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Abbreviations

ADF	Average daily flow
ADMM	Average day in the maximum month
APLR	Annual pollutant loading rate
AWSAR	Annual whole sludge application rate
BFP	Belt filter press
BTU	British thermal unit
CFM, SCFM	Cubic feet per minute, standard cubic feet per minute
CFR	Code of Federal Regulations
CHP	Combined heat and power
CPLR	Cumulative Pollutant Loading Rate
CY	Cubic yard
DT	Dry ton
DWPC	TDEC's Division of Water Pollution Control
ENRCCI	Engineering News-Record Construction Cost Index
EPA, USEPA	United States Environmental Protection Agency
EQ	Exceptional Quality
FOG	Fats, oils and greases
GBT	Gravity belt thickener
GC	General Contractor <u>or</u> General Conditions
GPM, gpm	Gallons per minute
H_2S	Hydrogen sulfide
HP, hp	Horsepower
kW, kWh	Kilowatt, kilowatt hour
MAD	Mesophilic anaerobic digestion
MBBR	Moving bed biofilm reactor
MBR	Membrane bioreactor
MD	Maximum day
MG	Million gallons
MGD, mgd	Million gallons per day
MMBTU	Million British thermal units
MOR	Monthly operating report
MPN	Most probable number
MSWLF	Municipal solid waste landfill
NPDES	National Pollutant Discharge Elimination System

O&M	Operation and maintenance
OPCC	Opinion of probable construction cost
PC	Pollutant Concentration
PFD	Process flow diagram
PFRP	Process to further reduce pathogens
POTW	Publicly owned treatment works
PS	Primary sludge or pump station
psi, PSI	Pounds per square inch
PW, NPW	Present worth, net present worth
PSRP	Process to significantly reduce pathogens
RCRA	Resource Conservation and Recovery Act
RDT	Rotary drum thickener
SBR	Sequencing batch reactor
SRT	Solids retention time
TDEC	Tennessee Department of Environment & Conservation
TM	Technical Memorandum
TWAS	Thickened waste activated sludge
TS	Total solids
VFD	Variable frequency drive
VS, VSD, VSR	Volatile solids, volatile solids destruction/reduction
WAS	Waste activated sludge
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WRF	Water reclamation facility
WT	Wet ton
WWTF, WWTP	Wastewater treatment facility/plant

Executive Summary

As part of its Integrated Water Resources Plan (IWRP), the City of Franklin is developing a plan to improve the solids handling facilities at its wastewater treatment plant (WWTP). Work performed to date by CDM Smith in support of this IWRP included an assessment of the existing solids handling facilities; a review of historical operating data and operations and maintenance (O&M) costs; an overview of solids treatment requirements based on projected future wastewater flows to the WWTP; an assessment of capital, O&M and life cycle costs of four potential solids process trains; and an evaluation of the relative capital and O&M costs of one or two biosolids facilities – one at the Franklin WWTP, and another at a new WWTP.

At the September 28, 2011, Steering Committee meeting, the City expressed a desire to proceed with further analysis of Option 2, which consists of rotary drum thickening followed by mesophilic anaerobic digestion, screw press dewatering, and solar drying. The City preferred anaerobic digestion because it could achieve Class B treatment, reduce the quantity of biosolids, and potentially produce energy (methane from digester biogas) in support of the City's sustainability goals. Furthermore, solar drying offers relatively low O&M costs and a product that can be beneficially reused. Although the selected option includes rotary drum thickening and screw press dewatering, the City may choose to use alternate thickening and dewatering technologies. CDM Smith is working with the City to organize visits to WWTPs in February 2012 where candidate technologies are in use, and CDM Smith is also working with equipment manufacturers to schedule onsite demonstrations of thickening and dewatering technologies at the Franklin WWTP.

This Conceptual Design Report presents the results of CDM Smith's continued analysis of Option 2: an examination of a phased approach to construction of the proposed solids handling facilities; conceptual process flow diagrams and mass balances; proposed site and solids handling building layouts; and a revised opinion of probable construction cost (OPCC) and O&M costs based on the recommended 16 + 4 + 4 project phasing. The report also provides a brief review of the City's options for beneficial reuse of biosolids at each stage of the treatment process. These options should be explored further in subsequent phases of the work.

Section 1
Introduction

1.1 Purpose and Scope of Report

As part of its Integrated Water Resources Plan (IWRP), the City of Franklin is developing plans for multiple aspects of its collection system, wastewater treatment plant (WWTP), water treatment plant, distribution system, reclaimed water system, stormwater infrastructure, and ecological and conservation efforts within the City. The solids handling system at the City's WWTP is in need of significant improvements. Currently, the solids produced by the wastewater treatment process are disposed at a landfill located over 100 miles away. The City has expressed interest, as part of the IWRP, in upgrading this system to meet the City's future goals of sustainability and efficiency.

This Conceptual Design Report has been developed to document the work completed thus far; describe the decisions made based on the work produced to date; discuss potential biosolids use/disposal options and associated solids processing requirements; present conceptual design of improvements to the solids processing facilities at the existing Franklin WWTP; and present updated financial analyses, including an opinion of probable construction cost (OPCC), annual operation and maintenance (O&M) costs, and life cycle cost. Further evaluation of this conceptual design and costs will need to be completed prior to final design if the City proceeds with the recommended improvements.

1.2 Completed Biosolids Work to Date

Biosolids Workshop No. 1 was held on February 2, 2011, to determine the preliminary alternatives (individual treatment technologies and potential solids process trains) that would be further analyzed during the alternatives selection process.

During the workshop, a list of criteria was developed to evaluate alternative solids processes. These criteria are listed and described below.

- **Efficiency of operations:** Equipment and operating trains that provide efficient solids processing with little effect upon other treatment processes, consume less energy, and require less maintenance.

- **Decreased energy consumption:** Processes that require reduced quantities of fossil fuel-derived energy, employ high-efficiency equipment, beneficially reuse waste energy, or sequester carbon dioxide tend to have lower carbon footprints.

- **Sustainability:** Processes that will sustain themselves through various disposal options including lower energy consumption, efficient operations, and high quality solids.

- **Diverse portfolio of product use/disposal options:** Class B biosolids use is limited to agricultural land application, but the regulations place fewer restrictions on the use of

Class A biosolids. Class A biosolids have a larger portfolio of options and may be applied or used in home gardens and lawns.

- **Reliability:** Redundant equipment that will allow for continuous solids processing operations while other equipment is taken out of service.
- **Risk reduction:** Single use/disposal options, like private landfills, determine what type and how much solids they can accept from a municipality. Private landfills can also eliminate biosolids disposal at a moment's notice, leaving the municipality without disposal options. Risk reduction would include the potential to provide more than one end use/disposal alternative.
- **Environmental/public acceptance:** Public buy in of solids processing effects and the resulting minimal impact to the environment are important to the community's achievement of sustainable goals.
- **Odor control:** Because the Franklin WWTP is located near several residential neighborhoods and a school, processes with a lower potential to generate odors are preferred.
- **Automated processes:** A new process that is automated will require less training of staff and less of a learning curve immediately after it is implemented.
- **Class A biosolids:** A quality product with a variety of use/disposal options.
- **Expandability strategy for growth:** A solids train upgrade with a compact layout leaves more space available for future expansion of the facility, thus reducing or eliminating the need for building expansion or additional land acquisition. Also favorable are processes whose solids treatment capacity can be expanded simply, such as by installing additional pieces of equipment.

Workshop participants also developed four solids treatment process trains that would be examined in further detail. These process trains are summarized in **Table 1-1.**

Table 1-1
Biosolids Treatment Alternatives

Process Train	Thickening	Stabilization	Dewatering	Drying	Biosolids Class
Option 1 (Existing)	DAF	None	Belt Filter Press	None	N/A
Option 2	Drum Thickener	Anaerobic	Screw Press	Solar	A
Option 3	Screw Thickener	Anaerobic	Centrifuge	Rotary Drum/ Belt Dryer	A
Option 4	Gravity Belt Thickener	None	Centrifuge	Belt Dryer with ERS	N/A

Technical Memorandum (TM) No. 1 (Evaluation of Existing Equipment & Sludge Production Forecast) described the existing conditions identified during site visits to the WWTP, reviews of the historical monthly operating reports (MORs), a preliminary analysis of the current operation and maintenance (O&M) requirements and costs of solids treatment, and an overview of the solids projections based on current conditions and the availability of existing equipment to meet future needs of the WWTP for the duration of the planning period.

In preparing **TM No. 2 (Evaluation of Biosolids Alternatives and Technologies)**, CDM Smith developed preliminary capital, O&M, and present worth costs of the four solids treatment trains discussed during Biosolids Workshop No. 1. Concurrent with this economic analysis, CDM Smith analyzed the relative capital construction and O&M costs to operate one biosolids treatment facility at Franklin WWTP or two biosolids facilities—one at the Franklin WWTP and one at a new WWTP. In **TM No. 2A (Evaluation of One Versus Two Biosolids Facilities),** two alternatives were evaluated during the decision process to determine the feasibility of the one versus two WWTP option. Alternative A discussed no new WWTP construction, and all resultant biosolids would be treated at the existing WWTP. Alternative B discussed construction of a new WWTP that would accept flows between 2 and 6 mgd. Varying degrees of solids processing would occur at the new WWTP and the existing WWTP. From the results of the capital construction and O&M cost analyses, it was determined that we would proceed with Alternative A, with a definite decision being made at the time of construction for the new future WWTP.

TM No. 2 discussed the selected solids treatment technologies and the four potential process trains in further detail. These process trains were evaluated to identify the conceptual sizing of equipment and facilities, as well as to develop planning level capital and O&M costs and life cycle costs. The planning level costs for each process train were compared to the O&M costs for the existing solids treatment process which were developed in TM No. 1. This financial analysis showed that Options 2, 3 and 4 all had similar capital construction and life cycle costs, but Option 2 had the lowest treatment cost per dry ton (DT) of solids treated.

1.3 Review of Sept. 28, 2011, Steering Committee Meeting

Members of the Steering Committee and CDM Smith held a workshop on September 28, 2011, in order to select the biosolids process that would form the basis for this Conceptual Design Report. CDM Smith provided an overview of the work completed and provided an overview of the project thus far. The four biosolids treatment alternatives listed in Table 1-1 were discussed at the meeting.

The City expressed a desire to proceed further with Option 2 after evaluation of this option with respect to the non-cost criteria listed in Section 1.2. The City preferred the option of anaerobic digestion because it could achieve Class B treatment, reduce the amount of biosolids, and potentially produce energy (methane) in support of the City's sustainability goals. The City also wished to further investigate solar drying because of the low O&M costs and because the dried biosolids can offer more beneficial reuse opportunities.

Phased implementation of Option 2 would allow the City to build additional biosolids processing facilities in stages, as the area grows and wastewater flows increase. The phased approach to facility construction is discussed in **Section 2.**

The Steering Committee also wished to explore the option of contracting with a third party to operate the proposed solids treatment facilities. This option is discussed in **Section 3.**

Composting was also discussed as a potential future biosolids option. The composting process has a relatively high odor potential and will require a larger land area. The local compost market should also be explored to ensure that there is adequate demand for the product. Composting is discussed further, along with the potential for energy recovery from the digestion process, in **Section 4.**

1.4 Report Organization

This report is divided into the following sections:

- **Section 1 – Introduction** provides an overview of the project, a summary of the biosolids work completed to date, a review of the September 28, 2011 Steering Committee meeting, and report organization.
- **Section 2 – Conceptual Facility Design** provides a summary of the selected processes, updated facility design criteria, a phased approach to facility construction, and proposed layouts of the selected equipment on the existing WWTP site. The section also includes a discussion of coordination and integration with the existing and potential WWTP liquid process improvements and solar panel project. Installation lists of the selected equipment for potential site visits and planned on-site technology demonstrations are also included.
- **Section 3 – Updated Economic Analysis** presents the updated OPCC, updated O&M costs, and project life cycle costs for the selected treatment process. The section also includes a brief discussion of options for management of the proposed facilities by an outside contractor.
- **Section 4 – Options for Beneficial Reuse of Biosolids** describes options for beneficial reuse and disposal of biosolids throughout the various parts of the solids treatment process. Also included is a review of methods that could be used to maximize biogas production (and hence energy recovery) in the digesters.

1.5 Existing Reports

Information gathered from the following documents and sources is incorporated in this Conceptual Design Report:

- Technical Memorandum Number 1 – Evaluation of Existing Equipment and Sludge Production Forecast prepared by CDM Smith (2011).
- Technical Memorandum Number 2A – Evaluation of One versus Two Biosolids Facilities prepared by CDM Smith (2011).
- Technical Memorandum Number 2 – Evaluation of Biosolids Alternatives and Technologies prepared by CDM Smith (2011).
- City of Franklin WWTP construction project record drawings.
- Standard Operating Procedures for the Franklin WWTP prepared by Black and Veatch (2002).

Section 2
Conceptual Facility Design

2.1 Review of the Selected Process

During the September 28, 2011, Steering Committee meeting, the City decided to move forward with the selection of the biosolids process consisting of rotary drum thickening, mesophilic anaerobic stabilization, screw press dewatering, and solar drying. This process meets the goals of the non-cost criteria developed at Biosolids Workshop No. 1 and, based on conceptual cost estimates provided in TM No. 2, is expected to have the lowest O&M cost per DT.

The following sections briefly summarize each part of the solids treatment process. Once the City begins to implement a process, varying levels and degrees of treatment can occur that provide the City with flexibility in reuse/disposal options. Class A biosolids can be used by the general public for agronomic purposes, including fertilizing feed and food crops, lawns, and home gardens. Class B biosolids cannot be handled by the public and can be land applied to agricultural fields. Options for beneficial reuse and/or disposal of the biosolids are discussed in **Section 4.**

Final thickening and dewatering equipment selections have not been made; the selected anaerobic digestion and solar drying processes do not require a specific type of thickening or dewatering technology. Though this report discusses layouts and other considerations for rotary drum thickening and screw press dewatering, the City may elect to use different technologies in place of rotary drum thickening and/or screw press dewatering. CDM Smith is assisting the City in organizing visits to facilities where the candidate technologies are installed, and onsite technology demonstrations are also planned. These efforts are discussed in Section 2.6.

2.1.1 Rotary Drum Thickening

WAS from the secondary clarifiers will be pumped by the existing sludge pumps to a new WAS storage tank, from which it will be fed to the rotary drum thickeners. Rotary drum thickening consists of a polymer feed system and rotating drums covered with a metal mesh screen. Polymer is mixed with dilute sludge in a flocculator, and the conditioned sludge is fed into rotating-screen drums that separate the flocculated solids from the water. Thickened sludge rolls out the end of the drums, while separated water decants through the screens.

For this report, it was assumed that the thickened WAS (TWAS) would have a solids content of about 5 percent. It was also assumed that the new WWTP will include thickening facilities only; the TWAS produced at the new WWTP will be transported to the Franklin WWTP for further treatment. Three rotary drum thickeners (two duty, one standby) would be installed at each treatment plant to meet thickening needs in the design planning period.

2.1.2 Mesophilic Anaerobic Digestion

After the sludge is thickened to approximately 5 percent solids, the TWAS is pumped to the anaerobic digesters, where anaerobic microbes perform a series of biochemical transformations that break down the complex organic compounds in wastewater sludges into methane and carbon dioxide. Conventional mesophilic anaerobic digestion (MAD) was selected for this concept-level analysis due to its relatively low energy consumption, the potential for beneficial use of the biogas produced by the digestion process, and well-established operating procedures. The digestion system will consist of two insulated digester tanks, a mixing system, a heating system, and biogas handling equipment. The digester tanks will have a volume of 0.8 MG each and will operate at temperatures between 90°F and 100°F. Biogas produced by the anaerobic microbes will be captured from the headspace of the tank; the biogas can be treated and stored for reuse, or it can be disposed via flare. Energy from the biogas can be used to heat the digester, generate electricity, or serve other heating needs around the WWTP.

The conceptual basis of design for a MAD system was based on a minimum design solids retention time (SRT) of 17 days at maximum month conditions and a volatile solids destruction of 40 percent. A MAD system is an approved process to meet Class B pathogen reduction standards.

Enhancements to the digestion process to increase solids destruction and boost biogas production are discussed in Section 4.

2.1.3 Screw Press Dewatering

Following MAD, the digested biosolids will be pumped to screw presses for dewatering. For this report, it was assumed that the screw presses would dewater the sludge to a solids content of approximately 20 percent. Actual cake solids and polymer requirements cannot be determined until sludge is available for testing.

Feed solids for the screw press, after being conditioned with polymer in a flocculation reactor, are introduced at the bottom end of an inclined trough that contains a perforated bucket surrounding a slowly, continuously rotating screw. The solids move upward along the screw, first losing their free water via gravity drainage, and then as the solids are squeezed against a cone at the top of the unit to force any additional water out. When the cake reaches the top of the unit, the sludge drops out of the unit and onto a conveyor, and is hauled via truck to the solar dryers.

The screw press is compact and completely enclosed. Energy consumption and noise are low due to the low speed and low horsepower of the variable-speed, screw drive motor, and the polymer consumption for dewatering is relatively low. Typical solids capture rate is 95 percent or more. Four screw presses (three duty, one standby) would be required for the design planning period.

2.1.4 Solar Drying

Once the solids are dewatered with the screw press, the City has multiple options for reuse or disposal. This report will discuss potential reuse/disposal options for varying levels of treatment. For ultimate treatment to a Class A biosolids status, the City could construct a solar drying facility to produce Class A biosolids.

In the solar drying system proposed for the City, dewatered cake is transferred to large greenhouse-like structures where it is spread uniformly on the floor to dry in a continuous, year-round operation. Solar radiation evaporates the moisture and machines automatically till the solids, exposing moist solids to the air for further drying. The moisture-laden air is removed from the solar dryers and can be treated for odors before being released to the atmosphere. Overall, the system requires minimal operator attention, is energy efficient, and requires low operations and maintenance costs. The proposed solar dryers would consume approximately 5 acres of drying area for the design planning period.

2.2 Updated Facility Design Criteria

Following the submittal of TM No. 1, CDM Smith's subsequent WWTP process modeling work showed that the anticipated solids production would be higher than the current solids production. New solids loadings were presented in TM No. 2. Recent updates to the WWTP models, including selection of the new WWTP's treatment process, have resulted in slight changes to these loadings. **Table 2-1** lists the revised design parameters and solids loadings, and **Table 2-2** lists the anticipated WAS production to 2040.

Table 2-1
Updated Solids Loading Design Parameters

Parameter		Value	
		Franklin WWTP	New WWTP
Yield (lbs WAS/lb BOD_5 removed)		0.81	0.79
BOD_5 Loading	Influent	212 mg/L (1,768 lbs/MG)	
	Effluent	5 mg/L (42 lbs/MG)	
BOD_5 Removed (lbs/MG)		1,726	
Solids Production (lbs WAS/MG)[1]	Average Day	1,398	1,364
	Max Month	1,818	1,773
WAS Solids Content		0.84%	1.0%

[1] Includes chemical sludge.

Table 2-2
Projected Wastewater Flows and Estimated WAS Production, 2010 to 2040

Year	Total Average Daily Flow (MGD)	Total Average Day Solids Production (lbs/day)	Total Maximum Month Solids Production (lbs/day)
2010	9.4	13,100	17,100
2015	11.8	16,500	21,500
2020	14.3	20,000	25,900
2025	16.7	23,300	30,300
2030	19.1	26,600	34,600
2035	21.6	30,000	39,000
2040	24.0	33,300	43,300

CDM Smith used these updated design criteria to develop a solids treatment train that includes the process equipment listed in **Table 2-3.** This list represents the complete process that will be in place to treat solids in 2040. A stepwise approach to construction of the facility is discussed in detail in Section 2.3.

Table 2-3
Summary of Proposed Solids Treatment Process Design Criteria

Parameter	Value
Thickening	
Thickening technology	Rotary drum thickener
Solids loading rate	700 lbs TS/hour
Feed solids	0.84 to 1.0 percent
Thickened WAS solids	5.0 percent
Number of units	Franklin WWTP: 2 duty, 1 standby New WWTP: 2 duty, 1 standby
Operating schedule	Franklin WWTP: 7 days/week, 16 hours/day New WWTP: 5 days/week, 11 hours/day
Conceptual equipment selection	Andritz 12x3 RST or equal
WAS storage	Franklin WWTP: 420,000 gallons New WWTP: 170,000 gallons
TWAS storage	Franklin WWTP: 70,000 gallons New WWTP: 33,000 gallons
Anaerobic Digestion	
Type of digestion	Mesophilic anaerobic digestion
Number of digesters	Two
Digester tank dimensions	48’ diameter x 60’ sidewater depth
Digester tank type	Prestressed concrete
Minimum solids retention time	20 days at average day conditions; 17 days at maximum month conditions
Volatile solids destruction	40 percent
Biogas produced	86 SCFM (2040)
Digester heating required	1.7 MMBTU/hour
Heat available from biogas engines	1.4 MMBTU/hour
Dewatering	
Dewatering technology	Rotary screw press
Solids loading rate	900 lbs TS/hour
Feed solids	3.7 percent
Dewatered cake solids	20 percent
Number of units	3 duty, 1 standby
Operating schedule	7 days/week, 9 hours/day
Conceptual equipment selection	Huber Technology RoS3 Q800 or equal
Solar Drying	
Number of drying chambers	12
Drying chamber dimensions	264’ L x 42’ W
Dried product output	13.9 WT/day
Dried product solids content	80 percent
Conceptual equipment selection	Krüger Solia, Parkson Thermo-System or equal

2.3 Phased Approach to Improvements

Following submittal of TM No. 2 and selection of Option 2 at the September Steering Committee meeting, CDM Smith examined the possibilities for a phased improvements strategy that would add solids treatment capacity in a stepwise fashion and minimize the initial cost to construct the solids treatment facilities. CDM Smith examined the following phasing options:

- **12 + 4 + 4 + 4 Phasing:** The initial solids treatment facilities are constructed to treat solids produced by a 12 MGD WWTP. Three subsequent phases add process equipment in 4-MGD increments.
- **12 + 6 + 6 Phasing:** In this option, the initial solids treatment facilities are also constructed for 12 MGD, but there are only two subsequent phases in which capacity is added in 6-MGD increments.
- **16 + 4 + 4 Phasing:** Consistent with the proposed WWTP improvements, the initial solids treatment facilities are constructed for a 16-MGD plant. Two subsequent phases add capacity in 4-MGD increments.

After apportioning process equipment and structures to each phase of construction, CDM Smith developed new concept-level OPCCs for the three options. **Tables 2-4, 2-5,** and **2-6** present the results of this analysis.

The tables show a Phase I capital cost of approximately $52 million for the 12 + 4 + 4 + 4 and 12 + 6 + 6 phasing options. Although this capital cost is $14 million less than the approximately $66 million Phase I capital cost of the 16 + 4 + 4 option, current wastewater flows at the plant are already nearing 10 MGD. Therefore, a Phase I solids treatment facility constructed to a capacity of 12 MGD would reach its design capacity quickly – as early as 2015. Design of Phase II improvements would have to begin during Phase I construction.

On the other hand, a Phase I solids treatment facility constructed to a capacity of 16 MGD would not reach its design capacity until about 2023, and Phase II design would begin six years after the Phase I facilities were completed. Furthermore, CDM Smith's work on the Franklin WWTP's liquid treatment process is expected to include a capacity expansion to 16 MGD.

In order to coordinate with the proposed liquid treatment capacity expansion to 16 MGD, and because a 12 MGD Phase I facility would reach its design capacity soon after completion, CDM Smith continued its mass balance calculations and updated the cost analyses based on the 16 + 4 + 4 phasing strategy.

Table 2-4

Summary of 12 + 4 + 4 + 4 Phased Solids Treatment Improvements

Phase	Wastewater Capacity (MGD)			Max Month Solids Production (lbs/day)	Design & Construction Schedule & Costs						
	Total	Franklin WWTP	New WWTP		Franklin WWTP Scope of Work	New WWTP Scope of Work	Estimated Capital Cost	Design Year[1]	Begin Design	Begin Const.	Complete Const.
I	12.0	12.0	0.0	21,800	3 RDTs 1 digester 3 screw presses 6 solar drying chambers Solids handling building	None	$52,000,000	2015	2011	2012	2015
II	16.0	16.0	0.0	29,100	1 digester 2 solar drying chambers	None	$15,000,000	2023	2013	2014	2015
III	20.0	16.0	4.0	36,200	1 screw press 2 solar drying chambers	2 RDTs Thickening building	$15,000,000	2031	2021	2022	2023
IV	24.0	16.0	8.0	43,300	2 solar drying chambers	1 RDT	$8,000,000	2040	2029	2030	2031

[1] Design Year is the calendar year in which plant solids production matches the facility's solids treatment capacity.

Table 2-5

Summary of 12 + 6 + 6 Phased Solids Treatment Improvements

Phase	Wastewater Capacity (MGD)			Max Month Solids Production (lbs/day)	Design & Construction Schedule & Costs						
	Total	Franklin WWTP	New WWTP[2]		Franklin WWTP Scope of Work	New WWTP Scope of Work	Estimated Capital Cost	Design Year[1]	Begin Design	Begin Const.	Complete Const.
I	12.0	12.0	0.0	21,800	3 RDTs 1 digester 3 screw presses 6 solar drying chambers Solids handling building	None	$52,000,000	2015	2011	2012	2015
II	18.0	16.0	2.0	32,600	1 digester 3 solar drying chambers	2 RDTs Thickening building	$25,000,000	2027	2013	2014	2015
III	24.0	16.0	8.0	43,300	1 screw press 3 solar drying chambers	1 RDT	$12,000,000	2040	2025	2026	2027

[1] Design Year is the calendar year in which plant solids production matches the facility's solids treatment capacity.

[2] New WWTP is constructed to a capacity of 4.0 MGD in Phase II, but actual wastewater treated in 2027 is expected to be approximately 2.0 MGD.

Table 2-6

Summary of 16 + 4 + 4 Phased Solids Treatment Improvements

Phase	Wastewater Capacity (MGD)			Max Month Solids Production (lbs/day)	Design & Construction Schedule & Costs						
	Total	Franklin WWTP	New WWTP		Franklin WWTP Scope of Work	New WWTP Scope of Work	Estimated Capital Cost	Design Year[1]	Begin Design	Begin Const.	Complete Const.
I	16.0	16.0	0.0	29,100	3 RDTs 2 digesters 3 screw presses 8 solar drying chambers Solids handling building	None	$66,000,000	2023	2011	2012	2015
II	20.0	16.0	4.0	36,200	2 solar drying chambers	2 RDTs Thickening building	$13,000,000	2031	2021	2022	2023
III	24.0	16.0	8.0	43,300	1 screw press 2 solar drying chambers	1 RDT	$10,000,000	2040	2029	2030	2031

[1] Design Year is the calendar year in which plant solids production matches the facility's solids treatment capacity.

2.4 Process Flow Diagram & Mass Balance

Figures 2-1 through 2-5 present the process flow diagram and mass balance for the proposed solids treatment process. The process is briefly described below.

- **Thickening at Franklin WWTP (Figure 2-1):** WAS produced by the secondary clarifiers is stored in a WAS storage tank and thickened in rotary drum thickeners. These thickeners are expected to produce TWAS with a solids content of approximately 5 percent.

- **Thickening at New WWTP (Figure 2-2):** CDM Smith assumed that the new WWTP would employ the same thickening technology as the Franklin WWTP. After being thickened onsite, TWAS from the new WWTP will be transported via tanker truck to the Franklin WWTP for subsequent treatment and disposal.

- **Anaerobic Digestion (Figure 2-3):** After thickening, the TWAS from both the Franklin WWTP and the new WWTP will be fed to mesophilic anaerobic digesters, where approximately 40 percent of the volatile solids will be destroyed. The biochemical reaction will produce digester gas containing methane, which can be used for power generation and/or digester heating. The Class B digested biosolids will have a solids content of approximately 3.7 percent.

- **Dewatering (Figure 2-4):** The digested biosolids will be dewatered in screw presses to a solids content of approximately 20 percent before being transferred via screw conveyor to trucks, which will haul the dewatered biosolids to the solar dryer.

- **Solar Drying (Figure 2-5):** Solar dryer greenhouses will use the sun's energy to dry the dewatered biosolids to a solids content of about 80 percent. After the drying process is completed, the Class A dried biosolids can be hauled away for use in agriculture and landscaping.

2.5 Proposed Site Plans & Building Layouts

Site plans and building layouts for the Franklin WWTP and the new WWTP were developed from the design criteria summarized in Table 2-3.

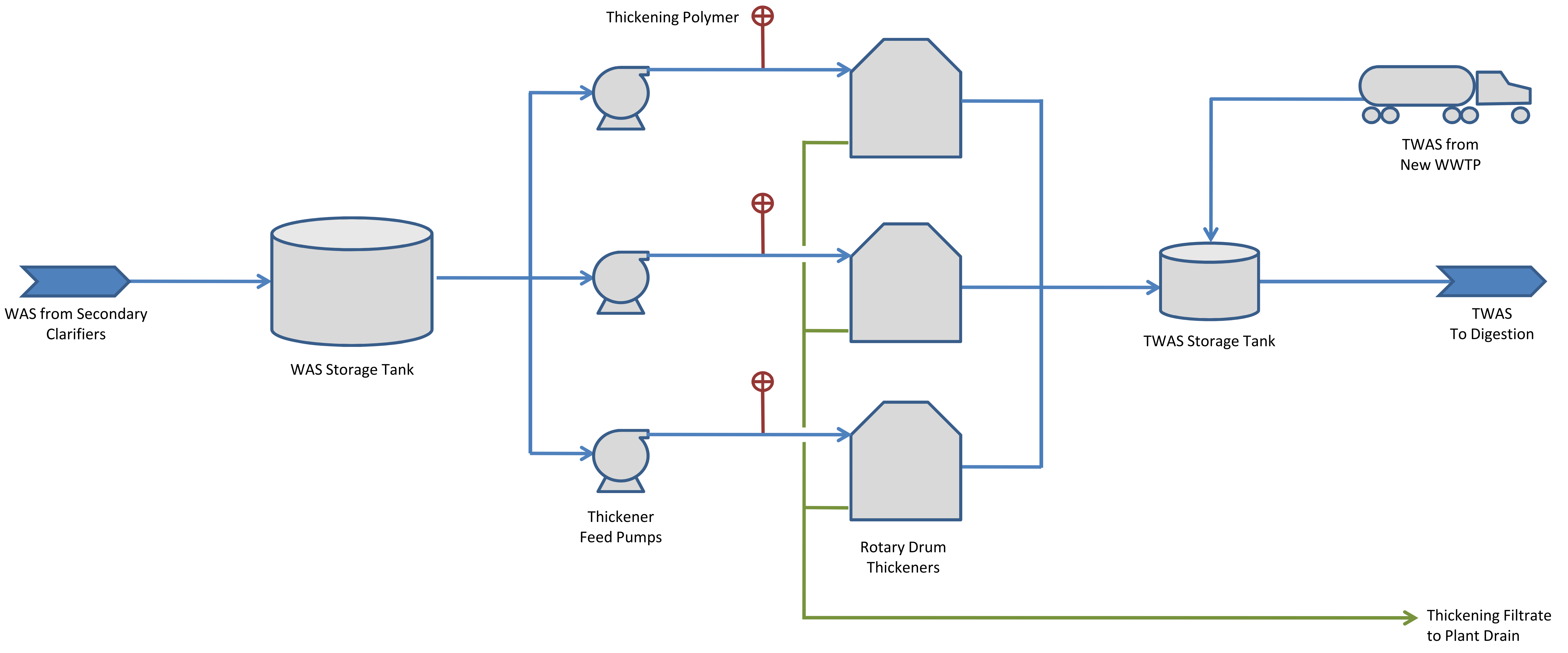
2.5.1 Franklin WWTP

2.5.1.1 Proposed Site Plan

Figure 2-6 presents the proposed site plan for the new solids treatment facilities at the Franklin WWTP. There is sufficient space to construct the proposed solids handling building and ancillary storage tanks in the open area northwest of the existing sludge processing structures.

The proposed solids handling building measures approximately 105 feet by 82 feet, with a truck loading bay occupying the northernmost end of the structure. Two storage tanks, one 50-foot and one 30-foot in diameter, situated southwest of the proposed solids handling building will provide storage for WAS and TWAS, respectively. Two 48-foot diameter digester tanks will be located across the existing gravel drive from the solids handling building. Biogas captured from the digesters will be stored in a tank to be constructed adjacent to the northeast end of the solids handling building. The site will be paved so that trucks transporting dewatered cake to the solar dryers will pull through the truck loading bay and turn around in front of the filter building.

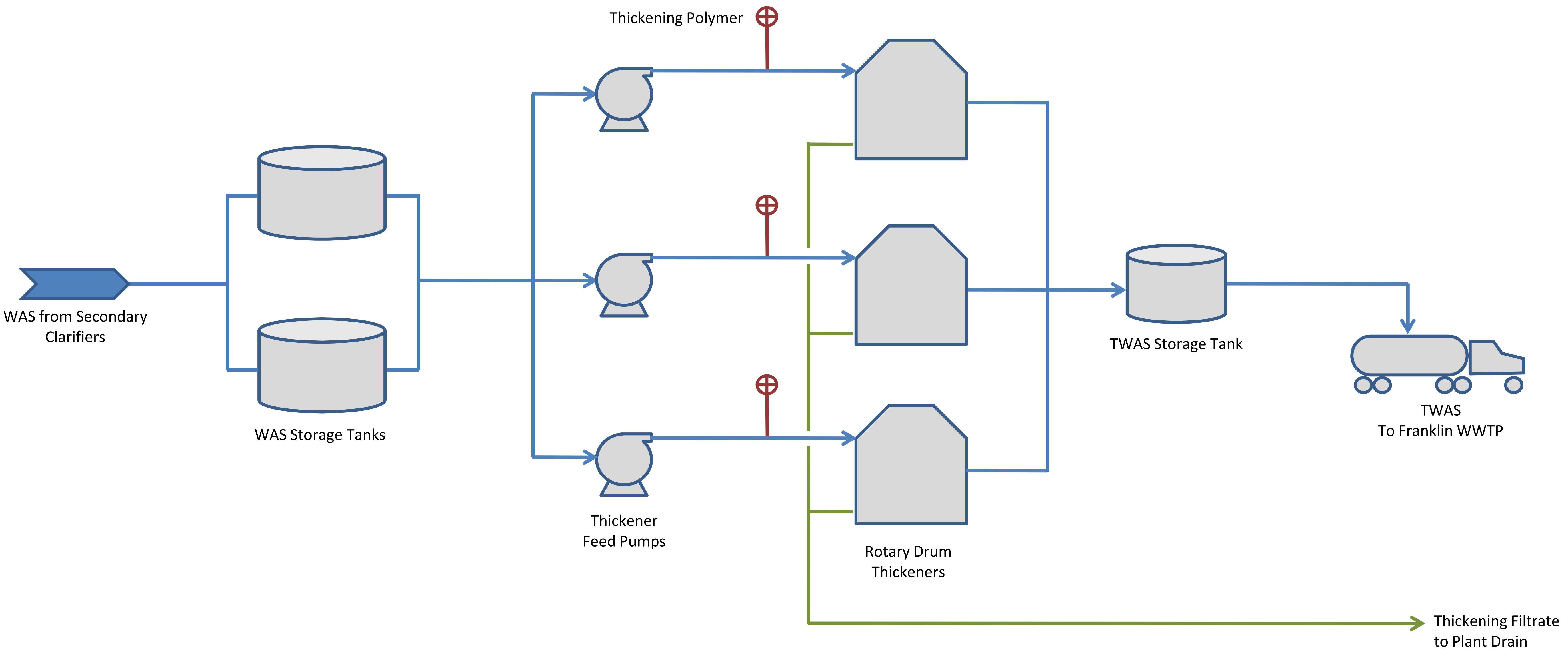
The solar drying chambers will be arranged on either side of a central access drive in the undeveloped area west of the existing sludge storage tanks. Each of the proposed solar dryers measures approximately 264-feet long by 42-feet wide. The eight solar dryers proposed for Phase I construction are illustrated in green, while the two additional dryers proposed in each subsequent phase are outlined in red (Phase II) and blue (Phase III), respectively. A 25-foot-wide paved access drive forms the perimeter of the facility and will be designed to transition into the existing roadway, with sufficient turning radius for trucks. Additional paved area is provided on the north end of the solar dryer facility for odor control equipment.



	WAS				Thickened WAS				Thickening Filtrate	
	gal/day	lbs TS/day	lbs VS/day	% solids	gal/day	lbs TS/day	lbs VS/day	% solids	gal/day	lbs TS/day
Phase I (2023)	314,000	22,000	14,300	0.8%	50,000	20,900	13,600	5.0%	264,000	1,100
Phase II (2031)	319,000	22,400	14,500	0.8%	51,000	21,300	13,800	5.0%	268,000	1,100
Phase III (2040)	319,000	22,400	14,500	0.8%	51,000	21,300	13,800	5.0%	268,000	1,100

Note: Quantities listed are average daily values (7-day basis).

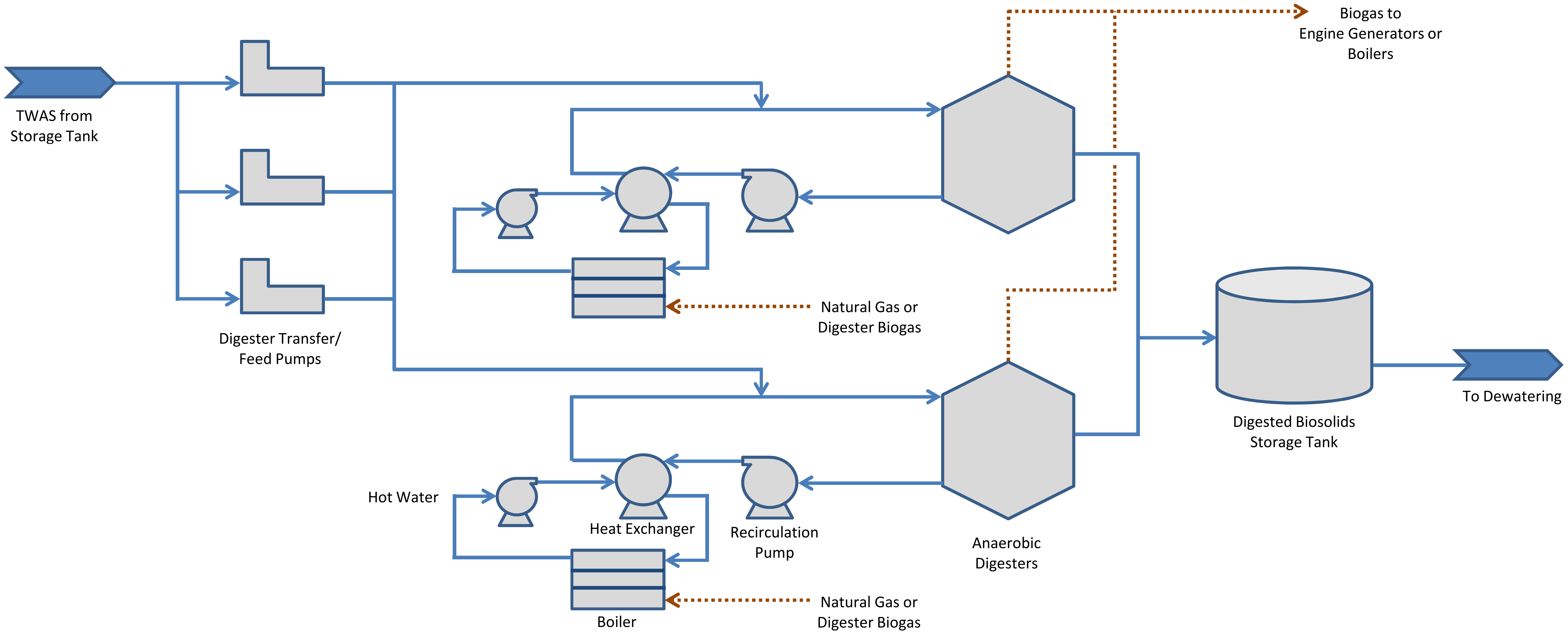
Figure 2-1
Process Flow Diagram & Mass Balance
Rotary Drum Thickening at Franklin WWTP



	WAS				Thickened WAS				Thickening Filtrate	
	gal/day	lbs TS/day	lbs VS/day	% solids	gal/day	lbs TS/day	lbs VS/day	% solids	gal/day	lbs TS/day
Phase I (2023)	0	0	0	1.0%	0	0	0	5.0%	0	0
Phase II (2031)	59,000	4,900	3,300	1.0%	11,000	4,700	3,100	5.0%	48,000	200
Phase III (2040)	131,000	10,900	7,200	1.0%	25,000	10,400	6,800	5.0%	106,000	500

Note: Quantities listed are average daily values (7-day basis).

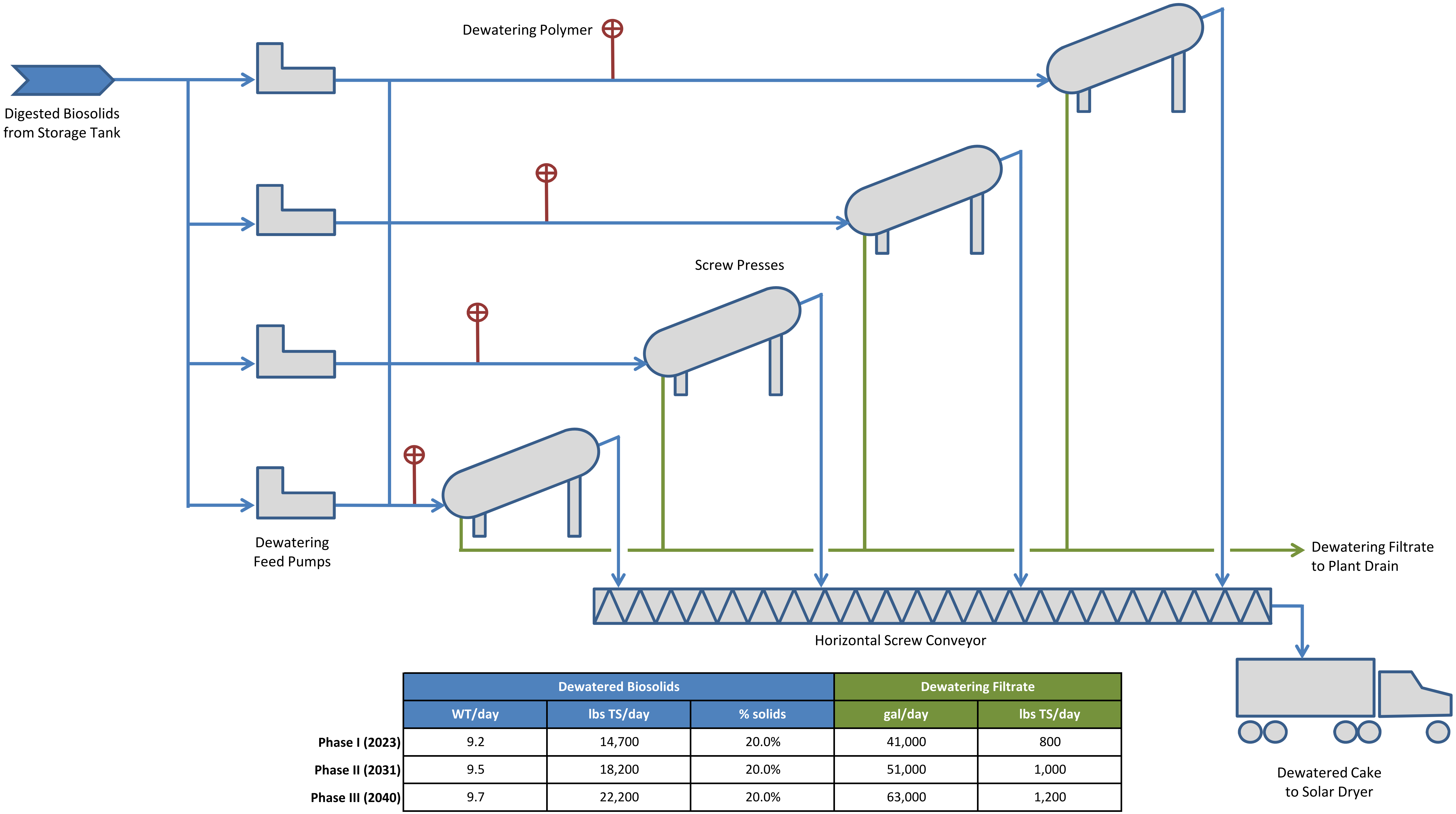
Figure 2-2
Process Flow Diagram & Mass Balance
Thickening at New WWTP



	Digested Biosolids				Digester Biogas Produced		
	gal/day	lbs TS/day	lbs VS/day	% solids	SCFM	Heat, MMBTU/yr	or Electricity, kW
Phase I (2023)	50,000	15,500	8,100	3.7%	57	17,800	227
Phase II (2031)	62,000	19,200	10,100	3.7%	70	22,200	282
Phase III (2040)	76,000	23,400	12,400	3.7%	86	27,100	345

Note: Quantities listed are average daily values (7-day basis).

Figure 2-3
Process Flow Diagram & Mass Balance
Anaerobic Digestion at Franklin WWTP



	Dewatered Biosolids			Dewatering Filtrate	
	WT/day	lbs TS/day	% solids	gal/day	lbs TS/day
Phase I (2023)	9.2	14,700	20.0%	41,000	800
Phase II (2031)	9.5	18,200	20.0%	51,000	1,000
Phase III (2040)	9.7	22,200	20.0%	63,000	1,200

Note: Quantities listed are average daily values (7-day basis).

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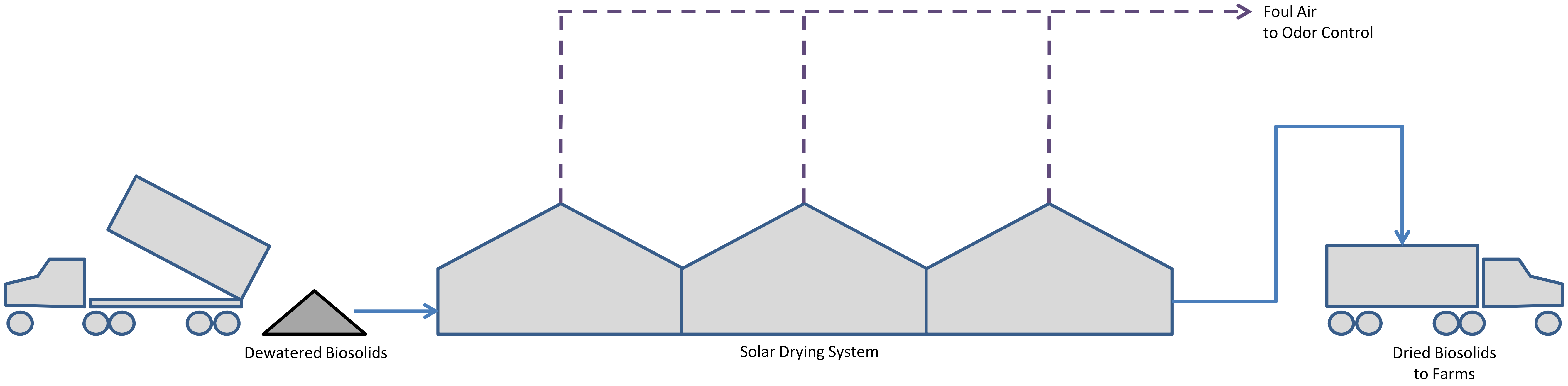
Figure 2-4
Process Flow Diagram & Mass Balance
Screw Press Dewatering at Franklin WWTP



	Dried Biosolids		
	WT/day	lbs TS/day	% solids
Phase I (2023)	9.2	14,700	80.0%
Phase II (2031)	11.4	18,200	80.0%
Phase III (2040)	13.9	22,200	80.0%

Note: Quantities listed are average daily values (7-day basis).

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Figure 2-5
Process Flow Diagram & Mass Balance
Solar Drying at Franklin WWTP

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CITY OF FRANKLIN, TN

CONCEPTUAL DESIGN REPORT

FIGURE 2-6

PROPOSED SITE PLAN

JANUARY 2012

2.5.1.2 Proposed Solids Handling Building Layout

It is CDM Smith's understanding that the thickening and dewatering equipment selection has not been finalized; these building layouts were created using the dimensions and service clearances of the largest pieces of thickening and dewatering equipment that could be installed. A building layout based on the rotary drum thickener and screw press, both part of the selected Option 2 treatment process, is likely to result in a slightly smaller footprint than what is presented here.

Figures 2-7 and **2-8** present the first and second floors of the proposed solids handling building. The solids handling building is to be a two-story structure with a 25-foot wide truck loading bay at the northeastern end. In addition to laboratory space and control and electrical rooms, the first floor includes space for the feed pumps and polymer systems for the dewatering and thickening equipment, which is located on the second floor. The digester equipment will also be located on the first floor. Each of the two digesters will have a heat exchanger and set of two mixing pumps. The two digesters require a duty and standby set of transfer feed pumps and recirculation pumps which will be situated adjacent to the heat exchangers and mixing pumps.

The second floor, illustrated in Figure 2-8, houses the proposed dewatering and thickening units. If the City selects screw thickeners or screw presses, each of these machines require a substantial amount of service clearance at one end; consequently, 23 feet of clearance is provided between the dewatering and thickening units. If both screw presses and screw thickeners are selected, they would share this service clearance area. Both the thickening and dewatering units would be fed by the pumps and polymer feed equipment located on the first floor. The thickening units would be fed sludge from the WAS storage tank, and the dewatering units would be fed from the TWAS storage tank. Thickened sludge would be discharged to the TWAS storage tank, and dewatered sludge would discharge to horizontal screw conveyors, which would transfer the cake to trucks in the loading bay below. All of the proposed thickening equipment and all but one dewatering machine will be installed during Phase I. A fourth dewatering unit will be installed in Phase III.

2.5.2 New WWTP

The design memorandum describing the proposed new WWTP includes the thickening building. The building will measure approximately 70 feet by 45 feet. The thickening machines will be located on the ground floor, and there will be a basement level where the polymer systems, sludge feed pumps, and TWAS pumps will be installed. The basement level will also feature an integral, rectangular storage tank for TWAS; the thickened sludge will drop into the tank from the machines above. The TWAS will be mixed with pumps and discharged to tanker trucks parked next to the building.

2.5.3 Integration of Existing & New Facilities

During Phase I construction, new yard piping will be constructed to connect the discharge of the existing WAS pumps to the new WAS storage tank. Because the Franklin WWTP's existing solids treatment facilities must remain in service until the new facilities are online, the existing facilities should be demolished, either as the final part of the Phase I construction contract or as part of a separate demolition contract, after the Phase I facilities are completed and capable of treating solids.

A more detailed analysis of maintenance of plant operations will follow in later phases of design.

2.5.4 Coordination With Other Work

The solar drying facility shown in Figure 2-6 should be located as far north as possible in order to avoid interference with the planned future solar panel array being developed separately by Merville & Howe

Engineering. Work related to the solar panel array is not a part of the scope of this Conceptual Design Report. Design activities at the Franklin WWTP should be closely coordinated with this and other projects.

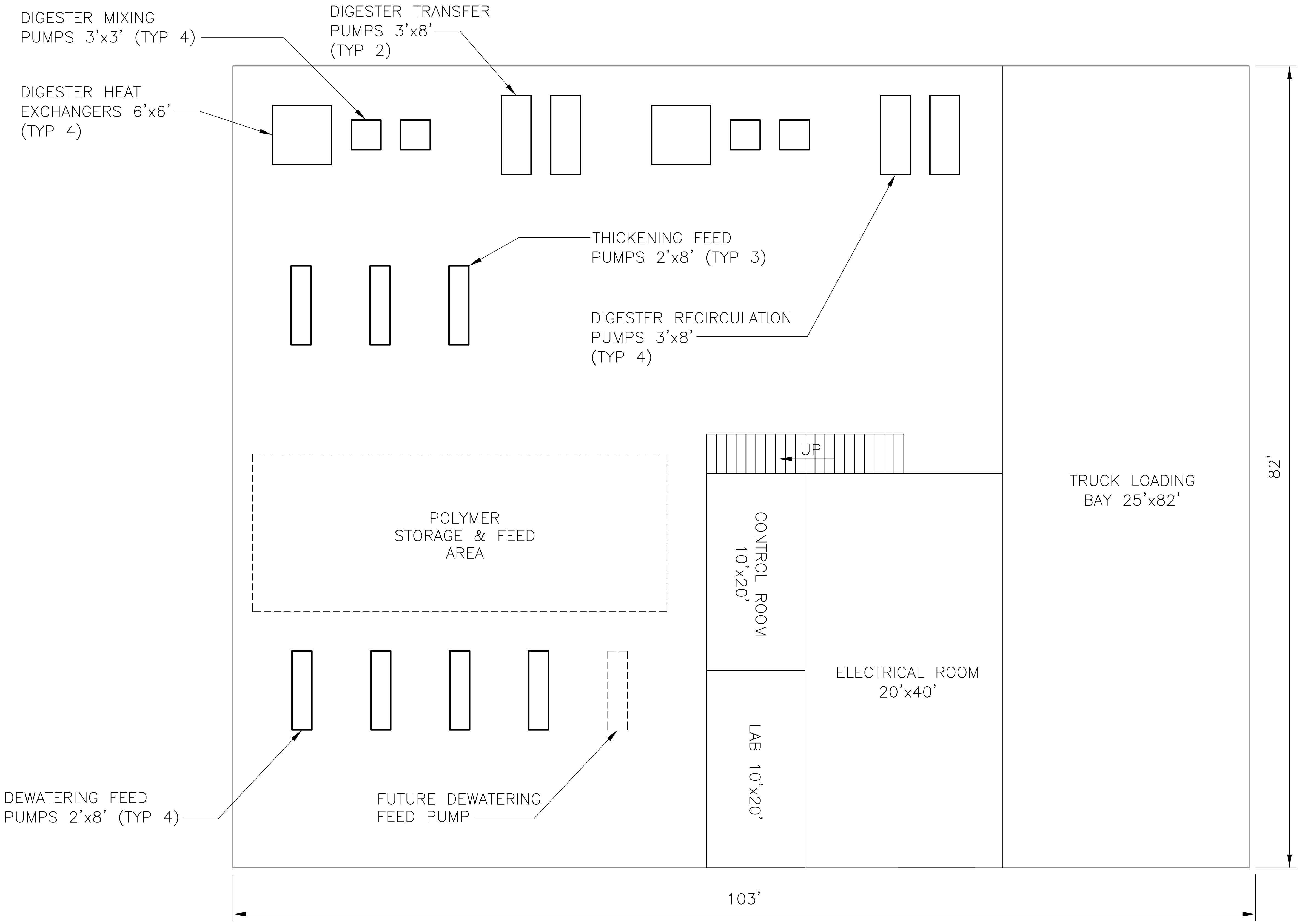

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Figure No. 2-7
Proposed Solids Handling Building
First Floor Plan
January 2012

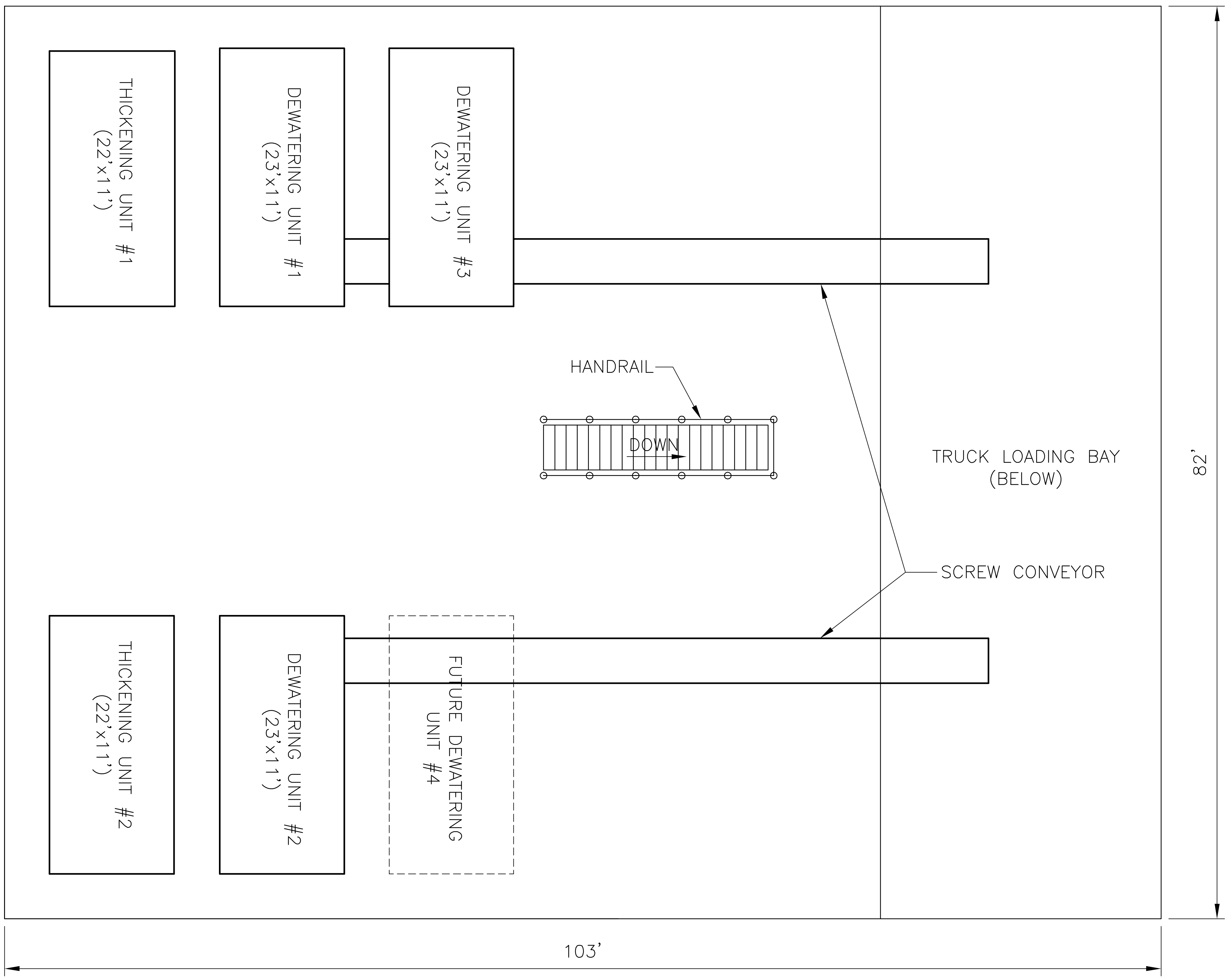

Figure No. 2-8
Proposed Solids Handling Building
Second Floor Plan
January 2012

2.6 Process Equipment Selections

2.6.1 Visits to Regional Installations

Though solar drying is used extensively throughout Europe, there are only few solar dryer installations in the United States. One installation is located in Okeechobee, Florida. This 3-MGD facility receives and processes trucked-in sludges from nearby municipal WWTPs. Three Parkson Thermo-System solar dryer chambers dry the sludge for about 130 days to a solids content of approximately 80 percent. The dried product is considered Class A biosolids and is land applied to city land and agricultural fields. The Okeechobee staff samples every truckload of dried biosolids removed from the solar dryer for land application to ensure that the biosolids meet Class A pathogen reduction requirements.

In addition to viewing the solar dryer, City staff that visit Okeechobee can also examine the facility's anaerobic digester, which produces a digested sludge that is subsequently dewatered five days per week and loaded into the solar drying chambers twice per day. A visit to the Okeechobee solar dryer and digester installation would also allow City staff to also visit a nearby Andritz rotary drum thickening installation in Indian River County.

Table 2-7 summarizes the equipment installations at and near Okeechobee. The City and CDM Smith intend to visit these facilities in February 2012. Other site visits may be planned in the future.

Table 2-7
Summary of Upcoming Site Visits

Facility	Process Equipment	Comments
Okeechobee, FL	Anaerobic Digester	Digested sludge sent to dewatering 5 days/wk
	Solar Dryer	Parkson Thermo-System™ Solar Dryer Constructed in 2007 Three drying chambers - 42' x 200'; drying area = 2,800yd² Final solids target = 75% Currently 2 of 3 chambers used Maintain < 135°F in chambers 130 days to process one batch Produces Class A biosolids
Indian River County, FL	Rotary Drum Thickener	One Andritz 12 x 3 RST Installed in 2004

2.6.2 On-Site Pilot Demonstrations

The major thickening and dewatering equipment vendors have mobile demonstration trailers available for on-site pilot testing. Although it will not be possible to test the sludges that the projected solids facility is expected to handle, an on-site demonstration would enable City staff to gain valuable hands-on experience in the operation and maintenance of the equipment. CDM Smith has assisted numerous other clients in coordinating, pricing, and scheduling on-site demonstrations and has requested a demonstration of the Huber Technology screw press that is proposed for dewatering at the Franklin WWTP's new solids treatment facilities. Huber's demonstration trailer will be touring the southeastern United States from March to May 2012, and CDM Smith is currently working with Huber and City staff to schedule a demonstration at the Franklin WWTP.

2.7 Sidestream Treatment Options

Sidestreams discharged from the proposed solids treatment processes consist primarily of water and suspended solids removed from the thickening and dewatering processes. Like other waste streams generated in a wastewater treatment plant, these sidestreams are recycled to the head of the plant for treatment. Because these sidestreams are known to contain large amounts of nitrogen and phosphorus, they can have a significant impact on the size and cost of the liquid treatment process.

Two processes that have been developed to reduce nutrient loads are discussed briefly in the following sections. These and other emerging technologies may be explored in subsequent design studies. A present worth analysis during preliminary design is recommended to assist in the decision on whether to include these treatment technologies in the WWTP improvements.

2.7.1 Anaerobic Ammonium Oxidation (ANAMMOX)

Practiced in wastewater treatment since the late 1980s, the ANAMMOX process uses a naturally-occurring biochemical reaction to remove ammonium from a high-strength wastewater sidestream. The process consists of two steps. First, ammonia oxidizing bacteria are used to convert a portion of the ammonium in the wastewater to nitrite in a process called nitritation or partial nitrification. In the second step, the ANAMMOX bacteria convert the nitrite and ammonium into nitrogen gas.

Because the ANAMMOX bacteria grow very slowly, the process is usually contained in a sequencing batch reactor (SBR) or a moving bed biofilm reactor (MBBR). The nitrite and dissolved oxygen concentrations must be carefully monitored in order to avoid inhibiting the process. Full scale ANAMMOX treatment processes have been constructed in Europe, but there are few installations in the United States.

2.7.2 Nutrient Recovery (Ostara PEARL® Process)

The presence of a dewatering process presents the opportunity to capture nutrients from the dewatering filtrate stream for beneficial reuse. The Pearl® process, developed by Ostara Nutrient Recovery Technologies (Ostara), recovers nitrogen and phosphorus from the sidestream through application of magnesium chloride and caustic soda to the sidestream, followed by precipitation of struvite pellets in a patented fluidized bed reactor. After the struvite pellets are removed from the reactor, they are dried and packaged for sale as Crystal Green® fertilizer. Full-scale Pearl® processes have been installed in Pennsylvania, Oregon, and Virginia.

Section 3
Updated Economic Analysis

3.1 Updated Opinion of Probable Construction Cost

A preliminary opinion of probable construction cost (OPCC), along with assumptions made during the cost estimating process, was presented in Section 5 of TM No. 2. The following sections describe the major changes made to the OPCC based on requests from the Steering Committee and other stakeholder comments.

3.1.1 Phasing of Improvements

As part of an initial screening process, the OPCCs in TM No. 2 had been based on the construction of complete solids treatment trains for the design year of 2040. For this Conceptual Design Report, construction of the selected process was divided into phases in order to minimize the initial cost of construction and coordinate with improvements to the liquid treatment facilities. The phasing method and selection of the 16 + 4 + 4 strategy were explained in Section 2.

3.1.2 Modification of Contingency Calculation

At the September Steering Committee meeting, it was commented that the 30 percent contingency should be removed from the process equipment costs, as budgetary proposals given at the planning stages of a project tend to already include a significant contingency added by the vendors.

CDM Smith's cost estimating division considers it good practice to carry a contingency on process equipment to account for factors such as design changes, equipment obsolescence, and materials cost escalation. The OPCC was therefore recalculated with a 10 percent contingency applied to the process equipment costs.

3.1.3 Revised OPCC & Assumptions

Table 3-1 presents the revised OPCC for the 16 + 4 + 4 phased improvements. The updated assumptions and markups applied to this OPCC are listed below and in **Table 3-2.**

- This is a planning level OPCC only, based on a three-phase construction of a solids treatment train for the design years of 2023, 2031, and 2040, respectively.
- It was assumed that Franklin WWTP and the new WWTP would use identical thickening machines.
- Thickening and dewatering equipment costs are based on the rotary drum thickener and screw press; however, these costs may change during preliminary design to reflect the City's final equipment selections.

- As mentioned in Section 2.5.1.2, the buildings housing dewatering and thickening equipment were sized according to the dimensions and service clearances of the largest pieces of thickening and dewatering equipment that could be installed. The cost of the building may change during preliminary design after the City finalizes its thickening and dewatering equipment selections.

- The capital cost of the new WWTP solids handling facilities includes procurement of two new tanker trucks, as well as construction of truck loading and receiving facilities at the new WWTP and Franklin WWTP, respectively. The tanker trucks will be loaded with TWAS at the new WWTP and transport it to the Franklin WWTP for further treatment.

- The capital cost includes a combined heat and power (CHP) system consisting of a 250-kW microturbine suitable for outdoor installation adjacent to the digester gas storage facility.

- Rock excavation is not included.

- Only nominal dewatering is needed for new structures.

- No contaminated soil or hazardous materials will be encountered.

- Construction costs are based on a normal 40-hour work week.

- Construction costs are based on 2011 dollars (no escalation applied).

Table 3-1
Revised Opinion of Probable Construction Cost for Solids Treatment Improvements - 16 + 4 + 4 Phasing

		Phase I (16 MGD)					**Phase II (+4 MGD)**					**Phase III (+4 MGD)**				
		Thickening	**Stabilization**	**Dewatering**	**Drying**	**New WWTP**	**Thickening**	**Stabilization**	**Dewatering**	**Drying**	**New WWTP**	**Thickening**	**Stabilization**	**Dewatering**	**Drying**	**New WWTP**
Construction Cost Component	**% of Cost**	**Rotary Drum Thickener**	**Mesophilic Anaerobic Digestion**	**Screw Press**	**Solar Dryer**	**Rotary Drum Thickener**	**Rotary Drum Thickener**	**Mesophilic Anaerobic Digestion**	**Screw Press**	**Solar Dryer**	**Rotary Drum Thickener**	**Rotary Drum Thickener**	**Mesophilic Anaerobic Digestion**	**Screw Press**	**Solar Dryer**	**Rotary Drum Thickener**
Facilities & Equipment																
Process Equipment	n/a	$952,500	$2,710,000	$1,430,000	$5,669,091	$0	$0	$0	$0	$1,167,273	$765,000	$0	$350,000	$320,000	$1,167,273	$312,500
Structure (where applicable)	n/a	$665,000	$2,309,056	$5,400,000	$1,056,000	$0	$0	$0	$0	$264,000	$1,766,000	$0	$0	$0	$264,000	$170,000
Demolition (where applicable)	n/a	$40,000	$50,000	$20,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$285,750	$813,000	$429,000	$1,700,727	$0	$0	$0	$0	$350,182	$229,500	$0	$105,000	$96,000	$350,182	$93,750
Allowances																
Sitework	5%	$97,163	$294,103	$363,950	$421,291	$0	$0	$0	$0	$89,073	$138,025	$0	$22,750	$20,800	$89,073	$28,813
Piping	15%	$291,488	$882,308	$1,091,850	$1,263,873	$0	$0	$0	$0	$267,218	$414,075	$0	$68,250	$62,400	$267,218	$86,438
Instrumentation & Electrical	25%	$485,813	$1,470,514	$1,819,750	$2,106,455	$0	$0	$0	$0	$445,364	$690,125	$0	$113,750	$104,000	$445,364	$144,063
CONSTRUCTION SUBTOTAL		**$2,817,713**	**$8,528,981**	**$10,554,550**	**$12,217,436**	**$0**	**$0**	**$0**	**$0**	**$2,583,109**	**$4,002,725**	**$0**	**$659,750**	**$603,200**	**$2,583,109**	**$835,563**
Permits	1.0%	$28,177	$85,290	$105,546	$122,174	$0	$0	$0	$0	$25,831	$40,027	$0	$6,598	$6,032	$25,831	$8,356
Sales Tax	9.25%	$96,917	$275,743	$145,503	$576,830	$0	$0	$0	$0	$118,770	$77,839	$0	$35,613	$32,560	$118,770	$31,797
Bonds & Insurance																
Builder's Risk	0.5%	$14,089	$42,645	$52,773	$61,087	$0	$0	$0	$0	$12,916	$20,014	$0	$3,299	$3,016	$12,916	$4,178
General Liability	1.0%	$28,177	$85,290	$105,546	$122,174	$0	$0	$0	$0	$25,831	$40,027	$0	$6,598	$6,032	$25,831	$8,356
GC Bonds	1.5%	$42,266	$127,935	$158,318	$183,262	$0	$0	$0	$0	$38,747	$60,041	$0	$9,896	$9,048	$38,747	$12,533
SUBTOTAL #1		**$3,027,338**	**$9,145,882**	**$11,122,235**	**$13,282,964**	**$0**	**$0**	**$0**	**$0**	**$2,805,203**	**$4,240,673**	**$0**	**$721,753**	**$659,888**	**$2,805,203**	**$900,782**
General Conditions/OH&P																
General Conditions	10%	$302,734	$914,588	$1,112,223	$1,328,296	$0	$0	$0	$0	$280,520	$424,067	$0	$72,175	$65,989	$280,520	$90,078
Overhead & Profit	10%	$302,734	$914,588	$1,112,223	$1,328,296	$0	$0	$0	$0	$280,520	$424,067	$0	$72,175	$65,989	$280,520	$90,078
SUBTOTAL #2		**$3,632,805**	**$10,975,059**	**$13,346,681**	**$15,939,557**	**$0**	**$0**	**$0**	**$0**	**$3,366,244**	**$5,088,807**	**$0**	**$866,103**	**$791,866**	**$3,366,244**	**$1,080,938**
Contingency																
Construction Contingency	30%	$899,342	$2,750,518	$3,718,004	$3,648,049	$0	$0	$0	$0	$776,419	$1,373,642	$0	$189,831	$173,560	$776,419	$261,781
SUBTOTAL #3		**$4,532,147**	**$13,725,576**	**$17,064,686**	**$19,587,605**	**$0**	**$0**	**$0**	**$0**	**$4,142,663**	**$6,462,449**	**$0**	**$1,055,934**	**$965,425**	**$4,142,663**	**$1,342,720**
Escalation	0.0%	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CONSTRUCTION TOTAL		**$4,532,000**	**$13,726,000**	**$17,065,000**	**$19,588,000**	**$0**	**$0**	**$0**	**$0**	**$4,143,000**	**$6,462,000**	**$0**	**$1,056,000**	**$965,000**	**$4,143,000**	**$1,343,000**
Design & Construction Services	15%	$680,000	$2,059,000	$2,560,000	$2,938,000	$0	$0	$0	$0	$621,000	$969,000	$0	$158,000	$145,000	$621,000	$201,000
City Project Administration	2.0%	$91,000	$275,000	$341,000	$392,000	$0	$0	$0	$0	$83,000	$129,000	$0	$21,000	$19,000	$83,000	$27,000
Legal/Finance	3.0%	$136,000	$412,000	$512,000	$588,000	$0	$0	$0	$0	$124,000	$194,000	$0	$32,000	$29,000	$124,000	$40,000
Allowances		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$175,000**	**$0**	**$0**	**$0**	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$5,439,000**	**$16,472,000**	**$20,478,000**	**$23,506,000**	**$0**	**$0**	**$0**	**$0**	**$4,971,000**	**$7,929,000**	**$0**	**$1,267,000**	**$1,158,000**	**$4,971,000**	**$1,611,000**
EACH PHASE CAPITAL COST		**$66,000,000**					**$13,000,000**					**$10,000,000**				
YEAR INCURRED		**2012**					**2022**					**2030**				

Notes
1. Engineering cost includes preliminary and final design, construction administration, and field services.
2. Capital cost for the new WWTP is based on construction of 4 MGD facility.
3. Life Cycle Cost Parameters
    Interest Rate 5%
    Life Cycle 20 years
4. 10% contingency applied to process equipment.

ENR Construction Cost Index 8938.30 for January 2011

Table 3-2
Updated Planning Level Capital Cost Assumptions

Cost Item	Value
Allowances Applied to Estimated Construction Cost	
Labor & Material	30 percent
Piping	15 percent
Instrumentation & Electrical	25 percent
Markups Applied to Estimated Contractor's Cost	
Permits	1.0 percent
Sales Tax	9.25 percent[1]
Builder's Risk	0.5 percent
General Liability	1.0 percent
GC Bonds	1.5 percent
General Conditions	10 percent
Overhead & Profit	10 percent
Markups Applied to Estimated Construction Cost	
Construction Contingency	30 percent[2]
Design & Construction Services	15 percent
City Project Admin.	2.0 percent
Legal/Finance	3.0 percent

[1] Applied to equipment and material costs.

[2] 10 percent contingency is applied to process equipment costs.

3.2 Updated Operation & Maintenance Costs

CDM Smith refined the O&M costs to incorporate comments received at the Steering Committee meeting. The goal of these refinements was to improve the accuracy of the O&M costs previously presented in TM No. 2.

In addition to refining the existing set of O&M costs for a facility operated by City staff, CDM Smith has begun discussions with a third party to discuss the relative costs of a contract operation. These developments are discussed in the following sections.

3.2.1 O&M Costs of Owner Operated Facility

In addition to modifying the OPCC, CDM Smith refined the O&M costs to include the following items:

- **Unit cost escalation.** CDM Smith applied an inflation rate of 3 percent per year to unit costs including labor, chemicals, utilities, landfill tipping fees, and truck maintenance and insurance.

- **New tipping fee for 2011.** The tipping fee was recently raised to $24.40 per WT. This tipping fee replaces the previously used tipping fee of $22.24 per WT.

- **CHP and digester heating.** A combined heat and power (CHP) system is discussed in Section 4. The updated O&M costs assume that a CHP system will be installed to generate electricity from the digester biogas, and the electricity generated by the CHP system will be used to power solids handling equipment. The waste heat recovered from the microturbine will be used to heat the digesters. Supplemental heating is required, as there is not enough waste heat to meet the digesters' heating demands. The cost of natural gas for supplemental heating was included in the O&M costs.

Planning level annual O&M cost calculations were based on the parameters and assumptions listed in **Table 3-3.** The labor required to operate and maintain the solids treatment train was based on the relative complexity of each technology and its anticipated operating schedule. **Table 3-4** presents the assumptions that were used to calculate the 20-year life cycle cost.

Table 3-3
Updated O&M Cost Assumptions

Cost Item	Value
Labor	
Fully Loaded Labor Rate	$35.08 per hour
Utilities	
Electricity	$0.06/kWh
Natural Gas	$10/MMBtu
Chemicals	
Thickening/Dewatering Polymers	$1.60/lb delivered
Sodium Hypochlorite Solution (odor control)	$1.57/gal delivered
Caustic Soda (odor control)	$1.54/gal delivered
Muriatic Acid (odor control)	$2.38/gal delivered
Biosolids Hauling	
Solids Disposal Location	Local Farms
Truck Capacity	20 CY
Landfill Tipping Fee	$24.40/WT
Diesel Fuel Cost	$3.88/gallon
Truck Fuel Economy	5 miles/gallon
Average Round Trip Distance	100 miles
Driver's Labor Per Load	6 hours
Fleet Maintenance	$6,480 per year
Insurance	$440 per year

Table 3-4
Life Cycle Cost Assumptions

Cost Item	Value
Interest Rate	5 percent
Period	20 years

3.2.2 O&M Costs of Contract Operations

Some municipalities choose to contract with an operator to provide biosolids services that include operation and maintenance of the municipality's solids handling facilities. Costs of chemicals, utilities, and final disposal can be included in these contracts. The scope of the contract operator's services and the structure of the contract can vary greatly from contract to contract; the contract structure and overall cost are influenced by factors including the owner's preferences and budgetary goals, as well as the quantity of biosolids that is to be treated.

CDM has contacted Synagro Technologies to begin discussion of the possibility of contract operations at the proposed Franklin WWTP solids handling facility. This conversation is ongoing, and the results of this discussion will be shared with the City at a later date.

3.3 Updated Project Life Cycle Cost

The updated 20-year life cycle cost of the project is **$86,000,000. Table 3-5** presents the annual capital and O&M costs from Year 1 to Year 20.

Table 3-5
Updated Project Life Cycle Cost – 16 + 4 + 4 Phasing

Year	Capital Cost	PW of Capital Cost	O&M Cost	PW of O&M Cost	O&M Cost per DT
2011			$429,000	$429,000	$170
2012	$66,000,000	$62,857,143	$451,000	$429,524	$170
2013			$491,000	$445,351	$177
2014			$515,000	$444,876	$178
2015			$540,000	$444,259	$179
2016			$566,000	$443,476	$180
2017			$613,000	$457,430	$187
2018			$641,000	$455,547	$189
2019			$680,000	$460,251	$193
2020			$711,000	$458,317	$195
2021			$766,000	$470,258	$203
2022	$13,000,000	$7,600,831	$801,000	$468,328	$206
2023			$837,000	$466,073	$209
2024			$956,000	$506,987	$231
2025			$1,037,000	$523,755	$244
2026			$1,097,000	$527,676	$251
2027			$1,160,000	$531,409	$258
2028			$1,225,000	$534,463	$265
2029			$1,293,000	$537,268	$273
2030	$10,000,000	$3,957,340	$1,393,000	$551,257	$286
20- Year Present Worth: $86,000,000					

Section 4
Options for Beneficial Reuse of Biosolids

4.1 Benefits of Stabilization & Drying

The many benefits of stabilization and drying of WWTP sludges were presented to the Steering Committee during the September 28, 2011, meeting. Stabilized sludge and dried biosolids satisfy the City's selection criteria for a biosolids process as defined in Section 1.2. Two key benefits of adding these processes are the potential for beneficial reuse and the reduction in the quantity of solids to be disposed.

Sludge produced by the WWTP must first be converted into biosolids in order to be reused. Stabilization processes such as anaerobic digestion can accomplish this treatment. In addition to producing a useful biosolids product, the digestion process reduces solids and produces biogas. The Class B biosolids produced by a stabilization process can be applied to agricultural land. Dried biosolids meeting Class A pathogen reduction requirements can be handled by the public and applied to home lawns or gardens. Drying of the biosolids reduces its moisture content and achieves the greatest volume reduction, thus minimizing storage, handling, and transportation costs.

This section discusses the reuse potential of biosolids at different stages along the solids treatment train and presents an overview of process enhancements to maximize the production of energy from the biosolids.

4.2 Biosolids Disposal & Beneficial Reuse Options

Figure 4-1 summarizes the biosolids reuse and/or disposal options available to the City at each stage of the solids treatment process. Some options, such as landfill disposal, are included but are not considered desirable. Other options are better suited to the City's goals. Consideration of these options can assist the City in deciding when and how to expand the Franklin WWTP's solids treatment capabilities.

4.2.1 Mesophilic Anaerobic Digestion

Anaerobic digestion is the biological process that stabilizes organic matter in the absence of oxygen. During this process, biodegradable organic matter is converted to water and biogas containing methane (CH_4) and carbon dioxide (CO_2). The biogas is suitable for use as an energy source; methods to enhance biogas production are discussed later in this section.

In addition to reducing the quantity of the solids, anaerobic digestion can produce a stabilized product meeting regulatory requirements of pathogen reduction and vector attraction reduction. Digested biosolids are often less odorous and attract fewer vectors (such as rodents, flies, mosquitoes, or other organisms capable of transporting infectious agents) than raw sludge. Organic matter, nitrogen, and phosphorus in the digested biosolids can be used as a soil amendment and fertilizer.

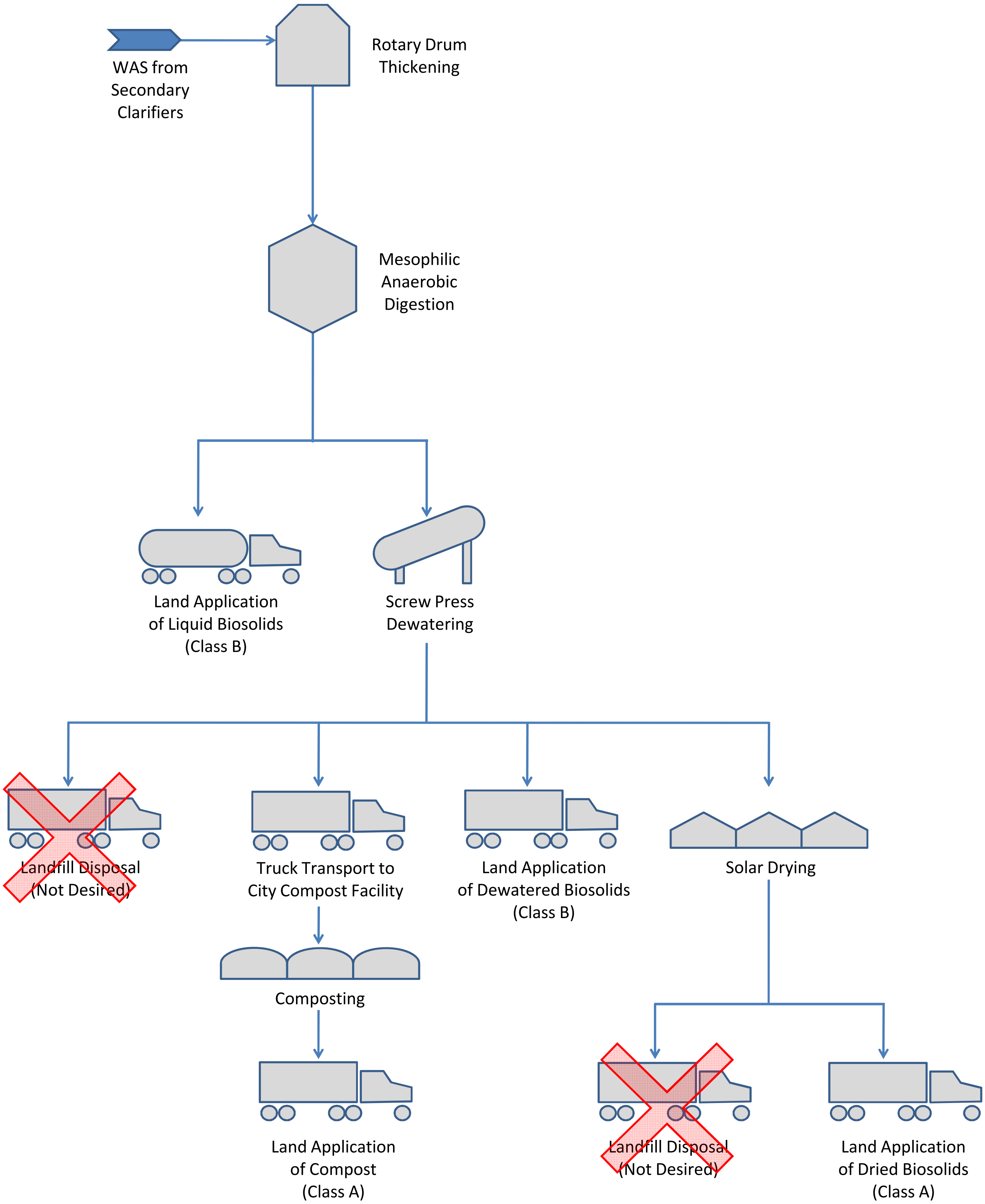

Figure 4-1
Biosolids Disposal Options

4.2.1.1 Land Application as Class B Liquid Biosolids

The anaerobically digested, Class B biosolids produced at the Franklin WWTP may be disposed via land application. In a land application process, the liquid biosolids can be sprayed from a tanker truck as the truck moves through the land application site. It is a relatively inexpensive option that requires minimal capital cost; however, it can be labor intensive. Increased restrictions are placed on Class B biosolids to include restricting public access to the application site, limiting livestock grazing, and controlling crop harvesting schedules.

4.2.1.2 Uses of Digester Biogas

Combined Heat and Power (CHP) is an integrated energy system located at or near the point of use at a facility to provide at least a portion of the electrical or mechanical load while utilizing the waste/reject heat from the power application to provide heating, process steam, cooling, and/or dehumidification. **Figure 4-2** shows a typical CHP arrangement.

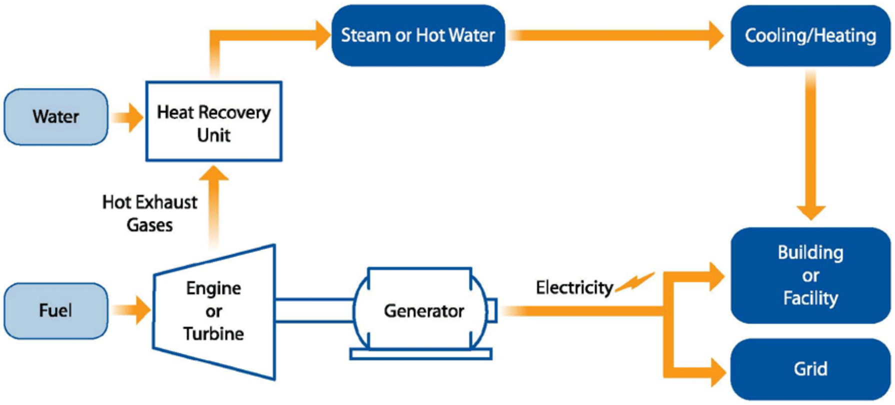

Figure 4-2: Typical Combined Heat and Power Diagram

(Source: U.S. Environmental Protection Agency. Combined Heat and Power Partnership: Basic Information. http://www.epa.gov/chp/basic/index.html)

Digester biogas produced at WWTPs presents a promising potential application for CHP technology. According to the EPA, the benefits of utilizing biogas in a CHP application at a WWTP include:

- Generation of power at a cost below that of retail electricity.
- Displacement of purchased fuels for other thermal needs.
- Qualification as a renewable fuel for green power programs.
- Enhancement of the plant's power reliability – serves as an additional back-up supply.
- Act as a long-term price and volatility hedge against purchased fuels and electricity.

Several options are available for CHP, including fuel cells, microturbines, and reciprocating engines. The suitability of a particular technology for a WWTP depends on the owner's goals and the amount of biogas available. The equipment selection for this project was based on the projected maximum biogas production at a wastewater flow of 16 MGD in the year 2023. Based on the anticipated average sludge production and assuming an energy content of 9,000 BTU per pound of VS reduced, a maximum of 2.04 MMBTU/hr of digester gas will be produced. Typical mechanical devices are approximately 35 to 38 percent efficient at producing electrical power from digester gas. If all of the biogas is used for electricity production, the maximum potential production is approximately 227 kW. At wastewater flows of 24 MGD, the electricity production increases to approximately 345 kW.

For the above range of potential biogas production, a 250 kW microturbine was selected as the basis of this conceptual analysis, as most of the commercially available reciprocating engines have a much larger capacity. Microturbines were derived from turbocharger technologies found in automobiles or the turbines in aircraft auxiliary power units. Most microturbines are single-stage, radial flow devices with high rotating speeds of 90,000 to 120,000 revolutions per minute (rpm). However, a few manufacturers have developed alternative systems with multiple stages and/or lower rotation speeds.

Ingersoll Rand (IR) had been the only manufacturer of 250kW microturbines with a proven track record. Recently, however, IR sold off its microturbine business to FlexEnergy, located in Irvine, California. FlexEnergy continues to manufacture and sell the IR microturbine unit, which is a gas-powered turbine, 250 kW synchronous electric generator. It comes as a pre-engineered and tightly integrated package that is ready to be installed on-site either indoors or outdoors. The microturbines are designed to run 24 hours a day, 7 days a week with startups and shutdowns limited to once per day, or less frequently. An optional waste heat recovery system is available.

Microturbines can run on a range of gaseous fuels ranging from low- to medium- and high-BTU fuel sources; however, when compared to reciprocating engines, microturbines have more stringent restrictions on the inlet fuel quality. The required inlet fuel gas pressure for microturbines is approximately 100 psi. Additionally, the digester gas must be treated to rid it of unwanted constituents before being used in a microturbine. The reliability of a microturbine depends on the fuel conditioning systems; improper gas treatment can cause problems with maintenance and operation and could potentially shorten the unit's service life.

Since the quality of digester gas varies from facility to facility, a fuel gas analysis is performed prior to the start of design in order to recommend the fuel treatment required for any particular application. The manufacturer typically does not guarantee equipment performance or adherence to emissions limits without first performing this fuel gas analysis, at the inlet to the microturbine, to verify the effectiveness of the digester gas treatment system. A typical digester gas treatment system involves removal of sulfur compounds, halogenated organic compounds (HOCs), siloxane, and any particulate larger than 10 microns.

There are thousands of microturbine installations ranging from 25kW to 500kW. It should be noted that microturbines that run on cleaner fuels, such as natural gas or gases with lower siloxane levels (*e.g.,* landfill gas), are expected to perform better than units that run on digester gas. The approximate capital cost (estimated per EPA reports) for installation of a single 250kW microturbine is $350,000.

The advantages and disadvantages of microturbines are summarized below in **Table 4-1.**

Table 4-1
Advantages & Disadvantages of Microturbines

Advantages	Disadvantages
• Small number of moving parts • Compact size • Light weight • Low emissions • Long maintenance intervals • Higher combined efficiency	• Low Electrical efficiency • Cleaner fuel requirements • Loss of power output and efficiency with higher ambient temperature and elevation • Very high gas pressure

(thermal and electrical)	requirements • No partial loading

The electricity produced would be available for use at the plant, or it could be sold to the utility power grid. It is expected that all power produced by the microturbine could be consumed at the plant. However, with potential economic incentives, it may be more beneficial to sell power to the utility grid, thereby generating revenue for the City.

As mentioned above, in addition to power production, CHP systems offer increased energy recovery by capturing waste heat from the power producing equipment. For this system, evaluated at maximum power production, 45 percent of the input energy becomes waste heat that could be captured through a series of heat recovery loops. Through heat exchangers, energy can be transferred and used to heat sludge in the digesters. On average, 0.92 MMBTU/hr could be recovered from the microturbine. This provides approximately 80 percent of the annual average digester winter heating demand of 1.16 MMBTU/hr at 16 MGD operating conditions in the year 2023. Additional heat could be provided by either diverting digester gas away from electrical production or supplementing the digester gas with another fuel source, such as natural gas. The proposed microturbine could also be operated at full-load electrical production with supplemental natural gas and therefore provide a higher heat recovery, which may be sufficient to meet the average winter sludge heating demands. A second option is to fire the diverted digester gas or supplemental fuel in a boiler dedicated to the sludge heating system.

Methods to increase digester biogas production are discussed in Section 4.3.

4.2.2 Screw Press Dewatering

Though the City has not yet finalized its dewatering equipment selection, it was assumed that the chosen equipment would be capable of dewatering the digested biosolids to a solids content of approximately 20 percent, to be confirmed by onsite testing. The dewatered biosolids could be land applied or incorporated into the City's current composting process. Landfill disposal is included here as a backup to the selected disposal method but is not recommended.

4.2.2.1 Land Application as Class B Dewatered Biosolids

Solids from the dewatering process can be land applied once they achieve Class B status, which is achieved through stabilization. The requirements for a Class B process appear in the Federal Part 503 Biosolids Rule and are summarized in the US EPA's *A Plain English Guide to the EPA Part 503 Biosolids Rule (Plain English Guide)*. Biosolids applied to land must meet the listed pollutant ceiling concentrations, Class B requirements for pathogens, and vector attraction reduction requirements. Class B biosolids have site application restrictions to minimize potential for human and animal exposure until the pathogens are further reduced by environmental factors such as heat and sunlight. Class B biosolids cannot be sold or distributed in bags or containers, and cannot be used at public contact sites.

The Tennessee Department of Environment and Conservation (TDEC) Division of Water Pollution Control (DWPC) also provides *Guidelines for the Land Application and Surface Disposal of Biosolids* (February 2011), based on the EPA Part 503 Biosolids Rule. The *Guidelines* provide guidance on aspects of biosolids disposal including setback distances for land application, limits on staging and storage of biosolids, and agronomic loading rates. All new land application sites for Class B biosolids must be approved by TDEC-DWPC, but Class A biosolids or biosolids considered EQ do not require site approvals by TDEC-DWPC.

4.2.2.2 Addition to the City's Composting Process

Composting is a process in which organic material undergoes biological degradation to a stable end product. In a well run, efficient process, approximately 20 to 30 percent of the VS is converted to carbon dioxide and water. Methods of composting include the aerated static pile, windrow, and in-vessel systems.

Composting at the existing City facility is achieved by the windrow composting method. Rows are created and turned and mixed periodically; they are typically turned a minimum of five times while the temperature is maintained at or above 130°F (55°C). Turning of the compost may result in the release of odors, as maintaining aerobic conditions in a windrow during the process is difficult. The moisture content of the feed sludge is important to the process and affects the amount of bulking agent that must be added to the mixture. The higher the moisture content of the feed biosolids, the larger amount of bulking agent required, and the larger the land required to complete the process.

If the City were to divert part of the Franklin WWTP's dewatered biosolids production to the existing composting facility, or blend the biosolids with the existing composting process, requirements to achieve a Class A composted biosolids material must be met. **Table 4-2** summarizes the requirements for producing Class A and B biosolids from the composting process. These requirements are also found in the US EPA's *Plain English Guide.*

Table 4-2
Summary of Class A and Class B Requirements for Composting of Biosolids

In-Vessel or Static Aerated Pile Composting	Windrow Composting
Class A Requirements	
Temperature maintained at 55°C or higher for 3 days	Temperature maintained at 55°C or higher for 15 days or longer. During this period when the compost is maintained at 55°C or higher, the windrow is turned a minimum of five times.
Class B Requirements	
Temperature raised to 40°C or higher and maintained for 5 days. For 4 hours during the 5-day period, the temperature in the compost pile exceeds 55°C.	

Source: A Plain English Guide to the EPA Part 503 Biosolids Rule, EPA/832/R-93/003

The City can also choose to blend the final biosolids product with the final compost product as an additional bulking agent. If this were to be done, all biosolids requirements of achieving a Class A product during the solids management process described in the Part 503 regulations must be met before the product can be distributed to the public for agronomic use.

4.2.2.3 Landfill Disposal

The dewatered biosolids discharged from the screw presses could be disposed at a landfill. The City can contract with a local landfill to accept the dewatered biosolids as long as they continue to meet landfill standards as determined by the results of the Paint Filter Liquids Test to which the City's hauled biosolids are currently subject. While a disposal contract for the City's current biosolids output has been negotiated and is secure in the near future, the City's long-term prospects for landfill disposal of its biosolids are uncertain and susceptible to future restrictions that could be imposed by US EPA, TDEC, and the private landfills that accept biosolids.

Landfill disposal is included in this discussion only as a "worst case" or backup option for emergency disposal of dewatered biosolids. The City does not intend to continue using a landfill as the primary means of disposal.

4.2.3 Solar Drying

Solar drying uses the sun's energy to dry the dewatered biosolids to approximately 80 percent dry solids content. Each solar drying greenhouse consists of a rectangular concrete base slab, with translucent side walls and roof that allow light to transmit through the walls, reaching the solids and ultimately drying them. The dried biosolids can be disposed via land application as Class A biosolids. Landfill disposal is briefly discussed here; however, the City does not intend to continue landfill disposal of its biosolids.

4.2.3.1 Land Application as Class A Dried Biosolids

Solids from the solar dryer can be land applied once they achieve Class A status. Class A biosolids are treated to reduce the presence of pathogens to below detectable levels and can be used without any pathogen-related restrictions. Class A biosolids can be bagged and sold to the public.

4.2.3.2 Landfill Disposal

As with the dewatered biosolids, landfill disposal of dried biosolids is included in this discussion only as a "worst case" or backup option for emergency disposal of the dried biosolids, and it is not recommended or desired as a means of primary disposal.

4.3 Options to Maximize Digester Biogas Production

Anaerobic digesters are increasingly perceived as assets that can do more than just stabilize and process wastewater solids. Biogas produced by the digestion process can be used to fuel boilers and CHP systems, thus enhancing energy recovery and reducing the plant's energy costs.

Production of biogas can be further enhanced through various modifications to the conventional digestion process; these modifications include the addition of organic wastes (co-digestion) and pre-processing of the sludge feed (hydrolysis). This section provides a brief discussion of both methods.

4.3.1 Co-Digestion

Co-digestion refers to the digesting of domestic sludge with other organic wastes such fats, oil, and grease (FOG), restaurant waste, food processing waste, and the organic fraction of municipal solid waste.

Key drivers for co-digestion are maximizing the facility's assets, increasing biogas production, and generating a revenue stream from tipping fees associated with receiving organic wastes. In addition, feeding excess waste to digesters is a way to keep this waste out of collection systems and landfills, thereby reducing the amount of material that might otherwise plug sewers and increase system maintenance costs.

Some WWTPs in the United States are currently collecting excess wastes and feeding them to their digesters at centralized FOG receiving facilities to accomplish these goals. Co-digestion with feedstocks that contain a high solids concentration of 15 to 20 percent are typically "dry" digested in plug-flow-type silo reactors. These processes were originally used in the solid waste industry. Feedstocks containing less than 10 to 15 percent solids are more easily pumped and mixed and are, therefore, more amenable to conventional "wet" digestion.

From an environmental perspective, co-digestion can reduce greenhouse gas emissions by reducing the amount of methane that would otherwise be released during anaerobic decomposition in landfills, and by producing more biogas that can beneficially be used in lieu of nonrenewable fossil fuels. Operationally, co-digestion has the potential to improve the stability, biogas production, and volatile solids reduction (VSR) of the digesters and secondary treatment system. There are also social/political benefits to the nearby community, which may value the conversion of waste products into a valuable renewable resource such as biogas.

Some advantages of co-digestion its ability to improve the nutrient balance of the digester and help dilute many high-strength waste streams. Also, if a digester feed is too dry, cosubstrates can help supplement the moisture requirements of the digester. Easier access to handling of mixed wastes, the use of common access facilities, and economies of scale are also potential advantages of the process.

Both carbon (C) and nitrogen (N) are required in proper proportions to foster growth of microorganisms in the digester and to prevent process upset. If the carbon content is too high relative to nitrogen, then a nitrogen deficiency and process upset can occur as a result of propionate accumulation because of lower buffering capacity. Similarly, if the carbon content is too low relative to nitrogen, digester performance will likely suffer because of ammonia toxicity. The addition of certain cosubstrates to the digester can help balance nutrient deficiencies and improve performance. For example, adding a nitrogen-rich animal slurry (*e.g.,* chicken manure) to a digester with a high C:N ratio can help achieve a favorable nutrient balance and reduce the potential toxic effects of free ammonia and hydrogen sulfide in the cosubstrate waste stream. Likewise, adding a carbon-rich cosubstrate (*e.g.,* cattle manure) to a digester with a low C:N ratio can provide the necessary growth substrate and enhance microbial growth in the reactor. A site-specific analysis is preferred to determine the optimal C:N ratio for a combination of cosubstrates.

Potential disadvantages of co-digestion include construction of the infrastructure required to receive and process additional waste, handling of additional wastes in dewatering systems, handling and treatment of additional gas, and the liquid-stream effects of increased loading on the digesters. Increased gas production and tipping fees, however, typically can compensate for the capital investment in co-digestion upgrades.

4.3.1.1 FOG Addition

The most common organic waste cosubstrate is FOG, which is generated by a myriad of sources, including households, restaurants, hotels, commercial kitchens, bakeries, schools, prisons, and large food-preparation facilities. The solids concentration of FOG typically varies from less than 2 percent to more than 15 percent, and the volatile solids to total solids (VS/TS) ratio typically ranges from 94 to 97 percent.

To prevent blockages of the sanitary sewer system, FOG wastes are collected using waste drums, grease traps, and grease interceptors. Dedicated vacuum pumper trucks are typically used to retrieve FOG from traps and interceptors and transport it back to the FOG receiving system. A FOG receiving system can be as simple as a connection to a digester to allow the truck to discharge directly to a heated receiving tank with settling tanks (rock traps) and a digested sludge circulation loop used to convey the FOG to the digester. Processing of the incoming FOG should include screening and grinding to remove stones, rags, metallic objects, and other inert material that could impair downstream operations. Concentration of the FOG may also be performed.

FOG is readily biodegradable and can provide both enhanced biogas production and increased VSR when added to anaerobic digestion systems. In fact, FOG is among the highest-rated cosubstrates in terms of methane production.

Digesters have been reported to remain stable at FOG loads as high as 30 percent of feedstock or volatile solids loading. At higher loadings between 30 and 50 percent, digesters can become susceptible to instability during a peak FOG load. It should be noted that one crucial characteristic for successful FOG digestion is good digester mixing, particularly at the surface. Without adequate surface mixing, FOG will tend to collect at the surface of the digester.

Limited literature is available regarding methane production rates from FOG co-digestion and tends to differ in terms of units and FOG loading rate. Gas production potential from lipid-rich cosubstrates (i.e., FOG) is 1.4 m^3/kg (23 cu ft/lb) VSR, significantly higher than that expected from carbohydrate and protein-rich cosubstrates, which is 0.8 to 0.9 m^3/kg (13 to15 cu ft/lb) VSR. For comparison, gas production from conventional mesophilic digestion fed municipal biosolids ranges from 0.8 to 1.1 m^3/kg (12 to 18 cu ft/lb) VSR. Also, because a relatively large percentage of the FOG waste is destroyed during digestion, little of the FOG feedstock remains in the digested product to be handled and disposed.

4.3.1.2 Food Waste Addition

Food waste is a broad category that includes wastes from the following sources:

- Industrial sources - fruit and vegetable processing, beverage industry
- Commercial sources - restaurants
- Residential sources - the organic fraction of municipal solid waste

Although most food wastes are easily digested and require little pretreatment, food wastes with large inert materials, such as animal parts and carcasses, may require detailed pretreatment and are not typically recommended for co-digestion. Other wastes from livestock, poultry, fish, and even fruit-juice processing may simply require chopping as part of the pretreatment scheme.

4.3.2 Hydrolysis Technologies

WAS, in its raw form, is difficult to digest because a large percentage of the nutrient-rich, digestible cell material is trapped within a lignin-rich cell wall. A pre-digestion processing step can be added to rupture this cell wall and increase the amount of material available for digestion. This addition enhances the naturally-occurring hydrolysis process – the conversion of organic solids to soluble compounds – which is often identified as a rate-limiting step in the anaerobic digestion process.

Expediting the hydrolysis process yields the following benefits to digestion:

- It allows for increased organic loading to the anaerobic digester.
- It results in increased VS destruction in the digesters. Increased VS destruction correlates to an increase in biogas production and a reduction in the amount of biosolids to be disposed.
- It is also reported to reduce the viscosity of the biosolids, which makes the digested product easier to pump and dewater. The need for polymer as a dewatering aid is often reduced.
- It reduces foaming in the digesters.

There are various ways to enhance hydrolysis; two methods discussed here are thermal hydrolysis and electroporation.

4.3.2.1 Thermal Hydrolysis

Thermal hydrolysis uses elevated temperatures and pressures to improve the digestibility of biosolids. First, the digester feed solids are thickened to reduce the amount of water in the material. The thickened solids are then pumped through a macerator before entering the hydrolysis batch reactor tank. The thermal hydrolysis reaction occurs in this reactor, which operates at 160 to 170 °C (320 to 338 °F) for a 20 to 60 minute retention time, typically averaging 30 minutes. The reactor is operated under pressure, typically 500 to 800 kPa (70 to 120 psi).

Although the processes of preheating, hydrolysis reaction, and depressurization can occur in a single tank, an alternate process configuration is to have three tanks in series with a specific function occurring in each vessel. The addition of heat-and-energy recovery units is common through the process. Steam generated by boilers or heat captured from CHP systems typically provide the heat for thermal hydrolysis processes. The use of digester biogas as a fuel may offset the energy requirements of the thermal hydrolysis reaction.

A drawback of thermal hydrolysis is that the process gas is highly odorous and saturated with water vapor. Two treatment methods available for the process gas are as follows.

- Pass the process gas through a condenser to remove water vapor. The condensed liquid is pumped to the anaerobic digester for treatment and the remaining gas is burned in a thermal oxidizer.
- Use the process gas to aerate the activated sludge tanks. The activated sludge acts as a biofilter to remove odors and other organics from the gas.

Full-scale thermal hydrolysis facilities are in operation in more than 20 locations around the world; however, the only facility in the United States – at the Blue Plains Advanced Wastewater Treatment Plant in Washington, DC – is currently under construction.

4.3.2.2 Electroporation

Electroporation is the process by which the permeability of the cell wall is increased through exposure to an electrical field. This technique, practiced since the 1960s, is used by molecular biologists to introduce material into a cell, and it is also used by the food processing industry to sterilize and preprocess foods.

One vendor of electroporation technology for wastewater sludge treatment is OpenCEL. OpenCEL was acquired by Trojan Technologies and made a division of US Peroxide in October 2011. In OpenCEL's patented Focused Pulsed technology, the sludge is passed between two electrodes, where it is exposed to pulses of high-voltage electricity. This exposure breaks down the cell membrane and makes it more permeable. The cells subsequently swell and rupture, releasing their digestible material.

There are two full-scale OpenCEL installations in the United States. The installation at the Northwest Water Reclamation Plant in Mesa, Arizona, has been operating since 2007. The OpenCEL process at this 12 MGD facility treats a 50:50 mixture of primary sludge and WAS, and the treated sludge now provides about 90 percent of the supplemental carbon needed for the plant's denitrification process. The second full-scale installation, located in Racine, Wisconsin, was undergoing startup and testing as of December 2011. Two OpenCEL units are on order for a CDM Smith-designed digester enhancements project at the Regional Water Quality Control Plant (RWQCP) in Riverside, California.

In addition to increasing the organic loading to the digester, increasing VS destruction, reducing foaming, and boosting biogas production, an electroporation technology such as OpenCEL can provide at least 50 percent of a plant's supplemental carbon needs. It also raises the temperature of the feed sludge by about 20^{o}F, reducing the supplemental heating requirements for the digester. Depending on how the treated sludge is used, payback can occur in as little as two to three years. Pilot testing for the RWQCP project indicated that the OpenCEL process would result in up to 13 percent reduction in biosolids mass, a 15 percent increase in biogas production, and a 4-year payback period.

CDM Smith's discussions with OpenCEL indicate that for full-scale treatment at the Franklin WWTP, one OpenCEL unit would be installed during Phase I to treat up to 40 gpm of sludge. A second unit would be installed in Phase II. The capital cost of the first unit would be approximately $1.5 million, and the second unit could be added for a cost of approximately $800,000. The operating cost of the OpenCEL process would be between $30 and $35 per DT. While the operating cost for this process appears high, it could be significantly offset by the resulting reductions in polymer usage and digester heating costs.