogen applied to the site.

7.6.11 Land Application Site Evaluation

For non-exceptional quality sludge, as defined in s. NR 204.07(4), Wis. Adm. Code, a Land Application Site Request Form 3400-053 shall be submitted to the Department for the proposed land application site. The Department will evaluate the proposed site for acceptability and will either approve or deny use of the proposed site. The permittee may obtain permission to approve their own sites in accordance with s. NR 204.06(6), Wis. Adm. Code.

7.6.12 Class A Sludge: Fecal Coliform Density Requirement

The fecal coliform density which must be < 1000 MPN/g TS as required in s. NR 204.07, Wis. Adm. Code, shall be satisfied immediately after the treatment process is completed. If the material is bagged or distributed at that time, no re-testing is required. If the material is bagged, distributed or land applied at a later time, the sludge shall be re-tested and this requirement satisfied at that time also, to ensure that regrowth of bacteria has not occurred. See Municipal Wastewater Sludge Guidance Memo #3 (Fecal Coliform Monitoring - Sampling and Analytical Procedures).

7.6.13 Class A Sludge: Salmonella Density Requirements

The salmonella density which must be < 3 MPN/4 g TS as required in s. NR 204.07, Wis. Adm. Code, shall be satisfied immediately after the treatment process is completed. If the material is bagged or distributed at that time, no re-testing is required. If the material is bagged, distributed or land applied at a later time, the sludge shall be re-tested and this requirement satisfied at that time also, to ensure that regrowth of bacteria has not occurred.

7.6.14 Class B Sludge: Fecal Coliform Limitation

Compliance with the fecal coliform limitation for Class B sludge shall be demonstrated by calculating the geometric mean of at least 7 separate samples. (Note that a Total Solids analysis must be done on each sample). The geometric mean shall be less than 2,000,000 MPN or CFU/g TS. Calculation of the geometric mean can be done using one of the following 2 methods.

Method 1:
Geometric Mean = $(X_1 \times X_2 \times X_3 \ldots \times X_n)^{1/n}$
Where X = Coliform Density value of the sludge sample, and where n = number of samples (at least 7)

Method 2:
Geometric Mean = antilog$[(X_1 + X_2 + X_3 \ldots + X_n) \div n]$
Where X = $\log_{10}$ of Coliform Density value of the sludge sample, and where n = number of samples (at least 7)
Example for Method 2

Sample Number	Coliform Density of Sludge Sample	$\log_{10}$
1	6.0×10^5	5.78
2	4.2×10^6	6.62
3	1.6×10^6	6.20
4	9.0×10^5	5.95
5	4.0×10^5	5.60

6	1.0×10^6	6.00
7	5.1×10^5	5.71

The geometric mean for the seven samples is determined by averaging the $\log_{10}$ values of the coliform density and taking the antilog of that value.
$(5.78 + 6.62 + 6.20 + 5.95 + 5.60 + 6.00 + 5.71) \div 7 = 5.98$
The antilog of $5.98 = 9.5 \times 10^5$

7.6.15 Vector Control: Volatile Solids Reduction

The mass of volatile solids in the sludge shall be reduced by a minimum of 38% between the time the sludge enters the digestion process and the time it either exits the digester or a storage facility. For calculation of volatile solids reduction, the permittee shall use the Van Kleeck equation or one of the other methods described in "Determination of Volatile Solids Reduction in Digestion" by J.B. Farrell, which is Appendix C of EPA's *Control of Pathogens in Municipal Wastewater Sludge* (EPA/625/R-92/013). The Van Kleeck equation is:

$$VSR\% = \frac{VS_{IN} - VS_{OUT}}{VS_{IN} - (VS_{OUT} \times VS_{IN})} \times 100$$

Where: VS_{IN} = Volatile Solids in Feed Sludge (g VS/g TS)

VS_{OUT} = Volatile Solids in Final Sludge (g VS/g TS)

$VSR\%$ = Volatile Solids Reduction, (Percent)

7.6.16 Class B Sludge - Vector Control: Incorporation

Class B sludge shall be incorporated within 6 hours of surface application, or as approved by the Department.

8 Summary of Reports Due

FOR INFORMATIONAL PURPOSES ONLY

Description	Date	Page
Mercury Pollutant Minimization Program - Implement the Mercury Pollutant Minimization Program	See Permit	18
Mercury Pollutant Minimization Program -Submit Annual Status Reports	See Permit	18
Chloride Target Value -Annual Chloride Progress Report	June 30, 2010	18
Chloride Target Value -Annual Chloride Progress Report #2	June 30, 2011	18
Chloride Target Value -Annual Chloride Progress Report #3	June 30, 2012	18
Chloride Target Value -Annual Chloride Progress Report #4	June 30, 2013	18
Chloride Target Value -Final Chloride Report	June 30, 2014	18
Compliance Maintenance Annual Reports (CMAR)	by June 30, each year	20
Industrial User Compliance Evaluation and Violation Reports	Semiannual	26
Pretreatment Program Report	Annually	27
General Sludge Management Form 3400-48	prior to any significant sludge management changes	29
Characteristic Form 3400-49 and Lab Report	by January 31 following each year of analysis	29
Land Application Report Form 3400-55	by January 31, following each year non-exceptional quality sludge is land applied	30
Report Form 3400-52	by January 31, following each year sludge is hauled, landfilled, incinerated, or when exceptional quality sludge is distributed or land applied	30
Annual Land Treatment Reports	by January 31st of each year for the previous calendar year	29
Wastewater Discharge Monitoring Report	no later than the date indicated on the form	19

Report forms shall be submitted to the address printed on the report form. Any facility plans or plans and specifications for municipal, industrial, industrial pretreatment and non industrial wastewater systems shall be submitted to the Bureau of Watershed Management, P.O. Box 7921, Madison, WI 53707-7921. All other submittals required by this permit shall be submitted to:
Mr. Larry Benson, South Central Region, 3911 Fish Hatchery Road, Fitchburg, WI 53711-5397

APPENDIX B

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APPENDIX C

Technical Memorandum No. 1
Basis of Design

Applied Technologies
Engineers - Architects

carollo
Engineers...Working Wonders With Water™

MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 1
BASIS OF DESIGN

Date: Revised February 18, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to perform a general review of the 2005-2007 process and operating data from the Nine Springs Wastewater Treatment Plant (WWTP) and compare them to the 10th Addition Project design criteria and the 50-Year Master Plan to establish the design criteria for the Solids Handling Facilities Plan.

2.0 Summary of findings and recommendations

The key findings and recommendations of this TM are summarized below:

- The 10th Addition Report projections adequately predicted the measured 2007 influent flows and loadings. The projected influent flows and loadings obtained using a linear extrapolation of the 10th Addition Report data were comparable to the 50-Year Master Plan values.
- The influent loading peaking factors recommended in the 50-Year Master Plan are higher than the values observed in the 2007 data and the recommended values from the 10th Addition Report.
- The 50-Year Master Plan peaking factors and projected influent flow and loadings were selected as the basis of design for the Nine Springs WWTP digestion facility.
- The primary sludge (PS) and waste activated sludge (WAS) projections were estimated based on the 50-Year Master Plan projected influent flow and loadings and using a process model calibrated with 2007 data and the 10th Addition Project mass balance spread sheet.

- The analysis of the 2007 data showed an inconsistency in the primary sludge solids stream. Per discussion with the MMSD staff, the solids loading in the gravity thickeners was selected for the model calibration.

3.0 Background

The Nine Springs WWTP is a 50 mgd rated facility that is owned and operated by the Madison Metropolitan Sewerage District (MMSD). The treatment processes include primary treatment, activated sludge with biological phosphorus removal and nitrification, ultraviolet disinfection, and anaerobic digestion. Stabilized biosolids are applied to agricultural lands as a liquid (Metrogro) or are incorporated into a soil-like material (Metromix) for horticultural use.

The latest major modifications to the Nine Springs WWTP were performed under the10th Addition Improvements Project, which was designed in 2002 and substantially completed in 2006. As part of this project, the biosolids facility was converted to a temperature phased anaerobic digestion (TPAD) process to increase the digestion capacity and produce Class A biosolids. The project included the addition of a new anaerobic digester (Digester No. 7) and a high solids centrifuge to produce cake needed for the Metromix portion of the recycled biosolids material.

Severe foaming episodes and insufficient heating capacity in the thermophilic digesters led the MMSD to abandon the TPAD process and to switch operation of the digestion facility to an acid-phase process (mesophilic-thermophilic-mesophilic). During stable operation, the acid-phase digestion process showed increased biogas production, volatile solids reduction (VSR), and fecal coliform destruction. However, the digestion process was frequently interrupted due to process upset and foaming events. Another problem frequently experienced at the Nine Springs WWTP digestion facility is inorganic phosphate precipitation in the piping (struvite) and heat exchangers (vivianite or struvite). Several of these issues were attributed to the converted facilities, which did not include all the design characteristics needed for a stable acid-phase operation.

In 2008, the MMSD contracted Applied Technologies Inc. (ATI) and Carollo Engineers to develop the Nine Springs WWTP Solids Handling Facilities Plan to review available alternatives and provide a detailed recommendation of facilities necessary for a reliable, sustainable digestion process for producing Class A biosolids.

4.0 Data analysis

A general review of the process and operating data for 2005-2007 was performed and compared to the 50-Year Master Plan data to obtain the basis of design for the digestion facility.

4.1 Influent Flows and Loads

Trending of the 2005-2007 influent wastewater flow, total suspended solids (TSS), Biochemical Oxygen Demand (BOD), Total Kjeldahl Nitrogen (TKN), and total phosphorus (TP) was performed. Table 1.1 summarizes the 2007 average influent flow and loadings at Nine Springs WWTP and the projected values for 2030. A graphical representation of the data is presented in Appendix A.

The measured 2007 average influent flow and loadings were accurately estimated by the projections of the 10th Addition Report. The projected values estimated using a linear extrapolation of the 10th Addition Report data were comparable to those reported in the 50-Year Master Plan. For design purposes, the more up-to-date values and most conservative peaking factors of the 50-Year Master Plan were selected.

Table 1.1 Average Influent Flow and Loading				
Process Parameter	2007 Process Data (1)	10th Addition Projection (2)	10th Addition Projection (3)	Master Plan Projection (4)
Year	2007	2007	2030	2030
Influent Flow				
Flow, mgd	42.9	44.2	55.4	53.75 - 60.6
Peaking Factor (5)	1.28	1.15	1.15	1.25
Total Solids				
Loading, ppd	75,700	80,800	111,480	117,754
Peaking Factor (5)	1.10	1.15	1.15	1.20
Biochemical Oxygen Demand				
Loading, ppd	85,100	84,900	124,000	122,092
Peaking Factor (5)	1.12	1.15	1.15	1.20
Total Kjeldahl Nitrogen				
Loading, ppd	12,900	12,170	16,730	19,748
Peaking Factor (5)	1.04	1.10	1.10	1.20
Total Phosphorus				
Loading, ppd	2,100	2,518	3,460	2,847
Peaking Factor (5)	1.05	1.10	1.10	1.20

Notes:
(1) Based on the Nine Springs WWTP 2007 process data.
(2) Based on the 10th Addition Report.
(3) Based on linear extrapolation using projections from the 10th Addition Report.
(4) Based on the 50-year Master Plan total plant loading projection.
(5) Maximum month influent flow or loading peaking factors.

4.2 Sludge Production

The sludge production at future flow scenarios was estimated using a process model implemented in Biowin and calibrated with the 2007 Nine Springs WWTP data. After model calibration, the simulations were performed using the 50-Year Master Plan projected influent flow and loadings for 2030. Table 1.2 shows the sludge production for current and future flow conditions and compares them to MMSD Staff projections based on the 10th Addition Project mass balance spread sheet. See Appendix B for a graphical representation of the data.

Table 1.2 Sludge Production				
Process Parameter	**2007 Data (1)**	**2030 Projections**		
		Process Model	**50-Year Master Plan**	**10th Addition Spread Sheet (2)**
Influent flow, mgd	42.9	53.75 (3)	53.75 (3)	53.75 (3)
Primary Sludge				
Total Solids, ppd	60,800 (4)	83,800 (5)	N.A.	88,400 (6)
Peaking Factor (7)	1.07			
Waste Activated Sludge				
Total Solids, ppd	49,700 (8)	63,700 (5)	N.A.	72,200 (6)
Peaking Factor (7)	1.16			
Digester Feed				
Total Solids, ppd	106,300	142,000 (6)	165,476 (3)	154,500
Flow, gpd	277,100	370,300 (9)	423,257 (3)	402,900 (9)

Notes:

(1) Based on the Nine Springs WWTP 2007 process data.
(2) Based on the 10th Addition Model Results provided by MMSD staff.
(3) Based on the 50-Year Master Plan projections.
(4) Based on gravity thickener solids loading and MMSD staff communication.
(5) Based on the process model results.

(6) Based on the 2007 data average solids capture efficiency of gravity thickening and DAFT of 98 and 94 percent, respectively.
(7) Maximum month loading peaking factors based on 2007 process data.
(8) Based on dissolved air flotation thickener solids loading.
(9) Based on the 2007 data average total solids concentration of 4.6 percent.

The sludge projections based on the Biowin simulations were lower than the 10th Addition Report design values of 154,500 ppd and 389,000 gpd. The sludge projections based on the 10th Addition Mass Balance spread sheet were selected as basis of design for the MMSD Solids Handling Facilities Plan. A detailed evaluation of capacity of the Nine Springs WWTP digestion facility is included in TM No. 3 Anaerobic Digestion Process Evaluation.

5.0 Summary of the basis of design

Based on the Nine Springs WWTP 2005-2007 process and operating data, the 10th Addition Report, and the 50-Year Master Plan technical memoranda, the recommended parameters for use as the basis of design for the anaerobic digestion process are summarized in Table 1.3.

Table 1.3 Summary of Basis of Design				
	2007 Conditions		2030 Conditions (1)	
Process Parameter	**Average**	**Max Month (2)**	**Average**	**Max Month (2)**
Flow, mgd	42.9	54.8	53.8	67.2
TSS Loading, ppd	75,700	90,800	117,800	141,400
BOD Loading, ppd	85,100	102,100	122,100	146,500
N Loading, ppd	12,900	15,500	19,800	23,800
P Loading, ppd	2,100	2,300	2,900	3,200
Total Solids, ppd	60,800	73,000	88,400	105,600
Total Solids, ppd	49,700	59,600	72,200	85,400
Total Solids, ppd	106,300	127,600	154,500	183,800
Volatile Solids, ppd (3)	80,800	97,000	117,400	139,700

Notes:

(1) Based on the 50-Year Master Plan

(2) Based on the 50-Year Master Plan recommended 30-day peaking factors for influent flow (1.25), and TSS (1.20), BOD (1.20), TKN (1.20), and phosphorus (1.10) loadings and a maximum month peaking factor of 1.20 for primary sludge, WAS, and thickened sludge loadings.

(3) Based on the 2007 process data average thickened sludge volatile solids concentration of 76 percent.

APPENDIX A
2005-2007 INFLUENT DATA ANALYSIS

Figure A1
Daily influent flow to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

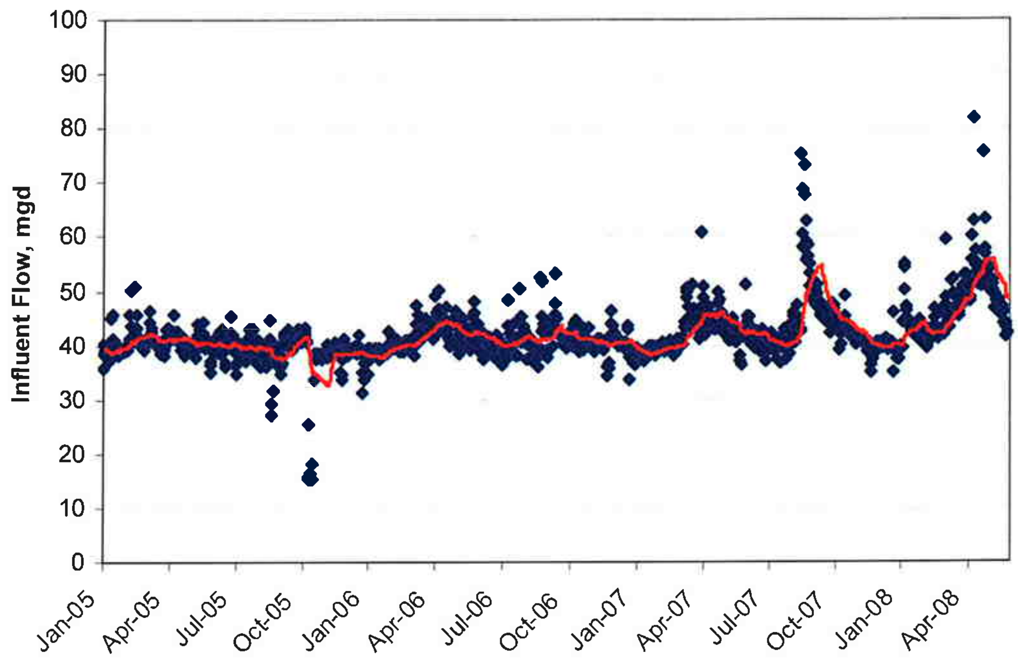


Figure A2
Daily total suspended solids (TSS) concentration in the influent to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

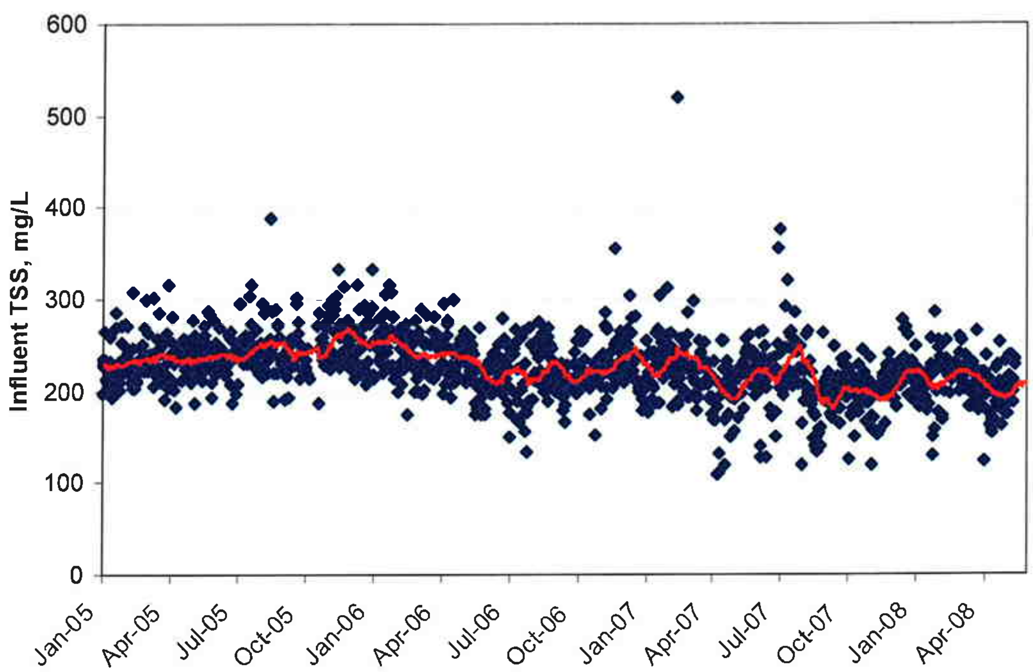


Figure A3
Daily influent TSS loading to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

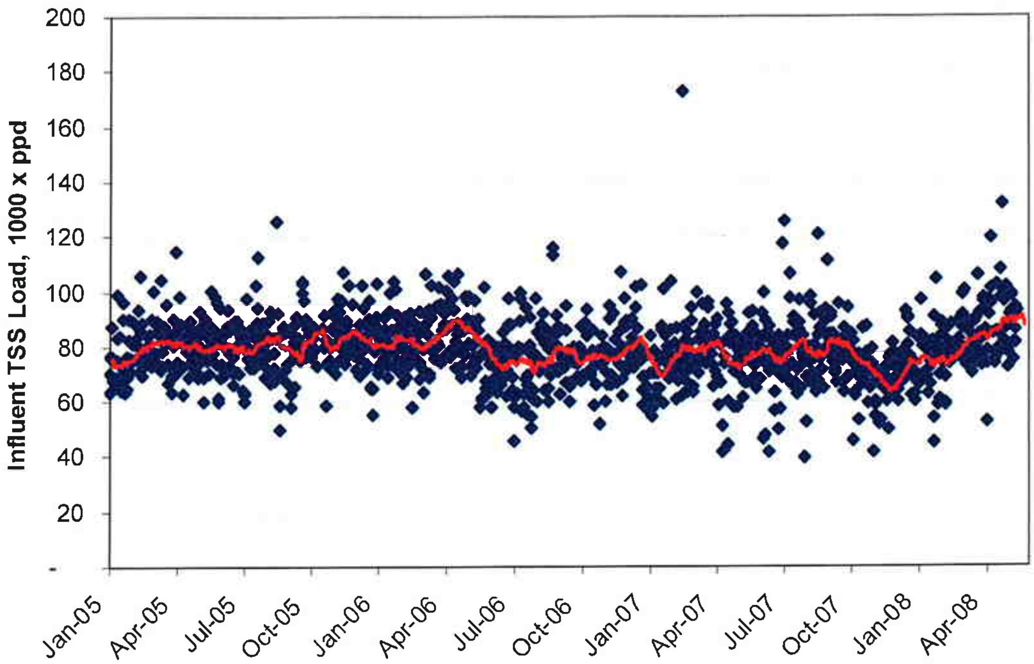


Figure A4
Daily BOD concentration in the influent to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

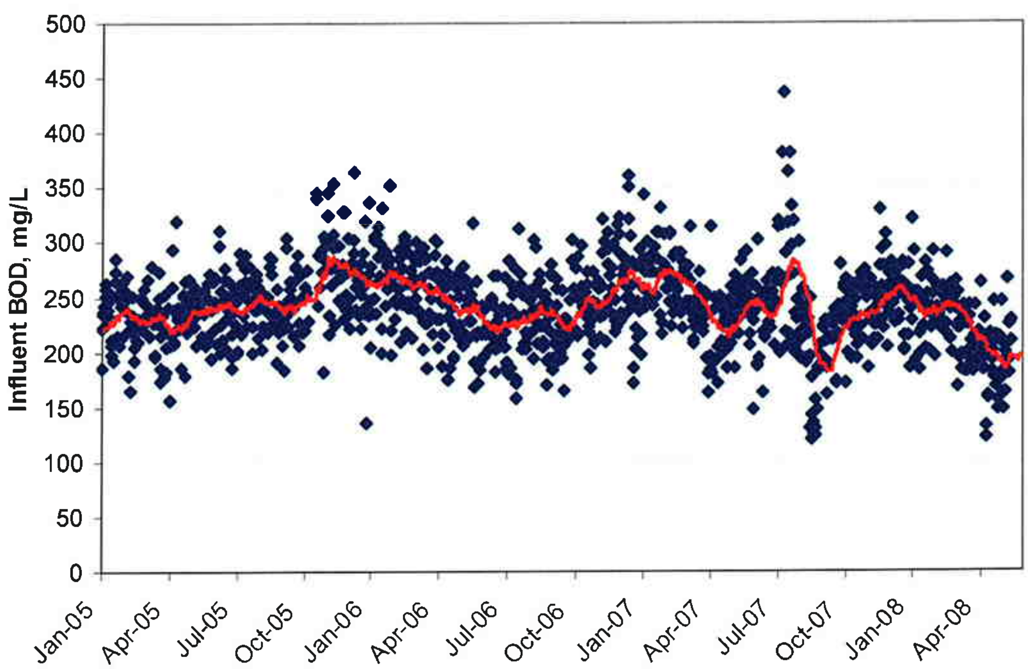


Figure A5
Daily influent BOD loading to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

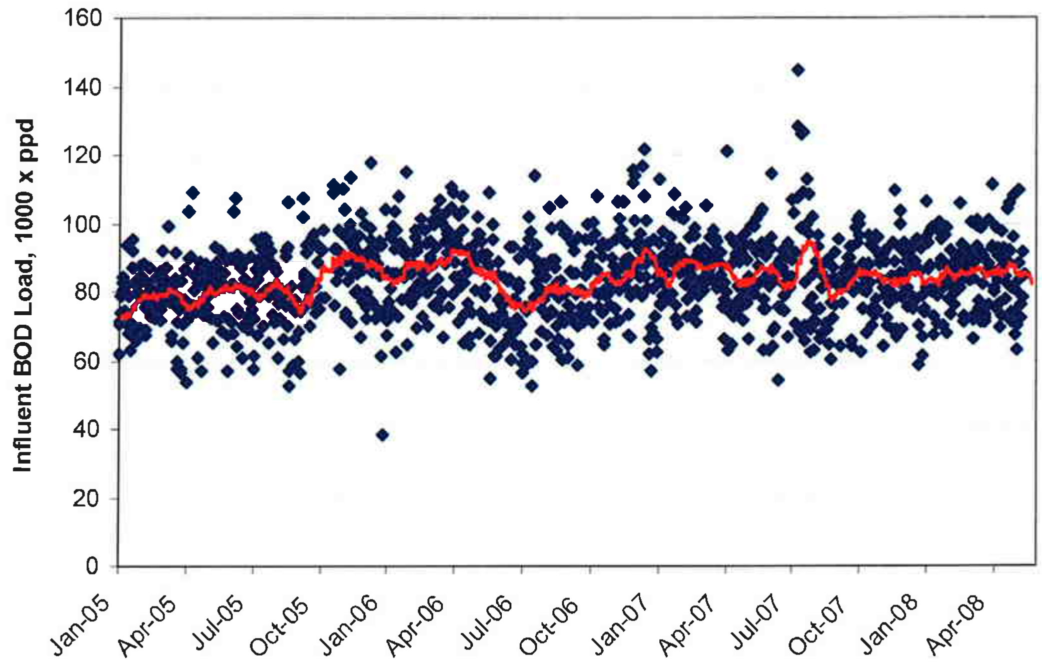


Figure A6
Daily Total Kjeldahl Nitrogen (TKN) concentration in the influent to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

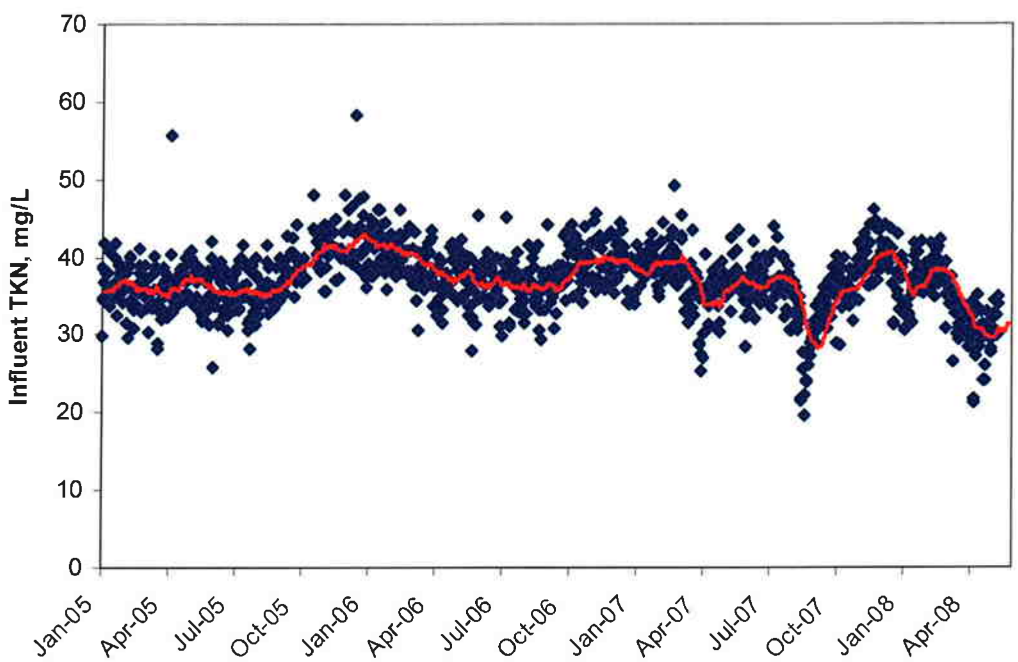


Figure A7
Daily influent nitrogen loading to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

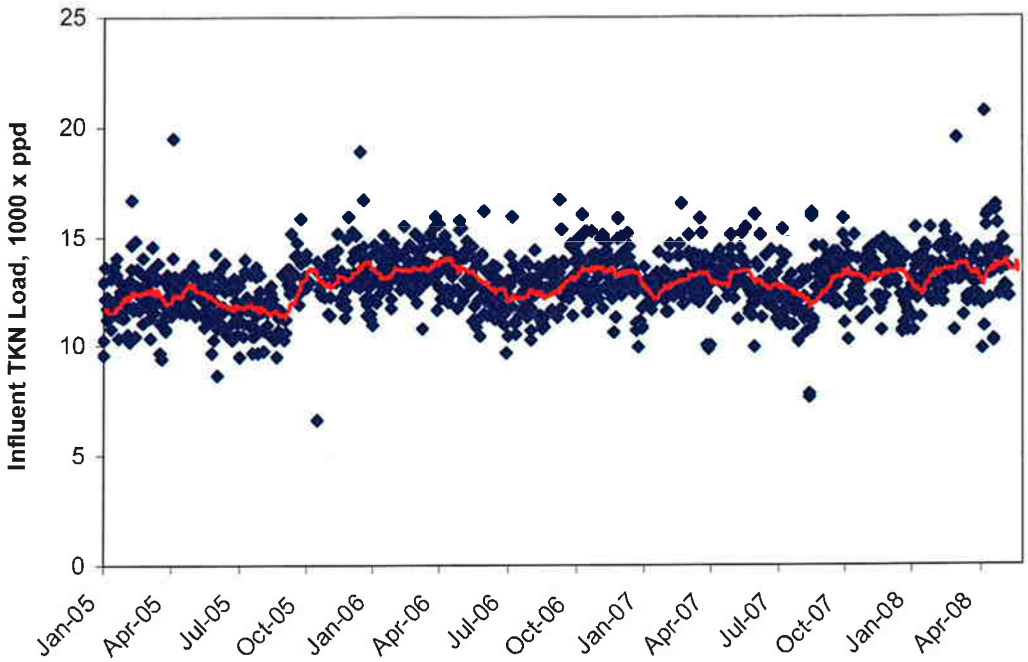


Figure A8
Daily phosphorus concentration in the influent to the Nine Springs WWTP.
The red line indicates a 30-day moving average.

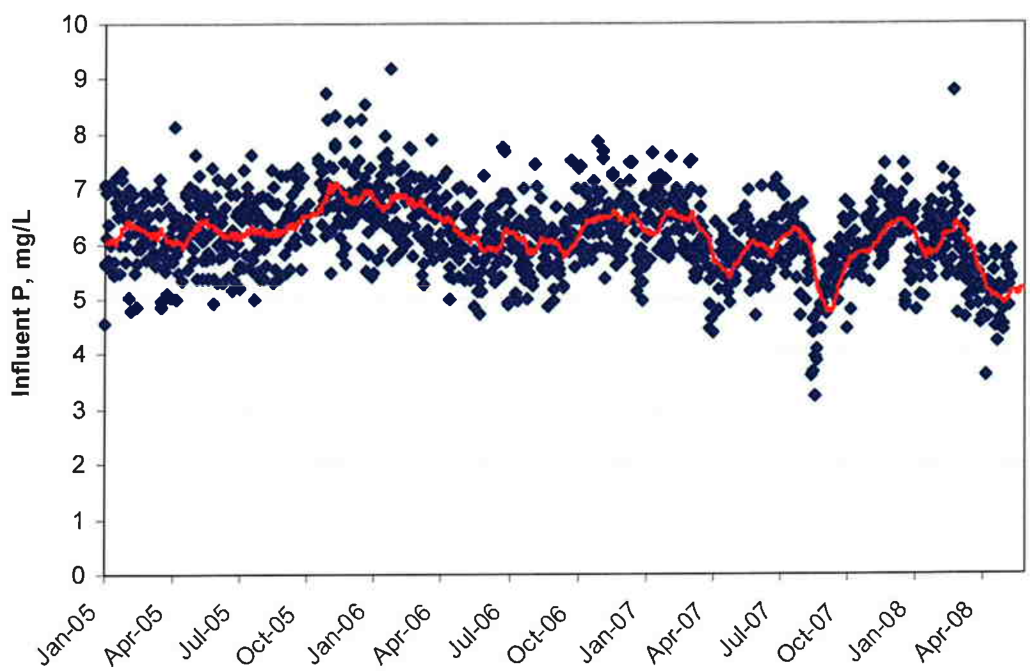
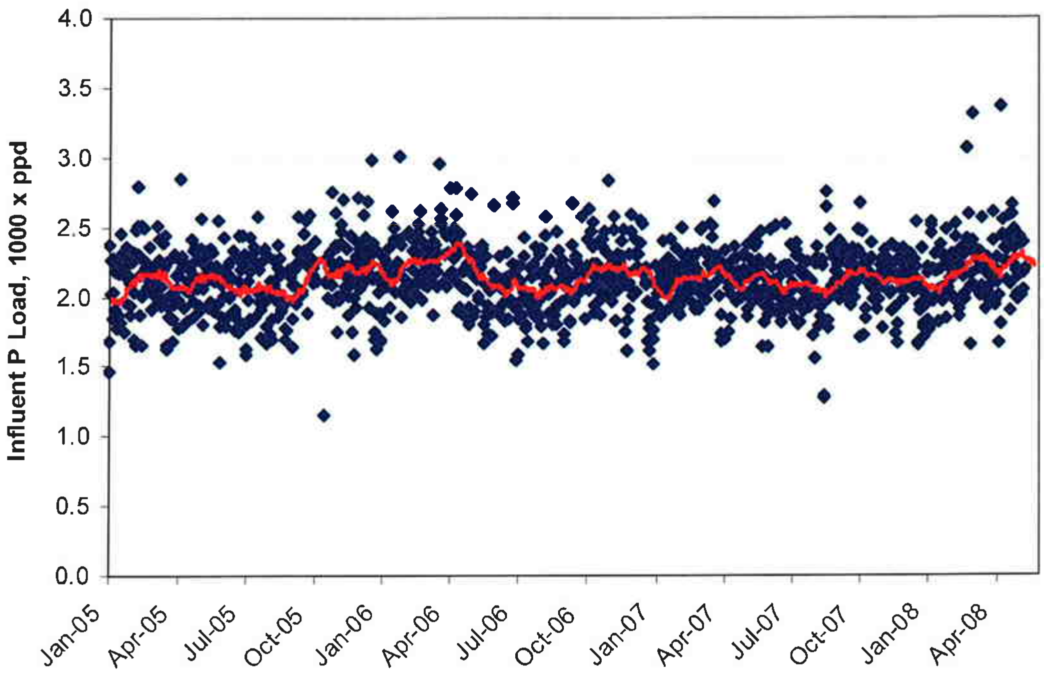


Figure A9
Daily influent phosphorus loading to the Nine Springs WWTP.
The red line indicates a 30-day moving average.



APPENDIX B
2007 SOLIDS DATA ANALYSIS

Figure B1
Daily primary sludge production at the Nine Springs WWTP.
The red line indicates a 30-day moving average.

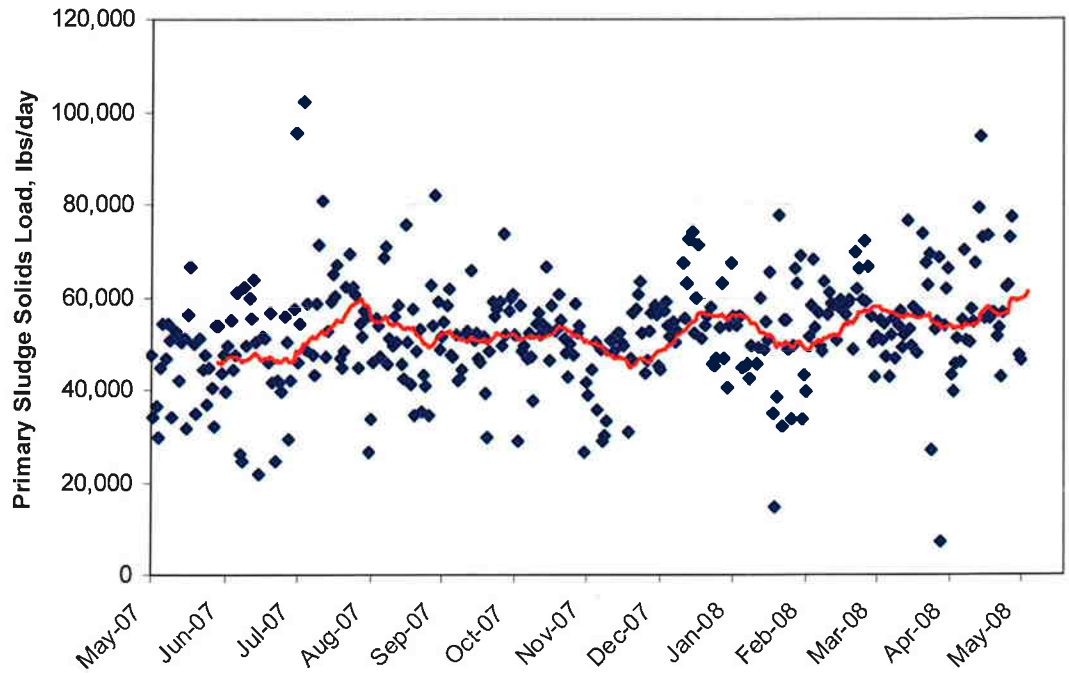


Figure B2
Monthly waste activated sludge (WAS) production at the Nine Springs WWTP.

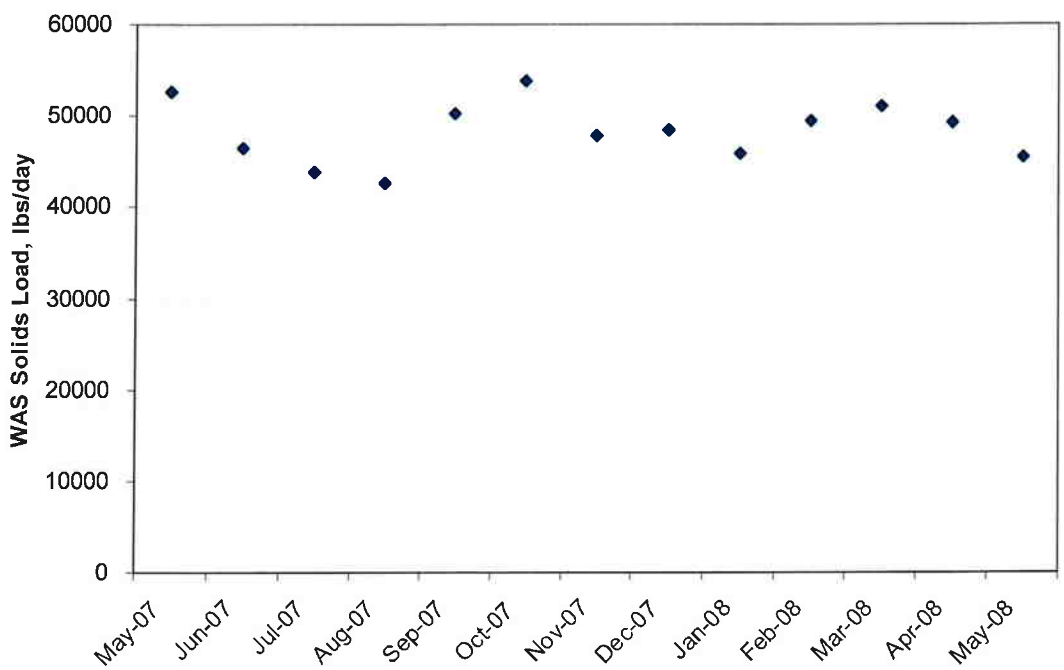


Figure B3
Total Solids concentration in the thickened sludge fed to the Nine Springs WWTP digesters.
The red line indicates a 30-day moving average.

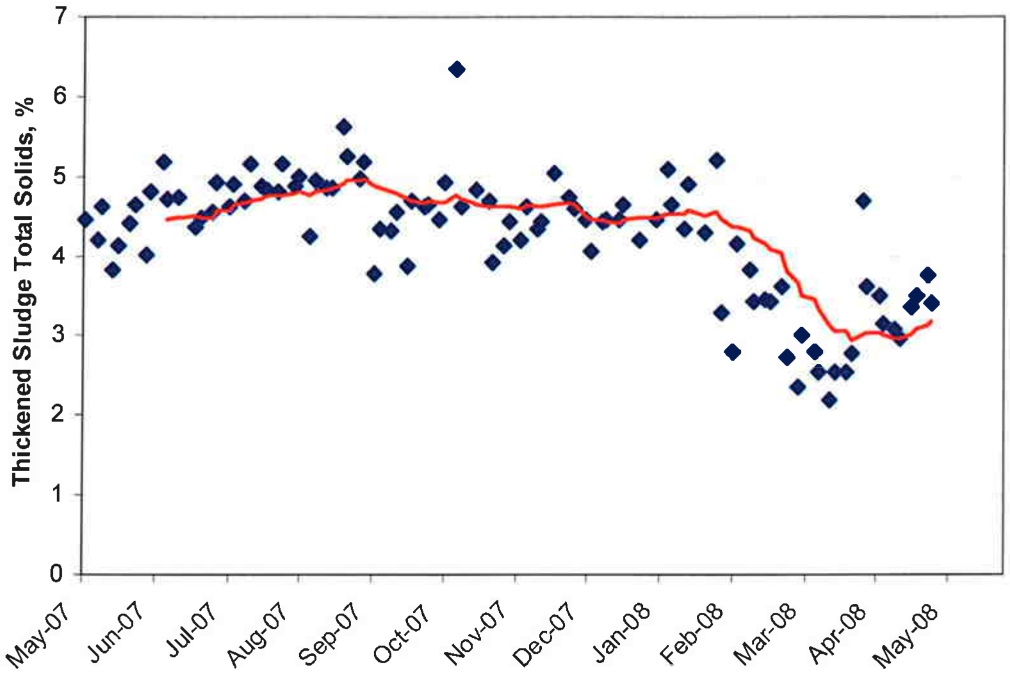
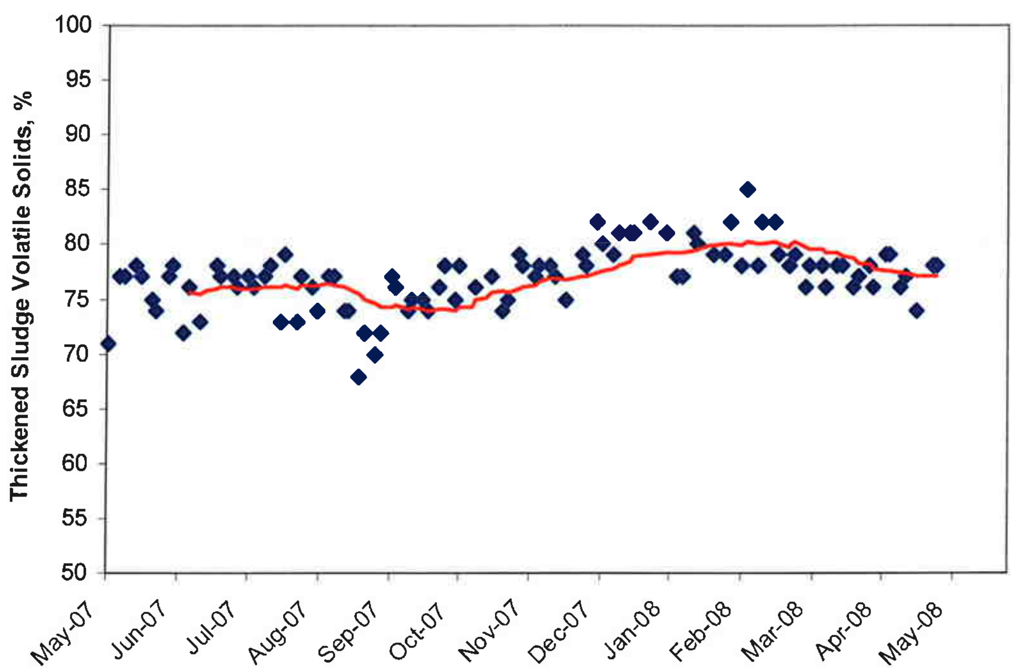


Figure B4
Volatile Solids concentration in the thickened sludge fed to the Nine Springs WWTP digesters.
The red line indicates a 30-day moving average.



APPENDIX D

Technical Memorandum No. 2
Sludge Stabilization Alternatives Evaluation

Applied Technologies
Engineers - Architects

carollo
Engineers...Working Wonders With Water™

MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 2
SLUDGE STABILIZATION ALTERNATIVES EVALUATION

Date: Revised – April 10, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to provide an overview of Class A sludge stabilization technologies and evaluate the alternatives that meet the Madison Metropolitan Sewerage District (MMSD) long-term biosolids management goals and objectives.

2.0 Summary of findings and recommendations

The key findings and recommendations of this TM are summarized below:

- Heat Stabilization using the Cambi Thermal Hydrolysis Process (THP) followed by conventional anaerobic digestion, acid-phase digestion with a mesophilic-thermophilic-mesophilic operating mode, and temperature phased anaerobic digestion (TPAD) were identified as sludge stabilization technologies that meet the MMSD biosolids management objectives and are compatible with the Nine Springs Wastewater Treatment Plant (WWTP) digestion facility.

- Other process alternatives were not considered for further evaluation because they did not meet the MMSD biosolids management objectives, were not compatible with the Nine Springs WWTP digestion facility, and/or were considered unproven technologies.

3.0 Background

In 2008, the MMSD contracted Applied Technologies Inc. (ATI) and Carollo Engineers to develop the Nine Springs WWTP Solids Handling Facilities Plan that reviews available alternatives and provides a detailed recommendation of facilities necessary to assure a reliable, sustainable process for producing Class A biosolids.

Currently, the Nine Springs WWTP produces approximately 9,130 dry tons of Class B digested biosolids per year. The 10th Addition planned for approximately 25% to be dewatered and hauled in trucks for bulk land application and reuse (Metromix). The remainder is stored in liquid form and land applied (Metrogro).

4.0 Basis of Evaluation

The goal of the Solids Handling Facility Plan is to identify sludge stabilization options that provide the Nine Springs WWTP the ability to meet the goals of the 10th Addition and produce Class A quality Metrogro and Metromix products for the land application programs. The sludge stabilization alternatives shall be evaluated using the following criteria:

- Ability to produce Class A biosolids.
- Economic feasibility.
- Proven technology with successful full-scale installations in biosolids facilities at municipal WWTPs of equivalent size and complexity as the Nine Springs WWTP.
- Consistent with the Nine Springs WWTP digestion facility and the MMSD land application programs (Metrogro and Metromix).
- Consistent with local environmental conditions.

5.0 Sludge Stabilization Alternatives

5.1 Composting

Composting is a stabilization process where the organic material of dewatered biosolids is aerobically decomposed. The high temperatures achieved during the microbial decomposition reduce the levels of pathogenic organisms. A bulking agent is added to increase the carbon-to-nitrogen ratio and produce a higher quality product. The final product is a humus-like material that is typically used as a soil amendment. Composting operations can meet Class A and Class B pathogen reduction. There are three types of composting processes: windrow, aerated static piles, and in-vessel composting.

5.1.1 Windrow

In windrow composting, the biosolids and bulking agent mixture is formed into long, open-air piles. The mixture is turned frequently to ensure an adequate oxygen supply and uniform temperature for optimum pathogen reduction. This process requires large amounts of land and generates strong objectionable odors.

5.1.2 Aerated Piles

In aerated piles, blowers supply air through perforated pipes running under the piles to provide an adequate oxygen level and remove excess moisture. A layer of composted material is placed over the surface to insulate the pile. Aerated piles require large amounts of land and are typically enclosed in buildings to collect and scrub the gases emitted from the process.

5.1.3 In-Vessel

In this composting process, biosolids, bulking agent, and recycled compost are mixed in an enclosed vessel. The mixture is maintained under aerobic conditions using blowers or continuous mixing. The stabilization period is typically 14 to 21 days followed by a curing period of approximately 30 days. For curing, the composted material is stockpiled. The composting and curing locations are enclosed to capture the gases emitted from the process. There are two types of in-vessel composting reactors: tunnel and plug-flow.

Composting produces Class A biosolids and has general public acceptance. Due to the extensive land requirements (windrows and aerated piles) and the incompatibility with the MMSD biosolids facility and the Metrogro land application program, this process was eliminated from further evaluation during the screening workshop.

5.2 Heat Drying

Heat drying involves reduction of the moisture content of biosolids by induced evaporation. This process uses mechanical agitation and auxiliary heat to increase the evaporation rate and has the capability and flexibility to produce pathogen free biosolids with any desired percent solids. Heat drying can be achieved with direct or indirect methods. Direct heating exposes biosolids to full contact with hot gases. Indirect drying uses hot gas to heat up surfaces, which then come in contact with the biosolids to evaporate moisture from the biosolids. Direct heat drying alternatives include flash drying, spray drying, and rotary heat drying. Indirect heat dryers include disk/paddle drying, and fluidized bed drying.

5.2.1 Rotary Dryers

Rotary dryers are essentially cylindrical rotary kilns that mechanically mix the biosolids as the drum rotates. Rotary dryers can be either direct or indirect heat dryers. Various agencies in the U.S. are using rotary dryers in pelletization operations.

5.2.2 Indirect Heat Dryers

Indirect heat dryers use a heat transfer medium or carrier to convey the heat generated in boilers or heat recovery equipment to the sludge. These units may be rotary, fluidized bed or multiple-plate. Fluidized bed dryers use the combustion gases to fluidize the sludge inside the dryer. The fluidized materials quickly lose moisture due to the loosely aggregated particles. The costs associated with thermal sludge drying are approximately the same with respect to the energy consumption to evaporate the water. Technologies that use air as fluidization media or those that have to treat large volumes of air incur increased operating costs.

Due to elevated costs associated with energy consumption, intensive operation requirements, potential safety issues, and incompatibility with the Metrogro and Metromix application programs, this process was eliminated from further evaluation during the screening workshop.

5.3 Heat Treatment

Heat treatment is the stabilization of raw sludge at elevated temperatures. Available heat treatment processes include the Zimpro, Ver-Tech, and Cambi systems.

5.3.1 Zimpro

The Zimpro Thermal Sludge Conditioning System is a wet air oxidation process where raw sludge is treated at high pressures and elevated temperatures. Depending on the final solids content desired, the biosolids could be directly applied to land or dewatered. The product may be used as a soil amendment, in compost, or combusted. The U.S. Environmental Protection Agency (EPA) identifies Zimpro as a heat treatment process that can meet PFRP or Class A requirements. This process is energy intensive, generates considerable odors, and produces a high-strength organic side stream that is difficult to treat in a conventional WWTP.

Zimpro has been decommissioned at most U.S. installations because of process problems; consequently, this process was eliminated from further evaluation during the screening workshop.

5.3.2 Ver-Tech

The Ver-Tech process converts biosolids to carbon dioxide, water, and a small amount of reusable sand-like residual. The sand residual could be included in the admixture to make construction bricks. The process occurs in concentric tubes between 4,000 and 5,000 feet deep. The Ver-Tech system has not been approved by the U.S. EPA as a PRFP or Class A process. However, heat treatment processes qualify as a PFRP if the raw sludge is heated to a temperature of at least 180°C for 30 minutes.

Due to the elevated costs associated with the installation of the mile-deep concentric tubes and the lack of successful full-scale installations at municipal WWTPs, this process was eliminated from further evaluation during the screening workshop.

5.3.3 Cambi

The Cambi thermal hydrolysis process (THP) is a high-pressure steam pre-treatment for anaerobic digestion of municipal sludge. Thermal hydrolysis disintegrates cell structure and organic materials and dissolves naturally occurring cell polymers into an easily digestible feed for anaerobic digestion. The sludge is heated to 165 C for 20 minutes producing pathogen-free biosolids that could meet Class A requirements. The Cambi THP provides increased digester loading capacity, biogas production, and dewaterability. Currently, there are no Cambi THP installations in the United States.

Due to the compatibility with the Nine Springs WWTP digestion facilities and the Metrogro and Metromix land application programs, the Cambi THP is considered viable for further evaluation.

5.4 Pasteurization

Pasteurization is intended to kill pathogens in raw sludge at elevated temperatures. In the pasteurization process, the raw sludge is heated to a temperature of 70°C for 30 minutes or longer. Eco-Therm (Ashbrook) and BioPasteur (Kruger) are two pasteurization systems available for municipal wastewater treatment utilities. These systems are configured as batch (BioPasteur) or plug-flow (Eco-therm) processes to prevent short-circuiting. The storage of the sludge after process completion is a concern because of the potential for regrowth of pathogens and odors. Currently, there are no full-scale installations of the Eco-Therm system in the U.S and previous trials at the Eastern Municipal Water District were unsuccessful. The only Bio-Pasteur full-scale installation in the U.S. is at the Alexandria Sanitation Authority WWTP (Alexandria, VA).

Pasteurization was eliminated from further evaluation during the screening workshop because of Carollo's experience with the unsuccessful trials at the Eastern Municipal Water District, a high potential for temperature-induced struvite precipitation, and it is an operator intensive process.

5.5 Anaerobic Digestion

Anaerobic digestion is a widely used sludge stabilization process that relies on anaerobic microorganisms to convert the organic matter in sludge to methane and carbon dioxide. This complex process can be divided into three steps: hydrolysis of complex organic matter, conversion of soluble organics into low molecular weight organic acids, and methane production (methanogenesis). Methane gas produced in anaerobic digesters is combustible and can provide approximately 600 BTU energy per cubic foot of gas. The digester gas can be used to provide energy for the hot water boilers, heat exchangers, and internal combustion or microturbine engines, which drive the generator supplying energy to the plant. The digester gas can also be recirculated to mix the sludge in the primary digester, and can also be used to mechanically dewater the sludge. Typically, a 50 to 65% volatile solids reduction is observed in anaerobic digesters treating sludge from municipal WWTPs. Depending on the anaerobic digestion process, the digested product may be suitable for land application.

5.5.1 Conventional Digestion

In conventional digestion, the three steps of the anaerobic digestion process are combined in the same vessel. Primary sludge and/or waste activated sludge are introduced to the digester and maintained at 35°C with a minimum detention time of 15 days. To prevent process instability, the volatile solids loading rate for conventional digesters should be less than 0.18 lbs per cubic feet per day.

As a stand alone process, conventional digestion was not considered for further evaluation because it does not meet Class A requirements without additional pre or post-treatment of the solids and would not be consistent with the Metromix practice.

5.5.2 Acid-Phase Digestion

Acid-phase digestion separates the organic acid and methane production steps of the anaerobic digestion process. This separation promotes optimal growth conditions for the different microorganisms and allows for volatile solids loading rates of at least 3 lbs per cubic feet per day. To accomplish the phase separation, the sludge is fed into a small reactor where the volatile solids are converted into volatile fatty acids (VFAs). The acidified slurry is transferred into a larger reactor where the methane-producing organisms convert the organic acids into methane and carbon dioxide.

When operated with a mesophilic (35°C) acid-phase and a thermophilic (54°C) methane-phase, this process can produce pathogen levels comparable to Class A criteria. To be considered a Class A technology, additional monitoring is required to confirm that the coliform reductions will meet the PFRP requirements.

Due to the increased performance observed in the Nine Springs WWTP digesters during operation in the acid-phase mode and the ability to meet Class A requirements, acid-phase digestion with mesophilic-thermophilic-mesophilic mode was selected for further evaluation. Alternatives will include batch operation of the methane digesters and continuous operation meeting Class A through periodic testing. Acid-phase digestion with mesophilic-mesophilic mode was discarded because it is unlikely to meet Class A requirements.

5.5.3 Single-Stage Thermophilic Digestion

In single-stage thermophilic digestion, the three steps of the anaerobic digestion process are combined in the same vessel. Temperature is maintained at 58°C to provide increased microbial activity and pathogen reduction levels comparable to Class A criteria. Increasing the raw sludge temperature to thermophilic conditions in a single step is an energy intensive process. Heating by steam injection may be required for Class A compliance. The only known facilities that currently have Class A approval operate in batch mode.

Single-Stage Thermophilic digestion was eliminated from further evaluation during the screening workshop because it is energy intensive, has a high foaming potential, generates odors at the solids handling facility, and may require batch operation.

5.5.4 Temperature Phased Anaerobic Digestion (TPAD)

The TPAD process consists of digesters with different operating temperatures that are operated in series. A thermophilic digester is operated at 58°C to improve the disinfection potential and physical separation. There are various configurations, including mesophilic-thermophilic, thermophilic-mesophilic, and three-phase (mesophilic-thermophilic-mesophilic) systems. The most prevalent configuration has a mesophilic stage downstream of the thermophilic stage to mitigate the odors generated in the thermophilic digester. TPAD with batch mesophilic digesters is able to meet the time and temperature Class A criteria.

The 10th Addition TPAD implementation at the Nine Springs WWTP resulted in frequent foaming events and the existing heating system is inadequate to maintain the temperatures required for TPAD operation in a batch mode. However, TPAD was selected for further evaluation due to the ability to meet Class A requirements and because the biosolids facility was designed for this digestion process.

5.6 Autothermal Thermophilic Aerobic Digestion (ATAD)

ATAD operates at a range of 50°C to 60°C and utilizes aerobic microorganisms. The high temperature increases the biological activity and results in a relatively short detention time (8-12 days). The increase in temperature also reduces the number of pathogenic organisms to levels acceptable to Class A requirements. This process is approved by 40 CFR Part 503 as a technology capable of producing Class A biosolids. The ATAD process is difficult to control and has an elevated foaming and odor generation potential. The heating of the incoming sludge and the high aeration requirements make ATAD an energy intensive process. This process would require major modifications to the Nine Springs WWTP biosolids facility and would eliminate the biogas production from the anaerobic digesters.

This process was eliminated from further evaluation during the screening workshop due to foaming, odor generation, and incompatibility with the Nine Springs WWTP digestion facility.

5.7 Air Drying

This method involves drying biosolids on sand beds or in paved or unpaved basins for a minimum of 3 months. During 2 of the 3 months, the ambient average daily temperature must exceed 0°C. Air Drying was eliminated from further evaluation during the screening workshop because it is land intensive, not compatible with Wisconsin climate, and the has the potential for odors generation and vector attraction.

5.8 Chemical Addition

Chemical addition processes are used to dewater and stabilize biosolids and, in some cases, to immobilize toxic compounds and render an inert final product.

5.8.1 Post-Dewatering Lime Stabilization

A common chemical addition process is lime stabilization where lime is used to reduce the pathogen levels by raising the pH. Lime stabilization requires combination with other processes to produce Class A biosolids. The final product must be mixed with a bulking agent and windrowed before final disposal.

5.8.2 En-Vessel Pasteurization

This patented process reduces pathogen levels and vector attraction using a combination of chemical addition and heat treatment. En-Vessel Pasteurization uses electrical power to heat the sludge to 70°C and lime addition to increase the pH to 12. The final product meets Class A requirements.

Due to the cost of the chemicals and the larger volume for disposal, the chemical addition processes were eliminated from further evaluation during the screening workshop.

5.9 Other Technologies

Other sludge stabilization processes that do not fall into the previous categories are included in this section.

5.9.1 Glassification (Minergy)

The glassification process is a technology that recovers the mineral content of the sludge and transforms it into a useful glass aggregate product. This industrial material is used in sandblasting grit, abrasives, and cement additives. Organic compounds in the sludge are destroyed in a high-temperature, high-retention mixing environment. Trace metals present in the sludge are permanently stabilized in the product. The organic component of sludge provides a significant portion of the energy required for the process.

The glassification process was eliminated from further evaluation during the screening workshop because it is not compatible with the MMSD digestion facility and there are no current successful full-scale installations.

5.9.2 Sludge-To-Oil Reactor System (STORS)

STORS is a hydrothermal process that uses an elevated temperature and pressure to convert sludge into a useful combustible fuel, either as an oil with 90% of the heating value of diesel, or a solid "char" product broadly similar to medium grade coal but with only 10% of the volume of the original input material. STORS was eliminated from further evaluation during the screening workshop because there are no successful full-scale installations in WWTPs and it is not compatible with the MMSD digestion facility.

5.9.3 Incineration (Biosolids to Energy)

Incineration is the complete combustion or rapid exothermic oxidation of combustible materials such as fixed carbon, hydrogen, and sulfur in biosolids. Other combustible materials include grease and scum, which have very high fuel value. Incineration can produce a Class A material. Ash produced from the furnaces can be beneficially used and/or disposed in the same way as biosolids. Pyrolysis is an incineration process where the combustion process is starved for oxygen by supplying less air than is required for combustion. An afterburner is required to destroy particulate carry-over and odors.

Because of public scrutiny, present air-quality regulations, and incompatibility with the MMSD land application program, this technology was eliminated from further evaluation during the screening workshop.

5.9.4 Cement Kiln

In this process alternative, wet biosolids are dried using the process heat form a cement kiln. The dried solids are combusted within the cement kiln. A portion of ash resulting from the biosolids combustion is used to reduce the quantities of limestone, clay, or shale added to the cement.

Cement Kiln was eliminated from further evaluation during the screening workshop because it is not consistent with the MMSD biosolids management objectives.

5.9.5 Deep Well Injection

Deep Well Injection is a technology that converts biosolids into clean energy by deep well injection and geothermal biodegradation. Slurry mixtures of treated, non-hazardous, municipal sludge and water are injected into a wells drilled into sand formations at depths from about 3,800 to 5,300 ft. At this depth, the material undergoes a natural process of high-temperature anaerobic biodegradation. Retention in the high temperature saline environment of the deep geologic formation converts the biosolids into methane, carbon dioxide, and non-volatile residual solids. The carbon dioxide is dissolved and sequestered in the formation brine, while the methane is collected in the reservoir to be recovered for beneficial use at the surface.

Deep well injection was eliminated from further evaluation during the screening workshop because it is considered an unproven technology, the geology in the Madison area is unlikely to be compatible with injection, and it is not consistent with the Metromix and Metrogro programs.

5.9.6 OpenCEL

OpenCEL is a patented process that lyses microbial cells to reduce the biosolids volume and increase the biogas production. This process uses pulses of high voltage electricity to breaks down microbial cell membranes.

This process was not considered for further evaluation because it does not meet Class A requirements and there is only one full-scale installation in municipal WWTPs (Mesa, AZ).

5.9.7 Vermiculture

Vermiculture is a process in which earthworms consume biosolids and produce feces or castings, which are used as a soil conditioner. The anaerobically digested biosolids require a pre-treatment aeration process to keep the biosolids porous and to provide oxygen for the worms. This is typically accomplished by adding bulking agents. The worms are placed on a bed of biosolids. After the consumption of the organics is complete, the worms are separated from their odorless castings, typically through the use of a rotating drum screen. Vermiculture requires an equal weight of worms to biosolids to consume the material. Therefore, a sizable parcel of land is needed for the worm beds or windrows, making this system more feasible for plants in rural areas with large land space.

Vermiculture was eliminated from further evaluation during the screening workshop because it does not meet Class A requirements and was not compatible with the MMSD biosolids management objectives.

5.9.8 Alternative Daily Cover for Landfill

This method of disposal involves transporting the dewatered biosolids to a local landfill for use as an alternative daily cover (ADC). The biosolids are hauled to landfill sites where they are mixed with soil or other materials before it is placed over disposed refuse to control refuse blowing and vector attraction.

Due to incompatibility with the MMSD biosolids management objectives, this alternative was eliminated from further evaluation during the screening workshop.

5.9.9 Out of State Hauling

This alternative consists of hauling the dewatered sludge produced at Nine Springs WWTP for disposal in a facility outside Wisconsin. Out of state hauling was eliminated from further evaluation during the screening workshop because it is not compatible with the MMSD biosolids management objectives.

6.0 Sludge stabilization alternatives summary

Based on the sludge stabilization alternatives evaluation presented in this TM, the Cambi THP followed by conventional anaerobic digestion, acid-phase digestion with mesophilic-thermophilic mode of operation, and TPAD were considered for further evaluation. Table 1.1 presents a summary of the sludge stabilization alternatives evaluated in this study.

Table 2.1
Sludge Stabilization Technology Alternatives Summary

Stabilization Technology	Produces Class A/EQ	Compatible with Operation	Proven technology at full-scale WWTP	Compatible with Cogeneration or Energy Recovery	Additional Operational Considerations
Composting	X		X		Land intensive, odor, fire danger, requires bulking agent, dewatering and scrubbing equipment
Heat Drying	X		X	X	High energy consumption, intensive operation requirements, fire danger, not compatible with Metromix and Metrogro programs.
Zimpro (Heat Treatment)	X				Odors, energy intensive, high-strength side stream
Ver-Tech (Heat Treatment)	X				Odors, energy intensive, high installation cost.
Cambi THP (Heat Treatment)	X	X	X	X	Odors, energy intensive, requires digestion, high-strength side stream.
Pasteurization	X	X	X	X	Pathogen re-growth; requires chemicals or digestion
Conventional Digestion		X	X	X	Requires more digester volume than other digestion processes
Acid-Phase Digestion (mesophilic-mesophilic)		X	X	X	Requires high volatile solids loading and short detention time in acid digester
Acid-Phase Digestion (mesophilic-thermophilic)	X	X	X	X	Requires high volatile solids loading and short detention time in acid digester
Single-Stage Thermophilic Digestion	X		X	X	Foam, odors, energy intensive

Table 2.1 Sludge Stabilization Technology Alternatives Summary					
Stabilization Technology	**Produces Class A/EQ**	**Compatible with Operation**	**Proven technology at full-scale WWTP**	**Compatible with Cogeneration or Energy Recovery**	**Additional Operational Considerations**
Temperature-phase Anaerobic Digestion	X	X	X	X	Difficulty with temperature changes, unsuccessful implementation at Nine Springs WWTP
ATAD	X		X		Foam, odors, energy intensive
Air Drying (Post-anaerobic digestion)	X		X	X	Land intensive, odors, requires dust control
Post-Dewatering Lime Addition (Chemical Addition)	X		X		Chemically intensive, odor, increased biosolids volume
En-Vessel Pasteurization (Chemical Addition)	X		X		Chemically intensive, increased biosolids volume
Glassification	X				
Sludge-To-Oil Reactor System	X				
Incineration	X		X		
Cement Kiln	X		X		
Deep Well Injection	X			X	Requires appropriate geologic formation
OpenCEL		X		X	Requires digestion
Vermiculture					Land intensive, requires digestion
Alternative Daily Cover for Landfill			X		
Out of State Hauling			X		

APPENDIX E

Technical Memorandum No. 3
Anaerobic Digestion Process Evaluation

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 3
ANAEROBIC DIGESTION PROCESS EVALUATION

Date: December 18, 2009 (Revised) **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM-03) is to evaluate acid-phase digestion with mesophilic-thermophilic mode of operation, temperature phased anaerobic digestion (TPAD), conventional digestion with Cambi thermal hydrolysis process (THP) pretreatment, and conventional digestion with a Class A post-treatment to accommodate the influent flow and loading projections for the year 2030 at the Nine Springs Wastewater Treatment Plant (WWTP). The recommended alternative will be selected based on economic and non-economic factors. TM-03 provides documentation of process evaluation prior to Workshop #4, which took place on 5/8/09. Documentation of process evaluations subsequent to Workshop #4 are in TM-03A.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- Conventional digestion with Cambi THP is the only alternative that meets the time-temperature requirement for Class A biosolids (Alternative 1 of the 503 regulations). Acid phase digestion with mesophilic-thermophilic-mesophilic mode of operation and TPAD would require monthly testing to obtain site specific Class A approval.
- Conventional digestion with Cambi THP is the only alternative expected to prevent *Microthrix* associated foaming. Acid phase digestion and TPAD reduce the potential of *Nocardia* associated foaming in the anaerobic digesters but by themselves will likely not eliminate the foaming issues associated with *Microthrix*. Acid phase digestion, TPAD, and conventional digestion with thermal post-treatment require the implementation of foam mitigation measures, which are presented in TM-05 Foam Mitigation Alternatives.
- Conventional digestion with Cambi THP and acid-phase digestion provide enhanced fats, oil, and grease degradation and reduce the potential of non-filamentous foaming.

- Implementation of a mesophilic-thermophilic-mesophilic acid-phase digestion facility requires the construction of two new acid digesters, the conversion of Digester No. 7 to a thermophilic methane digester, improvements to sludge thickening, and the installation of foam mitigation measures. Construction of a new thermophilic methane digester is recommended to meet future loadings.

- Implementation of TPAD requires the construction of a new mesophilic digester, the operation of Digester No. 7 as a mesophilic digester, and the installation of foam mitigation measures. To meet future loadings, the construction of one additional new mesophilic digester, the operation of Digester No. 7 as a thermophilic digester, and improvements in sludge thickening are recommended.

- Implementation of conventional digestion with a Cambi THP pre-treatment requires the installation of the THP system, operation of Digesters No. 4 - No. 7 as conventional digesters, and improvements in sludge thickening.

- Implementation of conventional digestion with post-treatment requires the construction of four new mesophilic digesters, and the installation of a post-treatment facility (i.e., heat drying, En-Vessel pasteurization, or batch thermophilic treatment) and foam mitigation measures.

- Conventional digestion with Cambi THP and conventional digestion with thermal post-treatment have considerably higher present worth costs than acid phase digestion and TPAD. The present worth costs of TPAD and acid phase digestion are within 6% of one another (within the estimating accuracy for this phase of the project).

- Based on an economic and non-economic comparison of the digestion alternatives, conventional digestion with Cambi THP and acid-phase digestion with mesophilic-thermophilic-mesophilic mode of operation were selected for further evaluation that includes foam and struvite mitigation, grease co-digestion, and production of Class A through Alternative 1 of the 503 regulations (See TM-03A).

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements while maintaining the current biosolids land application programs. TM-02, Sludge Stabilization Alternatives Evaluation, identified acid-phase digestion with mesophilic-thermophilic-mesophilic mode of operation, TPAD, and conventional digestion with Cambi THP pretreatment as alternatives that will allow the MMSD to meet these biosolids management objectives.

In the 10th Addition to the Nine Springs WWTP the anaerobic digestion facilities were designed to operate in TPAD mode but switched to the acid-phase mode with a mesophilic-thermophilic-mesophilic configuration due to operating difficulties experienced during the startup of the TPAD facility. Stable performance was not achieved in acid phase mode of operation because the tank used as the acid digester was not designed for this purpose. Operational problems experienced under TPAD and acid phase operation at the Nine Springs WWTP include foaming in the anaerobic digesters and phosphate crystallization in pipes and heat exchangers. Currently, the anaerobic digestion facility is operating in conventional mode under mesophilic temperatures. Although, conventional digestion resulted in lower volatile solids reduction and consequently reduced the capacity of the gravity belt thickeners (GBTs) and Metrogro storage tanks, stable volatile acid and alkalinity levels and manageable digester foaming during the interim operation led the MMSD staff to evaluate conventional digestion with thermal post-treatment as part of the Solids Handling Facilities Plan.

4.0 Digester Capacity Evaluation

The digestion capacity of acid-phase digestion, TPAD, and conventional digestion with Cambi THP pretreatment were evaluated for the projected flows and loadings for both annual average and maximum month (max month) conditions developed in TM-01, Basis of Design.

4.1 Existing Anaerobic Digestion Facilities

The Nine Springs WWTP solids facilities have seven (7) anaerobic digesters and two (2) sludge storage tanks. Table 3.1 presents a summary of the anaerobic digesters and sludge storage tank characteristics. Digesters No. 1, 2, 3, and 7 were designed for mesophilic operation. Digesters No. 4, 5, and 6 were designed for thermophilic operation. Under acid-phase operation, Digester No. 7 was operated as the acid digester. A detailed evaluation of the existing digester mixing, heating, and gas collection systems is presented in TM-04, Digestion Ancillary Systems Evaluation.

Table 3.1
Existing Anaerobic Digesters

	East Complex Digesters (1)	East Complex Digesters (2)	West Complex Digesters (3)	Sludge Storage Tanks
Number of Units	3	1	3	2
Diameter, ft	80	80	75	70
Side Water Depth, ft	26.4	26.4	15.4	12
Cone Depth, ft	1.67	6.67	11.8	12
Unit Volume, gal	1,014,000	1,076,000	639,000	450,000

Notes:
(1) Digesters No. 4, 5, and 6
(2) Digester No. 7
(3) Digesters No. 1, 2, and 3

The digester feed consists of thickened primary sludge and waste activated sludge (WAS). Primary sludge and waste activated sludge are thickened using gravity thickening (GT) and dissolved air flotation thickening (DAFT), respectively. The DAFT units also receive primary and secondary scum. Digested sludge is thickened using two (2) gravity belt thickeners (GBT), one of these units also serves as backup for WAS thickening when a DAFT unit is out of service. The thickened digested sludge (Metrogro) is stored in three (3) 160-ft diameter tanks with a combined capacity of 19.4 MG. Table 3.2 presents a summary of the GT and DAFT characteristics and the performance during the period of May 2007 to December 2007.

Table 3.2 Existing Sludge Thickening Units		
	Gravity Thickeners	**DAFT**
Number of Units	2	2
Diameter, ft	55	55
Total Surface Area, sqf	4,752	4,752
Solids Loading, ppd	60,800 (1)	49,700 (2)
Solids Capture Efficiency, %	98.3	93.8
Thickened Sludge Solids, %	5.0	4.2

Notes:
(1) Primary sludge based on historical plant TSS loadings
(2) Waste activated sludge

4.2 Digestion Design Criteria

Table 3.3 presents the recommended hydraulic residence time (HRT) and volatile solids loading rate (VSLR) design and redundancy criteria for acid-phase digestion, TPAD, conventional digestion with Cambi THP pre-treatment, and conventional digestion with thermal post-treatment.

Table 3.3 Recommended Design Criteria for Anaerobic Digestion Processes		
Digestion Process	**Design Criteria**	**Controlling Criteria**
Acid-Phase Digestion		
Acid Digester (mesophilic)	VSLR 1 to 2.5 lbs VS/cfd	Maximum Month with one unit out of service
	HRT 1.5 to 3 days	Maximum Month with all units in service and annual average with one unit out of service
Methane Digester (thermophilic)	HRT ≥ 12 days	Maximum Month with all units in service and annual average with largest unit out of service
Methane Digester (mesophilic)	HRT ≥ 2 days	Maximum Month with all units in service and annual average with largest unit out of service
TPAD		
Thermophilic Digester	VSLR < 0.30 lbs VS/cf/day HRT ≥ 5 days	Maximum Month with all units in service and annual average with largest unit out of service
Mesophilic Digester	HRT ≥ 10 days	Maximum Month with all units in service and annual average with largest unit out of service
Conventional with Cambi THP		
Conventional Digester (1)	VSLR < 0.37 lbs VS/cfd (2) HRT ≥ 15 days	Maximum Month with all units in service and annual average with largest unit out of service
Conventional with Thermal Post-Treatment		

Table 3.3 Recommended Design Criteria for Anaerobic Digestion Processes		
Digestion Process	**Design Criteria**	**Controlling Criteria**
Conventional Digester	VSLR < 0.13 lbs VS/cfd	Annual average with all units in service
	VSLR < 0.18 lbs VS/cfd HRT ≥ 20 days (3)	Maximum Month with all units in service and annual average with largest unit out of service
Batch Thermal Tank	Holding Time ≥ 1 day (4)	Maximum Month with all units in service

Notes:

(1) Conventional digesters downstream of a Cambi THP system.

(2) Based on information provided by Cambi. Assumes a total solids concentration in the thermally hydrolyzed sludge of 10 percent with a volatile fraction of 80 percent.

(3) Based on operation experience at the Nine Springs WWTP

(4) Based on operating temperature of 131 deg F.

4.3 Acid-Phase Digestion

Acid-phase digestion relies on the separation of the biological processes that occur in anaerobic digestion. In the acid digester, a relatively low HRT maintains high levels of acid forming organisms and negligible levels of methane producing organisms, which results in low pH conditions. These acidic conditions improve the degradation rate of proteins and lipids. Most of the biogas production takes place downstream in the methane digesters. Table 3.4 presents the design VSLR and HRT for these alternatives based on the solids loading projections developed in TM-01.

To meet current conditions, implementation of acid-phase digestion at the Nine Springs WWTP requires the construction of two new 0.38 MG acid digesters. As previously reported by the MMSD staff, the existing acid digester (Digester No. 7) is oversized for the current solids flows and loading and its configuration does not allow for adequate operation at lower liquid levels. In this mode of operation, all the existing 1.014 MG tanks (Digesters No. 4 -6) and the existing 1.076 MG tank (Digester No. 7) would be operated as thermophilic methane digesters and the existing 0.639 MG tanks (Digesters No. 1, 2, and 3) would be operated as mesophilic methane digesters. A process schematic and the preliminary layout for this alternative are presented in Figures 3.1 and 3.2, respectively.

To meet the capacity requirements for 2030 conditions, the construction of an additional 1.076 MG thermophilic methane digester (proposed Digester No. 8) is required. In this mode of operation, the existing Digesters No. 4 -7 and the proposed Digester No. 8, would be operated as thermophilic methane digesters and the existing Digesters No. 1, 2, and 3 would be operated as mesophilic methane digesters. A process schematic and the preliminary layout for this alternative are presented in Figures 3.1 and 3.2, respectively. Based on the 50-Year Master Plan projections, the proposed Digester No. 8 would need to be in service by 2015.

Typically, the mesophilic methane digesters are strictly for polishing purposes and may not operate as a true mesophilic system in summer. Operation experience at the Inland Empire Utilities Agency has shown that a 3-day HRT in the mesophilic methane digesters is adequate to remove odors and maintain a stable dewatering system.

4.3.1 Sludge Thickening

To meet current redundancy requirements, improvements to the sludge thickening operations are recommended. Two new 400 gpm thickeners will be required to provide the necessary thickening capacity with the existing 2-meter gravity belt thickener (GBT) acting as standby unit. For the purposes of this study, it is assumed that GBTs would be added in year 2010 to provide the required thickening capacity. Thickening technology analysis and selection is included in TM-08. A solids concentration of 6.0 percent in the digester feed was used to estimate the digester loadings and HRT. With the addition of the GBTs this target concentration should be reliably achieved.

4.3.2 Digester Foaming

Non-filamentous foaming is typically prevented in acid-phase digestion because of limited gas production in the acid digester where the protein and lipid concentrations are higher. Increased lipid and protein degradation in the acid digester prevent non-filamentous foaming in the methane digesters. Filamentous foaming associated with *Gordona* (*Nocardia*) decreased in the Woodridge-Green Valley Wastewater Treatment Facility (DuPage County) after implementation of acid-phase digestion. Currently, there are no reports on *Microthrix*-related foaming and the fate of *Microthrix* in acid phase digestion. To prevent *Microthrix*-associated foaming, acid phase digestion must be coupled to a foam mitigation alternative (See TM-05 Foam Mitigation Alternatives).

4.3.3 Class A Biosolids

The mesophilic-thermophilic- mesophilic acid phase digestion process does not meet the Alternative 1 (Thermally Treated Sewage Sludge) requirements for Class A biosolids due to a continuous flow and completely mixed reactor configuration. A site specific Class A permit can be met through Alternative 3 (Sewage Sludge Treated in Other Processes) with extensive testing of bacteria, enteric viruses, and viable helminth ova to demonstrate the reduction of pathogens. The Woodridge-Green Valley Wastewater Treatment Facility and the Inland Empire Utilities Agency (IEUA) have site specific Class A permits.

Should Alternative 3 become unavailable in the future, Alternative 1 requirements can be met through operation of Digesters No. 1, No. 2, and No. 3 in a batch thermal treatment mode (See TM-3A).

4.3.4 Full-Scale Installations

Acid-phase digestion installations in the U.S. include Black Water Wastewater Treatment Plant (Baltimore, MD), Inland Empire Utilities Agency (Chino, CA), Truckee Meadows Water Reclamation Facility (Reno, NV), Turlock Regional Water Quality Control Facility (Turlock, CA), City of Petaluma Water Recycling Facility (Petaluma, CA), and Woodridge-Greene Valley Wastewater Treatment Facility (Downers Grove, IL). The Truckee Meadows Water Reclamation Facility is an enhanced biological phosphorus removal facility.

Table 3.4 Design Criteria for Acid-Phase Digestion				
Process Parameter	**Current Conditions**		**2030 Conditions**	
	Average	**Maximum Month**	**Average**	**Maximum Month**
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Digestion, ppd (1)	80,800	97,000	117,400	139,700
TS Concentration, %	6.0	6.0	6.0	6.0
Solids Flow to Digestion, gpd	212,500	255,100	308,800	367,400
Acid Digester				
Digester Volume, MG (2)	0.38	0.38	0.38	0.38
VS Loading Rate, lbs VS/cfd	1.59	1.91	2.31	2.75
Hydraulic Retention Time, days	1.8	1.5	1.2	1.0
Thermophilic Methane Digesters				
Digester Volume, MG	3.04 (3)	4.12 (3,4)	4.12 (3,4)	5.20 (3,4,5)
Hydraulic Retention Time, days	14.3	16.1	13.3	14.1
Mesophilic Methane Digesters				
Digester Volume, MG	1.28 (6)	1.92 (6,7)	1.28 (6)	1.92 (6,7)
Hydraulic Retention Time, days	6.0	7.5	4.1	5.2

Notes:
(1) Assumes volatile solids fraction of 76 percent.
(2) New 0.38 MG acid digester with adjustable operational volume
(3) Existing 1.014 MG Digesters (No. 4, 5, and 6)
(4) Existing 1.076 MG Digester (No. 7)
(5) Proposed 1.076 MG Digester (No. 8)
(6) Existing 0.639 MG Digesters (No. 1 and 2)
(7) Existing 0.639 MG Digester No. 3

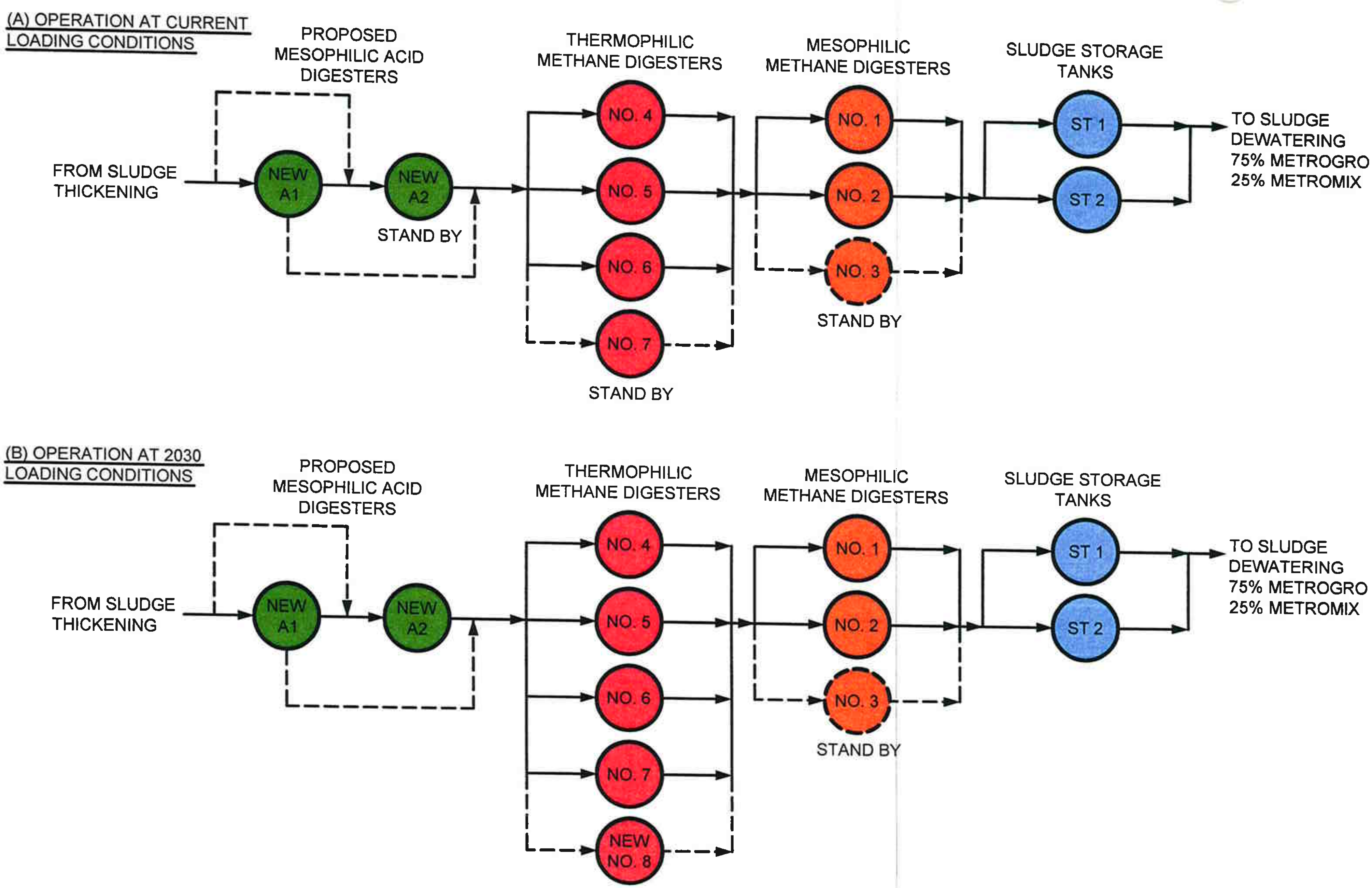

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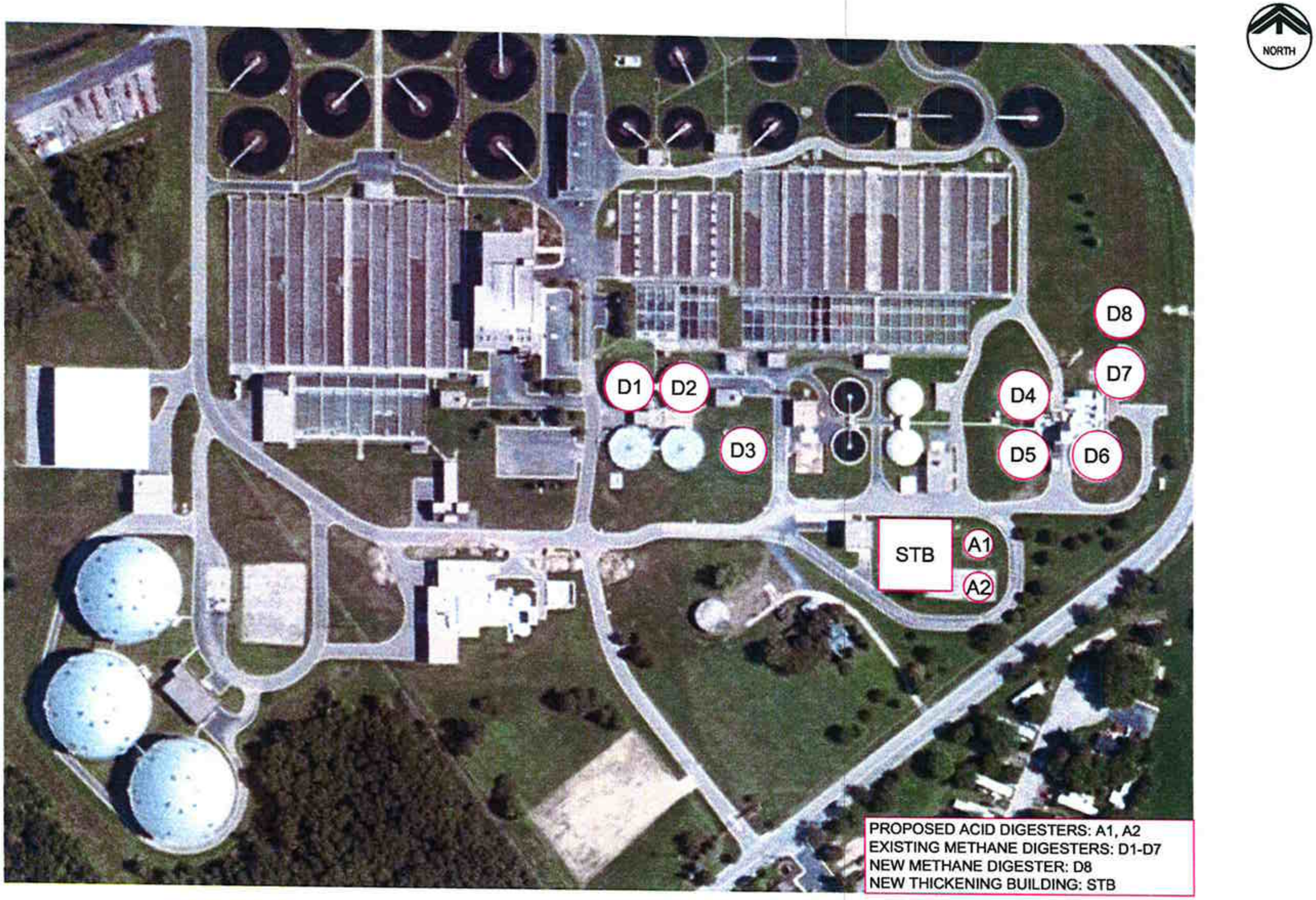
FIGURE 3.1
ACID-PHASE DIGESTION PROCESS SCHEMATIC
Madison Metropolitan Sewage District



ACID PHASE DIGESTION
PRELIMINARY LAYOUT

FIGURE 3.2

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4.4 Temperature Phased Anaerobic Digestion

An alternative to the two-phase digestion (mesophilic-thermophilic) process for Class A biosolids is the TPAD process operated in the thermophilic-mesophilic mode. The thermophilic stage can increase the reaction rates of the digestion process and eliminate pathogens. The mesophilic stage reduces the odorous compounds and increases the dewaterability, two major concerns associated with high-temperature digestion. Table 3.5 presents the design VSLR and HRT for the TPAD process based on the solids loading projections developed in TM No. 1.

To meet current conditions, implementation of TPAD at the Nine Springs WWTP requires the conversion of Digester No. 7 to a mesophilic digester and the construction of a new 1.076 MG mesophilic digester (Digester No. 8). In this mode of operation, the three 1.014 MG tanks (existing Digesters No. 4-6) would be operated as thermophilic methane digesters and the two 1.076 MG tanks (existing Digester No. 7 and proposed Digester No. 8) and the 0.639 MG tanks (existing Digesters No. 1, 2, and 3) would be operated as mesophilic methane digesters. A process schematic and the preliminary layout for this alternative are presented in Figures 3.3 and 3.4, respectively.

To meet the capacity requirements for 2030 conditions, the construction of an additional new 1.076 MG tank (proposed Digester No. 9) is required. In this mode of operation, the existing Digesters No. 4 and No. 7 would be operated as thermophilic methane digesters and the remaining two 1.076 MG tanks and the 0.639 MG tanks would be operated as mesophilic methane digesters. A process schematic and the preliminary layout for this alternative are presented in Figures 3.3 and 3.4, respectively.

Although the thermophilic stage HRT for current and future conditions is higher than the design criteria of 5 days and a 15-day HRT for the entire TPAD system would result in good volatile solids reduction, a minimum HRT of 10 days is still recommended for the mesophilic stage to degrade the odorous compounds generated in thermophilic digestion.

4.4.1 Sludge Thickening

To meet year 2030 capacity requirements, improvements to the sludge thickening operations are recommended. Two new 400 gpm thickeners will be required to provide the necessary thickening capacity with the existing 2-meter gravity belt thickener (GBT) acting as standby unit. For the purposes of this study, it is assumed that GBTs would be added in year 2020 to provide the required thickening capacity. Thickening technology analysis and selection will be included in a future technical memorandum. A solids concentration of 6 percent solids in the digester feed was used to estimate the digester loadings and HRT. With the addition of the GBTs this target concentration should be reliably achieved. The improvements in thickening will not reduce the thermophilic tankage required for TPAD because the limiting condition for this scenario would be the solids loading rate and not the hydraulic loading rate.

4.4.2 Digester Foaming

The thermophilic stage of TPAD has been reported to prevent filamentous foaming due to *Gordona* (*Nocardia*) organisms. However, the thermophilic sludge has a high potential for non-filamentous foaming. *Microthrix* is not degraded in thermophilic anaerobic digestion. To prevent *Microthrix*-associated foaming, TPAD must be coupled to a foam mitigation alternative (See TM-05 Foam Mitigation Alternatives).

4.3.2 Class A Biosolids

The conventional TPAD process does not meet the Alternative 1 (Thermally Treated Sewage Sludge) requirements for Class A biosolids due to its continuous flow configuration. Alternative batch or plug flow configurations would be required to meet the time-temperature regimes of Alternative 1. In review meetings with the District, the intent to operate the digestion system in a batch TPAD mode was discussed. Operation of the thermophilic digesters in a sequencing batch mode is not recommended for the following reasons.

1. There are no full-scale installations that have successfully operated a batch TPAD system (thermophilic stage in a sequencing batch mode).

2. The thermal load on the digesters operating in batch mode will be significantly higher as the exchanged volumes account for up to 15 percent of the individual digester volume. Raw sludge preheating would be required to prevent a significant amount of cold liquid volume depressing the operating temperature of the digester.

3. The batch contribution of the feed will increase the peak gas production and increase the potential for foaming during the feed periods.

A site specific Class A permit can be met through Alternative 3 (Sewage Sludge Treated in Other Processes) with extensive testing of bacteria, enteric viruses, and viable helminth ova to demonstrate the reduction of pathogens. Currently, there are no conventional TPAD facilities with a site specific Class A permit.

4.4.3 Full-Scale Installations

Based on published literature and telephone surveys there are 6-8 small utilities operating TPAD in the United States. Currently, the Western Lake Superior Sanitary District is the only large U.S. utility operating a TPAD facility. One of the larger worldwide utilities, the Cologne-Stammheim WWTP (Cologne Germany) recently shut down their TPAD process due to frequent problems with their heat exchangers.

Table 3.5 Design Criteria for Temperature Phased Anaerobic Digestion				
Process Parameter	**Current Conditions**		**2030 Conditions**	
	Average	**Maximum Month**	**Average**	**Maximum Month**
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Digestion, ppd (1)	80,800	97,000	117,400	139,700
TS Concentration, %	4.6	4.6	6.0	6.0
Solids Flow to Digestion, gpd	277,200	332,800	308,800	367,400
Thermophilic Digesters				
Digester Volume, MG				
All Units In Service	2.03 (2)	3.04 (2,3)	3.04 (2,3)	4.12 (2,3,4)
VS Loading Rate, lbs VS/cfd	0.30	0.24	0.29	0.25
Hydraulic Retention Time, days	7.3	9.1	9.9	11.2
Mesophilic Digesters				
Digester Volume, MG	2.99 (5)	4.07 (4,5)	2.99 (5)	4.07 (5,6)
Hydraulic Retention Time, days	10.8	12.2	9.7	11.1

Notes:
(1) Assumes volatile solids fraction of 76 percent.
(2) Existing 1.014 MG Digesters (No. 4and 5)
(3) Existing 1.014 MG Digester (No. 6)
(4) Existing 1.076 MG Digester (No. 7)
(5) Existing 0.639 MG Digesters (No. 1, 2, and 3) and New 1.076 MG Digester (No. 8).
(6) New 1.076 MG Digester (No. 9)

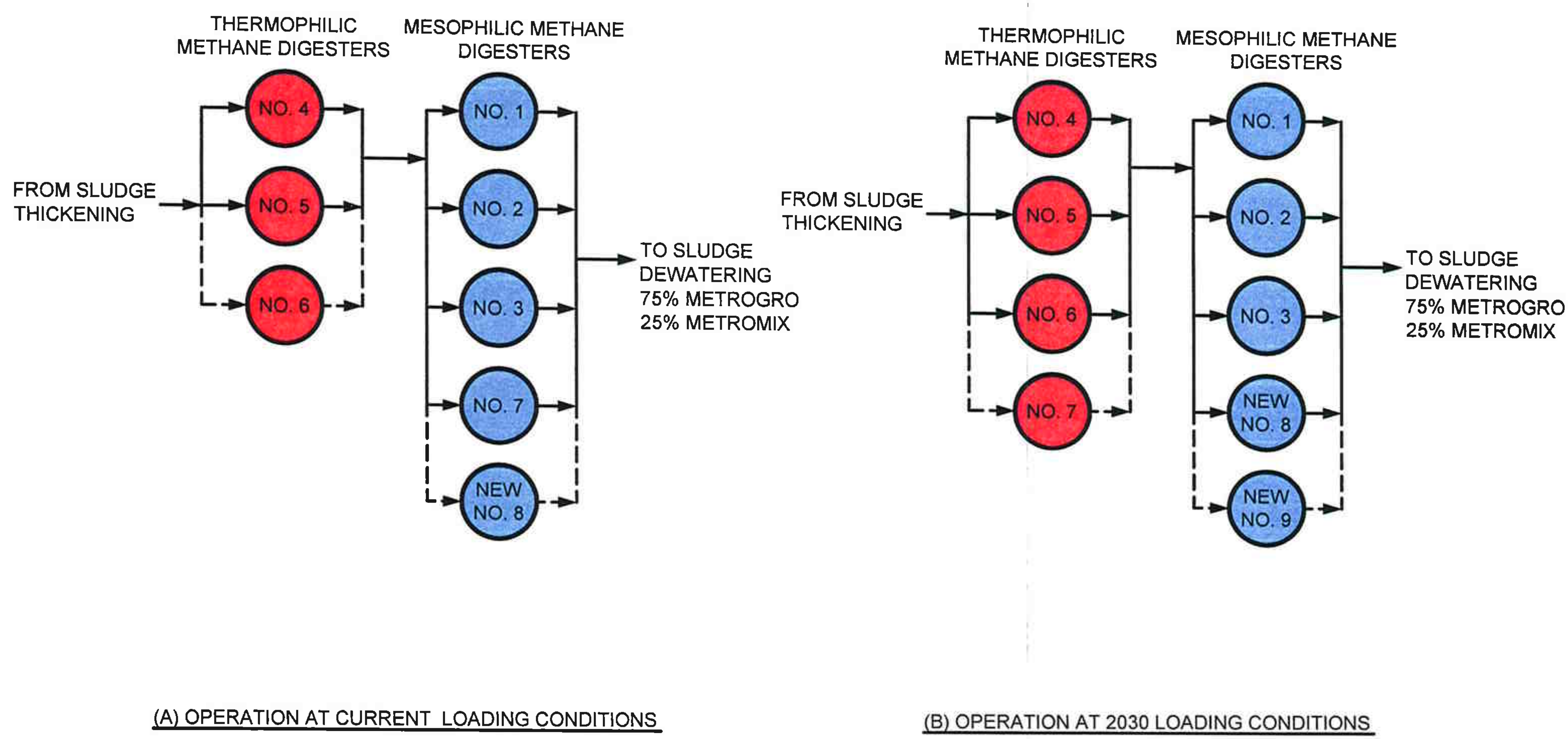

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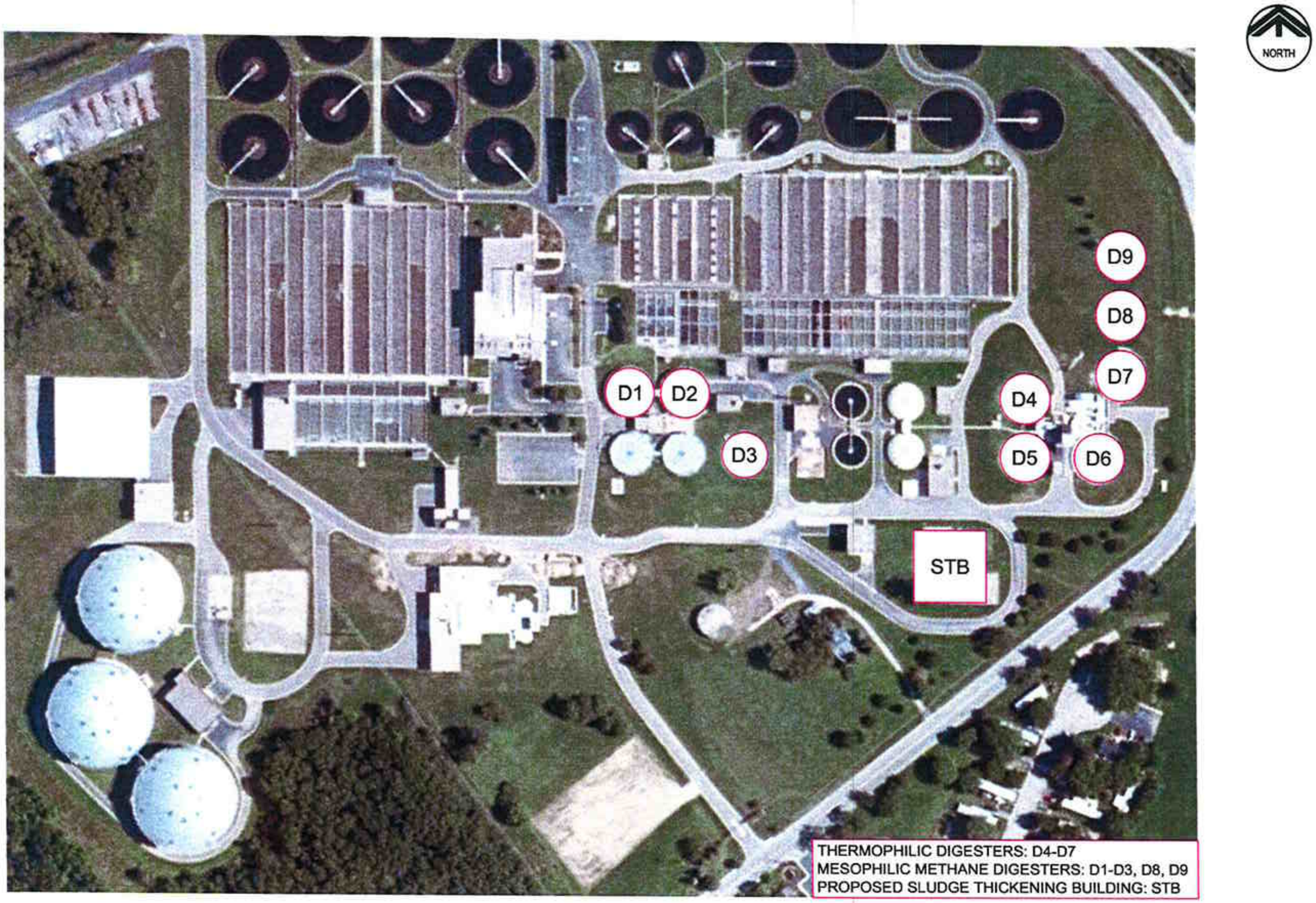
FIGURE 3.3
TPAD PROCESS SCHEMATIC
Madison Metropolitan Sewage District



TPAD
PRELIMINARY LAYOUT

FIGURE 3.4

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4.5 Conventional Digestion with Cambi THP

The Cambi THP is a patented process, which uses high temperature and pressure to solubilize the volatile solids in sludge. The resulting slurry is typically fed to conventional mesophilic digesters. Operation of the digesters downstream of the Cambi THP units in the thermophilic mode is not recommended by the manufacturer due to a high potential for high volatile acids concentrations and low pH. Table 3.6 presents the design VSLR and HRT for the conventional digestion process with Cambi THP pre-treatment, based on the solids loading projections developed in TM-01.

To operate the digestion facility with a Cambi THP system, the existing 1.014 MG tanks (Digesters No. 4 -6) and the existing 1.076 MG tank (Digester No. 7) would be operated as conventional mesophilic digesters and the existing 0.639 MG tanks (Digesters No. 1-3) would be taken out of service, operated as standby conventional mesophilic digesters, and/or or operated as sludge storage tanks. Installation of a Cambi THP system would allow the Nine Springs WWTP to operate with a total of four units (3 duty and 1 standby). A process schematic and the preliminary layout for this alternative are presented in Figures 3.5 and 3.6, respectively. The use of the Cambi THP as a WAS pretreatment technology is presented in TM-05, Foam Mitigation Alternatives.

4.5.1 Sludge Thickening

The Cambi THP process operates with a high solids concentration in the feed, approximately 17 percent solids. The sludge coming out of CAMBI and fed to the mesophilic digesters has a solids concentration of 10%. In order to achieve this solids concentration, the use of centrifuge thickening will be required. Based on the maximum month 2030 sludge feed to the thickeners of 479,000 gallons per day (assuming the existing thickeners will pre-thicken centrifuge feed to 4.6% solids) two 500 gpm centrifuges operating continuously will be required to thicken the sludge to 17% solids prior to the Cambi THP system.

4.5.2 Digester Foaming

Filamentous foaming in the anaerobic digesters is prevented with the Cambi THP due to thermal hydrolysis of filamentous organisms.

4.3.2 Class A Biosolids

Heat treatment of sewage sludge at 356 deg F or higher for more than 30 minutes is listed as a Process to Further Reduce Pathogens (PFRP). Therefore, the conventional digestion process with Cambi THP pretreatment meets the Alternative 5 (Use of PFRP) requirements for Class A biosolids.

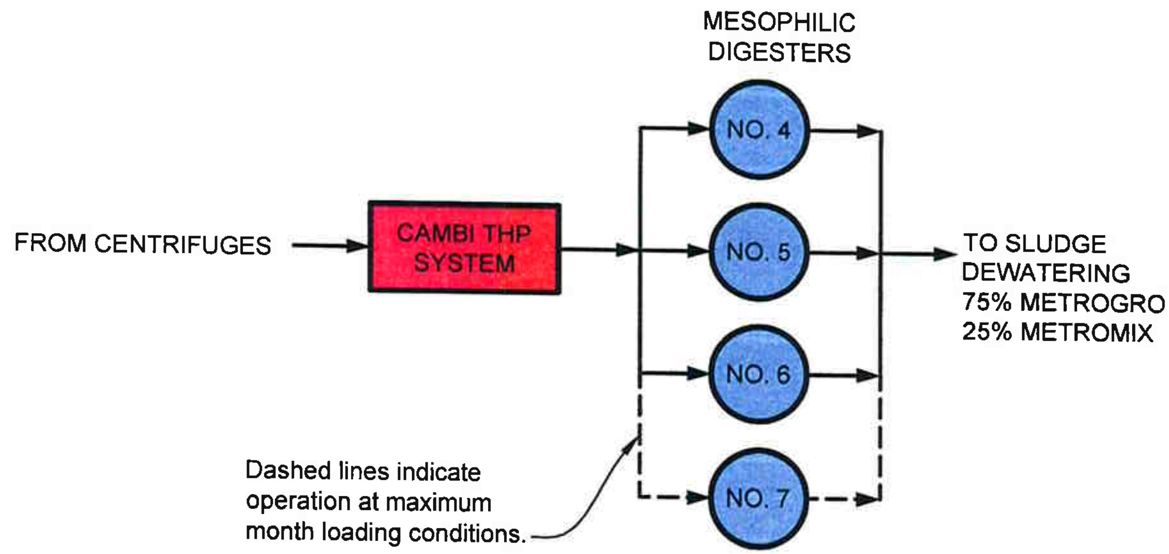
4.5.3 Full-Scale Installations

Currently, there are no full-scale installations of Cambi THP in the U.S. Worldwide large full-scale installations include Dublin Bay WWTP (Dublin, Ireland), Nigg Bay WWTP (Aberdeen, UK), Norwich WWTP (Whitlingham, UK), Cotton Valley Wastewater Treatment Works (Milton Keynes,UK).

Table 3.6 Design Criteria for Conventional Digestion with Cambi THP				
Process Parameter	**Current Conditions**		**2030 Conditions**	
	Average	**Maximum Month**	**Average**	**Maximum Month**
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Cambi THP, ppd (1)	80,800	97,000	117,400	139,700
TS Concentration, %	17	17	17	17
Solids Flow to Cambi THP, gpd (2)	127,500	153,000	185,200	220,400
Conventional Digesters				
Digester Volume, MG	3.04 (3)	4.12 (3,4)	3.04 (3)	4.12 (3,4)
VS Loading Rate, lbs VS/cfd	0.20	0.18	0.29	0.25
Hydraulic Retention Time, days	23.9	26.9	16.4	18.7

Notes:
(1) Assumes volatile solids fraction of 76 percent.
(2) Based on a specific gravity of 0.59.
(3) Existing 1.014 MG Digesters (No. 4, 5, and 6)
(4) Existing 1.076 MG Digester (No. 7)

(A) OPERATION AT CURRENT LOADING CONDITIONS



(B) OPERATION AT 2030 LOADING CONDITIONS

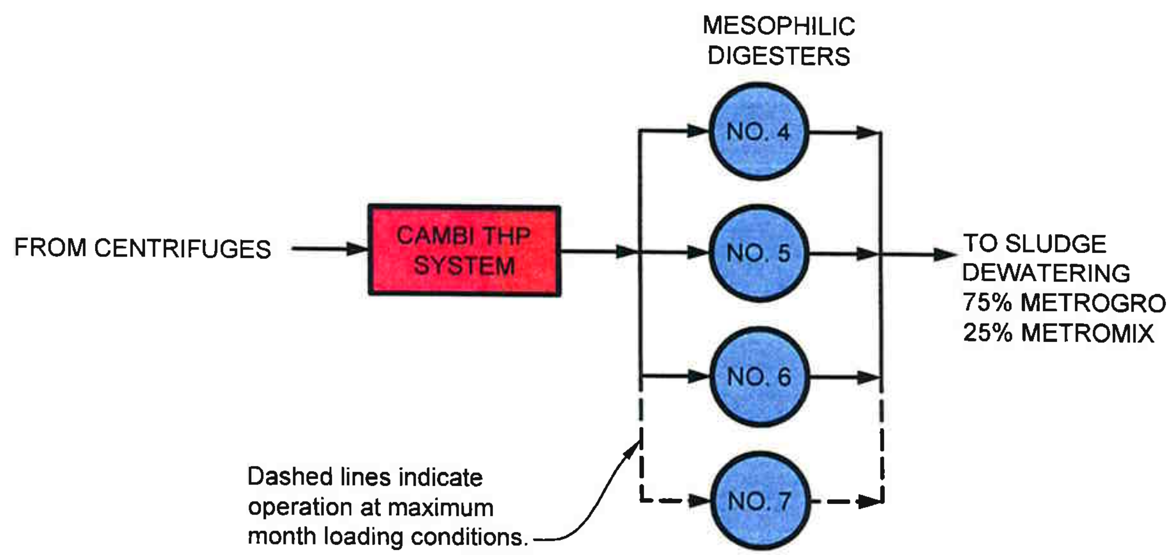


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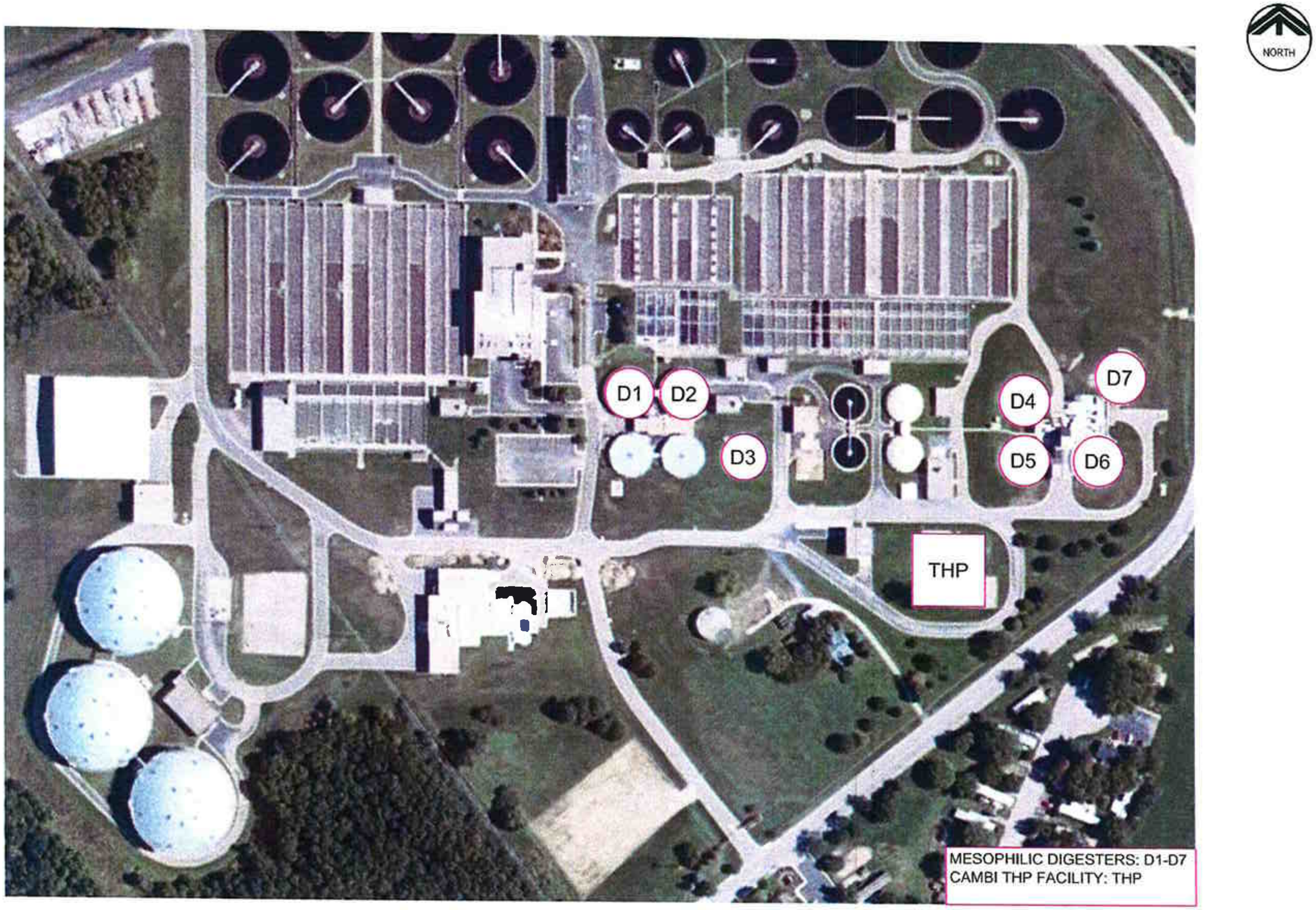
FIGURE 3.5
CONVENTIONAL DIGESTION WITH CAMBI
THP PRETREATMENT PROCESS SCHEMATIC
Madison Metropolitan Sewage District



CONVENTIONAL DIGESTION WITH CAMBI THP PRELIMINARY LAYOUT

FIGURE 3.6

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4.5 Conventional Digestion with Thermal Post-Treatment

In 2008, operation was switched to conventional digestion due to digester foaming and struvite problems experienced while operating in TPAD and Acid-Phase Digestion modes. Conventional digestion resulted in lower volatile solids destruction and biogas production rates but stable performance (volatile acids and alkalinity levels) with manageable digester foaming. Per MMSD request, conventional digestion with thermal post-treatment of 25% of the digested sludge stream was evaluated as part of this study. Table 3.7 presents the design VSLR and HRT for the conventional digestion process, based on the solids loading projections developed in TM-01.

To meet current conditions, implementation of conventional digestion at the Nine Springs WWTP requires the operation of the existing 0.639 MG tanks (Digesters No. 1-3), 1.014 MG tanks (Digesters No. 4 -6), and 1.076 MG tank (Digester No. 7) as conventional mesophilic digesters and the installation of new 1.076 MG tank (Digester No. 8) and a thermal post-treatment facility. Process schematics and the preliminary layout for this alternative are presented in Figures 3.7, 3.8, and 3.9.

To meet the capacity requirements for 2030 conditions, the construction of three additional 1.076 MG tanks (proposed Digesters No. 9, No. 10 and No. 11) would be required. In this mode of operation, the existing and new digesters would be operated as mesophilic methane digesters. Process schematics and the preliminary layout for this alternative are presented in Figures 3.7, 3.8, and 3.9.

The technologies evaluated for thermal post-treatment include indirect heat drying, En-Vessel pasteurization, and batch thermophilic treatment. As stand alone stabilization alternatives, heat drying and En-Vessel pasteurization were not considered for further evaluation in TM-02 because of incompatibility with the Metrogro land application program. Used as thermal post-treatment processes, these technologies would treat up to 25% of the Metrogro sludge to yield a Class A Metromix product.

The proposed thermal treatment process includes three sequencing batch tanks. Based on a holding time of 2 days at 127 deg F, three (3) 130,000-gallon tanks would be required for implementation of the batch thermal treatment alternative.

4.5.1 Sludge Thickening and Dewatering

Due to the relatively low volatile solids loading rates recommended for conventional digestion, thickening improvements are not required for this mode of operation at the Nine Springs WWTP. To decrease the heat dryer and En-vessel pasteurization sizing requirements, the post-treatment facility would receive thickened solids (Metrogro) that would be dewatered using the existing centrifuge.

4.5.2 Digester Foaming

Conventional digestion has a lower potential for *Microthrix*-associated foaming than acid phase digestion and TPAD because the lower sludge loading rates result in lower filament concentrations and lower gas production (less gas entrainment of filaments). However, digester foaming would still occur because conventional mesophilic digestion does not destroy *Microthrix* and other foam-forming filamentous organisms. To prevent *Microthrix*-associated foaming, acid phase digestion must be coupled to a foam mitigation alternative (See TM-05, Foam Mitigation Alternatives).

4.3.2 Class A Biosolids

Thermal post-treatment of sludge is required to produce Class A biosolids because the pathogen reduction in conventional mesophilic digestion does not meet the required levels. En-Vessel pasteurization and heat drying are listed as Processes to Further Reduce Pathogens (PFRP). To meet the time-temperature Class A requirements, the batch thermophilic tanks will maintain the sludge at 131 deg F for 24 hours. Under conventional digestion with thermal post-treatment, a considerable fraction of the digested sludge will be disposed as Class B because the thermal post-treatment facilities will only treat 25% of the digested sludge.

4.5.3 Full-Scale Installations

- Currently, there are no large utilities with full-scale belt heat dryer installations in the U.S. Worldwide installations include Pomorzany WWTP (Poland), CUS - SOGEA (Strasbourg, France), and Antalya Greater City Municipality (Antalya, Turkey). Full-scale installations at small U.S. utilities include the Alderwood Water District WWTP (Alderwood, WA) and the City of Buffalo WWTP (Buffalo, MN).

- Full-scale installations of En-Vessel pasteurization include the South Coastal WWTP (Bethany Beach, DE), the Seymour WWTP (Seymour, IN), the Kiel WWTP (Kiel, WI) and the Greenwood Metropolitan District (Greenwood, SC).

- The Hyperion Treatment Plant (Playa del Rey, CA) and the Terminal Island Water Reclamation Plant (Los Angeles, CA) operate with full-scale installations of conventional digestion with batch thermophilic post-treatment to meet the Class A requirements through Alternative 1 (Time-Temperature).

Table 3.7 Design Criteria for Conventional Digestion with Thermal Post-Treatment				
Process Parameter	**Current Conditions**		**2030 Conditions**	
	Average	**Maximum Month**	**Average**	**Maximum Month**
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Digestion, ppd (1)	80,800	97,000	117,400	139,700
TS Concentration, %	4.6	4.6	4.6	4.6
Solids Flow to Digestion, gpd	277,200	332,800	402,700	479,300
Mesophilic Digesters				
Digester Volume, MG	6.04 (2)	7.11 (2,3)	9.26 (2,3,4)	10.34 (2,3,4,5)
VS Loading Rate, lbs VS/cfd	0.10	0.10	0.09	0.10
Hydraulic Retention Time, days	21.8	21.4	23.0	21.6
Thermal Post-Treatment (6)				
VS Load to Post-Treatment, ppd (7)	10,100	12,100	14,700	17,500
TS Load to Post-Treatment, ppd (7)	16,500	19,800	24,000	28,500
Solids Flow at 5% TS, gpd (8)	39,600	47,500	57,600	68,400
Solids Flow at 20% TS, gpd (9)	19,800	23,800	28,800	34,200

Notes:
(1) Assumes volatile solids fraction of 76 percent.
(2) Existing 0.639 MG Digesters (No. 1, 2, and 3), existing 1.014 MG Digesters (No. 4, 5, and 6), and existing 1.076 MG Digester (No. 7)
(3) New 1.076 MG Digester (No. 8)
(4) New 1.076 MG Digesters (No. 10 and 9).
(5) New 1.076 MG Digester (No. 11)
(6) Assumes 25 percent of the digested sludge with thermal post-treatment.
(7) Assumes 50 percent volatile solids reduction in the digesters.
(8) Batch thermophilic tank feed. Based on current GBT operation.
(9) Heat dryer or En-Vessel pasteurization feed. Assumes BFP or centrifuge dewatering.

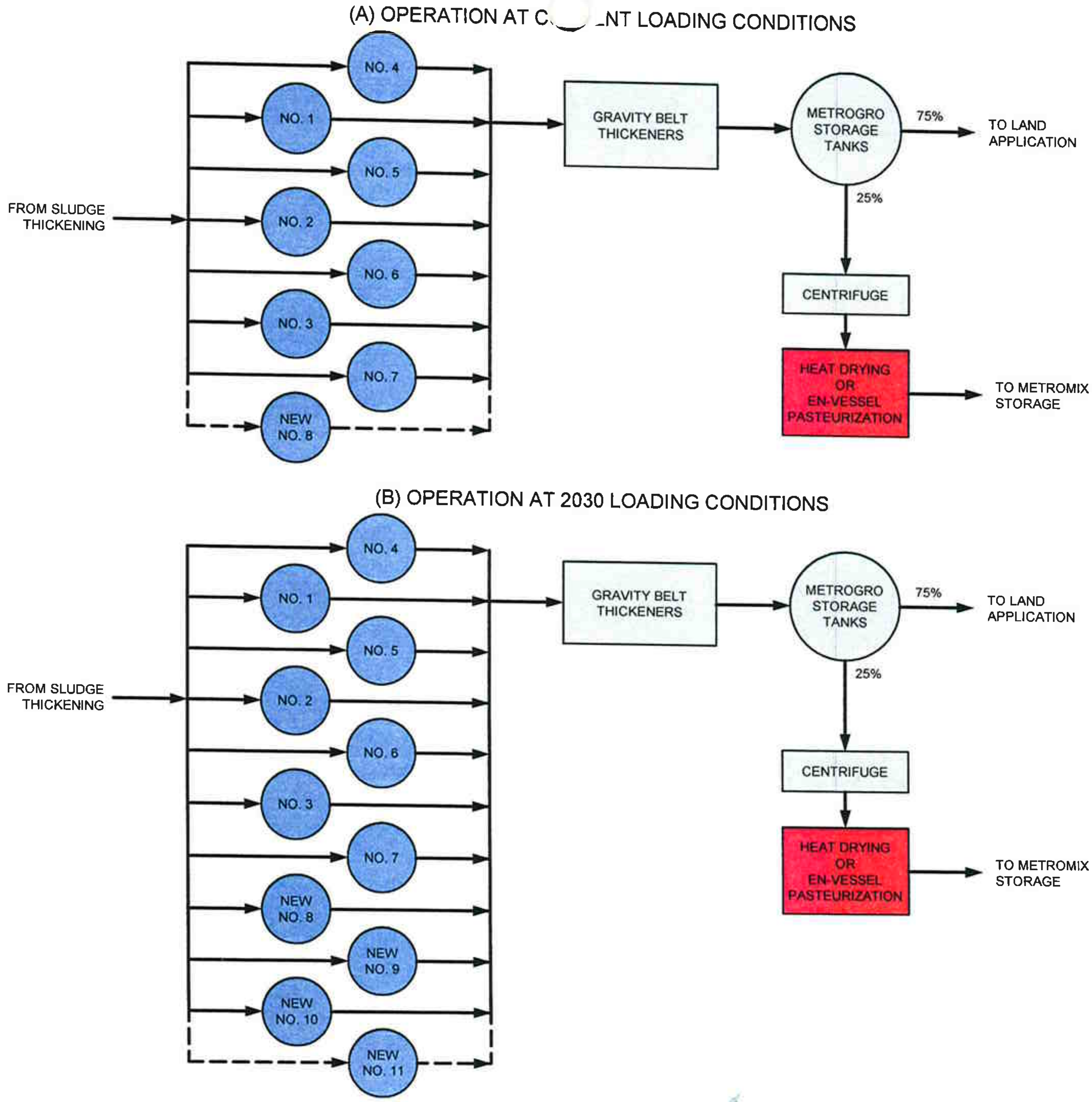

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FIGURE 3.7
PROCESS SCHEMATIC FOR CONVENTIONAL
DIGESTION WITH THERMAL POST TREATMENT
Madison Metropolitan Sewage District

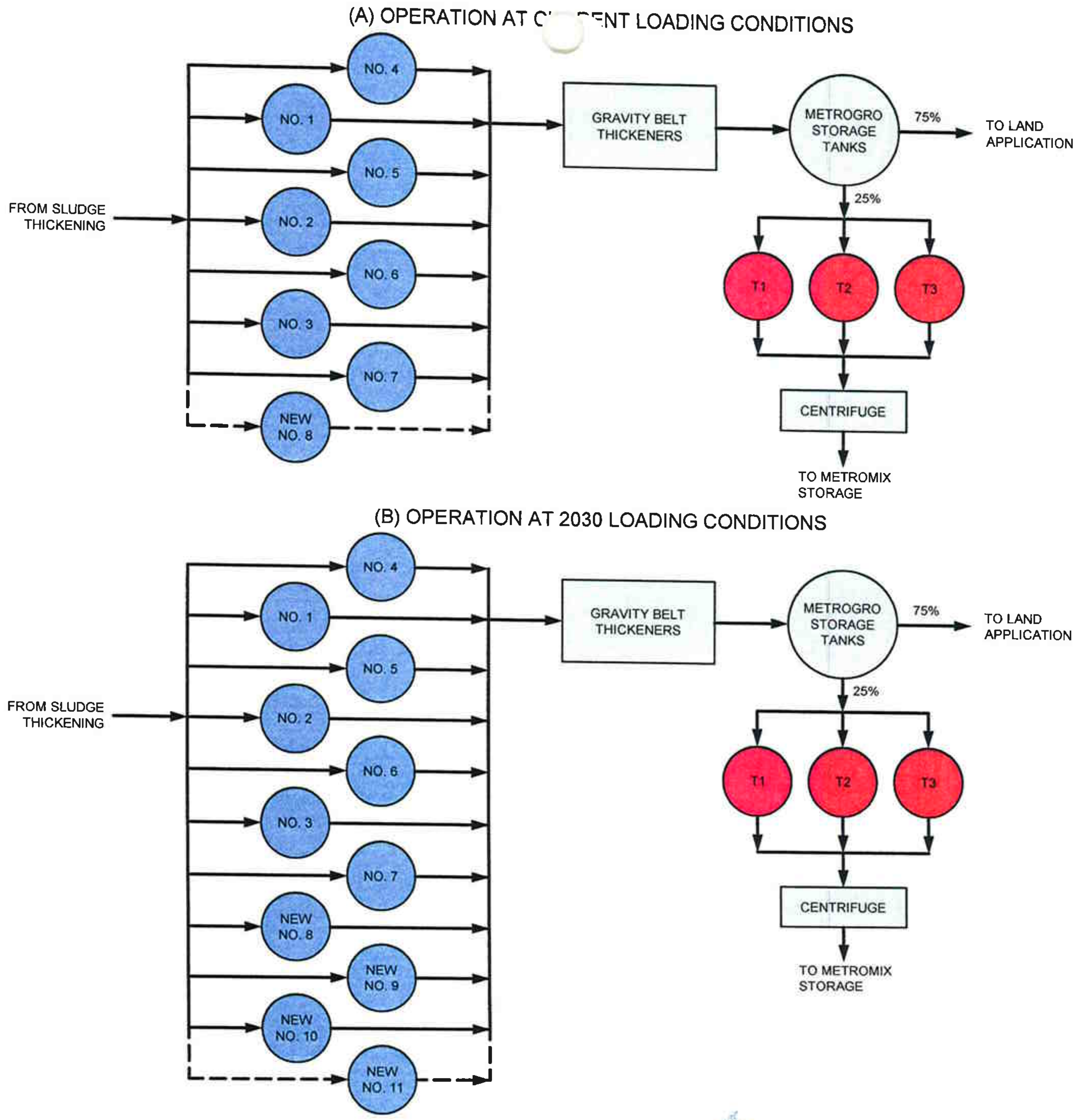

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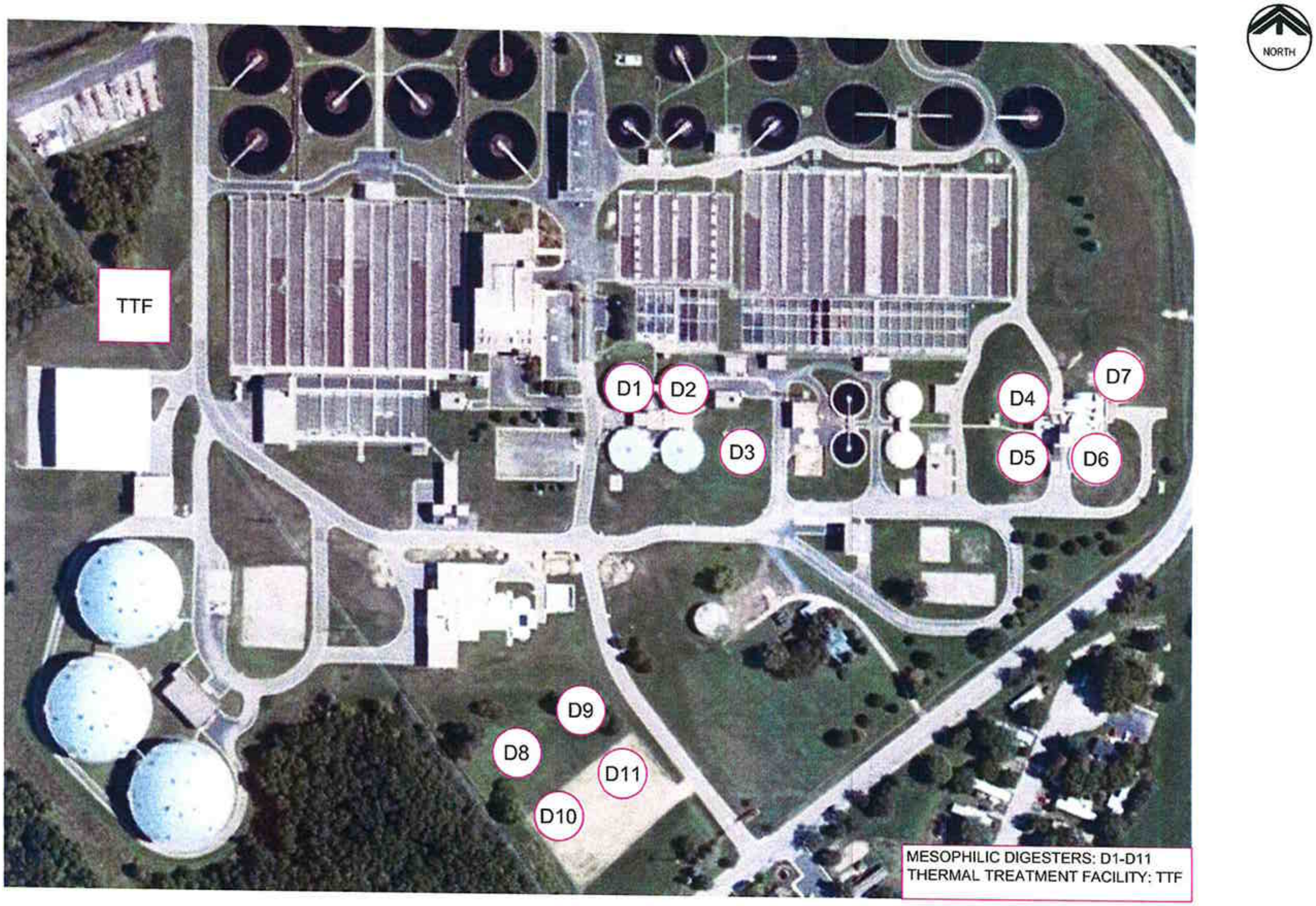
FIGURE 3.8
PROCESS SCHEMATIC FOR CONVENTIONAL DIGESTION WITH THERMAL POST TREATMENT
Madison Metropolitan Sewage District



CONVENTIONAL DIGESTION WITH POST-TREATMENT PRELIMINARY LAYOUT

FIGURE 3.9

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5.0 Comparison of Digestion Alternatives

Economic and non-economic comparisons of acid-phase digestion with mesophilic-thermophilic mode of operation, TPAD, conventional digestion with Cambi THP pretreatment, and conventional digestion with thermal post-treatment are presented in Tables 3.8 and 3.9, respectively. The Appendix contains the detailed cost development tables. A summary of the comparison of the alternatives is presented in Table 3.10.

Table 3.8
Economic Comparison of Digestion Alternatives

Anaerobic Digestion Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Acid-Phase Digestion	$9,967,000	$21,267,000	$18,913,000	$50,147,000
TPAD (Thermo-Meso)	$9,631,000	$18,329,000	$18,913,000	$46,873,000
Conventional Digestion with Cambi THP	$23,108,000	$30,912,000	$17,933,000	$71,953,000
Conventional Digestion with Heat Drying	$29,133,000	$25,562,000	$18,428,000	$73,123,000
Conventional Digestion with En-Vessel Pasteurization	$17,380,000	$23,385,000	$21,938,000	$62,703,000
Conventional Digestion with Batch Thermal Tanks	$19,349,000	$24,450,000	$20,961,000	$64,760,000

As shown on Table 3.8, the conventional digestion with heat drying alternative has the highest capital cost and the highest present worth cost. Acid phase digestion and TPAD have similar capital costs. In this analysis, TPAD has the lowest present worth cost, about 7% lower than acid phase. The present worth difference between acid phase and TPAD is not considered to be significant, because it is less than the margin of error for budget level cost estimating. Conventional digestion with Cambi THP has the second highest capital and present worth costs. Acid phase digestion and TPAD have the lowest capital costs, as well as the lowest overall O&M costs (including hauling).

Table 3.9 Non-Economic Comparison of Digestion Alternatives		
Alternative	**Advantages**	**Disadvantages**
Acid-Phase Digestion	• Production of Class A Biosolids • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Improved biogas quality in methane digesters • Decreased non-filamentous foaming potential • Gradual temperature increase • Enhanced digestion of fats, oil, and grease	• Does not meet time-temperature Class A requirement • Requires extensive monitoring to obtain site-specific Class A permit • Requires pretreatment to remove *Microthrix* • Site constraint issues (requires two new 0.38 MG acid digesters and a 1.08 MG methane digester) • Requires separate gas system for acid digesters due to high sulfur levels and low BTU content in acid-phase digester gas • Requires improvements to sludge thickening system • Odor issues during cleaning of acid digester equipment for maintenance
TPAD	• Production of Class A Biosolids • High volatile solids reduction • Successful full-scale installations in the US • Consistent with Metrogro and Metromix programs • Existing facility designed for TPAD • Only requires improvements to sludge thickening system for 2030 conditions	• Does not meet time-temperature Class A requirement • Requires extensive monitoring to obtain site-specific Class A permit • Requires pretreatment to remove *Microthrix* • Higher potential for non-filamentous foaming than acid phase digestion • Prone to excessive struvite formation during thermophilic to mesophilic heat recovery • Requires preheating of raw sludge • Site constraint issues (requires two new 1.08 MG digesters) • Most of the gas produced in the thermophilic stage (poorer quality than the mesophilic stage)

Table 3.9
Non-Economic Comparison of Digestion Alternatives

Alternative	Advantages	Disadvantages
Conventional Digestion with Cambi THP	• Production of Class A Biosolids • Meets time-temperature Class A requirement • High volatile solids reduction • Successful full-scale installations in Europe • Destruction of *Microthrix* • Lower digester tankage requirements, when compared to acid-phase digestion and TPAD • Lower capacity requirements for dewatering and hauling	• Energy use/costs may increase • No full-scale installations in the US • New high solids thickening facility is required • Dark-colored side stream • Side stream treatment for nutrient removal may be required • Odor control
Conventional Digestion with Heat Drying	• Production of Class A Biosolids for 25% of the sludge flow (Metromix) • Process listed as a PFRP • Successful full-scale installations in the U.S. • Lower struvite scaling potential • Lower polymer usage than TPAD and acid phase digestion	• Requires pre-treatment to remove *Microthrix* and other foam-causing organisms • Lower volatile solids destruction and thickening/dewatering than other alternatives • Energy use/costs may increase • Site constraint issues (requires two new 1.08 MG conventional digester) • Production of Class B Biosolids for 75% of solids production • Increases Carbon Footprint by 28,500 tons per year @ 2030 flows
Conventional Digestion with En-Vessel Pasteurization	• Production of Class A Biosolids for 25% of sludge flow • Process listed as PRFP • Successful full-scale installations in the U.S. • Lower struvite scaling potential • Lower polymer usage than TPAD and acid phase digestion	• Requires pre-treatment to remove *Microthrix* and other foam-causing organisms. • Lower volatile solids destruction and thickening/dewatering than other alternatives. • Energy use/costs may increase • Site constraint issues (requires four

Table 3.9
Non-Economic Comparison of Digestion Alternatives

Alternative	Advantages	Disadvantages
		new 1.08 MG conventional digester) • Costs associated with chemical addition and additional solids production • Production of Class B Biosolids for 75% of solids production
Conventional Digestion with Batch Thermophilic Tanks	• Production of Class A Biosolids for 25% of sludge flow • Meets time-temperature Class A requirements • Lower struvite scaling potential • Lower polymer usage than TPAD and acid phase digestion	• Requires pre-treatment to remove *Microthrix* and other foam-causing organisms. • Lower volatile solids destruction and thickening/dewatering than other alternatives • Energy use/costs may increase • Site constraint issues (requires two new 1.08 MG conventional digester) • Site Constraint Issues (requires three 2-day batch tanks) • Production of Class B Biosolids for 75% of solids production

6.0 Recommended Alternative

Conventional digestion with Cambi THP and acid-phase digestion with mesophilic-thermophilic-mesophilic mode of operation for were selected for further evaluation based on the following reasons:

- These alternatives meet the MMSD biosolids management goals of producing Class A quality land application products (Metrogro and Metromix).
- These alternatives treat 100 percent of the biosolids to meet Class A requirements.
- Acid-phase digestion has a considerably lower capital cost than conventional digestion with thermal post-treatment and comparable costs with TPAD.
- These alternatives are preferred for co-digestion of fats, oil, and grease due to enhanced digestion of these materials and single point of feeding.

A detailed comparison between Cambi THP and acid-phase digestion that incorporates foam and struvite mitigation alternatives, grease co-digestion, and production of Class A biosolids through Alternative 1 of the 503 regulations is presented in TM No. 3A.

Table 3.10 Overall Comparison of Digestion Alternatives						
Digestion Alternative	**Acid Phase**	**TPAD**	**Conventional with Cambi**	**Conventional with Dryer**	**Conventional with En-Vessel**	**Conventional with Batch**
Production of Class A Biosolids for 100% of the stabilized solids output	0	0	+	-	-	-
Meets Alternative 1 or is listed as a PFRP	-	-	+	0	0	0
Operating Facilities with Class A permits	0	-	0	0	0	0
High Volatile Solids Reduction	0	0	+	-	-	-
Decreased Non-Filamentous Foaming Potential	0	-	0	-	-	-
Decreased potential for *Microthrix* foaming	0	-	+	0	0	0
Decreased Potential for Struvite Scaling	-	-	0	0	0	0
Consistent with Metrogro & Metromix	0	0	0	0	0	0
Full-Scale Installations	0	0	0	0	0	0
Full-Scale Installations in the U.S.	0	0	-	-	0	0
Enhanced fats, oil, and grease degradation	+	0	+	-	-	-
Low Mechanical complexity	+	0	-	-	-	-
Low Capital cost	0	0	-	-	-	-
Low Plant O&M Cost	0	0	-	-	-	-
Low Disposal Cost	0	0	+	0	-	-
Low Total Present worth cost	+	+	-	-	-	-
Odors	-	-	-	0	-	-

<u>Legend</u>
+ = Strongly favors this alternative
0 = Favors this alternative about equally with another, or is not a significant factor
- = Distinct disadvantage for this alternative

APPENDIX A
DETAIL COST ESTIMATES

Table 1. Summary
Economic Comparison of Digestion Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Anaerobic Digestion Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Acid-Phase (Meso-Thermo) Digestion	$9,967,000	$21,267,000	$18,913,000	$50,147,000
TPAD (Thermo-Meso)	$9,631,000	$18,329,000	$18,913,000	$46,873,000
Conventional Digestion with Cambi THP	$23,108,000	$30,912,000	$17,933,000	$71,953,000
Conventional Digestion with Heat Drying	$29,133,000	$25,562,000	$18,428,000	$73,123,000
Conventional Digestion with En-Vessel Pasteurization	$17,380,000	$23,385,000	$21,938,000	$62,703,000
Conventional Digestion with Batch Thermophilic Tanks	$19,349,000	$24,450,000	$20,961,000	$64,760,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table 2
Economic Comparison of Digestion Alternatives
Acid-Phase (Meso-Thermo) Digestion

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Modifications to Sludge Thickening							
Two (2) 2m Gravity Belt Thickener		$ 450,000	20	$ -	$ -	$ -	Energenics - 150k
Polymer Feed system		$ 100,000	20	$ -	$ -	$ -	$50k x 2
Sludge Feed system		$ 30,000	20	$ -	$ -	$ -	Beaver Dam - $15k x 2
New Sludge Thickening Building		$ 500,000	40	$ -	$ 250,000	$ -	2000 sqft @ $250/sqft
Two (2) 0.380 MG Acid Digesters							
Digester Concrete		$ 1,520,000	40	$ -	$ 760,000	$ -	(2) 380,000 gal @ $2.00/gal
Digester Cover		$ 220,000	40	$ -	$ 110,000	$ -	concrete
Digester Mixing System		$ 206,000	20	$ -	$ -	$ -	mechanical mixing system
Heating System		$ 107,000	20	$ -	$ -	$ -	(1) Hex, (1) Hot Water Pump
Control Building (30' x 35')		$ 263,000	40	$ -	$ 131,500	$ -	1,050 sqft @ $250.00/sqft
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Off-gas flare system		$ 300,000	20	$ -	$ -	$ -	Enclosed flare quote $200k
Accessories		$ 50,000	20	$ -	$ -	$ -	
One (1) 1.076 MG Anaerobic Digester @ 80' Diameter (No. 8)							
Digester Concrete		$ -	40	$ 2,152,000	$ -	$ 1,614,000	(1) 1,076,000 gal @ $2.00/gal
80' Digester Cover		$ -	40	$ 300,000	$ -	$ 225,000	concrete
Digester Mixing System		$ -	20	$ 233,000	$ -	$ 117,000	draft tube mixing system
Heating System		$ -	20	$ 113,000	$ -	$ 57,000	(1) hex, (1) hot water pump.
Control Building (30' x 35')		$ -	40	$ 263,000	$ -	$ 197,000	1,050 sqft @ $250.00/sqft
Tunnel extension			40	$ 200,000	$ -	$ 150,000	100' @ $2000/ft
Accessories		$ -	20	$ 50,000	$ -	$ 25,000	
Modifications to Existing Digester NO.7							
Mixing System		$ -	20	$ -	$ -	$ -	Use existing
Heating System		$ -	20	$ -	$ -	$ -	Use existing
Biogas Handling System		$ -	20	$ -	$ -	$ -	Use existing
Modifications to Existing Digester NOS.1-3							
Mixing System		$ -	20	$ -	$ -	$ -	Use existing
Heating System		$ -	20	$ -	$ -	$ -	Use existing
Biogas Handling System		$ -	20	$ -	$ -	$ -	Use existing
Piping Modifications		$ -	20	$ -	$ -	$ -	Use existing
Modifications to Sludge Dewatering							
None		$ -	20	$ -	$ -	$ -	Use existing
Site Work	8%	$ 332,000	40	$ 265,000	$ 166,000	$ 199,000	
Mechanical Process Piping	10%	$ 415,000	40	$ 331,000	$ 208,000	$ 248,250	
Instrumentation and Control	7%	$ 290,000	20	$ 232,000	$ -	$ 116,000	
Electrical	8%	$ 332,000	20	$ 265,000	$ -	$ 133,000	
Subtotal		$ 5,515,000		$ 4,404,000	$ 1,825,500	$ 3,081,250	
Allowance for Undefined Design Details	25%	$ 1,379,000		$ 1,101,000			
Total Construction Cost		$ 6,894,000		$ 5,505,000			
Engineering, Legal and Administrative	15%	$ 1,034,000		$ 826,000			
Total		$ 7,928,000		$ 6,331,000	$ 1,825,500	$ 3,081,250	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 7,928,000		$ 3,933,000	$ 705,000	$ 1,189,000	
Annual O & M Cost							
Labor		$ 51,480		$ 68,640			
Energy (electrical and thermal)		$ 455,277		$ 533,672			
Chemicals		$ 922,767		$ 1,097,563			
Hauling		$ 1,402,616		$ 1,660,659			
Maintenance		$ 118,900		$ 213,900			1.5% of Construction Total
Total Annual O & M Cost		$ 2,951,040		$ 3,574,434			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 22,926,000		$ 17,254,000			
Total Present Worth Capital Cost		$ 9,967,000					
Total Present Worth O&M Cost		$ 40,180,000					
Total Present Worth		$ 50,147,000					

TABLE 3 - ALTERNATE NO.1 - ACID PHASE DIGESTION O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	30	hr/wk	Hours	40	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$51,480.00	$/yr	Annual	$68,640.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	3		# Mesophilic Reactors	3	
# Thermophilic Reactors	3		# Thermophilic Reactors	4	
Cost	$386,114	per yr	Cost	$459,587	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	2	
# Centrifuges	0		# Centrifuges	0	
Cost	$42,412	per yr	Cost	$42,412	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion	106,316	lbs/d	Solids Flow to Digestion	125,875	lbs/d
Solids Flow to Digestion	212,462	gpd @ 6%	Solids Flow to Digestion	251,549	gpd @ 6%
Digested Sludge Production	61,876	lbs/d	Digested Sludge Production	73,259	lbs/d
Digested Sludge Production	296,766	gpd @2.5%	Digested Sludge Production	351,363	gpd @2.5%
% to GBT	75%		% GBT	75%	
% to Centrifuge	25%		% Centrifuge	25%	
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	2	
# Centrifuges	1		# Centrifuges	1	
Cost	$26,751	per yr	Cost	$31,673	per yr
Total Power Cost	***$455,277***	***$/yr***	***Total Power Cost***	***$533,672***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge	110,500	lbs/d	Raw Sludge	132,500	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
# DAF	0		# DAF	0	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# GBT	2		# GBT	2	
# Centrifuge	0		# Centrifuge	0	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$332,743	$/yr	Cost	$398,991	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	61,876	lbs/day	Digested Sludge	73,259	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$590,024		Cost	$698,573	
Total Chemical Cost	***$922,767***	***$/yr***	***Total Chemical Cost***	***$1,097,563***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	20	%	Metrogro cake concentration	20	%
Gallons liquid per day	92,739	gpd	Gallons liquid per day	109,801	gpd
Dewatered Sludge per day	45.9	cu yds/d	Dewatered Sludge per day	54.4	cuyds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cuyd	Dewatered Sludge Hauling Cost	$13.00	$/cuyd
Total Hauling Cost	***$1,402,616***	***$/yr***	***Total Hauling Cost***	***$1,660,659***	***$/yr***

Table 4
Economic Comparison of Digestion Alternatives
TPAD (Thermo-Meso)

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Two (2) 2m Gravity Belt Thickener		$ -	20	$ 450,000	$ -	$ 225,000	Energenics - 150k
Polymer Feed system		$ -	20	$ 100,000	$ -	$ 50,000	$50k x 2
Sludge Feed system		$ -	20	$ 30,000	$ -	$ 15,000	Beaver Dam - $15k x 2
New Sludge Thickening Building		$ -	40	$ 500,000	$ -	$ 375,000	2000 sqft @ $250/sqft
Construct one (1) 1.076 MG Anaerobic Digester @ 80' Diameter (No. 8)							
Digester Concrete		$ 2,152,000	40	$ -	$ 1,076,000	$ -	(1) 1,076,000 gal @ $2.00/gal
80' Digester Cover		$ 300,000	40	$ -	$ 150,000	$ -	concrete
Digester Mixing System		$ 233,000	20	$ -	$ -	$ -	draft tube mixing system
Heating System		$ 113,000	20	$ -	$ -	$ -	(1) Hex, (1) Hot Water Pump
Control Building (30' x 35')		$ 263,000	40	$ -	$ 131,500	$ -	1,050 sqft @ $250/sqft
Tunnel extension		$ 200,000	40		$ 100,000	$ -	100' @ $2000/ft
Accessories		$ 50,000	20	$ -	$ -	$ -	
Construct one (1) additional 1.076 MG digester (No. 9)							
Digester Concrete		$ -	40	$ 2,152,000	$ -	$ 1,614,000	(1) 1,076,000 gal @ $2.00/gal
80' Digester Cover		$ -	40	$ 300,000	$ -	$ 225,000	(1) Concrete
Digester Mixing System		$ -	20	$ 233,000	$ -	$ 116,500	(1) draft tube mixing system
Heating System		$ -	20	$ 113,000	$ -	$ 56,500	(1) Hex, (1) Hot Water Pump
Control Building (30' x 35')		$ -	40	$ 525,000	$ -	$ 394,000	1,050 sqft @ $250/sqft
Tunnel extension		$ -	40	$ 300,000	$ -	$ 225,000	150' @ $2000/ft
Accessories		$ -	20	$ 50,000	$ -	$ 25,000	
Modifications to Sludge Dewatering							
None			20	$ -	$ -	$ -	Use existing
Site Work	8%	$ 265,000	40	$ 380,000	$ 132,500	$ 285,000	
Mechanical Process Piping	10%	$ 331,000	40	$ 475,000	$ 165,500	$ 356,250	
Instrumentation and Control	7%	$ 232,000	20	$ 333,000	$ -	$ 166,500	
Electrical	8%	$ 265,000	20	$ 380,000	$ -	$ 190,000	
Subtotal		$ 4,404,000		$ 6,321,000	$ 1,755,500	$ 4,318,750	
Allowance for Undefined Design Details	25%	$ 1,101,000		$ 1,580,000			
Total Construction Cost		$ 5,505,000		$ 7,901,000			
Engineering, Legal and Administrative	15%	$ 826,000		$ 1,185,000			
Total		$ 6,331,000		$ 9,086,000	$ 1,755,500	$ 4,318,750	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 6,331,000		$ 5,645,000	$ 678,000	$ 1,667,000	
Annual O & M Cost							
Labor		$ 51,480		$ 68,640			
Energy (electrical and thermal)		$ 434,944		$ 514,363			
Chemicals		$ 590,024		$ 1,097,563			
Hauling		$ 1,402,616		$ 1,660,659			
Maintenance		$ 95,000		$ 231,300			1.5% of Total
Total Annual O & M Cost		$ 2,574,064		$ 3,572,525			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 19,997,000		$ 17,245,000			

Total Present Worth Capital Cost	$	9,631,000
Total Present Worth O&M Cost	$	37,242,000
Total Present Worth	**$**	**46,873,000**

TABLE 5 - ALTERNATE NO.2 - TPAD O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	30	hr/wk	Hours	40	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$51,480.00	$/yr	Annual	$68,640.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	4		# Mesophilic Reactors	4	
# Thermophilic Reactors	2		# Thermophilic Reactors	3	
Cost	$366,804	per yr	Cost	$440,278	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	2		# DAFs	0	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners	0		# Gravity Belt Thickeners	2	
# Centrifuges	0		# Centrifuges	0	
Cost	$34,701	per yr	Cost	$42,412	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion	106,316	lbs/d	Solids Flow to Digestion	125,875	lbs/d
Solids Flow to Digestion	277,124	gpd @ 4.6%	Solids Flow to Digestion	251,549	gpd @ 6%
Digested Sludge Production	61,876	lbs/d	Digested Sludge Production	73,259	lbs/d
Digested Sludge Production	370,958	gpd @2%	Digested Sludge Production	351,363	gpd @2.5%
% to GBT	75%		% GBT	75%	
% to Centrifuge	25%		% Centrifuge	25%	
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	2	
# Centrifuges	1		# Centrifuges	1	
Cost	$33,439	per yr	Cost	$31,673	per yr
Total Power Cost	***$434,944***	***$/yr***	***Total Power Cost***	***$514,363***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge	110,500	lbs/d	Raw Sludge	132,500	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
# DAF	2		# DAF	0	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# GBT	0		# GBT	2	
# Centrifuge	0		# Centrifuge	0	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$0	$/yr	Cost	$398,991	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	61,876	lbs/day	Digested Sludge	73,259	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$590,024		Cost	$698,573	
Total Chemical Cost	***$590,024***	***$/yr***	***Total Chemical Cost***	***$1,097,563***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	20	%	Metrogro cake concentration	20	%
Gallons liquid per day	92,739.5	gpd	Gallons liquid per day	109,801.0	gpd
Dewatered Sludge per day	45.9	cu yds/d	Dewatered Sludge per day	54.4	cu yds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cu yd	Dewatered Sludge Hauling Cost	$13.00	$/cu yd
Total Hauling Cost	***$1,402,616***	***$/yr***	***Total Hauling Cost***	***$1,660,659***	***$/yr***

Table 6
Economic Comparison of Digestion Alternatives
Conventional Digestion with Cambi THP

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Two (2) 500 gpm Centrifuges		$ 2,000,000	20	$ -	$ -	$ -	$1.0M/each
Sludge Feed system		$ 37,500	20	$ -	$ -	$ -	
Polymer feed system		$ 100,000	20	$ -	$ -	$ -	
New Centrifuge Building (40'x60')		$ 600,000	40	$ -	$ 300,000	$ -	2,400 sqft @ $250/sqft
Construct CAMBI							
CAMBI equipment cost		$ 10,784,000	20	$ -	$ -	$ -	
New Cambi THP Building (40'x72')		$ 432,000	40	$ -	$ 216,000	$ -	2,880 sqft @ $150/sqft (pre-enginee
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Modifications to Sludge Dewatering							
None			20	$ -	$ -	$ -	Use existing
Site Work	8%	$ 1,148,000	40	$ -	$ 574,000	$ -	
Mechanical Process Piping	10%	$ 1,435,000	40	$ -	$ 717,500	$ -	
Instrumentation and Control	7%	$ 1,005,000	20	$ -	$ -	$ -	
Electrical	8%	$ 1,148,000	20	$ -	$ -	$ -	
Subtotal		$ 19,089,500		$ -	$ 2,007,500	$ -	
Allowance for Undefined Design Details	25%	$ 2,616,000		$ -			5% used for CAMBI
Total Construction Cost		$ 21,705,500		$ -			
Engineering, Legal and Administrative	15%	$ 2,177,000		$ -			5% used for CAMBI
Total		$ 23,882,500		$ -	$ 2,007,500	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 23,883,000		$ -	$ 775,000	$ -	
Annual O & M Cost							
Labor		$ 85,800		$ 102,960			
Energy (electrical and thermal)		$ 974,284		$ 982,812			
Chemicals		$ 956,047		$ 1,138,643			
Hauling		$ 1,329,993		$ 1,574,675			
Maintenance		$ 358,200		$ 358,200			1.5% of Total
Total Annual O & M Cost		$ 3,704,324		$ 4,157,290			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 28,778,000		$ 20,067,000			
Total Present Worth Capital Cost		$ 23,108,000					
Total Present Worth O&M Cost		$ 48,845,000					
Total Present Worth		**$ 71,953,000**					

TABLE 7 - ALTERNATE NO.3 - CONVENTIONAL DIGESTION W/ CAMBI THP O&M					
2010			**2030**		
Labor					
Description					
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	50	hr/wk	Hours	60	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$85,800.00	$/yr	Annual	$102,960.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	3		# Mesophilic Reactors	3	
Cambi THP System	1		Cambi THP System	1	
Cost	$860,889	per yr	Cost	$860,889	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	2		# DAFs	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners	0		# Gravity Belt Thickeners	0	
Flow to Centrifuges	0.277	mgd @4.6%	Flow to Centrifuges	0.403	mgd @4.6%
# Centrifuges in service	1		# Centrifuges	1	
Cost	$67,044	per yr	Cost	$67,044	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Cambi THP	106,316	lbs/d	Solids Flow to Cambi THP	125,875	lbs/d
Solids Flow to Cambi THP	126,500	gpd @ 17%	Solids Flow to Cambi THP	155,850	gpd @ 17%
Digested Sludge Production	61,876	lbs/d	Digested Sludge Production	73,259	lbs/d
Digested Sludge Production	148,383	gpd @5%	Digested Sludge Production	175,682	gpd @5%
% to GBT	0%		% GBT	0%	
% to Centrifuge	100%		% Centrifuge	100%	
# Gravity Belt Thickeners	0		# Gravity Belt Thickeners	0	
# Centrifuges	1		# Centrifuges	1	
Cost	$46,352	per yr	Cost	$54,879	per yr
Total Power Cost	***$974,284***	***$/yr***	***Total Power Cost***	***$982,812***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge	110,500	lbs/d	Raw Sludge	132,500	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	8	lbs/DT	Centrifuge Polymer Rate	8	lbs/DT
# DAF	2		# DAF	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# GBT	0		# GBT	0	
# Centrifuge	1		# Centrifuge	1	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$443,658	$/yr	Cost	$531,988	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	61,876	lbs/day	Digested Sludge	73,259	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	30	lbs/DT	Centrifuge Polymer Rate	30	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$512,390		Cost	$606,655	
Total Chemical Cost	***$956,047***	***$/yr***	***Total Chemical Cost***	***$1,138,643***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	30	%	Metrogro cake concentration	30	%
Gallons liquid per day	92,739	gpd	Gallons liquid per day	109,801	gpd
Dewatered Sludge per day	30.6	cu yds/d	Dewatered Sludge per day	36.2	cuyds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cuyd	Dewatered Sludge Hauling Cost	$13.00	$/cuyd
Total Hauling Cost	***$1,329,993***	***$/yr***	***Total Hauling Cost***	***$1,574,675***	***$/yr***

Table 8
Economic Comparison of Digestion Alternatives
Conventional Digestion with Heat Drying

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
None		$ -	20	$ -	$ -	$ -	Use existing
Construct one (1) additional 1.076 MG digester (No. 8)							
Digester Concrete		$ 2,152,000	40		$ 1,076,000	$ -	(1) 1,076,000 gal @ $2.00/gal
80' Digester Covers		$ 300,000	40		$ 150,000	$ -	(1) Concrete
Digester Mixing Systems		$ 233,000	20		$ -	$ -	(1) draft tube mixing systems
Heating Systems		$ 213,000	20		$ -	$ -	(1) Hex, (1) HW Pump, (1) Boiler
Control Building (30' x 35')		$ 263,000	40		$ 131,500	$ -	1,050 sqft @ $250/sqft
Tunnel extension		$ 800,000	40		$ 400,000	$ -	400' @ $2000/ft
Accessories		$ 50,000	20		$ -	$ -	
Construct three (3) additional 1.076 MG digesters (Nos. 9, 10, 11)							
Digester Concrete		$ -	40	$ 6,456,000	$ -	$ 4,842,000	(3) 1,076,000 gal @ $2.00/gal
80' Digester Covers		$ -	40	$ 900,000	$ -	$ 675,000	(3) Concrete
Digester Mixing Systems		$ -	20	$ 699,000	$ -	$ 350,000	(3) draft tube mixing systems
Heating Systems		$ -	20	$ 539,000	$ -	$ 270,000	(3) Hex, (3) Hot Water Pump, (2) Boilers
Control Building (30' x 35')		$ -	40	$ 263,000	$ -	$ 197,000	1,050 sqft @ $250/sqft
Tunnel extension		$ -	40	$ -	$ -	$ -	
Accessories		$ -	20	$ 50,000	$ -	$ 25,000	
Modifications to Sludge Dewatering							
None		$ -	20	$ -	$ -	$ -	Use existing
Thermal Treatment System							
Belt Dryer System Package		$ 6,650,000	20	$ -	$ -	$ -	Andritz quote $3.8 million + 75% installed
Process Building (60' x 80')		$ 1,200,000	40	$ -	$ 600,000	$ -	4,800 sq ft @ $250/sqft
Odor Control System		$ 200,000	20	$ -	$ -	$ -	
Site Work	8%	$ 965,000	40	$ 713,000	$ 482,500	$ 535,000	
Mechanical Process Piping	10%	$ 1,206,000	40	$ 891,000	$ 603,000	$ 668,000	
Instrumentation and Control	7%	$ 844,000	20	$ 623,000	$ -	$ 312,000	
Electrical	8%	$ 965,000	20	$ 713,000	$ -	$ 357,000	
Subtotal		$ 16,041,000		$ 11,847,000	$ 3,443,000	$ 8,231,000	
Allowance for Undefined Design Details	25%	$ 4,010,000		$ 2,962,000			
Total Construction Cost		$ 20,051,000		$ 14,809,000			
Engineering, Legal and Administrative	15%	$ 3,008,000		$ 2,221,000			
Total		$ 23,059,000		$ 17,030,000	$ 3,443,000	$ 8,231,000	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 23,059,000		$ 10,580,000	$ 1,329,000	$ 3,177,000	
Annual O & M Cost							
Labor		$ 85,800		$ 102,960			
Energy (electrical and thermal)		$ 591,187		$ 829,912			
Chemicals		$ 727,793		$ 943,751			
Hauling		$ 1,313,678		$ 1,703,486			
Maintenance		$ 345,900		$ 601,400			1.5% of Total
Total Annual O & M Cost		$ 3,064,358		$ 4,181,509			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 23,806,000		$ 20,184,000			
Total Present Worth Capital Cost		$ 29,133,000					
Total Present Worth O&M Cost		$ 43,990,000					
Total Present Worth		**$ 73,123,000**					

TABLE 9 - ALTERNATE NO.4A - CONVENTIONAL DIGESTION WITH HEAT DRYING O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	50	hrs/wk	Hours	60	hrs/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$85,800.00	$/yr	Annual	$102,960.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	7		# Mesophilic Reactors	10	
# Thermophilic Reactors	0		# Thermophilic Reactors	0	
Cost	$382,349	per yr	Cost	$544,842	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	2		# DAFs	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners	0		# Gravity Belt Thickeners	0	
# Centrifuges	0		# Centrifuges	0	
Cost	$34,701	per yr	Cost	$34,701	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion	106,316	lbs/d	Solids Flow to Digestion	125,875	lbs/d
Solids Flow to Digestion	277,124	gpd @ 4.6%	Solids Flow to Digestion	328,107	gpd @ 4.6%
Digested Sludge Production	65,916	lbs/d	Digested Sludge Production	85,475	lbs/d
Digested Sludge Production	395,179	gpd @2%	Digested Sludge Production	512,440	gpd @2%
% to GBT	100%		% GBT	100%	
Digested Sludge Production	158,071	gpd@ 5%	Digested Sludge Production	204,976	gpd@ 5%
% to Centrifuge	25%		% Centrifuge	25%	
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	2	
# Centrifuges	1		# Centrifuges	1	
Cost	$18,693	per yr	Cost	$48,251	per yr
Thermal Treatment			*Thermal Treatment*		
Digested Sludge Production	16,479	lbs/day	Digested Sludge Production	21,369	lbs/day
# Belt Dryers	1		# Belt Dryers	1	
Cost	$155,444	per yr	Cost	$202,119	per year
Total Power Cost	***$591,187***	***$/yr***	***Total Power Cost***	***$829,912***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge	110,500	lbs/d	Raw Sludge	132,500	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
# DAF	2		# DAF	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# GBT	0		# GBT	0	
# Centrifuge	0		# Centrifuge	0	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	65,916	lbs/day	Digested Sludge	85,475	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	100%		% GBT	100%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$727,793		Cost	$943,751	
Total Chemical Cost	***$727,793***	***$/yr***	***Total Chemical Cost***	***$943,751***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	90	%	Metrogro cake concentration	90	%
Gallons liquid per day	98,795	gpd	Gallons liquid per day	128,110	gpd
Dewatered Sludge per day	10.9	cu yds/d	Dewatered Sludge per day	14.1	cu yds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cu yd	Dewatered Sludge Hauling Cost	$13.00	$/cu yd
Total Hauling Cost	***$1,313,678***	***$/yr***	***Total Hauling Cost***	***$1,703,486***	***$/yr***

Table 10
Economic Comparison of Digestion Alternatives
Conventional Digestion with En-Vessel Pasteurization

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
None		$ -	20	$ -	$ -	$ -	Use existing
Construct one (1) additional 1.076 MG digester (No. 8)							
Digester Concrete		$ 2,152,000	40		$ 1,076,000	$ -	(1) 1,076,000 gal @ $2.00/gal
80' Digester Covers		$ 300,000	40		$ 150,000	$ -	(1) Concrete
Digester Mixing Systems		$ 233,000	20		$ -	$ -	(1) draft tube mixing systems
Heating Systems		$ 213,000	20		$ -	$ -	(1) Hex, (1) HW Pump, (1) Boiler
Control Building (30' x 35')		$ 263,000	40		$ 131,500	$ -	1,050 sqft @ $250/sqft
Tunnel extension		$ 800,000	40		$ 400,000	$ -	400' @ $2000/ft
Accessories		$ 50,000	20		$ -	$ -	
Construct three (3) additional 1.076 MG digesters (Nos. 9, 10, 11)							
Digester Concrete		$ -	40	$ 6,456,000	$ -	$ 4,842,000	(3) 1,076,000 gal @ $2.00/gal
80' Digester Covers		$ -	40	$ 900,000	$ -	$ 675,000	(3) Concrete
Digester Mixing Systems		$ -	20	$ 699,000	$ -	$ 350,000	(3) draft tube mixing systems
Heating Systems		$ -	20	$ 539,000	$ -	$ 270,000	(3) Hex, (3) Hot Water Pump, (2) Boilers
Control Building (30' x 35')		$ -	40	$ 263,000	$ -	$ 197,000	1,050 sqft @ $250/sqft
Tunnel extension		$ -	40	$ -	$ -	$ -	
Accessories		$ -	20	$ 50,000	$ -	$ 25,000	
Modifications to Sludge Dewatering							
None		$ -	20	$ -	$ -	$ -	Use existing
Pasteurization Treatment System							
EnVessel Pasteurization Package		$ 859,000	20	$ -	$ -	$ -	RDP quote + 75% install
Air Treatment Blowers		$ 68,000	20	$ -	$ -	$ -	(2) pd blowers
Process Building (40' x 60')		$ 600,000	40	$ -	$ 300,000	$ -	2,400 sq ft @ $250/sqft
Odor Control System		$ 200,000	20	$ -	$ -	$ -	
Site Work	8%	$ 459,000	40	$ 713,000	$ 229,500	$ 535,000	
Mechanical Process Piping	10%	$ 574,000	40	$ 891,000	$ 287,000	$ 668,000	
Instrumentation and Control	7%	$ 402,000	20	$ 623,000	$ -	$ 312,000	
Electrical	8%	$ 459,000	20	$ 713,000	$ -	$ 357,000	
Subtotal		$ 7,632,000		$ 11,847,000	$ 2,574,000	$ 8,231,000	
Allowance for Undefined Design Details	25%	$ 1,908,000		$ 2,962,000			
Total Construction Cost		$ 9,540,000		$ 14,809,000			
Engineering, Legal and Administrative	15%	$ 1,431,000		$ 2,221,000			
Total		$ 10,971,000		$ 17,030,000	$ 2,574,000	$ 8,231,000	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 10,971,000		$ 10,580,000	$ 994,000	$ 3,177,000	

Annual O & M Cost			
Labor	$ 85,800	$ 102,960	
Energy (electrical and thermal)	$ 471,930	$ 650,707	
Chemicals	$ 863,126	$ 1,119,242	
Hauling	$ 1,563,823	$ 2,027,857	
Maintenance	$ 164,600	$ 420,100	1.5% of Total
Total Annual O & M Cost	$ 3,149,279	$ 4,320,866	
Present Worth Factor	7.769	4.827	Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost	$ 24,466,000	$ 20,857,000	
Total Present Worth Capital Cost	$ 17,380,000		
Total Present Worth O&M Cost	$ 45,323,000		
Total Present Worth	**$ 62,703,000**		

TABLE 11 - ALTERNATE NO.4B - CONVENTIONAL DIGESTION WITH EN-VESSEL PASTEURIZATION O&M			
2010		**2030**	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	50 hr/wk	Hours	60 hr/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$85,800.00 $/yr	Annual	$102,960.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors	7	# Mesophilic Reactors	10
# Thermophilic Reactors	0	# Thermophilic Reactors	0
Cost	$382,349 per yr	Cost	$544,842 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	1.195 mgd @1.5%	Flow to Thickening	1.195 mgd @1.6%
# DAFs	2	# DAFs	2
# Gravity Thickeners	2	# Gravity Thickeners	2
# Gravity Belt Thickeners	0	# Gravity Belt Thickeners	0
# Centrifuges	0	# Centrifuges	0
Cost	$34,701 per yr	Cost	$34,701 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	106,316 lbs/d	Solids Flow to Digestion	125,875 lbs/d
Solids Flow to Digestion	277,124 gpd @ 4.6%	Solids Flow to Digestion	328,107 gpd @ 4.6%
Digested Sludge Production	65,916 lbs/d	Digested Sludge Production	85,475 lbs/d
Digested Sludge Production	395,179 gpd @2%	Digested Sludge Production	512,440 gpd @2%
% to GBT	100%	% GBT	100%
Digested Sludge Production	158,071 gpd@ 5%	Digested Sludge Production	204,976 gpd@ 5%
% to Centrifuge	25%	% Centrifuge	25%
# Gravity Belt Thickeners	2	# Gravity Belt Thickeners	2
# Centrifuges	1	# Centrifuges	1
Cost	$18,693 per yr	Cost	$24,240 per yr
Lime Pasterization		*Lime Pasterization*	
Digested Sludge Production	16,479 lbs/day	Digested Sludge Production	21,369 lbs/day
Cost	$36,187 per yr	Cost	$46,925 per year
Total Power Cost	***$471,930 $/yr***	***Total Power Cost***	***$650,707 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Raw Sludge	110,500 lbs/d	Raw Sludge	132,500 lbs/d
Gravity Thickener Polymer Rate	0 lbs/DT	Gravity Thickener Polymer Rate	0 lbs/DT
DAF Polymer Rate	0 lbs/DT	DAF Polymer Rate	0 lbs/DT
GBT Polymer Rate	12 lbs/DT	GBT Polymer Rate	12 lbs/DT
Centrifuge Polymer Rate	40 lbs/DT	Centrifuge Polymer Rate	40 lbs/DT
# DAF	2	# DAF	2
# Gravity Thickeners	2	# Gravity Thickeners	2
# GBT	0	# GBT	0
# Centrifuge	0	# Centrifuge	0
Cost of Polymer	$2.75 $/lb Polymer	Cost of Polymer	$2.75 $/lb Polymer
Cost	$0 $/yr	Cost	$0 $/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	65,916 lbs/day	Digested Sludge	85,475 lbs/day
GBT Polymer Rate	12 lbs/DT	GBT Polymer Rate	12 lbs/DT
Centrifuge Polymer Rate	40 lbs/DT	Centrifuge Polymer Rate	40 lbs/DT
% GBT	100%	% GBT	100%
% Centrifuge	25%	% Centrifuge	25%
Cost of Lime	$45 $/DT	Cost of Lime	$45 $/DT
Digested Sludge to EnVessel	16,479 lbs/day	Digested Sludge to EnVessel	21,369 lbs/day
% Lime Solids Added	30%	% Lime Solids Added	30%
Total Solids	21,423 lb/day	Total Solids	27,779 lb/day
Cost	$863,126	Cost	$1,119,242
Total Chemical Cost	***$863,126 $/yr***	***Total Chemical Cost***	***$1,119,242 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	6 %	Metrogro liquid concentration	6 %
Metrogro cake concentration	20 %	Metrogro cake concentration	20 %
Gallons liquid per day	98,794.6 gpd	Gallons liquid per day	128,110.0 gpd
Dewatered Sludge per day	63.6 cu yds/d	Dewatered Sludge per day	82.5 cu yds/d
Liquid Hauling Cost	$0.035 $/gal	Liquid Hauling Cost	$0.035 $/gal
Dewatered Sludge Hauling Cost	$13.00 $/cu yd	Dewatered Sludge Hauling Cost	$13.00 $/cu yd
Total Hauling Cost	***$1,563,823 $/yr***	***Total Hauling Cost***	***$2,027,857 $/yr***

Table 12
Economic Comparison of Digestion Alternatives
Conventional Digestion with Batch Thermophilic

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
None		$ -	20	$ -	$ -	$ -	Use existing
Construct one (1) additional 1.076 MG digester (No. 8)							
Digester Concrete		$ 2,152,000	40		$ 1,076,000	$ -	(1) 1,076,000 gal @ $2.00/gal
80' Digester Covers		$ 300,000	40		$ 150,000	$ -	(1) Concrete
Digester Mixing Systems		$ 233,000	20		$ -	$ -	(1) draft tube mixing systems
Heating Systems		$ 213,000	20		$ -	$ -	(1) Hex, (1) HW Pump, (1) Boiler
Control Building (30' x 35')		$ 263,000	40		$ 131,500	$ -	1,050 sqft @ $250/sqft
Tunnel extension		$ 800,000	40		$ 400,000	$ -	400' @ $2000/ft
Accessories		$ 50,000	20		$ -	$ -	
Construct three (3) additional 1.076 MG digesters (Nos. 9, 10, 11)							
Digester Concrete		$ -	40	$ 6,456,000	$ -	$ 4,842,000	(3) 1,076,000 gal @ $2.00/gal
80' Digester Covers		$ -	40	$ 900,000	$ -	$ 675,000	(3) Concrete
Digester Mixing Systems		$ -	20	$ 699,000	$ -	$ 350,000	(3) draft tube mixing systems
Heating Systems		$ -	20	$ 539,000	$ -	$ 270,000	(3) Hex, (3) HW Pumps, (2) Boilers
Control Building (30' x 35')		$ -	40	$ 263,000	$ -	$ 197,000	1,050 sqft @ $250/sqft
Tunnel extension		$ -	40	$ -	$ -	$ -	
Accessories		$ -	20	$ 50,000	$ -	$ 25,000	
Modifications to Sludge Dewatering							
None		$ -	20	$ -	$ -	$ -	Use existing
Construct three (3) 130,000 gallon Batch Thermophilic Tanks							
Digester Concrete		$ 975,000	40	$ -	$ 487,500	$ -	(3) 130,000 gal @ $2.50/gal
Digester Mixing Systems		$ 180,000	20	$ -	$ -	$ -	
Heating Systems		$ 552,000	20	$ -	$ -	$ -	(4) Hex, (4) HW Pumps, (1) Boiler
Control Building (30' x 35')		$ 262,500	40	$ -	$ 131,000	$ -	1,050 sqft @ $250/sqft
Digester Building (100' x 50')		$ 750,000	40	$ -	$ 375,000	$ -	5,000 sq ft @$150/sq ft
Odor Control System		$ 200,000	20	$ -	$ -	$ -	
Site Work	8%	$ 554,000	40	$ 713,000	$ 277,000	$ 535,000	
Mechanical Process Piping	10%	$ 693,000	40	$ 891,000	$ 347,000	$ 668,000	
Instrumentation and Control	7%	$ 485,000	20	$ 623,000	$ -	$ 312,000	
Electrical	8%	$ 554,000	20	$ 713,000	$ -	$ 357,000	
Subtotal		$ 9,216,500		$ 11,847,000	$ 3,375,000	$ 8,231,000	
Allowance for Undefined Design Details	25%	$ 2,304,000		$ 2,962,000			
Total Construction Cost		$ 11,520,500		$ 14,809,000			
Engineering, Legal and Administrative	15%	$ 1,728,000		$ 2,221,000			
Total		$ 13,248,500		$ 17,030,000	$ 3,375,000	$ 8,231,000	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 13,249,000		$ 10,580,000	$ 1,303,000	$ 3,177,000	

Item	Initial	Future	
Annual O & M Cost			
Labor	$ 85,800	$ 102,960	
Energy (electrical and thermal)	$ 656,468	$ 878,609	
Chemicals	$ 727,793	$ 943,751	
Hauling	$ 1,494,195	$ 1,937,568	
Maintenance	$ 198,700	$ 454,200	1.5% of Total
Total Annual O & M Cost	$ 3,162,956	$ 4,317,088	
Present Worth Factor	7.769	4.827	Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost	$ 24,572,000	$ 20,839,000	
Total Present Worth Capital Cost	$ 19,349,000		
Total Present Worth O&M Cost	$ 45,411,000		
Total Present Worth	**$ 64,760,000**		

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TABLE 13 - ALTERNATE NO.4C - CONVENTIONAL DIGESTION WITH BATCH THERMOPHILIC O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	50	hr/wk	Hours	60	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$85,800.00	$/yr	Annual	$102,960.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	7		# Mesophilic Reactors	10	
# Thermophilic Batch Tanks	3		# Thermophilic Batch Tanks	3	
Cost	$603,074	per yr	Cost	$819,669	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	2		# DAFs	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners	0		# Gravity Belt Thickeners	0	
# Centrifuges	0		# Centrifuges	0	
Cost	$34,701	per yr	Cost	$34,701	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion	106,316	lbs/d	Solids Flow to Digestion	125,875	lbs/d
Solids Flow to Digestion	277,124	gpd @ 4.6%	Solids Flow to Digestion	328,107	gpd @ 4.6%
Digested Sludge Production	65,916	lbs/d	Digested Sludge Production	85,475	lbs/d
Digested Sludge Production	395,179	gpd @2%	Digested Sludge Production	512,440	gpd @2%
% to GBT	100%		% GBT	100%	
Digested Sludge Production	158,071	gpd@ 5%	Digested Sludge Production	204,976	gpd@ 5%
% to Centrifuge	25%		% Centrifuge	25%	
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	2	
# Centrifuges	1		# Centrifuges	1	
Cost	$18,693	per yr	Cost	$24,240	per yr
Total Power Cost	***$656,468***	***$/yr***	***Total Power Cost***	***$878,609***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge	110,500	lbs/d	Raw Sludge	132,500	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
# DAF	2		# DAF	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# GBT	0		# GBT	0	
# Centrifuge	0		# Centrifuge	0	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	65,916	lbs/day	Digested Sludge	85,475	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	100%		% GBT	100%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$727,793		Cost	$943,751	
Total Chemical Cost	***$727,793***	***$/yr***	***Total Chemical Cost***	***$943,751***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	20	%	Metrogro cake concentration	20	%
Gallons liquid per day	98,794.6	gpd	Gallons liquid per day	128,110.0	gpd
Dewatered Sludge per day	48.9	cu yds/d	Dewatered Sludge per day	63.4	cu yds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cu yd	Dewatered Sludge Hauling Cost	$13.00	$/cu yd
Total Hauling Cost	***$1,494,195***	***$/yr***	***Total Hauling Cost***	***$1,937,568***	***$/yr***

APPENDIX F

Technical Memorandum No. 3A
Anaerobic Digestion Process Evaluation II

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 3A
ANAEROBIC DIGESTION PROCESS EVALUATION II

Date: December 15, 2009 (Revised) **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate the digestion alternatives for the Nine Springs Wastewater Treatment Plant (NSWWTP) that were selected by the Project Team during Workshop No. 4: conventional digestion with Cambi thermal hydrolysis process (THP) pretreatment, multi-stage (mesophilic-thermophilic-thermophilic) acid-phase digestion, and acid-phase digestion with thermal treatment. The recommended alternative will be selected based on economic and non-economic factors.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- Conventional digestion with Cambi THP and acid-phase digestion with thermal post-treatment are the only alternatives that meet the time-temperature requirement for Class A biosolids (Alternative 1 of the 503 regulations). Multi-stage acid phase digestion would require monthly testing to obtain site specific Class A approval.
- Conventional digestion with Cambi THP is the only alternative expected to prevent *Microthrix* associated foaming. Acid phase digestion will likely not eliminate the foaming issues associated with *Microthrix*.
- Conventional digestion with Cambi THP and acid-phase digestion provide enhanced fats, oil, and grease degradation and reduce the potential of non-filamentous foaming.
- Implementation of a multi-stage acid-phase digestion facility requires the construction of two new acid digesters, the conversion of Digester No. 7 to a thermophilic methane digester, improvements to sludge thickening, and the installation of foam mitigation measures.

Construction of a new thermophilic methane digester (Digester No. 8) is recommended to meet future loadings.

- Implementation of acid-phase digestion with thermal treatment requires the construction of two new acid digesters, the conversion of Digesters No. 1, No. 2, and No. 3 to thermal treatment tanks, improvements to sludge thickening, and the installation of foam mitigation measures. Construction of a new mesophilic methane digester is recommended to meet future loadings.

- Implementation of conventional digestion with a Cambi THP pre-treatment requires the installation of the THP system, operation of Digesters No. 4 - No. 7 as conventional digesters, and improvements in sludge thickening.

- Conventional digestion with Cambi THP has the highest capital costs, but has a slightly lower present worth cost than the acid phase digestion alternatives with foam and struvite mitigation improvements. Multi-stage acid-phase digestion has lower present worth capital and operation costs than acid-phase digestion with thermal treatment.

- Based on reduced operational complexity, comparable present worth costs, multi-stage acid phase digestion is the recommended alternative for sludge stabilization at the NSWWTP. This option would also provide for the use of existing Digesters No. 1, 2, and 3 for thermal treatment to comply with Alternative 1 of the 503 regulations.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements while maintaining the current biosolids land application programs. TM-03 Anaerobic Digestion Process Evaluation and Workshop No. 4 identified acid-phase digestion and conventional digestion with Cambi THP pretreatment as alternatives that will allow the MMSD to meet these biosolids management objectives. The MMSD Staff requested the evaluation of two different acid-phase digestion configurations: multi-stage with mesophilic-thermophilic-thermophilic operation and mesophilic-mesophilic operation with thermal batch treatment. Per MMSD Staff request, the alternatives evaluation presented in this TM include struvite mitigation strategies. The acid phase digestion alternatives incorporate the foam mitigation improvements recommended in TM-05 Foam Mitigation Alternatives.

4.0 Digester Capacity Evaluation

The digestion capacity of multi-stage acid-phase digestion, acid-phase digestion with thermal treatment, and conventional digestion with Cambi THP pretreatment were evaluated for the projected flows and loadings for both annual average and maximum month (max month) conditions developed in TM No. 1 Basis of Design. A summary of the existing sludge thickening and anaerobic digestion facilities is presented in TM-03 Anaerobic Digestion Process Evaluation.

4.1 Digestion Design Criteria

Table 3A.1 presents the recommended hydraulic residence time (HRT) and volatile solids loading rate (VSLR) design and redundancy criteria for acid-phase digestion and conventional digestion with Cambi THP pretreatment.

Table 3.A1
Recommended Design Criteria for Anaerobic Digestion Processes

Digestion Process	Design Criteria	Controlling Criteria
Multi-Stage Acid-Phase		
Acid Digester (mesophilic)	VSLR 1 to 2.5 lbs VS/cfd	Maximum Month with one unit out of service
	HRT 1.5 to 3 days	Maximum Month with all units in service and annual average with one unit out of service
Methane Digester (first-stage thermophilic)	HRT ≥ 12 days	Maximum Month with all units in service and annual average with largest unit out of service
Methane Digester (second-stage thermophilic)	HRT ≥ 3 days	Maximum Month with all units in service and annual average with largest unit out of service
Sludge Holding Tank	HRT ≥ 2 days	Maximum Month with all units in service and annual average with largest unit out of service
Acid-Phase with Thermal Post-Treatment		
Acid Digester (mesophilic)	VSLR 1 to 2.5 lbs VS/cfd	Maximum Month with one unit out of service
	HRT 1.5 to 3 days	Maximum Month with all units in service and annual average with one unit out of service
Methane Digester (mesophilic)	HRT ≥ 13 days	Maximum Month with all units in service and annual average with largest unit out of service
Thermal Treatment Tank	Holding Time ≥ 1 day (1)	Maximum Month with all units in service
Conventional with Cambi THP		
Conventional Digester (2)	VSLR < 0.37 lbs VS/cfd (3) HRT ≥ 15 days	Maximum Month with all units in service and annual average with largest unit out of service

Notes:
(1) Based on operating temperature of 131 deg F.
(2) Conventional digesters downstream of a Cambi THP system.
(3) Based on information provided by Cambi. Assumes a total solids concentration in the thermally hydrolyzed sludge of 10 percent with a volatile fraction of 80 percent.

4.2 Multi-Stage Acid-Phase Digestion

Multi-stage acid-phase digestion consists of a mesophilic acid digestion step followed by two-stage thermophilic methane digestion. Table 3A.2 presents the design VSLR and HRT for multi-stage acid-phase digestion based on the solids loading projections developed in TM-01.

Table 3A.2
Design Criteria for Multi-Stage Acid-Phase Digestion

Process Parameter	Current Conditions		2030 Conditions	
	Average	Maximum Month	Average	Maximum Month
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Digestion, ppd (1)	80,800	97,000	117,400	139,700
Solids Flow to Digestion, gpd	236,100	283,500	343,100	408,200
Acid Digester				
Digester Volume, MG (2)	0.5	0.5	0.5	1.0
VS Loading Rate, lbs VS/cfd	1.21	1.45	1.76	1.05
Hydraulic Retention Time, days	2.1	1.8	1.5	2.4
First-Stage Thermophilic Methane Digesters				
Digester Volume, MG	3.04 (3)	4.12 (3,4)	4.12 (3,4)	5.20 (3,4,5)
Hydraulic Retention Time, days	12.9	14.5	12.0	12.7
Second-Stage Thermophilic Methane Digesters				
Digester Volume, MG	1.28 (6)	1.92 (6,7)	1.28 (6)	1.92 (6,7)
Hydraulic Retention Time, days	5.4	6.8	3.7	4.7
Sludge Storage Tanks				
Digester Volume, MG (8)	0.90	0.90	0.90	0.90
Hydraulic Retention Time, days	3.8	3.2	2.6	2.2

Notes:
(1) Assumes a total solids concentration of 5.4 percent and a volatile solids fraction of 76 percent.
(2) New 0.5 MG acid digesters with adjustable operational volume
(3) Existing 1.014 MG Digesters (No. 4, 5, and 6)
(4) Existing 1.076 MG Digester (No. 7)
(5) Proposed 1.076 MG Digester (No. 8)
(6) Existing 0.639 MG Digesters (No. 1 and 2)
(7) Existing 0.639 MG Digester No. 3
(8) Existing 0.450 MG Sludge Storage Tanks

To meet current conditions, implementation of acid-phase digestion at the NSWWTP requires the construction of two new 0.5 MG acid digesters. As previously reported by the MMSD staff, the existing acid digester (Digester No. 7) is oversized for the current solids flows and loading and its configuration does not allow for adequate operation at lower liquid levels. In this mode of operation, all the existing 1.014 MG tanks (Digesters No. 4-6) and the existing 1.076 MG tank (Digester No. 7) would be operated as first-stage thermophilic methane digesters, the existing 0.639 MG tanks (Digesters No. 1, 2, and 3) would be operated as second-stage thermophilic methane digesters, and the two existing sludge storage tanks would be operated as mesophilic methane digesters. A process schematic and the preliminary layout for this alternative are presented in Figures 3A.1 and 3A.2, respectively.

To meet the capacity requirements for 2030 conditions, the construction of an additional 1.076 MG thermophilic methane digester (proposed Digester No. 8) is required. In this mode of operation, the existing Digesters No. 4 -7 and the proposed Digester No. 8, would be operated as first-stage thermophilic methane digesters, the existing Digesters No. 1, 2, and 3, would be operated as second-stage thermophilic methane digesters, and the two existing sludge storage tanks would be operated as mesophilic methane digesters. A condition assessment of Digesters No. 1, 2, and 3 during preliminary design is recommended. A process schematic and the preliminary layout for this alternative are presented in Figures 3A.1 and 3A.2, respectively. Based on the 50-Year Master Plan projections, the proposed Digester No. 8 would need to be in service by 2011.

During winter conditions, the sludge storage tanks would serve for polishing purposes. Operation experience at the Inland Empire Utilities Agency has shown that a 3-day HRT at mesophilic temperature removes odors and maintains a stable dewatering system. Due to limited heat dissipation, the sludge storage tanks would operate at pseudo-thermophilic temperature during summer conditions resulting in an increase in polymer use at the gravity belt thickeners. Based on previous experience at Inland Empire Utilities Agency and the Woodridge-Greene Valley Wastewater Treatment Facility a polymer usage increase of up to 10 percent would be anticipated. Polymer testing with pseudo-thermophilic sludge is recommended.

4.2.1 Sludge Thickening

To meet current redundancy requirements, improvements to the sludge thickening operations are recommended. Three new 400 gpm thickeners will be required to provide the necessary thickening capacity, with one unit acting as standby unit. For the purposes of this study, it is assumed that the new thickening units would be added in year 2010. Year 2030 loadings would be met by adding a fourth thickener unit in year 2020. A solids concentration of 5.4 percent solids in the digester feed was used to estimate the digester loadings and HRT. With the addition of the new thickening units, this concentration should be reliably achieved. Thickening technology analysis and selection is included in TM-08 Sludge Thickening Systems Evaluation.

4.2.2 Digester Heating

The existing spiral heat exchangers for Digesters No. 4-7 do not have sufficient capacity for operation in thermophilic mode. The use of the existing shell and tube heat exchangers is recommended to provide supplemental heat to Digesters No. 4-7. The installation of a new spiral heat exchanger with a capacity of 1.3 MMBTU/hr per unit is recommended for the proposed Digester No. 8. A new direct steam injection system is recommended for the proposed Acid Digesters No. 1 and No. 2. The proposed system includes two direct steam injectors with a capacity of 6.8 MMBTU/hr and a new steam generator. Digester heating technology and selection is included in TM-04 Digester Ancillary Systems Evaluation.

4.2.3 Digester Mixing

Either draft tube mixing or plunger mixing may be used to mix the proposed methane Digester No. 8. Due to a variable digester operating elevation, either pump mixing or linear motion plunger mixing is recommended for the proposed Acid Digesters No. 1 and No. 2. The replacement of the gas mixing system of the existing Digesters No. 4- 7 with either draft tube mixing or plunger mixing systems is recommended due to increased foaming potential, inefficient scum layer incorporation, excessive grit accumulation, and short-circuiting. Digester mixing technology and selection is included in TM-04 Digester Ancillary Systems Evaluation.

4.2.4 Class A Biosolids

The multi-stage (mesophilic-thermophilic-thermophilic) acid phase digestion process does not meet the Alternative 1 (Thermally Treated Sewage Sludge) requirements for Class A biosolids due to a continuous flow and completely mixed reactor configuration. A site specific Class A permit can be met through Alternative 3 (Sewage Sludge Treated in Other Processes) with extensive testing of bacteria, enteric viruses, and viable helminth ova in the digester feed and effluent to demonstrate the reduction of pathogens. The Woodridge-Green Valley Wastewater Treatment Facility and the Inland Empire Utilities Agency (IEUA) have site specific Class A permits. Should Alternative 3 become unavailable in the future or the monitoring and testing requirements become unfeasible, Alternative 1 requirements can be met by changing operation to acid-phase digestion with thermal treatment with Digesters No. 1, No. 2, and No. 3 operating in a thermal treatment mode (See Section 4.3). Achieving Class A through Alternative 3 would likely involve a multi-year effort. A meeting at the NSWWTP early in the preliminary design effort with a representative from the Wisconsin Department of Natural Resources (DNR) and the Regional Biosolids Coordinator to discuss the proposed Class A alternatives is recommended.

4.2.5 Digester Foaming

Non-filamentous foaming is typically prevented in acid-phase digestion because of limited gas production in the acid digester where the protein and lipid concentrations are higher. Increased lipid and protein degradation in the acid digester prevent non-filamentous foaming in the methane digesters. Currently, there are no reports on *Microthrix*-related foaming and the fate of *Microthrix* in acid phase digestion. However, previous experience at the NSWWTP has shown that foaming problems are less severe under operation in acid-phase digestion mode. To mitigate *Microthrix*-associated foaming problems, a steam pretreatment system for WAS will be installed and the existing digester mixing systems will be replaced with mechanical mixing systems (See TM-04 Digester Ancillary Systems Evaluation and TM-05 Foam Mitigation Alternatives).

4.2.6 Struvite Mitigation

Under multi-stage acid-phase digestion, the ferric chloride would be added directly to the first-stage thermophilic digesters. Iron salts provide the dual benefit of struvite and hydrogen sulfide mitigation. Based on previous experience at the NSWWTP, up to 2,450 lbs Fe/day (3,450 lbs Fe/day at 2030 conditions) would be required for struvite mitigation. These Fe levels resulted in vivianite formation in the surfaces of the heat exchangers in the 10^{th} Addition facilities. The digester heating system can be designed and operated to minimize vivianite scaling by limiting the temperature increment through the heat exchangers.

4.2.7 Full-Scale Installations

Multi-stage acid-phase digestion installations in the U.S. include the Inland Empire Utilities Agency (Chino, CA), and the Woodridge-Greene Valley Wastewater Treatment Facility (Downers Grove, IL).

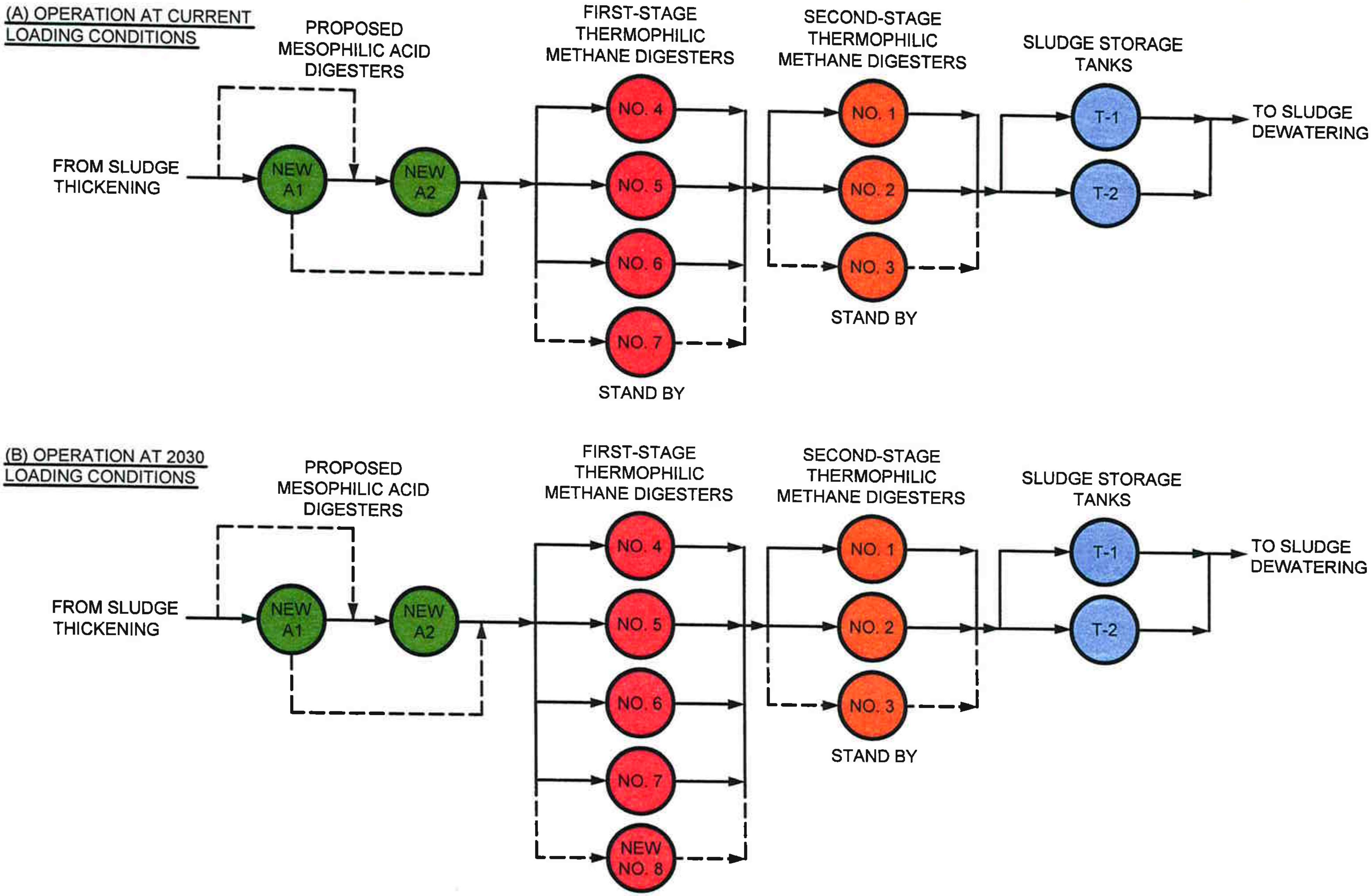

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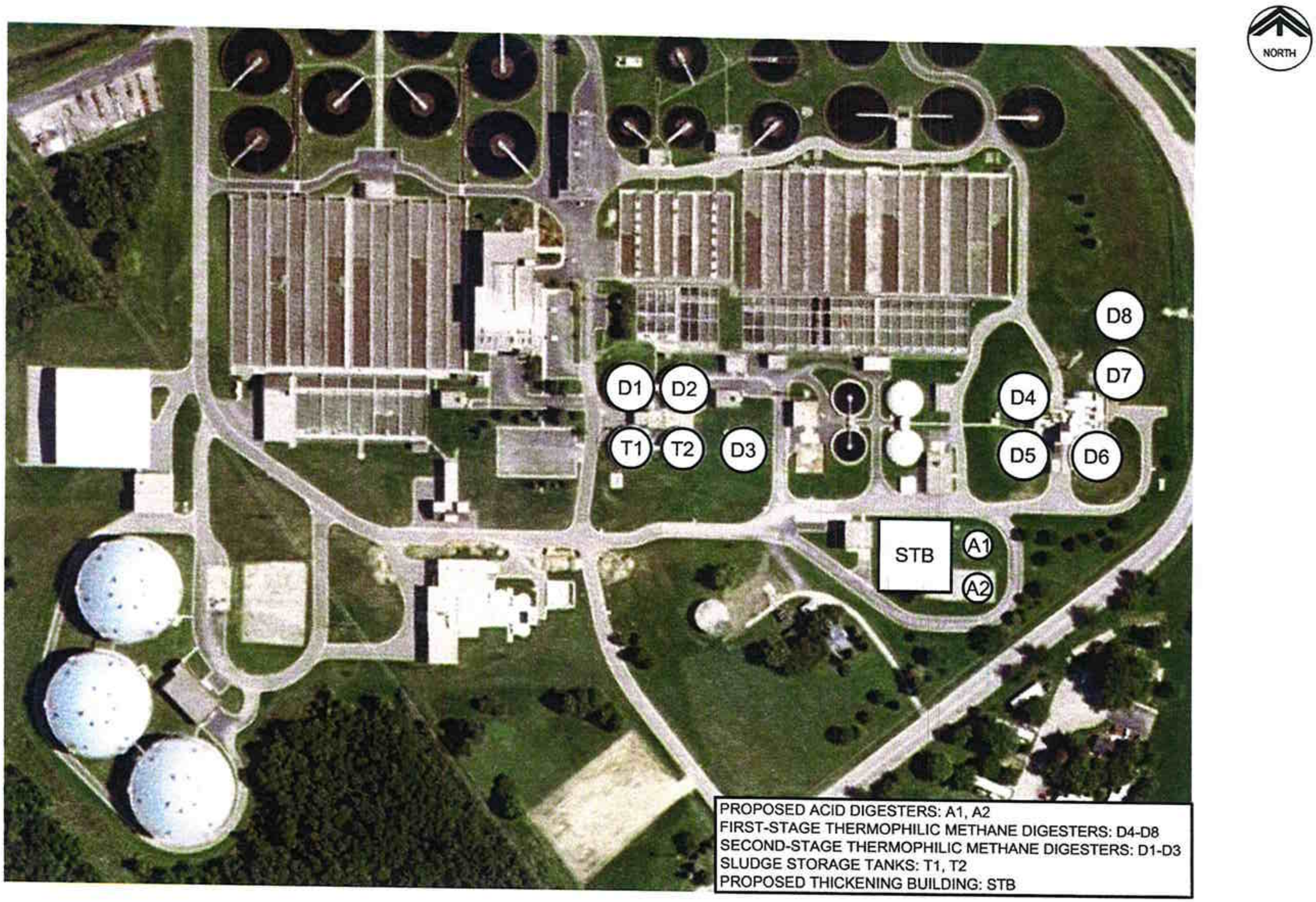
FIGURE 3A.1
MULTI-STAGE ACID-PHASE DIGESTION
PROCESS SCHEMATIC
Madison Metropolitan Sewage District



MULTI-STAGE ACID PHASE DIGESTION
PRELIMINARY LAYOUT

FIGURE 3A.2

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4.3 Acid-Phase Digestion with Thermal Treatment

Acid-phase digestion with thermal treatment consists of a mesophilic acid digester, mesophilic methane digester, and thermal treatment tanks. Table 3A.3 presents the design VSLR and HRT for acid-phase digestion with thermal treatment based on the solids loading projections developed in TM-01.

Table 3A.3
Design Criteria for Acid-Phase Digestion with Thermal Treatment

Process Parameter	Current Conditions		2030 Conditions	
	Average	Maximum Month	Average	Maximum Month
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Digestion, ppd (1)	80,800	97,000	117,400	139,700
Solids Flow to Digestion, gpd	236,100	283,500	343,100	408,200
Acid Digester				
Digester Volume, MG (2)	0.5	0.5	0.5	1.0
VS Loading Rate, lbs VS/cfd	1.21	1.45	1.76	1.05
Hydraulic Retention Time, days	2.1	1.8	1.5	2.4
Mesophilic Methane Digesters				
Digester Volume, MG	3.04 (3)	4.12 (3,4)	4.12 (3,4)	5.20 (3,4,5)
Hydraulic Retention Time, days	12.9	14.5	12.0	12.7
Thermal Treatment Tanks				
Digester Volume, MG (6)	1.92 (6)	1.92 (6)	1.92 (6)	1.92 (6)
Holding Time, days (7,8)	2.7	2.3	1.9	1.6

Notes:
(1) Assumes a total solids concentratio of 5.4 percent and a volatile solids fraction of 76 percent.
(2) New 0.5 MG acid digesters with adjustable operational volume
(3) Existing 1.014 MG Digesters (No. 4, 5, and 6)
(4) Existing 1.076 MG Digester (No. 7)
(5) Proposed 1.076 MG Digester (No. 8)
(6) Existing 0.639 MG Digesters (No. 1, 2 and 3)
(7) Hydraulic retention time divided by number of tanks.
(8) Minimum holding time = 1.0 days at specified temperature of 131 deg F

To meet current conditions, implementation of acid-phase digestion with thermal treatment requires the construction of two new 0.5 MG acid digesters. In this mode of operation, all the existing 1.014 MG tanks (Digesters No. 4-6) and the existing 1.076 MG tank (Digester No. 7) would be operated as mesophilic methane digesters and the existing 0.639 MG tanks (Digesters No. 1, 2, and 3) would be operated as thermal treatment tanks. A process schematic and the preliminary layout for this alternative are presented in Figures 3A.3 and 3A.4, respectively.

To meet the capacity requirements for 2030 conditions, the construction of an additional 1.076 MG mesophilic methane digester (proposed Digester No. 8) is required. In this mode of operation, all the existing 1.014 MG tanks (Digesters No. 4 -6), the existing 1.076 MG tank (Digester No. 7), and the proposed 1.076 MG tank (Digester No. 8) would be operated as mesophilic methane digesters and the existing 0.639 MG tanks (Digesters No. 1, 2, and 3) would be operated as batch thermal treatment tanks. A condition assessment of Digesters No. 1, 2, and 3 during preliminary design is recommended. A process schematic and the preliminary layout for this alternative are presented in Figures 3A.3 and 3A.4, respectively. The thermal treatment tanks would operate in sequencing batch mode. To meet the time-temperature regimes, the proposed thermal treatment process would operate with minimum holding times of 1 day at 131 deg F or 2 days at 127 deg F. Based on previous experience at the Hyperion Treatment Plant and the Terminal Island Water Reclamation Plant polymer usage increase of up to 10 percent would be anticipated. Polymer testing with thermophilic sludge is recommended.

4.3.1 Sludge Thickening

To meet current redundancy requirements, improvements to the sludge thickening operations are recommended. Three new 400 gpm thickeners will be required to provide the necessary thickening capacity, with one unit acting as standby unit. For the purposes of this study, it is assumed that the new thickening units would be added in year 2010 to provide the required thickening capacity. Year 2030 loadings would be met by adding a fourth thickener unit in year 2020. A solids concentration of 5.4 percent solids in the digester feed was used to estimate the digester loadings and HRT. With the addition of the new thickening units, this concentration should be reliably achieved. Thickening technology analysis and selection is included in TM-08 Sludge Thickening Systems Evaluation.

4.3.2 Digester Heating

The existing heat exchangers for Digesters No. 4, 5, 6, and 7 have sufficient capacity for operation in mesophilic mode at 2030 maximum month conditions. The installation of a new spiral heat exchanger with a capacity of 1.65 MMBTU/hr is recommended for the proposed Digester No. 8 to match the capacity of the heat exchangers servicing Digesters No. 4, 5, 6, and 7. A new direct steam injection system is recommended for the proposed Acid Digesters No. 1 and No. 2 that includes two direct steam injectors with a capacity of 6.8 MMBTU/hr and a new steam generator.

The installation of two new direct steam injectors with a capacity of 5.6 MMBTU/hr to preheat the feed to the thermal tanks is recommended because the existing heat exchangers for Digesters No. 1, 2, and 3 do not have sufficient capacity to operate with mesophilic sludge feed. Digester heating technology analysis and selection is presented in TM-04 Digester Ancillary Systems Evaluation.

4.3.3 Digester Mixing

Either draft tube mixing or plunger mixing may be used to mix the proposed methane Digester No. 8. Due to a variable digester operating elevation, either pump mixing or linear motion plunger mixing is recommended for the proposed Acid Digesters No. 1 and No. 2. The replacement of the gas mixing system of the existing Digesters No. 4- 7 with either draft tube mixing or plunger mixing systems is recommended due to increased foaming potential, inefficient scum layer incorporation, excessive grit accumulation, and short-circuiting. Digester mixing technology analysis and selection is presented in TM-04 Digester Ancillary Systems Evaluation.

4.3.4 Class A Biosolids

The acid-phase (mesophilic-mesophilic) digestion with thermal treatment mode meets the Alternative 1 (Thermally Treated Sewage Sludge) requirements for Class A biosolids. This alternative will allow the MMSD to produce Class A biosolids when the thermal treatment facility is in operation.

4.3.5 Digester Foaming

Non-filamentous foaming is typically prevented in acid-phase digestion because of limited gas production in the acid digester where the protein and lipid concentrations are higher. Increased lipid and protein degradation in the acid digester prevent non-filamentous foaming in the methane digesters. Currently, there are no reports on *Microthrix*-related foaming and the fate of *Microthrix* in acid phase digestion. However, previous experience at the NSWWTP has shown that foaming problems are less severe under operation in acid-phase digestion mode. To mitigate *Microthrix*-associated foaming problems, a steam pretreatment system for WAS will be installed the existing digester mixing systems will be replaced with mechanical mixing systems and the digester domes will be modified to incorporate foam abatement mechanisms (See TM-04 Digester Ancillary Systems Evaluation and TM-05 Foam Mitigation Alternatives).

4.3.6 Struvite Mitigation

Under acid-phase digestion with thermal treatment, the ferric chloride would be added directly to the methane phase digesters. Iron salts provide the dual benefit of struvite and hydrogen sulfide mitigation. Based on previous experience at the NSWWTP, up to 2,450 lbs Fe/day (3,450 lbs Fe per day at 2030 conditions) would be required for struvite mitigation. Iron binding to phosphate results in vivianite formation, which has been observed in the surfaces of the heat exchangers at the NSWWTP. Vivianite scaling can be minimized through changes in the operation of the digester heating system by limiting the temperature increment through the heat exchangers.

4.3.7 Full-Scale Installations

Acid-phase (mesophilic-mesophilic) digestion installations in the U.S. include Back River WWTP (Baltimore, MD), the Truckee Meadows Water Reclamation Facility (Reno, NV), the Turlock Regional Water Quality Control Facility (Turlock, CA), and the City of Petaluma Water Recycling Facility (Petaluma, CA). Acid-phase digestion facilities under construction include Moreno Valley Regional Water Reclamation Facility (Moreno Valley, CA) and the Waco Metropolitan Area Regional Sewerage System WWTP (Waco, TX). The acid-phase digestion at the Back River WWTP is a demonstration-scale facility that treats only a fraction of the solids. The Truckee Meadows Water Reclamation Facility is an enhanced biological phosphorus removal (EBPR) facility.

There are no full-scale facilities with acid-phase digestion with thermal treatment but anaerobic digestion facilities with thermal treatment in the U.S. include the Hyperion Treatment Plant (Playa del Rey, CA) and the Terminal Island Water Reclamation Plant (Los Angeles, CA).

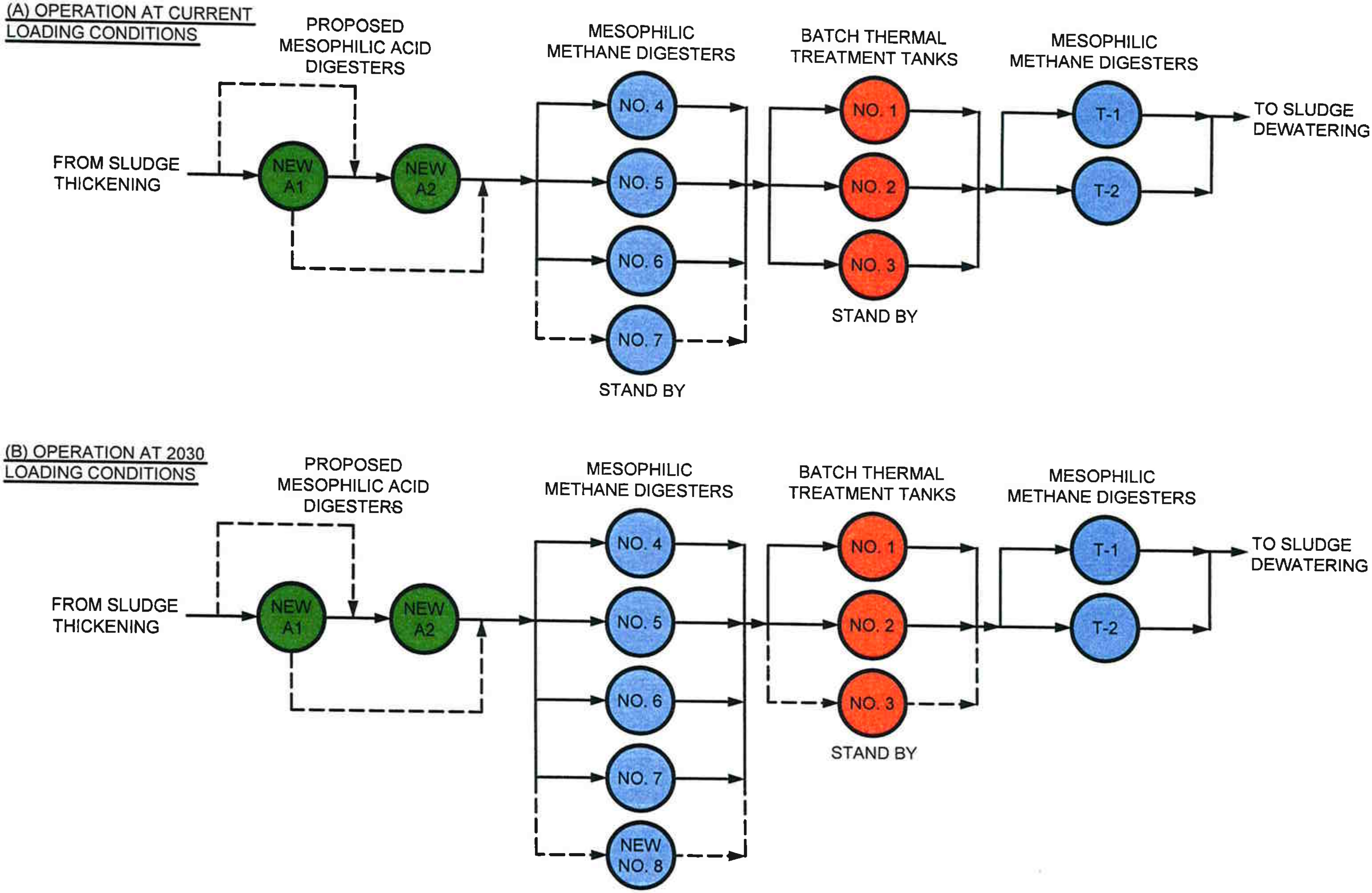

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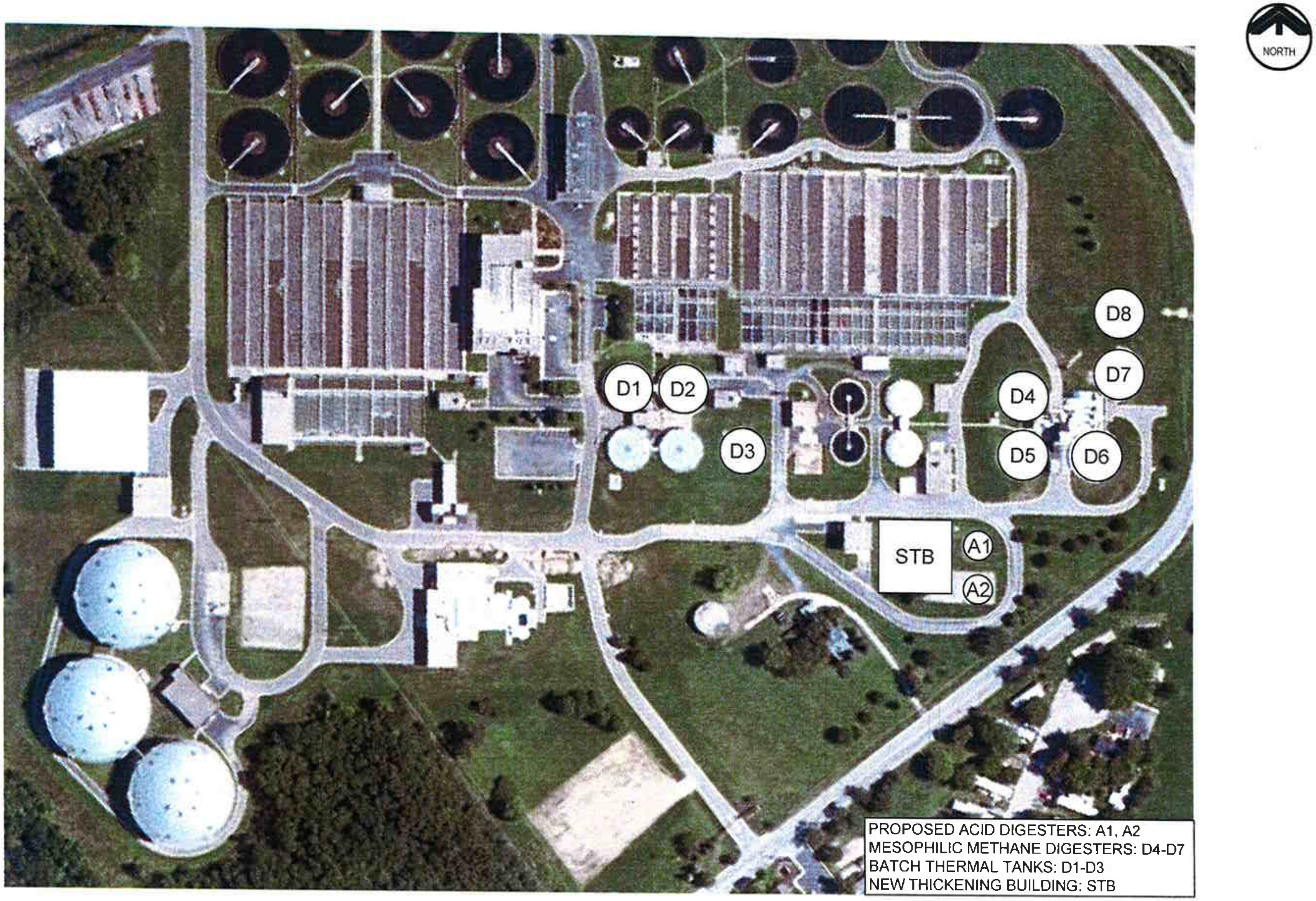
FIGURE 3A.3
ACID-PHASE DIGESTION WITH THERMAL TRATMENT
PROCESS SCHEMATIC
Madison Metropolitan Sewage District



ACID PHASE DIGESTION WITH THERMAL TREATMENT PRELIMINARY LAYOUT

FIGURE 3A.4

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4.4 Conventional Digestion with Cambi THP

The Cambi THP is a patented process, which uses high temperature and pressure to solubilize the volatile solids in sludge. The resulting slurry is typically fed to conventional mesophilic digesters. Table 3A.4 presents the design VSLR and HRT for the conventional digestion process with Cambi THP pre-treatment, based on the solids loading projections developed in TM-01.

Table 3A.4
Design Criteria for Conventional Digestion with Cambi THP

Process Parameter	Current Conditions		2030 Conditions	
	Average	Maximum Month	Average	Maximum Month
Plant Influent Flow, mgd	42.9	54.8	53.8	67.2
VS Load to Cambi THP, ppd (1)	80,800	97,000	117,400	139,700
Solids Flow to Digestion, gpd (2)	127,500	153,000	185,200	220,400
Conventional Digesters				
Digester Volume, MG	3.04 (3)	4.12 (3,4)	3.04 (3)	4.12 (3,4)
VS Loading Rate, lbs VS/cfd	0.20	0.18	0.29	0.25
Hydraulic Retention Time, days	23.9	26.9	16.4	18.7

Notes:
(1) Assumes a thickened solids concentration of 17 percent and a volatile solids fraction of 76 percent.
(2) Based on a specific gravity of 0.59.
(3) Existing 1.014 MG Digesters (No. 4, 5, and 6)
(4) Existing 1.076 MG Digester (No. 7)

To operate the digestion facility with a Cambi THP system, the existing 1.014 MG tanks (Digesters No. 4 -6) and the existing 1.076 MG tank (Digester No. 7) would be operated as conventional mesophilic digesters. The existing 0.639 MG tanks (Digesters No. 1-3) would remain in service, operated as standby conventional mesophilic digesters or sludge storage tanks. A condition assessment of Digesters No. 1, 2, and 3 during preliminary design is recommended. Installation of a Cambi THP system would allow the NSWWTP to operate with a total of four units (3 duty and 1 standby). Process schematics and the preliminary layout for this alternative are presented in Figures 3A.5 and 3A.6, respectively.

4.4.1 Sludge Thickening

The Cambi THP process operates with a high solids concentration in the feed, approximately 17 percent solids. The sludge coming out of CAMBI and fed to the mesophilic digesters has a solids concentration of 10%. In order to achieve this solids concentration, the use of centrifuge thickening will be required. Based on the maximum month 2030 sludge feed to the thickeners of 2.3 million gallons per day, assuming the existing thickeners will pre-thicken to 4.6% solids, three 500 gpm centrifuges will be required to thicken the sludge to 17% solids prior to the Cambi THP system. The third centrifuge would be installed in 2020.

4.4.2 Digester Heating

The existing heat exchangers for Digesters No. 4-7 have sufficient capacity for operation in mesophilic mode at 2030 maximum month conditions.

4.4.3 Digester Mixing

The replacement of the gas mixing system of the existing Digesters No. 4- 7 with either draft tube mixing or plunger mixing systems is recommended due to inefficient scum layer incorporation, excessive grit accumulation, and short-circuiting. Digester mixing and heating technology analysis and selection is presented in TM-04 Digester Ancillary Systems Evaluation.

4.4.4 Digester Foaming

Filamentous foaming in the anaerobic digesters is prevented with the Cambi THP due to thermal hydrolysis of filamentous organisms. Cambi THP was evaluated as a WAS pretreatment alternative for *Microthrix* foaming mitigation (See TM-05 Foam Mitigation Alternatives). No additional foam mitigation improvements are required.

4.4.5 Class A Biosolids

Heat treatment of sewage sludge at 356 deg F or higher for more than 30 minutes is listed as a Process to Further Reduce Pathogens (PFRP). Therefore, the conventional digestion process with Cambi THP pretreatment meets the Alternative 5 (Use of PFRP) requirements for Class A biosolids. No additional testing and monitoring is required for compliance.

4.4.6 Struvite Mitigation

Per communication from Cambi, the elevated temperatures in the THP process result in decreased potential for struvite scaling in the downstream digesters. This claim is based on a laboratory-scale study with a glass anaerobic reactor and Teflon-coated mixers, which are materials that are resistant to struvite crystalline growth. Struvite mitigation was included for the conventional digestion with Cambi THP alternative because the assumed struvite mitigation properties have not been proven at full-scale EBPR facilities.

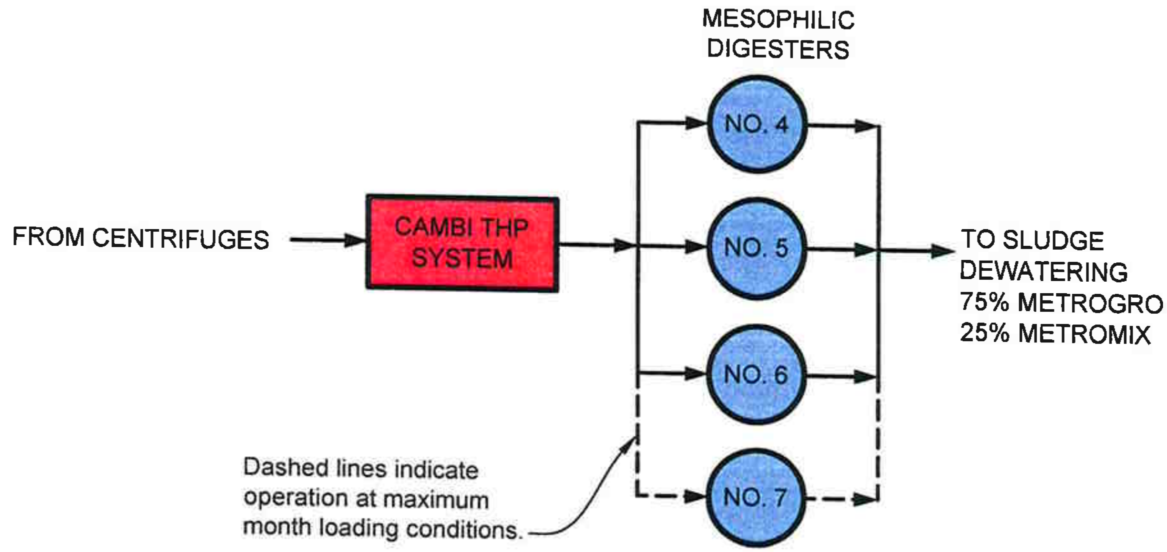
Under conventional digestion with Cambi THP, ferric chloride would be added directly to the conventional digesters. Based on previous experience at the NSWWTP, up to 2,450 lbs Fe/day (3,450 lbs Fe per day at 2030 conditions) would be required for struvite mitigation. Iron binding to phosphate results in vivianite formation. Vivianite scaling can be minimized through changes in the operation of the digester heating system by limiting the temperature increment through the heat exchangers.

4.4.7 Full-Scale Installations

Currently, there are no full-scale installations of Cambi THP in the U.S. The District of Columbia Water and Sewer Authority completed a thermal hydrolysis pilot study and plans to implement conventional digestion with Cambi THP at the Blue Plains WWTP. Worldwide large full-scale installations include the Dublin Bay WWTP (Dublin, Ireland), the Nigg Bay WWTP (Aberdeen, UK), and the Cotton Valley Wastewater Treatment Works (Milton Keynes, UK). A Cambi THP facility is under construction at the Norwich WWTP (Whitlingham, UK), which is an EBPR facility.

J:\4364\GRAPHICS\DRAWINGS\Figure 3A.5.dwg

(A) OPERATION AT CURRENT LOADING CONDITIONS



(B) OPERATION AT 2030 LOADING CONDITIONS

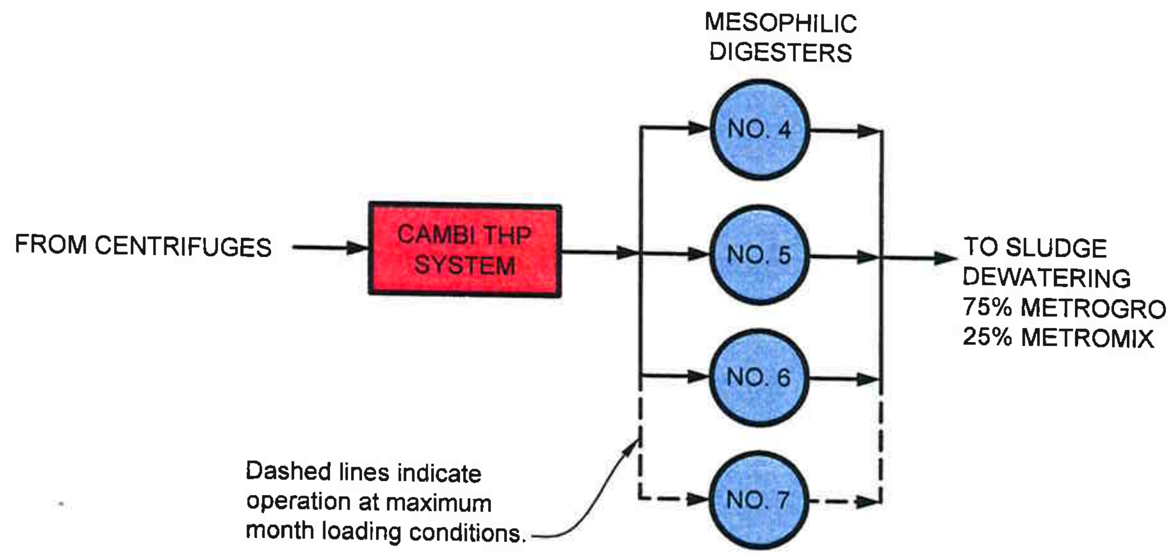


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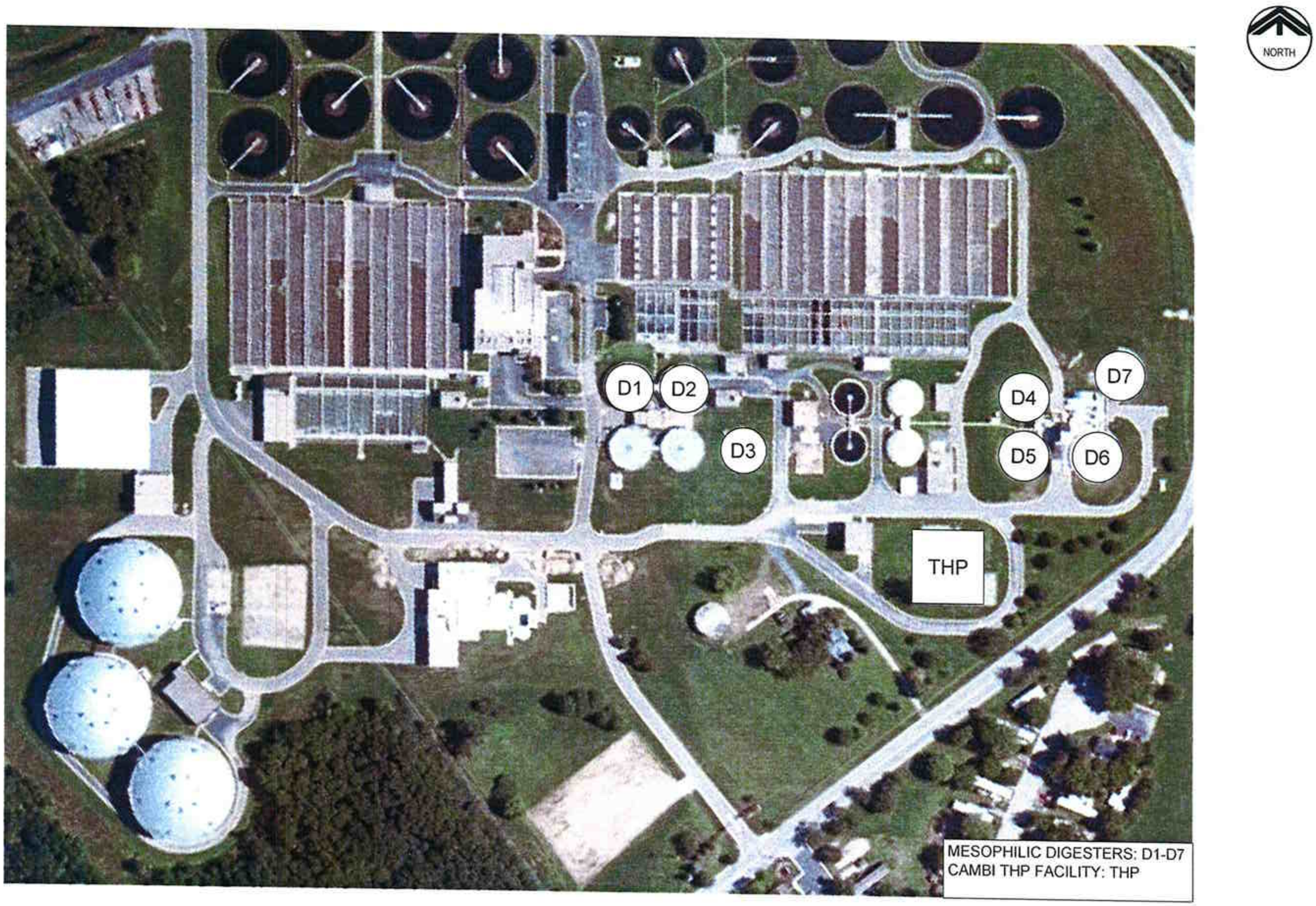
FIGURE 3A.5
CONVENTIONAL DIGESTION WITH CAMBI
THP PRETREATMENT PROCESS SCHEMATIC
Madison Metropolitan Sewage District



CONVENTIONAL DIGESTION WITH CAMBI THP PRELIMINARY LAYOUT

FIGURE 3A.6

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5.0 Comparison of Digestion Alternatives

Economic and non-economic comparisons of multi-stage acid-phase digestion, acid-phase digestion with thermal treatment, and conventional digestion with Cambi THP pretreatment, and conventional digestion with thermal post-treatment are presented in Tables 3A.5 and 3A.6, respectively. The Appendix contains the detailed cost development tables.

Table 3A.5
Economic Comparison of Digestion Alternatives

Anaerobic Digestion Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Multi-Stage Acid-Phase Digestion	$19,365,000	$40,404,000	$22,036,000	$81,805,000
Acid-Phase Digestion with Thermal Treatment	$21,281,000	$41,092,000	$22,036,000	$84,409,000
Conventional Digestion with Cambi THP	$26,186,000	$42,500,000	$20,895,000	$89,581,000

As shown on Table 3A.5, the conventional digestion with Cambi THP pretreatment alternative has the highest capital cost and the highest present worth cost. In this analysis, multi-stage acid-phase digestion has the lowest capital cost, about 10% lower than acid phase digestion with thermal treatment. Multi-stage acid-phase digestion has the lowest present worth cost, about 3% lower than acid phase digestion with thermal treatment, and about 10% lower than conventional digestion with Cambi. The present worth difference between multi-stage acid phase and acid phase digestion with thermal treatment is not considered to be significant because it is less than the margin of error for budget level cost estimating. The high cost of iron addition with its resultant solids production is reflected in the high O&M costs for all three digestion alternatives.

Table 3A.6 Non-Economic Comparison of Digestion Alternatives		
Alternative	**Advantages**	**Disadvantages**
Multi-Stage Acid-Phase Digestion	• Potential for production of Class A Biosolids • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Improved biogas quality in methane digesters • Decreased non-filamentous foaming potential • Gradual temperature increase • Enhanced digestion of fats, oil, and grease (FOG)	• Does not meet time-temperature Class A requirement • Requires extensive monitoring and testing to obtain site-specific Class A permit • Requires foam mitigation improvements to prevent Microthrix foaming problems • Site constraint issues (requires two new 0.4 MG acid digesters and a 1.08 MG methane digester) • Requires separate gas system for acid digesters due to high H2S levels and low CH4 content in acid digester gas • Requires new sludge thickening facility • Odor issues during cleaning of acid digester equipment for maintenance and other activities that result in acid sludge exposure to the atmosphere • Odors in digested sludge thickening facilities during summer conditions
Acid-Phase Digestion with Thermal Treatment	• Production of Class A Biosolids • Meets Time-Temperature Class A Requirement • High volatile solids reduction • Successful full-scale installations in the US with Class A permit • Consistent with Metrogro and Metromix programs • Improved biogas quality in methane digesters • Decreased non-filamentous foaming potential • Gradual temperature increase • Enhanced digestion of FOG	• Requires foam mitigation improvements to prevent *Microthrix* foaming problems • Site constraint issues (requires two new 0.4 MG acid digesters and a 1.08 MG methane digester) • Requires separate gas system for acid digesters due to high H_2S levels and low CH_4 content in acid digester gas • Requires new sludge thickening facility • Odor issues during cleaning of acid digester equipment for maintenance and other activities that result in acid sludge exposure to the atmosphere. • Odors in digested sludge thickening facilities during summer conditions

Table 3A.6 Non-Economic Comparison of Digestion Alternatives		
Alternative	**Advantages**	**Disadvantages**
Conventional Digestion with Cambi THP	• Production of Class A Biosolids • Meets time-temperature Class A requirement • High volatile solids reduction • Successful full-scale installations in Europe • Destruction of *Microthrix* • Foam mitigation improvements are not required • Lower digester tankage requirements, when compared to acid-phase digestion • Lower capacity requirements for dewatering and hauling	• Energy use/costs may increase • No full-scale installations in the US • New high solids thickening facility is required • Dark-colored side stream • Side stream treatment for nutrient removal may be required • Odor control

6.0 Recommended Alternative

An overall comparison of alternatives is presented in Table 3A.7. The recommended alternative is multi-stage acid-phase digestion for the following reasons:

- This alternative has the lowest lifecycle costs of the three digestion alternatives examined.
- This alternative has a considerably lower capital cost than conventional digestion with Cambi THP and acid-phase digestion with thermal treatment.
- This alternative should have less operation and maintenance complexity than the other alternatives.
- This alternative can be modified to operate as acid-phase digestion with thermal treatment if future regulations eliminate Alternative 3 of the 503 regulations or if monitoring and testing become unfeasible.

Table 3A.7 Overall Comparison of Digestion Alternatives			
Digestion Alternative	**Multi-Stage Acid Phase**	**Acid-Phase with Thermal Treatment**	**Conventional with Cambi**
Meets Alternative 1 or is listed as a PFRP	-	0	0
Operating Facilities with Class A permits	0	0	0
High Volatile Solids Reduction	0	0	0
Decreased potential for *Microthrix* foaming	0	0	+
Decreased Potential for Struvite Scaling	-	0	0
Consistent with Metrogro and Metromix	0	0	0
Full-Scale Installations	0	0	0
Full-Scale Installations in the U.S.	0	0	-
Low Mechanical complexity	+	0	0
Low Capital cost	0	0	-
Low Plant O&M Cost	0	0	0
Low Disposal Cost	0	0	+
Low Total Present worth cost	0	0	0
Odors	0	0	0

Legend
+ = Strongly favors this alternative
0 = Favors this alternative about equally with another, or is not a significant factor
- = Distinct disadvantage for this alternative

APPENDIX A
DETAIL COST ESTIMATES

Table 1. Summary
Economic Comparison of Digestion Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Anaerobic Digestion Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Mult-Stage Acid-Phase Digestion	$19,365,000	$40,369,000	$22,036,000	$81,770,000
Acid Phase with Thermal Post-Treatment	$21,281,000	$41,055,000	$22,036,000	$84,372,000
Conventional Digestion with Cambi THP	$26,186,000	$42,800,000	$20,895,000	$89,881,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table 2
Economic Comparison of Digestion Alternatives
Acid-Phase (Meso-Thermo) Digestion

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Modifications to Sludge Thickening							
Three (3) 2m Gravity Belt Thickeners		$ 675,000	20	$ -	$ -	$ -	Energenics - 150k
Polymer Feed system		$ 150,000	20	$ -	$ -	$ -	$50k x 3
Sludge Feed system		$ 67,500	20	$ -	$ -	$ -	$22.5k x 3 installed cost
New Sludge Thickening Building		$ 750,000	40	$ -	$ 375,000	$ -	3000 sqft @ $250/sqft
Future Modifications to Sludge Thickening							
One (1) 2m Gravity Belt Thickener			20	$ 225,000	$ -	$ 112,500	Energenics - 150k
Polymer Feed system			20	$ 50,000	$ -	$ 25,000	$50k x 1
Sludge Feed system			20	$ 22,500	$ -	$ 11,000	$22.5k x 1 installed cost
New Sludge Thickening Building			40	$ 250,000	$ -	$ 187,500	1000 sqft @ $250/sqft
Two (2) 0.380 MG Acid Digesters							
Digester Concrete		$ 1,520,000	40	$ -	$ 760,000	$ -	(2) 380,000 gal @ $2.00/gal
Digester Cover		$ 220,000	40	$ -	$ 110,000	$ -	concrete
Digester Mixing System		$ 400,000	20	$ -	$ -	$ -	plunger mechanical mixing system
Heating System		$ 730,000	20	$ -	$ -	$ -	(2) steam injectors, (2) steam generators
Control Building (35' x 40')		$ 350,000	40	$ -	$ 175,000	$ -	1,400 sqft @ $250/sqft
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Off gas flare system		$ 300,000	20	$ -	$ -	$ -	Enclosed flare quote $200K
Accessories		$ 50,000	20	$ -	$ -	$ -	
One (1) 1.076 MG Anaerobic Digester @ 80' Diameter (No. 8)							
Digester Concrete		$ 2,152,000	40	$ -	$ 1,076,000	$ -	(1) 1,076,000 gal @ $2.00/gal
80' Digester Cover		$ 300,000	40	$ -	$ 150,000	$ -	concrete
Digester Mixing System		$ 210,000	20	$ -	$ -	$ -	plunger mechanical mixing system
Heating System		$ 113,000	20	$ -	$ -	$ -	(1) hex, (1) hot water pump.
Control Building (30' x 35')		$ 263,000	40	$ -	$ 131,500	$ -	1,050 sqft @ $250.00/sqft
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Foam separator dome		$ 50,000	20	$ -	$ -	$ -	$50K per dome
Modifications to Existing Digesters nos. 4 - 7							
Digester Mixing Systems		$ 840,000	20	$ -	$ -	$ -	plunger mechanical mixing systems
Heating System		$ -	20	$ -	$ -	$ -	Use existing
Foam separator domes		$ 200,000	20	$ -	$ -	$ -	$50K per dome
Modifications to Existing Digester NOS.1-3							
Mixing System		$ -	20	$ -	$ -	$ -	Use existing
Heating System		$ -	20	$ -	$ -	$ -	Use existing
Foam separator domes		$ 150,000	20	$ -	$ -	$ -	$50K per dome
Piping Modifications		$ -	20	$ -	$ -	$ -	Use existing
Foam suppresant feed system		$ 300,000	20	$ -	$ -	$ -	
Ferric chloride feed system		$ 125,000	20	$ -	$ -	$ -	
Site Work	8%	$ 857,000	40	$ 44,000	$ 429,000	$ 33,000	
Mechanical Process Piping	10%	$ 1,072,000	40	$ 55,000	$ 536,000	$ 41,250	
Instrumentation and Control	7%	$ 750,000	20	$ 38,000	$ -	$ 19,000	
Electrical	8%	$ 857,000	20	$ 44,000	$ -	$ 22,000	
Subtotal		$ 14,251,500		$ 728,500	$ 4,142,500	$ 451,250	
Allowance for Undefined Design Details	25%	$ 3,563,000		$ 182,000			
Total Construction Cost		$ 17,814,500		$ 910,500			
Engineering, Legal and Administrative	15%	$ 2,672,000		$ 137,000			
Total		$ 20,486,500		$ 1,047,500	$ 4,142,500	$ 451,250	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 20,487,000		$ 651,000	$ 1,599,000	$ 174,000	
Annual O & M Cost							
Labor		$ 51,480		$ 68,640			
Energy (electrical and thermal)		$ 542,337		$ 636,981			
Chemicals		$ 1,937,820		$ 2,765,246			
Hauling		$ 1,486,035		$ 2,173,515			
Maintenance		$ 307,300		$ 323,000			1.5% of Construction Total
Total Annual O & M Cost		$ 4,324,971		$ 5,967,381			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 33,600,000		$ 28,805,000			
Total Present Worth Capital Cost		$ 19,365,000					
Total Present Worth O&M Cost		$ 62,405,000					
Total Present Worth		$ 81,770,000					

TABLE 3 - ALTERNATE NO.1 - ACID PHASE DIGESTION O&M			
2010		**2030**	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	30 hr/wk	Hours	40 hr/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$51,480.00 $/yr	Annual	$68,640.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors	2	# Mesophilic Reactors	2
# Thermophilic Reactors	5	# Thermophilic Reactors	6
Cost	$478,645 per yr	Cost	$552,083 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	1.195 mgd @1.5%	Flow to Thickening	1.195 mgd @1.6%
# DAFs	0	# DAFs	0
# Gravity Thickeners	2	# Gravity Thickeners	2
# Gravity Belt Thickeners	2	# Gravity Belt Thickeners	3
# Centrifuges	0	# Centrifuges	0
Cost	$42,412 per yr	Cost	$53,979 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	106,316 lbs/d	Solids Flow to Digestion	154,474 lbs/d
Solids Flow to Digestion	236,068 gpd @ 5.4%	Solids Flow to Digestion	343,000 gpd @ 5.4%
Digested Sludge Production	61,876 lbs/d	Digested Sludge Production	89,904 lbs/d
Chemical Sludge Addnl	3,680 lbs/d	Chemical Sludge Addnl	5,980 lbs/d
Total Digested Sludge	65,556 lbs/d	Total Digested Sludge	95,884 lbs/d
Digested Sludge Production	236,068 gpd	Digested Sludge Production	343,000 gpd
% to GBT	75%	% GBT	75%
% to Centrifuge	25%	% Centrifuge	25%
# Gravity Belt Thickeners	2	# Gravity Belt Thickeners	2
# Centrifuges	1	# Centrifuges	1
Cost	$21,280 per yr	Cost	$30,919 per yr
Total Power Cost	***$542,337 $/yr***	***Total Power Cost***	***$636,981 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Primary Sludge	60,800 lbs/d	Primary Sludge	88,400 lbs/d
WAS	49,700 lbs/d	WAS	72,200 lbs/d
Gravity Thickener Polymer Rate	0 lbs/DT	Gravity Thickener Polymer Rate	0 lbs/DT
DAF Polymer Rate	0 lbs/DT	DAF Polymer Rate	0 lbs/DT
GBT Polymer Rate	10 lbs/DT	GBT Polymer Rate	10 lbs/DT
Centrifuge Polymer Rate	5 lbs/DT	Centrifuge Polymer Rate	5 lbs/DT
# DAF	0	# DAF	0
# Gravity Thickeners	2	# Gravity Thickeners	2
# GBT	2	# GBT	3
# Centrifuge	0	# Centrifuge	0
Cost of Polymer	$2.75 $/lb Polymer	Cost of Polymer	$2.75 $/lb Polymer
Cost	$249,432 $/yr	Cost	$362,354 $/yr
Struvite Mitigation		*Struvite Mitigation*	
Iron dosage rate	2500 lbs Fe/day	Iron dosage rate	3500 lbs Fe/day
Ferric chloride dosage rate	7,184 lbs FeCl3/day	Ferric chloride dosage rate	10,057 lbs FeCl3/day
Unit price of FeCl3	$811 $/dry ton FeCl3	Unit price of FeCl3	$811 $/dry ton FeCl3
Application rate	365 #/year	Application rate	365 #/year
Application duration	1 days/application	Application duration	1 days/application
Cost	$1,063,272 $/yr	Cost	$1,488,581 $/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Total Digested Sludge	65,556 lbs/day	Total Digested Sludge	95,884 lbs/day
GBT Polymer Rate	12 lbs/DT	GBT Polymer Rate	12 lbs/DT
Centrifuge Polymer Rate	40 lbs/DT	Centrifuge Polymer Rate	40 lbs/DT
% GBT	75%	% GBT	75%
% Centrifuge	25%	% Centrifuge	25%
Cost	$625,115	Cost	$914,311
Total Chemical Cost	***$1,937,820 $/yr***	***Total Chemical Cost***	***$2,765,246 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	6 %	Metrogro liquid concentration	6 %
Metrogro cake concentration	20 %	Metrogro cake concentration	20 %
Gallons liquid per day	98,255 gpd	Gallons liquid per day	143,711 gpd
Dewatered Sludge per day	48.6 cu yds/d	Dewatered Sludge per day	71.2 cuyds/d
Liquid Hauling Cost	$0.035 $/gal	Liquid Hauling Cost	$0.035 $/gal
Dewatered Sludge Hauling Cost	$13.00 $/cuyd	Dewatered Sludge Hauling Cost	$13.00 $/cuyd
Total Hauling Cost	***$1,486,035 $/yr***	***Total Hauling Cost***	***$2,173,515 $/yr***

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Table 4
Economic Comparison of Digestion Alternatives
Acid Phase (Meso-meso) with Thermo Post Treatment

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Three (3) 2m Gravity Belt Thickeners		$ 675,000	20	$ -	$ -	$ -	Energenics - 150k
Polymer Feed system		$ 150,000	20	$ -	$ -	$ -	$50k x 3
Sludge Feed system		$ 67,500	20	$ -	$ -	$ -	$22.5k x 3 installed cost
New Sludge Thickening Building		$ 750,000	40	$ -	$ 375,000	$ -	3000 sqft @ $250/sqft
Future Modifications to Sludge Thickening							
One (1) 2m Gravity Belt Thickener			20	$ 225,000	$ -	$ 112,500	Energenics - 150k
Polymer Feed system			20	$ 50,000	$ -	$ 25,000	$50k x 1
Sludge Feed system			20	$ 22,500	$ -	$ 11,000	$22.5k x 1 installed cost
New Sludge Thickening Building			40	$ 250,000	$ -	$ 187,500	1000 sqft @ $250/sqft
Two (2) 0.380 MG Acid Digesters							
Digester Concrete		$ 1,520,000	40	$ -	$ 760,000	$ -	(2) 380,000 gal @ $2.00/gal
Digester Cover		$ 220,000	40	$ -	$ 110,000	$ -	concrete
Digester Mixing System		$ 400,000	20	$ -	$ -	$ -	plunger mechanical mixing system
Heating System		$ 500,000	20	$ -	$ -	$ -	(2) steam injectors, (1) steam generator
Control Building (35' x 40')		$ 350,000	40	$ -	$ 175,000	$ -	1,400 sqft @ $250/sqft
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Off gas flare system		$ 300,000	20	$ -	$ -	$ -	Enclosed flare quote $200K
Accessories		$ 50,000	20	$ -	$ -	$ -	
One (1) 1.076 MG Anaerobic Digester @ 80' Diameter (No. 8)							
Digester Concrete		$ 2,152,000	40	$ -	$ 1,076,000	$ -	(1) 1,076,000 gal @ $2.00/gal
80' Digester Cover		$ 300,000	40	$ -	$ 150,000	$ -	concrete
Digester Mixing System		$ 210,000	20	$ -	$ -	$ -	plunger mechanical mixing system
Heating System		$ 113,000	20	$ -	$ -	$ -	(1) hex, (1) hot water pump.
Control Building (30' x 35')		$ 263,000	40	$ -	$ 131,500	$ -	1,050 sqft @ $250.00/sqft
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Foam separator dome		$ 50,000	20	$ -	$ -	$ -	$50K per dome
Modifications to Existing Digesters nos. 4 - 7							
Digester Mixing Systems		$ 840,000	20	$ -	$ -	$ -	plunger mechanical mixing systems
Heating System		$ -	20	$ -	$ -	$ -	Use existing
Foam separator domes		$ 200,000	20	$ -	$ -	$ -	$50K per dome
Modifications to Existing Digester NOS.1-3							
Digester Mixing System		$ 600,000	20	$ -	$ -	$ -	plunger mechanical mixing systems
Heating System		$ 500,000	20	$ -	$ -	$ -	(2) steam injectors, (1) steam generator
Foam separator domes		$ 150,000	20	$ -	$ -	$ -	$50K per dome
Piping/bldg modifications		$ 150,000	20	$ -	$ -	$ -	lump sum allowance
Foam suppresant feed system		$ 300,000	20	$ -	$ -	$ -	
Ferric chloride feed system		$ 125,000	20	$ -	$ -	$ -	
Site Work	8%	$ 939,000	40	$ 44,000	$ 469,500	$ 33,000	
Mechanical Process Piping	10%	$ 1,174,000	40	$ 55,000	$ 587,000	$ 41,250	
Instrumentation and Control	7%	$ 821,000	20	$ 38,000	$ -	$ 19,000	
Electrical	8%	$ 939,000	20	$ 44,000	$ -	$ 22,000	
Subtotal		$ 15,608,500		$ 728,500	$ 4,234,000	$ 451,250	
Allowance for Undefined Design Details	25%	$ 3,902,000		$ 182,000			
Total Construction Cost		$ 19,510,500		$ 910,500			
Engineering, Legal and Administrative	15%	$ 2,927,000		$ 137,000			
Total		$ 22,437,500		$ 1,047,500	$ 4,234,000	$ 451,250	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 22,438,000		$ 651,000	$ 1,634,000	$ 174,000	

Annual O & M Cost			
Labor	$ 68,640	$ 85,800	
Energy (electrical and thermal)	$ 557,846	$ 633,180	
Chemicals	$ 1,937,820	$ 2,765,246	
Hauling	$ 1,486,035	$ 2,173,515	
Maintenance	$ 336,600	$ 352,300	1.5% of Total
Total Annual O & M Cost	$ 4,386,940	$ 6,010,041	
Present Worth Factor	7.769	4.827	Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost	$ 34,081,000	$ 29,010,000	

Total Present Worth Capital Cost	$ 21,281,000
Total Present Worth O&M Cost	$ 63,091,000
Total Present Worth	**$ 84,372,000**

TABLE 5 - ALTERNATE NO.2 - ACID PHASE DIGESTION w/ THERMAL PT O&M

2010		2030	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	40 hr/wk	Hours	50 hr/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$68,640.00 $/yr	Annual	$85,800.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors	5	# Mesophilic Reactors	6
# Thermophilic Reactors	3	# Thermophilic Reactors	3
Cost	$494,154 per yr	Cost	$548,282 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	1.195 mgd @1.5%	Flow to Thickening	1.195 mgd @1.6%
# DAFs	0	# DAFs	0
# Gravity Thickeners	2	# Gravity Thickeners	2
# Gravity Belt Thickeners	2	# Gravity Belt Thickeners	3
# Centrifuges	0	# Centrifuges	0
Cost	$42,412 per yr	Cost	$53,979 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	106,316 lbs/d	Solids Flow to Digestion	154,474 lbs/d
Solids Flow to Digestion	236,068 gpd @ 5.4%	Solids Flow to Digestion	343,000 gpd @ 5.4%
Digested Sludge Production	61,876 lbs/d	Digested Sludge Production	89,904 lbs/d
Chemical Sludge Addnl	3,680 lbs/d	Chemical Sludge Addnl	5,980 lbs/d
Total Digested Sludge	65,556 lbs/d	Total Digested Sludge	95,884 lbs/d
Digested Sludge Production	236,068 gpd	Digested Sludge Production	343,000 gpd
% to GBT	75%	% GBT	75%
% to Centrifuge	25%	% Centrifuge	25%
# Gravity Belt Thickeners	2	# Gravity Belt Thickeners	2
# Centrifuges	1	# Centrifuges	1
Cost	$21,280 per yr	Cost	$30,919 per yr
Total Power Cost	***$557,846 $/yr***	***Total Power Cost***	***$633,180 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Primary Sludge	60,800 lbs/d	Primary Sludge	88,400 lbs/d
WAS	49,700 lbs/d	WAS	72,200 lbs/d
Gravity Thickener Polymer Rate	0 lbs/DT	Gravity Thickener Polymer Rate	0 lbs/DT
DAF Polymer Rate	0 lbs/DT	DAF Polymer Rate	0 lbs/DT
GBT Polymer Rate	10 lbs/DT	GBT Polymer Rate	10 lbs/DT
Centrifuge Polymer Rate	5 lbs/DT	Centrifuge Polymer Rate	5 lbs/DT
# DAF	0	# DAF	0
# Gravity Thickeners	2	# Gravity Thickeners	2
# GBT	2	# GBT	3
# Centrifuge	0	# Centrifuge	0
Cost of Polymer	$2.75 $/lb Polymer	Cost of Polymer	$2.75 $/lb Polymer
Cost	$249,432 $/yr	Cost	$362,354 $/yr
Struvite Mitigation		*Struvite Mitigation*	
Iron dosage rate	2500 lbs Fe/day	Iron dosage rate	3500 lbs Fe/day
Ferric chloride dosage rate	7,184 lbs FeCl3/day	Ferric chloride dosage rate	10,057 lbs FeCl3/day
Unit price of FeCl3	$811 $/dry ton FeCl3	Unit price of FeCl3	$811 $/dry ton FeCl3
Application rate	365 #/year	Application rate	365 #/year
Application duration	1 days/application	Application duration	1 days/application
Cost	$1,063,272 $/yr	Cost	$1,488,581 $/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	65,556 lbs/day	Digested Sludge	95,884 lbs/day
GBT Polymer Rate	12 lbs/DT	GBT Polymer Rate	12 lbs/DT
Centrifuge Polymer Rate	40 lbs/DT	Centrifuge Polymer Rate	40 lbs/DT
% GBT	75%	% GBT	75%
% Centrifuge	25%	% Centrifuge	25%
Cost	$625,115	Cost	$914,311
Total Chemical Cost	***$1,937,820 $/yr***	***Total Chemical Cost***	***$2,765,246 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	6 %	Metrogro liquid concentration	6 %
Metrogro cake concentration	20 %	Metrogro cake concentration	20 %
Gallons liquid per day	98,255 gpd	Gallons liquid per day	143,711 gpd
Dewatered Sludge per day	48.6 cu yds/d	Dewatered Sludge per day	71.2 cu yds/d
Liquid Hauling Cost	$0.035 $/gal	Liquid Hauling Cost	$0.035 $/gal
Dewatered Sludge Hauling Cost	$13.00 $/cu yd	Dewatered Sludge Hauling Cost	$13.00 $/cu yd
Total Hauling Cost	***$1,486,035 $/yr***	***Total Hauling Cost***	***$2,173,515 $/yr***

Table 6
Economic Comparison of Digestion Alternatives
Conventional Digestion with Cambi THP

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Three (3) 475 gpm Centrifuges		$ 2,325,000	20	$ -	$ -	$ -	Installed equipment cost = $775k/unit
Polymer Feed system		$ 150,000	20	$ -	$ -	$ -	$50k x 3
Sludge Feed system		$ 67,500	20	$ -	$ -	$ -	$22.5k x3 installed cost
New Sludge Thickening Building		$ 900,000	40	$ -	$ 450,000	$ -	3600 sqft @ $250/sqft
Construct CAMBI							
CAMBI equipment cost		$ 10,784,000	20	$ -	$ -	$ -	
New Cambi THP Building (40'x72')		$ 432,000	40	$ -	$ 216,000	$ -	2,880 sqft @ $150/sqft (pre-engr metal bldg)
Tunnel extension		$ 400,000	40	$ -	$ 200,000	$ -	200' @ $2000/ft
Modifications to Existing Digesters nos. 4 - 7							
Digester Mixing Systems		$ 840,000	20	$ -	$ -	$ -	plunger mechanical mixing systems
Heating System		$ -	20	$ -	$ -	$ -	Use existing
Biogas Handling System		$ -	20	$ -	$ -	$ -	Use existing
Ferric chloride feed system		$ 125,000	20	$ -	$ -	$ -	
Site Work	8%	$ 1,282,000	40	$ -	$ 641,000	$ -	
Mechanical Process Piping	10%	$ 1,602,000	40	$ -	$ 801,000	$ -	
Instrumentation and Control	7%	$ 1,122,000	20	$ -	$ -	$ -	
Electrical	8%	$ 1,282,000	20	$ -	$ -	$ -	
Subtotal		$ 21,311,500		$ -	$ 2,308,000	$ -	
Allowance for Undefined Design Details	25%	$ 3,171,000		$ -			5% used for CAMBI
Total Construction Cost		$ 24,482,500		$ -			
Engineering, Legal and Administrative	15%	$ 2,594,000		$ -			5% used for CAMBI
Total		$ 27,076,500		$ -	$ 2,308,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 27,077,000		$ -	$ 891,000	$ -	
Annual O & M Cost							
Labor		$ 85,800		$ 102,960			
Energy (electrical and thermal)		$ 718,942		$ 777,547			
Chemicals		$ 1,855,568		$ 2,644,942			
Hauling		$ 1,409,093		$ 2,060,977			
Maintenance		$ 406,100		$ 406,100			1.5% of Total
Total Annual O & M Cost		$ 4,475,502		$ 5,992,526			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 34,769,000		$ 28,926,000			
Total Present Worth Capital Cost		$ 26,186,000					
Total Present Worth O&M Cost		$ 63,695,000					
Total Present Worth		**$ 89,881,000**					

TABLE 7 - ALTERNATE NO.3 - CONVENTIONAL DIGESTION W/ CAMBI THP O&M					
2010			**2030**		
Labor					
Description					
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	50	hr/wk	Hours	60	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$85,800.00	$/yr	Annual	$102,960.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	3		# Mesophilic Reactors	3	
Cambi THP System	1	67% load	Cambi THP System	1	75% load
Cost	$640,441	per yr	Cost	$693,857	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	2		# DAFs	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners	0		# Gravity Belt Thickeners	0	
Flow to Centrifuges	0.277	mgd @4.6%	Flow to Centrifuges	0.403	mgd @4.6%
# Centrifuges in service	1		# Centrifuges	1	
Cost	$67,044	per yr	Cost	$67,044	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Cambi THP	106,316	lbs/d	Solids Flow to Cambi THP	154,474	lbs/d
Solids Flow to Cambi THP	127,096	gpd @ 17%	Solids Flow to Cambi THP	184,666	gpd @ 17%
Digested Sludge Production	61,876	lbs/d	Digested Sludge Production	89,904	lbs/d
Chemical Sludge Addnl	3,680	lbs/d	Chemical Sludge Addnl	5,980	lbs/d
Total Digested Sludge	65,556	lbs/d	Total Digested Sludge	95,884	lbs/d
Digested Sludge Production	127,096	gpd	Digested Sludge Production	184,666	gpd
% to GBT	75%		% GBT	75%	
% to Centrifuge	25%		% Centrifuge	25%	
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	2	
# Centrifuges	1		# Centrifuges	1	
Cost	$11,457	per yr	Cost	$16,646	per yr
Total Power Cost	***$718,942***	***$/yr***	***Total Power Cost***	***$777,547***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Primary Sludge	60,800	lbs/d	Primary Sludge	88,400	lbs/d
WAS	49,700	lbs/d	WAS	72,200	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	10	lbs/DT	GBT Polymer Rate	10	lbs/DT
Centrifuge Polymer Rate	5	lbs/DT	Centrifuge Polymer Rate	5	lbs/DT
# DAF	2		# DAF	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# GBT	0		# GBT	0	
# Centrifuge	1		# Centrifuge	1	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$249,432	$/yr	Cost	$362,354	$/yr
Struvite Mitigation			*Struvite Mitigation*		
Iron dosage rate	2500	lbs Fe/day	Iron dosage rate	3500	lbs Fe/day
Ferric chloride dosage rate	7,184	lbs FeCl3/day	Ferric chloride dosage rate	10,057	lbs FeCl3/day
Unit price of FeCl3	$811	$/dry ton FeCl3	Unit price of FeCl3	$811	$/dry ton FeCl3
Application rate	365	#/year	Application rate	365	#/year
Application duration	1	days/application	Application duration	1	days/application
Cost	$1,063,272	$/yr	Cost	$1,488,581	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	65,556	lbs/day	Digested Sludge	95,884	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	30	lbs/DT	Centrifuge Polymer Rate	30	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$542,863		Cost	$794,007	
Total Chemical Cost	***$1,855,568***	***$/yr***	***Total Chemical Cost***	***$2,644,942***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	30	%	Metrogro cake concentration	30	%
Gallons liquid per day	98,255	gpd	Gallons liquid per day	143,711	gpd
Dewatered Sludge per day	32.4	cu yds/d	Dewatered Sludge per day	47.4	cuyds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cuyd	Dewatered Sludge Hauling Cost	$13.00	$/cuyd
Total Hauling Cost	***$1,409,093***	***$/yr***	***Total Hauling Cost***	***$2,060,977***	***$/yr***

APPENDIX G

Technical Memorandum No. 4
Anaerobic Digestion Ancillary Systems Evaluation

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 4
ANAEROBIC DIGESTION ANCILLARY SYSTEMS EVALUATION

Date: December 15, 2009 (Revised) **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate key digester ancillary systems to support the multi-stage acid-phase digestion configuration at the Nine Springs Wastewater Treatment Plant (NSWWTP). This evaluation includes sludge feed systems, mixing systems, heating systems, and digester gas collection systems. The configuration and location of key digester ancillary systems will also be evaluated as part of this TM to facilitate the selected location and configuration of the new digesters.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- Either draft tube mixing or plunger mixing may be used to mix the proposed methane Digester No. 8. Either pump mixing or linear motion plunger mixing is recommended for the proposed Acid Digesters No. 1 and No. 2 due to a variable digester operating elevation,

- The replacement of the gas mixing system of the existing Digesters No. 4- 7 with either draft tube mixing or plunger mixing systems is recommended due to increased foaming potential, inefficient scum layer incorporation, excessive grit accumulation, and short-circuiting.

- A new direct steam injection system is recommended for the proposed Acid Digesters No. 1 and No. 2. The proposed system includes two direct steam injectors with a capacity of 6.8 MMBTU/hr and a new steam generator.

- The installation of one new spiral heat exchanger with a capacity of 1.3 MMBTU/hr is recommended for the proposed Digester No. 8 under thermophilic conditions.
- The existing spiral heat exchangers for Digesters No. 4-7 do not have sufficient capacity for operation in thermophilic mode. The use of the existing shell and tube heat exchangers is recommended to provide supplemental heat to Digesters No. 4-7.
- Under batch thermal treatment mode, the existing heat exchangers in Digesters No. 1, 2, and 3 have sufficient capacity to operate with thermophilic sludge feed but do not have sufficient capacity to operate with mesophilic sludge feed. To operate the methane digesters with mesophilic sludge feed, the installation of two new direct steam injectors with a capacity of 5.6 MMBTU/hr to preheat the feed to the batch thermal tanks is recommended.
- The NSWWTP has adequate heating supply to provide heating to the existing and proposed digester units during operation in multi-stage acid-phase digestion mode.
- The installation of a separate acid gas collection system and new low-BTU enclosed gas flare are recommended for implementation of acid phase digestion.
- Foam abatement improvements to the existing domes and gas collection systems of digesters No. 4-7 are recommended.
- Modifications to the domes and overflow systems of Digesters No. 1, 2, and 3 are recommended to accommodate the larger sludge volume exchange associated with batch operation for the acid digestion with batch thermal treatment alternative.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements while maintaining the current biosolids land application programs. TM-03A Sludge Stabilization Alternatives Evaluation identified multi-stage acid-phase digestion, acid-phase digestion with thermal treatment, and conventional digestion with Cambi Thermal Hydrolysis Process (THP) as viable alternatives. Based on economic and non-economic evaluations, the MMSD staff selected multi-stage acid-phase digestion for implementation at the NSWWTP. The equipment selection for the ancillary systems of the selected digestion technology must minimize the potential for foaming in the anaerobic digesters and phosphate crystallization in pipes and heat exchangers.

4.0 Digester Feed System

During operation in multi-stage acid phase digestion mode, thickened sludge (THS) is fed directly to the proposed Acid Digesters No. 1 or No. 2 (details of the proposed THS pumps are presented in TM-08 Sludge Thickening Evaluation). Under normal conditions, the proposed acid digesters operate in series with gravity flow from Acid Digester No. 1 to Acid Digester No. 2. Both digesters can operate as a single-stage acid digester when one unit is out of service. Sludge from the acid digesters is then pumped to the existing Digesters No. 4 to No. 7 and proposed Digester No. 8 through motorized feed valves. The feed valve is programmed to batch feed the digesters such that the quantity of sludge fed to the digesters is proportional to the digester volumes. To feed sludge proportionally to the new Digester

No. 8, an additional motorized feed valve must be added to the system. The existing batch feed system must be reprogrammed to feed the digesters in proportion to their volumes. A schematic of the proposed digester feeding system is presented in Figure 4.1. The acid digester recirculation line will be routed through the existing whey wells to feed grease and other high strength organics directly to the acid digesters, while preventing pipe clogging. Details of the proposed grease receiving improvements are presented in TM-07 Grease Receiving Facility.

4.1 Multi-Stage Acid Phase Digestion

After the acid digesters (Acid Digesters No. 1 or No. 2) the sludge is pumped into the first-stage thermophilic methane digesters (existing Digesters No. 4 to No. 7 and proposed Digester No. 8). After these digesters, the sludge will be transferred to the West Complex second-stage thermophilic methane digesters (existing Digesters No. 1, 2, and 3). The second-stage thermophilic digesters overflow to the existing Sludge Holding Tanks No. 1 and No. 2.

4.2 Acid Phase Digestion with Thermal Treatment

Under the acid-phase digestion with batch thermal treatment configuration, sludge from the acid digesters (Acid Digesters No. 1 or No. 2) is pumped into the mesophilic methane digesters (existing Digesters No. 4 to No. 7 and proposed Digester No. 8). The sludge from the methane digesters is pumped to the batch thermal treatment tanks (existing Digesters No. 1, 2, and 3). The sludge from the batch thermal tanks is pumped to the existing Sludge Holding Tanks No. 1 and No. 2.

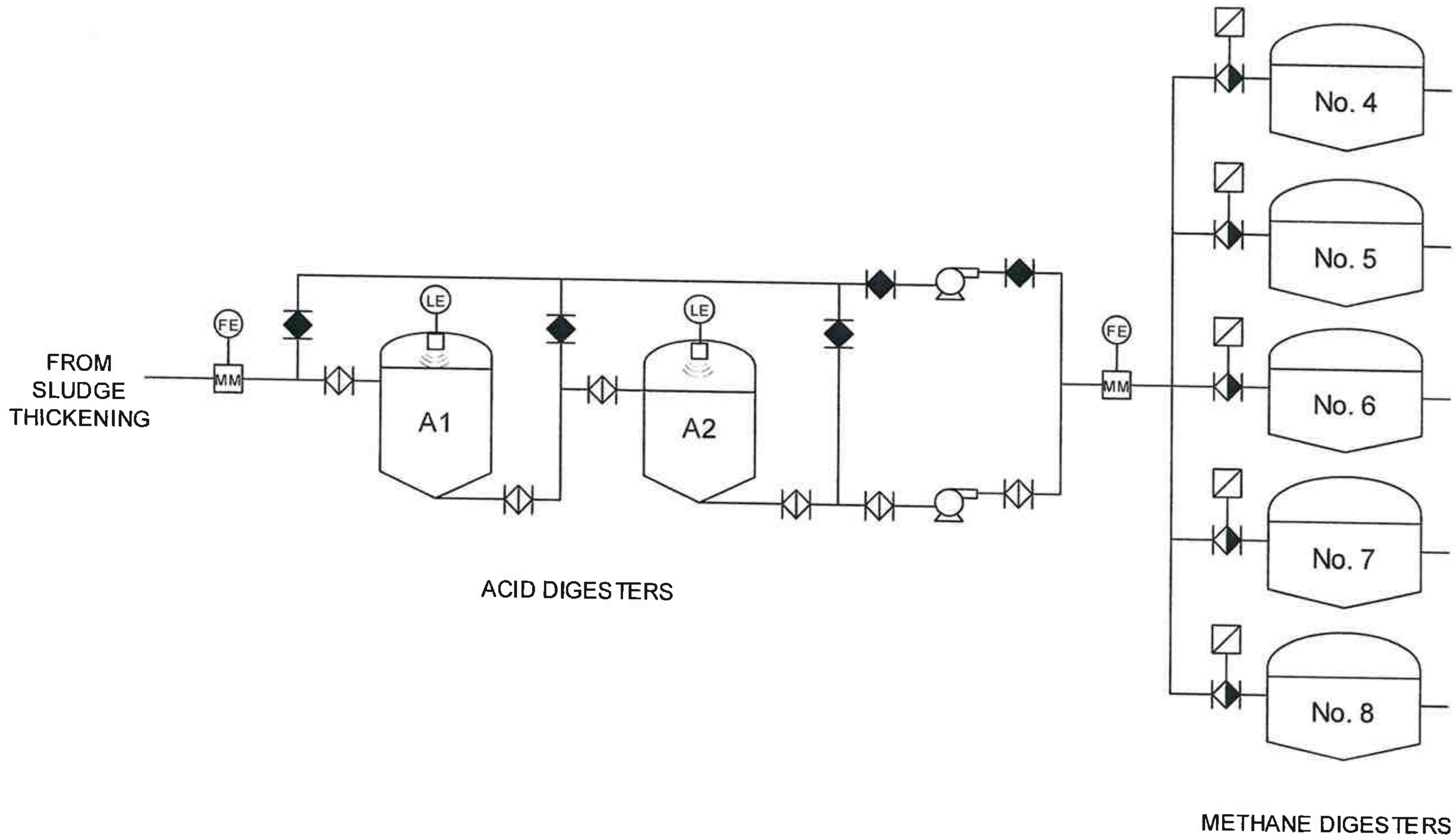
5.0 Digester Mixing System

Complete mixing of digester contents is critical to reduce short-circuiting and maintain contact between the active biomass inside the digester and the incoming feed sludge. Benefits of proper active mixing include improved volatile solids reduction and increased gas production by enhancing biological reaction rates and a uniform distribution of heat throughout the digester. Effective digester mixing also increases the digester active volume by breaking up surface scum layers and re-suspending grit and other solids that settle on the digester floor. All of these factors improve the operating safety margin and reduce the potential for process upsets.

5.1 Design Criteria

Digester mixing alternatives are compared using energy input, digester turnover rate, or velocity gradient. Energy input and turnover rates are more widely used than velocity gradient due to difficulties estimating the velocity gradient, which varies widely throughout the digester operation.

Energy input is expressed in terms of horsepower (hp) per digester volume, and the typical range for proper mixing is between 0.2 and 0.3 hp per 1,000 cubic feet of digester volume. However, the actual mixing effectiveness is dependent upon the transfer efficiency of input power to mixing energy for a particular system. Digester turnover rate is the sludge flow per unit volume. The typical range for proper mixing is between 20 and 30 minutes for gas mixing and draft tube mixing systems, and between 3 and 4 hours for pump mixing systems. For pump mixing systems, the mixing efficiency is equivalent to a 30 minutes turnover time because of nozzle-entrained flow where high fluid velocity through nozzle creates a secondary flow within the digester that increases the mixing energy. This mechanism has been confirmed through Computational Fluid Dynamics (CFD) analysis.



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DIGESTER FEEDING SYSTEM

FIGURE 4.1

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5.2 Existing Digester Mixing System

Digesters No. 1, 2, and 3 are mixed using internal roof-mounted draft tube mixers located inside steel draft tubes and have an estimated pumping capacity of 10,000 gpm each (20,000 gpm total). Digesters No. 4-7 are mixed using confined gas mixers and have an estimated pumping capacity of 4,200 gpm each (29,400 gpm total). Each gas mixed digester has seven eductor tubes that are shorter than typical installations to allow operation with a variable liquid elevation.

Table 4.1 presents the mixing energy and turnover rate of each digester mixing system. The existing mixing systems are within the recommended range of the mixing energy design criteria but are above the recommended values for turnover rate. The MMSD staff reported severe foaming episodes and short-circuiting in Digesters No. 4-7. These problems could be attributed in part to the short eductor tubes that were installed in these digesters, which may result in reduced mixing efficiency.

Table 4.1
Existing Digester Mixing Systems

	East Complex Digesters (1)	East Complex Digesters (2)	West Complex Digesters (3)	Sludge Storage Tanks
Type	Confined Gas	Confined Gas	Internal Draft Tubes	Unmixed
Units per Digester	7	7	2	-
Mixing Energy, hp/1000 cf (4)	0.30	0.28	0.23	-
Turnover Rate, min (5)	34	< 34 (6)	32	-

Notes:
(1) Digesters No. 4, 5, and 6.
(2) Digester No. 7.
(3) Digesters No. 1, 2, and 3.
(4) Typical Design Criteria is 0.2 to 0.3 hp per 1000 cf.
(5) Typical Design Criteria is 20 to 30 min
(6) Due to compressor modifications.

Based on lithium tracer tests and monitoring of sludge recirculation temperatures in Digesters No. 4 and No. 7, the MMSD Staff have reported short-circuiting and a considerable loss of active volume due to grit/struvite deposition in these digesters (MMSD memorandum dated April 2009). The short-circuiting in Digester No. 4 was attributed in part to intermittent mixing and was resolved by re-programming the digester operation to close the withdrawal valve during digester feeding. The short-circuiting in Digester No. 7 occurred during continuous mixing. Gas mixing systems are particularly sensitive to the height of water above the eductor tubes. Studies have shown a small variation of less than one foot can reduce the mixing efficiency to less than 30 percent of the design values. Figure 4.2 illustrates CFD modeling results for a digester gas mixing system.

5.3 Digester Mixing System Alternatives

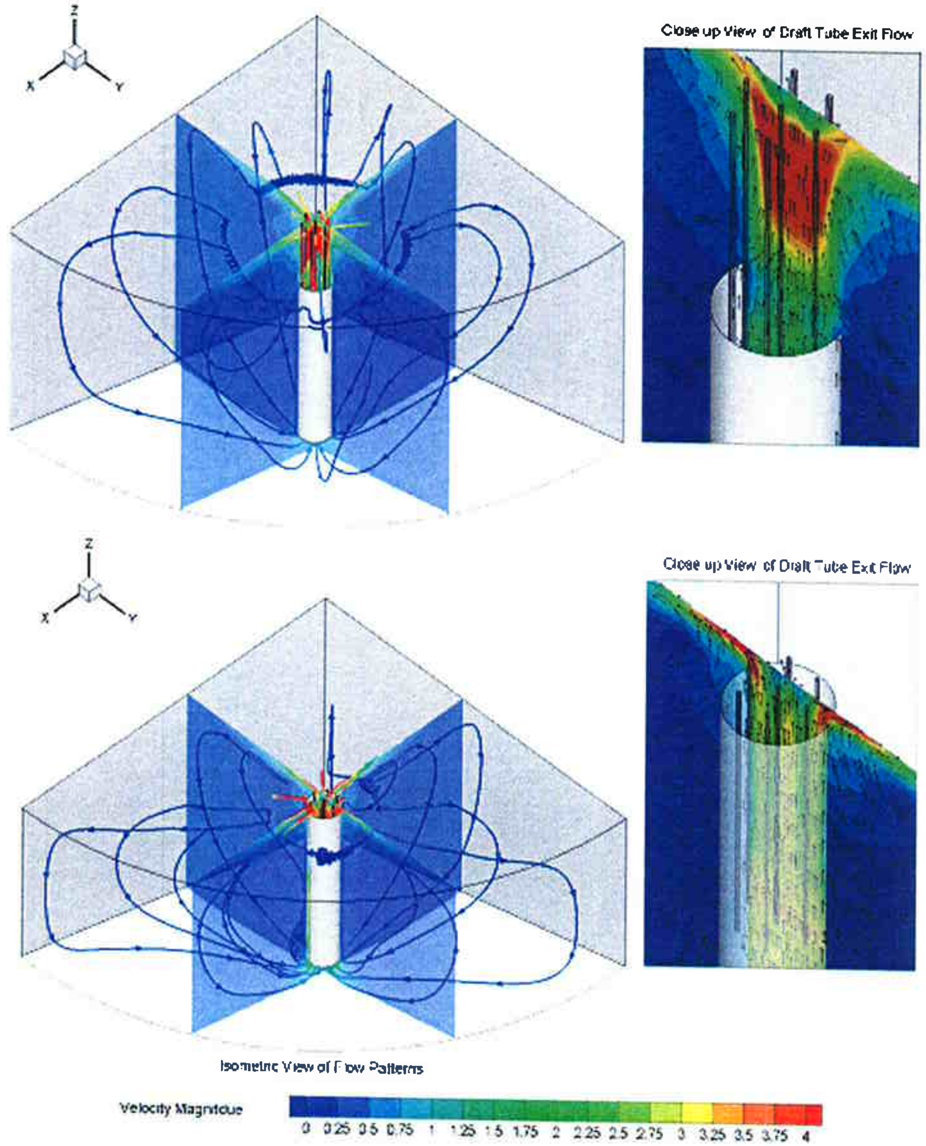
Draft tube, pump, plunger, and gas mixing systems were evaluated for the new acid digesters No. 1 and 2, the new thermophilic Digester No. 8, and the existing Digesters No. 4-7. These systems are described in more detail below. Table 4.2 presents a non-economic comparison of these mixing systems.

Table 4.2
Mixing Alternative Non-economic Comparison

	Advantages	Disadvantages
Draft Tube Mixers	• Plant staff familiar with existing equipment • Mixer can reverse flow to break scum blanket • Multiple mixers provide system redundancy • Motors can be maintained without taking digester out of service	• Structural modifications to the digester domes may be required • Struvite scaling requires tube withdrawal from digester • Less efficient in preventing grit accumulation than pump mixing and plunger mixing • Higher installed cost than pump mixing and plunger mixing • Cannot operate with variable liquid level
Pump Mixing	• Bottom suction minimizes grit accumulation • Operation with variable liquid level • Pumps can be maintained without taking digester out of service • Additional mixing energy provided by nozzle entrained flow	• Space constraint issues in existing digester building • Requires penetrations through existing digester walls • Digester must be taken out of service to access nozzles • Higher energy consumption than draft tube mixing and plunger mixing
Plunger Mixing	• Lowest energy consumption • Low mechanical complexity • Operation with variable liquid level • Mechanical equipment can be maintained without taking digester out of service	• Structural modifications to the digester domes may be required • Only one installation in the U.S. • No redundancy • Proprietary technology

Table 4.2
Mixing Alternative Non-economic Comparison

	Advantages	Disadvantages
Gas Mixing	• Plant staff familiar with existing equipment • Compressor can be maintained without taking digester out of service	• Increased foaming potential • Digester must be taken out of service to access eductor tubes and lances • Low mixing efficiency at low liquid elevations • Low efficiency in preventing grit accumulation • Low efficiency in incorporating scum layer



CFD MODELING OF A GAS MIXING SYSTEM

FIGURE 4.2

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5.3.1. Draft Tube Mixing

Draft tube mixing utilizes non-clog, axial flow propellers mounted inside vertical draft tubes to provide a tangential flow pattern within the digester. Draft tubes may be located internally with the motor mounted on the tank roof, or externally along the periphery of the digester. Typically, the flow pattern for draft tube mixing is from the bottom to the top of the digester. The strong surface agitation created by this flow pattern results in effective break-up of the scum layer. Draft tube mixing systems are also capable of reversible flow, allowing scum or foam at the surface to be redistributed throughout the digester. The installation of variable frequency drives on the propeller motor allows adjustments in the mixing intensity.

A draft tube mixing system for the new Digester No. 8 would consist of four (4) 10 hp roof-mounted draft tube mixers with a flow rate of 9,800 gpm each (39,200 gpm total). Structural modifications to the digester domes may be required for the installation of draft tubes in the existing Digesters No. 4-7. Due to variable digester operating elevation, draft tube mixing was not considered for the acid digesters.

5.3.2. Pump Mixing

Pump mixing systems use a combination of sludge recirculation pumps and mixing nozzles to uniformly mix the digester contents. Typically, screw centrifugal or centrifugal chopper pumps are used to circulate the sludge. The pump draws sludge from the center of the digester and discharges through nozzles located either inside the digester mounted on the tank floor, or externally located on the digester tank wall. The nozzles inside the digester or on the tank wall are aimed tangentially, which creates a spiral flow pattern. Because of the lasting momentum created inside the digester by this mixing pattern, pump mixing systems can be operated intermittently to decrease the operating cost. Pump mixing was considered for the new acid digesters and the new thermophilic Digester No. 8.

Based on the turnover rate criteria of 3 to 4 hours, a pump mix system for the new Digester No. 8 would consist of two (2) 30 hp chopper centrifugal pumps with a flow rate of 3,000 gpm each (6,000 total). Due to space constraints in the existing digester control building and the requirement to penetrate the digester walls, pump mixing was not considered for the existing Digesters No. 4-7. A pump mixing system for the new Acid Digesters No. 1 and No. 2 would consist of two (2) 25 hp chopper centrifugal pumps with a flow rate of 2,800 gpm each (one duty; one standby).

5.3.3. Plunger Mixing

Plunger mixing systems consist of a shaft and a disk that oscillate vertically creating a turbulent liquid-core of eddy currents and pulsating pressure waves that enhance mass movement. The force and velocity of the liquid-core are controlled by the frequency, stroke, and size of the disk. Due to high energy transfer efficiency, plunger mixing systems require smaller motors than draft tube or pump mixing systems, resulting in a significant reduction in energy usage. Conventional digester mixing design criteria (energy input and turnover rates) do not apply to plunger mixing systems. The turn over time is related to a pumping rate and plunger mixers utilize an unconfined displacement mixer with a dual motion. These mixers are designed with a power to volume ratio of 0.04 to 0.1 hp per 1000 ft^3 and a G value of 30 to 50 sec-1. Extensive testing and CFD modeling conducted for the Linear Motion Sludge Mixer (EIMCO Water Technologies) has shown that these values provide effective digester mixing. Plunger mixing systems include the Linear Motion Sludge Mixer (EIMCO Water Technologies). Figure 4.3 shows an example of the Linear Motion Sludge Mixer.

The only U.S. full-scale facility with plunger mixing systems is the Ina Road Water Reclamation Facility (Tucson, AZ). Two plunger mixing systems will be installed in the Waco Metropolitan Area Regional Sewerage System Central WWTP (Waco, TX). Worldwide full-scale installations include two wastewater treatment facilities in Canada (Fort Erie, ON and Napanee, ON).

A plunger mixing system for the proposed Digester No. 8 and the existing Digesters No. 4-7 would consist of one (1) 10 hp Linear Motion Sludge Mixer for each digester. A plunger mixing system for the proposed acid digesters No. 1 and No. 2 would consist of one (1) 7.5 hp Linear Motion Sludge Mixer for each acid digester. Structural modifications to the digester domes will be required for the installation of plunger mixers in the existing Digesters No. 4-7.

5.3.4. Confined Gas Mixing

Confined gas mixing uses one or more eductor tubes to mix the digester contents through the release of compressed gas within the tube. As compressed gas is released, the eductor tube acts as a gas lift pump, pulling sludge in from the bottom of the digester and causing an upward mixing pattern. The bottom to top mixing generated by eductor tube systems is meant to decrease grit accumulation, potentially reducing the frequency of digester cleaning. Because of inefficient floating scum layer incorporation and increased digester foaming problems, gas mixing was not considered for further evaluation.

5.3.5. Life Cycle Cost Analysis

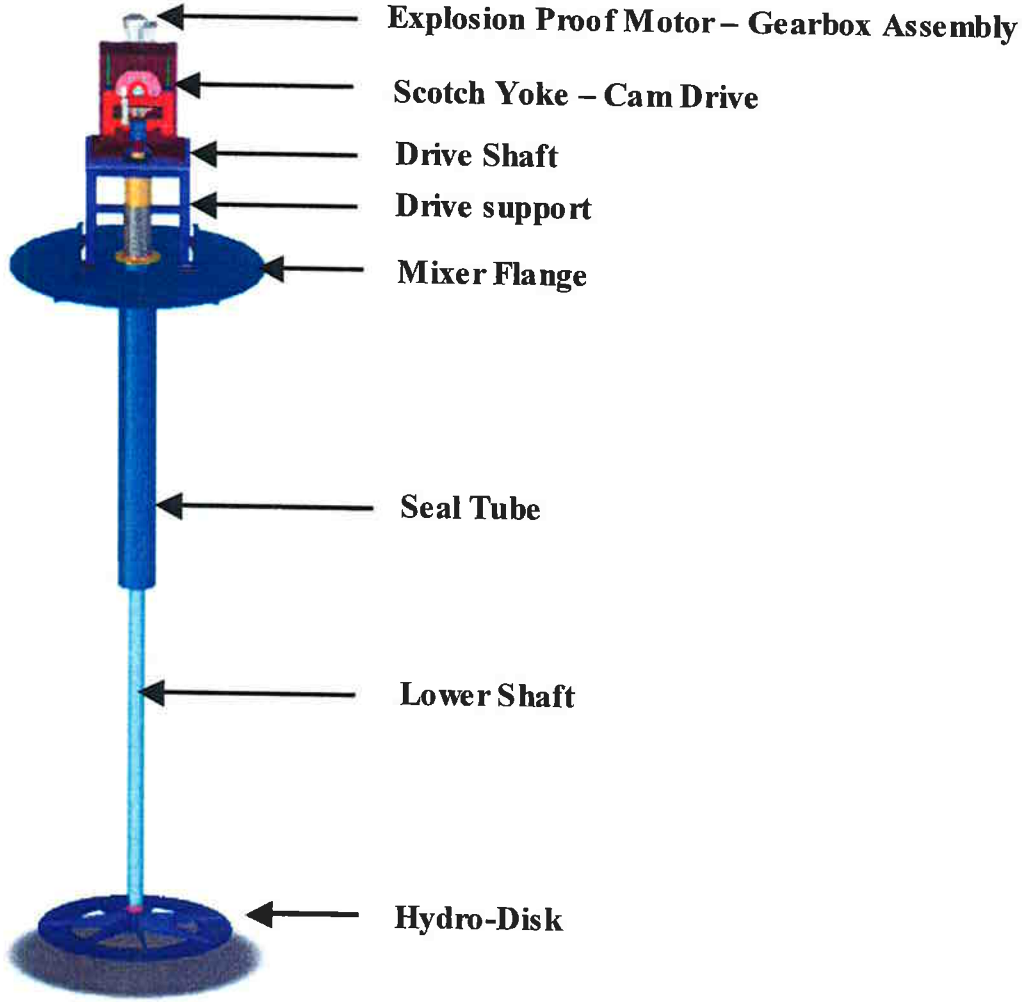
The cost comparison of draft tube mixing and pump mixing alternatives, including operating and maintenance costs, is summarized in Table 4.3. For the acid digesters, the present worth costs of pump mixing and plunger mixing was comparable. For the methane digesters, plunger mixing had a lower present worth cost than draft tube mixers. Draft tube mixers were not considered for the acid digesters due to variable level operation. Pump mixing was not considered for the methane digesters due to space limitations in the East Complex digesters.

Table 4.3 Mixing Alternatives Economic Comparison			
	Draft Tube Mixers (1)	**Pump Mixing (2)**	**Plunger Mixing (3)**
Acid Digester			
PW Capital Cost	N/A	$605,000	$732,000
PW O&M Cost	N/A	$391,000	$331,000
Total PW Cost	N/A	$996,000	$1,063,000
Methane Digester			
PW Capital Cost	$3,302,000	N/A	$1,933,000
PW O&M Cost	$1,421,000	N/A	$660,000
Total PW Cost	$4,723,000	N/A	$2,593,000

Notes:
(1) Includes four 10 hp roof mounted mixers per digester (Digesters No. 4, 5, 6, 7 & 8).
(2) Includes two 25 hp chopper centrifugal pumps (Acid Digesters 1 & 2).
(3) Includes one LM mixer per digester: 7.5 hp for each acid digester (Acid Digesters 1 & 2) and 10 hp for each methane digester (Digesters No. 4, 5, 6, 7, & 8).

5.3.1. Recommendation

Based on an economic and non-economic comparison, the installation of either pump or plunger mixing systems is recommended for the proposed Acid Digesters Nos. 1 and 2. The installation of draft tubes or plunger mixing systems is recommended for the proposed Digester No. 8. Based on increased foaming potential, inefficient scum reincorporation, excessive grit deposition, and short-circuiting, the replacement of the existing gas mixing systems in Digesters No. 4-7 with either draft tube or plunger mixing systems is recommended. Table 4.4 summarizes the recommended design criteria for the proposed mixing systems.



LINEAR MOTION SLUDGE
MIXING SYSTEM

FIGURE 4.3

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Table 4.4 Recommended Mixing System Design Criteria			
	Methane Digesters No. 4 - No. 6	**Methane Digesters (No. 7 and No. 8)**	**Acid Digesters (No. 1 and No. 2)**
Alternative 1			
Type	Draft Tube Mixing	Draft Tube Mixing	Pump Mixing
Number of Units per Tank	4	4	2
Energy, hp (total)	40	40	25
Energy Input, hp/1000 cf	0.30	0.28	0.33
Total Flow, gpm	39,200	39,200	2,800 [(1)]
Turnover Rate, min	26	27	198
Alternative 2			
Type	Plunger Mixing	Plunger Mixing	Plunger Mixing
Number of Units per Tank	1	1	1
Energy, hp (total)	10	10	7.5

Notes:
(1) Digester heating system provides 1,400 gpm.

6.0 DIGESTER HEATING AND RECIRCULATION SYSTEM

6.1 Existing Sludge Heating System

The existing digester sludge heating system at the NSWWTP consists of seven spiral heat exchangers (HEX 1-7) and five tube-and-shell heat exchangers (HEX 8-12). Each spiral heat exchanger and associated sludge recirculation pump is normally dedicated to a single digester. The tube-and-shell heat exchangers are used for heat recovery (HEX 8 and 9) and raw sludge preheating (HEX 9 and 10). The MMSD Staff reported leaks and ragging problems in the raw sludge preheating unit (HEX 10) and struvite/vivianite scaling in a heat recovery unit (HEX 8). Table 4.5 shows the heating capacity for the existing heat exchanger units.

Table 4.5 Existing Digester Heating System				
	Digester 7	**Digesters 4-6**	**Digesters 1-3**	**Raw Sludge**
ID	HEX 7	HEX 4-6	HEX 1-3	HEX 8-12
Type	Spiral	Spiral	Spiral	Tube and Shell
Units	1	3	3	3/2
Unit Capacity, MMBTU/hr (1)	1.65 (2)	1.65 (2)	1.53	5.4/ 6.1

Notes:

(1) Heating capacity for mesophilic operation

(2) Thermophilic operation heating capacity of 0.5 MMBTU/hr

6.2 Existing Hot Water System

Currently, heat is supplied from two engine generators and one engine-driven blower. With all units operating at a 1,500 kW load, approximately 6.0 MMBTU/hr of heating energy is recovered from the engines. Six hot water boilers can provide a total plant heat supply of 33.3 MMBTU/hr.

The hot water generated by the engines and boilers is used to heat several different processes at the plant, as presented in Table 4.6. To accommodate acid-phase digestion, the existing heating facilities must meet the total heat requirements with one large boiler unit in standby at all time. The NSWWTP has sufficient heating capacity and redundancy to meet the design criteria at 2030 maximum month flow. This section presents the preliminary design for the boiler facilities.

Table 4.6 Estimated Plant-Wide Heat Supply and Demand		
	Estimated Heat, MMBTU/hr	
Process	Winter	Summer
Heat Supply		
East Zone Boilers (1,2)	20.4	20.4
West Zone Boilers (1,3)	12.9	12.9
Engines (4)	5.7	5.7
Total Heat Supply	**39.0**	**39.0**
Heat Demand		
Digesters (5,6)	14.3	10.7
Building Ventilation Heating	11.05	N/A
Building Ventilation Cooling	N/A	3.30
Total Heat Demand	**23.00**	**11.42**

Notes:
(1) Based on 2008 MMSD 50-Year Master Plan.
(2) Three fire tube boilers with a heating capacity of 6.8 MMBTU/hr, each.
(3) Three fire tube boilers with a heating capacity of 4.3 MMBTU/hr, each.
(4) Two engine generators and one engine-driven blower.
(5) Based on maximum month sludge loading to digesters.
(6) Includes existing and future digesters.

6.3 Sludge Heating Requirements

As part of this project, the digestion capacity of the NSWWTP will be expanded to handle a 2030 wastewater capacity of 53.7 mgd annual average flow. As discussed in TM-03A, two new 0.38 MG acid digesters (Acid Digesters No. 1 and 2) and one new 1.076 MG thermophilic methane digester (Digester No. 8) will be required to achieve this capacity in the acid phase digestion mode. Table 4.7 shows the estimated heat requirements to operate the expanded digestion facilities at max month 2030 flows. The heat requirements were calculated based on the following assumptions:

(1) Total solids concentration = 5.4 percent.

(2) Max month flow to digestion = 408,200 gpd.

(3) Acid digesters target temperature = 98 deg F.

(4) Thermophilic methane digesters target temperature = 128 deg F.

(5) Air temperature = 80 deg F (summer); 4 deg F (winter).

(6) Ground temperature = 75 deg F (summer); 50 deg F (winter).

(7) Raw sludge temperature = 75 deg F (summer); 52 deg F (winter).

(8) Maximum sludge temperature increase through heat exchanger = 5 deg.

To minimize phosphate crystallization inside the heat exchangers, operation with a 5-degree temperature differential is recommended. This low temperature differential can result in high sludge flows and large contact surfaces. Strategies to minimize phosphate concentrations in the recycle streams are presented in TM-06 Struvite Mitigation Alternatives.

Table 4.7
Estimated Heat Requirements for Acid Phase Digestion

	Target Temperature	Units	Summer Requirement, MMBTU/hr/Unit	Winter Requirement, MMBTU/hr/Unit
Raw Sludge	105 deg F	-	4.3	7.6
Acid Digester (1)	Mesophilic	2	0.74	0.76
Methane Digester (2,3)	Thermophilic	5	1.20	1.25
Methane Digester (4)	Thermophilic	3	Unheated	Unheated
Sludge Storage (5)	NA	2	Unheated	Unheated
Batch Thermal				
Methane Digester (2)	Mesophilic	5	0.09	0.13
Thermal Tank (4)	131 deg F	3	5.3	6.2
Sludge Storage (5)	NA	2	Unheated	Unheated

Notes:
(1) Proposed 0.4 MG Acid Digesters No. 1 and No. 2.
(2) Existing digesters No. 4 - No. 7 and Proposed digester No. 8.
(3) Will requires supplemental heating from existing tube and shell heat exchangers.
(4) Existing digesters No. 1 - No. 3.
(5) Existing sludge storage tanks No. 1 and No. 2.

The existing heat exchangers for Digesters No. 4-7 were not designed for thermophilic operation and consequently do not have sufficient capacity to meet the thermophilic heating demands. Under multi-stage acid-phase digestion, the use of the existing spiral heat exchangers with supplemental heating from the existing shell-and-tube heat exchangers (HEX 11 and HEX12) is recommended.

For the acid-phase digestion with batch thermal treatment, the existing heat exchangers for Digesters Nos. 1, 2, and 3 have adequate capacity to heat thermophilic sludge (mesophilic-thermophilic operation) but do not have sufficient capacity to heat mesophilic sludge (mesophilic-mesophilic operation). If the methane digesters are operated at mesophilic temperatures, a new heating system is recommended for the batch thermal tanks (Digesters No. 1, 2, and 3).

Under both acid-phase digestion alternatives, the existing tube and shell heat exchangers (HEX 8 and HEX 9) could be used for heat recovery after the struvite scaling problems are solved. Advantages of heat recovery include potential energy savings and lower polymer usage due to the cooling of the digested sludge prior to thickening. Disadvantages of heat recovery include low heat recovery efficiency due to poor heat transfer capacity in sludge and potential struvite/vivianite scaling in the heat exchangers due to sudden decreases in temperature. MMSD Staff reported struvite scaling in heat recovery exchanger during operation in the acid phase mode.

6.4 Digester Heating Alternatives

Direct steam injection and water to sludge heat exchangers (spiral, shell-and-tube, and shell-and-tube with static mixers heat exchangers and direct steam injection) were evaluated for the new acid digesters No. 1 and No. 2, the new thermophilic Digester No. 8, and the existing thermophilic Digesters No. 4, 5, 6, and 7.

6.4.1. Spiral Heat Exchangers

Spiral heat exchangers are a circular heat exchanger with two circular spiral channels, one for sludge and one for water. The advantage of the spiral heat exchangers is heat is generally distributed throughout the sludge providing a better distribution than shell-and-tube designs. Spiral heat exchangers also have a smaller footprint, which is best for projects with space constraints. The major disadvantage of the spiral heat exchangers is the high propensity for scaling and fouling, which creates increased maintenance that requires taking the heat exchanger off-line and cleaning the inside of the heat exchanger. The small clearance between plates makes spiral units difficult to maintain, so sludge grinders or chopper pumps are usually employed.

Under multi-stage acid-phase digestion, the methane digesters will operate at thermophilic temperature. For this scenario, one spiral heat exchanger with a capacity of 1.25 MMBTU/hr is recommended to heat the proposed Digester No. 8.

Under acid-phase digestion with batch thermal treatment, the methane digesters will operate at mesophilic temperature. For this scenario, one spiral heat exchanger with a capacity of 0.15 MMBTU/hr is recommended to heat the proposed Digester No. 8.

6.4.2. Shell-and-Tube Heat Exchangers

Shell and tube heat exchangers consist of a shell with a tube inside. The shell contains the hot water to transfer heat to the interior tube containing the sludge. The advantages of this type of heat exchanger are the low-pressure drop across the heat exchanger and less clogging and maintenance compared to spiral heat exchangers. Disadvantages of the shell and tube heat exchangers include a larger footprint than the spiral heat exchangers and non-uniform flow with uneven distribution of the heat throughout the sludge. Fouling and scaling buildup along the tube cause a decrease in the heat transfer coefficient. The heat exchanger then must be taken off-line and cleaned.

Under multi-stage acid-phase digestion, the use of an existing shell-and-tube heat exchanger (HEX 8 or HEX 9) to heat the existing Digester No. 7 during thermophilic operation is recommended.

6.4.3. Direct Steam Injection

An alternative to heat exchanger technologies is direct steam injection, which incorporates pressurized steam into a sludge transfer line. Advantages of direct steam injection for digester heating include higher heat transfer efficiency than heat exchangers, increased gas production and volatile solids reduction, and potential for destruction of *Microthrix* filament cells (See TM-05 Foam Mitigation Alternatives). Disadvantages include the requirement of a new steam generator and additional safety requirements associated with handling pressurized steam.

A direct steam injection system for the acid digesters would include two (2) 10 MMBTU/hr steam generators (one duty, one standby), two (2) 4-inch 150-psi Hydroheater (Hydrothermal) steam injectors. The TWAS will be heated to a temperature of 180 deg F and blended with unheated thickened primary sludge to obtain a digester feed target temperature of 105 deg F. A secondary heating loop will be provided to each acid digester to compensate for radiation heat losses. The steam injector from the secondary heating loop will also serve as a backup for TWAS heating. During the summer periods, the TWAS temperature will be adjusted to maintain the target temperature in the blended sludge. Figure 4.4 shows a process schematic of the proposed heating system for the acid digesters.

Under acid-phase digestion with thermal treatment, the methane digesters will operate at mesophilic temperature. For this scenario, two (2) direct steam injectors (one duty and one standby) with a capacity of 5.6 MMBTU/hr are recommended to preheat the thermal tank sludge feed. Under this scenario, a larger steam generator (14 MMBTU/hr) will be required. The present worth cost for direct steam injection is presented in Table 4.8.

Table 4.8
Present Worth Cost of Direct Steam Injection

	Multi-Stage Digestion (1)	Acid Phase Digestion with Thermal Treatment (2)
PW Capital Cost	$1,453,000	$2,045,000
PW O&M Cost	$6,841,000	$6,998,000
Total Present Worth Cost	$8,294,000	$9,043,000

Notes:
(1) Includes two direct steam injectors and two 10 MMBTU/hr steam boilers.
(2) Includes four direct steam injectors and two 14 MMBTU/hr steam boilers.

6.4.4. Recommendation

The use of an existing shell-and-tube heat exchanger (HEX 11 and/or HEX 12) to heat Digesters No. 4-7 during thermophilic operation is recommended. The installation of one new spiral heat exchanger is recommended for the proposed methane Digester No. 8. The installation of a new direct steam injection heating system is recommended for the proposed Acid Digesters No. 1 and No. 2. Under acid phase digestion with thermal treatment mode and mesophilic operation of Digesters No. 4 through No. 8, the installation of direct steam injectors to preheat the thermal tank feed is recommended. Table 4.9 presents the preliminary design criteria for the proposed digesters sludge heating systems.

Table 4.9
Preliminary Design Criteria - Digester Sludge Heating System

Parameter	Acid Digesters No. 1 and No. 2 (1)	Digester No. 8 (2)
Heat Exchangers		
Total Units	2	1
Type	Direct Steam Injection	Spiral Heat Exchanger
Unit Capacity, MMBTU/hr	2 @ 6.80	1 @ 1.3 (3)
Sludge Recirculation Pumps		
Total Units	2	2
Units in service	1	1
Capacity per pump, gpm	150	300

Notes:
(1) New Acid Digesters No. 1 and 2.
(2) New Digester No. 8.
(3) Thermophilic operation.

7.0 DIGESTER OVERFLOW SYSTEM

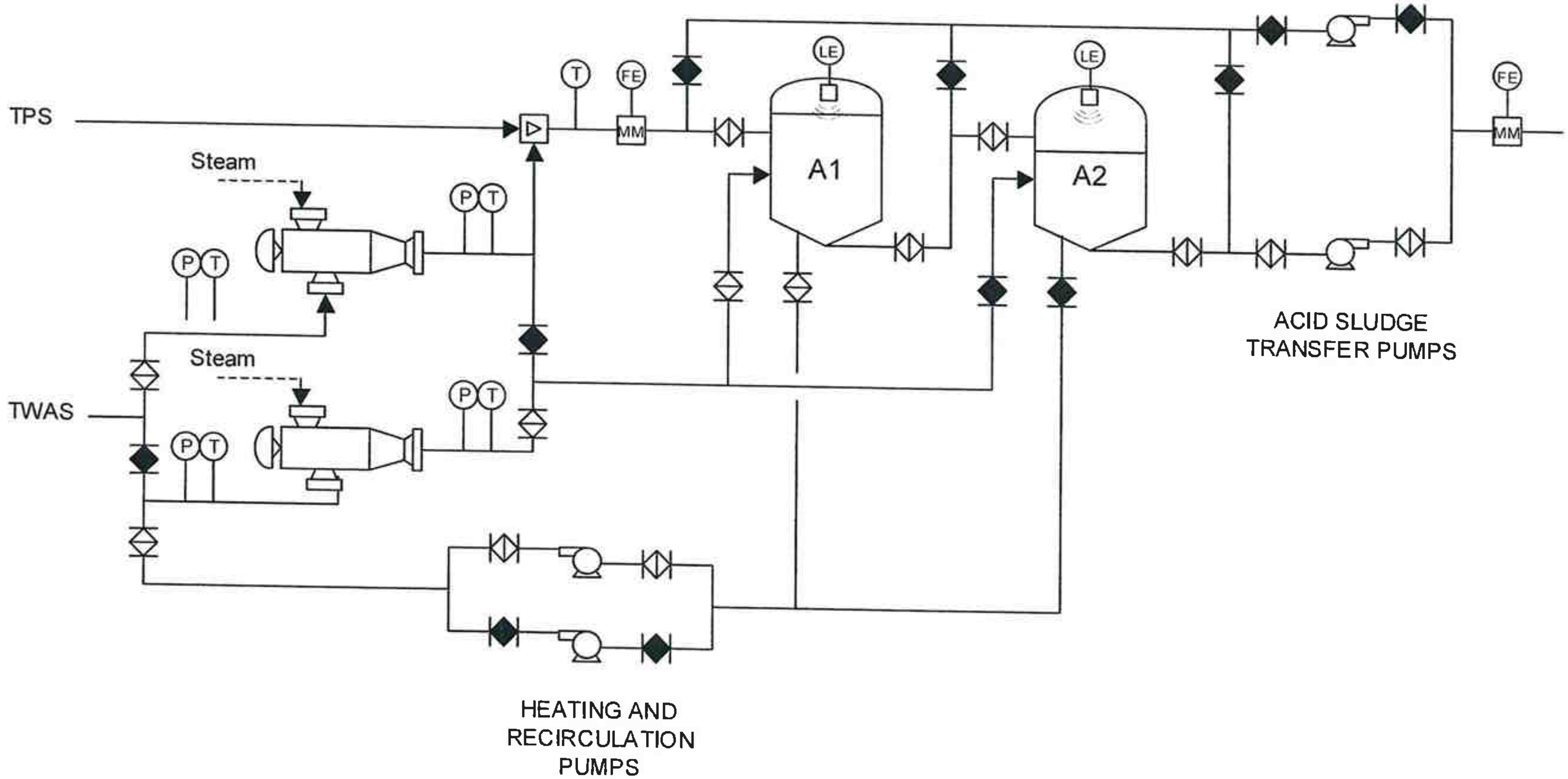
The digester overflow system for Digesters No. 4-7 will not be modified as part of this project. The batch thermophilic tanks (Digesters No. 1, 2, and 3) will be modified to accommodate the large change in volume required for the batch operation should this operating mode be implemented in the future.

8.0 DIGESTER GAS COLLECTION SYSTEM

Digester gas is currently collected in the headspace of each of the existing digesters and stored in tanks with floating covers (sludge holding tanks No. 1 and No. 2). Digester gas is maintained at a setpoint pressure through the SCADA system. Pressure and vacuum relief assemblies are located on each digester roof to protect the digesters in case of a clog in the piping. The digester gas is cooled to remove condensate and pressurized for use in the on-site engine generators to produce power. Excess gas is flared in an existing waste gas flare with a capacity of 160 cubic feet per minute. Based on the 2007 operating data, the annual average gas production was 770,000 cfd. At the 2030 annual average flows of 53.8 mgd (67.2 mgd max month), gas production is expected to increase to approximately 1,250,000 cfd (1,490,000 cfd max month).

Gas generated in the acid gas digesters has high hydrogen sulfide concentrations and a low BTU content. For this reason, an independent acid gas collection system with an enclosed flare is recommended.

The MMSD Staff reported maintenance issues with the foam abatement equipment in the existing gas collection system. The installation of a foam mitigation system in the proposed and existing digesters is recommended. Detailed information on the foam mitigation strategies is presented in TM-05 Foam Mitigation Alternatives.



ACID DIGESTER HEATING SYSTEM

FIGURE 4.4

APPENDIX A
DETAIL COST ESTIMATES
Digester Mixing

Table A-1. Summary
Economic Comparison of Digester Mixing Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Digester Mixing Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Acid Digester Pump Mixing	$605,000	$391,000	$0	$996,000
Acid Digester Plunger Mixing	$732,000	$331,000	$0	$1,063,000
Methane Digester Draft Tubes	$3,302,000	$1,421,000	$0	$4,723,000
Methane Digester Plunger Mixing	$1,933,000	$660,000	$0	$2,593,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table A-2
Economic Comparison of Digestion Alternatives
Acid Digester Pump Mixing

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Acid Digester Pump Mixing System							
Two (2) 25 hp chopper pumps/tank		$ 120,000	20	$ -	$ -	$ -	$30 K per mixing pump installed
Recirculation piping system		$ 150,000	40		$ 75,000	$ -	$75 K per tank
Building floor space allocation		$ 75,000	40	$ -	$ 37,500	$ -	150 sf per mixing system
Site Work	8%	$ 28,000	40	$ -	$ 14,000	$ -	
Mechanical Process Piping	10%	$ 35,000	40	$ -	$ 18,000	$ -	
Instrumentation and Control	7%	$ 24,000	20	$ -	$ -	$ -	
Electrical	8%	$ 28,000	20	$ -	$ -	$ -	
Subtotal		$ 460,000		$ -	$ 144,500	$ -	
Allowance for Undefined Design Details	25%	$ 115,000		$ -			
Total Construction Cost		$ 575,000		$ -			
Engineering, Legal and Administrative	15%	$ 86,000		$ -			
Total		$ 661,000		$ -	$ 144,500	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 661,000		$ -	$ 56,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 14,300		$ 14,300			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 9,900		$ 9,900			1.5% of Construction Total
Total Annual O & M Cost		$ 31,064		$ 31,064			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 241,000		$ 150,000			
Total Present Worth Capital Cost		$ 605,000					
Total Present Worth O&M Cost		$ 391,000					
Total Present Worth		**$ 996,000**					

TABLE A-3 - ALTERNATE NO.1 - ACID DIGESTER PUMPED MIXING O&M

2010			2030		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	4	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$6,864.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	2		# Mesophilic Reactors	2	
# Thermophilic Reactors			# Thermophilic Reactors		
Cost	$14,300	per yr	Cost	$14,300	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges	0		# Centrifuges	0	
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2.5%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$14,300***	***$/yr***	***Total Power Cost***	***$14,300***	***$/yr***
Chemical			**Chemical**		
Digester Feed Sludge			*Digester Feed Sludge*		
Sludge flow		gpd	Sludge flow		gpd
Foam Suppresant Dosage Rate		lbs/MG	Foam Suppresant Dosage Rate		lbs/MG
Cost of Foam Suppresant		$/lb Polymer	Cost of Foam Suppresant		$/lb Polymer
Application rate		#/year	Application rate		#/year
Application duration		days/application	Application duration		days/application
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$0***	***$/yr***	***Total Chemical Cost***	***$0***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table A-4
Economic Comparison of Digestion Alternatives
Acid Digester Plunger Mixing

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Acid Digester Plunger Mixing System							
One (1) 7.5 hp plunger mixer/tank		$ 300,000	20	$ -	$ -	$ -	$150 K per mixing plunger installed
Mixer structural support		$ 100,000	40		$ 50,000	$ -	$50 K per tank
Building floor space allocation			40	$ -	$ -	$ -	
Site Work	8%	$ 32,000	40	$ -	$ 16,000	$ -	
Mechanical Process Piping	10%	$ 40,000	40	$ -	$ 20,000	$ -	
Instrumentation and Control	7%	$ 28,000	20	$ -	$ -	$ -	
Electrical	8%	$ 32,000	20	$ -	$ -	$ -	
Subtotal		$ 532,000		$ -	$ 86,000	$ -	
Allowance for Undefined Design Details	25%	$ 133,000		$ -			5% used for CAMBI
Total Construction Cost		$ 665,000		$ -			
Engineering, Legal and Administrative	15%	$ 100,000		$ -			5% used for CAMBI
Total		$ 765,000		$ -	$ 86,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 765,000		$ -	$ 33,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 7,900		$ 7,900			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 11,500		$ 11,500			1.5% of Total
Total Annual O & M Cost		$ 26,264		$ 26,264			
Present Worth Factor		7.769		4.827			Ful PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 204,000		$ 127,000			
Total Present Worth Capital Cost		$ 732,000					
Total Present Worth O&M Cost		$ 331,000					
Total Present Worth		**$ 1,063,000**					

TABLE A-5 - ALTERNATE NO.2 - Acid Digester Plunger Mixing O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	4	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$6,864.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors	2		# Mesophilic Reactors	2	
# Thermophilic Reactors			# Thermophilic Reactors		
Cost	$7,900	per yr	Cost	$7,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening		mgd @1.5%	Flow to Thickening		mgd @1.6%
# DAFs			# DAFs		
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 4.6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$7,900***	***$/yr***	***Total Power Cost***	***$7,900***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
WAS		lbs/d	WAS		lbs/d
Gravity Thickener Polymer Rate		lbs/DT	Gravity Thickener Polymer Rate		lbs/DT
DAF Polymer Rate		lbs/DT	DAF Polymer Rate		lbs/DT
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# GBT			# GBT		
# Centrifuge			# Centrifuge		
Cost of Polymer		$/lb Polymer	Cost of Polymer		$/lb Polymer
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$0***	***$/yr***	***Total Chemical Cost***	***$0***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cu yds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cu yd	Dewatered Sludge Hauling Cost		$/cu yd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table A-6
Economic Comparison of Digestion Alternatives
Methane Digester Draft Tubes

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Methane Digester Draft Tube Mixing Systems							
Four (4) 10 hp draft tube mixers/tank		$ 1,400,000	20	$ -	$ -	$ -	$70K per draft tube mixer installed
Mixer structural supports		$ 400,000	40	$ -	$ 200,000	$ -	$80 K per tank
Building floor space allocation			40	$ -	$ -	$ -	
Site Work	8%	$ 144,000	40	$ -	$ 72,000	$ -	
Mechanical Process Piping	10%	$ 180,000	40	$ -	$ 90,000	$ -	
Instrumentation and Control	7%	$ 126,000	20	$ -	$ -	$ -	
Electrical	8%	$ 144,000	20	$ -	$ -	$ -	
Subtotal		$ 2,394,000		$ -	$ 362,000	$ -	
Allowance for Undefined Design Details	25%	$ 599,000		$ -			
Total Construction Cost		$ 2,993,000		$ -			
Engineering, Legal and Administrative	15%	$ 449,000		$ -			
Total		$ 3,442,000		$ -	$ 362,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 3,442,000		$ -	$ 140,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 48,400		$ 63,900			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 51,600		$ 51,600			1.5% of Total
Total Annual O & M Cost		$ 106,864		$ 122,364			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 830,000		$ 591,000			
Total Present Worth Capital Cost		$ 3,302,000					
Total Present Worth O&M Cost		$ 1,421,000					
Total Present Worth		**$ 4,723,000**					

TABLE A-7 - ALTERNATE NO.3 - METHANE DIGESTER DRAFT TUBE MIXERS O&M					
2010			**2030**		
Labor					
Description					
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	4	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$6,864.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors	3		# Thermophilic Reactors	4	
Cost	$48,400	per yr	Cost	$63,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening		mgd @1.5%	Flow to Thickening		mgd @1.6%
# DAFs			# DAFs		
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
Flow to Centrifuges		mgd @4.6%	Flow to Centrifuges		mgd @4.6%
# Centrifuges in service			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Cambi THP		lbs/d	Solids Flow to Cambi THP		lbs/d
Solids Flow to Cambi THP		gpd @ 17%	Solids Flow to Cambi THP		gpd @ 17%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @5%	Digested Sludge Production		gpd @5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$48,400***	***$/yr***	***Total Power Cost***	***$63,900***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge		lbs/d	Raw Sludge		lbs/d
Gravity Thickener Polymer Rate		lbs/DT	Gravity Thickener Polymer Rate		lbs/DT
DAF Polymer Rate		lbs/DT	DAF Polymer Rate		lbs/DT
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# GBT			# GBT		
# Centrifuge			# Centrifuge		
Cost of Polymer		$/lb Polymer	Cost of Polymer		$/lb Polymer
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$0***	***$/yr***	***Total Chemical Cost***	***$0***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table A-8
Economic Comparison of Digestion Alternatives
Methane Digester Plunger Mixing

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Methane Digester Plunger Mixing Systems							
One (1) 10 hp plunger mixer/tank		$ 850,000	20	$ -	$ -	$ -	$170K per plunger mixer installed
Mixer structural supports		$ 200,000	40	$ -	$ 100,000	$ -	$40 K per tank
Building floor space allocation			40	$ -	$ -	$ -	
Site Work	8%	$ 84,000	40	$ -	$ 42,000	$ -	
Mechanical Process Piping	10%	$ 105,000	40	$ -	$ 53,000	$ -	
Instrumentation and Control	7%	$ 74,000	20	$ -	$ -	$ -	
Electrical	8%	$ 84,000	20	$ -	$ -	$ -	
Subtotal		$ 1,397,000		$ -	$ 195,000	$ -	
Allowance for Undefined Design Details	25%	$ 349,000		$ -			
Total Construction Cost		$ 1,746,000		$ -			
Engineering, Legal and Administrative	15%	$ 262,000		$ -			
Total		$ 2,008,000		$ -	$ 195,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 2,008,000		$ -	$ 75,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 13,900		$ 17,900			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 30,100		$ 30,100			1.5% of Total
Total Annual O & M Cost		$ 50,864		$ 54,864			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 395,000		$ 265,000			
Total Present Worth Capital Cost		$ 1,933,000					
Total Present Worth O&M Cost		$ 660,000					
Total Present Worth		**$ 2,593,000**					

TABLE A-9 - ALTERNATE NO.4 - METHANE DIGESTER PLUNGER MIXING O&M

2010		2030	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	4 hrs/wk	Hours	4 hrs/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$6,864.00 $/yr	Annual	$6,864.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors		# Mesophilic Reactors	
# Thermophilic Reactors	3	# Thermophilic Reactors	4
Cost	$13,900 per yr	Cost	$17,900 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	mgd @1.5%	Flow to Thickening	mgd @1.6%
# DAFs		# DAFs	
# Gravity Thickeners		# Gravity Thickeners	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	lbs/d	Solids Flow to Digestion	lbs/d
Solids Flow to Digestion	gpd @ 4.6%	Solids Flow to Digestion	gpd @ 4.6%
Digested Sludge Production	lbs/d	Digested Sludge Production	lbs/d
Digested Sludge Production	gpd @2%	Digested Sludge Production	gpd @2%
% to GBT		% GBT	
Digested Sludge Production	gpd@ 5%	Digested Sludge Production	gpd@ 5%
% to Centrifuge		% Centrifuge	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Thermal Treatment		*Thermal Treatment*	
Digested Sludge Production	lbs/day	Digested Sludge Production	lbs/day
# Belt Dryers		# Belt Dryers	
Cost	$0 per yr	Cost	$0 per year
Total Power Cost	***$13,900 $/yr***	***Total Power Cost***	***$17,900 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Raw Sludge	lbs/d	Raw Sludge	lbs/d
Gravity Thickener Polymer Rate	lbs/DT	Gravity Thickener Polymer Rate	lbs/DT
DAF Polymer Rate	lbs/DT	DAF Polymer Rate	lbs/DT
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
# DAF		# DAF	
# Gravity Thickeners		# Gravity Thickeners	
# GBT		# GBT	
# Centrifuge		# Centrifuge	
Cost of Polymer	$/lb Polymer	Cost of Polymer	$/lb Polymer
Cost	$/yr	Cost	$/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	lbs/day	Digested Sludge	lbs/day
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
% GBT		% GBT	
% Centrifuge		% Centrifuge	
Cost	$0	Cost	$0
Total Chemical Cost	***$0 $/yr***	***Total Chemical Cost***	***$0 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	%	Metrogro liquid concentration	%
Metrogro cake concentration	%	Metrogro cake concentration	%
Gallons liquid per day	gpd	Gallons liquid per day	gpd
Dewatered Sludge per day	cu yds/d	Dewatered Sludge per day	cu yds/d
Liquid Hauling Cost	$/gal	Liquid Hauling Cost	$/gal
Dewatered Sludge Hauling Cost	$/cu yd	Dewatered Sludge Hauling Cost	$/cu yd
Total Hauling Cost	***$0 $/yr***	***Total Hauling Cost***	***$0 $/yr***

APPENDIX B
DETAIL COST ESTIMATES
Digester Heating

Table B-1. Summary
Economic Comparison of Digester Heating Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Digester Heating Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Multi-Phase Direct Steam Injection	$1,453,000	$6,841,000	$0	$8,294,000
Acid Digestion w/ Thermal Treatment	$2,045,000	$6,998,000	$0	$9,043,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table B-2
Economic Comparison of Digestion Alternatives
Multi-Phase Direct Steam Injection

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Modifications to Sludge Heating							
Two (2) Steam Injectors		$ 200,000	20	$ -	$ -	$ -	$100K each installed
Two (2) Steam Generators 10,000 MBH		$ 530,000	20	$ -	$ -	$ -	$265K each installed
Building space allowance		$ 50,000	40	$ -	$ 25,000	$ -	
Site Work	8%	$ 62,000	40	$ -	$ 31,000	$ -	
Mechanical Process Piping	10%	$ 78,000	40	$ -	$ 39,000	$ -	
Instrumentation and Control	7%	$ 55,000	20	$ -	$ -	$ -	
Electrical	8%	$ 62,000	20	$ -	$ -	$ -	
Subtotal		$ 1,037,000		$ -	$ 95,000	$ -	
Allowance for Undefined Design Details	25%	$ 259,000		$ -			
Total Construction Cost		$ 1,296,000		$ -			
Engineering, Legal and Administrative	15%	$ 194,000		$ -			
Total		$ 1,490,000		$ -	$ 95,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 1,490,000		$ -	$ 37,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 491,392		$ 549,910			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 22,400		$ 22,400			1.5% of Construction Total
Total Annual O & M Cost		$ 520,656		$ 579,174			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 4,045,000		$ 2,796,000			

Total Present Worth Capital Cost	$ 1,453,000
Total Present Worth O&M Cost	$ 6,841,000
Total Present Worth	**$ 8,294,000**

TABLE B-3 - ALTERNATE NO.1 - MULTI-PHASE DIRECT STEAM INJECTION O&M

2010			2030		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	4	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$6,864.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
Steam Injector System	1	@67% load	Steam Injector System	1	@75% load
Cost	$491,392	per yr	Cost	$549,910	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges	0		# Centrifuges	0	
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2.5%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$491,392***	***$/yr***	***Total Power Cost***	***$549,910***	***$/yr***
Chemical			**Chemical**		
Digester Feed Sludge			*Digester Feed Sludge*		
Sludge flow		gpd	Sludge flow		gpd
Foam Suppresant Dosage Rate		lbs/MG	Foam Suppresant Dosage Rate		lbs/MG
Cost of Foam Suppresant		$/lb Polymer	Cost of Foam Suppresant		$/lb Polymer
Application rate		#/year	Application rate		#/year
Application duration		days/application	Application duration		days/application
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$0***	***$/yr***	***Total Chemical Cost***	***$0***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table B-4
Economic Comparison of Digestion Alternatives
Acid Phase Digestion with Thermal Treatment

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Heating							
Four (4) Steam Injectors		$ 400,000	20	$ -	$ -	$ -	$100K each installed
Two (2) Steam Generators 14,000 MBH		$ 600,000	20	$ -	$ -	$ -	$300K each installed
Building modifications		$ 100,000	40	$ -	$ 50,000	$ -	
Site Work	8%	$ 88,000	40	$ -	$ 44,000	$ -	
Mechanical Process Piping	10%	$ 110,000	40	$ -	$ 55,000	$ -	
Instrumentation and Control	7%	$ 77,000	20	$ -	$ -	$ -	
Electrical	8%	$ 88,000	20	$ -	$ -	$ -	
Subtotal		$ 1,463,000		$ -	$ 149,000	$ -	
Allowance for Undefined Design Details	25%	$ 366,000		$ -			5% used for CAMBI
Total Construction Cost		$ 1,829,000		$ -			
Engineering, Legal and Administrative	15%	$ 274,000		$ -			5% used for CAMBI
Total		$ 2,103,000		$ -	$ 149,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 2,103,000		$ -	$ 58,000	$ -	
Annual O & M Cost							
Labor		$ 10,296		$ 10,296			
Energy (electrical and thermal)		$ 491,392		$ 549,910			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 31,500		$ 31,500			1.5% of Total
Total Annual O & M Cost		$ 533,188		$ 591,706			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 4,142,000		$ 2,856,000			
Total Present Worth Capital Cost		$ 2,045,000					
Total Present Worth O&M Cost		$ 6,998,000					
Total Present Worth		**$ 9,043,000**					

TABLE B-5 - ALTERNATE NO.2 - Acid Phase w/ Thermal Treatment O&M			
2010		**2030**	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	6 hr/wk	Hours	6 hr/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$10,296.00 $/yr	Annual	$10,296.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors		# Mesophilic Reactors	
Steam Injector System	1 @67% load	Steam Injector System	1 @75% load
Cost	$491,392 per yr	Cost	$549,910 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	mgd @1.5%	Flow to Thickening	mgd @1.6%
# DAFs		# DAFs	
# Gravity Thickeners		# Gravity Thickeners	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	lbs/d	Solids Flow to Digestion	lbs/d
Solids Flow to Digestion	gpd @ 4.6%	Solids Flow to Digestion	gpd @ 6%
Digested Sludge Production	lbs/d	Digested Sludge Production	lbs/d
Digested Sludge Production	gpd @2%	Digested Sludge Production	gpd @2.5%
% to GBT		% GBT	
% to Centrifuge		% Centrifuge	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Total Power Cost	***$491,392 $/yr***	***Total Power Cost***	***$549,910 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
WAS	lbs/d	WAS	lbs/d
Gravity Thickener Polymer Rate	lbs/DT	Gravity Thickener Polymer Rate	lbs/DT
DAF Polymer Rate	lbs/DT	DAF Polymer Rate	lbs/DT
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
# DAF		# DAF	
# Gravity Thickeners		# Gravity Thickeners	
# GBT		# GBT	
# Centrifuge		# Centrifuge	
Cost of Polymer	$/lb Polymer	Cost of Polymer	$/lb Polymer
Cost	$0 $/yr	Cost	$0 $/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	lbs/day	Digested Sludge	lbs/day
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
% GBT		% GBT	
% Centrifuge		% Centrifuge	
Cost	$0	Cost	$0
Total Chemical Cost	***$0 $/yr***	***Total Chemical Cost***	***$0 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	%	Metrogro liquid concentration	%
Metrogro cake concentration	%	Metrogro cake concentration	%
Gallons liquid per day	gpd	Gallons liquid per day	gpd
Dewatered Sludge per day	cu yds/d	Dewatered Sludge per day	cu yds/d
Liquid Hauling Cost	$/gal	Liquid Hauling Cost	$/gal
Dewatered Sludge Hauling Cost	$/cu yd	Dewatered Sludge Hauling Cost	$/cu yd
Total Hauling Cost	***$0 $/yr***	***Total Hauling Cost***	***$0 $/yr***

APPENDIX H

Technical Memorandum No. 5
Foaming Mitigation Alternatives

MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 5
FOAMING MITIGATION ALTERNATIVES

Date: December 16, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate different alternatives to prevent foaming in the anaerobic digesters at the Nine Springs Wastewater Treatment Plant (NSWWTP). The recommended alternative will be selected based on economic and non-economic factors.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- Control of *Microthrix* levels in the aeration basins can be achieved through increased aeration, addition of oxidizing chemicals, and/or addition of polyaluminium chloride. Increased aeration does not prevent digester foaming because the filament cells are not destroyed and the sludge thickening process considerably increases their concentration. Increased aeration should reduce the severity and length of the foaming episodes by limiting the growth of Microthrix in the activated sludge. The addition of oxidizing chemicals and/or coagulants may be considered as a temporary solution during a foaming incident, but are not recommended as a standard operating procedure due to the cost of the chemicals and the potential to upset other processes.

- Control of *Microthrix* levels can be achieved through the addition of sodium hypochlorite and polyaluminium chloride (PAX-14) but can negatively affect the NSWWTP effluent permit for chloride concentrations.

- Pre-treatment of waste activated sludge (WAS) using thermal hydrolysis, mechanical cavitation, or electric-pulsing will prevent *Microthrix* foaming in the anaerobic digesters, increase volatile solids reduction, and increase biogas production.

- Pre-treatment of WAS using direct steam injection has the potential to prevent *Microthrix* foaming, increase volatile solids reduction and biogas production, and provide required digester heating. Further pilot scale testing using NSWWTP thickened WAS (TWAS) is recommended.

- Mechanical mixing systems are less susceptible to cause foaming than gas mixing systems. The replacement of the gas mixing systems of the East Complex digesters with mechanical mixing systems will not eliminate *Microthrix* foaming, but should provide better mixing and reduce the severity of the foaming episodes.

- Digester foaming control chemicals may be used on an individual event basis. These chemicals reduce the surface tension and mitigate the foam generation. Due to their costs, these chemicals are only used once an active foam episode has begun. Therefore the facility will require retrofitting and automation to indicate the beginning of a foaming episode and the threshold when the chemicals will be applied.

- A combination of the foam mitigation measures identified in this TM is recommended. The modifications to the gas collection system with the addition of a foam suppressant and changes in the operation of the aeration basins should reduce all but the most severe foaming episodes. Modifications to the mixing system should be considered in conjunction with other process improvements for the digestion system.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements, maintains the current biosolids land application programs, and decreases foaming and struvite buildup in the anaerobic digesters. TM-03A Anaerobic Digestion Process Evaluation identified acid-phase digestion as the alternative that best meets the biosolids management objectives at the lowest present worth cost.

The MMSD Staff has reported recurring foaming events in the NSWWTP anaerobic digesters. Based on the biological nutrient removal (BNR) operation, reported winter foaming events, and previous microscopic analyses, it is likely that the filamentous organisms responsible for digester foaming at the NSWWTP are *Microthrix*, a slow-growing lipid-degrading filamentous bacterium that thrives under low dissolved oxygen (DO) conditions. While *Nocardia* foaming is prevalent in conventional activated sludge plants, *Microthrix* foaming is more prevalent in BNR plants. *Microthrix* foaming typically occurs during cold weather months due to its ability to grow at low temperatures. Most likely, *Microthrix* levels remain constant throughout the year and the level of other organisms decrease during cold weather conditions. There are no reports on *Microthrix*-related foaming and the fate of *Microthrix* in acid phase digestion. However, previous experience at the NSWWTP has shown that foaming problems are less severe under operation in acid-phase digestion mode. Acid-phase digestion also prevents digester foaming associated with surfactants (i.e., lipid and proteins) and *Nocardia* filaments.

4.0 Foam Mitigation Alternatives

Operational changes in the anaerobic digesters are not expected to destroy *Microthrix* filaments because these organisms can survive for many months under anaerobic conditions and can grow at a wide range of pH levels. In fact, the NSWWTP has experienced digester foaming under different modes of operation, including temperature phased anaerobic digestion (TPAD), acid-phase digestion, and conventional digestion. Strategies to mitigate foaming at the Nine Springs WWTP include limiting *Microthrix* growth in the aeration basins, destroying the *Microthrix* cells prior to digestion, and modifying the digester mixing system and gas draw-off system.

4.1 Activated Sludge Operation

To mitigate *Microthrix*-associated foaming at the NSWWTP, the activated sludge process operation can be adjusted to minimize the growth of *Microthrix* in the aeration basins. These alternatives prevent foaming in the aeration basins, but complete eradication of *Microthrix* is not achieved. These alternatives are not recommended for use as stand-alone strategies to mitigate digester foaming. Table 5.1 presents a summary of the different activated sludge operation alternatives.

Table 5.1
Activated Sludge Operation Alternatives

Alternative	Compatible with BNR Process	Limits *Microthrix* Growth	Destroys *Microthrix* Cells	Proven Technology	Additional Operational Considerations
Lower Solids Retention Time in Activated Sludge Process		X			Not compatible with nitrification
Uniform Dissolved Oxygen Level in Aeration Basins	X	X			Increased cost for aeration
Reduce Lipid Loading to Activated Sludge Process	X	X			Co-digestion of fats, oils, and grease
Aerobic Selectors for Microthrix foaming					Incompatible with EBPR
Addition of Sodium Hypochlorite	X	X	X	X	Impact on chloride permit
Addition of Hydrogen Peroxide	X	X	X	X	
Addition of Polyaluminium Chloride (PAX-14)	X	X		NA	Impact on chloride permit

4.1.1 Solids Retention Time

Control of *Microthrix* levels in the aeration basins can be achieved by decreasing the solids retention time (SRT) because *Microthrix* are slow-growing organisms. However, the decrease of the SRT required for *Microthrix* control would also eliminate nitrifying bacteria from the activated sludge and negatively impact the performance of a BNR plant. Due to incompatibility with the NSWWTP operation, this alternative was not considered for further evaluation.

4.1.2 Dissolved Oxygen Concentration

Control of *Microthrix* levels can be achieved by maintaining DO concentrations above 2 mg/L throughout the aerobic zones because *Microthrix* thrives under low DO conditions. Maintaining low ammonia concentrations through a fast and complete nitrification will reduce the *Microthrix* levels because *Microthrix* uses ammonia as its nitrogen source. Currently, the NSWWTP operates under an optimized aeration mode with most of the nitrification occurring at the end of the aeration basins. , The existing diffusers have limited capacity for increasing the aeration rates at the head of the basins. An increase in the diffuser density would be required to increase the aeration basin DO for *Microthrix* control. This alternative was considered for further evaluation.

4.1.3 Lipids Removal

Control of *Microthrix* levels can be achieved by decreasing the influent lipids concentration because these constitute the main carbon source for *Microthrix* and other filamentous organisms. Lipids removal from the source water is not feasible due to the elevated costs associated with this process. Currently, haulers discharge grease at the NSWWTP headworks. Adding grease directly to the anaerobic digesters can decrease the lipid loading to the activated sludge process and increase the biogas production. A detailed feasibility analysis of grease co-digestion is presented in TM-07 Grease Receiving and Co-digestion. Because grease hauling represents only a small fraction of the lipid loading to the NSWWTP, this alternative was not considered for further evaluation as a foam mitigation strategy.

4.1.4 Selectors

The use of anoxic and anaerobic selectors has been reported to control filamentous foaming. Selectors limit the growth of organisms that are unable to accumulate storage compounds, such as *Nocardia*. Anoxic or anaerobic selectors are expected to promote *Microthrix* growth because these organisms accumulate storage compounds under anoxic and anaerobic conditions. Aerobic selectors may mitigate Microthrix foaming but are not compatible with EBPR. This alternative was not considered for further evaluation.

4.1.5 Oxidizing Chemicals

A common method for filamentous foaming control is the use of oxidizing chemicals such as chlorine or hydrogen peroxide to destroy filaments. The oxidizing chemical solutions are typically added directly to the foam through a spray bar adjacent to the aeration basin scum trough. The oxidizing chemicals are believed to attack the filament sections that protrude outside the activated sludge floc structure, but the dosage must be closely controlled to minimize the destruction of other organisms. This alternative kills non-target organisms and has a cost related to the chemical addition. This alternative is intended to provide a temporary solution during foaming episodes and is not recommended as a long-term solution for the NSWWTP.

4.1.6 Coagulants

Control of *Microthrix* levels can be achieved through the addition of polyaluminium chloride (e.g. PAX-14) at a dosage of 2–3 g Al per kg MLSS in the recycled activated sludge stream. The PAX-14 mechanism of action for *Microthrix* control in activated sludge is still unknown. Proposed mechanisms for PAX-14 include the decrease of cell hydrophobicity, toxic effects, and removal of lipids from the aqueous phase. PAX-14 is commonly used for chemical phosphorus removal and may impact the performance of side stream treatment technologies, such as struvite-harvesting systems (See TM-06 Struvite Mitigation Alternatives). This alternative is intended to provide a temporary solution during foaming episodes and is not recommended as a long-term solution for the NSWWTP.

4.2 Waste Activated Sludge Pre-Treatment

Pre-treatment of WAS to destroy *Microthrix* may prevent digester foaming and result in increased biogas production rates. Although there are no reports of WAS pretreatmt technologies for digester foaming mitigation in full-scale facilities, technologies that destroy *Microthrix* cells should mitigate digester foaming (inactivation of *Microthrix* cells will not prevent foaming). A feasible WAS pre-treatment technology is not required to destroy 100% of the *Microthrix* filaments. Previous research found that digester foaming occurs above a certain filamentous bacteria concentration threshold (de los Reyes and Raskin, 2002, Water Research Vol. 36 p. 445-459). The absence of foaming in the NSWWTP aeration basins indicates that *Microthrix* levels in these treatment units are below the threshold for foaming. When WAS is thickened, the *Microthrix* concentration increases an order of magnitude causing foaming in the digesters. A summary of the various pre-treatment alternatives follows.

4.2.1 Thermal Hydrolysis

Cambi and Kruger (BioTHELYS) are two manufacturers of thermal hydrolysis equipment for the pre-treatment of municipal WWTP sludge. These patented thermal hydrolysis processes (THP) solubilize the organic fraction of the sludge by submitting it to elevated temperature and pressure. The thickened sludge is sterilized at 330 deg F for 20-30 min and cell destruction is achieved through a sudden pressure drop. Cambi THP was evaluated as a sludge stabilization alternative in TM-3A Anaerobic Digestion Process Evaluation.

Currently, there are no full-scale thermal hydrolysis installations in the United States. Cambi THP worldwide installations include Dublin Bay WWTP (Dublin, Ireland), Nigg Bay WWTP (Aberdeen, UK), Norwich WWTP (Whitlingham, UK), and Cotton Valley Wastewater Treatment Works (Milton Keynes, UK). There are only three worldwide BioTHELYS installations and the largest is at the 2.9 mgd Saumur WWTP (Saumur, France). This alternative was selected for further evaluation.

4.2.2 Direct Steam Injection

Direct steam injection is a direct method of heating that mixes precisely metered amounts of steam directly with a liquid or slurry, providing an instantaneous transfer of heat from steam to the liquid. In wastewater utilities including the BackRiver WWTP (Baltimore, MD) and the Hyperion WWTP (Los Angeles, CA), direct steam injection is typically used for digester heating. The Hydroheater (Hydro-Thermal) and the OptiShear (Prosonix) are direct steam injection technologies used in ethanol production. These technologies use a combination of high temperatures (up to 250 deg F) and mechanical shear to hydrolyze starch in slurry from dry grinding or wet milling processes.

Because it is uncertain whether *Microthrix* filament destruction will be achieved with direct steam injection, Hydro-Thermal and the MMSD are conducting pilot-scale tests of the Hydroheater direct steam injection system with thickened WAS and will conduct a full-scale trial at NSWWTP. Based on the additional benefit of hydrolysis of materials, direct steam injection will be the preferred heating mechanism for the acid phase digester.

4.2.3 Pasteurization

There are two manufacturers that provide pasteurization equipment for municipal wastewater treatment utilities: Eco-Therm (Ashbrook) and BioPasteur (Kruger). Both systems heat thickened sludge to 70 °C for a minimum of 30 minutes to provide pathogen reduction. Per manufacturer's communication, pasteurization will not destroy *Microthrix* cells. Currently, there are no full-scale installations of the Eco-Therm system in the U.S. The only Bio-Pasteur full-scale installation in the U.S. is at the Alexandria Sanitation Authority WWTP (Alexandria, VA). Because *Microthrix* filament destruction will not be achieved with pasteurization, this technology was not considered for further evaluation as a foam mitigation alternative.

4.2.4 Electric-Pulsing

OpenCEL is the only manufacturer of a cell-electroporation technology for the pre-treatment of sludge. This technology uses focused high-voltage pulses of electricity to rupture the cellular membranes. The electroporation technology was developed and successfully utilized for pathogen destruction in food processing for nearly 40 years. This technology is sized to treat the sludge stream associated with average daily conditions. Under peak conditions, a fraction of the WAS bypasses the OpenCEL system and is fed directly to the digesters. The only successful full-scale installation is at the Mesa Northwest Treatment Plant (Mesa, AZ). This alternative was selected for further evaluation.

4.2.5 Mechanical Cavitation

The Crown Sludge Disintegration system (Siemens) and MicroSludge (Paradigm Environmental Technologies) are two sludge pre-treatment technologies that rely on cavitation for cell destruction. Both manufacturers claim the destruction of foam-forming filamentous organisms.

4.2.5.1 MicroSludge

The MicroSludge process uses a combination of chemical and mechanical processes to pre-treat sludge. Thickened WAS (5 to 10% TS) flows through a coarse filter, receives NaOH, passes through a high shear mixer, and moves to a conditioning tank. The chemically conditioned WAS is transferred through a gas/liquid separator and fine self-cleaning filter, before being fed to one or more Cell Disrupters, where sudden pressure drop (from about 12,000 psi to about 50 psi) ruptures the bacterial cells. There are no full-scale installations of the MicroSludge system. A demonstration-scale test has been recently completed at the Des Moines Wastewater Reclamation Facility. Because there are no full-scale installations of the MicroSludge system, this alternative was not considered for further evaluation.

4.2.5.2 Crown Sludge Disintegration

The Crown Sludge Disintegration system is a mechanical process designed to treat 30% of the digester influent, preferably WAS. Thickened sludge (3 to 8% TS) is mixed, homogenized, pressurized, and forced through a disintegration nozzle, causing the cell structure to rupture. This cycle is repeated three times before the sludge is pumped into the digester. The Crown Sludge Disintegration system benefits include a solids disposal reduction of up to 20% and a biogas production increase of up to 30%. Full-scale installations of the Crown Sludge Disintegration System include the Wiesbaden WWTP (Germany), Taunusstein WWTP (Germany), and Rosedale WWTP (New Zealand). This alternative was selected for further evaluation.

4.2.6 Ultrasonic Cavitation

Three ultrasonic cavitation technologies for the pre-treatment of municipal WWTP sludge are the Sonolyzer system (EIMCO), the DIRK Power Ultrasound system, and the Sonix system (Sonico). These systems utilize ultrasonic shock waves to rupture the bacterial cell walls and reduce the particle size distribution of the sludge. Ultrasonic cavitation increases the fraction of biodegradable material resulting in lower sludge disposal and increased biogas production. Other benefits of ultrasonic cavitation include increased dewaterability and reduced digester foaming.

Full-scale installations of the Sonolyzer system include the Galindo STP (Spain), the San Jeronimo STP (Spain), the Bath STP (The Netherlands), and the Nieuwgraaf STP (The Netherlands). Full-scale installations of the DIRK Power Ultrasound system include the Süd Sewage Treatment Works (STW) (Germany), the Darnstadt STW (Germany), and the Mannheim STW (Germany). Full-scale installations of the Sonix system include the Kavlinge WWTP (Sweden) and the Mangere WWTP (New Zealand). Full-scale demonstration trials using the Sonix system have been completed for the City of Riverside (Riverside, CA) and the Orange County Sanitation District (Orange County, CA). The City of Riverside conducted trials with three different ultrasonic cavitation technologies and reported negligible changes in biogas production and volatile solids destruction.

Due to the results from the City of Riverside trials and the absence of full-scale installations in the U.S., this alternative was not selected for further evaluation.

4.3 Digester Operation

4.3.1 Digester Mixing

Inadequate digester mixing has been associated with digester foaming. Although not the source of the problem, insufficient mixing allows the formation of a scum layer at the liquid surface. Gas mixing systems are less effective and more likely to cause digester foaming than mechanical mixing systems. However, digester foaming has also been reported for mechanically mixed digesters. A detailed evaluation of different alternatives for digester mixing is presented in TM-04 Evaluation of Digester Ancillary Systems.

Changes in the mixing system will not eliminate *Microthrix* foaming in the digesters. However, mechanical mixing intensity can be reduced to provide a controlled level of mixing that may reduce the magnitude of the foam problems. Mechanical mixing was selected for further evaluation as a partial foam mitigation measure.

4.3.2 Gas Collection System Modifications

The NSWWTP has gas/foam separators to prevent foam intrusion into the gas collection system. Gas/foam separators utilize a direct spray of water that collapses the foam and drains it through the bottom of the unit, while allowing the gas to exit at the top. The MMSD Staff reported that the foam separators installed at the NSWWTP do not have sufficient capacity and clog frequently due to debris. Foam intrusion into the gas collection system has caused some gas meters to become inoperable.

Figure 5.1 shows modifications proposed to the gas collection dome to avoid the foam from entering the gas collection system altogether. These modifications may be readily implemented at the NSWWTP and should reduce or eliminate the problems with the foam entering the gas system.

4.3.3 Anti-foaming Chemicals

A common method for digester foaming control is the addition of anti-foaming chemical agents. Anti-foaming chemicals or defoamers are used to control foaming or prevent foam formation by reducing the surface tension. These chemical solutions are typically added directly to the foam through spray nozzles at the top of the digesters. Table 5.2 presents anti-foaming chemical dosing rates and costs.

Full-scale operations using anti-foaming chemicals to control digester foaming include the Central WWTP (Nashville, TN). The use of anti-foaming chemicals is recommended as part of a foam mitigation strategy that includes the foam suppression features described above. Due to cost, foam suppression chemicals should be used only after a foaming event has begun that will impair operations at the NSWWTP.

Table 5.2 Economic Comparison of Foam Mitigation Alternatives				
Product	Tramfloc 1147	Tramfloc 1159	D-FOAM-R W460	Foamblast 476
Manufacturer	Tramfloc	Tramfloc	Fibrochem	Emerald
Dosage, lbs/MG sludge feed	248	500	416	166
Unit price, $/lbs	$ 3.20	$ 2.20	$ 1.81	$2.35
Annual Cost (1,2)	$ 36,800	$ 51,000	$ 35,000	$ 18,100

Notes:

(1) Assumes ten applications per year with 15 days per application

(2) Based on projected annual average digester feed of 309,000 gpd (year 2030).

4.3.4 Dedicated WAS Digesters

Another alternative to mitigate *Microthrix* foaming in the anaerobic digesters is to separate primary sludge and WAS digestion. Dedicated WAS digesters have a lower foaming potential due to a considerably lower biogas production rate. This alternative can be achieved with dedicated WAS digesters or with a staged digestion configuration where the primary and secondary digesters receive primary sludge and WAS, respectively.

Full-scale operations with dedicated digesters for primary sludge and WAS included the Orange County Sanitation District WWTP (Fountain Valley, CA). However, this operation was abandoned after several years due to poor volatile solids reduction and foaming in the WAS digesters. Full-scale operations with staged primary and WAS digestion include the Kappala WWTP (Sweden). The Kappala WWTP experienced a decrease in *Microthrix* foaming after staging the digesters with WAS treatment in the secondary digester. This configuration requires a considerable digestion volume because the primary digesters require a 10-day HRT for primary sludge digestion and the secondary digesters require a minimum HRT of 15 days for regulatory compliance. This alternative was not considered for further evaluation.

5.0 Comparison of Foam Mitigation Alternatives

Non-economic and economic comparisons of the foam mitigation alternatives are presented in Table 5.3 and Table 5.4, respectively. The economic comparison only includes alternatives that control or destroy *Microthrix,* have successful full-scale installations, and are compatible with the MMSD operation. The Appendix contains the detailed cost development tables.

Table 5.3
Foam Mitigation Alternatives Summary

Foam Mitigation Alternative	Limits *Microthrix* Growth	Destroys *Microthrix* Cells	Compatible with MMSD Operation	Increased Biogas Production	Successful Full-scale installations	Additional Operational Considerations
Low Solids Retention Time in Activated Sludge Process	X				NA	Not compatible with BNR process
Uniform Dissolved Oxygen Level in Aeration Basins	X		X		NA	Used during cold weather operation. Increases energy costs.
Control Lipid Loading to Activated Sludge Process	X		X	X	X	From direct grease addition to anaerobic digesters.
Addition of Sodium Hypochlorite	X	X			X	Used during foaming events. Impact on chloride permit.
Addition of Hydrogen Peroxide	X	X	X		X	Used during foaming events.
Addition of Polyaluminium Chloride (PAX-14)	X				NA	Used during foaming events. Impact chloride permit.
Addition of Anti-foaming Chemicals to Digesters			X		X	Used during digester foaming events.
Thermal Hydrolysis		X	X	X	X	Energy intensive process.
Direct Steam Injection		?	X	X	X	Not proven for *Microthrix*. Energy intensive process
Pasteurization			X		X	Energy intensive process.
Electric-Pulsing		X	X	X	X	New technology with only one installation.
Crown Sludge Disintegration		X	X	X	X	Energy intensive process.
MicroSludge		X	X	X		Energy intensive process.
Ultrasonic Cavitation		X		X	X	Energy intensive process. Unsuccessful U.S. trials.

Table 5.4 Economic Comparison of Foam Mitigation Alternatives			
Foam Mitigation Process Alternative	**Present Worth Capital Cost [1]**	**Present Worth O&M Cost [1]**	**Total Present Worth Cost [1]**
Foam Suppression Methods [2]	$1,315,000	$714,000	$2,029,000
Thermal Hydrolysis (Cambi) [3]	$12,447,000	$12,102,000	$24,549,000
Direct Steam Injection [4]	$1,453,000	$6,841,000	$8,294,000
Electric-Pulsing (OpenCEL)	$14,726,000	$5,332,000	$20,058,000
Sludge Disintegration (Crown)	$5,478,000	$1,559,000	$7,037,000

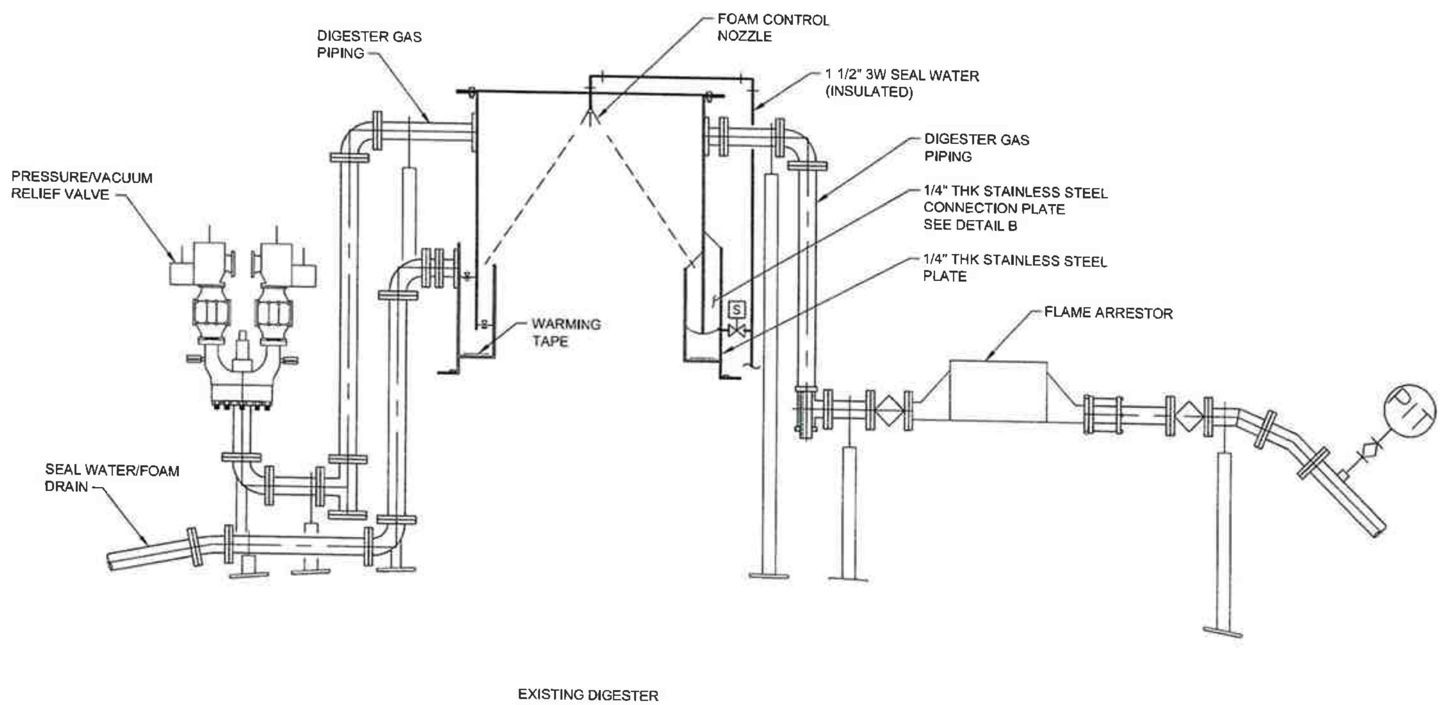
Notes:

(1) Excludes costs common to all alternatives (i.e., thickening, digestion, biosolids hauling and disposal)

(2) Includes digester dome improvements for Digesters 1 through 8. Based on addition of Tramfloc 1147.

(3) Based on a two-reactor Cambi THP system. Includes cost of feed sludge thickening.

(4) Based on a Hydroheater system and two 400 HP steam generators (one duty and one standby).



DIGESTER DOME
RETROFIT SECTION DETAIL

FIGURE 5.1

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AppliedTechnologies Engineers - Architects

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD

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6.0 Recommended Alternatives

A combination of the foam mitigation measures identified in this TM is recommended. The modifications to the gas collection system with the addition of a foam suppressant and changes in the operation of the aeration basins should reduce all but the most severe foaming episodes. Although modifications to the mixing system would reduce foaming intensity in the digesters, these modifications should be considered in conjunction with other process improvements to the digestion system. Increasing the DO concentration in the aeration basins is recommended to reduce *Microthrix* foaming during cold weather months.

APPENDIX A
DETAIL COST ESTIMATES

Table 1. Summary
Economic Comparison of Foam Mitigation Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Foam Mitigation Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Foam Suppression Methods	$1,315,000	$714,000	$0	$2,029,000
Thermal Hydrolysis (Cambi)	$12,447,000	$12,102,000	$0	$24,549,000
Direct Steam Injection	$1,453,000	$6,841,000	$0	$8,294,000
Electric Pulsing (OpenCEL)	$14,726,000	$5,332,000	$0	$20,058,000
Sludge Disintegration (Crown)	$5,478,000	$1,559,000	$0	$7,037,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table 2
Economic Comparison of Digestion Alternatives
Foam Suppression Methods

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Modifications to Gas Collection System							
Eight (8) foam separator domes		$ 400,000	20	$ -	$ -	$ -	$50 K per dome
Anti-foaming chemical feed							
Eight (8) chemical feed connections		$ 200,000	20	$ -	$ -	$ -	$25 K per dome
Chemical Feed / Storage System		$ 100,000	20	$ -	$ -	$ -	
Site Work	8%	$ 56,000	40	$ -	$ 28,000	$ -	
Mechanical Process Piping	10%	$ 70,000	40	$ -	$ 35,000	$ -	
Instrumentation and Control	7%	$ 49,000	20	$ -	$ -	$ -	
Electrical	8%	$ 56,000	20	$ -	$ -	$ -	
Subtotal		$ 931,000		$ -	$ 63,000	$ -	
Allowance for Undefined Design Details	25%	$ 233,000		$ -			
Total Construction Cost		$ 1,164,000		$ -			
Engineering, Legal and Administrative	15%	$ 175,000		$ -			
Total		$ 1,339,000		$ -	$ 63,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 1,339,000		$ -	$ 24,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ -		$ -			
Chemicals		$ 25,356		$ 36,783			
Hauling		$ -		$ -			
Maintenance		$ 20,100		$ 20,100			1.5% of Construction Total
Total Annual O & M Cost		$ 52,320		$ 63,747			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 406,000		$ 308,000			
Total Present Worth Capital Cost		$ 1,315,000					
Total Present Worth O&M Cost		$ 714,000					
Total Present Worth		**$ 2,029,000**					

TABLE 3 - ALTERNATE NO.1 - FOAM SUPPRESSION METHODS O&M

2010			2030		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	4	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$6,864.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors			# Thermophilic Reactors		
Cost		per yr	Cost		per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges	0		# Centrifuges	0	
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2.5%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$0***	***$/yr***	***Total Power Cost***	***$0***	***$/yr***
Chemical			**Chemical**		
Digester Feed Sludge			*Digester Feed Sludge*		
Sludge flow	213,000	gpd	Sludge flow	309,000	gpd
Foam Suppresant Dosage Rate	248	lbs/MG	Foam Suppresant Dosage Rate	248	lbs/MG
Cost of Foam Suppresant	$3.20	$/lb Polymer	Cost of Foam Suppresant	$3.20	$/lb Polymer
Application rate	10	#/year	Application rate	10	#/year
Application duration	15	days/application	Application duration	15	days/application
Cost	$25,356	$/yr	Cost	$36,783	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$25,356***	***$/yr***	***Total Chemical Cost***	***$36,783***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table 4
Economic Comparison of Digestion Alternatives
WAS Thermal Hydrolysis (Cambi)

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Two (2) 150 gpm Centrifuges		$ 1,000,000	20		$ -	$ -	$500K each
Polymer Feed system		$ 100,000	20		$ -	$ -	$50k x 2
Sludge Feed system		$ 30,000	20		$ -	$ -	Beaver Dam - $15k x 2
New Sludge Thickening Building		$ 500,000	40		$ 250,000	$ -	2000 sqft @ $250/sqft
Construct Cambi WAS treatment system							
Cambi Equipment Cost		$ 5,450,000	20	$ -	$ -	$ -	
New Cambi Bldg (35' x 70')		$ 367,500	40	$ -	$ 183,750	$ -	2,450 sqft @ $150/sqft
Tunnel extension		$ 200,000	40		$ 100,000	$ -	100' @ $2000/ft
Accessories		$ 50,000	20	$ -	$ -	$ -	
Modifications to Sludge Dewatering							
None			20	$ -	$ -	$ -	Use existing
Site Work	8%	$ 616,000	40	$ -	$ 308,000	$ -	
Mechanical Process Piping	10%	$ 770,000	40	$ -	$ 385,000	$ -	
Instrumentation and Control	7%	$ 539,000	20	$ -	$ -	$ -	
Electrical	8%	$ 616,000	20	$ -	$ -	$ -	
Subtotal		$ 10,238,500		$ -	$ 1,226,750	$ -	
Allowance for Undefined Design Details	25%	$ 1,470,000		$ -			5% used for CAMBI
Total Construction Cost		$ 11,708,500		$ -			
Engineering, Legal and Administrative	15%	$ 1,211,000		$ -			5% used for CAMBI
Total		$ 12,919,500		$ -	$ 1,226,750	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 12,920,000		$ -	$ 473,000	$ -	
Annual O & M Cost							
Labor		$ 34,320		$ 34,320			
Energy (electrical and thermal)		$ 478,057		$ 531,472			
Chemicals		$ 199,546		$ 289,883			
Hauling		$ -		$ -			
Maintenance		$ 193,800		$ 193,800			1.5% of Total
Total Annual O & M Cost		$ 905,722		$ 1,049,475			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 7,036,000		$ 5,066,000			
Total Present Worth Capital Cost		$ 12,447,000					
Total Present Worth O&M Cost		$ 12,102,000					
Total Present Worth		**$ 24,549,000**					

TABLE 5 - ALTERNATE NO.2 - WAS Cambi O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	20	hr/wk	Hours	20	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$34,320.00	$/yr	Annual	$34,320.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
Cambi THP System	1	67% load	Cambi THP System	1	75% load
Cost	$478,057	per yr	Cost	$531,472	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening		mgd @1.5%	Flow to Thickening		mgd @1.6%
# DAFs			# DAFs		
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 4.6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$478,057***	***$/yr***	***Total Power Cost***	***$531,472***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
WAS	49,700	lbs/d	WAS	72,200	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	8	lbs/DT	Centrifuge Polymer Rate	8	lbs/DT
# DAF	0		# DAF	0	
# Gravity Thickeners			# Gravity Thickeners		
# GBT	0		# GBT	0	
# Centrifuge	1		# Centrifuge	1	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$199,546	$/yr	Cost	$289,883	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge	0	lbs/day	Digested Sludge	0	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost	$0		Cost	$0	
Total Chemical Cost	***$199,546***	***$/yr***	***Total Chemical Cost***	***$289,883***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cu yds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cu yd	Dewatered Sludge Hauling Cost		$/cu yd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table 6
Economic Comparison of Digestion Alternatives
Direct Steam Injection

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Heating							
Two (2) Steam Injectors		$ 200,000	20	$ -	$ -	$ -	$100K each installed
Two (2) Steam Generators 10,000 MBH		$ 530,000	20	$ -	$ -	$ -	$265K each installed
Building space allowance		$ 50,000	40	$ -	$ 25,000	$ -	
Site Work	8%	$ 62,000	40	$ -	$ 31,000	$ -	
Mechanical Process Piping	10%	$ 78,000	40	$ -	$ 39,000	$ -	
Instrumentation and Control	7%	$ 55,000	20	$ -	$ -	$ -	
Electrical	8%	$ 62,000	20	$ -	$ -	$ -	
Subtotal		$ 1,037,000		$ -	$ 95,000	$ -	
Allowance for Undefined Design Details	25%	$ 259,000		$ -			
Total Construction Cost		$ 1,296,000		$ -			
Engineering, Legal and Administrative	15%	$ 194,000		$ -			
Total		$ 1,490,000		$ -	$ 95,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 1,490,000		$ -	$ 37,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 491,392		$ 549,910			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 22,400		$ 22,400			1.5% of Total
Total Annual O & M Cost		$ 520,656		$ 579,174			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 4,045,000		$ 2,796,000			
Total Present Worth Capital Cost		$ 1,453,000					
Total Present Worth O&M Cost		$ 6,841,000					
Total Present Worth		**$ 8,294,000**					

TABLE 7 - ALTERNATE NO.3 - DIRECT STEAM INJECTION O&M					
2010			**2030**		
Labor					
Description					
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	4	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$6,864.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
Steam Injector System	1	@67% load	Steam Injector System	1	@75% load
Cost	$491,392	per yr	Cost	$549,910	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening		mgd @1.5%	Flow to Thickening		mgd @1.6%
# DAFs			# DAFs		
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
Flow to Centrifuges		mgd @4.6%	Flow to Centrifuges		mgd @4.6%
# Centrifuges in service			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Cambi THP		lbs/d	Solids Flow to Cambi THP		lbs/d
Solids Flow to Cambi THP		gpd @ 17%	Solids Flow to Cambi THP		gpd @ 17%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @5%	Digested Sludge Production		gpd @5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$491,392***	***$/yr***	***Total Power Cost***	***$549,910***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge		lbs/d	Raw Sludge		lbs/d
Gravity Thickener Polymer Rate		lbs/DT	Gravity Thickener Polymer Rate		lbs/DT
DAF Polymer Rate		lbs/DT	DAF Polymer Rate		lbs/DT
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# GBT			# GBT		
# Centrifuge			# Centrifuge		
Cost of Polymer		$/lb Polymer	Cost of Polymer		$/lb Polymer
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$0***	***$/yr***	***Total Chemical Cost***	***$0***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table 8
Economic Comparison of Digestion Alternatives
Electric Pulsing (OpenCEL)

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
WAS Pretreatment System							
Two (2) Model 30 OpenCEL Units		$ 7,800,000	20		$ -	$ -	(2) OpenCEL units @ $7.8 million installed
Building modifications		$ 50,000	40		$ 25,000	$ -	
Site Work	8%	$ 628,000	40	$ -	$ 314,000	$ -	
Mechanical Process Piping	10%	$ 785,000	40	$ -	$ 393,000	$ -	
Instrumentation and Control	7%	$ 550,000	20	$ -	$ -	$ -	
Electrical	8%	$ 628,000	20	$ -	$ -	$ -	
Subtotal		$ 10,441,000		$ -	$ 732,000	$ -	
Allowance for Undefined Design Details	25%	$ 2,610,000		$ -			
Total Construction Cost		$ 13,051,000		$ -			
Engineering, Legal and Administrative	15%	$ 1,958,000		$ -			
Total		$ 15,009,000		$ -	$ 732,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 15,009,000		$ -	$ 283,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 163,300		$ 236,414			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 225,100		$ 225,100			1.5% of Total
Total Annual O & M Cost		$ 395,264		$ 468,378			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 3,071,000		$ 2,261,000			
Total Present Worth Capital Cost		$ 14,726,000					
Total Present Worth O&M Cost		$ 5,332,000					
Total Present Worth		**$ 20,058,000**					

TABLE 9 - ALTERNATE NO.4 - ELECTRIC PULSING (OPENCEL) O&M

2010		2030	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	4 hrs/wk	Hours	4 hrs/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$6,864.00 $/yr	Annual	$6,864.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors		# Mesophilic Reactors	
# Thermophilic Reactors		# Thermophilic Reactors	
Open Cell Reactor	1	Open Cell Reactor	1
Cost	$163,300 per yr	Cost	$236,414 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	mgd @1.5%	Flow to Thickening	mgd @1.6%
# DAFs		# DAFs	
# Gravity Thickeners		# Gravity Thickeners	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	lbs/d	Solids Flow to Digestion	lbs/d
Solids Flow to Digestion	gpd @ 4.6%	Solids Flow to Digestion	gpd @ 4.6%
Digested Sludge Production	lbs/d	Digested Sludge Production	lbs/d
Digested Sludge Production	gpd @2%	Digested Sludge Production	gpd @2%
% to GBT		% GBT	
Digested Sludge Production	gpd@ 5%	Digested Sludge Production	gpd@ 5%
% to Centrifuge		% Centrifuge	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Thermal Treatment		*Thermal Treatment*	
Digested Sludge Production	lbs/day	Digested Sludge Production	lbs/day
# Belt Dryers		# Belt Dryers	
Cost	$0 per yr	Cost	$0 per year
Total Power Cost	***$163,300 $/yr***	***Total Power Cost***	***$236,414 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Raw Sludge	lbs/d	Raw Sludge	lbs/d
Gravity Thickener Polymer Rate	lbs/DT	Gravity Thickener Polymer Rate	lbs/DT
DAF Polymer Rate	lbs/DT	DAF Polymer Rate	lbs/DT
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
# DAF		# DAF	
# Gravity Thickeners		# Gravity Thickeners	
# GBT		# GBT	
# Centrifuge		# Centrifuge	
Cost of Polymer	$/lb Polymer	Cost of Polymer	$/lb Polymer
Cost	$/yr	Cost	$/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	lbs/day	Digested Sludge	lbs/day
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
% GBT		% GBT	
% Centrifuge		% Centrifuge	
Cost	$0	Cost	$0
Total Chemical Cost	***$0 $/yr***	***Total Chemical Cost***	***$0 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	%	Metrogro liquid concentration	%
Metrogro cake concentration	%	Metrogro cake concentration	%
Gallons liquid per day	gpd	Gallons liquid per day	gpd
Dewatered Sludge per day	cu yds/d	Dewatered Sludge per day	cu yds/d
Liquid Hauling Cost	$/gal	Liquid Hauling Cost	$/gal
Dewatered Sludge Hauling Cost	$/cu yd	Dewatered Sludge Hauling Cost	$/cu yd
Total Hauling Cost	***$0 $/yr***	***Total Hauling Cost***	***$0 $/yr***

Table 10
Economic Comparison of Digestion Alternatives
Sludge Disintegration (Crown)

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
WAS Pretreatment System							
Crown Solids Disintegration System		$ 2,873,000	20		$ -	$ -	(1) Crown system $2,873,000 installed
Building modifications		$ 50,000	40		$ 25,000	$ -	
Site Work	8%	$ 234,000	40	$ -	$ 117,000	$ -	
Mechanical Process Piping	10%	$ 292,000	40	$ -	$ 146,000	$ -	
Instrumentation and Control	7%	$ 205,000	20	$ -	$ -	$ -	
Electrical	8%	$ 234,000	20	$ -	$ -	$ -	
Subtotal		$ 3,888,000		$ -	$ 288,000	$ -	
Allowance for Undefined Design Details	25%	$ 972,000		$ -			
Total Construction Cost		$ 4,860,000		$ -			
Engineering, Legal and Administrative	15%	$ 729,000		$ -			
Total		$ 5,589,000		$ -	$ 288,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 5,589,000		$ -	$ 111,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 6,864			
Energy (electrical and thermal)		$ 33,100		$ 33,100			
Chemicals		$ -		$ -			
Hauling		$ -		$ -			
Maintenance		$ 83,800		$ 83,800			1.5% of Total
Total Annual O & M Cost		$ 123,764		$ 123,764			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 962,000		$ 597,000			
Total Present Worth Capital Cost		$ 5,478,000					
Total Present Worth O&M Cost		$ 1,559,000					
Total Present Worth		**$ 7,037,000**					

TABLE 11 - ALTERNATE NO.4B - SLUDGE DISINTEGRATION (CROWN) O&M

2010		2030	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	4 hr/wk	Hours	4 hr/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$6,864.00 $/yr	Annual	$6,864.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors		# Mesophilic Reactors	
# Thermophilic Reactors		# Thermophilic Reactors	
Crown Sludge Disintegration	1	Crown Sludge Disintegration	1
Cost	$33,100 per yr	Cost	$33,100 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	mgd @1.5%	Flow to Thickening	mgd @1.6%
# DAFs		# DAFs	
# Gravity Thickeners		# Gravity Thickeners	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	lbs/d	Solids Flow to Digestion	lbs/d
Solids Flow to Digestion	gpd @ 4.6%	Solids Flow to Digestion	gpd @ 4.6%
Digested Sludge Production	lbs/d	Digested Sludge Production	lbs/d
Digested Sludge Production	gpd @2%	Digested Sludge Production	gpd @2%
% to GBT		% GBT	
Digested Sludge Production	gpd@ 5%	Digested Sludge Production	gpd@ 5%
% to Centrifuge		% Centrifuge	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Lime Pasterization		*Lime Pasterization*	
Digested Sludge Production	0 lbs/day	Digested Sludge Production	0 lbs/day
Cost	$0 per yr	Cost	$0 per year
Total Power Cost	***$33,100 $/yr***	***Total Power Cost***	***$33,100 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Raw Sludge	lbs/d	Raw Sludge	lbs/d
Gravity Thickener Polymer Rate	lbs/DT	Gravity Thickener Polymer Rate	lbs/DT
DAF Polymer Rate	lbs/DT	DAF Polymer Rate	lbs/DT
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
# DAF		# DAF	
# Gravity Thickeners		# Gravity Thickeners	
# GBT		# GBT	
# Centrifuge		# Centrifuge	
Cost of Polymer	$/lb Polymer	Cost of Polymer	$/lb Polymer
Cost	$0 $/yr	Cost	$0 $/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	lbs/day	Digested Sludge	lbs/day
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
% GBT		% GBT	
% Centrifuge		% Centrifuge	
Cost of Lime	$/DT	Cost of Lime	$/DT
Digested Sludge to EnVessel	lbs/day	Digested Sludge to EnVessel	lbs/day
% Lime Solids Added		% Lime Solids Added	
Total Solids	lb/day	Total Solids	lb/day
Cost	$0	Cost	$0
Total Chemical Cost	***$0 $/yr***	***Total Chemical Cost***	***$0 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	%	Metrogro liquid concentration	%
Metrogro cake concentration	%	Metrogro cake concentration	%
Gallons liquid per day	gpd	Gallons liquid per day	gpd
Dewatered Sludge per day	cu yds/d	Dewatered Sludge per day	cu yds/d
Liquid Hauling Cost	$/gal	Liquid Hauling Cost	$/gal
Dewatered Sludge Hauling Cost	$/cu yd	Dewatered Sludge Hauling Cost	$/cu yd
Total Hauling Cost	***$0 $/yr***	***Total Hauling Cost***	***$0 $/yr***

APPENDIX I

Technical Memorandum No. 6
Struvite and Chemical Precipitation Evaluation

Applied Technologies
Engineers - Architects

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 6
STRUVITE AND CHEMICAL PRECIPITATION EVALUATION

Date: December 17, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate the mitigation and control of phosphate precipitation at the Nine Springs Wastewater Treatment Plant (NSWWTP). This TM evaluates the historical problems observed at the NSWWTP and the potential mitigation measures available to minimize the maintenance required to operate the digestion system at the facility.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- To mitigate struvite formation in the anaerobic digesters, phosphorus removal in the sludge thickening filtrate is recommended.
- To promote secondary phosphorus release, operation with a fermentation tank for waste activated sludge (WAS) and primary sludge upstream of sludge thickening is recommended. To increase the efficiency of the secondary phosphorus release, supplement of acid phase sludge to achieve a volatile acid concentration of 150 mg/L is recommended.
- Based on the projected primary sludge and WAS flow rates, one of the existing dissolved air flotation (DAF) thickeners would have adequate capacity to operate as a fermentation tank. The other DAF thickener could operate as a chemical clarifier to isolate the phosphorus precipitates.
- The capital costs of struvite harvesting systems would be considerably higher than chemical addition alternatives. The economic viability of struvite harvesting relies on revenue from struvite fertilizer sales.

- Phosphorus removal in the pre-digestion and post-digestion thickening filtrate using chemical precipitation is recommended.

- The present worth cost of metal salt addition to the anaerobic digesters is marginally lower than chemical addition to the thickening filtrate due to costs associated with the fermentation tank, side stream clarifier, and chemical sludge handling. Metal salt addition only to the dewatering filtrate will decrease the phosphorus loading to the main treatment plant but will not mitigate struvite formation in the anaerobic digesters.

- Ferric chloride or ferrous chloride is recommended for direct addition to the anaerobic digesters. The cost of iron salts is considerably lower than aluminum salts.

- Ferric chloride is recommended for addition to the thickening and dewatering filtrate streams. When returned to the headworks, un-reacted ferric ions will help mitigate odors and enhance primary clarification. The chemical sludge from the phosphorus removal process may be disposed of by combining it with the Metrogro sludge for land application until a more environmentally sustainable practice can be identified.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to reduce the maintenance challenges and costs associated with the removal and control of phosphate based inorganic chemicals at the NSWWTP. The MMSD is interested in investigating the potential benefits of phosphate control through the precipitation of one or more of these chemicals to remove them from the system.

The NSWWTP operates with an Enhanced Biological Phosphorus Removal (EBPR) process, where soluble phosphorus is removed from the bulk liquid and stored as intracellular polyphosphate in phosphorus accumulating organisms (PAOs). Typically, the selective growth of PAOs is achieved through an operation with alternating anaerobic and aerobic conditions. Under anaerobic conditions, polyphosphate is used by PAOs as energy source to take up simple soluble organics and store them as intracellular solid compounds. The break down of polyphosphate results in the release of phosphate to the bulk liquid. Under aerobic conditions, the intracellular solids are consumed and phosphate is accumulated as polyphosphate.

Waste activated sludge (WAS) from an EBPR process contains high phosphorus concentrations that are further increased after sludge thickening. Secondary phosphorus release occurs when the sludge is fed to an anaerobic digester. Formation of struvite is a common problem in anaerobic digesters and the downstream dewatering equipment. Struvite crystals create scaling in pipelines, walls, and process equipment, which results in reduced capacity as well as operation and maintenance problems. The NSWWTP has experienced struvite scaling in draft tube mixers, heat exchangers, heat recirculation pumps, and sludge transfer lines. A considerable fraction of the phosphate removed in the EBPR process is recycled back to the EBPR system when gravity belt thickening (GBT) filtrate is recycled to the headworks. Sidestream treatment of the GBT filtrate is employed to reduce the phosphorus recycle. The sidestream treatment system is comprised of a ferric chloride storage and feed facility, located adjacent to the GBT Thickening Building. The system includes a 12,000-gallon storage tank and three feed pumps (5-280 gph ea.) that can dose three locations:

- GBT filtrate return to headworks
- Raw sludge feed to the digesters
- Digested sludge feed to the GBTs

Generally, the District employs treatment of GBT filtrate, feeding iron in a mole ratio of 1.5 times the P content in the filtrate. Historical records of ferric chloride consumption are shown in Table 6.1. Variability in the consumption of iron increased significantly after 10th Addition as attempts were made to deal with struvite and vivianite scaling that occurred with thermophilic digestion.

Table 6.1
Historic Ferric Chloride Usage

Year	$FeCl_3$ Solution Feed, gpd	Daily Chemical Use, dry lbs $FeCl_3$/day	Daily Iron Consumption, lbs Fe/day
2006	403	1652	575
2007	303	1241	432
2008	786	3226	1122
2009	631	2588	900

4.0 Phosphate Precipitation Chemistry

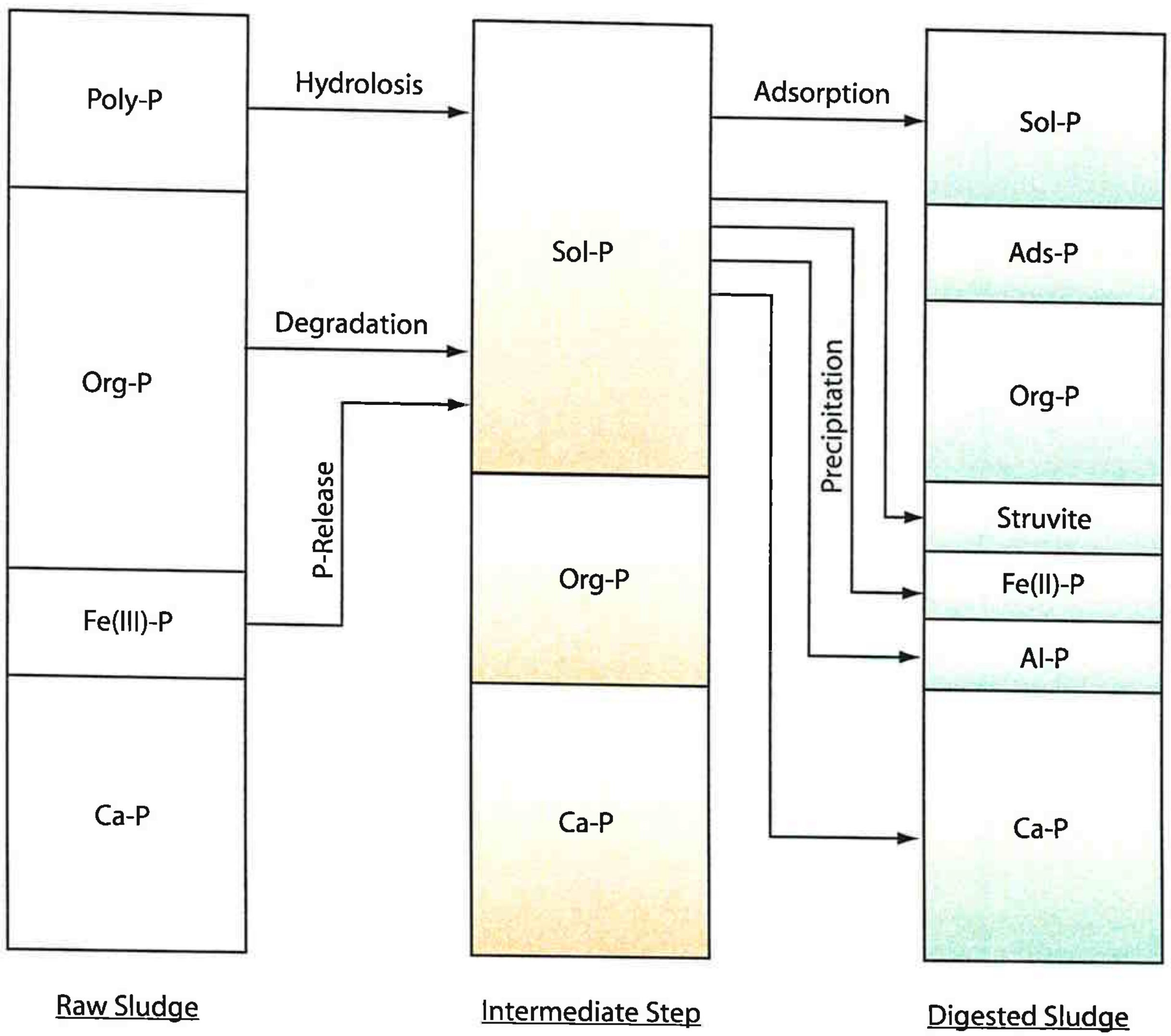
During the anaerobic digestion of WAS from an EBPR plant, phosphorus accumulated as polyphosphate and organic phosphorus from cell tissues are released to the bulk liquid. The transformations of phosphorus inside anaerobic digesters occur in a two-step process. The first step consists of phosphorus solubilization processes including polyphosphate hydrolysis, organic phosphorus compounds degradation, and oxidation of ferric-P compounds. The second step consists of phosphorus fixing processes including the soluble phosphorus adsorption and phosphorus precipitation with magnesium, calcium, iron and aluminum. Figure 6.1 presents a summary of the two-step transformation process.

The major phosphate precipitates in anaerobic digesters receiving WAS from an EBPR plant are struvite ($MgNH_4PO_4{\cdot}6H_2O$) and calcium phosphates. Struvite is a white crystalline solid formed by equal molar concentrations of ammonium, magnesium and phosphate. The solubility of struvite is dependent on pH (Figure 6.2), temperature (Figure 6.3), and the presence of impurities such as calcium. Due to the high pH and ionic strength conditions in anaerobic digesters, amorphous calcium phosphate ($Ca_5(PO_4)_2{\cdot}nH_2O$) is the major calcium precipitate. Other important phosphate minerals in anaerobic digesters include vivianite ($Fe_3(PO_4)_2{\cdot}8H_2O$) and variscite ($AlPO_4{\cdot}2H_2O$).

A common procedure to determine the struvite precipitation potential is to estimate the conditional solubility product. Struvite precipitation occurs when the product of the molar concentrations of ammonium, magnesium, and phosphate exceed the conditional solubility product. The series of steps that lead to struvite precipitation in anaerobic digesters include phosphorus solubilization, intracellular magnesium release, carbon dioxide loss to the gas phase and subsequent pH increase, equilibrium shift towards orthophosphate and ammonia, and struvite nucleation and crystal growth. The sludge temperature increase to the thermophilic range decreases struvite solubility, which probably results in struvite formation in the NSWWTP digestion equipment. Table 6.2 presents a summary of the chemical reactions and equilibrium constants for struvite formation.

Table 6.2
Chemical Reactions in Phosphorus Precipitation Chemistry

$NH_4^+ \Leftrightarrow NH_{3\,(aq)} + H^+$	$pK_a = 9.3$
$H_3PO_4 \Leftrightarrow H_2PO_4^- + H^+$	$pK_{a1} = 2.1$
$H_2PO_4^- \Leftrightarrow HPO_4^{2-} + H^+$	$pK_{a2} = 7.2$
$HPO_4^{2-} \Leftrightarrow PO_4^{3-} + H^+$	$pK_{a3} = 12.3$
$MgOH^+ \Leftrightarrow Mg^{2+} + OH^-$	$pK = 2.56$
$MgNH_4PO_4 \cdot 6H_2O \Leftrightarrow Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O$	$pK = 12.6$
$AlPO_{4(s)} \Leftrightarrow Al_3^+ + PO_4^{3-}$	$pK_{so} = 21$
$FePO_{4(s)} \Leftrightarrow Fe^{3+} + PO_4^{3-}$	$pK_{so} = 21.9$ to 23



PHOSPHATE TRANSFORMATIONS IN ANAEROBIC DIGESTION

FIGURE 6.1

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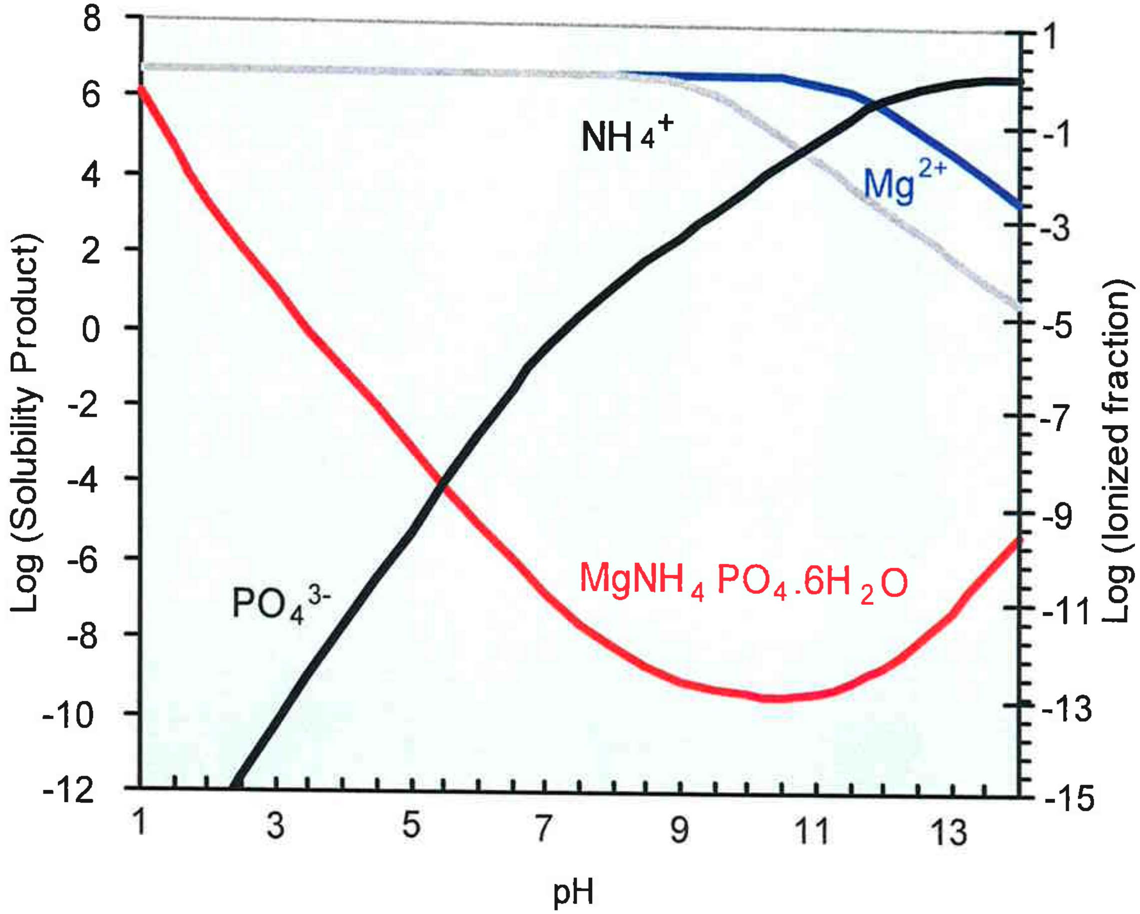

STRUVITE SOLUBILITY VERSUS pH

FIGURE 6.2

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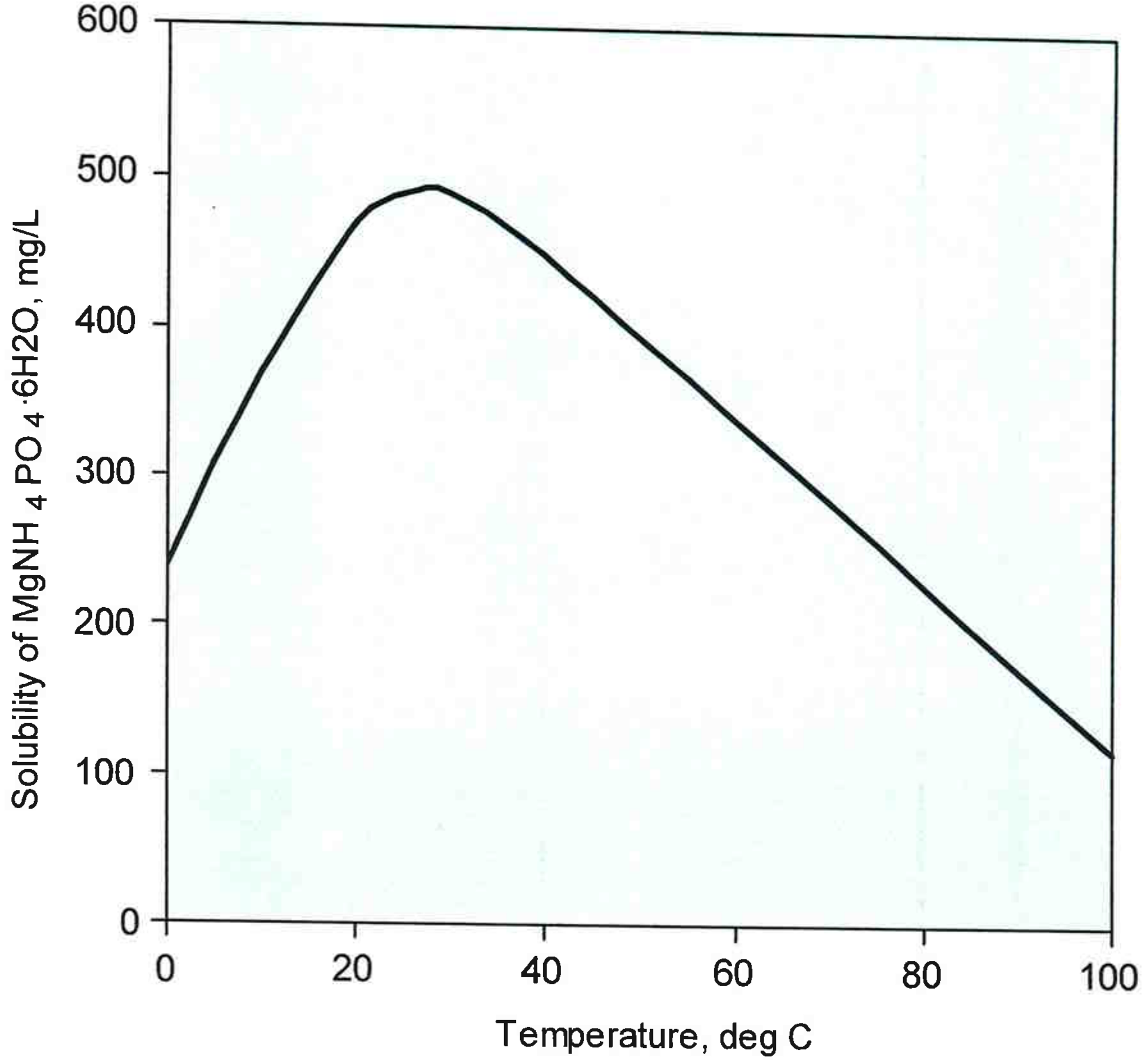


STRUVITE SOLUBILITY VERSUS TEMPERATURE

FIGURE 6.3

5.0 Mitigation Measures

To mitigate struvite and/or vivianite formation in anaerobic digesters, the product of the concentrations of magnesium, ammonium, and phosphate must be decreased below the conditional solubility product for struvite. In other words, the concentration of one or more of the reactants must be decreased. Alternatives to remove phosphate from the bulk liquid include chemical addition and struvite harvesting.

5.1 Chemical Addition to control struvite crystallization

Iron and aluminum salts, lime, and patented chemicals such as Poly-Gone Lines are typically used to precipitate phosphate out of solution and prevent struvite formation. Table 6.3 presents the preliminary design data for chemical addition.

Table 6.3
Preliminary Design Data for Chemical Addition

	Poly-Gone Lines	Ferric Chloride $FeCl_3$	Ferrous Chloride $FeCl_2$	Alum $Al_2(SO4)_3 \cdot 14H2O$	Lime $Ca(OH)_2$
Dosage Rate	1 gal per 20,000 gal raw sludge	2.7 lbs Fe per lbs P	2.7 lbs Fe per lbs P	2.2 lbs Al per lbs P	1.5 x Total Alkalinity
Daily Usage, dry chemical ppd	-	10,000 (1,2)	7,800 (1,2)	30,800(1,2)	8,400 (3)
Daily Usage, gpd	15 (4)	2,400 (5)	2,900 (6)	5,700 (7)	-
Unit Price	$23.26/gal	$811/dry ton $FeCl_3$	$960/dry ton $FeCl_2$	$660/dry ton $Al_2(SO4)_3 \cdot 14H2O$	$260/dry ton $Ca(OH)_2$
Annual Cost	$131,200	$1,480,000	$1,367,000	$3,710,000	$398,600

Notes:
(1) Based on 2030 average annual total phosphorus loadings of 2,900 ppd to the NSWWTP.
(2) Assumes 44 percent of phosphorus loading to the digesters is in soluble form.
(3) Assumes a combined recycle stream average flow of 1.9 MG with an alkalinity of 350 mg/L.
(4) Based on 2030 average annual digester feed of 0.309 mgd to the anaerobic digesters.
(5) Based on ferric chloride solution strength of 37 percent, SG=1.35.
(6) Based on ferrous chloride solution strength of 25 percent, SG=1.28.
(7) Based on alum solution strength of 48.5 percent, SG=1.335.

5.1.1 Poly-Gone Lines

Poly-Gone Lines (PGL, formerly known as Struv-off) is a patented product that prevents struvite crystal formation and removes existing struvite scaling. PGL is added to the influent line before the anaerobic digesters. Typical PGL to sludge volumetric ratios are 1 to 16,000 for struvite removal and 1 to 20,000 for struvite prevention. Figure 6.4 shows the schematic process for the struvite control using PGL. According to the manufacturer, PGL maintains phosphate in solution but there is no information available on the fate of phosphate bound to PGL. Due to uncertainty on the fate of the PGL-bound phosphate and a possible increase in the effluent total P concentrations, this alternative was not considered for as a long-term solution for struvite mitigation.

5.1.2 Iron and Aluminum Salts

Aluminum and ferric ions precipitate with phosphate at pH levels that are compatible with biological treatment. Typically, aluminum and iron salts dosage is 1.3 to 2.2 g Al/g P and 2.7 g Fe/g P. Aluminum and ferric iron addition depletes alkalinity and when low alkalinity and pH depression is a concern, lime is added to supplement alkalinity. Iron and aluminum salt addition result in increased sludge hauling volume. The iron and aluminum salts more commonly used for phosphorus precipitation are ferric chloride ($FeCl_3$), ferric sulfate ($Fe_2(SO_4)_3$), ferrous chloride ($FeCl_2$), ferrous sulfate ($FeSO_4$), alum ($Al_2(SO_4)_3 \cdot 14H_2O$), and sodium aluminate ($NaAlO_2$). Sulfate-containing salts are not recommended at facilities with anaerobic digesters due to the formation of hydrogen sulfide. Table 6.4 presents the chemical reactions for iron and aluminum phosphates.

5.1.2.1 Iron Salt Addition Upstream of Anaerobic Digestion

Aluminum and iron salts can be used to remove polyphosphate and soluble phosphate from the sludge upstream of the anaerobic digestion process. The addition of iron Fe(III) salts is preferred for treatment of the thickening and dewatering filtrate because un-reacted Fe(III) ions in the side streams will help to mitigate odors and enhance primary clarification when returned to the headworks.

Under this scenario, a blend tank is provided to receive primary sludge or fermented sludge from the acid phase and WAS. Secondary phosphorus release takes place in the blend tank due to the formation of volatile fatty acids during the fermentation of readily degradable organics. Addition of iron or aluminum salts to the thickening filtrate results in the precipitation of phosphate, which is collected using a clarifier. The mixed primary sludge and WAS is then routed to thickening and digestion. The chemical sludge from the phosphorus removal process may be disposed of by combining it with the Metrogro sludge for land application until a more environmentally sustainable practice can be identified. A process schematic of this treatment scenario is presented in Figure 6.5.

Based on EBPR design data, the blend tank should be sized for a hydraulic retention time (HRT) of approximately 1 to 2 hours for a complete secondary phosphorus release. The HRT should provide adequate time for the fermentation of readily degradable organics in the primary sludge. The production of VFAs at concentrations of 100 to 150 mg/L is required to promote the phosphorus release. One of the existing DAF tanks will be converted to serve as a blend tank. Based on typical design criteria, the other existing DAF tank (55-ft diameter, 10-ft side water depth) would be required to precipitate the ferric phosphate sludge.

5.1.2.2 Iron Salt Addition to Anaerobic Digesters

Aluminum and iron salts can be used to remove polyphosphate and soluble phosphate in the anaerobic digesters. The addition of iron salts is preferred because of the dual benefit of struvite and hydrogen sulfide mitigation. The addition of iron Fe(III) salts to the anaerobic digesters can improve the grease degradation but could result in lower methane production. The addition of iron salts can result in vivianite formation. Vivianite scaling has been observed in the surfaces of the heat exchangers at the NSWWTP. Improvements to the digester heating system and changes in operation to limit the temperature increment through the heat exchangers would be necessary to minimize vivianite formation. Alternatively, the location for iron salt addition can be moved to immediately upstream of the thermophilic digesters.

Under this scenario, iron salts would be added directly to the acid digesters and the precipitated phosphorus salt would be mixed with the stabilized sludge. The sludge is then routed to the methane phase digesters and thickening. A process schematic of this scenario is presented in Figure 6.6.

5.1.2.3 Iron or Aluminum Salt Addition Downstream of Anaerobic Digestion

Aluminum and iron salts can be used to remove polyphosphate and soluble phosphate from the sludge downstream of the anaerobic digestion process. The addition of Fe(III) salts to the dewatering filtrate is recommended due to the additional benefits of odor control and enhanced primary clarification associated with un-reacted Fe(III) ions returned to the headworks in the recycle streams. Secondary phosphorus release occurs when WAS from an EBPR plant is the presence of VFAs under anaerobic conditions. Under this scenario, the dewatering filtrate is mixed with iron salts, the ferric-phosphate sludge is wasted and the clarified supernatant is returned to the headworks. A process schematic of this scenario is presented in Figure 6.7.

Phosphate removal downstream of the digestion process results in a considerable decrease of the phosphorus loading to the EBPR plant and struvite formation in the recycle lines. The phosphorus loading in the dewatering filtrate of a typical EBPR facility contains up to 3 times more phosphorus than the raw influent. Due to the elevated phosphorus concentrations in the thickened sludge, this alternative does not prevent struvite formation in the anaerobic digestion and dewatering systems. This alternative was not selected for further evaluation.

5.1.3 Lime Addition

Another chemical commonly used to precipitate phosphate is lime ($Ca(OH)_2$). To precipitate phosphorus as apatite ($Ca_3(PO_4)_2$), an increase in pH to around 11 is required. A typical dosage for lime is 1.5 times the total alkalinity (as mg/L $CaCO_3$). Lime addition is used as part of the PhoStrip process where EBPR and chemical precipitation are combined. In the PhoStrip process, return activated sludge is thickened under anaerobic conditions and phosphate is released. The thickened sludge is returned to the aeration basin and the phosphate-rich supernatant is sent to high-lime precipitation. Figure 6.8 shows a process schematic of the PhoStrip process. Lime can be added upstream or downstream of digestion. Due to the high lime dosages required to elevate the pH to 11, issues related with a high pH side stream, and the significant footprint and capital expenditure required for the treatment of RAS, this alternative was not selected for further evaluation.

5.2 Struvite Harvesting

Struvite harvesting technologies uses up-flow fluidized bed reactors to precipitates struvite pellets and extract phosphorus and ammonia from the liquid stream. The struvite pellets are collected and used as fertilizer. The process relies on the addition of magnesium and alkalinity to achieve soluble phosphorus removal rates of up to 90%. Manufacturers of struvite harvesting reactors include Ostara, DHV (Crystallactor), and Unitika (Phosnix).

Two scenarios were evaluated. In the first scenario, the struvite-harvesting reactors receive pre-digestion and post-digestions thickening filtrate. Primary sludge and WAS are blended prior to thickening to promote secondary phosphorus release. In the second scenario, the struvite-harvesting reactors receive digested sludge thickening filtrate. Table 6.5 presents the design parameters. Figures 6.9 and 6.10 present the process schematics for both struvite-harvesting scenarios.

Table 6.5
Design Data (2030) for the Ostara Struvite-Harvesting System (1)

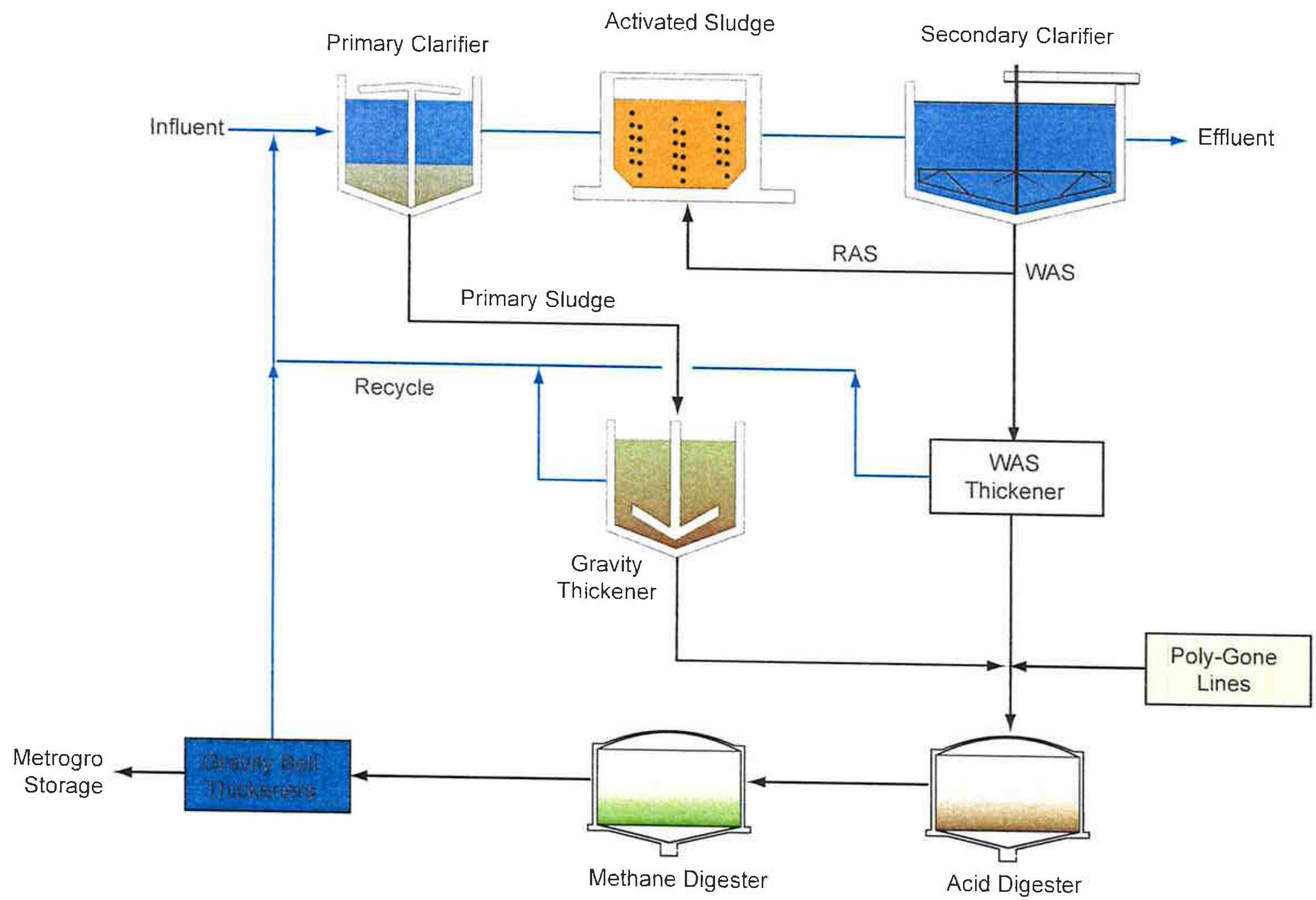
Parameter	Upstream of Digestion (Ostara System 2)	Downstream of Digestion (Ostara System 1)
Feed Flow Rate, gpd	1,250,000	264,000
Feed Ammonia Concentration, mg-N/L	224	1,057
Feed Ortho-Phosphate Concentration, mg-P/L	163	181
Treatment Capacity per Reactor, gpd	120,100	106,800
Proposed Number of Pearl 500 Reactors, units	11	3
Effluent Ortho-Phosphate, mg-P/L	21	17
Ortho-phosphate Removal Efficiency	87%	91%
Phosphorus Removed, ppd	1,481	361
Effluent Ammonia, mg-N/L	160	983
Ammonia Removal	29%	7%
Mass of Nitrogen Removed, ppf	670	163
Struvite Production Rate, tons/year	2,141	522
Building Footprint, sqf	12,900	4,500
Electricity Consumption, kWhr/day	3,273	777
Magnesium Chloride, tons/year	1,375-1,450	430-460

Note:
(1) Ostara Preliminary Proposal for Nutrient Recovery System at the NSWWTP, 4/23/2009

The costs of chemical addition (magnesium and alkalinity) would be offset by the revenue from fertilizer sales. The net positive effect of struvite harvesting would be a decrease in the phosphorus content of the Metrogro and Metromix products.

5.3 Preventive Maintenance

Another alternative for struvite control is to perform preventive maintenance on process piping and equipment. This alternative is operator intensive and is presented as a baseline for the struvite mitigation alternatives evaluation.



POLY-GONE LINES ADDITION

FIGURE 6.4

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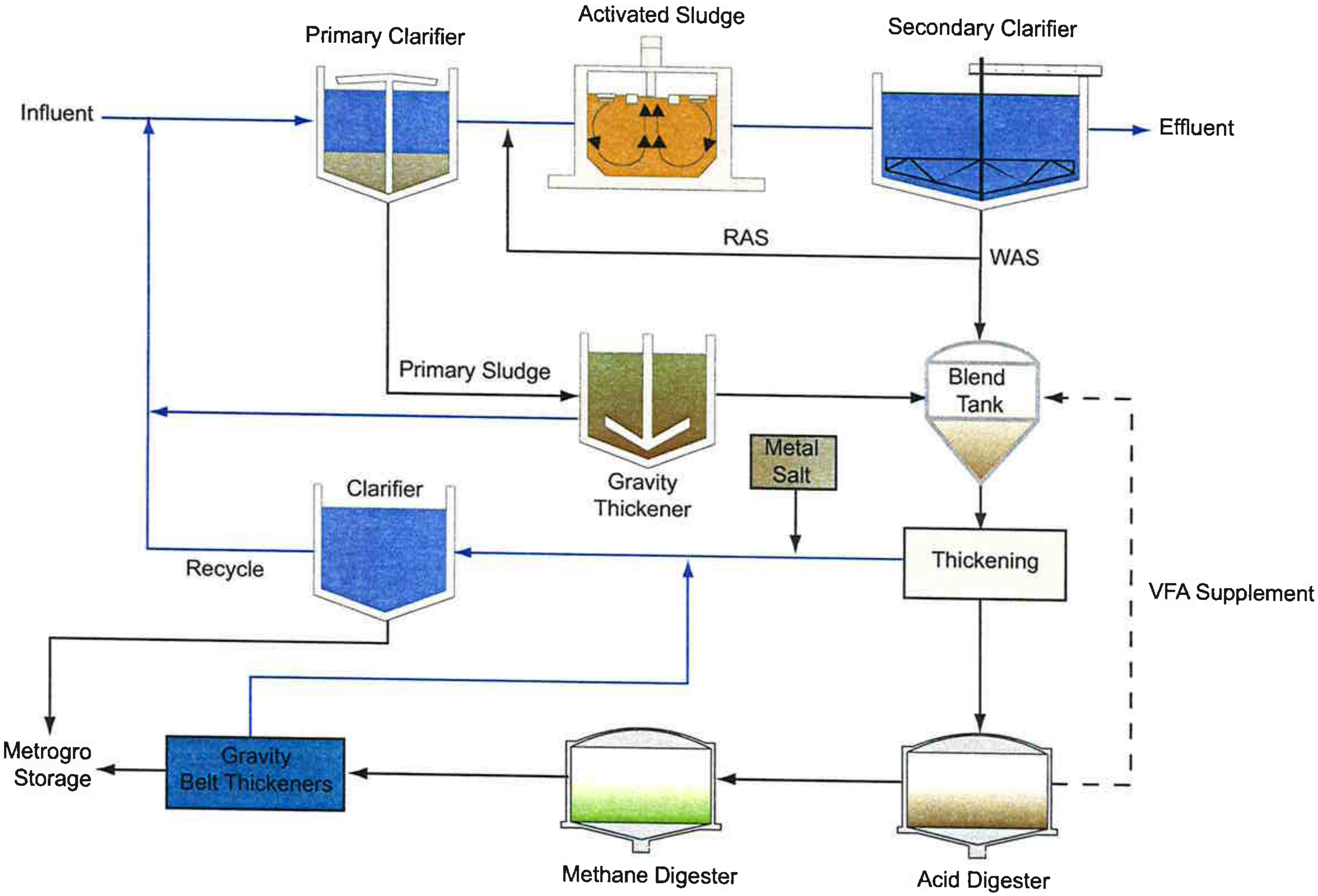

METAL SALT ADDITION UPSTREAM OF DIGESTION

FIGURE 6.5

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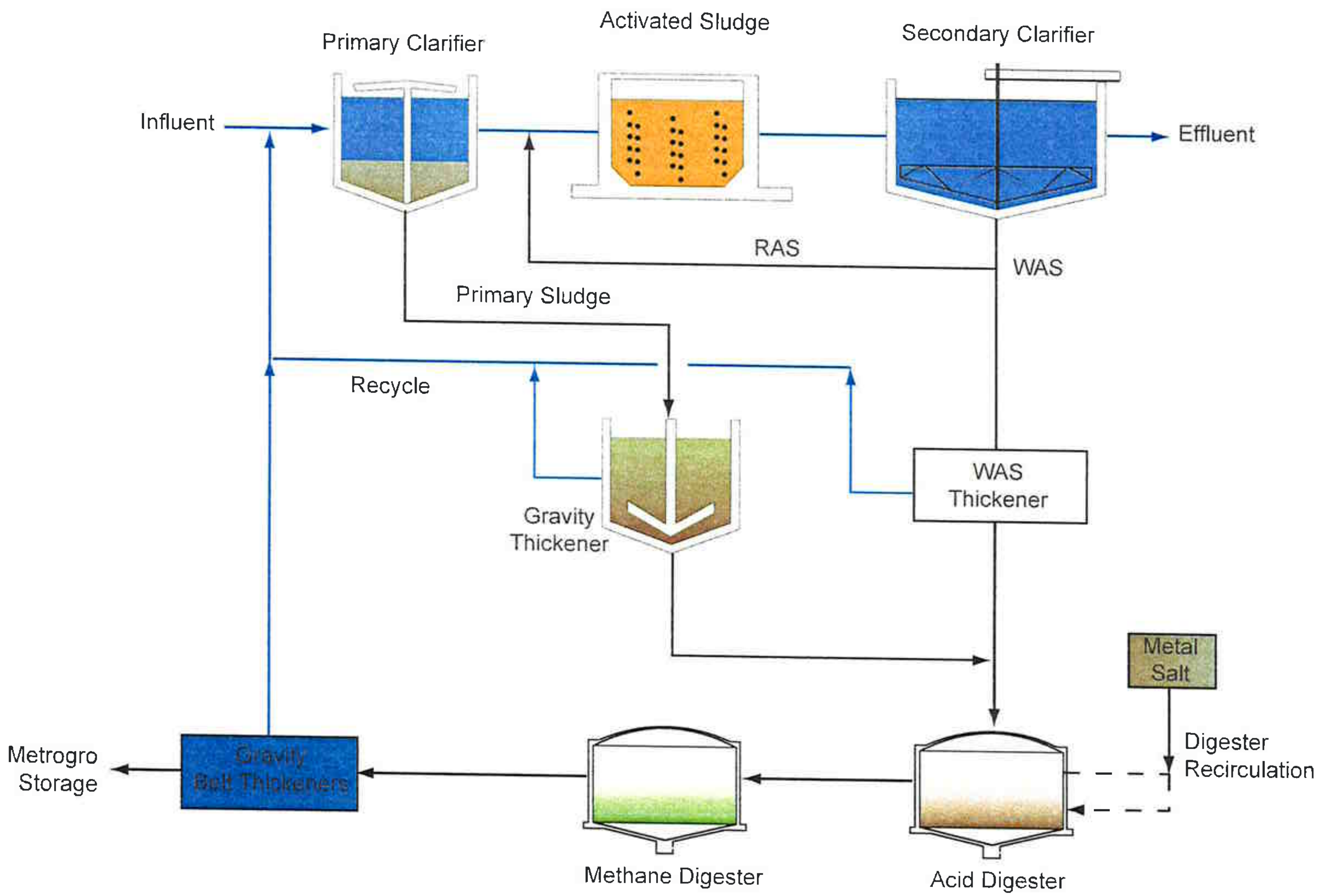

METAL SALTS ADDITION TO ANAEROBIC DIGESTERS

FIGURE 6.6

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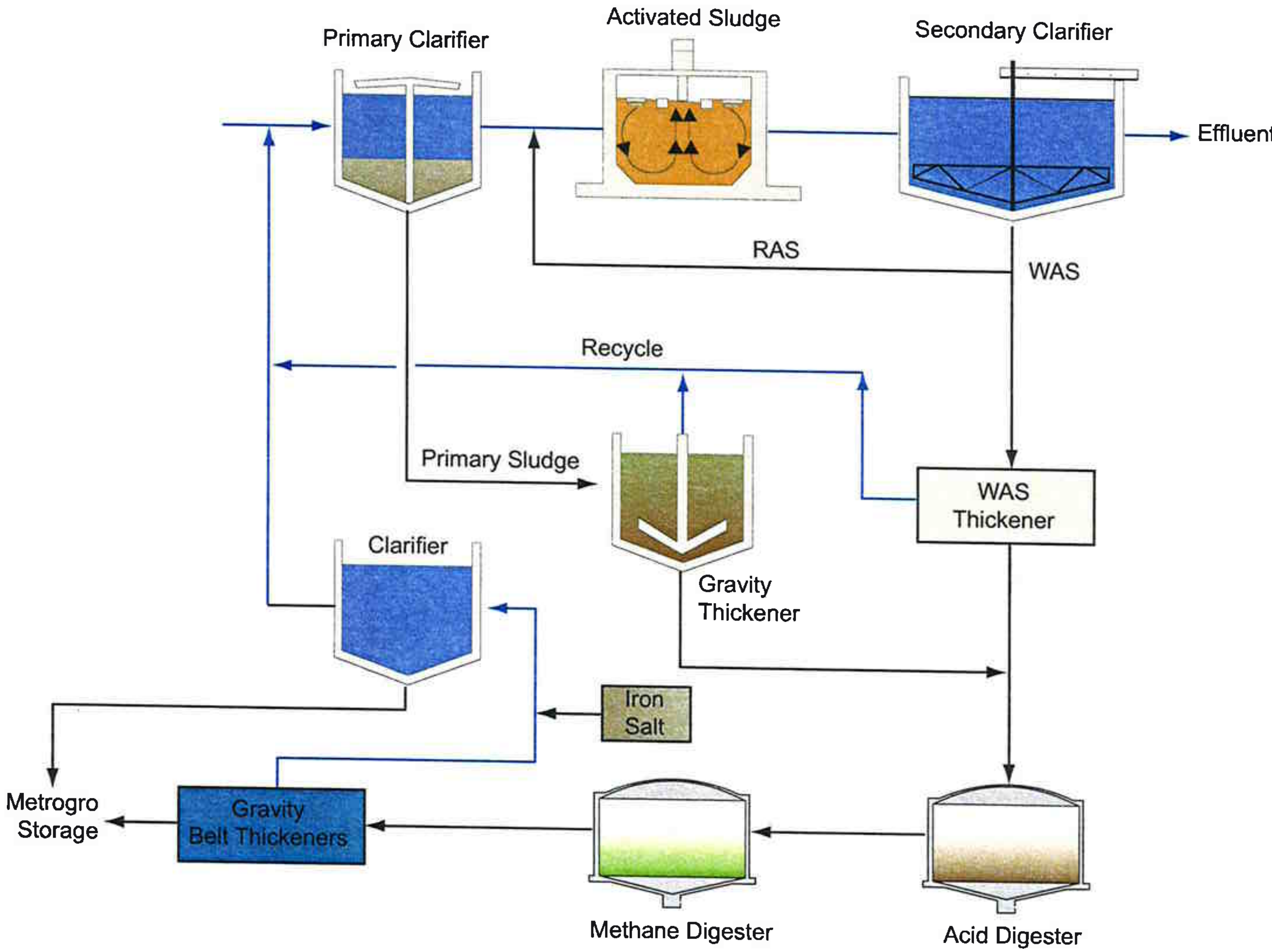

IRON SALT ADDITION DOWNSTREAM OF DIGESTION

FIGURE 6.7

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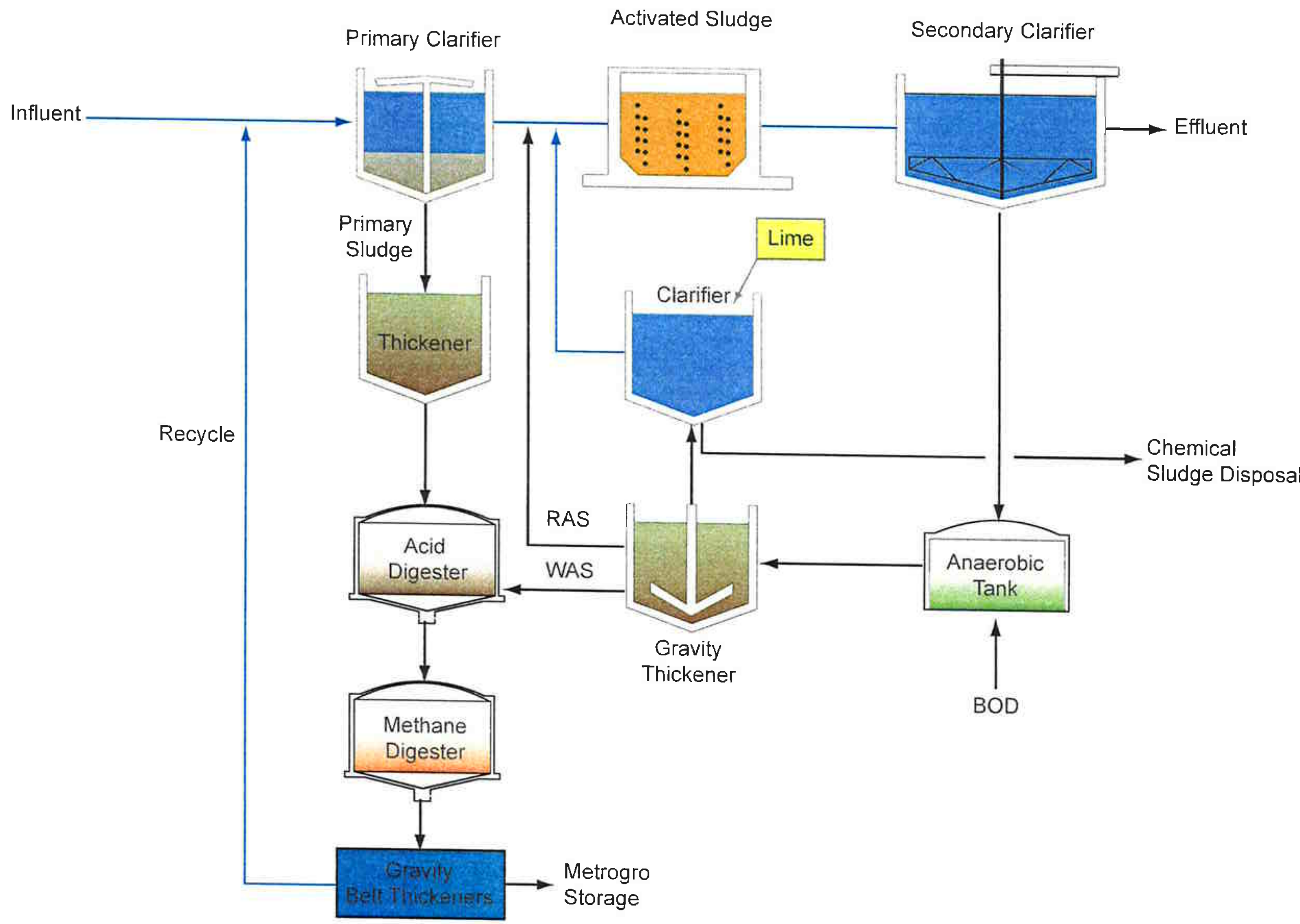

LIME ADDITION
(PHOSTRIP PROCESS)

FIGURE 6.8

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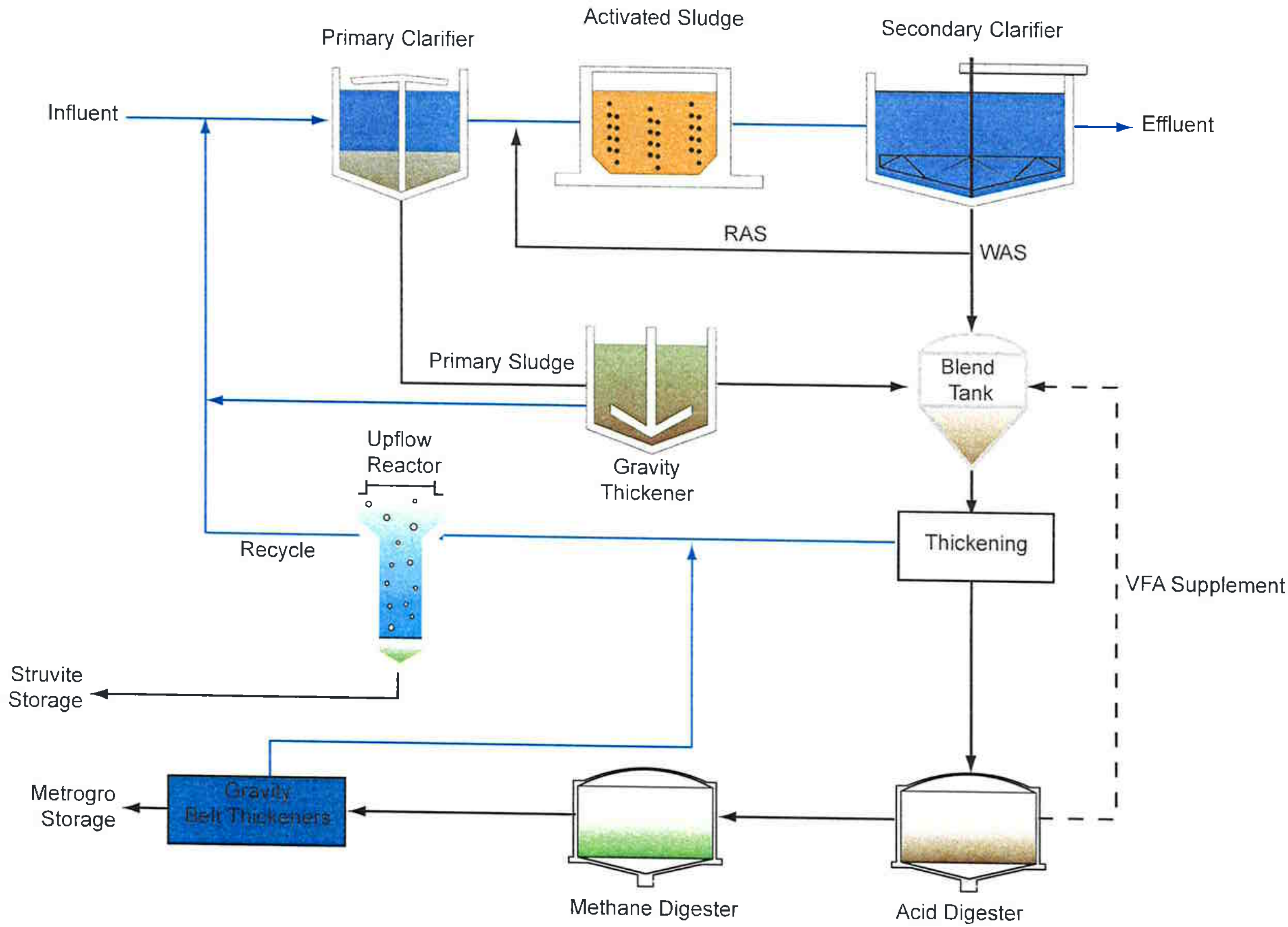

STRUVITE HARVESTING UPSTREAM OF DIGESTION

FIGURE 6.9

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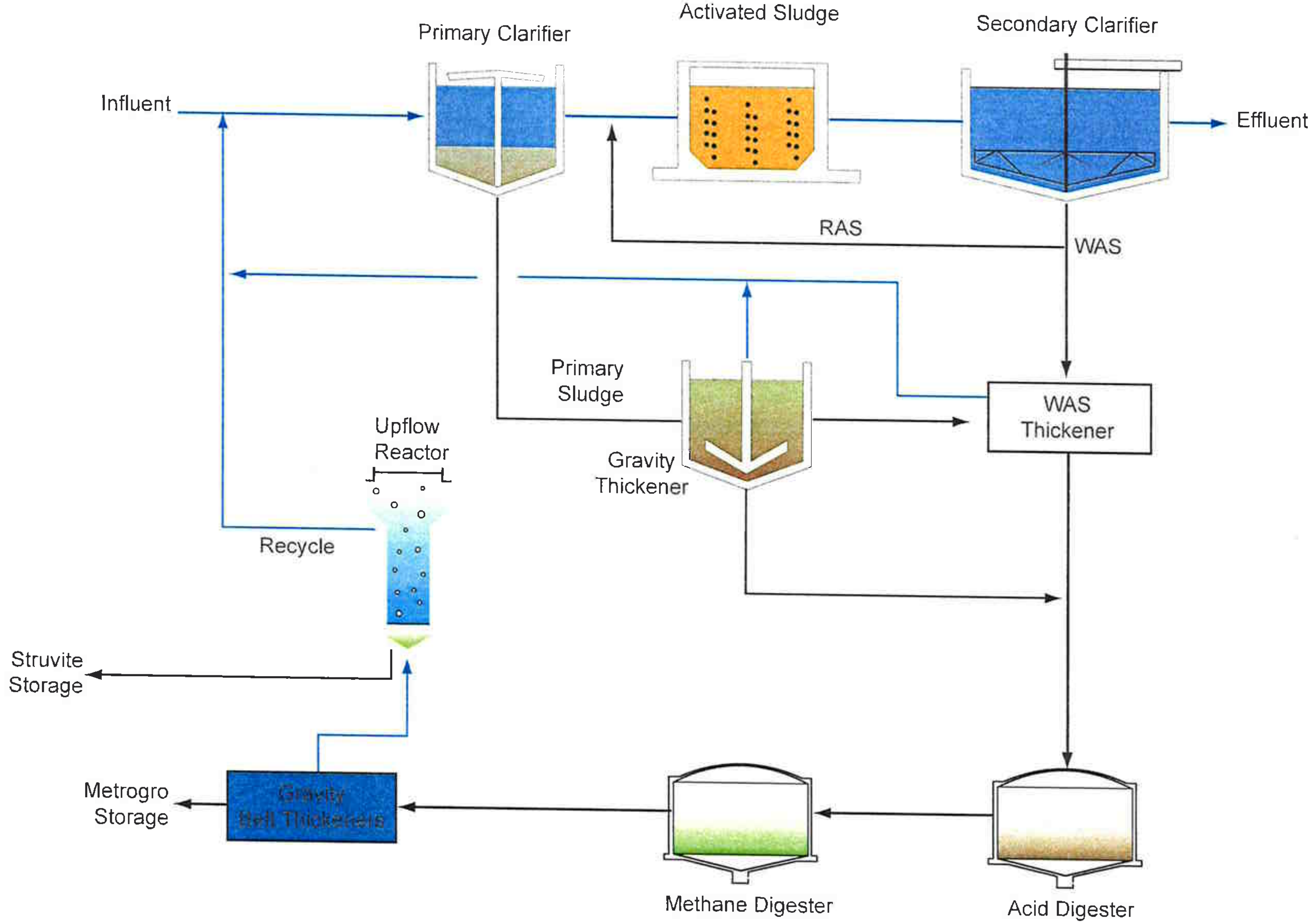

STRUVITE HARVESTING DOWNSTREAM OF DIGESTION

FIGURE 6.10

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6.0 Comparison of Struvite Mitigation Alternatives

Economic and non-economic comparisons of the struvite mitigation alternatives are presented in Tables 6.6 and 6.7, respectively.

Table 6.6
Economic Comparison of Struvite Mitigation Alternatives

Alternative	Present Worth Capital Cost	Present Worth O&M Cost	Total Present Worth Cost
Preventive maintenance of process piping and equipment (1)	-	\$1,300,000	\$1,300,000
Poly-Gone Lines	\$79,000	\$1,786,000	\$1,865,000
Iron Salt Addition Upstream of Digesters	\$845,000	\$17,962,000	\$18,807,000
Iron Salt Addition to Digesters	\$236,000	\$17,651,000	\$17,887,000
Struvite Harvesting Upstream of Digestion(2)	\$19,923,000	\$2,815,000(4)	\$22,738,000
Struvite Harvesting Downstream of Digestion(3)	\$9,021,000	\$1,624,000(4)	\$10,645,000

Notes:

(1) Based on information provided by the MMSD.

(2) Based on Ostara proposal, System 2 costs

(3) Based on Ostara proposal, System 1 costs

(4) Includes credit for revenue share of fertilizer sales; excludes credit for reduction in iron salt usage.

Table 6.7 Struvite Mitigation Alternatives Summary							
Alternative	**Reduces P loading to main treatment**	**Mitigation of Digester Struvite**	**Low operational complexity**	**Reduction in P content of Metrgro**	**Phosphorus Recovery**	**Proven Technology**	**Additional Operational Considerations**
Poly-Gone Lines	X	X	X			X	Patented chemical. Unknown impact on effluent Total P.
Iron Salt Addition Upstream of Digestion	X	X	X			X	Impact on effluent chloride permit.
Iron Salt Addition to Digesters	X	X	X			X	Impact on effluent chloride permit. Vivianite formation. Hydrogen sulfide removal.
Struvite Harvesting Upstream of Digestion	X	X		X	X		Sensitive to wastewater chemical characteristics
Struvite Harvesting Downstream of Digestion	X			X	X		Sensitive to wastewater chemical characteristics

7.0 Recommended Alternatives

The cost to install and own a phosphorus recovery (struvite harvesting) system is significant. The operating costs and removal rates are still not industry standard. There are two alternatives to provide a phosphorus recovery system at the NSWWTP. One is to establish a leasing agreement with a phosphorus recovery system to provide a turnkey system with a 5-year contract and 5-year extension. The second may be to purchase the equipment outright and provide for strict performance guaranties in the form of deductions from a retainer to ensure process costs. The chemical costs of struvite harvesting are offset by fertilizer sales that are subject to market conditions. Given that phosphorus is a finite resource derived from mining, the long-term outlook for phosphorus is that it will continue to grow in value.

Removal of the phosphorus as a metal salt may be done without the "phosphorus recovery". This process results in a chemical sludge that is disposed of by adding it to the sludge as it leaves the facility. Due to pending environmental regulations relating to the land application of phosphorus, the alternative of dewatering a chemical sludge and disposing of it with the Metrogro until a more environmentally sustainable practice can be identified will result in a lower capital cost than the phosphorus recovery systems.

APPENDIX A
DETAIL COST ESTIMATES

Table 1. Summary
Economic Comparison of Struvite Mitigation Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Struvite Mitigation Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Poly-Gone Lines	$79,000	$1,786,000	$0	$1,865,000
Iron Salt Addition Upstream of Digesters	$845,000	$16,660,000	$1,302,000	$18,807,000
Iron Salt Addition to Digesters	$236,000	$16,349,000	$1,302,000	$17,887,000
Struvite Harvesting Upstream of Digestion	$19,923,000	$2,815,000	$0	$22,738,000
Struvite Harvesting Downstream of Digestion	$9,021,000	$1,624,000	$0	$10,645,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table 2
Economic Comparison of Digestion Alternatives
Poly-Gone Lines

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Poly-Gone Lines Addition							
One storage tank 1000 gal		$ 3,000	20	$ -	$ -	$ -	
Two (2) chem feeders		$ 5,000	20		$ -	$ -	
Building floor space allocation		$ 37,500	40	$ -	$ 18,750	$ -	150 sf at $250/sf
Site Work	8%	$ 4,000	40	$ -	$ 2,000	$ -	
Mechanical Process Piping	10%	$ 5,000	40	$ -	$ 3,000	$ -	
Instrumentation and Control	7%	$ 3,000	20	$ -	$ -	$ -	
Electrical	8%	$ 4,000	20	$ -	$ -	$ -	
Subtotal		$ 61,500		$ -	$ 23,750	$ -	
Allowance for Undefined Design Details	25%	$ 15,000		$ -			
Total Construction Cost		$ 76,500		$ -			
Engineering, Legal and Administrative	15%	$ 11,000		$ -			
Total		$ 87,500		$ -	$ 23,750	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 88,000		$ -	$ 9,000	$ -	
Annual O & M Cost							
Labor		$ 1,716		$ 1,716			
Energy (electrical and thermal)		$ 21,178		$ 21,178			
Chemicals		$ 100,210		$ 145,602			
Hauling		$ -		$ -			
Maintenance		$ 1,300		$ 1,300			1.5% of Construction Total
Total Annual O & M Cost		$ 124,404		$ 169,796			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 966,000		$ 820,000			
Total Present Worth Capital Cost		$ 79,000					
Total Present Worth O&M Cost		$ 1,786,000					
Total Present Worth		**$ 1,865,000**					

TABLE 3 - ALTERNATE NO.1 - POLY-GONE LINES O&M

2010			2030		
bor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	1	hr/wk	Hours	1	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$1,716.00	$/yr	Annual	$1,716.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors			# Thermophilic Reactors		
Cost	$1,900	per yr	Cost	$1,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges	0		# Centrifuges	0	
Cost	$19,278	per yr	Cost	$19,278	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2.5%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
al Power Cost	***$21,178***	***$/yr***	***Total Power Cost***	***$21,178***	***$/yr***
Chemical			**Chemical**		
Digester Feed Sludge			*Digester Feed Sludge*		
Sludge flow	236,068	gpd	Sludge flow	343,000	gpd
PGL Dosage Rate	1	gal/20k Gal	PGL Dosage Rate	1	gal/20k Gal
Cost of PGL	$23.26	$/gal PGL	Cost of PGL	$23.26	$/gal PGL
Application rate	365	#/year	Application rate	365	#/year
Application duration	1	days/application	Application duration	1	days/application
Cost	$100,210	$/yr	Cost	$145,602	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$100,210***	***$/yr***	***Total Chemical Cost***	***$145,602***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table 4
Economic Comparison of Digestion Alternatives
Iron Salt Addition Upstream of Digestion

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Blend Tank Modifications							
Two (2) 10 hp submersible mixers		$ 150,000	20		$ -	$ -	$75K each
Tank modifications		$ 100,000	20		$ -	$ -	
Chemical clarifer modifications							
Tank modifications		$ 100,000	20	$ -	$ -	$ -	
Piping modifications / accessories		$ 100,000	20	$ -	$ -	$ -	
Modifications to Sludge Dewatering							
None			20	$ -	$ -	$ -	Use existing
Site Work	8%	$ 36,000	40	$ -	$ 18,000	$ -	
Mechanical Process Piping	10%	$ 45,000	40	$ -	$ 22,500	$ -	
Instrumentation and Control	7%	$ 32,000	20	$ -	$ -	$ -	
Electrical	8%	$ 36,000	20	$ -	$ -	$ -	
Subtotal		$ 599,000		$ -	$ 40,500	$ -	
Allowance for Undefined Design Details	25%	$ 150,000		$ -			
Total Construction Cost		$ 749,000		$ -			
Engineering, Legal and Administrative	15%	$ 112,000		$ -			
Total		$ 861,000		$ -	$ 40,500	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 861,000		$ -	$ 16,000	$ -	
Annual O & M Cost							
Labor		$ 3,432		$ 3,432			
Energy (electrical and thermal)		$ 36,601		$ 36,601			
Chemicals		$ 1,098,363		$ 1,545,604			
Hauling		$ 83,419		$ 135,556			
Maintenance		$ 12,900		$ 12,900			1.5% of Total
Total Annual O & M Cost		$ 1,234,715		$ 1,734,093			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 9,592,000		$ 8,370,000			
Total Present Worth Capital Cost		$ 845,000					
Total Present Worth O&M Cost		$ 17,962,000					
Total Present Worth		**$ 18,807,000**					

TABLE 5 - ALTERNATE NO.2 - IRON SALT ADDITION UPSTREAM OF ANAEROBIC DIGESTERS O&M

2010			2030		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	2	hr/wk	Hours	2	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$3,432.00	$/yr	Annual	$3,432.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
Cambi THP System			Cambi THP System		
Cost	$1,900	per yr	Cost	$1,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	2		# DAFs	2	
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$34,701	per yr	Cost	$34,701	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 4.6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Chemical Sludge Addnl	3,680	lbs/d	Chemical Sludge Addnl	5,980	lbs/d
Digested Sludge Production		gpd	Digested Sludge Production		gpd
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$36,601***	***$/yr***	***Total Power Cost***	***$36,601***	***$/yr***
Chemical			**Chemical**		
Struvite Mitigation			*Struvite Mitigation*		
Sludge flow	236,068	gpd	Sludge flow	343,000	gpd
Iron dosage rate	2500	lbs Fe/day	Iron dosage rate	3500	lbs Fe/day
Ferric chloride dosage rate	7,184	lbs FeCl3/day	Ferric chloride dosage rate	10,057	lbs FeCl3/day
Unit price of FeCl3	$811	$/dry ton FeCl3	Unit price of FeCl3	$811	$/dry ton FeCl3
Application rate	365	#/year	Application rate	365	#/year
Application duration	1	days/application	Application duration	1	days/application
Cost	$1,063,272	$/yr	Cost	$1,488,581	$/yr
Effluent Addnl Chem Sludge Thickening / Dewatering			*Effluent Addnl Chem Sludge Thickening / Dewatering*		
Addnl Chem Sludge	3,680	lbs/day	Addnl Chem Sludge	5,980	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$35,091		Cost	$57,023	
Total Chemical Cost	***$1,098,363***	***$/yr***	***Total Chemical Cost***	***$1,545,604***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	20	%	Metrogro cake concentration	20	%
Gallons liquid per day	5,516	gpd	Gallons liquid per day	8,963	gpd
Dewatered Sludge per day	2.7	cu yds/d	Dewatered Sludge per day	4.4	cu yds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cu yd	Dewatered Sludge Hauling Cost	$13.00	$/cu yd
Total Hauling Cost	***$83,419***	***$/yr***	***Total Hauling Cost***	***$135,556***	***$/yr***

Table 6
Economic Comparison of Digestion Alternatives
Iron Salt Addition to Digesters

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Ferric Chloride Addition							
Piping modifications		$ 100,000	20	$ -	$ -	$ -	
Accessories		$ 25,000	20	$ -	$ -	$ -	
Site Work	8%	$ 10,000	40	$ -	$ 5,000	$ -	
Mechanical Process Piping	10%	$ 13,000	40	$ -	$ 6,500	$ -	
Instrumentation and Control	7%	$ 9,000	20	$ -	$ -	$ -	
Electrical	8%	$ 10,000	20	$ -	$ -	$ -	
Subtotal		$ 167,000		$ -	$ 11,500	$ -	
Allowance for Undefined Design Details	25%	$ 42,000		$ -			
Total Construction Cost		$ 209,000		$ -			
Engineering, Legal and Administrative	15%	$ 31,000		$ -			
Total		$ 240,000		$ -	$ 11,500	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 240,000		$ -	$ 4,000	$ -	
Annual O & M Cost							
Labor		$ 3,432		$ 3,432			
Energy (electrical and thermal)		$ 21,178		$ 21,178			
Chemicals		$ 1,098,363		$ 1,545,604			
Hauling		$ 83,419		$ 135,556			
Maintenance		$ 3,600		$ 3,600			1.5% of Total
Total Annual O & M Cost		$ 1,209,993		$ 1,709,370			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 9,400,000		$ 8,251,000			
Total Present Worth Capital Cost		$ 236,000					
Total Present Worth O&M Cost		$ 17,651,000					
Total Present Worth		**$ 17,887,000**					

TABLE 7 - ALTERNATE NO.3 - IRON SALT ADDITION TO ANAEROBIC DIGESTERS O&M					
2010			**2030**		
Labor					
Description					
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	2	hr/wk	Hours	2	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$3,432.00	$/yr	Annual	$3,432.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
Steam Injector System			Steam Injector System		
Cost	$1,900	per yr	Cost	$1,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs			# DAFs		
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
Flow to Centrifuges		mgd @4.6%	Flow to Centrifuges		mgd @4.6%
# Centrifuges in service			# Centrifuges		
Cost	$19,278	per yr	Cost	$19,278	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Cambi THP		lbs/d	Solids Flow to Cambi THP		lbs/d
Solids Flow to Cambi THP		gpd @ 17%	Solids Flow to Cambi THP		gpd @ 17%
Chemical Sludge Addnl	3,680	lbs/d	Chemical Sludge Addnl	5,980	lbs/d
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd	Digested Sludge Production		gpd
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$21,178***	***$/yr***	***Total Power Cost***	***$21,178***	***$/yr***
Chemical			**Chemical**		
Struvite Mitigation			*Struvite Mitigation*		
Sludge flow	236,068	gpd	Sludge flow	343,000	gpd
Iron dosage rate	2500	lbs Fe/day	Iron dosage rate	3500	lbs Fe/day
Ferric chloride dosage rate	7,184	lbs FeCl3/day	Ferric chloride dosage rate	10,057	lbs FeCl3/day
Unit price of FeCl3	$811	$/dry ton FeCl3	Unit price of FeCl3	$811	$/dry ton FeCl3
Application rate	365	#/year	Application rate	365	#/year
Application duration	1	days/application	Application duration	1	days/application
Cost	$1,063,272	$/yr	Cost	$1,488,581	$/yr
Effluent Addnl Chem Sludge Thickening / Dewatering			*Effluent Addnl Chem Sludge Thickening / Dewatering*		
Addnl Chem Sludge	3,680	lbs/day	Addnl Chem Sludge	5,980	lbs/day
GBT Polymer Rate	12	lbs/DT	GBT Polymer Rate	12	lbs/DT
Centrifuge Polymer Rate	40	lbs/DT	Centrifuge Polymer Rate	40	lbs/DT
% GBT	75%		% GBT	75%	
% Centrifuge	25%		% Centrifuge	25%	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$35,091		Cost	$57,023	
Total Chemical Cost	***$1,098,363***	***$/yr***	***Total Chemical Cost***	***$1,545,604***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration	6	%	Metrogro liquid concentration	6	%
Metrogro cake concentration	20	%	Metrogro cake concentration	20	%
Gallons liquid per day	5,516	gpd	Gallons liquid per day	8,963	gpd
Dewatered Sludge per day	2.7	cu yds/d	Dewatered Sludge per day	4.4	cuyds/d
Liquid Hauling Cost	$0.035	$/gal	Liquid Hauling Cost	$0.035	$/gal
Dewatered Sludge Hauling Cost	$13.00	$/cuyd	Dewatered Sludge Hauling Cost	$13.00	$/cuyd
Total Hauling Cost	***$83,419***	***$/yr***	***Total Hauling Cost***	***$135,556***	***$/yr***

Table 8
Economic Comparison of Digestion Alternatives
Struvite Harvesting Upstream of Digestion (Ostara)

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Blend Tank Modifications							
Two (2) 10 hp submersible mixers		$ 150,000	20		$ -	$ -	$75K each
Tank modifications		$ 100,000	20		$ -	$ -	
Chemical clarifer modifications							
Tank modifications		$ 100,000	20	$ -	$ -	$ -	
Piping modifications / accessories		$ 100,000	20	$ -	$ -	$ -	
Construct Ostara System							
Ostara System		$ 9,790,000	20	$ -	$ -	$ -	Ostara proposal
Ostara Building		$ 1,935,000	40	$ -	$ 967,500	$ -	12900 sqft @ $150/sf (pre-engineered)
Tunnel Extension		$ 400,000	40	$ -	$ 200,000	$ -	200 feet @ $2000/ft
Site Work	8%	$ 1,006,000	40	$ -	$ 503,000	$ -	
Mechanical Process Piping	10%	$ 1,258,000	40	$ -	$ 629,000	$ -	
Instrumentation and Control	7%	$ 880,000	20	$ -	$ -	$ -	
Electrical	8%	$ 1,006,000	20	$ -	$ -	$ -	
Subtotal		$ 16,725,000		$ -	$ 2,299,500	$ -	
Allowance for Undefined Design Details	25%	$ 2,223,000		$ -			Ostara @ 5%
Total Construction Cost		$ 18,948,000		$ -			
Engineering, Legal and Administrative	15%	$ 1,863,000		$ -			Ostara @ 5%
Total		$ 20,811,000		$ -	$ 2,299,500	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 20,811,000		$ -	$ 888,000	$ -	
Annual O & M Cost							
Labor		$ 68,640		$ 85,800			
Energy (electrical and thermal)		$ 85,301		$ 107,508			
Chemicals		$ (218,400)		$ (321,150)			
Hauling		$ -		$ -			
Maintenance		$ 312,200		$ 312,200			1.5% of Total
Total Annual O & M Cost		$ 247,741		$ 184,358			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 1,925,000		$ 890,000			
Total Present Worth Capital Cost		$ 19,923,000					
Total Present Worth O&M Cost		$ 2,815,000					
Total Present Worth		**$ 22,738,000**					

TABLE 9 - ALTERNATE NO.4 - STRUVITE HARVESTING UPSTREAM OF DIGESTION O&M

2010		2030	
Labor		**Labor**	
Description	Estimated labor costs from 2010 to 2020	Description	Estimated labor costs from 2020 to 2030
Rate	$33.00 $/hr	Rate	$33.00 $/hr
Hours	40 hrs/wk	Hours	50 hrs/wk
Duration	52 wk/yr	Duration	52 wk/yr
Annual	$68,640.00 $/yr	Annual	$85,800.00 $/yr
Power and Heating		**Power and Heating**	
Digesters		*Digesters*	
# Mesophilic Reactors		# Mesophilic Reactors	
# Thermophilic Reactors		# Thermophilic Reactors	
Ostara System	1	Ostara System	1
Cost	$50,600 per yr	Cost	$72,807 per yr
Influent Sludge Thickening		*Influent Sludge Thickening*	
Flow to Thickening	mgd @1.5%	Flow to Thickening	mgd @1.6%
# DAFs	2	# DAFs	2
# Gravity Thickeners	2	# Gravity Thickeners	2
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$34,701 per yr	Cost	$34,701 per yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Solids Flow to Digestion	lbs/d	Solids Flow to Digestion	lbs/d
Solids Flow to Digestion	gpd @ 4.6%	Solids Flow to Digestion	gpd @ 4.6%
Digested Sludge Production	lbs/d	Digested Sludge Production	lbs/d
Digested Sludge Production	gpd @2%	Digested Sludge Production	gpd @2%
% to GBT		% GBT	
Digested Sludge Production	gpd@ 5%	Digested Sludge Production	gpd@ 5%
% to Centrifuge		% Centrifuge	
# Gravity Belt Thickeners		# Gravity Belt Thickeners	
# Centrifuges		# Centrifuges	
Cost	$0 per yr	Cost	$0 per yr
Thermal Treatment		*Thermal Treatment*	
Digested Sludge Production	lbs/day	Digested Sludge Production	lbs/day
# Belt Dryers		# Belt Dryers	
Cost	$0 per yr	Cost	$0 per year
Total Power Cost	***$85,301 $/yr***	***Total Power Cost***	***$107,508 $/yr***
Chemical		**Chemical**	
Influent Sludge Thickening		*Influent Sludge Thickening*	
Raw Sludge	lbs/d	Raw Sludge	lbs/d
Gravity Thickener Polymer Rate	lbs/DT	Gravity Thickener Polymer Rate	lbs/DT
DAF Polymer Rate	lbs/DT	DAF Polymer Rate	lbs/DT
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
# DAF		# DAF	
# Gravity Thickeners		# Gravity Thickeners	
# GBT		# GBT	
# Centrifuge		# Centrifuge	
Cost of Polymer	$/lb Polymer	Cost of Polymer	$/lb Polymer
Cost	$/yr	Cost	$/yr
Effluent Sludge Thickening / Dewatering		*Effluent Sludge Thickening / Dewatering*	
Digested Sludge	lbs/day	Digested Sludge	lbs/day
GBT Polymer Rate	lbs/DT	GBT Polymer Rate	lbs/DT
Centrifuge Polymer Rate	lbs/DT	Centrifuge Polymer Rate	lbs/DT
% GBT		% GBT	
% Centrifuge		% Centrifuge	
Ostara Revenue Share	($218,400) $/yr	Ostara Revenue Share	($321,150) $/yr
Cost	-$218,400	Cost	-$321,150
Total Chemical Cost	***-$218,400 $/yr***	***Total Chemical Cost***	***-$321,150 $/yr***
Hauling		**Hauling**	
Metrogro liquid concentration	%	Metrogro liquid concentration	%
Metrogro cake concentration	%	Metrogro cake concentration	%
Gallons liquid per day	gpd	Gallons liquid per day	gpd
Dewatered Sludge per day	cu yds/d	Dewatered Sludge per day	cu yds/d
Liquid Hauling Cost	$/gal	Liquid Hauling Cost	$/gal
Dewatered Sludge Hauling Cost	$/cu yd	Dewatered Sludge Hauling Cost	$/cu yd
Total Hauling Cost	***$0 $/yr***	***Total Hauling Cost***	***$0 $/yr***

Table 10
Economic Comparison of Digestion Alternatives
Struvite Harvesting Downstream of Digestion

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Blend Tank Modifications							
Two (2) 10 hp submersible mixers		$ 150,000	20		$ -	$ -	$75K each
Tank modifications		$ 100,000	20		$ -	$ -	
Chemical clarifer modifications							
Tank modifications		$ 100,000	20	$ -	$ -	$ -	
Piping modifications / accessories		$ 100,000	20	$ -	$ -	$ -	
Construct Ostara System							
Ostara System		$ 3,510,000	20	$ -	$ -	$ -	Ostara proposal
Ostara Building		$ 675,000	40	$ -	$ 337,500	$ -	4500 sqft @ $150/sf (pre-engineered)
Tunnel Extension		$ 400,000	40	$ -	$ 200,000	$ -	200 feet @ $2000/ft
Site Work	8%	$ 403,000	40	$ -	$ 201,500	$ -	
Mechanical Process Piping	10%	$ 504,000	40	$ -	$ 252,000	$ -	
Instrumentation and Control	7%	$ 352,000	20	$ -	$ -	$ -	
Electrical	8%	$ 403,000	20	$ -	$ -	$ -	
Subtotal		$ 6,697,000		$ -	$ 991,000	$ -	
Allowance for Undefined Design Details	25%	$ 1,539,000		$ -			Ostara @ 5%
Total Construction Cost		$ 8,236,000		$ -			
Engineering, Legal and Administrative	15%	$ 1,168,000		$ -			Ostara @ 5%
Total		$ 9,404,000		$ -	$ 991,000	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 9,404,000		$ -	$ 383,000	$ -	
Annual O & M Cost							
Labor		$ 17,160		$ 22,308			
Energy (electrical and thermal)		$ 34,078		$ 37,948			
Chemicals		$ (59,700)		$ (78,300)			
Hauling		$ -		$ -			
Maintenance		$ 141,100		$ 141,100			1.5% of Total
Total Annual O & M Cost		$ 132,638		$ 123,056			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 1,030,000		$ 594,000			
Total Present Worth Capital Cost		$ 9,021,000					
Total Present Worth O&M Cost		$ 1,624,000					
Total Present Worth		**$ 10,645,000**					

TABLE 11 - ALTERNATE NO.5 - STRUVITE HARVESTING DOWNSTREAM OF DIGESTION O&M

2010			2030		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	10	hr/wk	Hours	13	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$17,160.00	$/yr	Annual	$22,308.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors			# Thermophilic Reactors		
Ostara System	1		Open Cell Reactor	1	
Cost	$14,800	per yr	Cost	$18,670	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening		mgd @1.5%	Flow to Thickening		mgd @1.6%
# DAFs			# DAFs		
# Gravity Thickeners	2		# Gravity Thickeners	2	
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$19,278	per yr	Cost	$19,278	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 4.6%	Solids Flow to Digestion		gpd @ 4.6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2%	Digested Sludge Production		gpd @2%
% to GBT			% GBT		
Digested Sludge Production		gpd@ 5%	Digested Sludge Production		gpd@ 5%
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Lime Pasterization			*Lime Pasterization*		
Digested Sludge Production	0	lbs/day	Digested Sludge Production	0	lbs/day
Cost	$0	per yr	Cost	$0	per year
Total Power Cost	***$34,078***	***$/yr***	***Total Power Cost***	***$37,948***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Raw Sludge		lbs/d	Raw Sludge		lbs/d
Gravity Thickener Polymer Rate		lbs/DT	Gravity Thickener Polymer Rate		lbs/DT
DAF Polymer Rate		lbs/DT	DAF Polymer Rate		lbs/DT
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# GBT			# GBT		
# Centrifuge			# Centrifuge		
Cost of Polymer		$/lb Polymer	Cost of Polymer		$/lb Polymer
Cost	$0	$/yr	Cost	$0	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Ostara Revenue Share	($59,700)	$/yr	Ostara Revenue Share	($78,300)	$/yr
Cost	-$59,700		Cost	-$78,300	
Total Chemical Cost	***-$59,700***	***$/yr***	***Total Chemical Cost***	***-$78,300***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cu yds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cu yd	Dewatered Sludge Hauling Cost		$/cu yd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

APPENDIX J

Technical Memorandum No. 7
Grease Receiving Facility

MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 7
GREASE RECEIVING FACILITY

Date: December 18, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate the addition of a new grease receiving facility at the Nine Springs Wastewater Treatment Plant (NSWWTP). This TM evaluates historical grease hauling data and the design elements for the proposed grease receiving facility including anticipated gas production from grease, required storage tank volume, and tie-in configuration with the existing digestion facility.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- Based on the 2030 projected flows and loads, the proposed digestion facilities will have sufficient capacity for grease co-digestion at maximum flow conditions with all units in service. At 2030 conditions, the NSWWTP must stop receiving grease trap waste when an East Complex methane digester is out of service. Alternatively, the grease trap waste could be diverted to the septage receiving facility and discharged to the headworks until the digester is back in service.

- The conversion of the existing 20,000 gal whey wells to storage tanks is recommended to provide temporary storage of grease. The use of the whey well facility will result in lower construction costs and smaller footprint requirements. Major components of the grease receiving facility include a grease inlet grinding system, heating and recirculation systems, digester feed system, and a truck-unloading pad.

- Based on 2008 grease hauling data, the proposed grease receiving station will have sufficient capacity and redundancy to receive all the grease hauled to NSWWTP and high strength wastes from food processing industries.

- Direct addition of grease to the anaerobic digesters will increase the digester gas available for the co-generation facilities and decrease the lipids loading to the aeration basins. Lower lipid loadings will result in a decrease in the aeration requirements and the food source for *Microthrix* filaments.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements, maintains the current biosolids land application programs, and decreases foaming and struvite buildup in the anaerobic digesters. TM-03A identified multi-stage acid phase digestion and conventional digestion with Cambi THP as potential digestion alternatives for the NSWWTP.

The MMSD has received septage and grease at the NSWWTP since 1986. Haulers truck septage and grease trap contents to the facility and discharge them to screen influent channel at the headworks. Addition of grease to the headworks has often caused maintenance and operational problems due to rapid blinding of the fine screens. The NSWWTP also receives high strength wastes, such as ice cream waste and digested animal tissues. These wastes are trucked to the facility, discharged to the whey wells, and pumped directly to the anaerobic digesters.

4.0 Grease Co-Digestion Evaluation

Grease collected from food service establishments is readily biodegradable. Direct addition of grease to the anaerobic digesters for co-digestion with primary sludge and waste activated sludge (WAS) results in increased biogas production and increased volatile solids reduction (VSR). Removing grease from the collection system and the plant influent reduces the grease loading to the liquid treatment train and consequently results in less blinding of the fine screens at the headworks, less scum pumping volumes, decreased organic loadings to the secondary treatment, and less substrate availability for *Microthrix*. Adequate design and operation of the grease receiving facilities are critical to prevent clogging of the sludge piping, digester foaming, and the formation of a persistent scum layer in the digesters and grease storage tanks.

Successful full-scale grease co-digestion operations in the U.S. include the East Bay Municipal Utilities District (Oakland, CA), the Fresno/Clovis Regional Water Recycling Facility (Fresno, CA), the City of Riverside (Riverside, CA), the Waco Metropolitan Area Sewerage District (Waco, TX), and the South Cross Bayou WWTP (Pinellas County, FL).

4.1 Data Analysis

Currently, there are 13 companies that truck grease trap contents to the NSWWTP. During 2008, the daily grease-hauling volumes varied from less than 100 gallons per day to 19,100 gallons per day with an average of 2,100 gallons (per hauling day). In addition to the grease trap wastes, the WWTP receives four 3,500-gal truckloads per month of ice cream waste and one 6,000-gal truckload of digested animal tissues per month. Table 7.1 presents a summary of the hauling volumes and the composition of the high strength wastes hauled to the NSWWTP in 2008. A graphical representation of the grease hauling volumes and the 1999-2008 historical grease trap characteristics is presented in Appendices A and B.

Table 7.1
High Strength Waste Average Data

Parameter	Grease Trap Content (1)	Ice Cream Waste (2)	Animal Tissue Waste (3)
Hauling Frequency	4-5 days/week	1 day per week	1 day per month
Volume, gal per hauling day	2,000 (4)	3,500	6,000
TS, %	5.2	30.6	18.4
VS, %	NA	87.8	63.0
BOD, mg/L	32,200	135,900	88,200
TKN, mg/L	1,400	4,300	12,600
TP, mg/L	120	830	630

Notes:
(1) Based on 2008 average grease-hauling data.
(2) Based on 2002 Schoeps waste data.
(3) Based on 2004 Wisconsin Veterinary Diagnostic Laboratory waste data.
(4) Annual volume of 455,000 gallons averaged over 215 days.

Based on the reported grease trap waste characteristics, co-digestion of these materials in the NSWWTP digestion facility can provide high biochemical oxygen demand (BOD) loadings without considerably increasing the ammonia and phosphorus concentrations in the digesters. The ice cream and animal tissue wastes are currently received in the existing whey wells and fed directly to the digesters.

4.2 Anaerobic Digestion Capacity Evaluation

Table 7.2 presents a summary of the residual capacity in the anaerobic digesters for grease co-digestion. Detailed information on the treatment capacity for the NSWWTP digestion facility with different technologies is presented in TM-03A Anaerobic Digester Process Evaluation.

Under multi-stage acid-phase digestion operation at 2030 annual average conditions with the largest digester out of service the estimated residual capacity for co-digestion at the NSWWTP is negligible. However, the NSWWTP could stop receiving grease trap waste while a West Complex methane digester is out of service. Alternatively, the grease trap waste could be diverted to the septage receiving facility and discharged to the headworks until the digester is back in service. For this reason, the estimated 2030 residual capacity for co-digestion is 25,100 gal per day and was based on maximum month conditions with all units in service.

Based on the estimated residual capacity for co-digestion and the reported grease-hauling data, the proposed anaerobic digestion facility will have adequate capacity to receive all the grease trap waste that is currently hauled to the NSWWTP.

Table 7.2 Acid-Phase Co-Digestion Capacity Evaluation				
Process Parameter	Current Conditions		2030 Conditions	
	Average	Maximum Month	Average	Maximum Month
Digester Feed Flow, gpd				
Maximum Capacity Feed	254,000	344,000	344,500	434,000
Thickened Sludge (1)	236,100	283,500	343,100	408,200
Schoeps and WVDL Waste (2)	700	700	700	700
Residual Capacity (3)	17,200	59,800	700	25,100
Digester Feed Volatile Solids, ppd				
Thickened Sludge (4)	80,800	97,000	117,400	139,700
Schoeps and WVDL Waste (2)	1,200	1,200	1,200	1,200
Capacity for Grease Trap Waste (5)	6,800	23,700	277	9,900
Total Feed	88,800	121,900	118,900	150,900
Acid Digester				
Digester Volume, MG	0.4 (6)	0.8 (7)	0.4 (6)	0.8 (7)
VS Loading Rate, lbs VS/cfd	1.7	1.1	2.2	1.4
Hydraulic Retention Time, days	1.6	2.3	1.2	1.8
First-Stage Methane Digesters				
Digester Volume, MG	3.04 (6)	4.12 (7)	4.12 (6)	5.20 (7)
Hydraulic Retention Time, days	12.0	12.0	12.0	12.0

Notes:
(1) Assumes total solids concentration of 5.4 percent.
(2) Based on monthly hauling volumes averaged over 30 days.
(3) Based on a total solids concentration of 5 percent.
(4) Assumes volatile solids fraction of 76 percent.
(5) Assumes volatile solids fraction of 90 percent.
(6) Assumes largest unit out of service.
(7) Assumes all units in service.

4.3 Biogas Production from Grease Co-Digestion

Grease co-digestion can increase the digester gas production, reducing the dependence on outside sources of energy and helping to offset energy costs. Table 7.3 shows the estimated increase in digester gas production from the co-digestion of grease at the NSWWTP.

Table 7.3
Biogas Production Estimates

Parameter	Current Annual Average Conditions (1)	2030 Annual Average Conditions
Digester Volatile Solids Loading, ppd	80,800	117,400 (2)
Volatile Solids Reduced, ppd	52,500	76,300 (3)
Digester Gas Production, cfd	763,800	1,106,000 (4)
Average Grease Trap Loading, ppd	540 (5)	9,900 (6)
Additional Volatile Solids Reduced, ppd (7)	410	7,600
Additional Digester Gas Production, cfd (8)	8,200	152,000

Notes:
(1) Based on NSWWTP process and operations data for the period of 05/2007 to 05/2008
(2) Based on the projected 2030 values presented in TM No. 1.
(3) Based on a volatile solids concentration of 76 percent and a volatile solids reduction of 65 percent.
(4) Based on the 2007-2008 average gas production to VSR ratio of 14.5 cubic feet of gas per pound reduced.
(5) Based on the 2008 annual grease hauling volume averaged over 365 days.
(6) Assumes grease loading at maximum capacity.
(7) Assumes a volatile solids concentration of 90 percent and a volatile solids reduction of 85 percent.
(8) Based on 20 cubic feet of digester gas per pound of volatile solids reduced.

The co-digestion of the grease currently hauled to the NSWWTP can result in a digester gas production increase of approximately 1%. The net increase may be lower because a fraction of the grease trap waste that is currently dumped at the headworks is collected as scum and added to the digesters. If additional high strength organic waste is added to the digesters, the anaerobic facility could generate up to 152,000 cubic feet per day of additional digester gas, which represents 13% of the projected 2030 digester gas production.

5.0 Grease Receiving Facilities

Two alternatives were identified for the proposed grease receiving facility at the NSWWTP: (1) the construction of a new grease receiving station and (2) the retrofitting of existing whey receiving facility to receive grease trap contents. The major components of the proposed grease receiving facility include storage tanks (duty and standby), truck unloading pad, inlet grinder, tank recirculation and heating systems, digester feeding system, odor control system, wash down facilities, and other miscellaneous connections.

5.1 Grease Storage

Grease-receiving stations at utilities of similar size to the NSWWTP have one or more grease storage tanks with volumes ranging from 6,000 to 10,000 gallons. Based on the 2008 grease hauling data, two new 10,000-gallon tanks (one duty and one standby) can be provided to store grease and other high strength organic wastes. Alternatively, the existing 20,000 gal whey wells can be retrofitted to operate as grease storage tanks.

During 2008, the grease-hauling volumes per day varied from less than 100 gallons to 19,100 gallons with an average of 2,100 gallons (per hauling day). Based on the 2008 data, the storage capacity of a 10,000-gal storage tank would be exceeded one day per year. A 20,000 gal tank would have sufficient storage capacity for the peak day event. Based on the grease-hauling frequency and volumes, the use of the existing whey wells is preferred due to adequate capacity and lower construction costs. Rehabilitation of the whey wells will be required.

5.1.1 Tank Inlet

The grease-receiving facility includes a truck-unloading pad adjacent to the storage tanks. An unloading pump is typically provided to transfer the grease trap waste into the storage tanks. To protect downstream equipment, an inlet grinder will be provided to grind up debris and other materials collected in the grease traps. The inlet grinder flow rate will be designed to match the typical hauler truck unloading pump flow rate. The truck unloading pad will include plant water supply, drain, security camera, and a card reader station.

5.1.2 Heating and Recirculation

To avoid settling and stratification within the tank, the contents of the grease storage tanks will be continuously mixed. Because most of the installations will be underground or inside buildings, heat tracing is not necessary. To avoid potential problems associated with clogging of the piping with grease, heated digester sludge will be periodically circulated through the tanks.

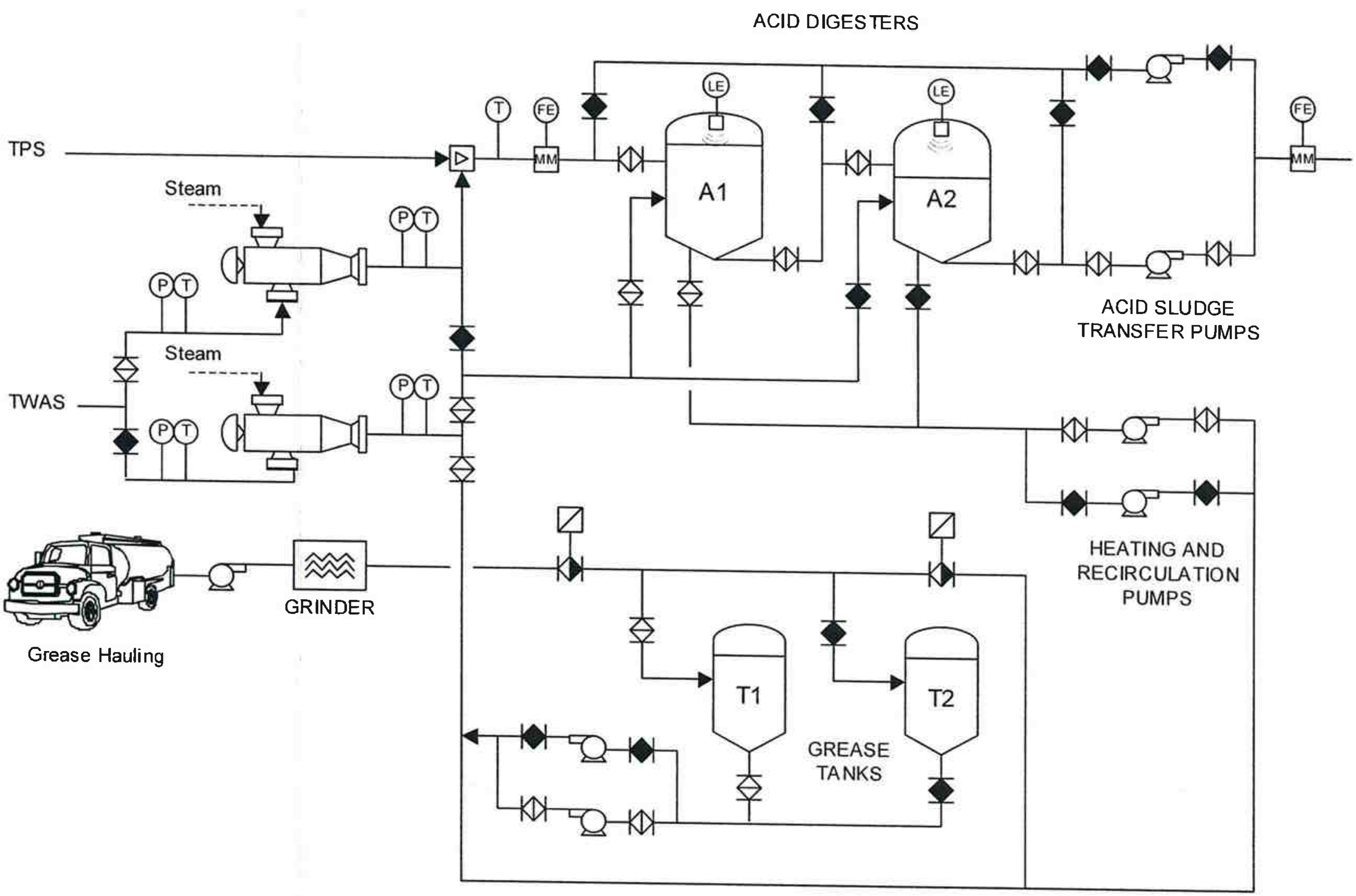
5.1.3 Odor Control

The installation of biofilters is recommended to manage potential odors from the grease storage tanks. Biofilters are good at removing the reduced sulfur compounds commonly associated with biosolids, but can also be designed to remove hydrogen sulfide. Auxiliary systems are limited to exhaust fans, a recirculation pump and a nutrient pump if plant water is not available. Activated carbon canisters will not be considered due previous experience with these units in the whey wells that resulted in frequent plugging of the canisters.

5.2 Digester Feed System

To obtain the maximum benefit from the organic materials introduced into the digester, the high strength organic materials must be quickly mixed with heated digester sludge. Proper feeding reduces the probability of scum layer formation from the stratification of grease and other hydrophobic materials. To accomplish adequate mixing, these materials are introduced into a digester sludge heating and recirculating line. The high temperature of the sludge maintains the fats, oils and grease as liquids and reduces their viscosity. To prevent grease accumulation, the grease storage tanks will be flushed with digester sludge after each grease load. A process schematic of the proposed grease receiving facility is presented in Figure 7.1.

Under acid-phase digestion mode, the grease tank contents would be fed to the acid digester sludge recirculation line. The high temperature and low pH prevents grease buildup in the piping. Low gas production helps to prevent the stratification of the grease in the acid digester. The high microbial activity in the acid digester promotes the grease degradation upstream of the methane digesters.



Note: Grease tank mixing and heating systems (pumps and grinders) not shown for clarity.

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GREASE CO-DIGESTION

FIGURE 7.1

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD

5.3 Preliminary Cost Estimate

A preliminary cost estimate for the grease receiving facility is presented in Table 7.4.

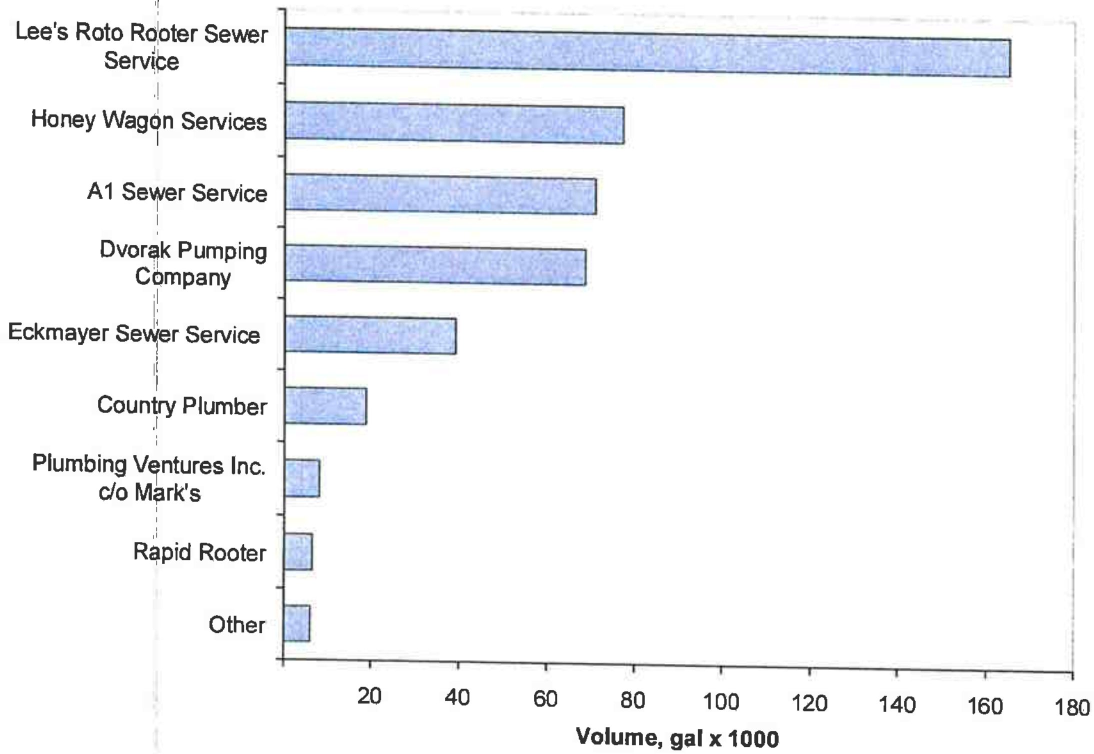
Table 7.4
Preliminary Cost Estimate
Improvements/Additions to Existing Whey Facilities

Unloading pad		$10,000
Inlet pumping / grinding		$100,000
Sludge piping modifications		$50,000
Odor control		$25,000
Mixing systems		$50,000
	Subtotal	$235,000
Site work		$19,000
Mechanical process piping		$24,000
I&C		$16,000
Electrical		$19,000
	Subtotal	$313,000
	Allowance for undefined design details (25%)	$78,000
	Total Construction Cost	$391,000
	Engineering, Legal, Admin (15%)	$59,000
	Total Project Cost	$450,000

5.4 Recommended Alternative

Diverting grease trap contents to the anaerobic digesters will eliminate grease-blinding of the influent fine screens, decrease the lipids loading to the NSWWTP liquid treatment process, and provide a minor increase in the digester gas available for the cogeneration facilities. Lower lipid loadings to the liquid treatment process will decrease operations and maintenance costs due to lower scum volumes in the primary clarifiers, decreased aeration requirements in the secondary treatment, and a reduction in the food source for Microthrix filaments. Primary scum diversion to the grease storage tanks will prevent gravity belt thickeners problems such as grease coating of plows and belt blinding, but will require substantial process piping changes. Further study in preliminary design is recommended. The conversion of the existing 20,000 gal whey wells to grease storage tanks is recommended to provide temporary storage of grease. The whey wells will continue to receive the high strength organic wastes that are currently hauled to the NSWWTP. The use of the whey well facility will result in lower construction costs and smaller footprint requirements.

APPENDIX A
2008 GREASE HAULING SUMMARY



Total grease hauling volumes for the period of 01/01/2008 to 12/31/2008.

V:\Client 44 (DAL)\Madison\MMSD_8045A.00\Fig7A.1

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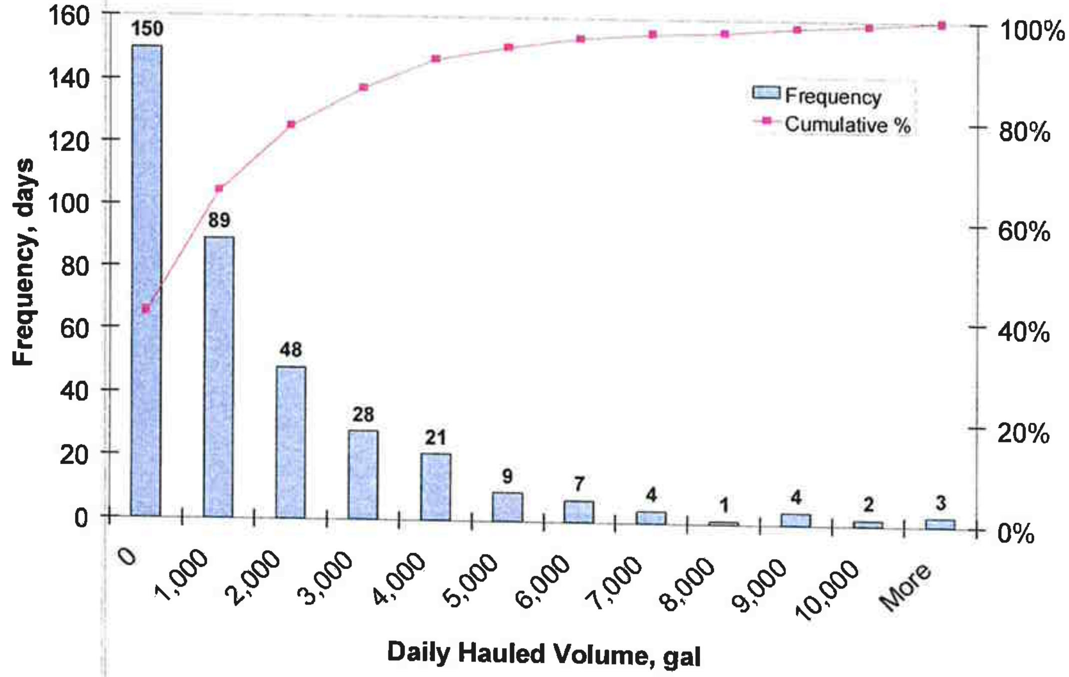
TOTAL GREASE HAULING VOLUMES

FIGURE 7A.1

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD



Daily grease hauling volumes for the period of 01/01/2008 to 12/31/08.

V:\Client 44 (DAL)\Madison\MMSD_8045A.00\Fig7A2

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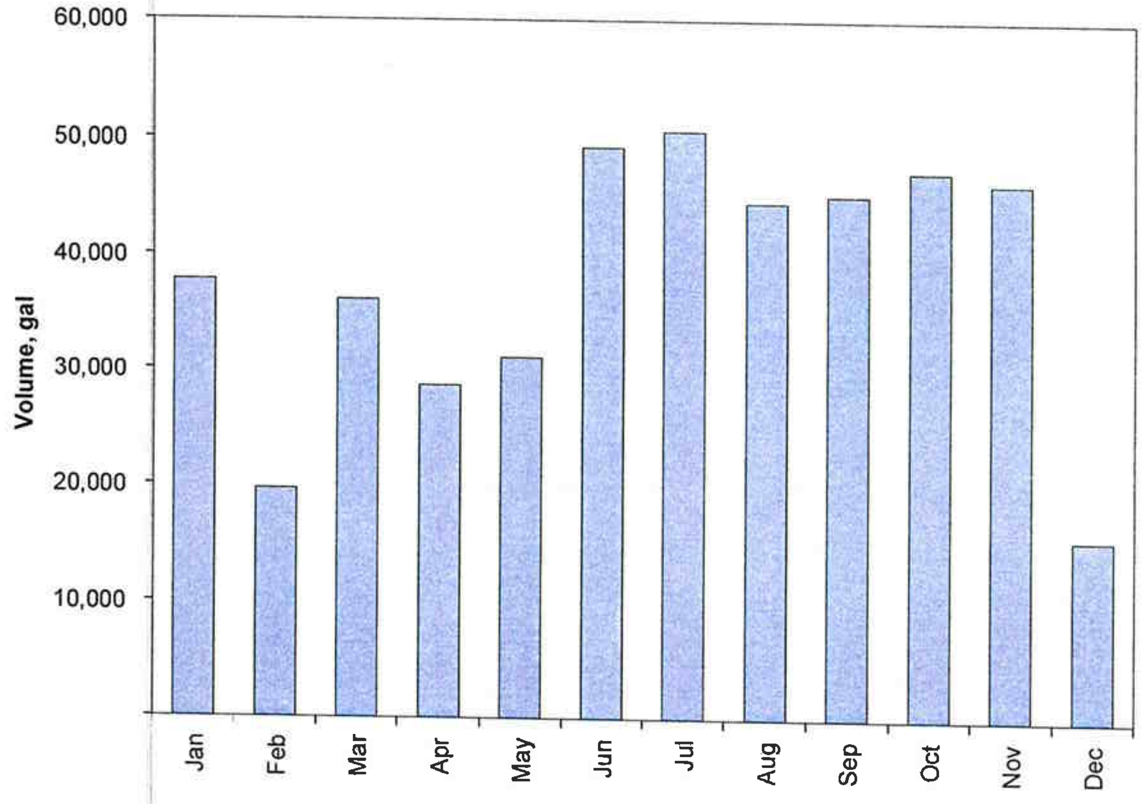
DAILY HAULING VOLUME

FIGURE 7A.2

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD



Monthly grease hauling volumes for the period of 01/01/2008 to 12/31/08.

V:\Client 44 (DAL)\Madison\MMSD_8045A.00\Fig7A.3

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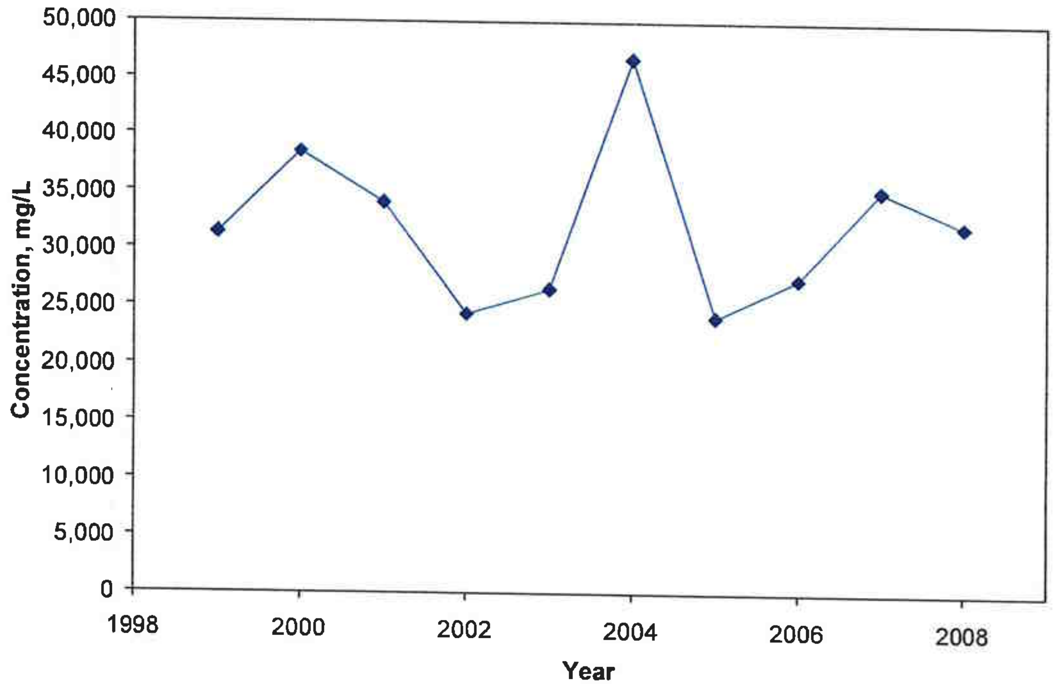
MONTHLY HAULING VOLUME

FIGURE 7A.3

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD

APPENDIX B
GREASE CHARACTERIZATION



Historic BOD concentration in grease trap waste.

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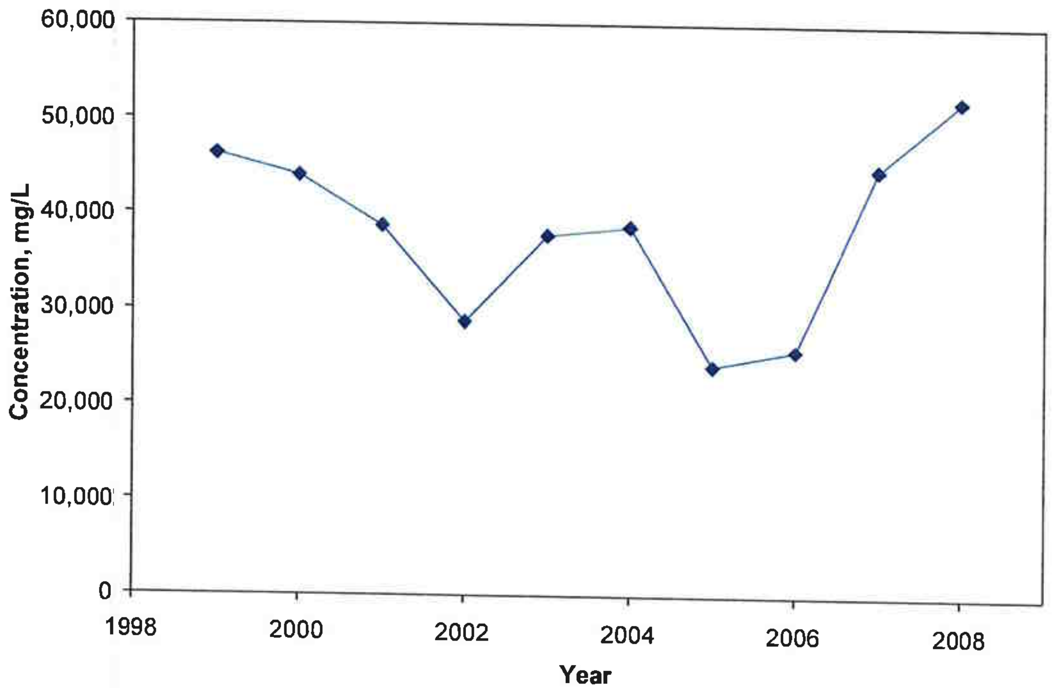
HISTORIC BOD CONCENTRATION

FIGURE 7B.1

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD



Historic total suspended solids concentration in grease trap waste.

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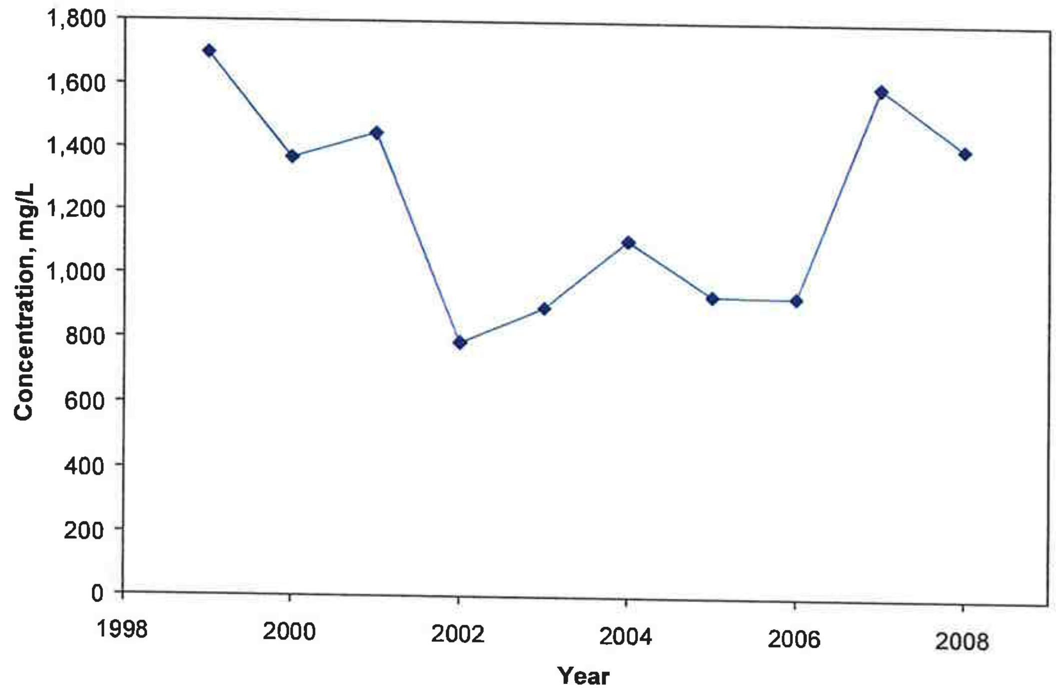
HISTORIC SUSPENDED SOLIDS CONCENTRATION

FIGURE 7B.2

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD



Historic TKN concentration in grease trap waste.

V:\Client 44 (DAL)\Madison\MMSD_8045A.00\Fig7B.3

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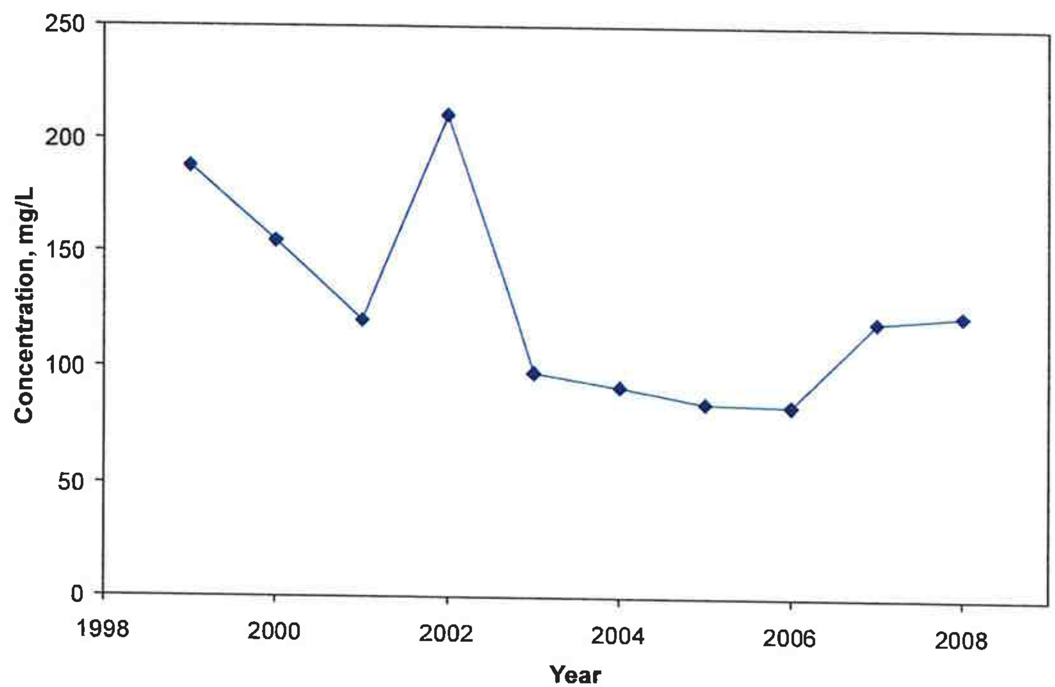
HISTORIC SUSPENDED SOLIDS CONCENTRATION

FIGURE 7B.3

MADISON METROPOLITAN SEWAGE DISTRICT

MMSD



Historic total phosphorus concentration in grease trap waste.

APPENDIX K

Technical Memorandum No. 8
Sludge Thickening Systems Evaluation

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 8
SLUDGE THICKENING SYSTEMS EVALUATION

Date: December 18, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate the existing sludge-thickening facilities and recommend the necessary improvements to support the acid-phase digestion configuration at the Nine Springs Wastewater Treatment Plant (NSWWTP). This evaluation includes the sludge-thickening equipment, the polymer-feeding system, and thickened sludge transfer pumps. The configuration and location of the sludge-thickening facilities will also be evaluated as part of this TM to facilitate the selected location and configuration of the new digesters.

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- The existing gravity thickeners have adequate capacity to handle the projected 2030 primary sludge flows and loads with all units in service. One of the existing dissolved air flotation thickeners (DAFTs) will be converted into a gravity thickener for redundancy purposes.
- The existing dissolved air flotation thickeners (DAFTs) do not have adequate capacity to handle the current waste activated sludge (WAS) annual average loads with one unit out of service. The thickening performance of the DAFTs does not meet the target solids concentration recommended for acid phase digestion. For these reasons, the installation of a new WAS thickening facility is recommended.
- The existing gravity belt thickeners (GBTs) have adequate capacity to handle the projected 2030 digested sludge maximum month flows and loads with both units in service. It is recommended that GBT unit No. 1 be replaced due to the age and condition of the existing unit. To meet the

design criteria at the projected 2030 annual average loads with one unit out of service, the installation of an additional GBT (Unit No. 3) is recommended.

- To meet the design criteria at the projected 2030 conditions, the construction of a new thickening building and the installation of either four GBTs or four rotary drum thickeners (RDTs) for the dewatering of digested sludge is recommended. The present worth costs of the two technologies are not significantly different.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements while maintaining the current biosolids land application programs. TM-03A Sludge Stabilization Alternatives Evaluation identified acid-phase digestion and conventional digestion with Cambi Thermal Hydrolysis Process (THP) as viable alternatives. Based on economic and non-economic evaluations, the MMSD staff selected acid-phase digestion for implementation at the NSWWTP.

In acid phase digestion, the process performance benefits from high solids loadings to the acid digester. High solids loadings result in higher volatile acid concentrations in the acid digester, lower digester heating requirements, and decreased the tankage requirements for the methane digesters. Typically, the acid digester feed is thickened to a solids concentration of 6 to 8% (dry solids). These solids concentrations cannot be achieved with gravity thickeners or DAFT, which are the technologies currently used at the NSWWTP. For this reason, other sludge-thickening alternatives were evaluated.

4.0 Existing Facilities

The sludge thickening facilities at the Nine Springs WWTP consist of two (2) gravity thickeners and two (2) DAFT units, which receive primary sludge and WAS, respectively. The sludge dewatering facilities consist of two (2) GBTs and one (1) high-solids centrifuge, which receive stabilized sludge from the anaerobic digesters. One of the GBTs functions as a backup thickener when a DAFT is out of service. Table 8.1 presents the characteristics of the existing facilities. Table 8.2 presents the 2030 projected solids flows and loads.

Based on the design criteria, the existing gravity thickeners have adequate capacity to operate at 2030 maximum month conditions with all units in service but do not have adequate capacity to operate at 2030 annual average conditions with one unit out of service. The conversion of one of the existing DAFTs into a gravity thickener is recommended for redundancy purposes.

Based on the design criteria, the existing GBTs have adequate capacity to operate at 2030 maximum month conditions with all units in service but do not have adequate capacity to operate at 2030 annual average conditions with one unit out of service. The replacement of GBT No. 1 within the planning period is recommended because the unit is at the end of its useful life. The installation of an additional GBT (proposed GBT No. 3) in 2020 is recommended to meet the projected 2030 annual average loads with one unit out of service. Based on the design criteria, the existing DAFT units do not have adequate capacity to operate at current average loading conditions with one unit out of service. To meet the maximum month conditions and the target solids concentration for acid phase digestion, the installation of a new WAS thickening facility is recommended. One of the existing DAFT tanks can be retrofitted to operate as fermentation tanks (See TM-06 Struvite Mitigation Alternatives).

Table 8.1
Existing Sludge Thickening Units

	Gravity Thickeners	Dissolved Air Flotation Thickeners	Gravity Belt Thickeners
Service	Primary Sludge	WAS	Digested Sludge
Number of Units	2	2	2
Diameter, ft	55	55	NA
Total Surface Area, sqf	4,752	4,752	NA
Belt Width, m	NA	NA	2
Hydraulic Capacity per Unit, gpm	990	1,540	250 (1)
Solids Capacity per Unit, lbs/hr	2,475	1,730	2,800 (1)
Solids Capture Efficiency, % (2)	98.3	92.0	97.4
Thickened Sludge Solids, % (2)	5.0	4.2	5.2

Notes:
(1) Capacity for digested sludge thickening
(2) Based on 2007-2008 operating data

Table 8.2 2030 Solids Flows and Loads			
	Primary Sludge	**WAS**	**Digested Sludge**
Current Solids Loading, lbs/hr			
Maximum Month [1,2]	3,000	2,500	2,700 [3]
Annual Average [1,2]	2,500	2,000	2,200 [3]
Current Flows, gpm			
Maximum Month [1,2]	240 [4]	1,000 [5]	195 [3]
Annual Average [1,2]	200 [4]	800 [5]	165 [3]
2030 Solids Loading, lbs/hr			
Maximum Month [2,6]	4,400	3,600	4,150 [3,7]
Annual Average [2,6]	3,700	3,000	3,550 [3,7]
2030 Flows, gpm			
Maximum Month [2,6]	350 [4]	1,000 [8]	255 [3]
Annual Average [2,6]	290 [4]	850 [8]	215 [3]

Notes:
(1) Based on the 2007-2008 average values presented in TM-01.
(2) Assumes 24-hr operation of thickening equipment.
(3) Based on the 2007 average volatile solids concentration in the digester feed of 76 percent and a volatile solids reduction of 65 percent.
(4) Assumes a total solids concentration of 2.5 percent.
(5) Based on the 2007 average total solids concentration of 0.5 percent.
(6) Based on the projected 2030 values presented in TM-01.
(7) Includes 300 lbs/hr of additional solids from iron salt addition for struvite mitigation
(8) Assumes a total solids concentration of 0.7 percent.

5.0 WAS Thickening Alternatives

Only proven sludge thickening technologies that can reliably achieve 6 to 8% solids concentrations were considered for the proposed WAS thickening facility. The evaluated technologies include GBTs, RDTs, and centrifuges.

5.1 Gravity Belt Thickeners

Gravity belt thickeners utilize a porous belt to separate the water from the solids. The MMSD Staff has extensive experience with this thickening technology. Table 8.3 presents the design criteria for gravity belt thickeners.

Table 8.3 Gravity Belt Thickener Design Criteria		
Element	**Current**	**2030**
Belt Width, m	2	2
Solids Loading Rate per Unit, lbs/hr	2,500 (1)	2,500 (1)
Hydraulic Loading Rate per Unit, gpm	500 (1)	500 (1)
TWAS Solids Concentration, %	6%	6%
Annual Average Conditions		
Loading Rate, lbs/hr	2,000	3,000
Flow, gpm	800	850
Units Installed/In Service (1)	3/2	3/2
Maximum Month Conditions		
Loading Rate, lbs/hr	2,500	3,600
Flow, gpm	1,000	1,000
Units Installed/In Service (1)	3/3	3/3

Notes:
(1) Capacity for WAS thickening
(2) Based on 24-hr operation.

5.2 Rotary Drum Thickeners

RDTs can achieve solids concentrations of up to 9% (dry solids). These units consist of a floc development tank, driven impeller, multiple-stage rotary drum with filtration media, supporting frame, spray deflection covering, spray wash header, and return water collection tank. The WAS, which is mixed with polymer, enters the floc development tank tangentially at the bottom and completes its flocculation. The WAS flows from a tangential outlet into the rotary drum screen through a step-down header. In the rotary drum screen the liquid separates from the flocculated solids through the woven wire mesh, is collected in the return water tank, and exits through a drain in the bottom. The solids pass through four dewatering stages before being discharged from the end of the unit. Mounted above the rotary drum screen is a self-cleaning wash water spray header. This spray header keeps the rotary drum screen openings clear of solids. Table 8.4 presents the design criteria for rotary drum thickeners.

Manufacturers of RDTs include IPEC, Parkson, US Filter and Vulcan. Full-scale installations include the Blue River WWTP (Stanley, KS), the Camp Lejeune WWTP (NC), and the Northeast WWTP (Lincoln, NE). Facilities under construction/design include the City of Avondale WWTP (Avondale, AZ) and the Waco Metropolitan Area Sewerage District Central WWTP (Waco, TX).

Table 8.4 Rotary Drum Thickener Design Criteria		
Element	**Current**	**2030**
Solids Loading Rate per Unit, lbs/hr	1,000	1,000
Hydraulic Loading Rate per Unit, gpm	400	400
TWAS Solids Concentration, %	6%	6%
Annual Average Conditions		
Loading Rate, lbs/hr	2,000	3,000
Flow, gpm	800	850
Units Installed/In Service (1)	3/2	4/3
Maximum Month Conditions		
Loading Rate, lbs/hr	2,500	3,600
Flow, gpm	1,000	1,000
Units Installed/In Service (1)	3/3	4/3

Notes:
(1) Based on 24-hr operation.

5.3 Decanting Centrifuges

The centrifuge is a rotating assembly that uses centrifugal force to separate solids from liquids. The materials fed into the centrifuge each have different specific gravities, which allow them to "settle" concentrically at different levels in the rotating assembly of the centrifuge. The solids have a higher specific gravity and will settle on the inside wall of the rotating assembly, while the liquids remain towards the core of the rotating assembly. The scroll is an internal conveyor, rotating at a slightly different speed to move the settled material towards the discharge ports. Solids are compacted and dewatered by the centrifugal force and released through these ports. Used liquids from the process are released at the opposite end of the machine through adjustable weir plates. Table 8.5 presents the design criteria for thickening centrifuges.

Manufacturers of centrifuges include Westfalia, Alfa Laval, Andritz, and Centrisys. Full-scale installations include the 91st Ave WWTP (Phoenix, AZ), the 23rd Ave WWTP (Phoenix, AZ), the Greenfield Water Reclamation Plant (Mesa, AZ), the Desert Dunes Water Reclamation Facility (Yuma, AZ), and the Broadway WWTP (Corpus Christi, TX).

As part of the evaluation, we considered relocating the existing dewatering centrifuge to a thickening role and providing belt presses for the Metromix dewatering facility. This retrofit is not recommended for the following reasons:

1) The original concern of pathogen reactivation has been shown not to be a health concern; the U.S. Environmental Protection Agency has not established any regulatory changes so far on the issue of reactivation since *Salmonella* and viruses do not appear to show any reactivation. It is recommended that MMSD's standard operating procedures include a 7-15 day hold of the Metromix to reduce the indicator organism levels back down to below Class A standards.

2) The Metromix dewatering facility was not set up for dewatering belt presses and lacks the clearances to properly maintain a dewatering belt press. While the installation may be possible, the maintenance of these units will be restricted.

3) The Metromix facility would lose 25-30% capacity as the maximum capacity of the dewatering belt press is lower than that of centrifuges with similar footprint.

Therefore, the use of the existing centrifuge in a new WAS thickening facility is not recommended.

Table 8.5
Centrifuge Design Criteria

Element	Current	2030
Solids Loading Rate, lbs/hr	Varies by Manufacturer	Varies by Manufacturer
Hydraulic Loading Rate, gpm	700	700
TWAS Solids Concentration, %	7	7
Annual Average Conditions		
Loading Rate, lbs/hr	2,000	3,000
Flow, gpm	800	850
Units Installed/In Service (1)	3/2	3/2
Maximum Month Conditions		
Loading Rate, lbs/hr	2,500	3,600
Flow, gpm	1,000	1,000
Units Installed/In Service (1)	3/2	3/2

Notes:
(1) Based on 24-hr operation.

6.0 POLYMER SYSTEM

The influent WAS has to be blended with polymer before thickening. A polymer-blending unit for every thickening unit will be installed. Table 8.6 shows the design criteria for the polymer system for the three thickening alternatives.

Table 8.6
Polymer System Design Criteria

Item	GBT	RDT	Centrifuge
Number of Polymer Blending Units (1)	3	4	3
Polymer Dosage, lbs of polymer/ton of solids (2)	10	10	5
2030 Annual Average Conditions			
Solids Feet Rate, lbs/hr (3)	3,000	3,000	3,000
Polymer Usage, lbs/hr	15	15	7.5
2030 Maximum Month Conditions			
Solids Feed Rate, lbs/hr (3)	3,600	3,600	3,600
Polymer Usage, lbs/hr	18	18	9

Notes:
(1) Each of the thickening units will be provided with a polymer-blending unit (Poly-Blend or similar).
(2) Dry weight assuming 100 percent active polymer.
(3) Assuming 24-hrs operation of the WAS thickening.

7.0 TWAS PUMPING

Each of the thickening units will be provided with a TWAS pump. Grinders will be installed to protect the pumps and downstream equipment. Table 8.7 shows the design criteria for the TWAS pumps.

Table 8.7 TWAS Pumps Design Criteria	
Item	**Description**
Number of Pumps	1 per thickening unit (1)
Capacity of Each Pump (gpm)	20-120 (2)
% Solids Concentration	Up to 7% (3)

Notes:
(1) One uninstalled standby pump will be provided per every four duty pumps.
(2) The pump hydraulic capacity is calculated assuming the thickening unit will produce about 3-percent effluent solids during peak loading.
(3) The pump solids concentration capacity is based on the maximum effluent concentration from the thickener.

8.0 TWAS BUILDING

For all three alternatives, a new building will be required to house the proposed TWAS thickening units and the associated sludge pumps and polymer systems. The new building would be located south and east of the existing thickening building. A preliminary layout with the proposed location of the new thickening building is shown in TM-3A, Figure 3A.2.

9.0 WAS Thickening Alternatives Evaluation

The sludge thickening alternatives were evaluated based on economic and non-economic comparisons. A summary of this evaluation is presented in Tables 8.8 and 8.9.

Table 8.8
Estimated Life-Cycle Costs for WAS Thickening Alternatives

	Gravity Belt Thickeners	Rotary Drum Thickeners	Centrifuges
Present Worth Capital Cost	$3,414,000	$3,994,000	$6,287,000
Present Worth O&M Cost	$4,831,000	$4,935,000	$4,428,000
Total Present Worth Cost for Alternative	$8,245,000	$8,929,000	$10,715,000

Notes:
- Detailed costs are presented in the Appendix.
- Costs common to all alternatives are not included.

Table 8.9
WAS Thickening Alternative Comparison

	Advantages	Disadvantages
Gravity Belt Thickener	• MMSD Staff has experience with this technology • Lower energy consumption than centrifuges	• Requires more wash water than RDTs during operation and for cleaning • Lower thickened solids concentration than other alternatives • Primary/secondary scum blinds the belt • Odor control can be difficult
Rotary Drum Thickener	• Lower energy consumption than centrifuges • Lower recycle water flows than GBTs. • Odor control easily installed because unit is completely enclosed. • Can handle primary sludge	• Primary/secondary scum cannot be fed to drum.
Centrifuge	• MMSD Staff has experience with this technology • Odor control easily installed because unit is completely enclosed. • Lower polymer consumption than other alternatives	• Higher energy consumption than other alternatives • Higher operation complexity than other alternatives • Higher polymer usage than other alternatives • Grit can result in abrasive damage to the equipment

10.0 Recommended Alternative

Based on economic and non-economic comparisons the installation of GBTs or RDTs is recommended. Final choice of thickening technologies will be completed during preliminary design since these technologies have very similar present worth costs.

APPENDIX A
DETAIL COST ESTIMATES

Table 1. Summary
Economic Comparison of Sludge Thickening Alternatives
Solids Handling Facilities Plan
Madison Metropolitan Sewerage District

Sludge Thickening Process Alternative	Present Worth Capital Cost	Present Worth O&M Cost Excluding Hauling	Present Worth Solids Hauling Cost	Total Present Worth Cost
Gravity Belt Thickeners	$3,414,000	$4,831,000	$0	$8,245,000
Rotary Drum Thickeners	$3,994,000	$4,935,000	$0	$8,929,000
Centrifuge Thickeners	$6,287,000	$4,428,000	$0	$10,715,000

interest rate	4.88%
P/F @ 10 yrs	0.621269827
P/F @ 20 yrs	0.385976197
F/P @ 10 yrs	1.609606579
F/P @ 20 yrs	2.590833338
P/A @ 10 yrs	7.768824069
P/A @ 20 yrs	12.59536005

Table 2
Economic Comparison of Digestion Alternatives
Gravity Belt Thickening

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value of Initial Cost ($)	Salvage Value of Future Cost ($)	Basis of Estimate
Modifications to Sludge Thickening							
Three (3) 2m Gravity Belt Thickener		$ 675,000	20	$ -	$ -	$ -	Energenics - 150k
Polymer Feed system		$ 150,000	20	$ -	$ -	$ -	$50k x 3
Sludge Feed system		$ 67,500	20	$ -	$ -	$ -	$22.5k x3 installed cost
New Sludge Thickening Building		$ 750,000	40	$ -	$ 375,000	$ -	3000 sqft @ $250/sqft
Future Modifications to Sludge Thickening							
One (1) 2m Gravity Belt Thickener			20	$ 225,000	$ -	$ 112,500	Energenics - 150k
Polymer Feed system			20	$ 50,000	$ -	$ 25,000	$50k x 1
Sludge Feed system			20	$ 22,500	$ -	$ 11,000	$22.5k x1 installed cost
Sludge Thickening Building			40	$ 250,000	$ -	$ 187,500	1000 sqft @ $250/sqft
Site Work	8%	$ 131,000	40	$ 44,000	$ 66,000	$ 33,000	
Mechanical Process Piping	10%	$ 164,000	40	$ 55,000	$ 82,000	$ 41,250	
Instrumentation and Control	7%	$ 115,000	20	$ 38,000	$ -	$ 19,000	
Electrical	8%	$ 131,000	20	$ 44,000	$ -	$ 22,000	
Subtotal		$ 2,183,500		$ 728,500	$ 523,000	$ 451,250	
Allowance for Undefined Design Details	25%	$ 546,000		$ 182,000			
Total Construction Cost		$ 2,729,500		$ 910,500			
Engineering, Legal and Administrative	15%	$ 409,000		$ 137,000			
Total		$ 3,138,500		$ 1,047,500	$ 523,000	$ 451,250	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 3,139,000		$ 651,000	$ 202,000	$ 174,000	
Annual O & M Cost							
Labor		$ 6,864		$ 10,296			
Energy (electrical and thermal)		$ 25,034		$ 36,601			
Chemicals		$ 249,432		$ 362,354			
Hauling		$ -		$ -			
Maintenance		$ 47,100		$ 62,800			1.5% of Construction Total
Total Annual O & M Cost		$ 328,430		$ 472,050			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 2,552,000		$ 2,279,000			
Total Present Worth Capital Cost		$ 3,414,000					
Total Present Worth O&M Cost		$ 4,831,000					
Total Present Worth		**$ 8,245,000**					

TABLE 3 - ALTERNATE NO.1 - GRAVITY BELT THICKENING O&M

2010			2030		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	6	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$10,296.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors			# Thermophilic Reactors		
Cost	$1,900	per yr	Cost	$1,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners			# Gravity Thickeners		
# Gravity Belt Thickeners	2		# Gravity Belt Thickeners	3	
# Centrifuges	0		# Centrifuges	0	
Cost	$23,134	per yr	Cost	$34,701	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2.5%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$25,034***	***$/yr***	***Total Power Cost***	***$36,601***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Primary Sludge	60,800	lbs/d	Primary Sludge	88,400	lbs/d
WAS	49,700	lbs/d	WAS	72,200	lbs/d
Total Raw Sludge	110,500	lbs/d	Total Raw Sludge	160,600	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
GBT Polymer Rate	10	lbs/DT	GBT Polymer Rate	10	lbs/DT
Centrifuge Polymer Rate	5	lbs/DT	Centrifuge Polymer Rate	5	lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# GBT	2		# GBT	3	
# Centrifuge	0		# Centrifuge	0	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$249,432	$/yr	Cost	$362,354	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$249,432***	***$/yr***	***Total Chemical Cost***	***$362,354***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table 4
Economic Comparison of Digestion Alternatives
Rotary Drum Thickening

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Three (3) 2m Rotary Drum Thickeners		$ 1,125,000	20	$ -	$ -	$ -	Equipment cost = $250k/unit
Polymer Feed system		$ 150,000	20	$ -	$ -	$ -	$50k x 3
Sludge Feed system		$ 67,500	20	$ -	$ -	$ -	$22.5k x3 installed cost
New Sludge Thickening Building		$ 600,000	40	$ -	$ 300,000	$ -	2400 sqft @ $250/sqft
Future Modifications to Sludge Thickening							
One (1) Rotary Drum Thickener			20	$ 375,000	$ -	$ 187,500	Equipment cost = $250k/unit
Polymer Feed system			20	$ 50,000	$ -	$ 25,000	$50k x 1
Sludge Feed system			20	$ 22,500	$ -	$ 11,000	$22.5k x1 installed cost
Sludge Thickening Building			40	$ 250,000	$ -	$ 187,500	1000 sqft @ $250/sqft
Site Work	8%	$ 155,000	40	$ -	$ 77,500	$ -	
Mechanical Process Piping	10%	$ 194,000	40	$ -	$ 97,000	$ -	
Instrumentation and Control	7%	$ 136,000	20	$ -	$ -	$ -	
Electrical	8%	$ 155,000	20	$ -	$ -	$ -	
Subtotal		$ 2,582,500		$ 697,500	$ 474,500	$ 411,000	
Allowance for Undefined Design Details	25%	$ 646,000		$ 174,000			5% used for CAMBI
Total Construction Cost		$ 3,228,500		$ 871,500			
Engineering, Legal and Administrative	15%	$ 484,000		$ 131,000			5% used for CAMBI
Total		$ 3,712,500		$ 1,002,500	$ 474,500	$ 411,000	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 3,713,000		$ 623,000	$ 183,000	$ 159,000	
Annual O & M Cost							
Labor		$ 6,864		$ 10,296			
Energy (electrical and thermal)		$ 25,034		$ 36,601			
Chemicals		$ 249,432		$ 362,354			
Hauling		$ -		$ -			
Maintenance		$ 55,700		$ 70,700			1.5% of Total
Total Annual O & M Cost		$ 337,030		$ 479,950			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 2,618,000		$ 2,317,000			
Total Present Worth Capital Cost		**$ 3,994,000**					
Total Present Worth O&M Cost		**$ 4,935,000**					
Total Present Worth		**$ 8,929,000**					

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TABLE 5 - ALTERNATE NO.2 - ROTARY DRUM THICKENING O&M					
2010			**2030**		
Labor			**Labor**		
Description	Estimated labor costs from 2010 to 2020		Description	Estimated labor costs from 2020 to 2030	
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	6	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$10,296.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors			# Thermophilic Reactors		
Cost	$1,900	per yr	Cost	$1,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners			# Gravity Thickeners		
# Rotary Drum Thickeners	2		# Rotary Drum Thickeners	3	
# Centrifuges	0		# Centrifuges	0	
Cost	$23,134	per yr	Cost	$34,701	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Digestion		lbs/d	Solids Flow to Digestion		lbs/d
Solids Flow to Digestion		gpd @ 4.6%	Solids Flow to Digestion		gpd @ 6%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @2%	Digested Sludge Production		gpd @2.5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$25,034***	***$/yr***	***Total Power Cost***	***$36,601***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Primary Sludge	60,800	lbs/d	Primary Sludge	88,400	lbs/d
WAS	49,700	lbs/d	WAS	72,200	lbs/d
Total Raw Sludge	110,500	lbs/d	Total Raw Sludge	160,600	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
RDT Polymer Rate	10	lbs/DT	RDT Polymer Rate	10	lbs/DT
Centrifuge Polymer Rate	5	lbs/DT	Centrifuge Polymer Rate	5	lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# RDT	2		# RDT	3	
# Centrifuge	0		# Centrifuge	0	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$249,432	$/yr	Cost	$362,354	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$249,432***	***$/yr***	***Total Chemical Cost***	***$362,354***	***$/yr***
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cu yds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cu yd	Dewatered Sludge Hauling Cost		$/cu yd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

Table 6
Economic Comparison of Digestion Alternatives
Centrifuge Thickening

Solids Handling Facilities Plan
Madison Metropolitan Sewage District

Item		Initial Cost ($)	Service Life (Years)	Future Cost at 10 Years ($)	Salvage Value Initial ($)	Salvage Value Future ($)	Basis of Estimate
Modifications to Sludge Thickening							
Three (3) 475 gpm Centrifuges		$ 2,325,000	20	$ -	$ -	$ -	Installed equipment cost = $775k/ur
Polymer Feed system		$ 150,000	20	$ -	$ -	$ -	$50k x 3
Sludge Feed system		$ 67,500	20	$ -	$ -	$ -	$22.5k x3 installed cost
New Sludge Thickening Building		$ 900,000	40	$ -	$ 450,000	$ -	3600 sqft @ $250/sqft
Site Work	8%	$ 275,000	40	$ -	$ 137,500	$ -	
Mechanical Process Piping	10%	$ 344,000	40	$ -	$ 172,000	$ -	
Instrumentation and Control	7%	$ 241,000	20	$ -	$ -	$ -	
Electrical	8%	$ 275,000	20	$ -	$ -	$ -	
Subtotal		$ 4,577,500		$ -	$ 759,500	$ -	
Allowance for Undefined Design Details	25%	$ 1,144,000		$ -			
Total Construction Cost		$ 5,721,500		$ -			
Engineering, Legal and Administrative	15%	$ 858,000		$ -			
Total		$ 6,579,500		$ -	$ 759,500	$ -	
Present Worth Factor		1.000		0.621	0.386	0.386	
Present Worth Capital Cost		$ 6,580,000		$ -	$ 293,000	$ -	
Annual O & M Cost							
Labor		$ 6,864		$ 10,296			
Energy (electrical and thermal)		$ 98,291		$ 98,291			
Chemicals		$ 124,716		$ 181,177			
Hauling		$ -		$ -			
Maintenance		$ 98,700		$ 98,700			1.5% of Total
Total Annual O & M Cost		$ 328,571		$ 388,464			
Present Worth Factor		7.769		4.827			Fut PW is P/F * P/A @ 10 yrs
Present Worth O & M Cost		$ 2,553,000		$ 1,875,000			
Total Present Worth Capital Cost		$ 6,287,000					
Total Present Worth O&M Cost		$ 4,428,000					
Total Present Worth		**$ 10,715,000**					

J:\4364\DATA\CALCS\TM08 Cost Calcs\Final Thickeing Cost Estimates.xls

TABLE 7 - ALTERNATE NO.3 - CENTRIFUGE THICKENING O&M					
2010			**2030**		
Labor					
Description					
Rate	$33.00	$/hr	Rate	$33.00	$/hr
Hours	4	hr/wk	Hours	6	hr/wk
Duration	52	wk/yr	Duration	52	wk/yr
Annual	$6,864.00	$/yr	Annual	$10,296.00	$/yr
Power and Heating			**Power and Heating**		
Digesters			*Digesters*		
# Mesophilic Reactors			# Mesophilic Reactors		
# Thermophilic Reactors			# Thermophilic Reactors		
Cost	$1,900	per yr	Cost	$1,900	per yr
Influent Sludge Thickening			*Influent Sludge Thickening*		
Flow to Thickening	1.195	mgd @1.5%	Flow to Thickening	1.195	mgd @1.6%
# DAFs	0		# DAFs	0	
# Gravity Thickeners			# Gravity Thickeners		
# Rotary Drum Thickeners	0		# Rotary Drum Thickeners	0	
# Centrifuges	2		# Centrifuges	2	
Cost	$96,391	per yr	Cost	$96,391	per yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Solids Flow to Cambi THP		lbs/d	Solids Flow to Cambi THP		lbs/d
Solids Flow to Cambi THP		gpd @ 17%	Solids Flow to Cambi THP		gpd @ 17%
Digested Sludge Production		lbs/d	Digested Sludge Production		lbs/d
Digested Sludge Production		gpd @5%	Digested Sludge Production		gpd @5%
% to GBT			% GBT		
% to Centrifuge			% Centrifuge		
# Gravity Belt Thickeners			# Gravity Belt Thickeners		
# Centrifuges			# Centrifuges		
Cost	$0	per yr	Cost	$0	per yr
Total Power Cost	***$98,291***	***$/yr***	***Total Power Cost***	***$98,291***	***$/yr***
Chemical			**Chemical**		
Influent Sludge Thickening			*Influent Sludge Thickening*		
Primary Sludge	60,800	lbs/d	Primary Sludge	88,400	lbs/d
WAS	49,700	lbs/d	WAS	72,200	lbs/d
Total Raw Sludge	110,500	lbs/d	Total Raw Sludge	160,600	lbs/d
Gravity Thickener Polymer Rate	0	lbs/DT	Gravity Thickener Polymer Rate	0	lbs/DT
DAF Polymer Rate	0	lbs/DT	DAF Polymer Rate	0	lbs/DT
RDT Polymer Rate	10	lbs/DT	RDT Polymer Rate	10	lbs/DT
Centrifuge Polymer Rate	5	lbs/DT	Centrifuge Polymer Rate	5	lbs/DT
# DAF			# DAF		
# Gravity Thickeners			# Gravity Thickeners		
# RDT	0		# RDT	0	
# Centrifuge	2		# Centrifuge	2	
Cost of Polymer	$2.75	$/lb Polymer	Cost of Polymer	$2.75	$/lb Polymer
Cost	$124,716	$/yr	Cost	$181,177	$/yr
Effluent Sludge Thickening / Dewatering			*Effluent Sludge Thickening / Dewatering*		
Digested Sludge		lbs/day	Digested Sludge		lbs/day
GBT Polymer Rate		lbs/DT	GBT Polymer Rate		lbs/DT
Centrifuge Polymer Rate		lbs/DT	Centrifuge Polymer Rate		lbs/DT
% GBT			% GBT		
% Centrifuge			% Centrifuge		
Cost	$0		Cost	$0	
Total Chemical Cost	***$124,716***	***$/yr***	***Total Chemical Cost***	***$181,177***	***$/yr***
Hauling			**Hauling**		
Metrogro liquid concentration		%	Metrogro liquid concentration		%
Metrogro cake concentration		%	Metrogro cake concentration		%
Gallons liquid per day		gpd	Gallons liquid per day		gpd
Dewatered Sludge per day		cu yds/d	Dewatered Sludge per day		cuyds/d
Liquid Hauling Cost		$/gal	Liquid Hauling Cost		$/gal
Dewatered Sludge Hauling Cost		$/cuyd	Dewatered Sludge Hauling Cost		$/cuyd
Total Hauling Cost	***$0***	***$/yr***	***Total Hauling Cost***	***$0***	***$/yr***

APPENDIX L

Technical Memorandum No. 9
Digester Gas Utilization

AppliedTechnologies
Engineers - Architects

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 9
DIGESTER GAS UTILIZATION

Date: December 21, 2009 **Project #:** 4364

To: Todd Gebert, MMSD

From: Rudy Kilian and Toshio Shimada, Carollo Engineers

Cc: Bill Ericson and Jim Smith, Applied Technologies
Allen Todd, Carollo Engineers

1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate the existing digester gas utilization facilities at the Nine Springs Wastewater Treatment Plant (NSWWTP).

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- The existing gas treatment and gas storage facilities have adequate capacity to handle the projected 2030 digester gas production.
- The existing hot water boilers and the proposed low-pressure steam boilers will provide adequate capacity for the 2030 projected digester and building heating requirements of 23.1 MMBTU/hr.
- The existing cogeneration units have adequate capacity to handle the 2030 projected digester gas available for cogeneration. The installation of additional cogeneration capacity is not recommended.
- The use of digester gas for electrical power generation or heating will depend on the cost of natural gas and electricity at the moment of use. Based on a preliminary estimate using the planning level costs of electricity and natural gas, digester gas utilization to offset natural gas purchases may be more economically favorable than cogeneration.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements while maintaining the current biosolids land application programs. TM-03A Sludge Stabilization Alternatives Evaluation identified acid-phase digestion and conventional digestion with Cambi Thermal Hydrolysis Process (THP) as viable alternatives for sludge stabilization at the NSWWTP. The implementation of these alternatives will result in increased digester gas production. In order to maximize the potential energy cost offsets, the capacity of the existing gas utilization facilities must be evaluated.

Digester gas generated at the NSWWTP is used for hot water heating and simultaneous production of electricity and heat in the cogeneration facilities. The NSWWTP uses the heat generated from the cogeneration equipment to maintain the digester target temperatures and use the electrical energy to run other plant processes. The 10th Addition Preliminary Design Report (PDR) evaluated the installation of an additional reciprocating engine at the NSWWTP and concluded that the anticipated gas production for 2020 would be insufficient to justify the installation of an additional reciprocating engine. Due to increased electricity and natural gas costs, the availability of funding, and more recent digester performance data including acid-phase digestion (mesophilic-thermophilic-mesophilic), the installation of additional cogeneration capacity at the NSWWTP is evaluated in this TM.

4.0 Digester Gas Production

Table 9.1 presents the gas production estimates for current and future flow conditions.

Table 9.1
Nine Springs WWTP
Digester Gas Production

	Current (1)	2030 Projection
Digester Solids Annual Average Loading, ppd	106,300	154,500 (2)
Volatile Solids Reduction, ppd	52,500	76,300 (3)
Digester Gas Production, cfd	763,800	1,106,700 (4)
Gas Production to VSR Ratio, cf/lbs	14.5	14.5
Energy Production, MMBTU/hr (5)	16.7	24.1

Note:
(1) Based on NSWWTP process and operations data for the period of 05/2007 to 05/2008.
(2) Based on 2030 projected values presented in TM No. 1.
(3) Based on 2007-2008 average volatile solids concentration of 76 percent in the digester feed and volatile solids reduction of 65 percent.
(4) Based on 2007-2008 gas production to VSR ratio
(5) Based on 524 BTU per cubic foot of digester gas.

5.0 Digester Gas Characteristics

Table 9.2 presents the digester gas characteristics based on the results from samples collected from 07/2008 to 12/2008. The levels of hydrogen sulfide (H_2S) and siloxanes in both sets of samples are within the typical range for anaerobic digesters.

Table 9.2
Nine Springs WWTP
Digester Gas Characteristics

Parameter	2008 Sampling [(1)]
Methane, % by volume	60.5
Carbon dioxide, % by volume	39.6
Hydrogen Sulfide, ppmv	1,200
Siloxanes, ppmv	1,750
Heating Value, BTU/cf	556

Note:
(1) Based on results from gas samples collected on 8/11/08 and 12/11/08.

6.0 Electricity and Gas Usage

Table 9.3 presents a summary of the gas and electricity usage at the NSWWTP. As part of the 10th Addition Improvements, the digestion facility was converted to temperature-phased digestion (TPAD) and Digesters No. 4 - 6 were retrofitted to operate in thermophilic mode. For this reason, only data from 2006 to 2008 was used to estimate the historic gas usage at the NSWWTP.

Table 9.3 Nine Springs WWTP *Current Energy Consumption*			
	Average	**Max**	**Min**
Gas Usage (1)			
Hot Water Boiler Digester Gas Usage, MMBTU/month	4,400	7,000	1,700
Cogeneration Digester Gas Usage, MMBTU/month	4,900	8,200	2,600
Total Digester Gas Requirements, MMBTU/month	9,300	12,300	7,100
Purchased Natural Gas, MMBTU/month	1,700	4,400	0
Electricity Demand			
Daily Purchased Electricity Demand, kWh (2)	61,000	89,500	38,500
Daily Cogeneration Output, kWh (1)	32,100	34,500	8,000
Total Daily Demand, kWh (1)	93,100	124,000	46,500
Purchased Electricity On-Peak Demand, kW (2)	3,300	4,300	2,600
Purchased Electricity Off-Peak Demand, kW (2)	3,400	4,100	2,800

Notes:
(1) Based on NSWWTP historic data during 2006-2007.
(2) Based on 50-Year Master Plan purchased electrical consumption during 2001-2007.

7.0 Existing Facilities

7.1 Digester Gas Treatment

Digester gas is treated in a packaged plant system to remove moisture, siloxanes, and H_2S to prevent fouling of the cogeneration equipment. The gas treatment system was designed by Applied Filter Technologies and includes iron sponge filters for H_2S removal, a gas chiller for moisture removal, and SAG system (patented media filters) for siloxanes removal. The packaged plant has a capacity of 800 cfm (1,152,000 cubic feet per day), which is adequate to treat the projected 2030 maximum month digester gas production.

7.2 Digester Gas Storage

Low-pressure gas storage provides a constant gas supply to the cogeneration facilities and maximizes energy production during peak utilization periods. Digester gas is stored during periods when production exceeds utilization, minimizing the amount of gas sent to the flares. During periods where digester gas production does not meet the minimum requirements of the cogeneration facility, stored gas can be used to continue operating at maximum levels. Gas storage at NSWWTP is provided inside two 70-ft diameter sludge storage tanks with gasholder covers and a combined storage capacity of 64,400 cubic feet (at 9.2 inches water column). The existing digester gas storage has adequate capacity for the projected 2030 gas production with approximately 84 minutes of storage, which is above the minimum recommended for cogeneration facilities (30 min).

7.3 Cogeneration Facilities

Digester gas produced at the NSWWTP is currently used to fuel two (2) reciprocating engines, one (1) engine-driven blower, and six hot water boilers. The heat generated in the reciprocating engines and the engine-driven blower is recovered and used to maintain the digester temperatures. Surplus digester gas is burned in a candlestick flare. Table 9.4 presents a summary of the existing digester gas utilization facilities.

Table 9.4
Nine Springs WWTP
Existing Digester Gas Utilization Facilities

	Reciprocating Engines	Engine-Driven Blower	Hot Water Boilers
No. Units	2	1	6
Electrical Capacity per Unit, kW	475	550	-
Heating Capacity per Unit, MMBTU/hr	1.85	2.00	4.3 - 5.9 (1)
Power Generation Efficiency, %	28	30	-
Maximum Gas Utilization (Combined), cfd (2,3)	527,600	247,300	1,402,000
Average Gas Utilization (Combined), cfd (2,4)	370,400	168,900	177,600

Notes:
(1) Three 4.3 MMBTU/hr units (Central Loop) and three 6.8 MMBTU/hr units (East Loop).
(2) Assumes 524 BTU per cubic foot of digester gas.
(3) Based on nominal electrical capacity.
(4) Based on NSWWTP 1992-2008 data.

8.0 Capacity Evaluation

A summary of the evaluation for the existing cogeneration capacity is presented in Table 9.5.

Table 9.5
Nine Springs WWTP
Digester Gas Production

	Current Conditions		2030 Conditions	
	Winter	Summer	Winter	Summer
Digester Gas Production, MMBTU/hr	16.7 (1)	16.7 (1)	24.1 (1,2)	24.1 (1,2)
Heating Requirements, MMBTU/hr				
Digester Heating Requirements (3)	8.5 (4)	6.1 (4)	14.0 (2,4)	10.3 (2,4)
Building Heating Requirements (5)	7.1	2.3	9.1 (6)	2.3
Total Heating Requirements	15.6	8.4	23.1	12.6
Engine-Driven Blower				
Digester Gas Usage, MMBTU/hr	3.5	3.5	4.4	4.4
Recovered Heat, MMBTU/hr (7)	1.2	1.2	1.5	1.5
Engine Generators (8)				
Available Gas, MMBTU/hr (9)	(1.2)	9.0	(1.9)	12.5
Recovered Heat, MMBTU/hr (7)	0	3.0	0	3.9

Note:
(1) Includes existing Digesters No. 1-6.
(2) Includes proposed Digester No. 8.
(3) Based on annual average solids loading.
(4) Includes existing Digesters No. 1-7.
(5) Based on 10th Addition Predesign Report
(6) Based on a heating demand of 2.0 MMBTU/hr for the proposed digester control and thickening buildings.
(7) Assumes 34 percent of the fuel energy is recovered as heat.
(8) Existing engine generators No. 1 and No. 2 with a total capacity of 11.5 MMBTU/hr
(9) Available gas for cogeneration = Gas produced - Heating requirements - Blower usage + Recovered heat

For the purposes of this capacity evaluation, the digester gas usage to offset natural gas purchase was considered a priority over cogeneration. The use of digester gas for electrical power generation or heating will depend on the cost of natural gas and electricity at the moment of use. Based on a preliminary estimate using the planning level costs for electricity ($0.08 per kWh) and a natural gas ($0.69 per therm), the cost per MMBTU is approximately $23 for electricity and $69 for natural gas. Therefore, digester gas utilization to offset natural gas purchases appears to be more economically favorable than cogeneration. In this scenario, the digester gas is first utilized to fuel the hot water boilers and the engine-driven blower and residual gas utilized to fuel the cogeneration units. A more detailed analysis for the development of strategies for digester gas usage may be conducted during design.

9.0 Recommendation

Based on the projected 2030 digester gas production, the digester and building heating requirements, and the capacity of the existing cogeneration units, the installation of additional cogeneration capacity is not recommended.

APPENDIX M

Workshop Handouts

Madison Metropolitan Sewer District

Solids Handling Facilities Plan

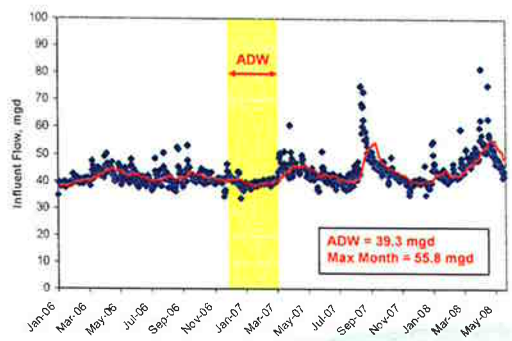
Kickoff Meeting
June 4, 2008

Applied Technologies
Engineers - Architects

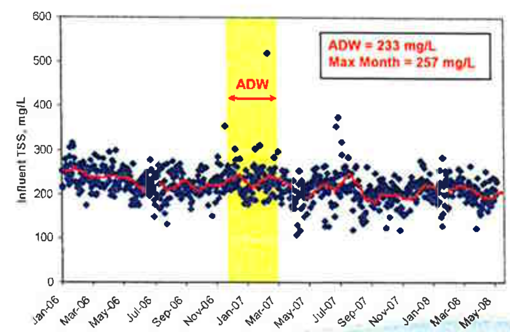
Carollo
Engineers... Working Wonders With Water

2006-2008 Process and Operations Data Review

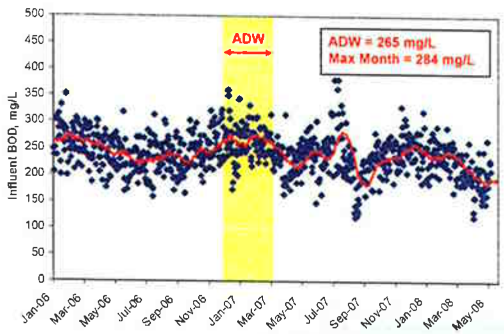
Influent Flow



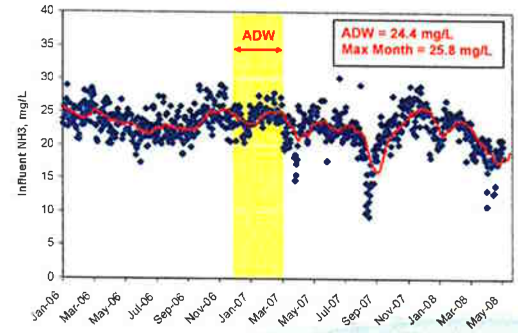
Influent Suspended Solids



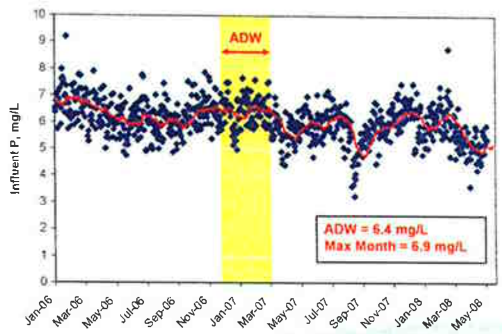
Influent BOD



Influent Ammonia



Influent Phosphorus

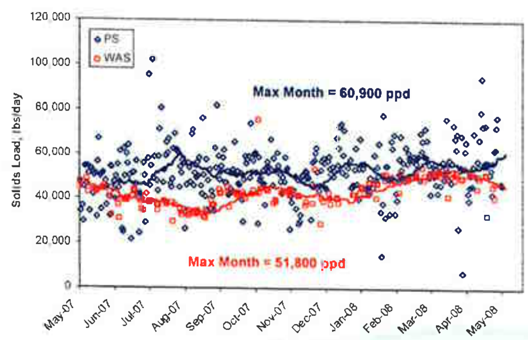


Influent Summary

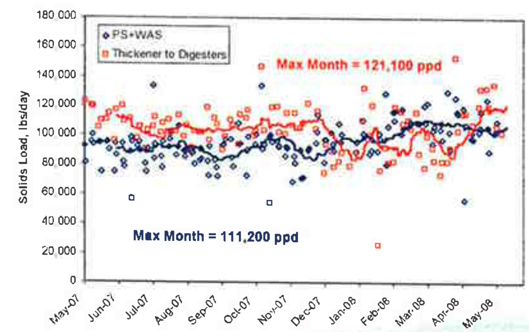
Process Parameter	Average Dry Weather [1]	Maximum Month
Influent ADW Flow, mgd	39.3	55.8
Influent ADW TSS		
Concentration, mg/L	233	257
Loading, lbs/day	76,500	91,000
Influent ADW BOD		
Concentration, mg/L	265	284
Loading, lbs/day	86,950	94,900
Influent ADW NH4		
Concentration, mg/L	24.4	25.8
Influent ADW P		
Concentration, mg/L	6.4	6.9

Notes:
(1) Average dry weather influent characteristics for the period of 01/06 to 05/08.

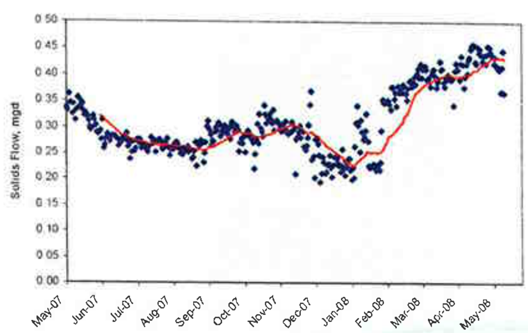
Sludge Production



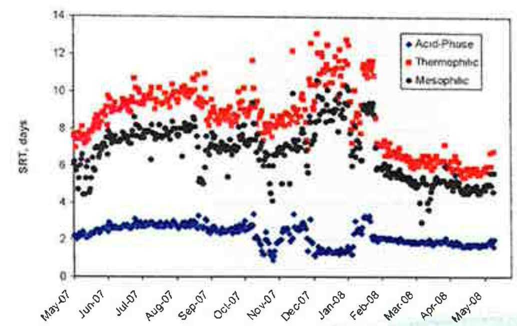
Sludge to Digestion



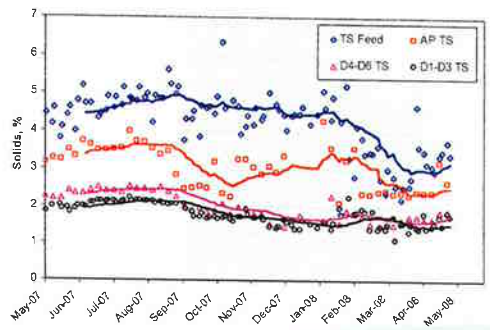
Digester Flow



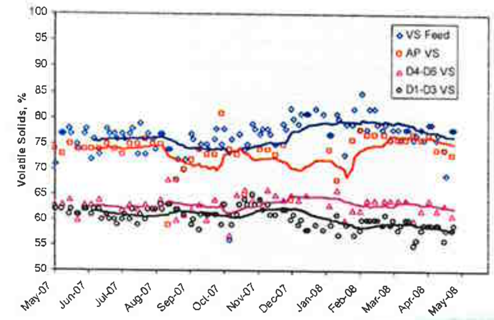
Digester HRT



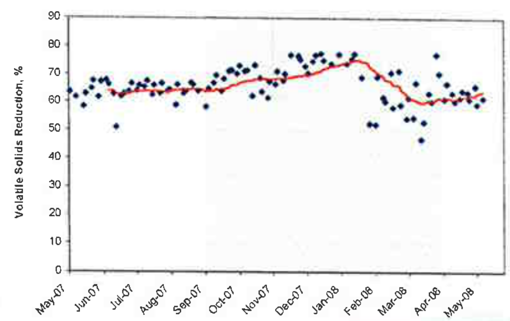
Total Solids



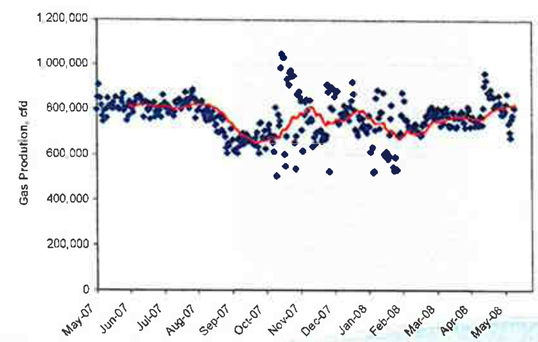
Volatile Solids



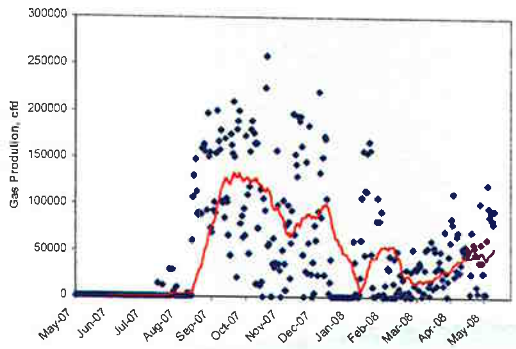
Volatile Solids Reduction (Reported)



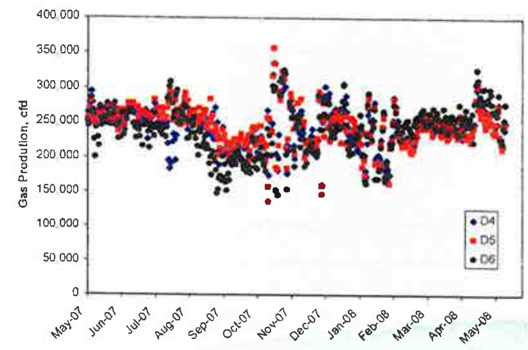
Biogas Production



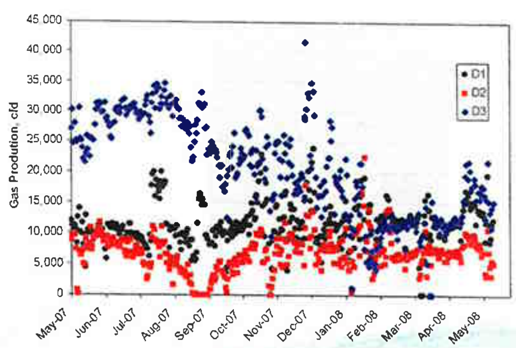
Biogas Production (Acid-Phase)



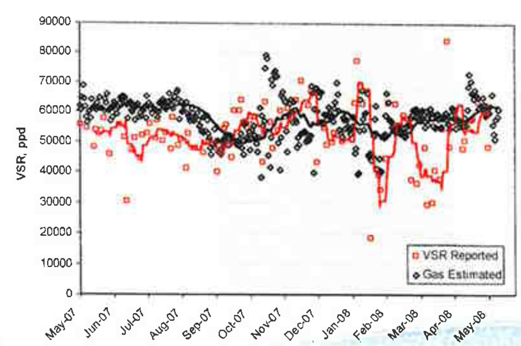
Biogas Production (Thermophilic)



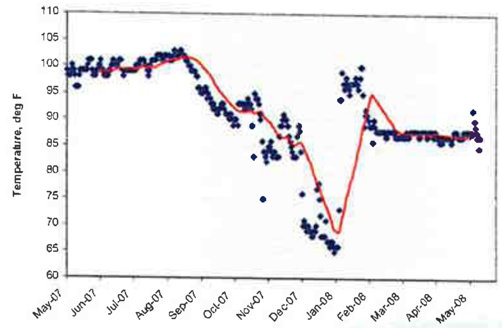
Biogas Production (Mesophilic)



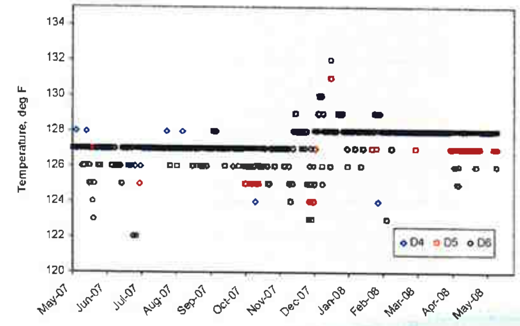
Analyzing Volatile Solids Reduction from Two Sources



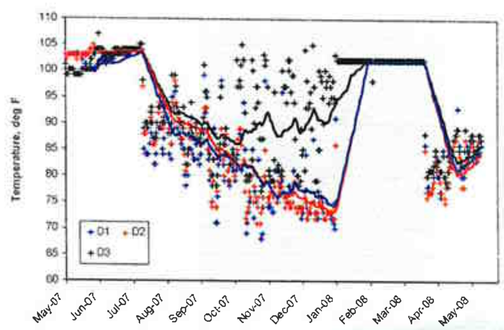
Digester Temperature (Acid Phase)



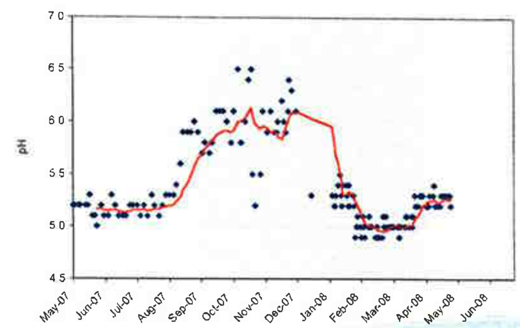
Digester Temperature (Thermophilic)



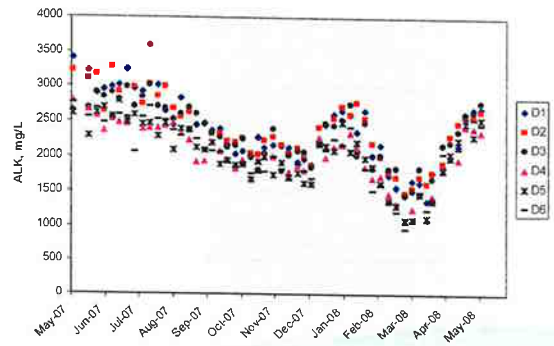
Digester Temperature (Mesophilic)



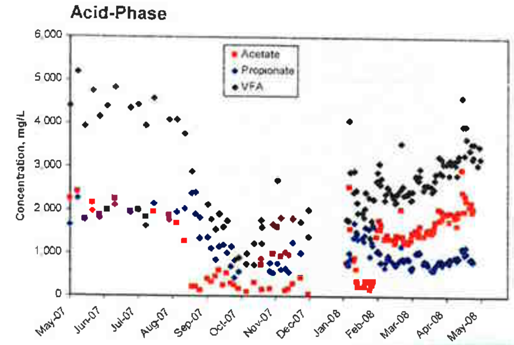
Acid-Phase Digester pH



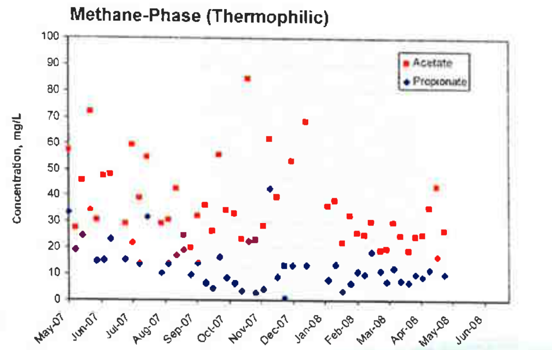
Digester Alkalinity



Digester Volatile Fatty Acids

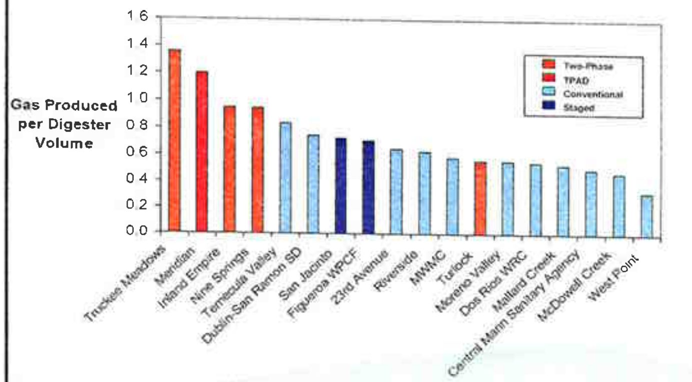


Digester Volatile Fatty Acids

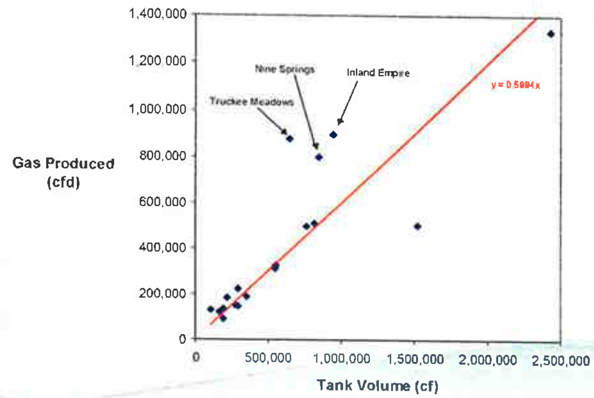


Confirmation of Findings

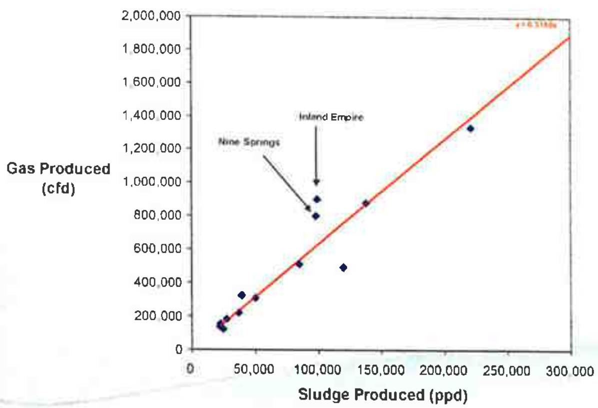
Advanced Digestion Improves Gas Production Efficiency



Advanced Digestion Improves Gas Production Efficiency



Advanced Digestion Improves Gas Production Efficiency



Digestion Process Alternatives

Digestion Process Alternatives

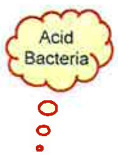
- Class B Alternatives (all mesophilic)
  - Conventional digestion
  - Staged digestion
  - Two-phase digestion
- Class A Alternatives
  - Temperature-phase anaerobic digestion (TPAD) with thermophilic batch digesters
  - Two-phase digestion (meso-thermo)

Digester Process Comparison

Digestion Process	SRT per Tank at Max Month (days)	Total SRT at Max Month (days)	Operating Temperature	VS Loading at Max Month (lb/cf/day)	Pathogen Level Produced
Conventional Digestion	15	15	Mesophilic	0.18	Class B
Stage Digestion	15/5	20	Mesophilic	0.18	Class B
Two-Phase Digestion	2/12	14	Mesophilic	1.5-2.5	Class B
Temperature-Phase Digestion	5/10	15	Thermophilic-Mesophilic	0.3	Class A
Two-Phase Digestion	2/12	14	Mesophilic-Thermophilic	1.5-2.5	Class A

Anaerobic Digestion is Naturally a Two Step Process

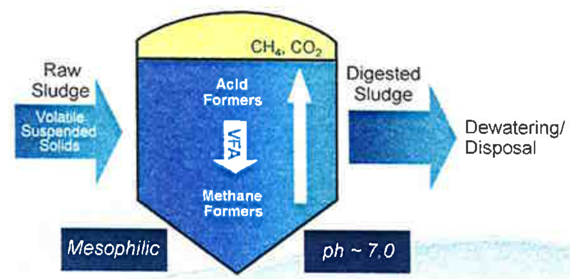
- Acid bacteria convert volatile suspended solids to volatile fatty acids (VFA)
  - Relies on fast growing bacteria (1-2 days SRT)
  - Like ph ~ 5



- Methane bacteria convert VFA to methane and carbon dioxide
  - Relies on slower growing bacteria (10-12 days SRT)
  - Like ph ~ 8

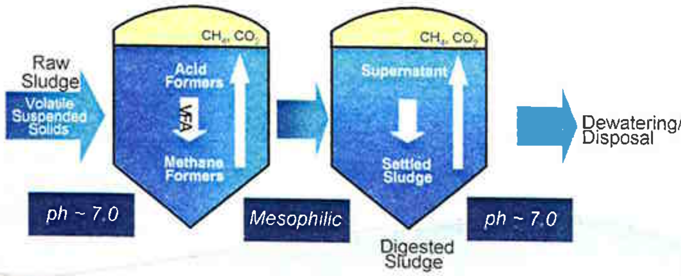
Conventional Digestion Process (Class B)

- Acid and methane bacteria live and compete in same tank
- Currently used at DSRSD



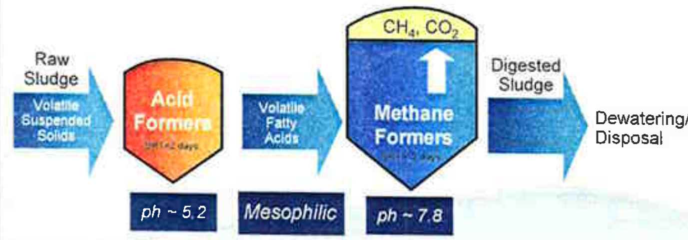
Staged Digestion Process (Class B)

- Similar to conventional digestion except operated in series instead of parallel configuration
- Can be used at DSRSD



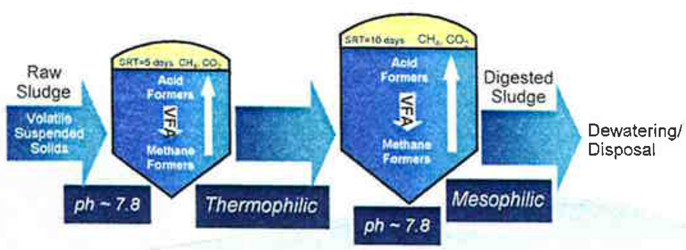
Two-Phase Digestion Process (Class B)

- Acid and methane bacteria live and thrive in separate tanks
- Currently used at City of Turlock and Inland Empire Utilities Agency, CA



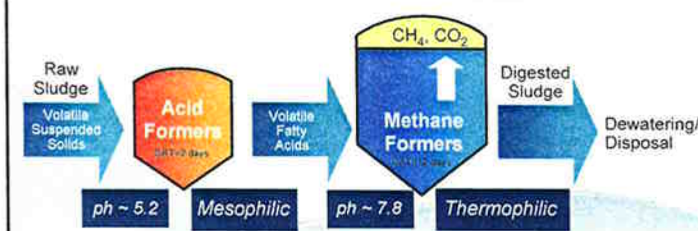
Temperature-Phase Digestion Process (Class A)

- Thermophilic temperature provides enhanced digestion
- Currently used at Sturgeon Bay, WI



Two-Phase Digestion Process (Class A)

- Same as two-phase digestion for Class B except change methane-phase digesters to thermophilic operation
- Currently used at Du Page County (IL) and can be used at Inland Empire (CA)



So How Will MMSD Decide Which Digestion Process to Use?

- Will depend on near-term and long-term goals
- Can implement improvements in phases?

Goal	Digestion Process
Add reliability and redundancy	Conventional digestion
Increase volatile solids destruction and gas production and reduce O&M costs	Two-phase digestion (mesophilic)
Implement FOG digestion	Conventional digestion, two-phase digestion, or temperature-phase digestion
Plan for Class A biosolids	Two-phase digestion or temperature-phase digestion

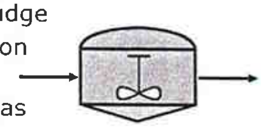
Site Visit Opportunities

- Objective
  - Learn first-hand about advanced digestion processes and FOG/septage facilities
- Two-phase Digestion
  - DuPage, IL
- Thermophilic Digestion
  - EBMUD, CA
- FOG/Septage Facilities
  - Watsonville, CA
  - South Bayside Sewer Authority, CA

Digester Mixing and Heating Options

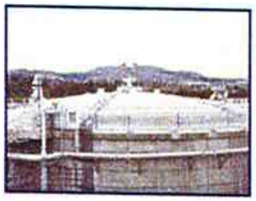
Effective Digester Mixing Is Important Because...

- Provides good mixing of active biomass and incoming feed sludge
- Increase volatile solids reduction efficiency
- Increase potential for higher gas production
- Minimizes foam/grit accumulation



Digester Mixing Alternatives

Draft tube mixing



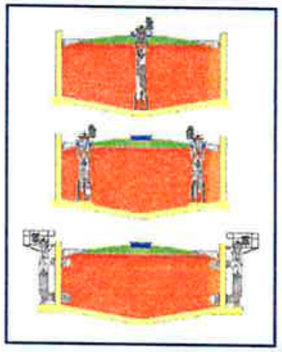
DSRSD

Pump mixing

Livermore

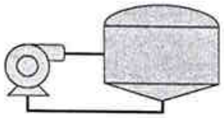
Draft Tube Mixing

- Technology currently used at DSRSD
- Reversible mixing pattern
- Internal (roof-mounted) or external mounted design
- Digester operating liquid elevation must remain constant



Pump Mixing

- Axial flow, screw centrifugal, or chopper type pumps
- Draw sludge from bottom or top of digester
- High-velocity discharge through perimeter or internal nozzles
- Allows variable digester operating liquid elevation
- Continuous or intermittent operation



Preliminary Digester Mixing Technology Comparison

Plant	Pump Mixing	Draft Tube Mixing	$/MG Mixed (Capital Cost)	$/MG Mixed (20-yr Life Cycle Cost)
Eugene, OR 85 ft Diameter 26 ft SWD 1 17 MG	NA	4 external 24-inch diameter draft tubes 40 hp total	$577,160	$1,085,000
Monterey, CA 86 ft Diameter 30 ft SWD 1 42 MG	1 Vaughan Chopper Pump 50 to 100 hp total	NA	$501,050	$1,039,000 to $1,488,000
DSRSD, CA 70 ft Diameter 37 5 ft SWD 1 03 MG	1 Vaughan Chopper Pump 37 5 to 75 hp total	3 roof mounted 24-inch diameter draft tubes 30 hp total	$575,000 (draft tube mixing) $500,000 (pump mixing)	$993,000 (draft tube mixing) $926,000 to $1,262,000 (pump mixing)

Preliminary Digester Mixing Technology Comparison

Mixing Technology	Advantages	Disadvantages
Draft Tube Mixing	• Plant staff familiar with operating procedures • Multiple mixers provide added reliability • Lower struvite formation potential than pump mixing	• Large dome/wall penetrations • Roof mounted motors are more difficult to access and maintain • Impeller can be prone to clogging with rags • Must run continuously
Pump Mixing	• Easier access to equipment for routine maintenance • Chopper pumps macerate rags and debris to reduce clogging • Allows variable digester operating liquid elevation • Can operate pump intermittently to reduce energy cost	• Higher struvite formation potential than draft tube mixing • Internal piping and nozzle mixing systems are located inside the digester

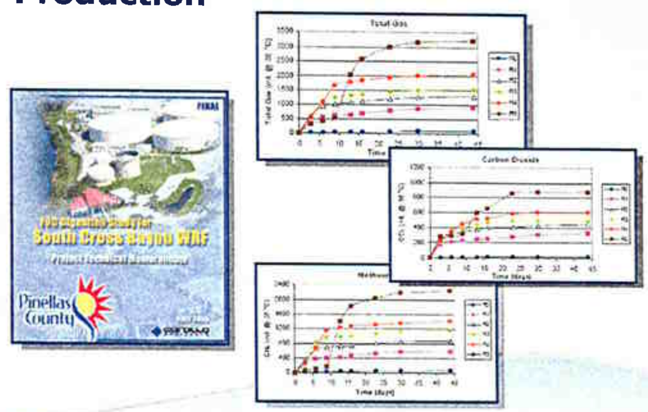
Digester Heating Design

- Spiral heat exchanger
- Others?

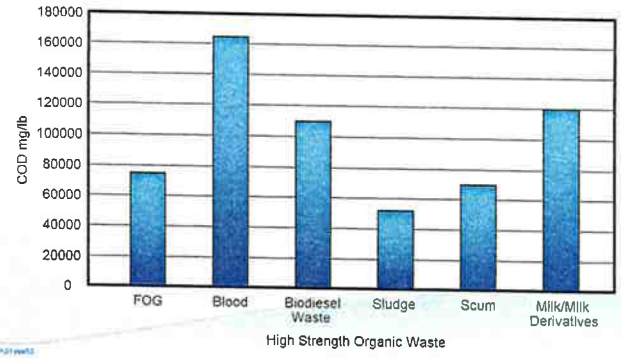
DSRSD

FOG Receiving Facility

FOG Digestion Increases Gas Production



Characterization of High Strength Wastes is Critical for the Estimation of Performance



Next Steps

MMSD

Madison Metropolitan Sewer District

Solids Handling Facilities Plan

Workshop No 2a
Interim Operation

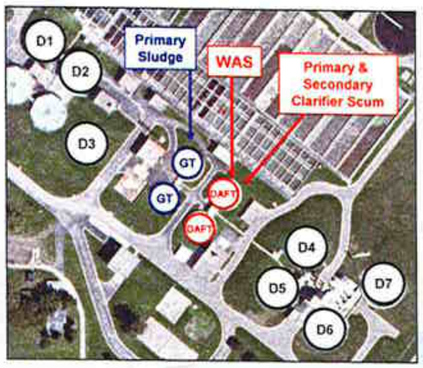
AppliedTechnologies
Engineers - Architects

carollo
Engineers...Working Wonders With Water

Agenda

1. Current Operation
2. Recent Problems
3. Operating the Digestion System for the Next 2-3 years
4. Alternative Operating Strategies
5. Field Visit
6. Post Field Visit Wrap-up

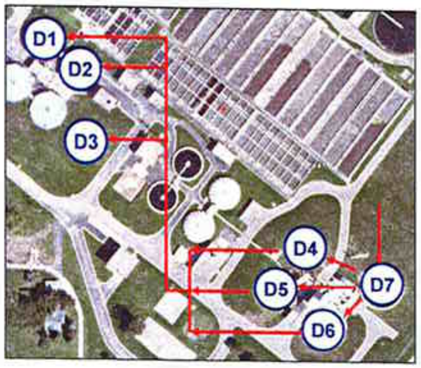
DAFT units receive WAS and clarifier scum.



Current foaming events may be attributed to clarifier scum.

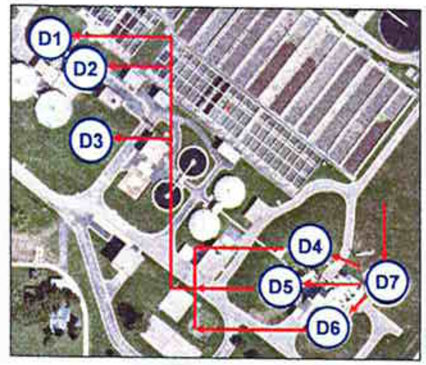
1. Foaming events associated with WAS digestion. WAS and scum are sent to DAFT.
2. Less grease problems in heat exchangers under acid-phase mode.
   a. Scum accumulation with gas mixing systems.
   b. Acid digester retains the scum. Increased foaming in acid digester and less grease problems downstream.
3. Poor Mixing in Acid Digester
   a. Operation at low-liquid level may reduce the mixing efficiency.
   b. Gas mixing in acid digester undermines benefit of low gas production during acidification.
   c. Interior columns may interfere with mixing.

Current Operation D7 as Acid Phase



Design Criteria	Avg
Acid Phase	
HRT	<2.7
VSLR	0.81
Methane Phase	
Thermo	9.2
Meso	7.2
Storage	
HRT	>3.0

Interim Operation in Staged Digestion Mode (Alternate)



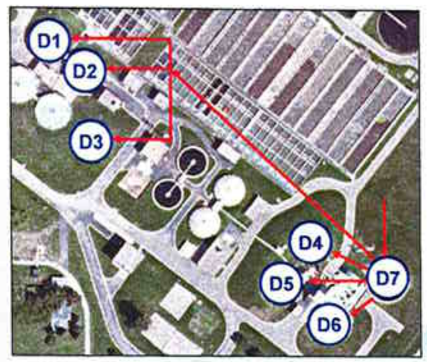
Design Criteria	Avg	Max Month
Stage 1		
HRT	3.9	3.3
VSLR	0.56	0.66
Stage 2		
HRT	7.8	10
Stage 3		
HRT	5.0	5.0

Interim Operation in Acid-Phase Digestion Mode

Design Criteria	Avg	Max Month
Acid		
HRT	2.0	1.3
VSLR	1.1	1.7
Methane		
HRT	15.6	16.6

- ✔ Meets AP criteria of 3 lbs/cfd max VSLR
- ✔ Meets AP criteria of 1 to 3-day HRT at Max Month flow
- ✔ Meets MP criteria of 13-day min HRT

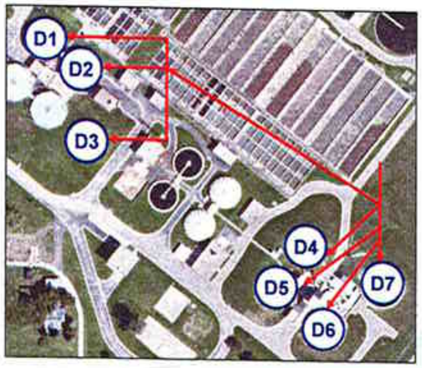
Interim Operation in Conventional Digestion Mode



Design Criteria	Avg	Max Month
HRT	13.6	15.0
VSLR	0.16	0.15

- ✔ Meets criteria of 0.18 lbs/cfd max VSLR
- ✔ Meets criteria of 15-day min HRT at Max Month flow with all tanks in service
- ✔ Close to criteria of 15-day min HRT at Average flow with Largest out of service

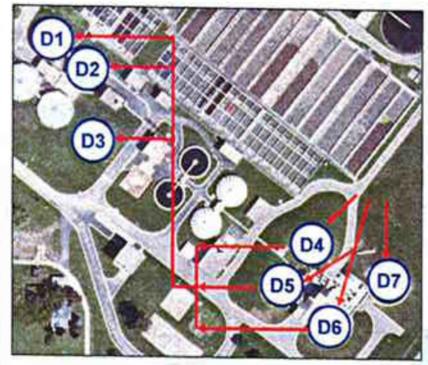
Interim Operation in Conventional Digestion Mode



Design Criteria	Avg	Max Month
HRT	13.6	15.0
VSLR	0.16	0.15

- ✓ Meets criteria of 0 18 lbs/cfd max VSLR.
- ✓ Meets criteria of 15-day min HRT at Max Month flow with all tanks in service.
- ✓ Close to criteria of 15-day min HRT at Average flow with Largest out of service.

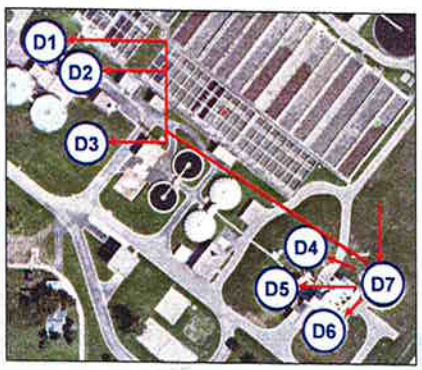
Interim Operation in Staged Digestion Mode



Design Criteria	Avg	Max Month
Primary		
HRT	13.3	11.7
VSLR	0.16	0.19
Secondary		
HRT	5.0	5.0

- ☐ Does not meet criteria of 0 18 lbs/cfd max VSLR at average flow with largest unit out of service.
- ☐ Does not meet criteria of 15-day min HRT in primary digesters.
- ✓ Meets criteria of 5-day min HRT in secondary digester.

Interim Operation in D7 Cold Storage Mode



Design Criteria	Avg	Max Month
Stage 1		
HRT	3.9	3.3
VSLR	0.56	0.66
Stage 2		
HRT	18	15

Field Visit

Post Field Visit Wrap-Up

1. Feasibility of Interim Operation Alternatives
2. Additional Alternatives
3. Addressing Operating Problems
   a. Foaming
   b. Struvite/Vivianite formation
   c. Stable Digestion
4. Other Issues
5. Adjourn

MMSD

Madison Metropolitan Sewer District

Solids Handling Facilities Plan

Workshop No 2b
Project Update

AppliedTechnologies
Engineers - Architects

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Agenda

1. Conclusions from TM 1 and 2
2. TM 3 Selected Alternative Evaluation
   a. Differences between operation and Master Plan assumptions – Effect on Process Sizing
   b. Other improvements required for long term acid phase operation
3. TM 4 Interim Operation
4. Wrap-up

TM 1 Identifies the Design Criteria

Table 1.3 Summary of Basis of Design
Solids Handling Facilities Plan
Madison Metropolitan Sewer District

Process Parameter	2007 Conditions		2030 Conditions	
	Average	Max Month [1,2]	Average	Max Month [1,2]
Plant Influent				
Flow, mgd	42.9	53.6	53.6	67.2
TSS Loading, ppd	77,700	93,200	115,100	138,100
BOD Loading, ppd	85,100	102,100	120,300	144,800
N Loading, ppd	12,900	15,500	19,600	23,500
P Loading, ppd	2,100	2,300	2,200	2,400
Primary Sludge to Thickening				
Total Solids, ppd	65,400	76,500	83,800	98,000
Waste Activated Sludge to Thickening				
Total Solids, ppd	40,200	45,800	53,000	60,400
Thickened Sludge to Digestors				
Total Solids, ppd [3]	101,100	117,100	130,900	151,300
Volatile Solids, ppd [4]	76,800	85,800	99,500	115,000

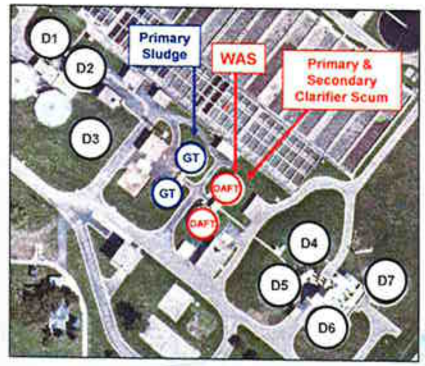
Notes:
(1) Based on the 50-Year Master Plan recommended 30-day peaking factors for influent flow (1.25), and TSS (1.20), BOD (1.20), TKN (1.20), and phosphorus (1.10) loadings
(2) Based on the 2007 process data 30-day peaking factors for primary sludge (1.17) and WAS (1.14) loadings.
(3) Based on the 2007 data average solids capture efficiency of gravity thickening and DAFT of 98 and 92 percent, respectively
(4) Based on the 2007 process data average thickened sludge volatile solids concentration of 76 percent

TM 2 Presents Class A Biosolids Processing Technology Screening

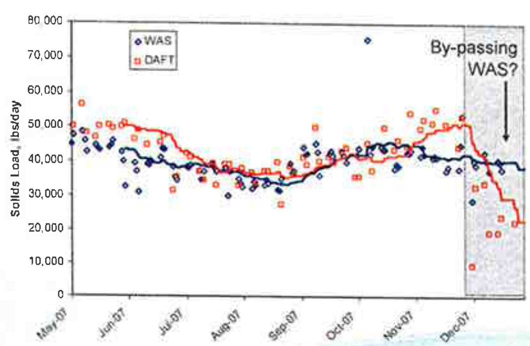
Table 2.1 Sludge Stabilization Technology Alternatives Summary
Biosolids Handling Facility Plan
Madison Metropolitan Sewer District

Stabilization Technology	[illegible]	[illegible]	[illegible]	[illegible]	Additional Operational Considerations
Composting	X		X		Land intensive, odor, fire danger, requires bulking agent dewatering and scrubbing equipment
Heat Drying	X		X	X	High energy consumption intensive operation requirements, fire danger, not compatible with Metromix and Metrogro programs
Zimpro (Heat Treatment)	X				Odors, energy intensive, high-strength side stream
Ver-Tech (Heat Treatment)	X				Odors, and energy intensive and high installation cost
Cambi THP (Heat Treatment)	X	X	X	X	Odors, energy intensive and requires digestion and high-strength side stream
Pasteurization	X	X		X	Pathogen re-growth, requires chemicals or digestion
Conventional Digestion		X	X	X	Requires more digester volume than other digestion processes
Acid-Phase Digestion (mesophilic-mesophilic)		X	X	X	Requires high volatile solids loading and short detention time in acid digester
Acid-Phase Digestion (mesophilic-	X	X	X	X	Requires high volatile solids loading and short detention time

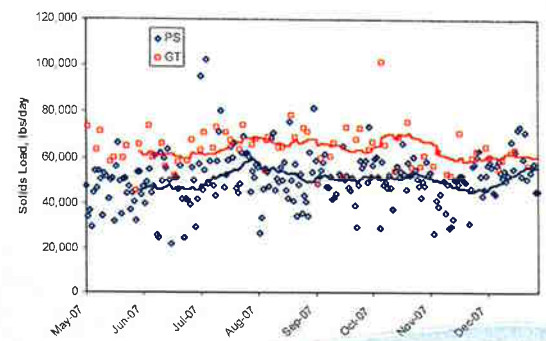
DAFT units receive WAS and clarifier scum.



Consistency between WAS and DAFT



Inconsistency between Primary Sludge and Gravity Thickeners



Technical Memorandum No. 3 Presents Evaluation of Cambi and Acid Phase MTM

Conventional Digestion with Cambi THP Requires Less Tankage than Acid Digestion.

	Conventional Digestion with Cambi THP	Acid Phase Digestion
Future Flow (20.7 mgd)	10% Solids Feed	6% Solids Feed

Existing digester

New 0.6 MG Acid Digester

New Cambi THP System

New Methane Digester Required for Solids Concentration less than 6%

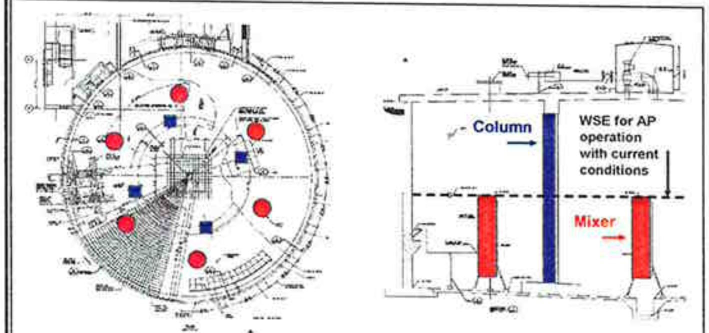
Sludge Thickening Improvements Required for Modified Digestion Facility.

Table 4.1 Existing Sludge Thickening Units
Solids Handling Facilities Plan
Madison Metropolitan Sewer District

	Gravity Thickeners	DAFT
Number of Units	2	2
Diameter, ft	55	55
Total Surface Area, sqf	4,752	4,752
Solids Loading, ppd	65,400 (1)	40,200 (2)
Solids Capture Efficiency, %	98 3	92 0
Thickened Sludge Solids, %	5.0	4.2

Notes:
(1) Primary sludge
(2) Waste activated sludge

Internal structure of digesters may affect the mixing system design.



Digester Plan

Digester Section

Temperature input to estimate the digester heating requirements.

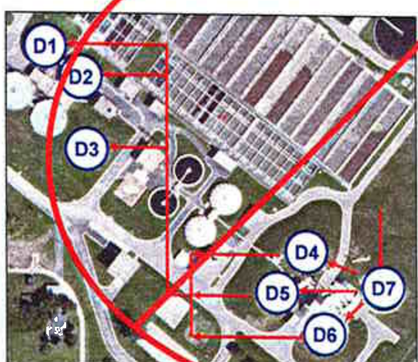
	Summer	Winter
Air	71	16
Ground	70	40
Raw Sludge	70?	65?

Temperature in degrees Fahrenheit.

TM4 Identifies Interim Operation Modifications

1. Boundary Conditions
   a. Must be In-Place before Winter 2008
   b. Must improve:
      - Reliability
      - Foaming
      - Struvite/Vivianite
      - Grease in Heat Exchangers
   c. Must not require large capital expenses

Current Operation D7 as Acid Phase

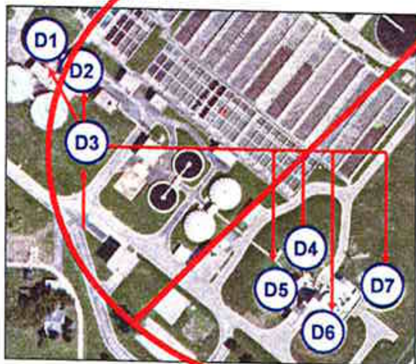


Design Criteria	Av
Acid Phase	
HRT	<1.7
VSLR	0.51
Methane Phase	
Thermo	7.2
Meso	4.2
Storage	
HRT	<3.0

Interim Operation in Staged Digestion Mode (Alternate)

Design Criteria	Av	Max Month
Stage 1		
HRT	3.9	3.3
VSLR	0.56	0.66
Stage 2		
HRT	7.8	10
Stage 3		
HRT	5.0	5.0

Interim Operation in Acid-Phase Digestion Mode



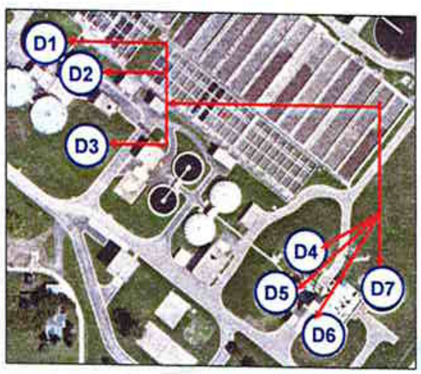
Design Criteria	Avg	Max Month
Acid		
HRT	2.0	1.3
VSLR	1.1	1.7
Methane		
HRT	15.6	16.6

Interim Operation in Two Stage Digestion Mode

Design Criteria	Avg	Max Month
Primary		
HRT	13.3	11.7
VSLR	0.16	0.19
Secondary		
HRT	5.0	5.0

Interim Operation in Conventional Digestion Mode

Design Criteria	Avg	Max Month
Primary		
HRT	>15	>15
VSLR	<.13	<.17
Secondary		
HRT	>3.0	>3.0



Interim Operation in D7 Cold Storage Mode

Design Criteria	Avg	Max Month
Stage 1		
HRT	3.9	3.3
VSLR	0.56	0.66
Stage 2		
HRT	18	15

Summary of Interim Operation

1. Operating D3 as an acid phase will not be possible before winter, requires significant piping modifications
2. Operating in staged digestion mode will not resolve operating challenges
3. Operation in single stage mesophilic digestion for the interim period resolves operational issues and can be implemented before winter.

MMSD

Madison Metropolitan Sewer District

Solids Handling Facilities Plan

Workshop No 2b
Project Update

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MADISON METROPOLITAN
SEWERAGE SYSTEM

MMSD

SOLIDS HANDLING FACILITIES PLAN

WORKSHOP 3: PROGRESS MEETING
November 5, 2008

Applied Technologies
Engineers - Architects

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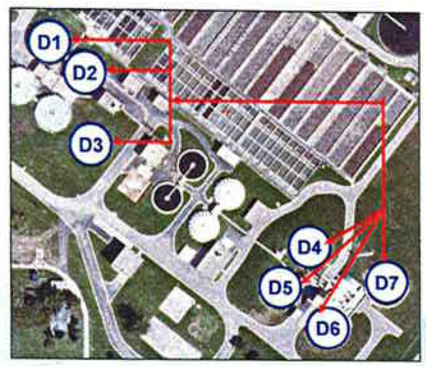
Agenda

- Workshop Goals
- Interim Operation - Update
- TM 03 – Anaerobic Digestion Process Evaluation
- Anaerobic Digestion Process Selection
- TM 04 – Digester Ancillary Systems Evaluation
- Next Steps and Wrap-up

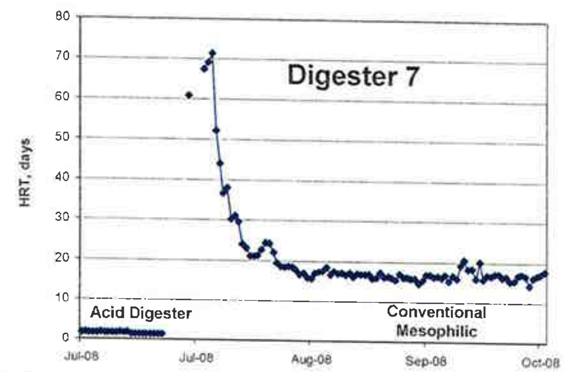
Workshop No. 3 Goals

1. Select Sludge Stabilization Process
2. Key Decision to Finalize TM No. 3
3. Future Technical Memoranda
4. Define Next Steps and Timeline

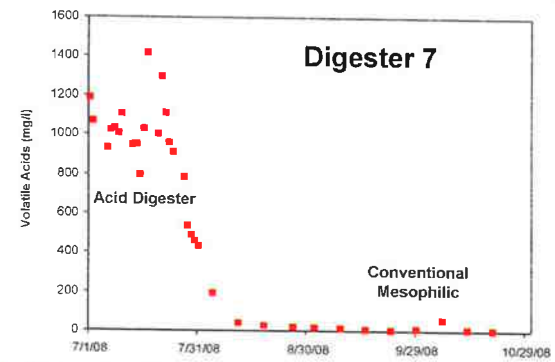
Conventional Digestion was Selected for Interim Operation



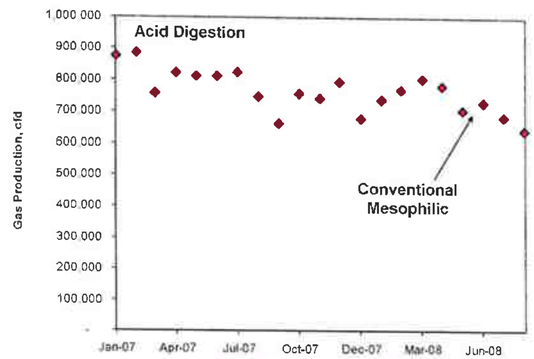
Interim Operation Resulted in Stable Digestion Performance



Interim Operation Resulted in Stable Digestion Performance



Interim Operation Resulted in Stable Digestion Performance



Lessons Learned

1. Conventional mesophilic has provided stable operation at Nine Springs.
2. Struvite problems have been mitigated
3. Vivianite?
4. Digester gas production has dropped from 800 kcf/d to 700 cf/d
5. Foam has not been detected in 1,2,3 and 7. 4,5,6 show minimal foam.
6. Propionate in Digester 7 took approximately 2 months to subside.

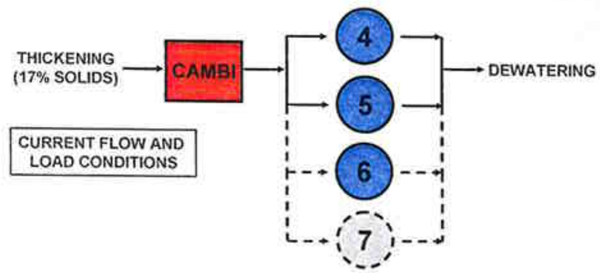
Technical Memorandum 3: Anaerobic Digestion Process Evaluation

Three proven technologies were compatible with MMSD's goals.

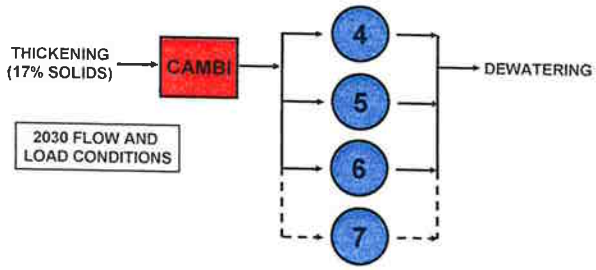
TECHNOLOGY	CLASS A/EQ	MMSD PROGRAMS	FULL-SCALE INSTALLATIONS	ENERGY RECOVERY
Conventional Digestion with Cambi THP	x	x	x	x
Acid-Phase Digestion (mesophilic-thermophilic)	x	x	x	x
TPAD	x	x	x	x

Non-Economic Evaluation

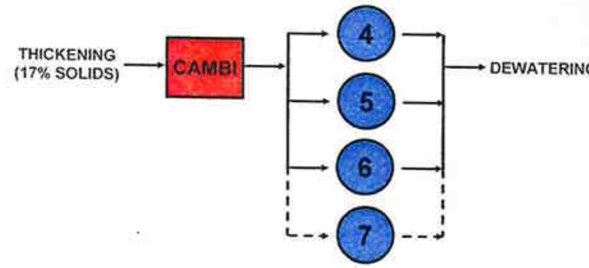
Conventional Digestion with Cambi THP



Conventional Digestion with Cambi THP



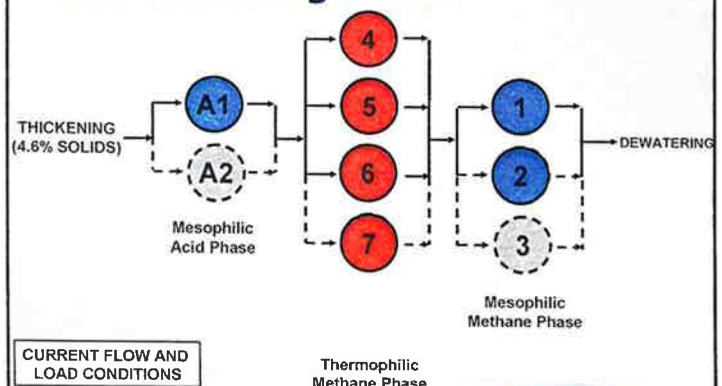
Conventional Digestion with Cambi THP



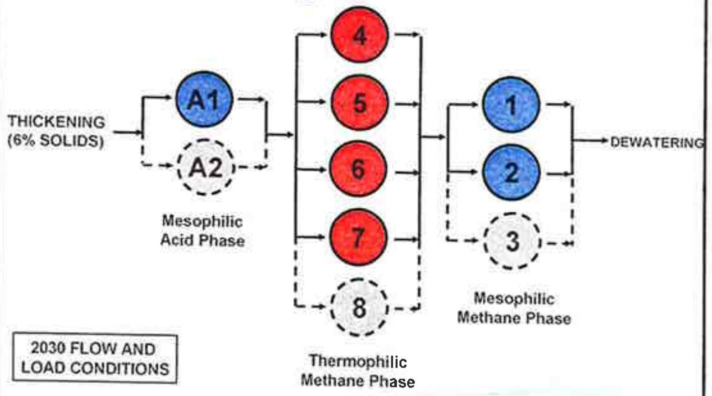
ADVANTAGES		DISADVANTAGES	
• Solids Reduction	• Biogas Production	• Capital Cost	• Energy Usage
• Dewaterability	• Biosolids Volume	• Dark Sidestream	• Thickening
• Filaments	• Class A	• U.S. Installations	

Conventional Digestion with Cambi THP Layout

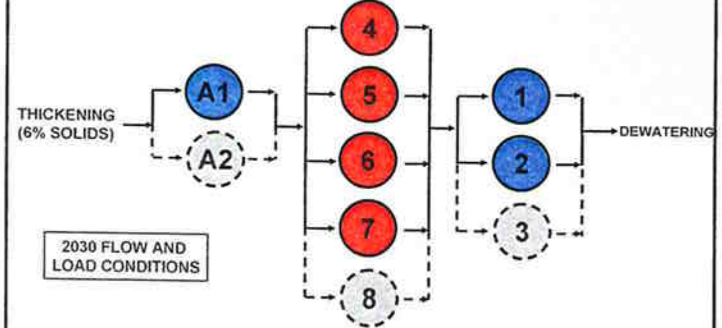
Acid Phase Digestion



Acid Phase Digestion



Acid Phase Digestion



ADVANTAGES		DISADVANTAGES	
• Solids Reduction	• Biogas Production	• Site Constraints	• Thickening
• Dewaterability	• Biogas Quality	• Hydrogen Sulfide	• Monitoring
• Class A	• U.S. Installations		

Acid Phase Digestion Layout

Acid Phase Digestion can operate without acid digester redundancy

IEUA
40 MGD

RENO-SPARKS
33 MGD

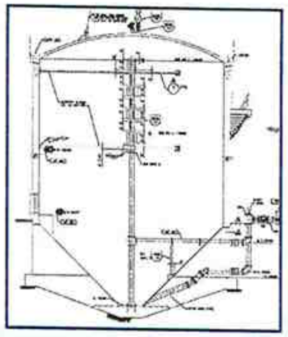
TURLOCK
13 MGD

BLACK RIVER
40 MGD

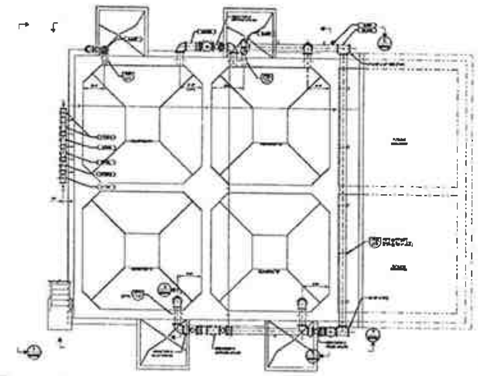
DU PAGE
30 MGD

Acid Phase Digestion can operate without acid digester redundancy

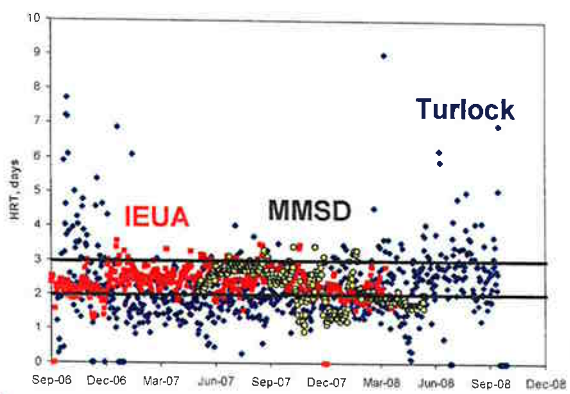
1. Digester design prevents grit accumulation
2. Methane Phase satisfies minimum HRT for digestion



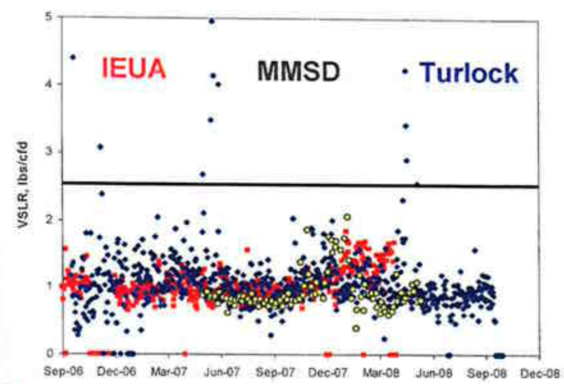
Multi-Cell Design Provides Redundancy Without Extra Tank



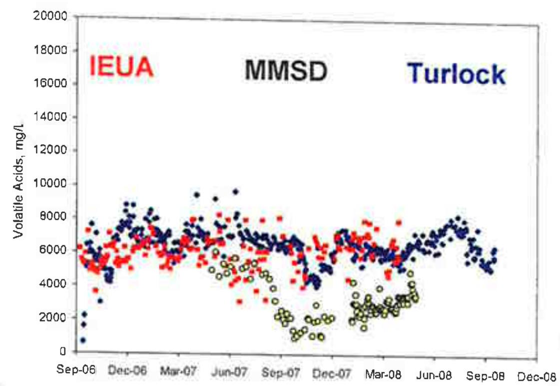
Acid Phase Design Criteria is Consistent with Existing Facilities



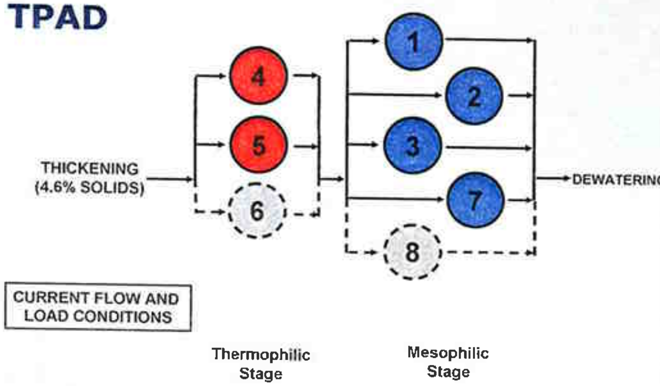
Acid Phase Design Criteria is Consistent with Existing Facilities



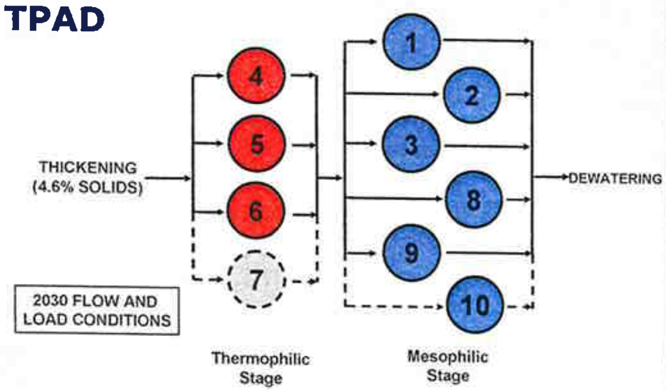
Volatile Acids are Good Indicators of Acid Phase Performance



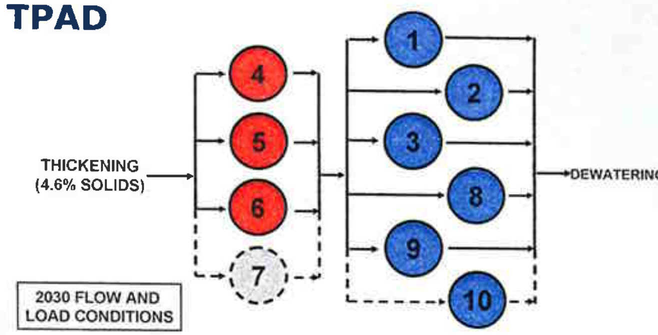
TPAD



TPAD



TPAD



ADVANTAGES	DISADVANTAGES
• Solids Reduction • Biogas Production	• Site Constraints • Biogas Quality
• Dewaterability • Current Design	• Testing
• Class A • U.S. Installations	

TPAD Layout

HRT Criteria for TPAD is Consistent with Existing Facilities

	Thermophilic	Mesophilic
Cologne	7	27
Wilhelmshaven	3-5	13-18
Western Lake Superior Sanitary District	5	15

Errata:
Large US TPAD Facility = WLSSD
Annacis Island = Staged Thermophilic not TPAD

Batch Configuration Presents Significant Operational Challenges

1. Nine Springs first full-scale installation.
2. Bench-scale operation at Iowa State University.
3. Sequencing batch configuration problems:
   a. Preheating Issues
      - Raw Sludge
      - 300% Increase in heat demand
   b. Instantaneous gas production
   c. Balance gas with draw digester
4. Thermal capacity of heat supply system needs to match thermal loads

Pre-treatment Process required to destroy *Microthrix*

Proven Technologies

1. Cambi Thermal Hydrolysis Process
2. Crown Sludge Disintegration (Cavitation)

New Technologies

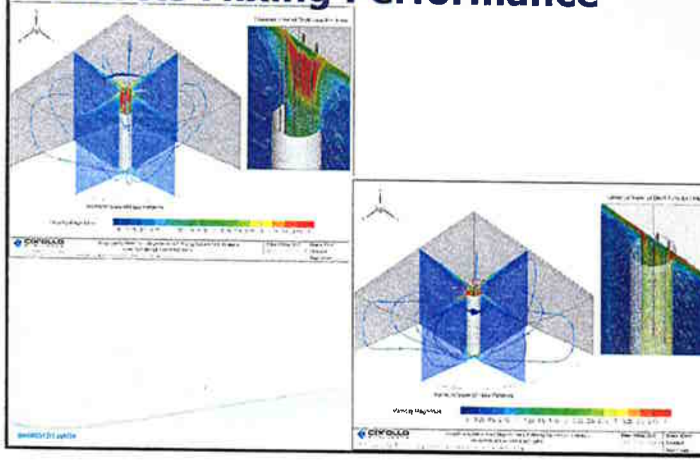
1. Micro-Sludge (Pressure + Chemicals)
2. OpenCEL – Electroporation
3. Other

ANAEROBIC DIGESTION DOES NOT DESTROY MICROTHRIX!

Modifications to mixing system may reduce foaming potential

1. Gas mixing systems
2. Nine Springs Eductor Tubes are short
    a. Decreased mixing efficiency
    b. Gas bubble dispersion
3. Alternative analysis is not impacted by mixing alternatives
4. Ultimate mixing system change dependant on MMSD decision.

Sludge Depth Significantly Affects Mixing Performance



Economic Evaluation

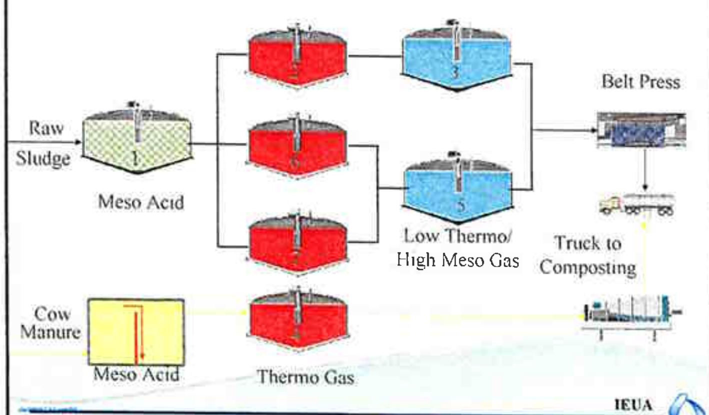
Space for ATI Slide

Conventional Digestion with Cambi Requires Less Tankage

Conventional Digestion with Cambi THP	Acid Phase Digestion (Meso-Thermo-Meso)	TPAD
4 5 6 7 THP	A B 8 1 2 3	7 1 2 3 8 9 10
17% SOLIDS FEED	6% SOLIDS FEED	4.6% SOLIDS FEED
$ XX,XXX,000	$ XX,XXX,000	$ XX,XXX,000

Process Selection Group Discussion

RP-1 Operations



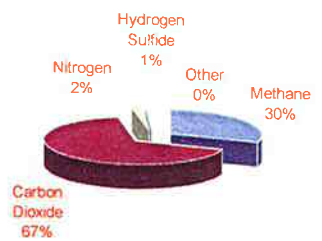
Increasing Solids Concentration has Upper Limit under Conventional Digestion

% Solids	Organic Loading @ 15 day HRT Lbs VSS/ft3-d[1]	Limiting Criteria [1]
1	0.03	Hydraulic Limited
2	0.07	Hydraulic Limited
3	0.10	Hydraulic Limited
4	0.13	Hydraulic Limited
5	0.17	Solids Limited
6	0.20	Solids Limited
7	0.23	Solids Limited
8	0.27	Solids Limited
9	0.30	Solids Limited
10	0.33	Solids Limited

1. Assumes 80% Volatile Suspended Solids

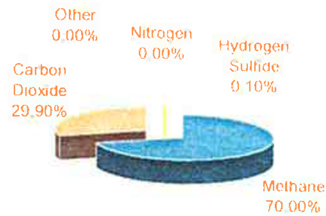
Two Phase Systems Maximize the Production of High-Quality "Useful" Gas

Acid Phase Gas



1.6 ft^3 ~ 10%
IEUA Ave. 8 %

Methane Phase Gas



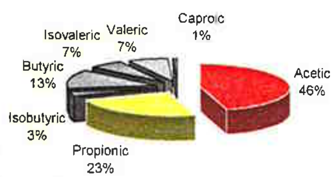
16.6 ft^3 ~90%
IEUA Ave. 92%

Acid Phase Digester Sampling

1. Daily Samples
   a. Total solids, volatile solids, pH, volatile acids, alkalinity
2. Weekly Samples
   a. Ammonia
3. Revised sampling protocol to process samples within 15 minutes of receiving them

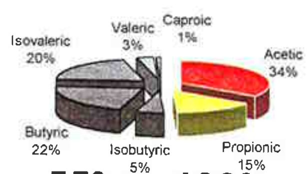
Temperature Effects on Acidogenesis

69% **of products are easily Biodegradable**



35°C 98°F

49% **of products are easily Biodegradable**



55°C 133°F

250% Increase in Offensive Odor Acids

Next Steps

Technical Memoranda

TM01 – Basis of Design
TM02 – Sludge Stabilization Alternatives
TM03 – Anaerobic Digestion Processes
TM04 – Digester Ancillary Systems
TM05 – Mitigation of Scale Formation
TM06 – Biogas Utilization
TM07 – Implementation Plan

Technical Memorandum No. 4 Digester Ancillary Systems

Next Meeting

MADISON METROPOLITAN SEWERAGE SYSTEM

SOLIDS HANDLING FACILITIES PLAN

WORKSHOP 4: PROGRESS MEETING
May 8, 2009

AppliedTechnologies Engineers - Architects

carollo Engineers...Working Wonders With Water

Agenda

- Workshop Goals
- TM 03 – Anaerobic Digestion Process Evaluation
- Class A Biosolids
- TM 05 – Foaming Mitigation
- TM 06 – Struvite Mitigation
- TM 07 – Grease Co-digestion
- Anaerobic Digestion Process Selection
- Next Steps

Workshop No. 4 Goals

1. Compare Sludge Stabilization Alternatives
   a. Class A Biosolids
   b. Digester Foaming
   c. Struvite
   d. Grease Co-digestion
2. Select Sludge Stabilization Process
3. Define Next Steps and Timeline

Technical Memorandum 3: Anaerobic Digestion Process Evaluation

Alternatives compatible with the District's goals

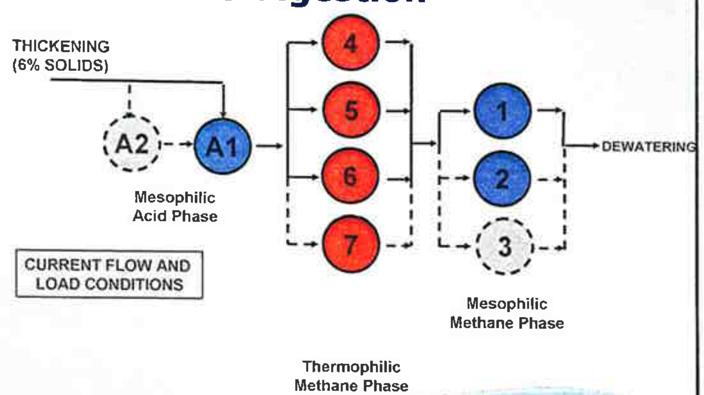
TECHNOLOGY	CLASS A/EQ	MMSD PROGRAMS	FULL-SCALE INSTALLATIONS	ENERGY RECOVERY
Conventional Digestion with Cambi THP	X	X	X	X
Acid-Phase Digestion (mesophilic-thermophilic)	X	X	X	X
TPAD	X	X	X	X
Conventional Digestion with Heat Drying	X	X	X	X
Conventional Digestion with En-Vessel P	X	X	X	X
Conventional Digestion with Batch Thermo	X	X	X	X

2nd Tier Evaluation for Major Operational Issues and Cost

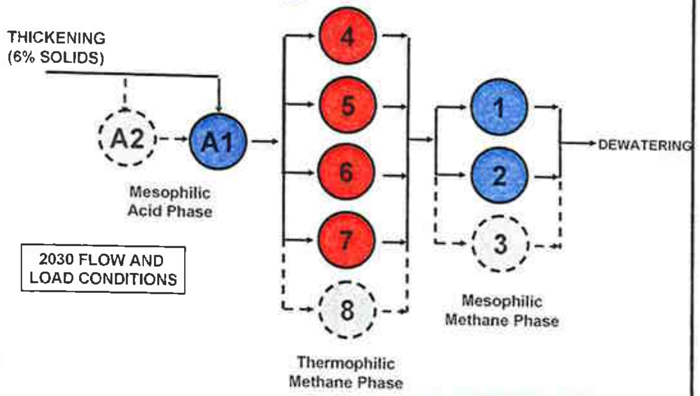
TECHNOLOGY	FOAMING	STRUVITE	GREASE	COST
Conventional Digestion with Cambi THP				
Acid Phase Digestion (Meso-Thermo-Meso)				
TPAD				
Conventional Digestion with Heat Drying				
Conventional Digestion with En-Vessel Pasteurization				
Conventional Digestion with Batch Thermophilic				

TM No. 3
Non-Economic Evaluation

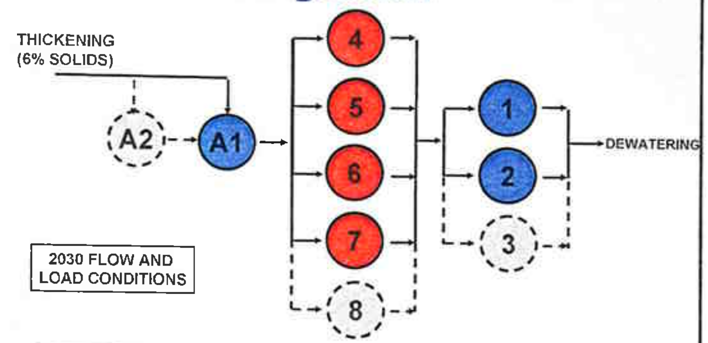
Acid Phase Digestion



Acid Phase Digestion



Acid Phase Digestion



ADVANTAGES		DISADVANTAGES	
• Solids Reduction	• Biogas Production	• Site Constraints	• Thickening
• Dewaterability	• Biogas Quality	• Hydrogen Sulfide	• Class A Monitoring
• Class A	• U.S. Installations	• Odors	

Acid Phase Digestion Full-Scale Installations

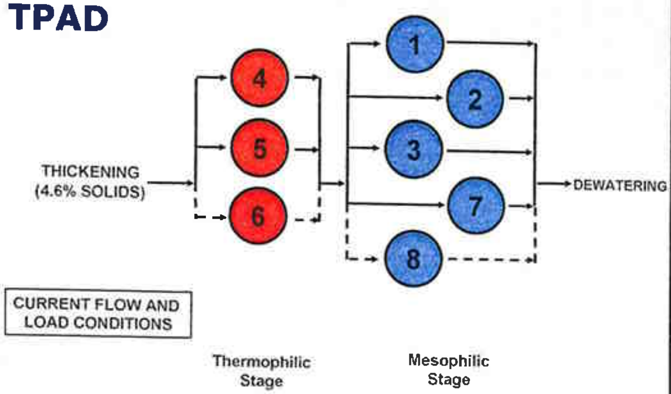
Inland Empire Utilities Agency
(Chino, CA)

Woodridge-Green Valley WWTP
(DuPage County, IL)

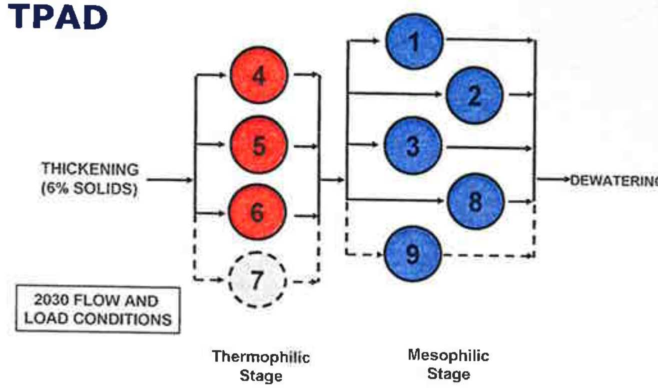
Class A Biosolids

Preliminary Layout: Acid Phase Digestion

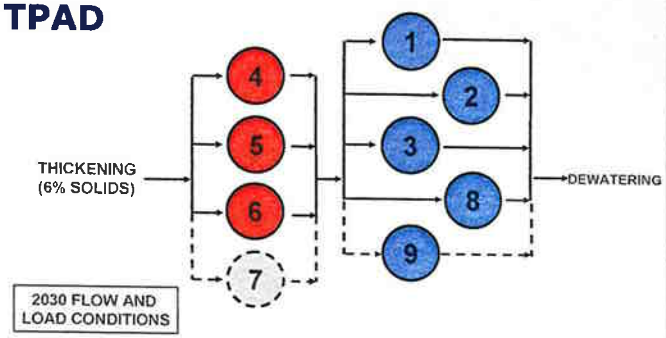
TPAD



TPAD



TPAD



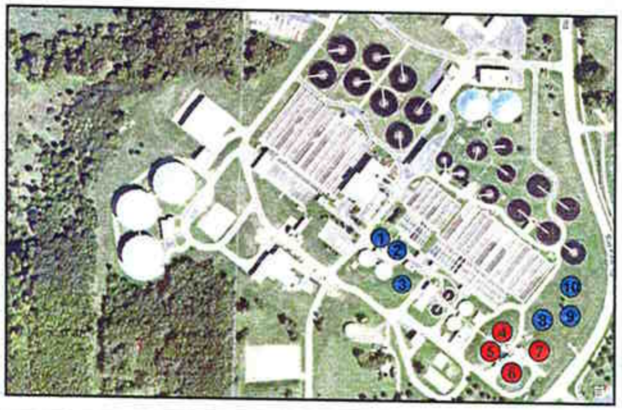
ADVANTAGES	DISADVANTAGES
• Solids Reduction • Biogas Production • Dewaterability • Current Design • Class A • U.S. Installations	• Site Constraints • Biogas Quality • Monitoring Class A • Sludge Preheating • Odors

TPAD Digestion Full-Scale Installations

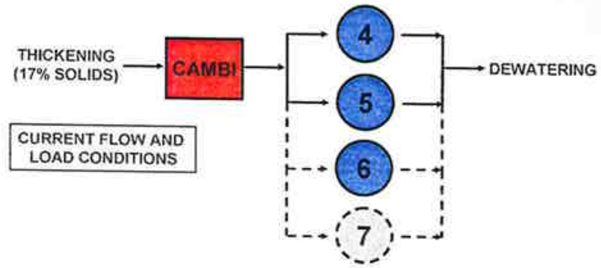

Western Lake Superior Sanitary District (MN)


Nine Springs WWTP (Madison, WI)

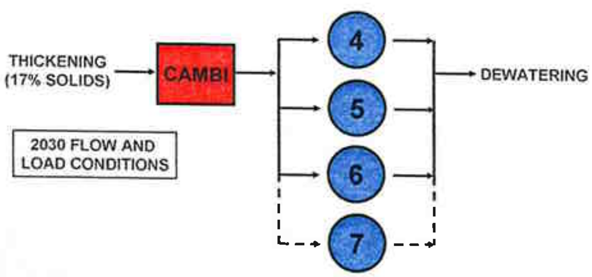
Preliminary Layout: TPAD



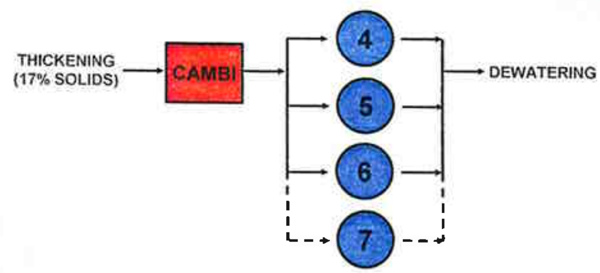
Conventional Digestion with Cambi THP



Conventional Digestion with Cambi THP



Conventional Digestion with Cambi THP



ADVANTAGES		DISADVANTAGES	
• Solids Reduction	• Biogas Production	• Capital Cost	• Energy Usage
• Dewaterability	• Biosolids Volume	• Dark Sidestream	• Thickening
• Filaments	• Class A	• U.S. Installations	

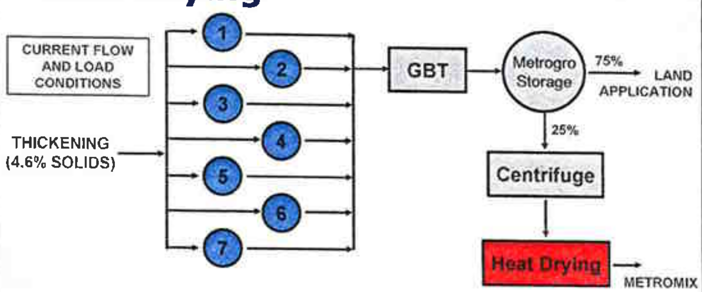
Conventional Digestion with Cambi Full-Scale Installations

Dublin Bay WWTP (Ireland)

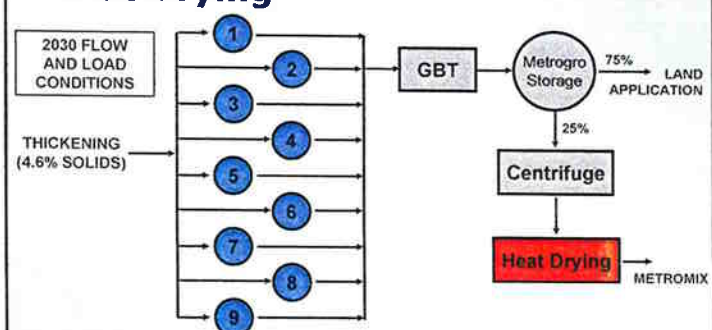
Cotton Valley WWTW (UK)

Preliminary Layout: Conventional Digestion with Cambi THP

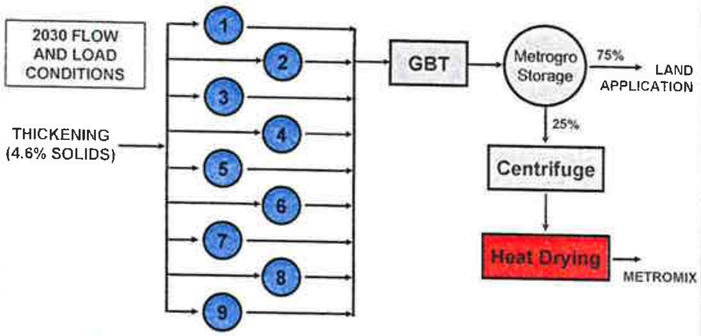
Conventional Digestion with Heat Drying



Conventional Digestion with Heat Drying



Conventional Digestion with Heat Drying



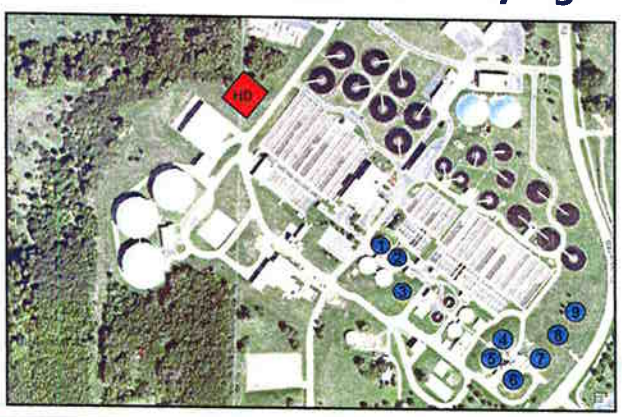
ADVANTAGES	DISADVANTAGES
• Stable Operation • Class A	• Energy Use • Site Constraints • Class B • Carbon Footprint • U.S. Installations

Conventional Digestion with Heat Drying Installations

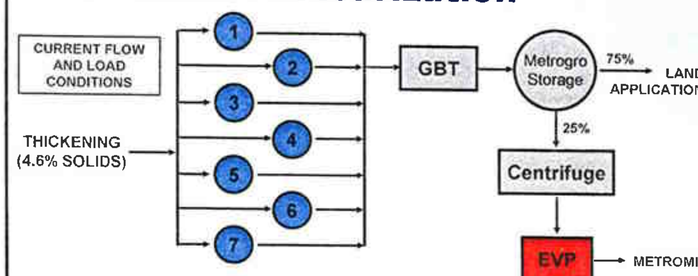
City of Buffalo (NY)
Water Evaporation=1,200 kg/hr

Landkreis Boblingen WWTP (Germany)
Water Evaporation=1,700 kg/hr

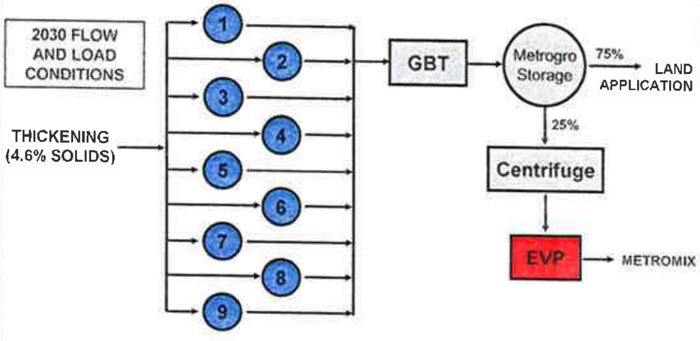
Preliminary Layout: Conventional Digestion with Heat Drying



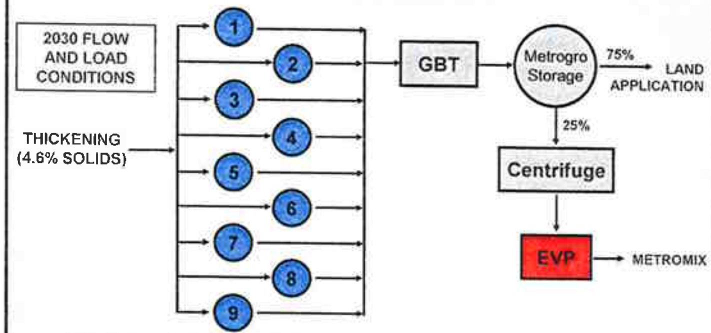
Conventional Digestion with En-Vessel Pasteurization



Conventional Digestion with En-Vessel Pasteurization



Conventional Digestion with En-Vessel Pasteurization



ADVANTAGES		DISADVANTAGES	
• Stable Operation	• Class A	• Energy Use	• Site Constraints
• U.S. Installations		• Class B	• Chemical Costs

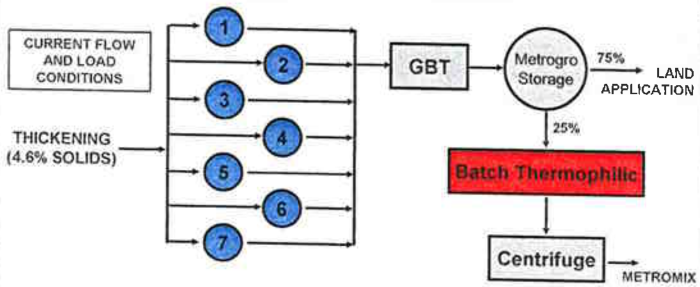
Conventional Digestion with En-Vessel Pasteurization Installations

South Coastal WWTP (DE)
900 dry tons per year

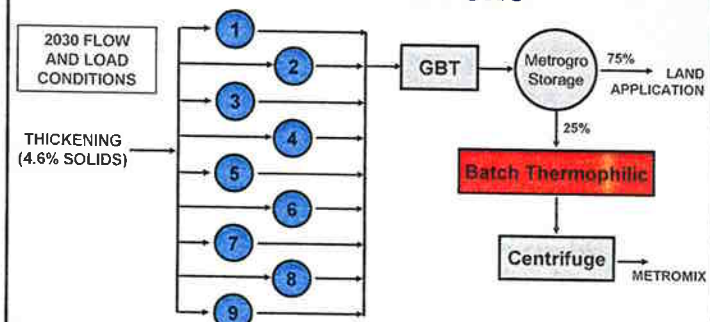
Seymour WWTP (IN)
700 dry tons per year

Preliminary Layout: Conventional Digestion with EVP

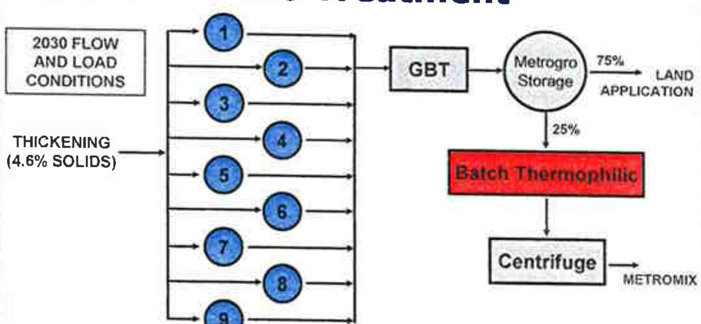
Conventional Digestion with Batch Thermo Treatment



Conventional Digestion with Batch Thermo Treatment



Conventional Digestion with Batch Thermo Treatment



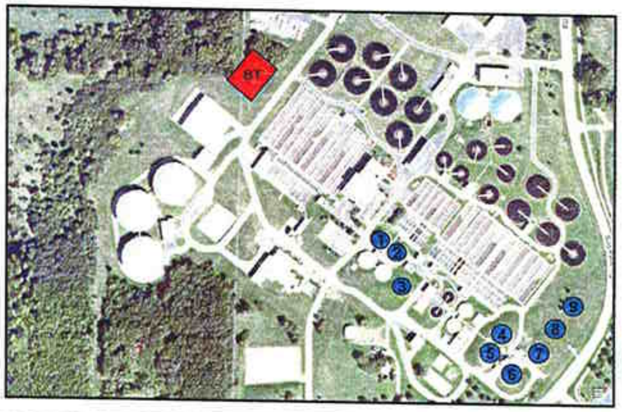
ADVANTAGES		DISADVANTAGES	
• Stable Operation	• Class A	• Energy Use	• Site Constraints
• U.S. Installations		• Class B	• Pathogen Regrowth

Conventional Digestion with Batch Thermo Treatment Installations

Hyperion WWTP (CA)
Biosolids: 650 wet tons per day

Terminal Island (CA)
Biosolids: 50 wet tons per day

Preliminary Layout: Conventional Digestion with Batch Thermo



Class A Biosolids

Class A Biosolids Comparison

	Acid Phase	TPAD	Cambi	Heat Drying	EVP	Batch Thermo
Class A Alternative	3	3	1, 5	5	2	1
No Additional Monitoring			✓	✓	✓	✓
Installations with Class A	✓			✓	✓	✓
100% of Solids Stream	✓	✓	✓			

<u>Class A Alternatives:</u>
1 - Thermal Treatment
2 - High pH and High Temperature
3 - Site-Specific Permit
5 - PFRP

Site Constraints

Site Constraints and Present Worth Cost Comparison

	Acid Phase	TPAD	Cambi	Heat Drying	EVP	Batch Thermo
	A 4 1 B 5 2 3 8 THI	1 2 3 7 8 9 THI	4 5 6 7 DW THP	1 7 2 8 3 9 4 5 6 HD	1 7 2 8 3 9 4 5 6 EVP	1 7 2 8 3 9 4 5 6 BT
CAPITAL	$10.2 M	$ 9.1 M	$24.0 M	$20.0 M	$ 8.2 M	$ 8.8 M
O&M	$16.5 M	$14.0 M	$56.0 M	$18.2 M	$17.7 M	$15.7 M
HAULING	$19.9 M	$19.9 M	$11.8 M	$22.0 M	$25.5 M	$24.5 M
TOTAL	$46.7 M	$43.0 M	$91.8 M	$60.2 M	$51.4 M	$49.0 M

Foam Mitigation

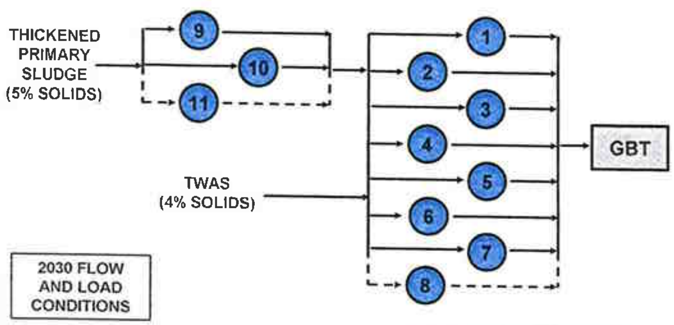
Digester Foaming Comparison

	Acid Phase	TPAD	Conventional with Cambi	Conventional with Post-Treatment
Microthrix Destruction			?	
Prevents Lipid and Protein Foaming	✓		✓	
Compatible with Cell Lysis Systems	✓		✓	✓
Compatible with Mechanical Mixing	✓	✓	✓	✓
Overall *Microthrix* Foaming Risk	High	High	?	High

Foam Mitigation Alternatives

	Low SRT	High DO	Chem Addition	WAS Treatment	Digester Mixing	WAS only AD
Microthrix Destruction				✓		
Compatible with BNR		✓	✓	✓	✓	✓
AB Foaming	✓	✓	✓			
AD Foaming	✓			✓	✓	✓*
Capital Cost	None	None	Low	High	High	?

Kappala WWTP Configuration Requires Four New Digesters



Pre-treatment Process required to destroy *Microthrix*

Proven Technologies

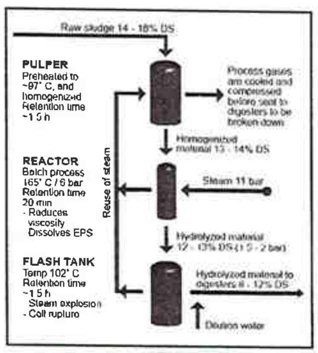
1. Cambi Thermal Hydrolysis Process
2. Crown Sludge Disintegration (Cavitation)

Other Technologies

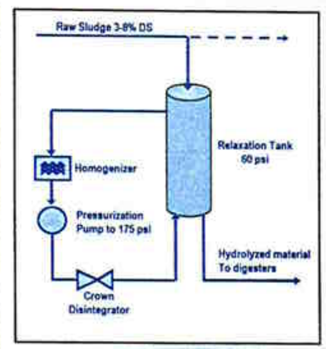
1. Micro-Sludge (Cavitation + Chemicals)
2. OpenCEL – Electric Pulsing
3. Direct Steam Injection
4. Ultrasonic Cavitation

ANAEROBIC DIGESTION ALONE DOES NOT DESTROY MICROTHRIX!

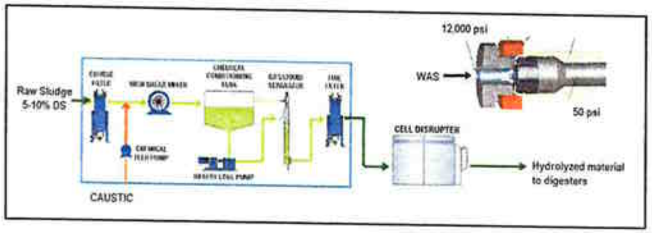
Cambi Thermal Hydrolysis Process



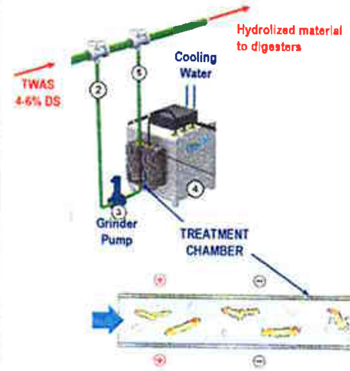
Crown Sludge Disintegration System



MicroSludge System



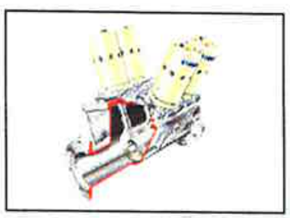
OpenCEL System



Northwest WRP (Gilbert, AZ)

Ultrasonic Cavitation Technology

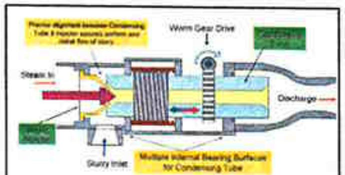
1. Vibrating probe generates high-frequency sound (20-40 kHz).
2. Formation/collapse of micro-bubbles cause localized gradients of high temperature and pressure.
3. Cells ruptured through cavitation.



Mangere WWTP (New Zealand)
Average Flow = 80 mgd

Jetcooker (Direct Steam Injection)

1. Used for Starch Hydrolysis in Ethanol Production
2. Combines Mechanical Shear and temperatures up to 250 deg F
3. Blend with primary sludge to reduce temperature
4. Decreases digester heating requirement



Cell Lysis Alternatives Evaluation

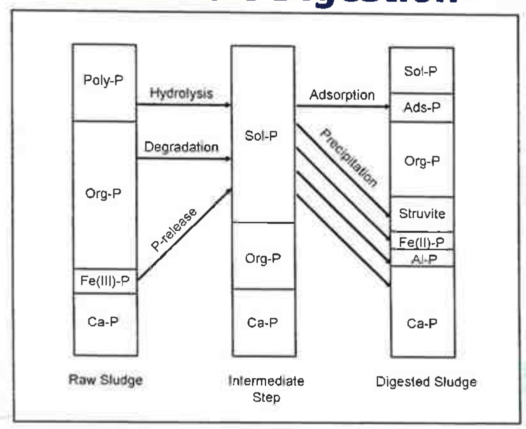
	Cambi	Crown	Micro Sludge	OpenCEL	Sonic	Steam Injection
Full Scale Installations	✓	✓		✓	✓	✓*
U.S. Installations				✓		
Full-Scale Trials	✓	✓	✓	✓	✓	
Cost Estimate	?		$ 2.7 M	$ 6.0 M	$ 3.0 M	?
Energy Usage per dry ton			450 kWh	300 kWh		?
O&M Cost per dry ton			$90	$30	$70	?

Struvite Mitigation

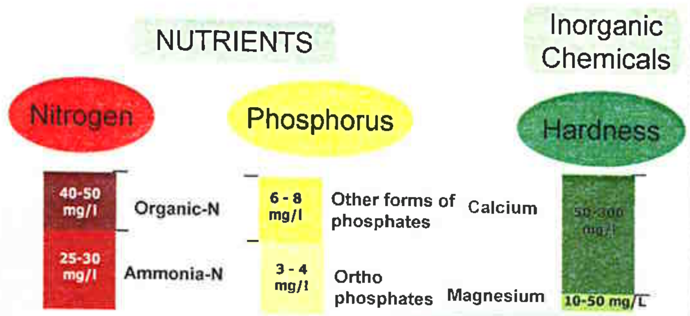
Digester P-Scaling Comparison

	Acid Phase	TPAD	Conventional with Cambi	Conventional with Post-Treatment
Struvite Scaling Risk	High	High	?	Med
Vivianite Scaling Risk	High	High	Low	Low
Compatible with Chemical Addition	✓	✓	✓	✓
Compatible with Struvite Harvesting	✓	✓	✓	✓
Provides VFAs for Secondary Release	✓			

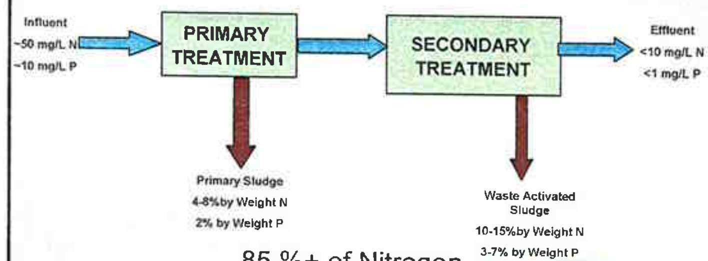
Phosphate Transformations in Anaerobic Digestion



Basic Components of Struvite are Abundant in Wastewater

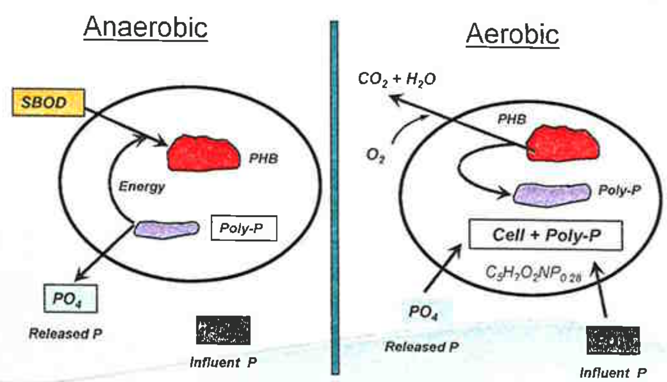


Treatment Partitions Components into the Sludge



85 %+ of Nitrogen
90 %+ of Phosphorus

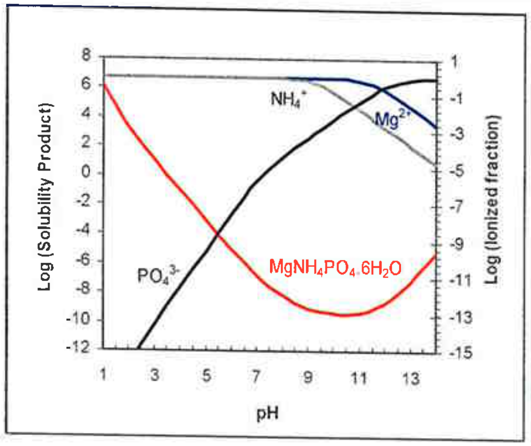
Biological Phosphorus Removal Increases Concentration in Sludge



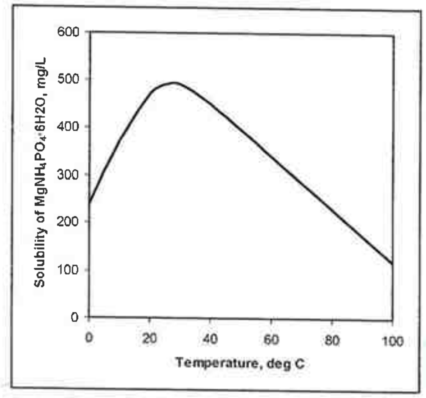
Struvite forms when concentration product exceeds solubility product

$NH_4^+ \Leftrightarrow NH_{3\,(aq)} + H^+$	pKa=9.3
$H_3PO_4 \Leftrightarrow H_2PO_4^- + H^+$	pK_{a1}= 2.1
$H_2PO_4^- \Leftrightarrow HPO_4^{2-} + H^+$	pK_{a2}= 7.2
$HPO_4^{2-} \Leftrightarrow PO_4^{3-} + H^+$	pK_{a3}= 12.3
$MgOH^+ \Leftrightarrow Mg^{2+} + OH^-$	pK=2.56
$MgNH_4PO_4.6H_2O \Leftrightarrow Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O$	pK=12.6

pH Impacts Struvite Solubility



Temperature Impacts Struvite Solubility



Struvite Formation in Sludge Processing

Chemical Equilibrium is disturbed

↓

Carbon dioxide stripping (increases pH)

↓

pH elevation

↓

Phosphate equilibrium shifts towards PO_4^{3-}

(Ammonia equilibrium Shifts towards NH_3)

↓

$[Mg^{2+}]\ [NH_4^+][PO_4^{3-}]$ exceeds struvite solubility product

↓

Nucleation and crystal growth

↓

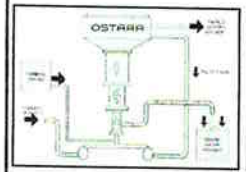
Struvite precipitates

Nine Springs WWTP Struvite Experience

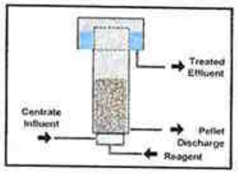
Mitigating Struvite Formation

- Struvite Harvesting Systems
  - Phosnix
  - Crystalactor
  - Ostara
- Chemical Precipitation
  - Lime
  - Aluminum
  - Iron
  - Patented Chemicals

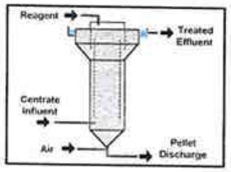
Struvite-Harvesting Systems



OSTARA



CRYSTALACTOR



PHOSNIX

Gold Bar WWTP (Canada)
700,000 p.e

Geesmerambacht WWTP (The Netherlands)
230,000 p.e.

SECC (Japan)
Centrate Flow = 130,000 gpd

Struvite-Harvesting Systems

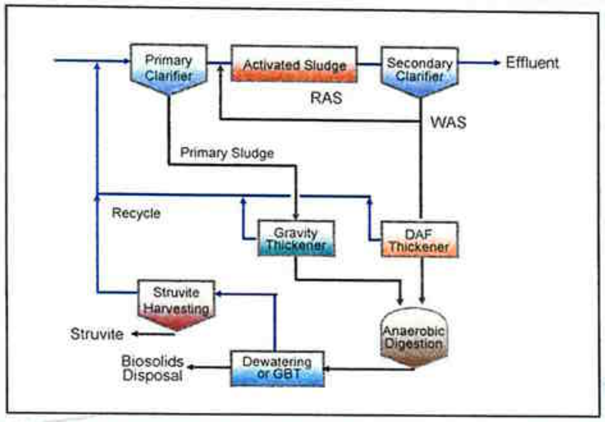
Advantages

1. Valuable end product
2. No biosolids volume increase
3. Lower Phosphorus levels in Metrogro and Metromix

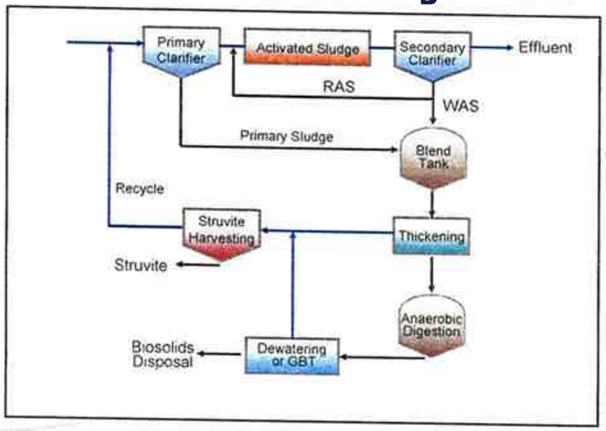
Disadvantages

1. High capital cost
2. No operational facilities in U.S.A.
3. High operational complexity
4. Large footprint

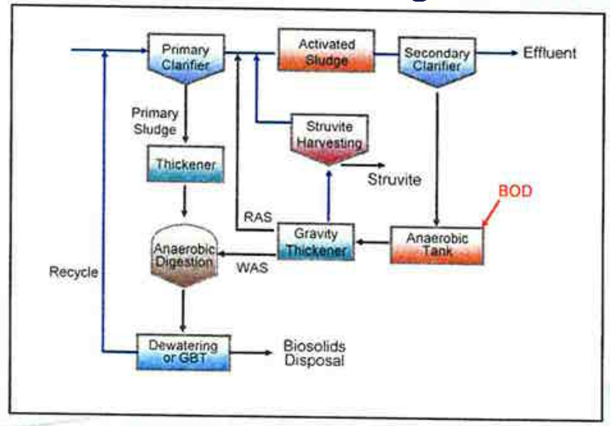
Struvite Harvesting: Dewatering



Struvite Harvesting: Thickening and Dewatering



Struvite Harvesting: Return Activated Sludge

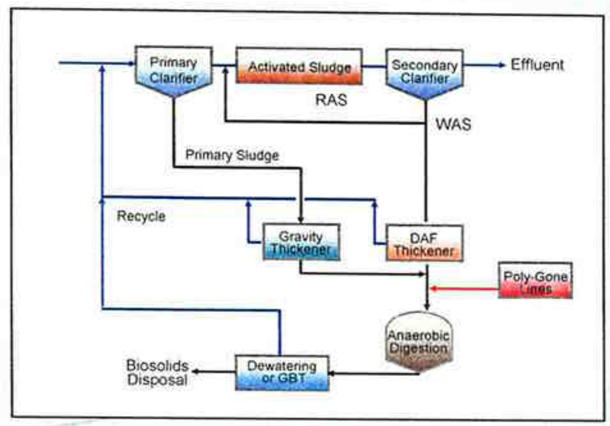


Poly-Gone Lines Addition

1. Patented Formulation
2. Prevents crystal agglomeration
3. Removes existing scaling
4. Volumetric Dosage
   a. Initial: 1 to 16,000
   b. Preventive: 1 to 20,000
   c. Recommended for 2030: 20 gpd

<u>Kankakee River Metropolitan Agency (IL)</u>
- Average flow = 13 mgd
- Primary Clarification
- Conventional Activated Sludge
- Staged Primary-Secondary Digestion

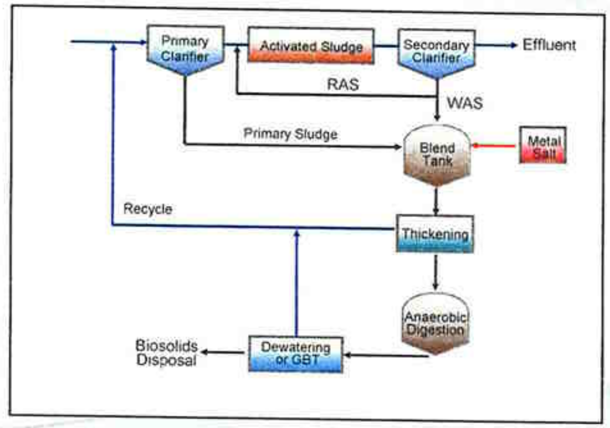
Poly-Gone Lines Addition



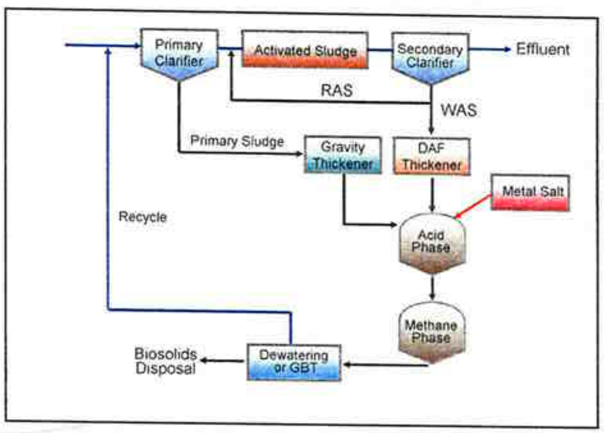
Limited Metal Salts Compatible with Nine Springs Operation

1. Ferric salts release phosphate in anaerobic digesters and converted to ferrous.
2. Ferrous salts form vivianite at high temperatures (heat exchangers).
3. Aluminum salts require low pH to precipitate phosphate.
4. Sulfate addition results in H2S in biogas.
5. Chloride addition affects NPDES permit.
6. Lime addition increases pH to 11

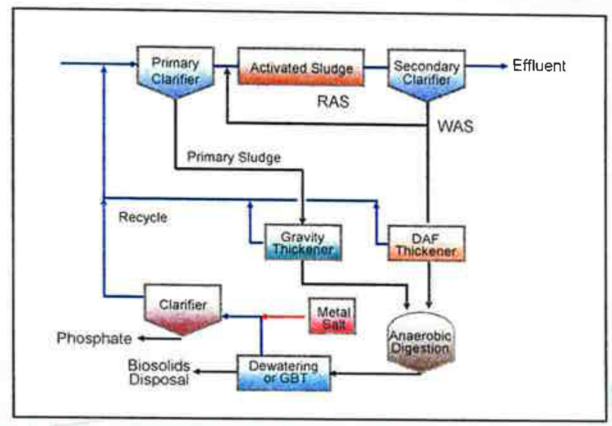
Metal Salt Addition: Digester Feed



Metal Salt Addition: Acid Phase



Metal Salt Addition: Dewatering



Cost and Treatment Efficiency Depend on Location of Stream

	RAS	PS/WAS	Dewatering Filtrate
Average Flow, mgd	37	2.4	0.37
Digester Struvite Mitigation	High	High	Low
Requires Additional Carbon Source	Yes	No	No
Requires Blend Tank	Yes	Yes/No	No
Requires New Thickening Facility	Yes	No	No

Struvite Mitigation Alternatives (PS/WAS) Evaluation

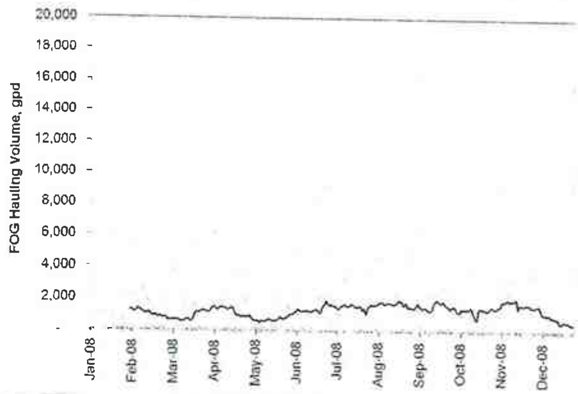
	Poly-Gone Lines	Struvite Harvesting	Metal Salt	Al^{3+} Salt (APAD)
Full Scale Installations	✓	✓	✓	
U.S. Installations	✓		✓	
Blend Tank	No	Yes	Yes	No
Capital Cost	Reagent Tank and pump?	$ 9.8 M	Blend Tank	Reagent Tank and Pump?
Annual O&M Cost		$ 0.25 M		

Co-Digestion Evaluation

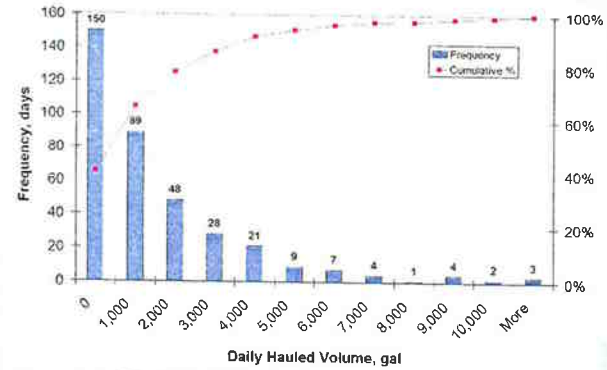
Co-Digestion Comparison

	Acid Phase	TPAD	Conventional with Cambi	Conventional with Post-Treatment
Increased Hydrolysis			✓	
High Rate Lipid and Protein Destruction	✓		✓	
Single Feeding Location	✓		✓	
High Volatile Solids Loading Rate	✓	✓	✓	
Compatible with Co-digestion	✓	✓	✓	✓
Residual Capacity for Co-digestion	30,000 ppd	20,000 ppd	7,500 ppd	30,000 ppd

Grease Trap Hauling to Nine Springs WWTP



Grease Trap Hauling to Nine Springs WWTP



Process Selection Group Discussion

Next Steps

Technical Memoranda

- ✓ TM01 – Basis of Design
- ✓ TM02 – Sludge Stabilization Alternatives
- ✓ TM03 – Anaerobic Digestion Process Evaluation
- TM04 – Digester Ancillary Systems
- ✓ TM05 – Foaming and Scale Formation
- ✓ TM06 – Co-Digestion Evaluation
- TM07 – Biogas Utilization
- TM08 – Implementation Plan

Next Meeting

APPENDIX N

Public Hearing

- Home
- Search
- 50 Year Master Plan
- About us
- Commission Business
- Construction Projects
- Contact Us
- Employment
- FAQ
- Links
- Programs and Initiatives
- Public Education
- Publications
- Questions/Suggestions
- Sewer Use Ordinance

Protecting public health and the environment



What's New

Solids Handling Facility Plan

The Madison Metropolitan Sewerage District will hold a Public Hearing on **Tuesday, February 16, 2010 at 6:30 p.m. at the Nine Springs Wastewater Treatment Plant**, 1610 Moorland Road, Madison, WI, 53713. The hearing will be held in the Multi-Purpose Room of the Operations Building, which is handicap accessible. MMSD staff will be present to answer questions and receive comments prior to a short presentation at 7:00 p.m.

The purpose of the hearing is to receive public input regarding submission of a Solids Handling Facilities Plan to the Wisconsin Department of Natural Resources. The Plan provides recommendations for improvements to the District's facilities for the thickening and digestion of biosolids through the Year 2030. The Plan is available for public inspection at the Nine Springs Wastewater Treatment Plant on weekdays from 7:00 a.m – 4:00 p.m. A summary report is also available for viewing here.

Anyone interested is invited to attend this meeting. If you wish to comment but cannot be present at the public hearing, please submit a written statement by 3:00 p.m., Friday, February 12, 2010, to Mr. Jon Schellpfeffer, Madison Metropolitan Sewerage District, 1610 Moorland Road, Madison, WI 53713.

Dated this 29th day of January, 2010.

Jon W. Schellpfeffer
Chief Engineer & Director, MMSD

Governor Doyle's press conference at MMSD

Click here to view the press conference.

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MADISON METROPOLITAN SEWERAGE DISTRICT
NOTICE OF PUBLIC HEARING
February 16, 2010
SOLIDS HANDLING FACILITIES PLAN - 11TH ADDITION TO THE NINE SPRINGS WASTEWATER TREATMENT PLANT

The Madison Metropolitan Sewerage District will hold a Public Hearing on **Tuesday, February 16, 2010 at 6:30 p.m. at the Nine Springs Wastewater Treatment Plant**, 1610 Moorland Road, Madison, WI, 53713. The hearing will be held in the Multi-Purpose Room of the Operations Building, which is handicap accessible. MMSD staff will be present to answer questions and receive comments prior to a short presentation at 7:00 p.m.

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Dated this 29th day of January, 2010.

Jon W. Schellpfeffer
Chief Engineer & Director, MMSD
PUB. WSJ: February 2, 2010
#1533256 WNAXLP

Arlene Staff

being duly sworn, doth depose and say that he (she) is an authorized representative of Capital Newspapers, publishers of

Wisconsin State Journal

a newspaper, at Madison, the seat of government of said State, and that an advertisement of which the annexed is a true copy, taken from said paper, was published therein on February 2nd, 2010

FEB 0 _ 2010

Mtng/Hrg/Sol 01

(Signed) Arlene Staff

(Title) Principal Clerk

Subscribed and sworn to before me on

2-2-10

Ellen M. Morgan

Notary Public, Dane County, Wisconsin

My Commission expires May 24th, 2013

08015171/01

W/O
828-00-58 DO0099

south ACT

PUBLIC HEARING ATTENDANCE

Solids Handling Facilities Plan
11th Addition to Nine Springs Wastewater Treatment Plant
Madison Metropolitan Sewerage District
Tuesday, February 16, 2010, 6:30 p.m.

NAME	REPRESENTING	ADDRESS
Bill Ericson	ATI	Brookfield WI.
Jon Schellpfeffer	MMSD	
Mike Simon	MMSD	
TODD GEBERT	MMSD	

Madison MSD

Solids Handling Facilities Plan Public Hearing

February 16, 2010

AppliedTechnologies
Engineers - Architects

MMSD

Solids Handling Facilities Plan

- Key elements
  - DNR requirement for wastewater biosolids management
  - Identifies most cost-effective alternative
  - 20-year planning period (2030)
  - Capacity for future growth
  - Meets biosolids quality standards
  - Required for Clean Water Fund Loan program

AppliedTechnologies
Engineers - Architects

MMSD

Existing Plant Wasteloads

Parameter	Average	Max Month
Flow (mgd)	42.9	54.8
BOD (lbs/d)	85,100	102,100
TSS (lbs/d)	75,700	90,800
N Loading (lbs/d)	12,900	15,500
P Loading (lbs/d)	2,100	2,300

AppliedTechnologies
Engineers - Architects

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Existing Plant Solids Handling

- Current solids loading 100,000 lbs/day
- Mesophilic anaerobic digestion
- Produces Class B biosolids for agricultural use
- Land application 40 MG/year

AppliedTechnologies
Engineers - Architects

MMSD

Projected Plant Wasteloads

Parameter	Year 2030 Average	Year 2030 Max Month
Flow (mgd)	53.8	67.2
BOD (lbs/d)	122,100	146,500
TSS (lbs/d)	117,800	141,400
N Loading (lbs/d)	19,800	23,800
P Loading (lbs/d)	2,900	3,200

Applied Technologies
Engineers - Architects

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Existing Solids Handling Facilities

- Future solids loadings will increase to 150,000 lbs/d, 50% increase above existing
- 10th Addition TPAD process discontinued due to process problems; AD system operating in stable mesophilic mode
- Achieving Class A biosolids will require process modifications/additions

Applied Technologies
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Advanced AD Process Alternatives

- Conventional meso digestion w/ thermal pretreatment
- Multi-stage acid phase digestion ⇦
- Acid phase digestion w/ thermal post treatment

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Major Plant Upgrade Items

- WAS thickening
- Acid digesters
- Thermo Digester No. 8
- Struvite harvesting (P-recovery)
- Digester heating/mixing modifications
- Related plant improvements

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Estimated Project Costs

- Total project cost = $45 million
- Annual plant O&M increase = $160,000
- Average annual residential sewer bills
  - Existing rate = $245
  - Yr 2014 rate w/o project = $284
  - Yr 2014 rate w/ project = $302
  - Project rate impact = 6.5%

AppliedTechnologies Engineers - Architects

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Schedule

- Complete Facilities Plan/submit to WDNR in Jan 2010
- Conduct Public Hearing in Feb 2010
- Begin design in Feb 2010
- Submit plans and specs to WDNR in December 2010
- Bidding/contract award in March 2011
- Construction of new facilities begins in April 2011
- 11th Addition construction completed December 2013

AppliedTechnologies Engineers - Architects

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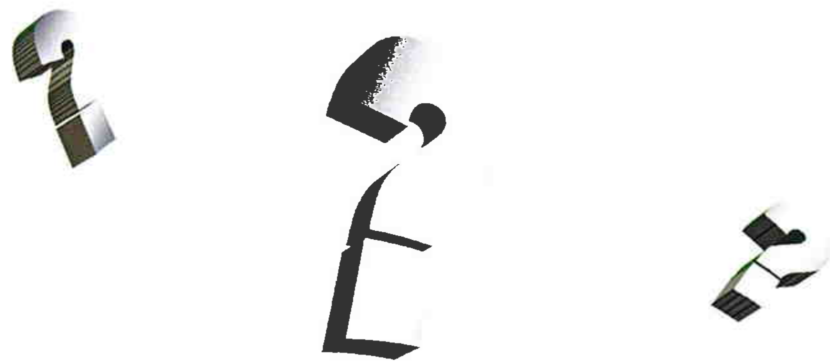
Questions?



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