Technical Memorandum

To: *City of Franklin*

From: *CDM Smith*

Date: *June 24, 2013*

Subject: *Franklin WRF Modifications & Expansion Project*
Biosolids Management Preliminary Engineering TM – FINAL DRAFT

Executive Summary

CDM Smith performed preliminary engineering to assess the following alternatives for biosolids management at the Franklin WRF. Evaluation of these process trains included conceptual sizing of the equipment and facilities for the Year 2040 design condition, development of planning level capital and O&M costs and net present cost (NPC); and a non-cost evaluation and scoring based on each alternative's ability to achieve the City's biosolids management goals.

Table ES-1 Summary of Solids Treatment Alternatives

Process Train	Thickening	Digestion	Dewatering	Drying	Disposal
Alternative 1: Continue Current Treatment Process	DAF	None	BFP	None	Haul Dewatered Sludge to Landfill
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	RDT	MAD	BFP/ Screw Press	None	Class B Biosolids for Agricultural Use
Alternative 3: Alternative 2 Plus Solar Drying	RDT	MAD	BFP/ Screw Press	Solar Dryer	Class A Biosolids[1] for Public Use

Table ES-1 Summary of Solids Treatment Alternatives (cont.)

Process Train	Thickening	Digestion	Dewatering	Drying	Disposal
Alternative 3A: Alternative 3 with Partial Solar Drying	RDT	MAD	BFP/ Screw Press	Solar Dryer (Partial Installation)	Dried Class A Biosolids[1], Dewatered Class B Biosolids
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	None	THP + MAD	Pre-THP: Centrifuge Post-Digestion: BFP	Solar Dryer	Class A Biosolids for Public Use
Alternative 4A: Alternative 4 with Partial Solar Drying	None	THP + MAD	Pre-THP: Centrifuge Post-Digestion: BFP	Solar Dryer (Partial Installation)	Dried Class A Biosolids, Dewatered Class A Biosolids

[1] Class A status of solar drying process is subject to approval by Tennessee Department of Environment & Conservation (TDEC).

The estimated capital costs, adjusted 20-year operating cost, adjusted O&M cost per dry ton (DT) and net present cost (NPC) of each alternative are summarized in the following tables. The operating costs in these tables include the potential cost offset associated with electricity generation where applicable.

Table ES-2 Adjusted Year 2023 & 2040 O&M Costs – Power Generation Cost Offset Included

Process Train	Adjusted 2023 Total O&M Cost[1] (millions)	Adjusted 2023 O&M Cost per DT[1]	Adjusted 2040 Total O&M Cost[1] (millions)	Adjusted 2040 O&M Cost per DT[1]	Adjusted Rank
Alternative 1: Continue Current Treatment Process	$1.4 (no change)	$344 (no change)	$1.4 (no change)	$228 (no change)	6
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$0.7 (↓$0.2)	$167 (↓$48)	$0.5 (↓$0.2)	$89 (↓$36)	1
Alternative 3: Alternative 2 Plus Solar Drying	$0.9 (↓$0.2)	$227 (↓$48)	$0.8 (↓$0.2)	$124 (↓$36)	5 (was 3)
Alternative 3A: Alternative 3 with Partial Solar Drying	$0.8 (↓$0.2)	$187 (↓$48)	***$0.6[2]*** ***(↓$0.2)***	***$98[2]*** ***(↓$36)***	2
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$0.8 (↓$0.5)	$202 (↓$133)	$0.7 (↓$0.6)	$116 (↓$97)	4 (was 5)
Alternative 4A: Alternative 4 with Partial Solar Drying	$0.8 (↓$0.5)	$190 (↓$133)	***$0.7[2]*** ***(↓$0.6)***	***$106[2]*** ***(↓$97)***	3 (was 4)

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

Table ES-3 Adjusted NPC of Solids Process Alternatives – Power Generation Cost Offset Included

Process Train	Total NPC of Estimated Capital Costs[1] (millions)	Adjusted Total NPC of Est. Annual O&M Costs[1,2] (millions)	Adjusted Total NPC[1] (millions)	Revised Rank
Alternative 1: Continue Current Treatment Process	$18.5	$27.9	$46.0 (no change)	1 (no change)
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$38.1	$12.1	$50.0 (↓$4.0)	2 (no change)
Alternative 3: Alternative 2 Plus Solar Drying	$82.0	$16.8	$99.0 (↓$4.0)	6 (no change)
Alternative 3A: Alternative 3 with Partial Solar Drying	***$47.1[1]***	***$13.6[1]***	***$61.0[1] (↓$4.0)***	***3 (no change)***
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$68.7	$16.7	$85.0 (↓$12.0)	5 (no change)
Alternative 4A: Alternative 4 with Partial Solar Drying	***$55.1[1]***	***$15.2[1]***	***$70.0[1] (↓$12.0)***	***4 (no change)***

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

Based on these results, CDM Smith recommends replacement of the Franklin WRF's existing solids treatment process with the systems included in Alternative 3A. This alternative includes a "pilot" installation of two solar dryers in Phase I instead of the full complement of dryers included in Alternative 3.

After the two solar dryers are installed and the City demonstrates to the Tennessee Department of Environment and Conservation (TDEC) that the process can achieve Class A treatment, Alternative 3A is anticipated to produce Class A dried biosolids that can be distributed to the public, as well as Class B dewatered biosolids that can be land applied for agricultural uses. The estimated O&M cost for this alternative is substantially lower than the cost to continue with the current practice of thickening, dewatering and landfill disposal of the dewatered sludge.

Alternative 3A allows the City to gain real-world experience with solar drying at a Phase I construction cost that is $25 million less than the Phase I construction cost of Alternative 3. The NPC of Alternative 3A is also $39 million less than that of Alternative 3.

Introduction & Objectives

CDM Smith has been tasked by the City of Franklin (the City) to provide design services for the expansion of the Franklin Water Reclamation Facility (WRF). The project includes an expansion of the facility's existing sludge treatment processes.

The previous Phase II Integrated Water Resources Plan (IWRP) project, also performed by CDM Smith, included an assessment of the Franklin WRF's existing solids handling facilities; a review of historical operating data and operation and maintenance (O&M) costs; an overview of solids treatment requirements based on projected future wastewater flows to the facility; an assessment of capital, O&M and net present costs for four potential solids process trains; and finally, a concept-level analysis of the selected option, which consisted of rotary drum thickening (RDT) followed by mesophilic anaerobic digestion (MAD), 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.

The September 2012 Biosolids Conceptual Design Report recommended further study of the conceptual design and costs prior to final acceptance by the City and detailed design by CDM Smith.

Current Work and Objectives

CDM Smith has performed a preliminary engineering analysis of four solids process trains for the City's consideration. This analysis is intended to explore the varying levels of solids treatment that would provide the City with flexibility in its reuse and disposal options.

The goals of this Biosolids Management Preliminary Engineering Technical Memorandum (TM) are to present information on these four alternatives and to facilitate the City's selection of a solids process train. Upon selection of a process train by the City, CDM Smith will continue with preliminary engineering, preliminary design, and final design of the selected alternative as part of the Modifications & Expansion Project.

Process Alternatives

Table 1 summarizes the process alternatives that are discussed in this TM.

Alternatives 3A and 4A represent lower-cost versions of Alternatives 3 and 4. Instead of a full solar drying facility capable of handling the Franklin WRF's entire biosolids output, the first phase of construction includes a "pilot" installation of two solar dryers. A fraction of the dewatered biosolids is sent to these solar dryers, while the remaining dewatered biosolids are transported to local agricultural users for land application.

Table 1 Summary of Solids Treatment Alternatives

Process Train	Thickening	Digestion	Dewatering	Drying	Disposal
Alternative 1: Continue Current Treatment Process	DAF	None	BFP	None	Haul Dewatered Sludge to Landfill
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	RDT	MAD	BFP/ Screw Press	None	Class B Biosolids for Agricultural Use
Alternative 3: Alternative 2 Plus Solar Drying	RDT	MAD	BFP/ Screw Press	Solar Dryer	Class A Biosolids[1] for Public Use
Alternative 3A: Alternative 3 with Partial Solar Drying	RDT	MAD	BFP/ Screw Press	Solar Dryer (Partial Installation)	Dried Class A Biosolids[1], Dewatered Class B Biosolids
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	None	THP + MAD	Pre-THP: Centrifuge Post-Digestion: BFP	Solar Dryer	Class A Biosolids for Public Use
Alternative 4A: Alternative 4 with Partial Solar Drying	None	THP + MAD	Pre-THP: Centrifuge Post-Digestion: BFP	Solar Dryer (Partial Installation)	Dried Class A Biosolids, Dewatered Class A Biosolids

[1] Class A status of solar drying process is subject to approval by TDEC.

Alternatives 3A and 4A offer the following advantages.

- A partial solar dryer installation allows the City to evaluate the performance of solar drying in Franklin's climatic conditions; assess the local market for, and potential revenue from, the dried biosolids; and determine the size and scope of the solar dryer expansion in future phases of work based on these performance and market evaluations.
- The estimated Phase I capital cost is reduced. In this TM, the estimated Phase II and III capital and O&M costs for Alternatives 3A and 4A do not reflect the scope of future solar dryer installations; these costs would be determined following the City's evaluation of the two solar dryers during Phase I.
- Phase I O&M costs for the solar dryer are reduced compared to a full solar dryer installation.
- Compared to Alternative 2, the volume of dewatered biosolids hauled to agricultural users is reduced in Alternative 3A.

Although Phase I solar drying O&M costs would be reduced compared to a full solar dryer installation, O&M costs for hauling of the remaining dewatered biosolids would be higher because Alternatives 3 and 4 assume that all of the end product (the dried biosolids) would be picked up by a third party or the public with no associated trucking costs.

The following sections present a brief overview of each of the technologies listed in Table 1.

Thickening

Dissolved Air Flotation

The City currently utilizes dissolved air flotation (DAF) for its thickening process. Waste activated sludge (WAS) from the secondary clarifiers is pumped by existing pumps to the DAF tanks, where it is mixed with a pressurized, supersaturated mixture of DAF tank effluent and air. When this supersaturated mixture enters the DAF tank and depressurizes, the dissolved air is released as fine bubbles that carry the sludge to the top, where it is removed by skimmers.

Figure 1
RDT with Enclosure at Gilder Creek WWTP, Greenville, SC

Rotary Drum Thickening

The RDT system **(Figure 1)** 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.

Stabilization

Mesophilic Anaerobic Digestion (MAD)

Figure 2
Anaerobic Digesters at Gilder Creek WWTP, Greenville, SC

Anaerobic digestion **(Figure 2)** is a widely used stabilization method that uses anaerobic microbes to perform a series of biochemical transformations. These transformations break down complex organic compounds in wastewater sludges into methane and carbon dioxide. Biogas produced by the anaerobic microbes is captured from the headspace of the digester tank; the biogas can be treated and stored for reuse, or it can be disposed via flare. Energy from the biogas may be used to heat the digester, generate electricity, or serve other heating needs around a WRF.

Conventional MAD is the sole stabilization technology evaluated because, as previously stated, it supports the City's sustainability goals by producing Class B biosolids, reducing the quantity of solids to be disposed, and producing biogas that can be used as fuel.

FOG Receiving and Addition to Digesters

According to City records, approximately 60,000 gallons of fats, oil, and grease (FOG) are hauled from Franklin's restaurants each month. This material is currently hauled to processing facilities north of the city. Because it is readily biodegradable, FOG can provide increased biogas production when added to anaerobic digestion systems. With the proposed addition of MAD at the Franklin WRF, the FOG represents an opportunity to enhance biogas production and expanded utilization of the digestion process.

At the City's request, CDM Smith has included an allowance for a FOG receiving station in its capital cost calculations for Alternatives 2, 3, 3A, 4, and 4A. Design features of the FOG receiving station will include the following.

- Screening and grinding equipment to remove stones, rags, metallic objects, and other inert material that could damage downstream equipment.
- A heated, mixed storage tank and piping to prevent the FOG from solidifying and building up in the station. Because the quantity and quality of FOG hauled from the City's restaurants can vary widely, storage and blending of the FOG is recommended to ensure a consistent feed to the digesters.

- Positive-displacement pumps to transfer the heated FOG from the storage and blending tank to the digesters.

Equipment for conditioning of the FOG prior to addition to the digesters, such as thickening, may also be considered during preliminary design.

Thermal Hydrolysis Pretreatment

In Alternative 4, a thermal hydrolysis pretreatment (THP) process is added to condition the sludge prior to MAD. THP applies pressure and temperature to fracture the cellular material and long-chain fatty acids, thereby making the sludge more conducive to downstream digestion and dewatering processes. The increased volatile solids destruction further reduces the quantity of post-digestion solids to be treated and produces a larger quantity of biogas that can be used for digester and building heating, as well as power generation.

Prior to entering the THP process, the sludge must be dewatered. Once injected into the THP reactor, the dewatered solids are treated with steam for about 30 minutes at 285 to 330 degrees F and 90 to 220 psi before being fed to the digester at approximately 9 to 10 percent solids. Because these hydrolyzed solids fed to the digester are thicker compared to a typical digester feed sludge, the volume of the digester tanks can be reduced while still providing the required minimum solids retention time (SRT). The THP process also pre-heats the sludge feed to the digesters, eliminating the need for additional digester heating equipment. However, cooling of the sludge is needed.

With THP, the digested biosolids can produce a cake that typically exceeds 30 percent total solids concentration. The treatment conditions in this combination exceed those required by the U.S. Environmental Protection Agency (USEPA) for producing Class A biosolids. The final product exhibits excellent properties for soil blending and land application with minimal odor.

Two commercially-available THP processes include CAMBI and Krüger's Exelys. Exelys is a continuous, plug-flow process, and CAMBI is a batch process. The first CAMBI installation in the United States is currently under construction at the DC Water Blue Plains AWTF. Over a dozen CAMBI installations are operating in Europe. No Exelys systems are currently installed in the U.S., but there are eight installations in Norway and the United Kingdom.

Dewatering

Belt Filter Press

Introduced to North America in the 1970s and widely used, the belt filter press (BFP) employs two and as many as three moving belts to accomplish dewatering through a combination of gravity drainage and mechanical compression. Polymer-conditioned solids are first uniformly deposited on the belt in the gravity drainage section, where free water is removed. Next, low- and high-pressure sections squeeze the solids between two tensioned belts and into a filtrate drain at the bottom of the unit. Doctor blades scrape and remove the dewatered cake from the belts. BFPs typically produce cake solids ranging from 12 to 20 percent.

The City currently uses two 2-meter Ashbrook Simon-Hartley Klampress model BFPs to dewater thickened WAS (TWAS) from the DAF process.

Screw Press

Figure 3
Huber Technology Screw Press Installation in Blairsville, GA

In a screw press, the feed solids, after being conditioned with polymer in a flocculation reactor, are introduced at the feed end of a horizontal or inclined trough that contains a perforated bucket surrounding a slowly, continuously rotating screw. The solids move along the screw, first losing their free water via gravity drainage. As the screw conveys the solids along the tube, the screw flights become narrower or the screw diameter increases to reduce the volume inside the unit and force additional water out. When the cake reaches the discharge end of the unit, it drops out of the unit and onto a conveyor, into the inlet of a positive-displacement pump, or into a storage vessel. The filtrate flows out through the basket and drops out through a pipe at the bottom of the unit. Inside the unit, the screw flights are continuously brushed clean, and the basket is periodically flushed with a small quantity of wash water.

Centrifuge

In a dewatering centrifuge, solids are subjected to a centrifugal force of more than 3,000 times the force of gravity. This centrifugal force facilitates separation of solids from liquids based on the density difference between the solid and liquid fractions. Regardless of whether the centrifuge is co- or counter-current design, the main components of the solid-bowl centrifuge are the bowl and the scroll. Each component is driven by a separate electrical motor. The bowl spins at high speeds with the scroll spinning at a lower speed. Solids from the feed material settle against the inner wall of the bowl and are continuously swept to the solids discharge end by the scroll. An adjustable weir at the end of the bowl controls the flow of the removed liquid, or centrate, discharged from the centrifuge. Dewatered cake falls out of the bottom of the centrifuge through a discharge chute that can be connected directly to a storage container, such as a silo, or to a screw or belt conveyor. Centrate flows out through a separate discharge chute that can be piped to the head of the plant.

Drying

Solar Dryer

Figure 4
Parkson Thermo-System Solar Dryer in Okeechobee, FL

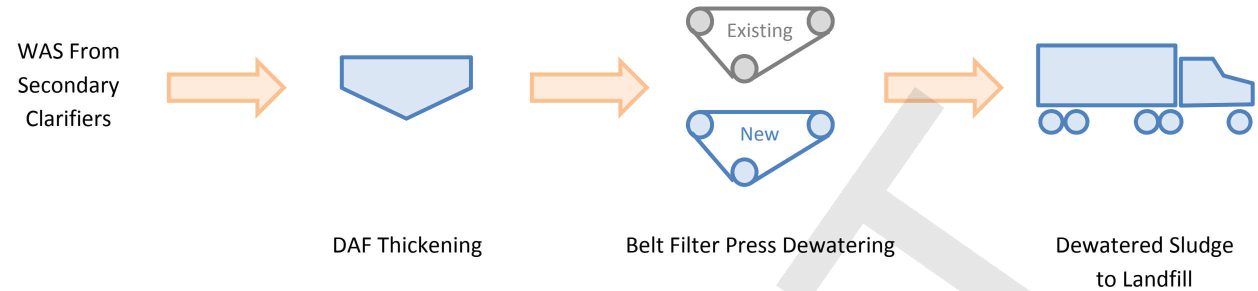
In a solar drying system **(Figure 4)**, the cake is transferred, manually or automatically, to large greenhouse-like structures where it is spread uniformly on the floor to dry. Some solar drying systems, such as Krüger's Solia system, encourage aerobic fermentation of the sludge by arranging the material in windrows. Solar radiation evaporates the moisture. Machines automatically till the solids, exposing moist solids to the air for further drying. The moisture-laden air is removed from the dryers and can be treated for odors before being released to the atmosphere. The air flow through the dryers is automatically controlled. Overall, the system requires minimal operator attention.

Continuous, year-round operation can be achieved with solar drying. If there is not enough incident sunlight to support the solar drying operation, or if there is not enough space for the drying beds, supplemental equipment can be added to speed the drying process. For example, the addition of radiant heating elements in the floor of the drying beds can facilitate heat transfer into the drying solids. Perforated flooring enables air to circulate better and remove more moisture. The circulated air can also be heated to further facilitation evaporation.

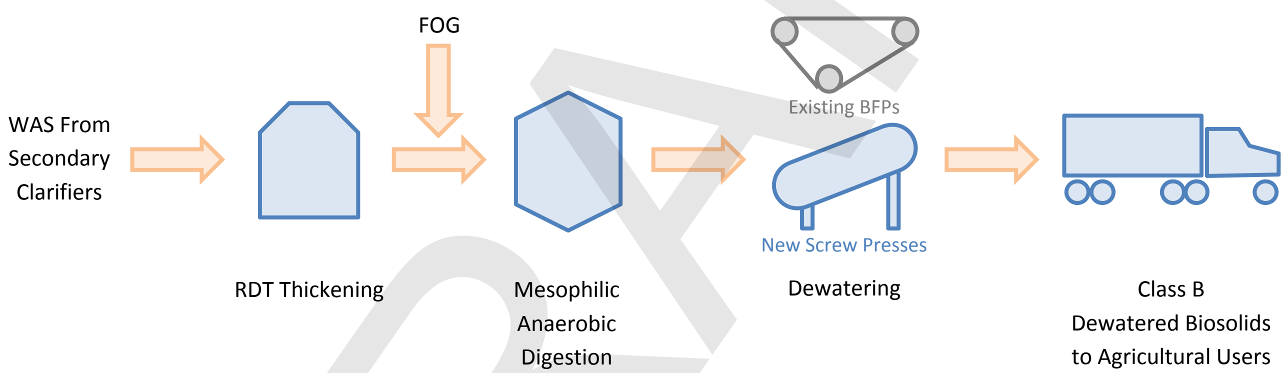
Solar drying is not an approved Process to Further Reduce Pathogens (PFRP) as defined by the USEPA due to the variations in the performance of the drying process in differing climate conditions. In this TM, it is anticipated that a solar drying installation at the Franklin WRF will produce Class A biosolids; however, final approval by the Tennessee Department of Environment and Conservation (TDEC) is required after the solar dryer installation is completed and the City demonstrates that the process can achieve Class A treatment.

The four solids process alternatives are summarized in **Figure 5.** Discussions of each alternative can be found in the following sections.

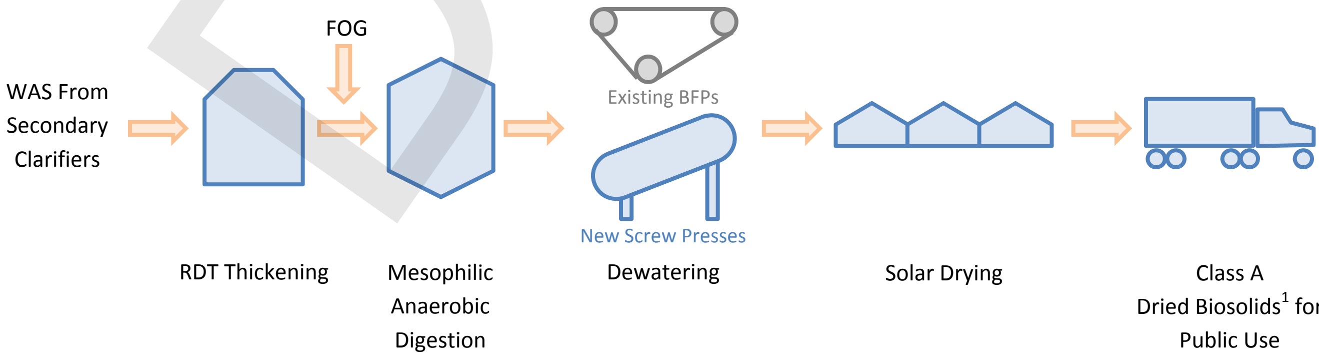
Alternative 1: Continue Current Solids Treatment Process



Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering



Alternative 3: Alternative 2 Plus Solar Drying



[1] Class A status of solar drying process is subject to approval by TDEC.

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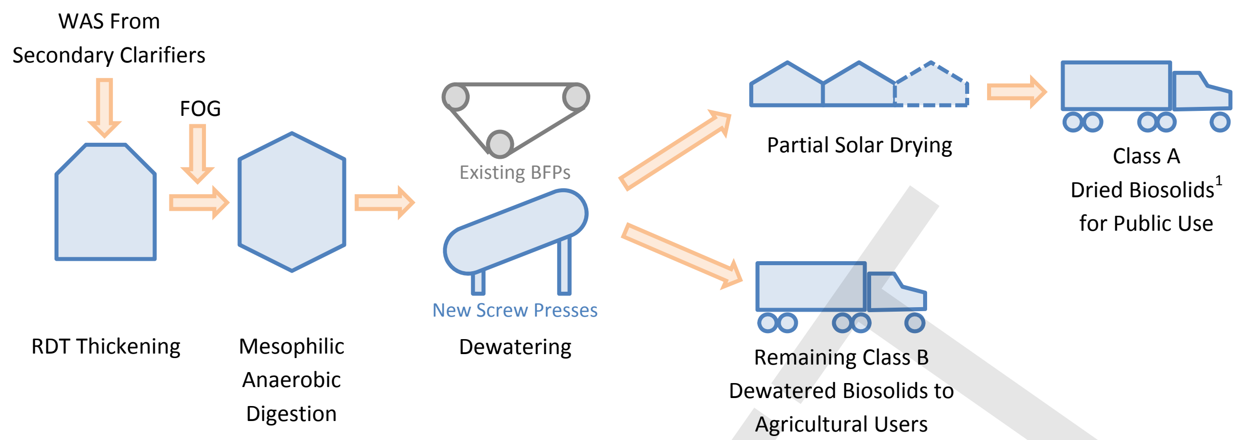
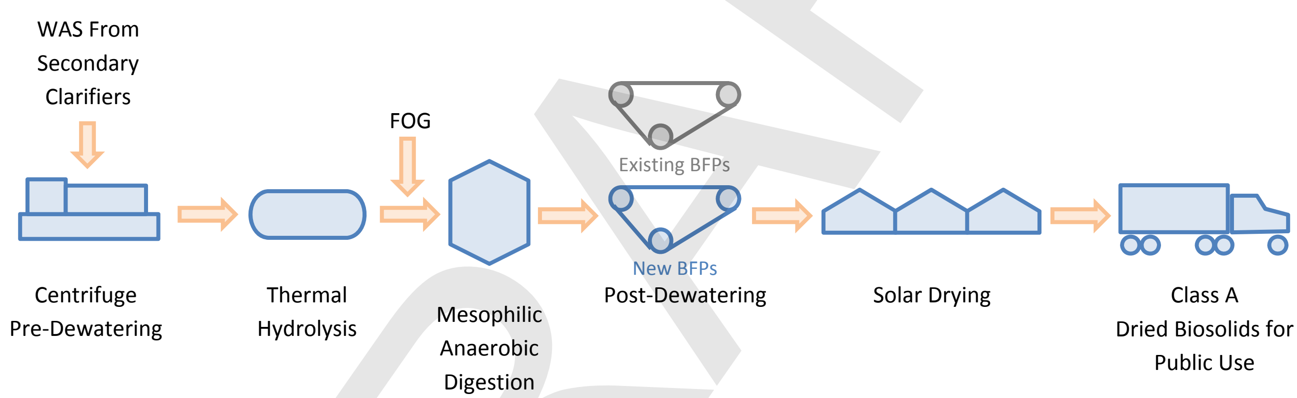
Figure 5
Summary of Solids Treatment Process Alternatives (Page 1 of 2)

Alternative 3A: Alternative 3 with Partial Solar Drying



[1] Class A status of solar drying process is subject to approval by TDEC.

Alternative 4: Alternative 3 Plus Thermal Hydrolysis



Alternative 4A: Alternative 4 with Partial Solar Drying

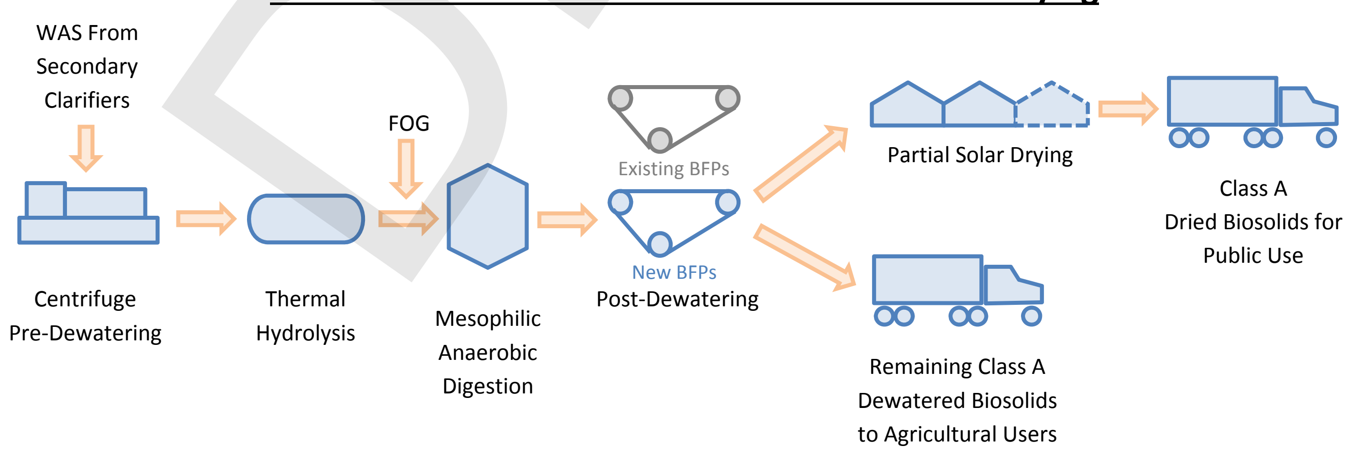


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Figure 5
Summary of Solids Treatment Process Alternatives (Page 2 of 2)

Conceptual Design & Cost Estimating Methods

Design Assumptions

The following design assumptions were applied to all four process alternatives.

- The new facilities will be completed, tested, and in service by 2018.
- Solids treatment for both the Franklin WRF and the future new South WRF will be consolidated at the Franklin WRF. WAS produced at the new South WRF will be thickened onsite and transported to the Franklin WRF via tanker truck for treatment. A tanker truck unloading facility will be included in this project.
- The anticipated quantity of WAS produced by the Franklin WRF treatment process was increased slightly to account for revisions to CDM Smith's process model. The updated solids loading design parameters and solids loadings are listed in **Tables 2 and 3.**

  Anticipated solids loading design parameters and loadings from the new South WRF were left unchanged from the IWRP. Further planning and design of the new South WRF's solids handling facilities will be performed in a separate project.

Table 2 Updated Solids Loading Design Parameters

Parameter		Value	
		Franklin WRF	New South WRF
Yield (lbs WAS/lb BOD_5 removed)		***0.82***	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	***1,416***	1,364
	Max Month	***1,840***	1,773
WAS Solids Content (percent)		0.84	1.0

[1] Includes chemical sludge.
Numbers in ***bold italics*** have been updated since the IWRP Biosolids Conceptual Design Report.

Table 3 Updated Wastewater Flows and WAS Production[1], 2015 to 2040

Year	Total Average Daily Flow (mgd)	Total Average Day Solids Production (lbs/day)	Total Maximum Month Solids Production (lbs/day)
2015	11.8	16,800	21,800
2020	14.3	20,200	26,300
2025	16.7	23,600	30,700
2030	19.1	26,900	35,000
2035	21.6	30,200	39,300
2040	24.0	33,600	43,600

[1] Total combined wastewater flows and solids production for Franklin WRF and future new South WRF.

- In the interest of reducing the initial construction cost of the new solids treatment process, CDM Smith has attempted to reuse existing solids treatment buildings and structures where practical.
    - The existing BFPs, which have been in service since 1997 and were recently refurbished, will remain in operation and be replaced no later than 2027. Additional dewatering capacity, either BFPs or screw presses, will be added in a new building located near the existing dewatering building.
    - The existing dewatering building was found to be in good condition during the 2011 operational assessment and will remain in service through Phase I. Modifications to the building will include replacement of the BFPs with new BFPs in Phase II (Alternatives 1, 4 and 4A) or retrofit of new screw presses in Phases II and III (Alternatives 2, 3 and 3A).
    - The DAF thickening tanks are also in good condition and will be reused for Alternative 1. In Alternatives 2, 3, and 4, the DAF tanks will be converted into TWAS storage.
- The quantity of FOG received at the Franklin WRF was assumed to increase 4 percent per year.
- It was assumed that a combined heat and power (CHP) system would be included for each alternative that uses anaerobic digestion. Fueled by the digester biogas, the CHP system will generate electricity that could be used to power treatment processes or be sold to the City power grid. The CHP system also produces heat, which can be recovered and used for building or process heating. Conceptual design of the CHP systems for Alternatives 2, 3, 3A, 4 and 4A is discussed in **Appendix B.** For the purposes of this analysis, it was assumed that the power generated by the CHP systems would be used onsite, and the heat generated would be used to heat the digesters in Alternatives 3 and 3A. No additional heating is required for the

digesters in Alternatives 4 and 4A because the hydrolyzed sludge is already heated by the THP process.

- The same project phasing proposed in the IWRP Biosolids Conceptual Design Report was used in this analysis. The design year represents the final year for which the treatment facilities are designed to operate before the next phase of expansion is required.
  - Phase I: Begin operation in Year 2018; design year 2023
  - Phase II: Begin operation in Year 2024; design year 2031
  - Phase III: Begin operation in Year 2032; design year 2040
- Preliminary configurations for the solids equipment for all alternatives were laid out on a site plan to determine feasibility for each equipment or building as it relates to existing structures at the WRF. When possible, many of the options were combined into similar buildings in order to conserve space and minimize construction costs.
- Year 2040 greenhouse gas (GHG) emissions impacts, in metric tons (mT) CO_2 per year, were calculated as follows.
  - Carbon emissions (additions of CO_2 to the atmosphere) were calculated from the estimated utility consumption for each alternative. CO_2 emissions resulting from the production and combustion of biogas, as well as the transport and landfilling of dewatered solids, where applicable, were also included.
  - Carbon emissions reductions (removals of CO_2 from the atmosphere) were calculated from recovery of landfill gas produced by landfilling of solids, emissions avoided by the use of power and heat generated by the CHP system, and replacement of the use of synthetic fertilizers in land application, where applicable.

Other assumptions made during the conceptual design process are listed in **Table 4.**

Table 4 Summary of Conceptual Design Assumptions

Parameter	Value
	Thickening
Thickening technology	DAF (Alternative 1); RDT (Alternatives 2 & 3)
Solids loading rate	DAF: 1.0 lb TS/hour/ft^2 RDT: 700 lbs TS/hour
Feed solids	0.84 percent
Thickened WAS solids	5.0 percent
Solids capture	95 percent
Thickening polymer usage	7.5 lbs active polymer/DT
Conceptual equipment selection	DAF: Ovivo or equal RDT: Parkson Corporation ThickTech RDT150 or equal
WAS storage	Alternatives 1, 2 & 3: One day at maximum month (420,000 gallons)
TWAS storage	Alternatives 2 & 3: One day at maximum month (100,000 gallons[1]) Alternative 4: One day at maximum month – new South WRF only (33,000 gallons)
	Anaerobic Digestion & FOG Addition
Type of digestion	Mesophilic anaerobic digestion (MAD)
Digester tank type	Prestressed concrete
Minimum solids retention time	20 days at average day conditions; 17 days at maximum month conditions
Volatile solids destruction	Alternatives 2 & 3: 40 percent Alternative 4: 53 percent
Biogas produced	15 SCFM per pound volatile solids destroyed
Heat available from biogas	600 BTU/ft^3
Digested biosolids storage	Alternatives 2 & 3: 50,000 gallons Alternative 4: 27,000 gallons
FOG receiving	Total solids content: 4 percent Volatile solids content: 85 percent Volatile solids destruction: 75 percent Biogas yield: 27 SCFM per pound volatile solids destroyed

[1] Includes TWAS received from new South WRF.

Table 4 Summary of Overall Design Assumptions (cont.)

Parameter	Value
	Dewatering
Dewatering technology	Alternative 1: BFP Alternatives 2 & 3: Screw press Alternative 4: Centrifuge (pre-THP), BFP (post-digestion)
Solids loading rate	BFP: 700 lbs/hour/meter of belt width (new); 500 lbs/hour/meter (end of useful life) Screw press: 900 lbs TS/hour Centrifuge: 1,200 to 1,600 lbs TS/hour
Feed solids	Alternative 1: 5 percent Alternatives 2 & 3: 3.7 percent Alternative 4: 0.84 to 1.1 percent (pre-THP), 6.2 percent (post-digestion)
Dewatered cake solids	Alternatives 1, 2 & 3: 20 percent Alternative 4: 20 percent (pre-THP), 30 percent (post-digestion)
Solids capture	95 percent
Dewatering polymer usage	20 lbs active polymer/DT
Conceptual equipment selection	BFP: Ashbrook Simon-Hartley Klampress or equal Centrifuge: Westfalia Separator CD536 or equal Screw press: Huber Technology RoS3 Q800 or equal
	Solar Drying
Feed solids	Alternatives 2 & 3: 20 percent Alternative 4: 30 percent
Dried product solids	75 percent
Conceptual equipment selection	Krüger Solia, Parkson Thermo-System or equal
Solar dryer dimensions	Approx. 336' x 49.5'
Solar dryer odor control chemical usage	14.8 lbs H_2SO_4 per hour per dryer

Capital Cost Assumptions

CDM Smith's cost analysis is based on recent experience in the design, bidding, and construction of WRF improvements and quotations received from suppliers and contractors. The opinions of probable construction cost (OPCCs) presented here include the clarifications and assumptions listed below and in **Table 5.** The detailed capital cost calculation tables for each alternative can be found in **Appendix A.**

- These are planning level OPCCs only, based on the three-phase construction of solids treatment trains for the design years of 2023, 2031, and 2040. Years in which costs are incurred were assumed to be the following:
  - Phase I: Year 2015
  - Phase II: Year 2022

  - Phase III: Year 2030
- Consistent with the recommendation of the September 28, 2011, City IWRP Steering Committee meeting, a 30 percent contingency was applied to all costs except for process equipment, which was assessed a 10 percent contingency.
- Budget costs for major process equipment obtained during the IWRP project were updated with input from the same equipment vendors.
- Capital costs for the new South WRF are not included.
- Demolition of the existing ATAD tanks, yard piping and equipment is included.
- Demolition of the existing DAF system is included.
- For the solar dryer in Alternatives 3, 3A, 4, and 4A, it was assumed that the units installed in Phase I would require refurbishment in Phase III, at a capital cost of approximately one-half of the initial equipment cost.
- 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 2013 dollars (no escalation applied).

Table 5 Planning Level Capital Cost Assumptions

Cost Item	Value
Allowances Applied to Estimated Construction Cost	
Labor & Material	30 percent
Sitework	5 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	10 percent (process equipment); 30 percent (all other costs)
Escalation to Midpoint of Construction	None
Design & Construction Services[2]	15 percent
City Project Administration	2.0 percent
Legal/Finance	3.0 percent

[1] Applied to equipment and material costs.
[2] Includes preliminary and final design, construction administration, and field services.

O&M Cost Assumptions

Planning level annual O&M cost calculations were based on the parameters and assumptions listed in **Table 6.** City staff assisted in updating some of these parameters. In addition to these assumptions of unit costs, updates were made to the previous estimates of the labor that would be required to operate and maintain each solids treatment train. These estimates are based on the relative complexity of each technology and its anticipated operating schedule at initial and design conditions. For a direct comparison to the Franklin WRF's existing solids treatment process, these annual O&M costs have also been converted to treatment costs per DT of solids processed.

O&M costs for the new South WRF were not included in the calculations. For alternatives that include anaerobic digestion, potential revenues from FOG dumping fees and operating costs for the FOG receiving station were ignored; it was assumed that the inclusion of FOG receiving would have no O&M impact.

For Alternatives 2, 3, 3A, 4, and 4A, it was assumed that natural gas would be used to fuel the backup boiler for digester heating (Alternatives 3 and 3A) and the boiler that provides steam for the THP process (Alternatives 4 and 4A) during times when the CHP system is out of service. The amount of CHP system downtime was assumed to be 2.5 percent of annual operating hours.

For Alternatives 3, 3A, 4, and 4A, potential cost offsets were calculated for the value of the electricity generated by the CHP system and the sale of dried biosolids. These offsets are included in Table 16.

Table 6 O&M Cost Assumptions

Cost Item	2012 Value	Annual Escalation
Labor		
Fully Loaded Labor Rate	$35.08 per hour	3 percent
Utilities		
Electricity	$0.095/kWh	3 percent
Natural Gas	$10.00/MMBtu	3 percent
Chemicals		
Thickening/Dewatering Polymers	***$1.37/lb delivered***	3 percent
Sodium Hypochlorite Solution (odor control)	$1.57/gal delivered	3 percent
Caustic Soda (odor control)	$1.54/gal delivered	3 percent
Muriatic Acid (odor control)	***$2.41/gal delivered***	***2 percent***
Sulfuric Acid (solar dryer odor control)	$150/ton delivered	3 percent
Miscellaneous		
O&M Materials & Supplies	2% of process equipment capital cost per year	n/a
Biosolids Hauling		
Solids Disposal Locations		
Alternative 1	• Dewatered Cake (20%) to Landfill	n/a
Alternative 2	• Class B Dewatered Biosolids (20%) to Agricultural Users	n/a
Alternative 3	• No Hauling of Class A Dried Biosolids (75%)[1,2]	n/a
Alternative 3A	• No Hauling of Class A Dried Biosolids (75%)[1,2] • Class B Dewatered Biosolids (20%) to Agricultural Users	n/a
Alternative 4	• No Hauling of Class A Dried Biosolids (75%)[1]	n/a
Alternative 4A	• No Hauling of Class A Dried Biosolids (75%)[1] • Class A Dewatered Biosolids (30%) to Agricultural Users	n/a
Truck Capacity	20 CY	n/a
Landfill Tipping Fee	***$24.40/WT***	3 percent
Diesel Fuel Cost	***$3.29/gal***	***Note 3***
Truck Fuel Economy	***6 miles/gallon***	n/a
Round Trip Distances & Driver's Labor Per Load	To Landfill: 216 miles / 13.5 hours To Farms: 100 miles / 6 hours	n/a
Fleet Maintenance	$6,480 per year	3 percent
Insurance	$440 per year	3 percent

Numbers in ***bold italics*** have been updated with City assistance since the IWRP Biosolids Conceptual Design Report.
[1] It was assumed that the public, or a distributor, would pick up the Class A biosolids from the Franklin WRF.
[2] Class A status of solar drying process is subject to approval by TDEC.
[3] Diesel fuel price increases are based on a linear projection of the U.S. Department of Energy, Energy Information Administration's Monthly Midwest No. 2 diesel fuel retail prices, with 12 percent City discount.

Net Present Cost Assumptions

Table 7 presents the assumptions that were used to calculate the NPC for each alternative. NPC calculations are included in Appendix A.

Table 7 Net Present Cost Assumptions

Cost Item	Value
Interest Rate	5 percent
Period	20 years
Year 1 of Operation	2018
Year 20 of Operation	2037

Alternative 1: Continue Current Solids Treatment Process

Alternative 1 is the "baseline" case that continues the Franklin WRF's current practice of DAF thickening, BFP dewatering, and landfill disposal of the dewatered solids.

Design Assumptions

The following assumptions were applied to the concept-level design of Alternative 1.

- The two existing DAF systems, which have reached the end of their useful life, will be replaced with new DAF equipment. The existing concrete DAF tanks, having been found to be in good condition during the Phase II IWRP project, will be reused, and a third, identical DAF tank will be constructed. New air compressors, pumps and other equipment for the third DAF system will be located in a new solids handling building.
- Odor control is included for the new solids handling building.
- Additional dewatering capacity will be provided in the form of two additional two-meter BFPs to match the belt width of the existing BFPs. These new BFPs will be located in the new solids handling building along with the air compressors, pumps, and supporting equipment for the third DAF system. Two new BFPs (one duty and one standby) will be installed for Phase I. The existing dewatering building and its odor control system will remain in service; when the original BFPs are retired in Phase II, new BFPs will be installed in their place.
- Dewatered solids will continue to be hauled by City-owned trucks, driven by City employees, to a privately-owned landfill located approximately 108 miles (one way) from the Franklin WRF.

Design Criteria & Mass Balance

Table 8 presents the conceptual design criteria for Alternative 1. The mass balance for Alternative 1 at 16 mgd average daily flow (ADF) is shown in **Figure 6.**

Project Phasing

The recommended scope of work for each phase of Alternative 1 is as follows.

- **Phase I (2018-2023):**
  - Demolition of the existing DAF equipment inside the DAF building and in the two existing DAF tanks, construction of one new 30-foot-diameter DAF tank, and installation of three new DAF systems (two duty, one standby).
  - Demolition of the existing ATAD tanks and equipment.
  - 420,000 gallons of WAS storage and 70,000 gallons of TWAS storage.
  - A new dewatering building with two 2-meter BFPs, a truck loading bay, and space for the third DAF system, as well as feed pumps and polymer systems for the BFPs.
  - An odor control system for the new dewatering building and WAS and TWAS storage tanks.
- **Phase II (2024-2031):**
  - Replacement of both BFPs, BFP feed pumps, polymer systems, and the belt conveyor in the existing dewatering building.
  - Replacement of the odor control system serving the existing dewatering building.
  - Facilities for unloading of tanker trucks delivering TWAS from the new South WRF.
- **Phase III (2032-2040):**
  - No work is anticipated in Phase III.

Preliminary Site Layout & Building Layouts

The proposed site plan for Alternative 1 is shown in **Figure 7.** The new third DAF tank will be located near the existing DAF tanks, in the site currently occupied by the existing, unused ATAD digesters.

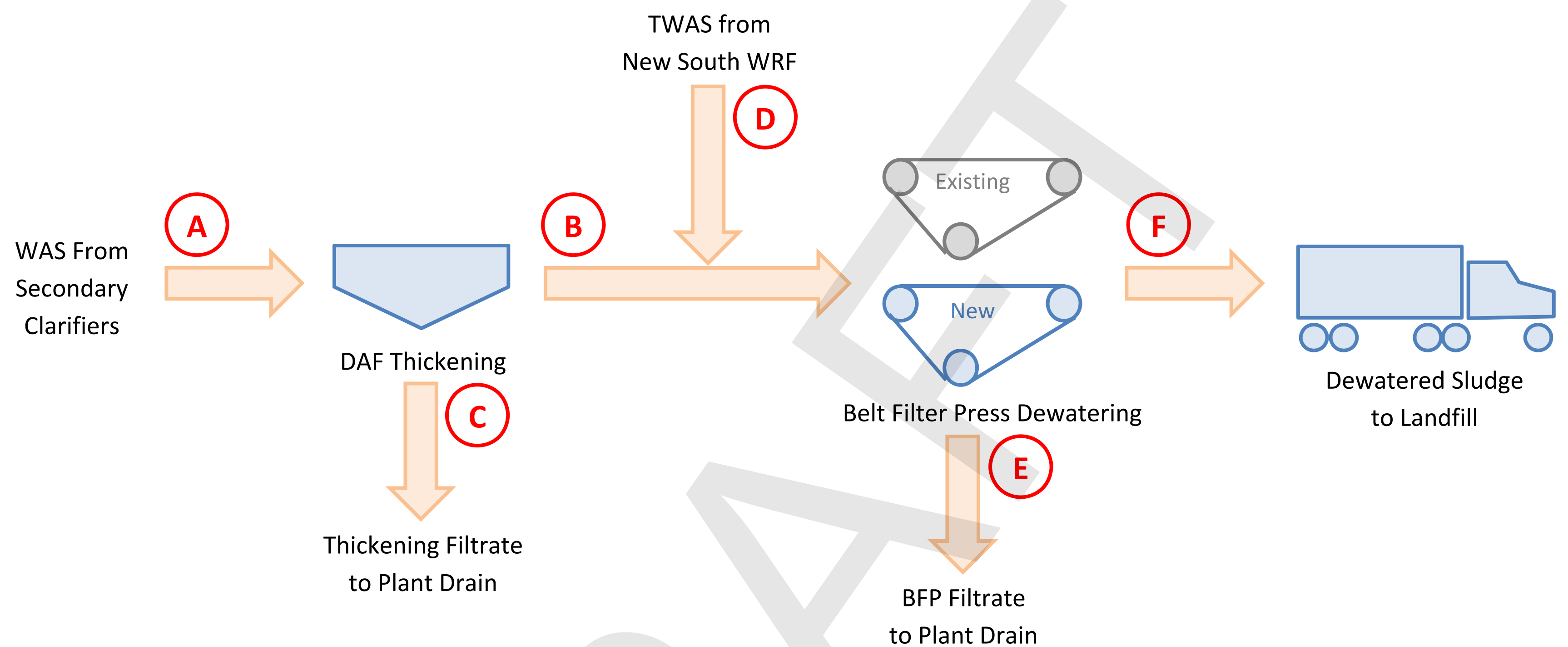
The proposed dewatering building shown in **Figure 8** will house the two new BFPs to be used for the future capacity conditions. Dewatered solids from the BFPs will be carried by an inclined belt conveyor to the truck loading bay.

Phase II modifications inside the existing dewatering building are shown in **Figure 9.**

Table 8 Conceptual Design Criteria
Alternative 1: Continue Current Treatment Process

Parameter	Value
	DAF Thickening
Configuration & dimensions	Circular tank, 30' diameter
Number of units[1]	Two duty, one standby
Operating schedule[2] (hours during which WAS is fed)	Average: 16 hours/day, 7 days/week Max. Month: 21 hours/day, 7 days/week
	Anaerobic Digestion
Number of digesters[1]	None
Tank dimensions & capacity	n/a
Biogas produced	n/a
Digester heating requirements	n/a
	Dewatering with Existing BFPs
Belt width	2 meters
Number of units[3]	Two duty, no standby
Operating schedule[3]	Average: 8 hours/day, 5 days/week Max. Month: 10 hours/day, 5 days/week
	Dewatering with New BFPs
Belt width	2 meters
Number of units[1]	Three duty, one standby
Operating schedule[2]	Average: 11 hours/day, 5 days/week Max. Month: 14 hours/day, 5 days/week
	Solar Drying
Number of solar dryers[1]	n/a

[1] Number of units required in 2040.
[2] Operating schedule in 2040.
[3] Units in service and operating schedule until existing BFPs are retired in Phase II.



Label	Mass Solids		Concentration		Volume	
A	22,700	lbs/day	0.84	% solids	323,000	gal/day
B	21,500	lbs/day	5.0	% solids	52,000	gal/day
C	1,100	lbs/day	480	mg/L	272,000	gal/day
D	10,400	lbs/day	5.0	% solids	25,000	gal/day
E	1,600	lbs/day	3,310	mg/L	58,000	gal/day
F	30,300	lbs/day	20	% solids	2,700	ft^3/day

Mass balance is for 2040 average day.

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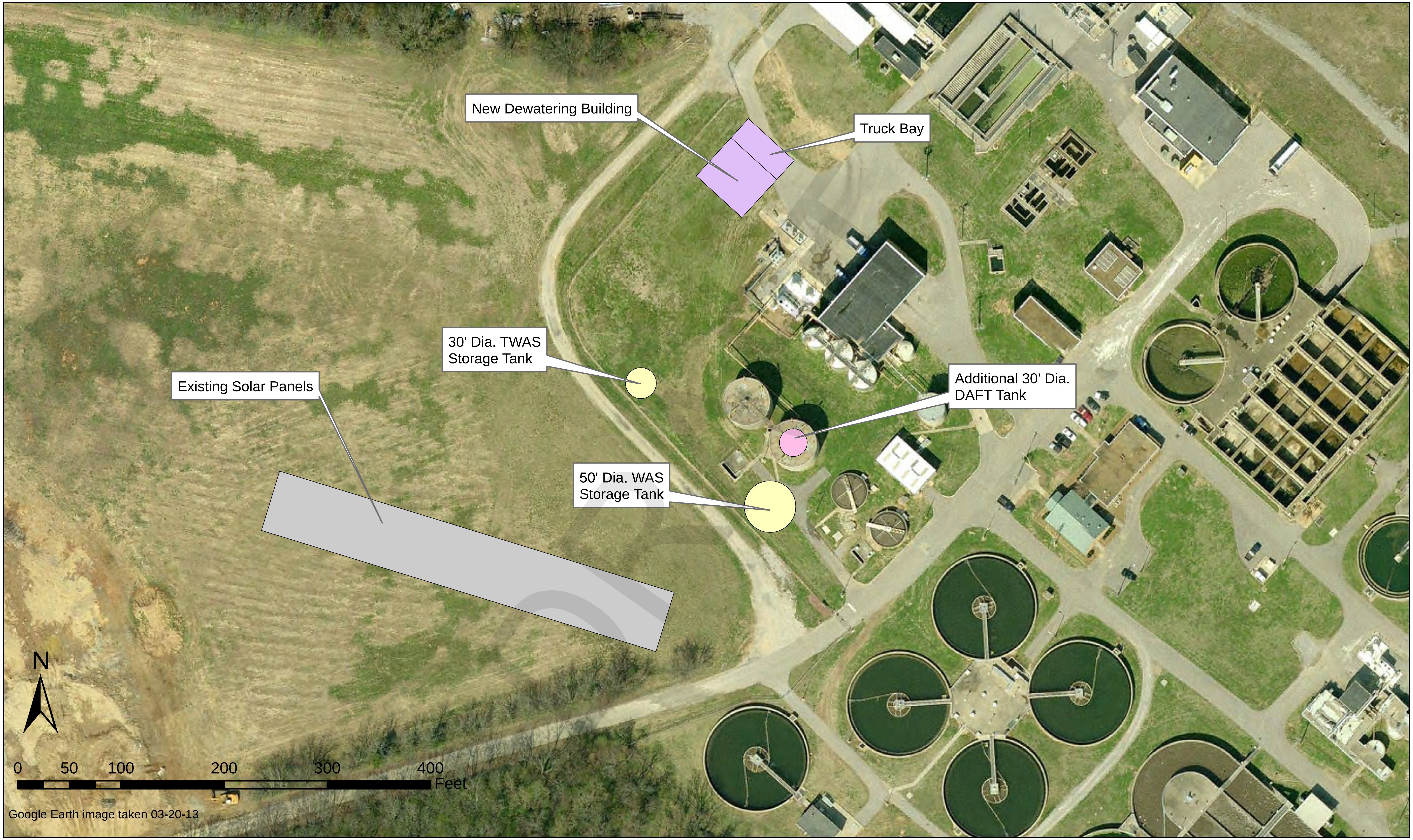
Figure 6
Mass Balance for Alternative 1



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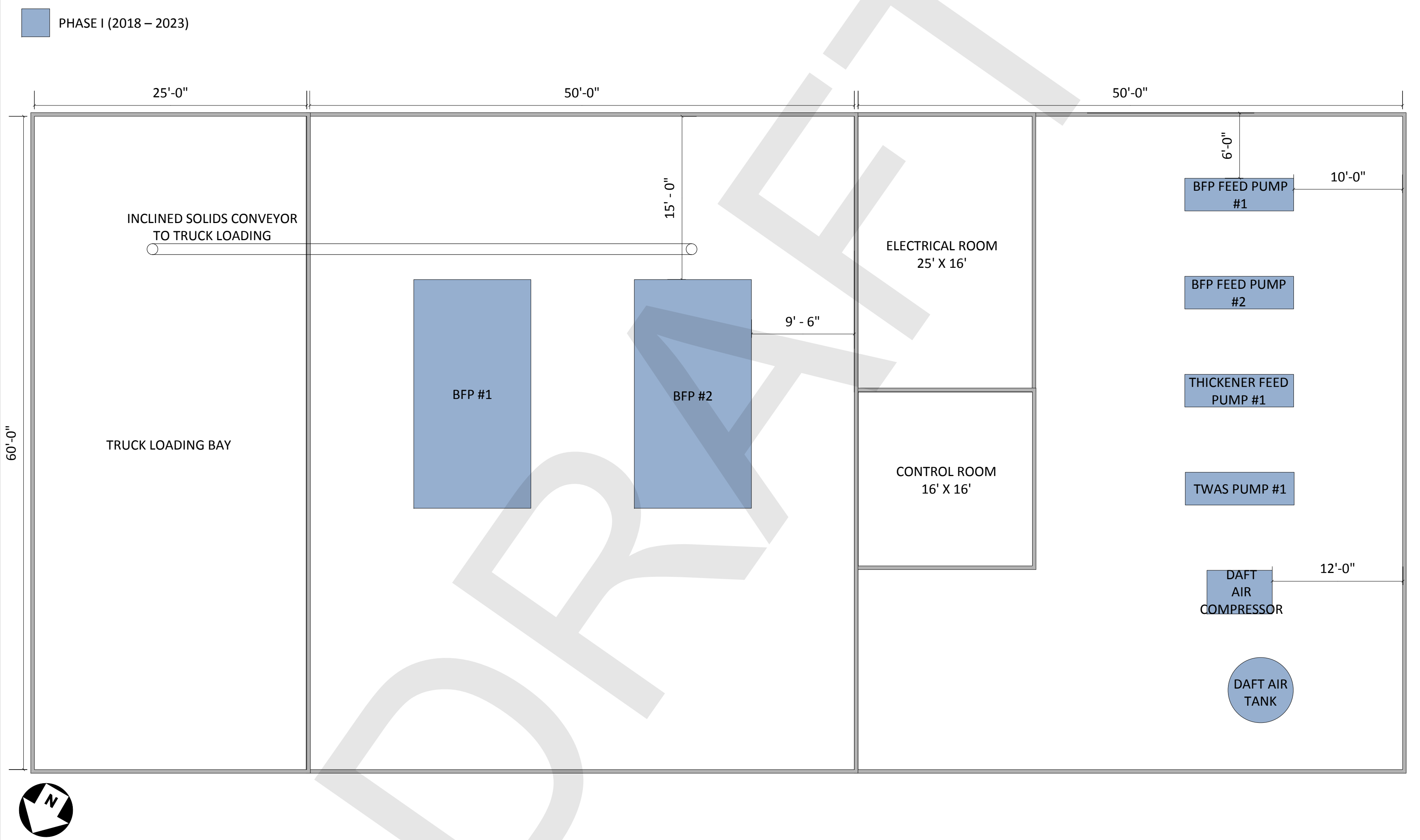
City of Franklin
Water Reclamation Facility

Figure 7
Proposed Site Layout for Alternative 1



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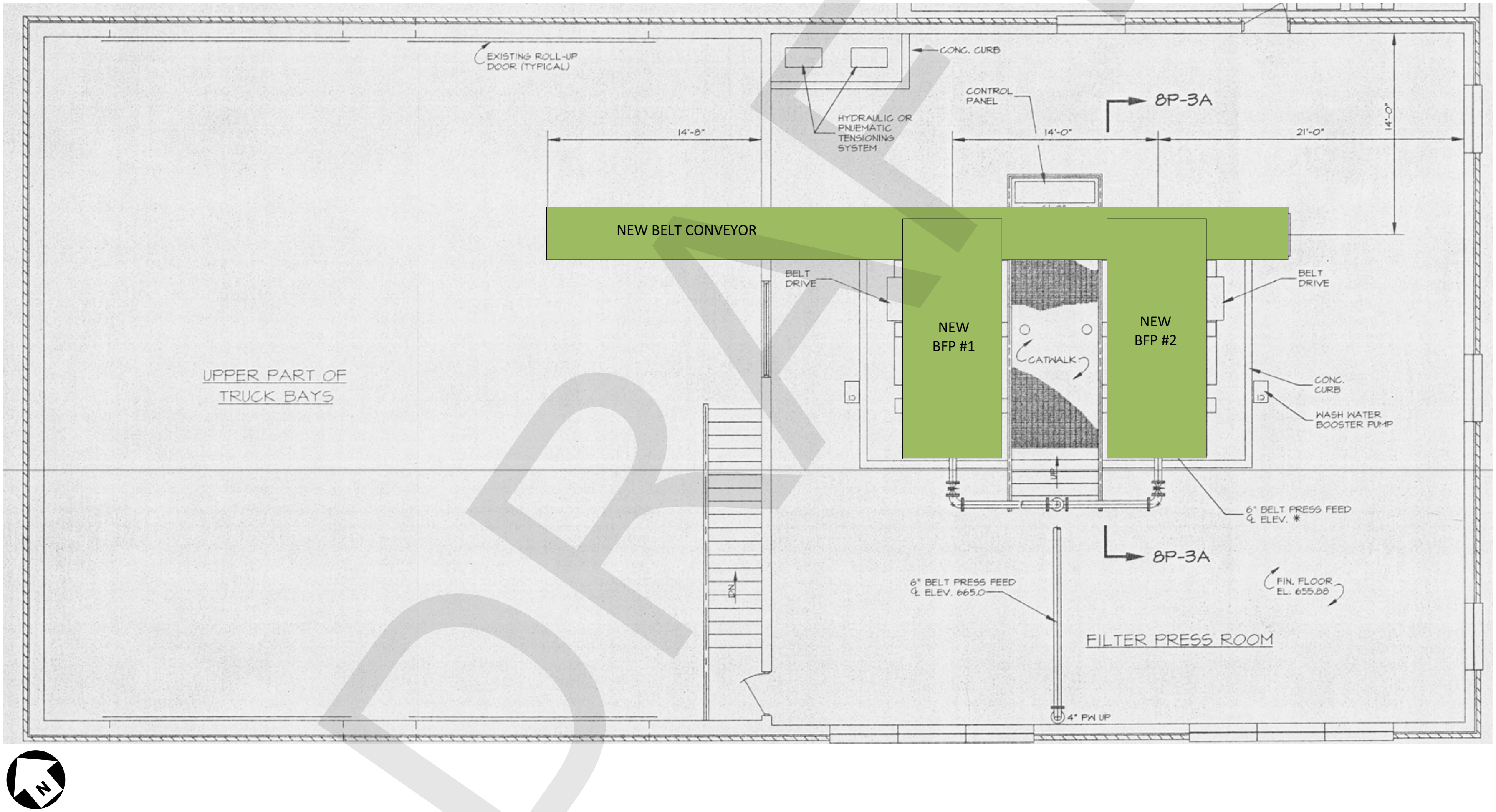
CITY OF FRANKLIN
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 8

PROPOSED DEWATERING BUILDING LAYOUT FOR ALTERNATIVE 1

PHASE II (2024 – 2031)



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CITY OF FRANKLIN
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 9

MODIFICATIONS TO EXISTING DEWATERING BUILDING

ALTERNATIVES 1, 4 & 4A

Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering

In Alternative 2, the DAF thickening process is replaced with RDTs; MAD is added; and existing dewatering capacity is supplemented by screw presses. This alternative is expected to produce Class B biosolids that are suitable for land application on agricultural fields.

Design Assumptions

The following assumptions were applied to the concept-level design of Alternative 2.

- A new thickening building will be constructed to house the new RDTs.
- All three RDTs (two duty and one standby) will be installed in Phase I.
- Demolition of the existing DAF system is included in this alternative. The DAF tanks will be converted into TWAS storage tanks.
- Digester biogas will be treated and used as fuel for a CHP system described in Appendix B.
- The existing BFPs will continue to operate until their retirement in Phase II. Addition of dewatering capacity, in the form of new screw presses, will begin in Phase II with the construction of the new dewatering building. The first two screw presses will be installed in the new dewatering building, with a third replacing one of the BFPs in the existing dewatering building. The fourth and final screw press will be installed in the existing dewatering building as part of the Phase III improvements.

Design Criteria & Mass Balance

Table 9 presents the conceptual design criteria for Alternative 2. The mass balance for Alternative 2 at 16 mgd ADF is shown in **Figure 10.**

Project Phasing

The recommended scope of work for each phase of Alternative 2 is as follows.

- **Phase I (2018-2023):**
  - A new thickening building to house three RDTs (two duty, one standby), polymer systems, feed pumps, and supporting equipment.
  - 420,000 gallons of WAS storage.
  - A FOG receiving station with storage, mixing and pumping equipment.
  - Two 0.85-MG digester tanks with biogas treatment and CHP system.
  - A digester building to house the digester heat exchangers, recirculation pumps, and other supporting equipment.

- An odor control system for the new thickening building and WAS and TWAS storage tanks.
- Demolition of the existing DAF system and conversion of the DAF tanks into TWAS storage tanks.
- Demolition of the existing ATAD tanks and equipment.

- **Phase II (2024-2031):**
  - A new dewatering building to house two screw presses, polymer systems, feed pumps, and supporting equipment.
  - Extension of the odor control system to serve the new dewatering building.
  - Retrofit of a third screw press, including polymer system, feed pump, and supporting equipment, into the existing dewatering building and replacement of the existing belt conveyor with an enclosed screw conveyor.
  - Replacement of the odor control system serving the existing dewatering building.
  - Facilities for unloading of tanker trucks delivering TWAS from the new South WRF.
  - Construction of an additional 36,000 gallons of TWAS storage.
- **Phase III (2032-2040):**
  - Retrofit of a second screw press into the existing dewatering building.

Preliminary Site Layout & Building Layouts

The proposed site plan for Alternative 2 is shown in **Figure 11**. In this site plan, the new thickening building and anaerobic digester building will be built to the west of the existing dewatering building, with the Phase II dewatering building to be added to the north of the thickening building.

Figures 12 and 13 show the two levels of the new thickening building that will be constructed in Phase I. The basement level will house the TWAS pumps and thickener feed pumps. The ground floor will house the RDTs, two duty and one standby, with the associated polymer skids and bulk polymer totes for each RDT. Also included on the ground floor will be the electrical equipment and the operator control room for all of the processes.

Figures 14 and 15 illustrate the new dewatering building that will be built in Phase II to house two screw presses. Each screw press will have an associated polymer skid and bulk polymer tote. An enclosed, inclined screw conveyor from the presses will transfer the dewatered cake to the truck loading bay.

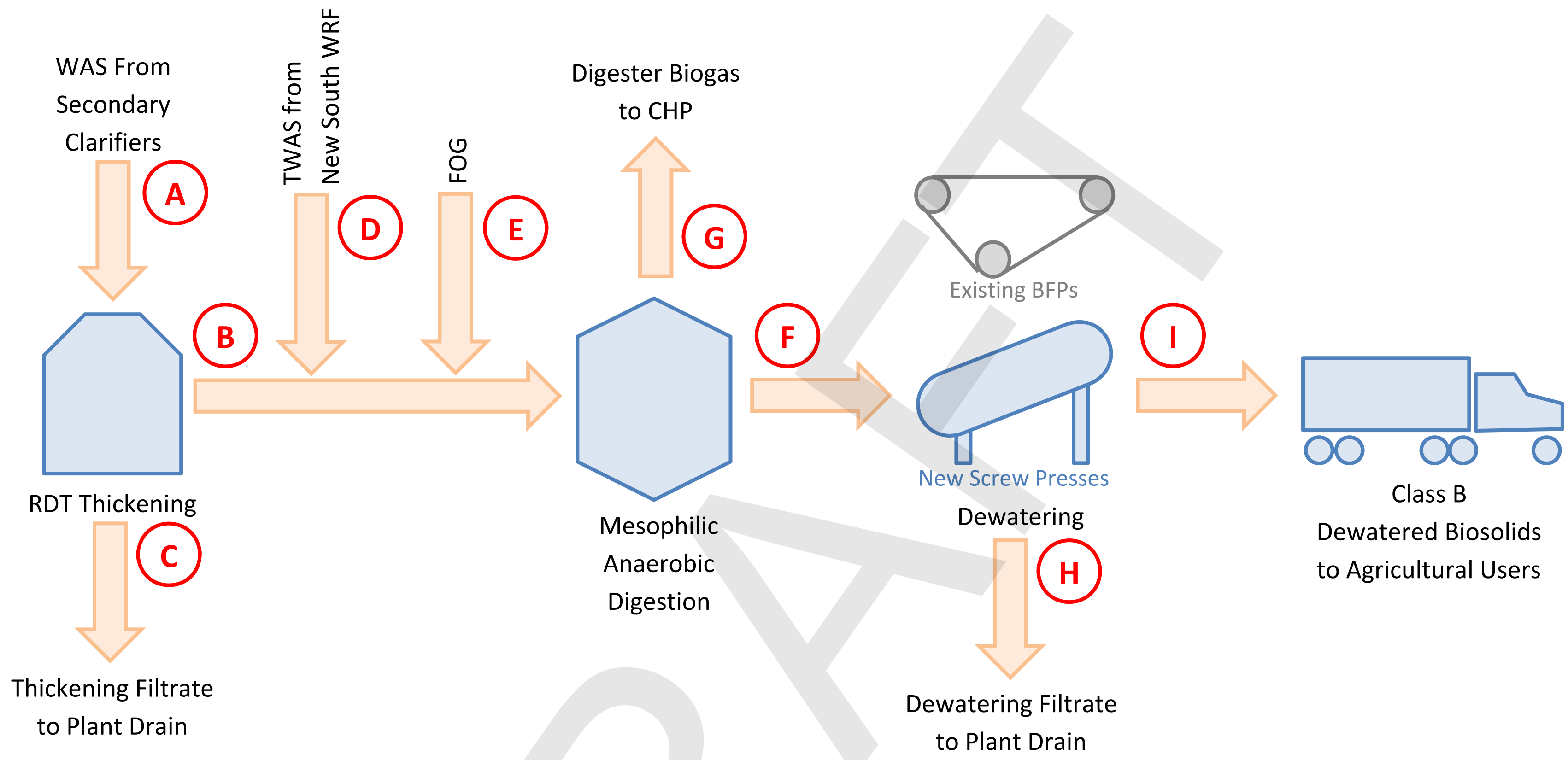
The anaerobic digester equipment will be housed in an adjacent building on the ground floor as shown in **Figure 16**. Each digester will have a heat exchanger, with a duty and standby mixing pump for reliability. Two dewatering feed/digester transfer pumps and one standby, and two recirculation pumps and one standby are also housed in this building for digester operation.

Phase II and III modifications to the existing dewatering building are shown in **Figure 17.**

Table 9 Conceptual Design Criteria
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering

Parameter	Value
RDT Thickening	
Number of units[1]	Two duty, one standby
Operating schedule[2]	Average: 16 hours/day, 7 days/week Max. Month: 21 hours/day, 7 days/week
Anaerobic Digestion	
Number of digesters[1]	Two
Tank dimensions & capacity	52’ diameter x 52’ sidewater depth, 0.87 MG each
Biogas produced	Average: 110 scfm (158,000 ft^3/day) Max. Month: 136 scfm (196,000 ft^3/day)
Digester heating requirements	Average: 1.11 MMBTU/hour Max. Month: 1.88 MMBTU/hour
Dewatering with Existing BFPs	
Belt width	2 meters
Number of units[3]	Two duty, no standby
Operating schedule[3]	Average: 8 hours/day, 6 days/week Max. Month: 10 hours/day, 6 days/week
Dewatering with New Screw Presses	
Number of units[1]	Three duty, one standby
Operating schedule[2]	Average: 9 hours/day, 7 days/week Max. Month: 12 hours/day, 7 days/week
Solar Drying	
Number of solar dryers[1]	n/a

[1] Number of units required in 2040.
[2] Operating schedule in 2040.
[3] Units in service and operating schedule until existing BFPs are retired in Phase II.



Label	Mass Solids	Concentration	Volume
A	22,700 lbs/day	0.84 % solids	323,000 gal/day
B	21,500 lbs/day	5.0 % solids	52,000 gal/day
C	1,100 lbs/day	480 mg/L	272,000 gal/day
D	10,400 lbs/day	5.0 % solids	25,000 gal/day
E	1,900 lbs/day	4.0 % solids	5,800 gal/day

Label	Mass Solids	Concentration	Volume
F	24,200 lbs/day	3.5 % solids	82,000 gal/day
G	n/a	n/a	158,000 ft^3/day
H	1,200 lbs/day	2,120 mg/L	68,000 gal/day
I	23,000 lbs/day	20 % solids	2,100 ft^3/day

Mass balance is for 2040 average day.

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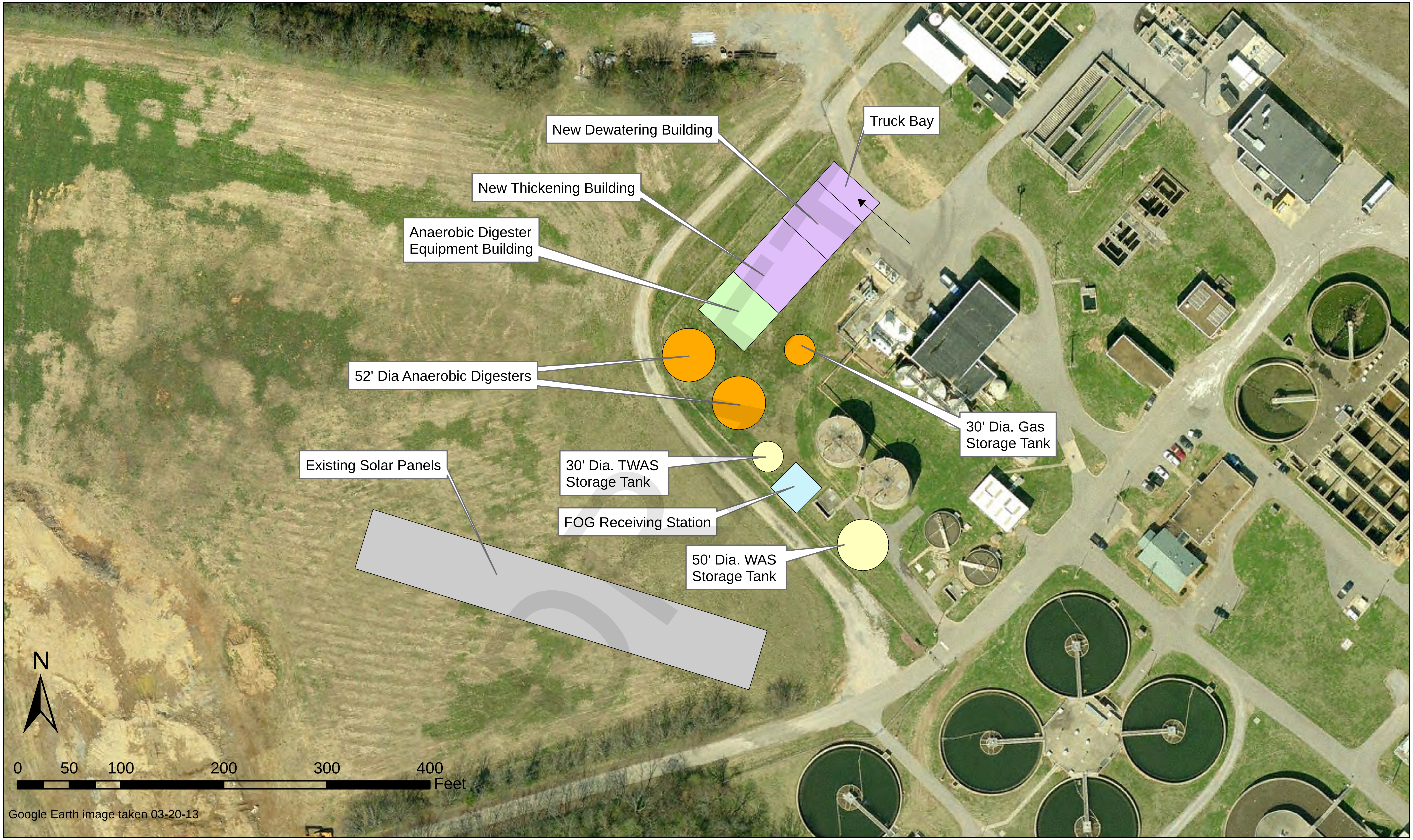
Figure 10
Mass Balance for Alternative 2



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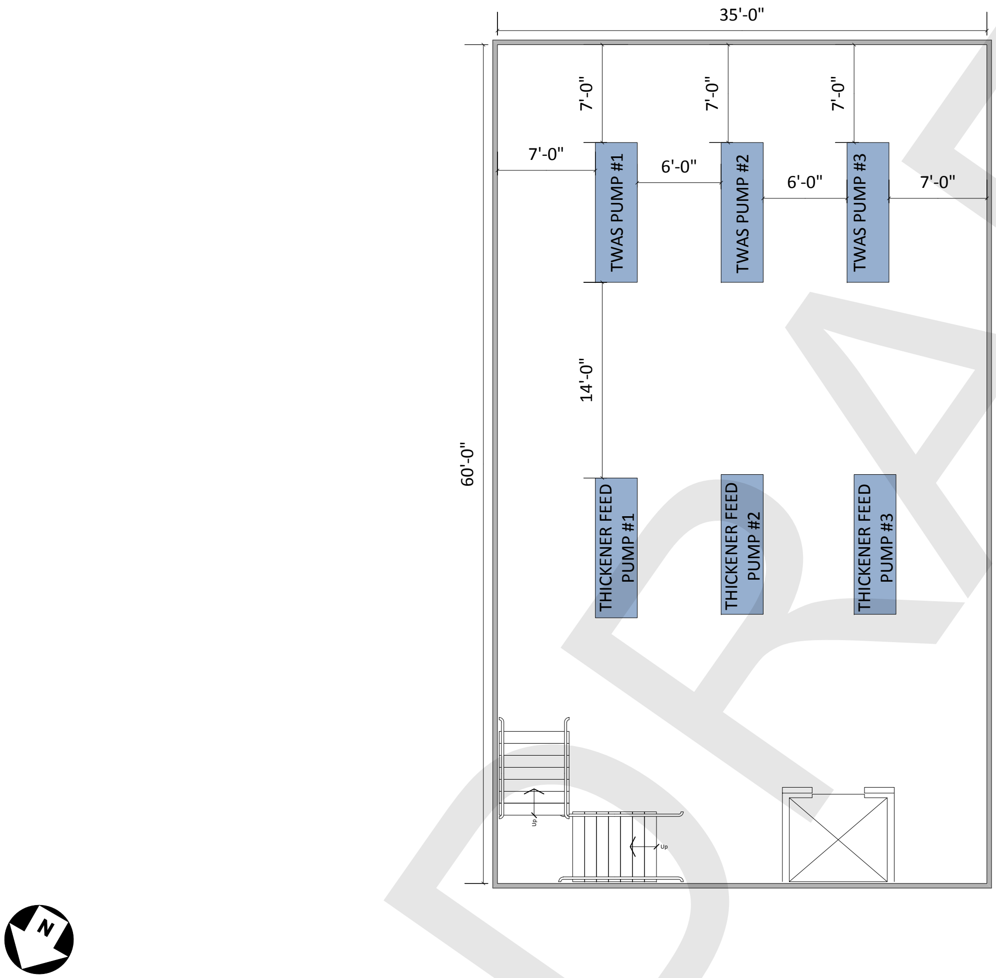
Water Reclamation Facility

Figure 11
Proposed Site Layout for Alternative 2

PHASE I (CURRENT – 2024)



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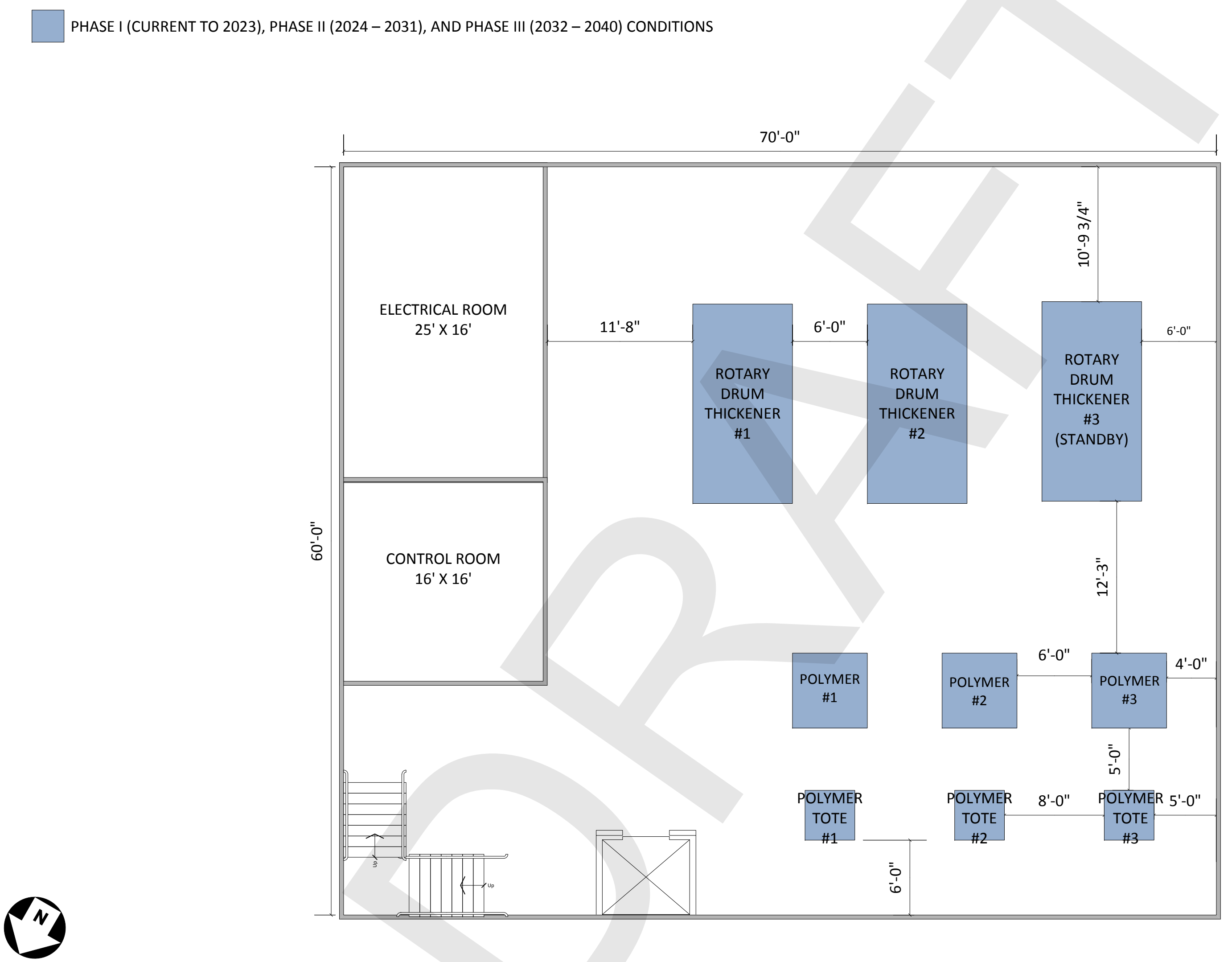
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 12

PROPOSED THICKENING BUILDING LAYOUT FOR ALTERNATIVE 2, 3 & 3A – BASEMENT FLOOR



Notes:
1: A minimum of 6 feet is needed for drum removal.

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WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 13

PROPOSED THICKENING BUILDING LAYOUT FOR ALTERNATIVE 2, 3 & 3A – GROUND FLOOR

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WATER RECLAMATION FACILITY EXPANSION

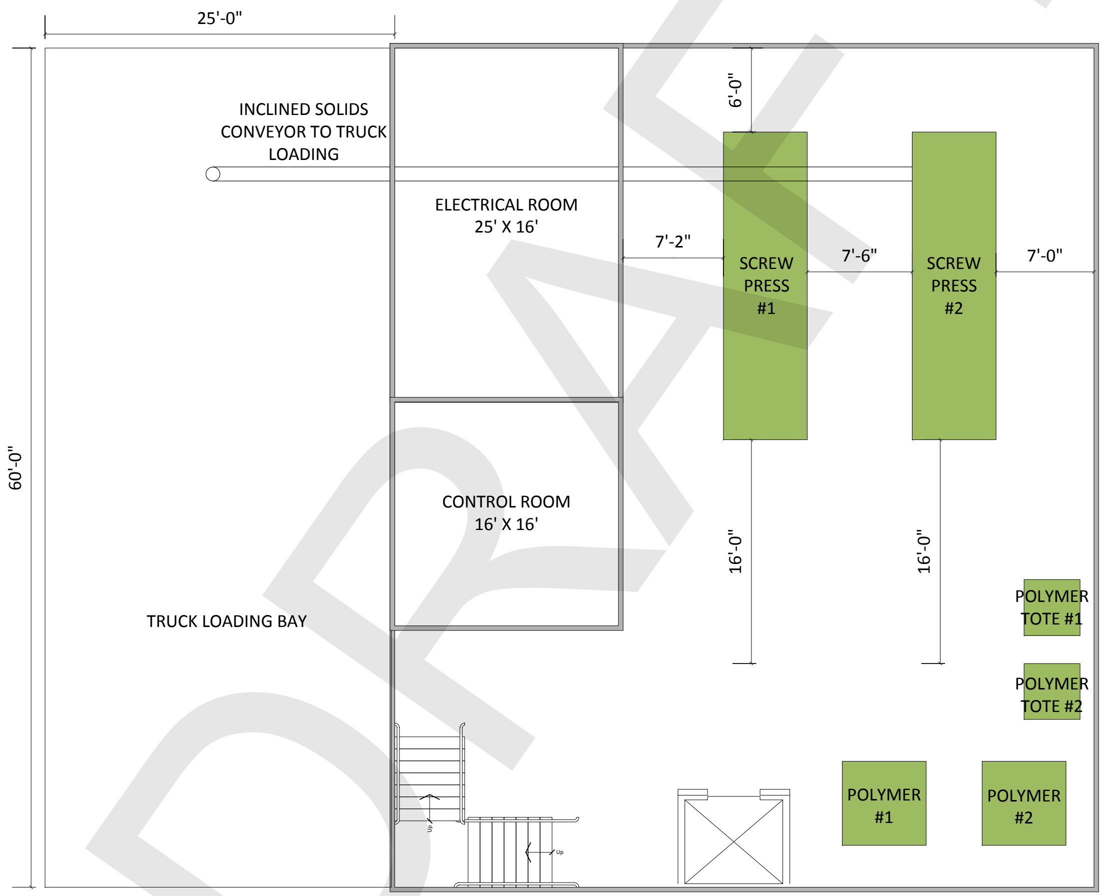
PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 14

PROPOSED DEWATERING BUILDING LAYOUT FOR ALTERNATIVE 2, 3 & 3A – BASEMENT FLOOR

PHASE II (2024 – 2031)

Notes:
1: A minimum of 16 feet is needed for screw removal.



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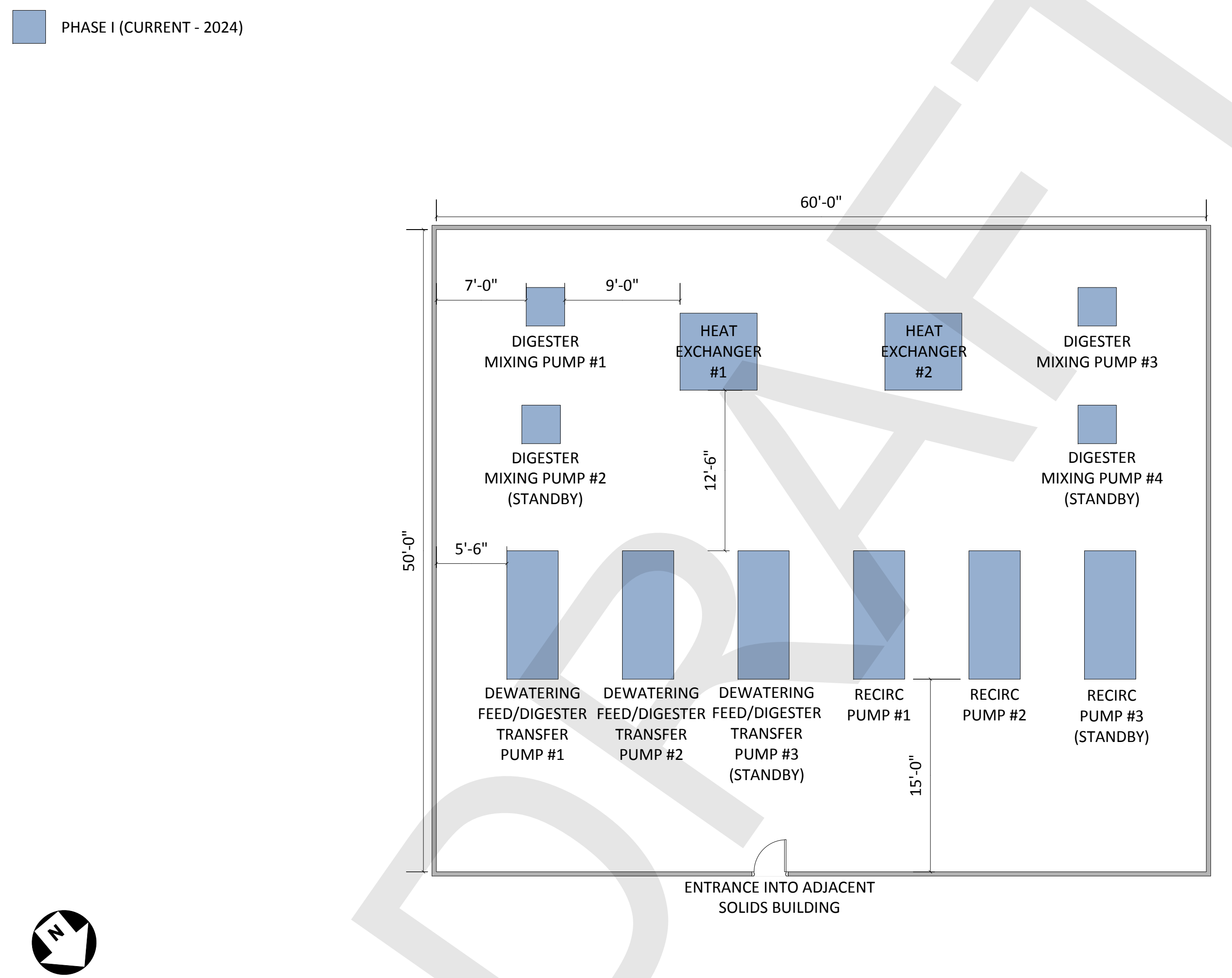
CITY OF FRANKLIN
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 15

PROPOSED DEWATERING BUILDING LAYOUT FOR ALTERNATIVE 2, 3 & 3A – GROUND FLOOR



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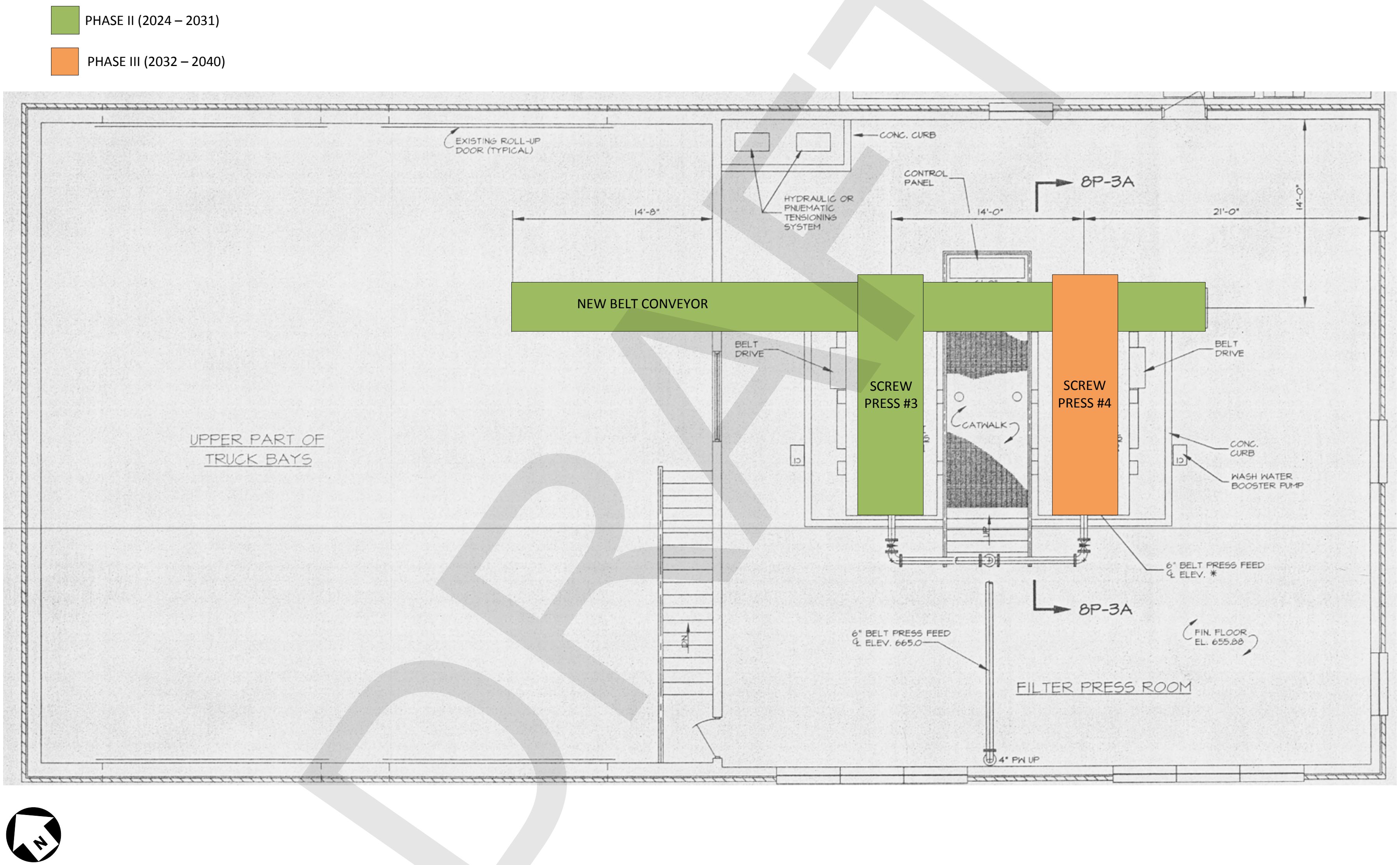
CITY OF FRANKLIN
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 16

PROPOSED DIGESTER BUILDING LAYOUT FOR
ALTERNATIVES 2, 3 & 3A –
GROUND FLOOR



CITY OF FRANKLIN
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 17

MODIFICATIONS TO EXISTING DEWATERING BUILDING

ALTERNATIVES 2, 3 & 3A

Alternative 3: Alternative 2 Plus Solar Drying & Alternative 3A: Alternative 3 with Partial Solar Drying

Alternative 3 adds solar drying to Alternative 2. The resulting process train is anticipated to produce Class A biosolids suitable for distribution to the public; Class A status of the solar drying process is subject to approval by TDEC.

Design Assumptions

The following assumptions were applied to the concept-level design of Alternatives 3 and 3A.

- The conceptual designs of the new thickening, digestion, CHP and dewatering systems are the same as in Alternative 2.
- Demolition of the existing DAF thickening system is also included in this alternative. The DAF tanks will be converted into TWAS storage tanks.
- The solar dryer will include an odor control system. Refurbishing of the Phase I solar dryer installation, recommended by the manufacturers at Year 15, was included as part of the Phase III improvements.

Design Criteria & Mass Balance

Table 10 presents the conceptual design criteria for Alternative 3. The mass balance for Alternative 3 in Year 2040 is shown in **Figure 18,** and the mass balance for Alternative 3A at the end of Phase I (Year 2023) is shown in **Figure 18A.**

Project Phasing

The recommended scopes of work for each phase of Alternatives 3 and 3A are as follows.

- **Phase I (2018-2023):**
  - A new thickening building to house three RDTs (two duty, one standby), polymer systems, feed pumps, and supporting equipment.
  - 420,000 gallons of WAS storage.
  - A FOG receiving station with storage, mixing and pumping equipment.
  - Two 0.85-MG digester tanks with biogas treatment and CHP system.
  - A digester building to house the digester heat exchangers, recirculation pumps, and other supporting equipment.
  - An odor control system for the new thickening building and WAS and TWAS storage tanks.
  - Solar dryers:

        - Alternative 3: Eight solar drying chambers with a dedicated odor control system.
        - Alternative 3A: Two solar drying chambers with a dedicated odor control system.
    - Demolition of the existing DAF system and conversion of the DAF tanks into TWAS storage tanks.
    - Demolition of the existing ATAD tanks and equipment.
- **Phase II (2024-2031):**
    - A new dewatering building to house two screw presses, polymer systems, feed pumps, and supporting equipment.
    - Extension of the odor control system to serve the new dewatering building.
    - Retrofit of a third screw press, including polymer system, feed pump, and supporting equipment, into the existing dewatering building and replacement of the existing belt conveyor with an enclosed screw conveyor.
    - Replacement of the odor control system serving the existing dewatering building.
    - Facilities for unloading of tanker trucks delivering TWAS from the new South WRF.
    - Construction of an additional 36,000 gallons of TWAS storage.
    - Solar dryers:
        - Alternative 3: Two solar drying chambers and expansion of the solar dryer odor control system.
        - Alternative 3A: To be determined following the City's evaluation of the Phase I solar dryers.
- **Phase III (2032-2040):**
    - Retrofit of a second screw press into the existing dewatering building.
    - Solar dryers:
        - Alternative 3: Two solar drying chambers.
        - Alternative 3A: To be determined following the City's evaluation of the Phase I solar dryers.
    - Refurbishment of the Phase I solar drying chambers.

Preliminary Site Layout & Building Layouts

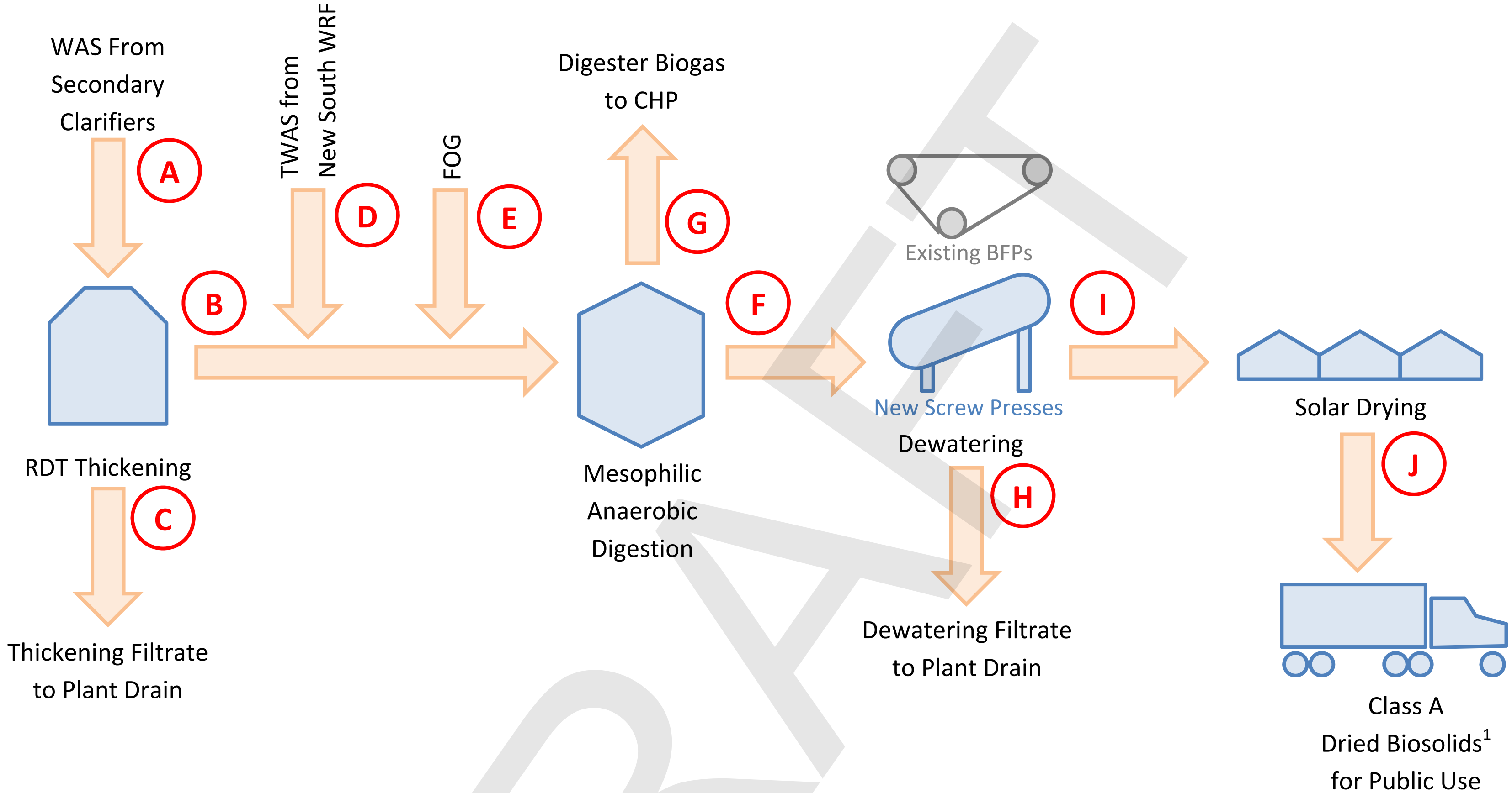
The proposed site plan for Alternatives 3 and 3A is shown in **Figure 19**. This layout is similar to Alternative 2, with the addition of the 11-bay solar dryer that is anticipated to achieve Class A biosolids. A 20-foot-wide paved road is provided on all sides of the solar dryer system for ease of truck access, as well as an additional 50-foot-wide area at each end to allow for the loading and unloading of the solids before and after treatment.

The thickening building, new dewatering building, digester building, and existing dewatering building layouts for these alternatives are identical to those prepared for Alternative 2.

Table 10 Conceptual Design Criteria
Alternative 3: Alternative 2 Plus Solar Drying &
Alternative 3A: Alternative 3 with Partial Solar Drying

Parameter	Value
RDT Thickening	
Number of units[1]	Two duty, one standby
Operating schedule[2]	Average: 16 hours/day, 7 days/week Max. Month: 21 hours/day, 7 days/week
Anaerobic Digestion	
Number of digesters[1]	Two
Tank dimensions & capacity	52' diameter x 52' sidewater depth, 0.87 MG each
Biogas produced	Average: 110 scfm (158,000 ft^3/day) Max. Month: 136 scfm (196,000 ft^3/day)
Digester heating requirements	Average: 1.11 MMBTU/hour Max. Month: 1.88 MMBTU/hour
Dewatering with Existing BFPs	
Belt width	2 meters
Number of units[3]	Two duty, no standby
Operating schedule[3]	Average: 8 hours/day, 6 days/week Max. Month: 10 hours/day, 6 days/week
Dewatering with New Screw Presses	
Number of units[1]	Three duty, one standby
Operating schedule[2]	Average: 9 hours/day, 7 days/week Max. Month: 12 hours/day, 7 days/week
Solar Drying	
Number of solar dryers[1]	12 (Alternative 3) 2 (Alternative 3A – Phase I only)

[1] Number of units required in 2040.
[2] Operating schedule in 2040.
[3] Units in service and operating schedule until existing BFPs are retired in Phase II.



Label	Mass Solids	Concentration	Volume
A	22,700 lbs/day	0.84 % solids	323,000 gal/day
B	21,500 lbs/day	5.0 % solids	52,000 gal/day
C	1,100 lbs/day	480 mg/L	272,000 gal/day
D	10,400 lbs/day	5.0 % solids	25,000 gal/day
E	1,900 lbs/day	4.0 % solids	5,800 gal/day

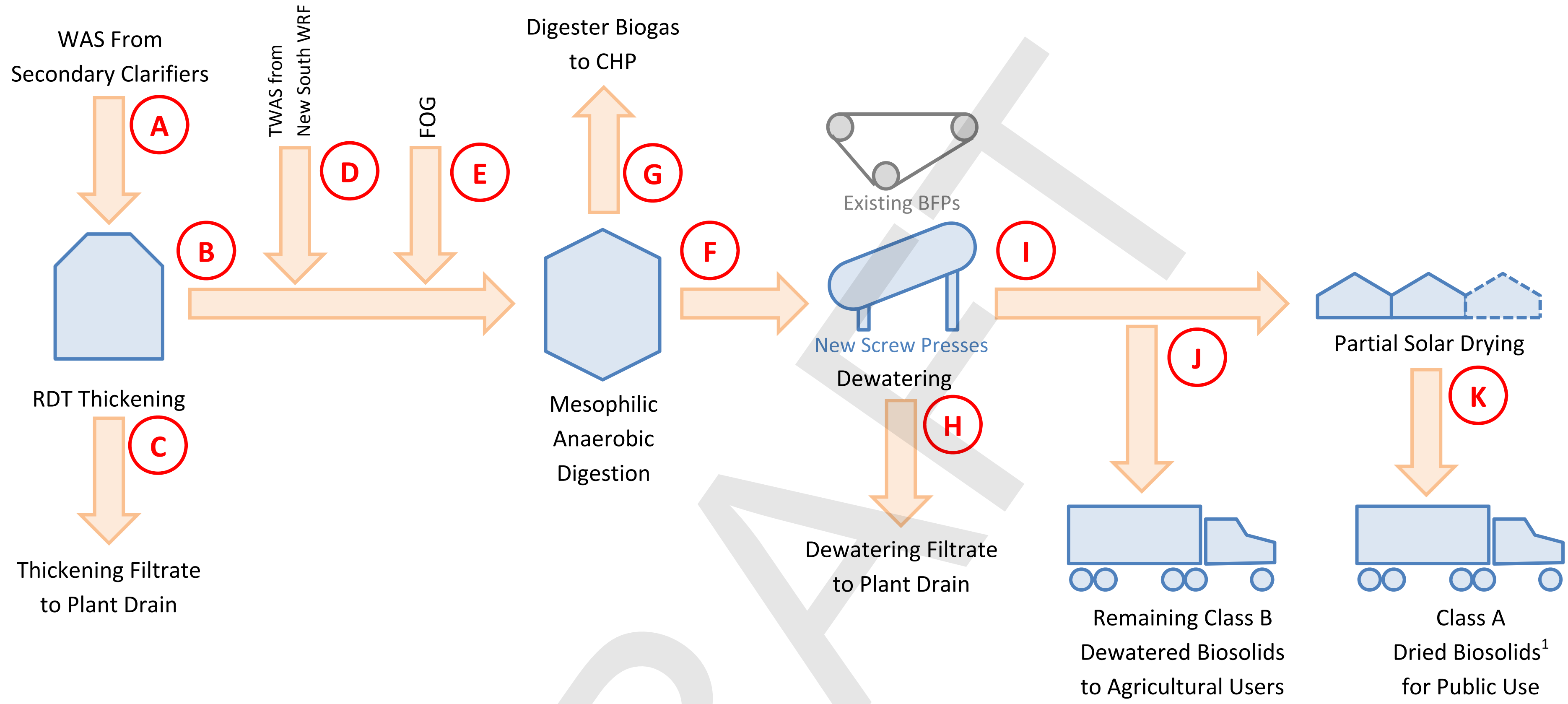
Label	Mass Solids	Concentration	Volume
F	24,200 lbs/day	3.5 % solids	82,000 gal/day
G	n/a	n/a	158,000 ft^3/day
H	1,200 lbs/day	2,120 mg/L	68,000 gal/day
I	23,000 lbs/day	20 % solids	2,100 ft^3/day
J	23,000 lbs/day	75 % solids	830 ft^3/day

Mass balance is for 2040 average day.

[1] Class A status of solar drying process is subject to approval by TDEC.

CDM Smith

Figure 18
Mass Balance for Alternative 3



Label	Mass Solids	Concentration	Volume
A	22,300 lbs/day	0.84 % solids	318,000 gal/day
B	21,200 lbs/day	5.0 % solids	51,000 gal/day
C	1,100 lbs/day	490 mg/L	267,000 gal/day
D	0 lbs/day	5.0 % solids	0 gal/day
E	1,900 lbs/day	4.0 % solids	5,800 gal/day
F	16,000 lbs/day	3.6 % solids	54,000 gal/day

Label	Mass Solids	Concentration	Volume
G	n/a	n/a	99,000 ft^3/day
H	800 lbs/day	2,130 mg/L	45,000 gal/day
I	15,200 lbs/day	20 % solids	1,400 ft^3/day
J	10,300 lbs/day	20 % solids	930 ft^3/day
K	4,900 lbs/day	75 % solids	180 ft^3/day

Mass balance is for 2023 average day.

[1] Class A status of solar drying process is subject to approval by TDEC.

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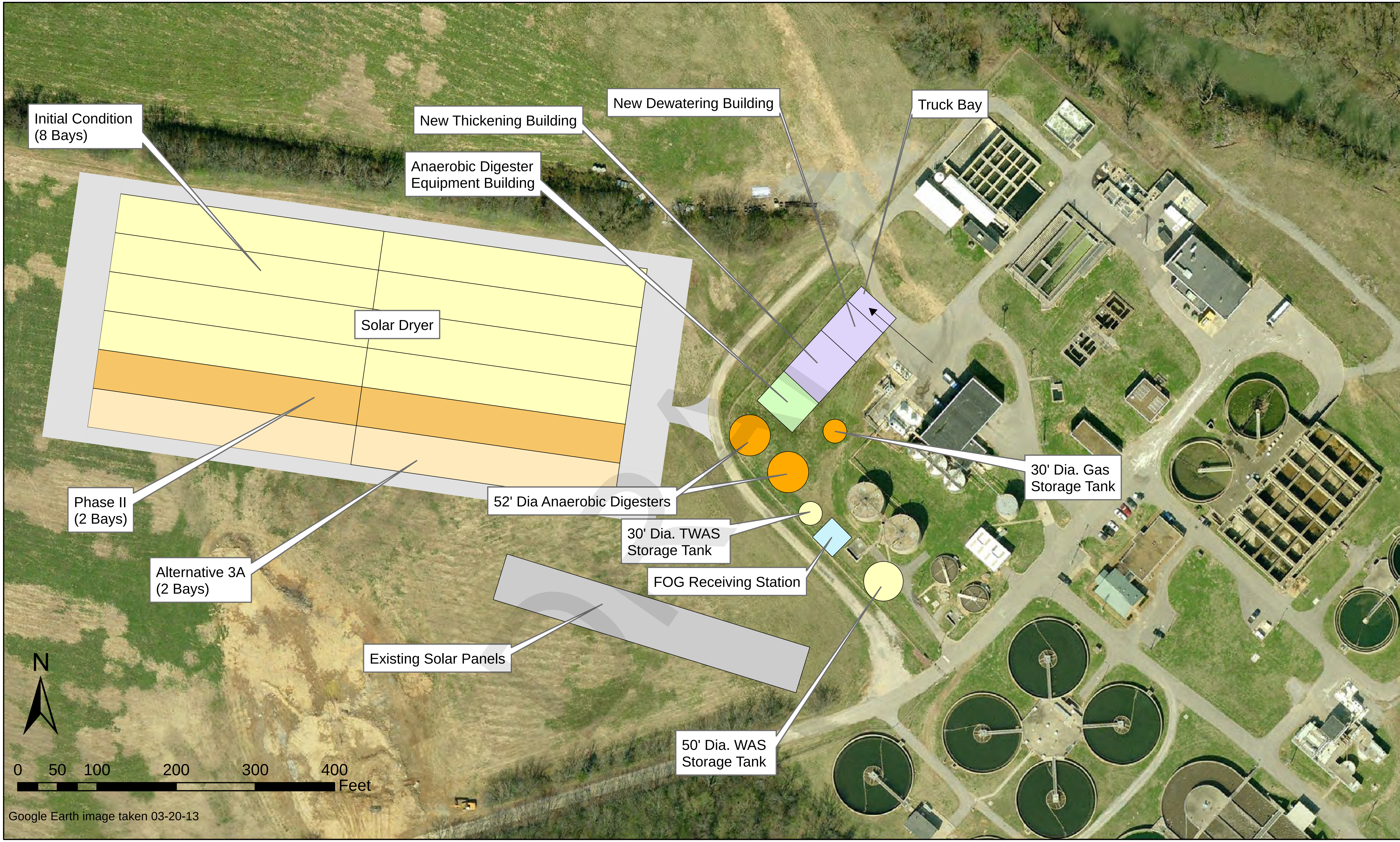
Figure 18A
Mass Balance for Alternative 3A



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Water Reclamation Facility

Figure 19
Proposed Site Layout for Alternatives 3 & 3A

Alternative 4: Alternative 3 Plus Thermal Hydrolysis & Alternative 4A: Alternative 4 with Partial Solar Drying

In this alternative, THP conditions the sludge prior to digestion, applying pressure and temperature to fracture the cellular material and long-chain fatty acids. This pretreatment process increases volatile solids destruction in the digesters, reduces the digesters' volume, produces a larger quantity of biogas, and reduces the quantity of solids that require downstream processing and disposal.

For the purposes of this analysis, Krüger's Exelys system was used as the basis of design.

Design Assumptions

The following assumptions were applied to the concept-level design of Alternatives 4 and 4A.

- Centrifuges will be used for pre-THP dewatering. Thickening will not be provided; the WAS from the Franklin WRF and TWAS from the new South WRF will be blended in the WAS/TWAS storage tank and fed to the pre-THP dewatering centrifuges.
- Because pathogen contamination concerns prohibit the pre- and post-digestion sludges from being dewatered in the same machines, a separate dewatering system is required to handle the digested biosolids. The two BFPs in the existing dewatering building will be used for post-digestion dewatering, with additional dewatering capacity provided in the form of one two-meter BFP added in Phase II. New BFPs will be installed in place of the existing BFPs in Phase II.
- Fugitive emissions from the THP process can be highly odorous. An allowance for a packaged odor control system to treat these odors is included.
- A CHP system, sized for the additional biogas production, is included. This system is further described in Appendix B.
- Dilution water added to the post-THP digester feed sludge can be disinfected plant effluent, but potable water is typically used. It was assumed that potable water would be used for dilution water.
- Similar to Alternatives 3 and 3A, refurbishing of the Phase I solar dryer installation, recommended by the manufacturers at Year 15, was included as part of the Phase III improvements.
- Demolition of the existing DAF thickening system is also included in this alternative.

Design Criteria & Mass Balance

Table 11 presents the conceptual design criteria for Alternatives 4 and 4A. The mass balance for Alternative 4 in Year 2040 is shown in **Figure 20,** and the mass balance for Alternative 4A at the end of Phase I (Year 2023) is shown in **Figure 20A.**

Project Phasing

The recommended scopes of work for each phase of Alternatives 4 and 4A are as follows.

- **Phase I (2018-2023):**
  - A 243,000-gallon WAS & TWAS storage and blending tank.
  - THP system with packaged odor control for treatment of fugitive emissions.
  - A FOG receiving station with storage, mixing and pumping equipment.
  - Two 0.425-MG digester tanks with biogas treatment and CHP system.
  - A digester building to house the following equipment.
    - Digester recirculation pumps, transfer pumps and other supporting equipment.
    - Three pre-THP dewatering centrifuges (two duty, one standby).
    - A third future BFP (to be added in Phase II).
  - An odor control system for the digester building and WAS/TWAS storage tank.
  - Solar dryers:
    - Alternative 4: Four solar drying chambers with a dedicated odor control system.
    - Alternative 4A: Two solar drying chambers with a dedicated odor control system.
  - Demolition of the existing DAF system.
  - Demolition of the existing ATAD tanks and equipment.
- **Phase II (2024-2031):**
  - Replacement of both BFPs, BFP feed pumps, polymer systems, and the belt conveyor in the existing dewatering building.
  - Addition of a third BFP to the digester building.
  - Replacement of the odor control system serving the existing dewatering building.
  - Facilities for unloading of tanker trucks delivering TWAS from the new South WRF.
  - Solar dryers:
    - Alternative 4: Two solar drying chambers and expansion of the solar dryer odor control system.
    - Alternative 4A: To be determined following the City’s evaluation of the Phase I solar dryers.

- **Phase III (2032-2040):**
  - Addition of one pre-THP dewatering centrifuge to the digester building.
  - Refurbishment of the Phase I solar drying chambers.

Preliminary Site Layout & Building Layouts

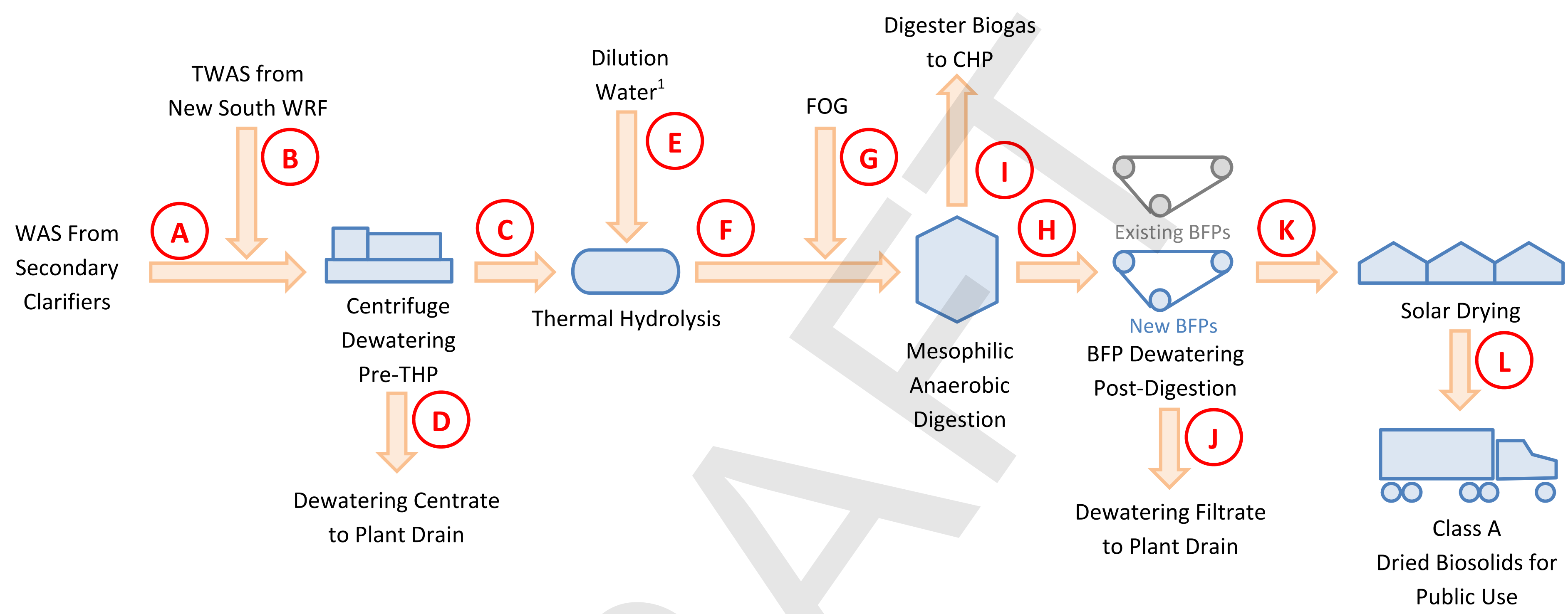
The proposed site plan for Alternatives 4 and 4A is shown in **Figure 21**. For these alternatives, fewer solar dryer chambers are ultimately required due to the drier cake achieved by the post-digestion dewatering process and the higher solids reduction in the digesters.

The digester building for Alternatives 4 and 4A includes a second floor **(Figure 22)** that houses the pre-dewatering centrifuges and their supporting equipment. The ground floor of the digester building **(Figure 23)** will include the digester mixing, recirculation and transfer pumps, as well as the third BFP. Modifications to the existing dewatering building are as illustrated in Alternative 1.

Table 11 Conceptual Design Criteria
Alternative 4: Alternative 3 Plus Thermal Hydrolysis &
Alternative 4A: Alternative 4 with Partial Solar Drying

Parameter	Value
Pre-THP Dewatering with Centrifuges	
Number of units[1]	Two duty, one standby
Operating schedule[2]	Average: 11 hours/day, 7 days/week Max. Month: 14 hours/day, 7 days/week
Thermal Hydrolysis Pretreatment	
Number of reactors	One
Reactor operating temperature	330 degrees F
Steam requirement	Average: 1,970 lbs/hr at 390 degrees F Max. Month: 2,560 lbs/hr at 390 degrees F
Anaerobic Digestion	
Number of digesters[1]	Two
Tank dimensions & capacity	40' diameter x 43' sidewater depth, 0.425 MG each
Biogas produced	Average: 142 scfm (205,000 ft^3/day) Max. Month: 178 scfm (256,000 ft^3/day)
Post-Digestion Dewatering with Existing BFPs	
Belt width	2 meters
Number of units[3]	Two duty, no standby
Operating schedule[3]	Average: 8 hours/day, 6 days/week Max. Month: 10 hours/day, 6 days/week
Post-Digestion Dewatering with New BFPs	
Belt width	2 meters
Number of units[1]	Two duty, one standby
Operating schedule[2]	Average: 8 hours/day, 7 days/week Max. Month: 10 hours/day, 7 days/week
Solar Drying	
Number of solar dryers[1]	6 (Alternative 4) 2 (Alternative 4A – Phase I only)

[1] Number of units required in 2040.
[2] Operating schedule in 2040.
[3] Units in service and operating schedule until existing BFPs are retired in Phase II.



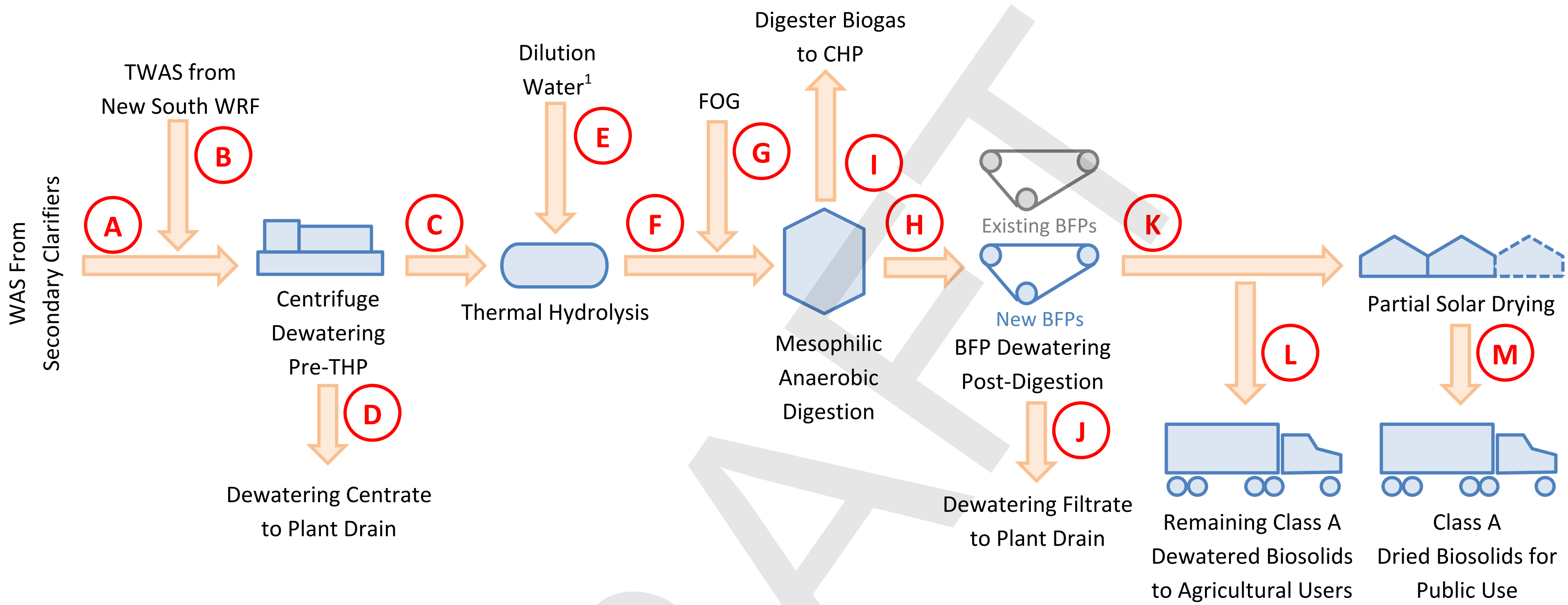
Label	Mass Solids	Concentration	Volume
A	22,700 lbs/day	0.84 % solids	323,000 gal/day
B	10,400 lbs/day	5.0 % solids	25,000 gal/day
C	31,400 lbs/day	20 % solids	2,830 ft^3/day
D	1,700 lbs/day	620 mg/L	329,000 gal/day
E	n/a	n/a	23,000 gal/day
F	31,400 lbs/day	9.0 % solids	42,000 gal/day

Label	Mass Solids	Concentration	Volume
G	1,900 lbs/day	4.0 % solids	5,800 gal/day
H	22,300 lbs/day	5.6 % solids	48,000 gal/day
I	n/a	n/a	205,000 ft^3/day
J	1,100 lbs/day	3,380 mg/L	39,000 gal/day
K	21,200 lbs/day	30 % solids	1,300 ft^3/day
L	21,200 lbs/day	75 % solids	760 ft^3/day

Mass balance is for 2040 average day.
[1] Potable water or disinfected reuse water.

CDM Smith

Figure 20
Mass Balance for Alternative 4



Label	Mass Solids	Concentration	Volume
A	22,300 lbs/day	0.84 % solids	318,000 gal/day
B	0 lbs/day	5.0 % solids	0 gal/day
C	21,200 lbs/day	20 % solids	1,900 ft^3/day
D	1,100 lbs/day	430 mg/L	305,000 gal/day
E	n/a	n/a	15,000 gal/day
F	21,200 lbs/day	9.0 % solids	28,000 gal/day
G	1,900 lbs/day	4.0 % solids	5,800 gal/day

Label	Mass Solids	Concentration	Volume
H	15,000 lbs/day	5.8 % solids	31,000 gal/day
I	n/a	n/a	132,000 ft^3/day
J	700 lbs/day	3,360 mg/L	25,000 gal/day
K	14,200 lbs/day	30 % solids	910 ft^3/day
L	6,800 lbs/day	30 % solids	440 ft^3/day
M	7,400 lbs/day	75 % solids	270 ft^3/day

Mass balance is for 2023 average day.
[1] Potable water or disinfected reuse water.

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Figure 20A
Mass Balance for Alternative 4A

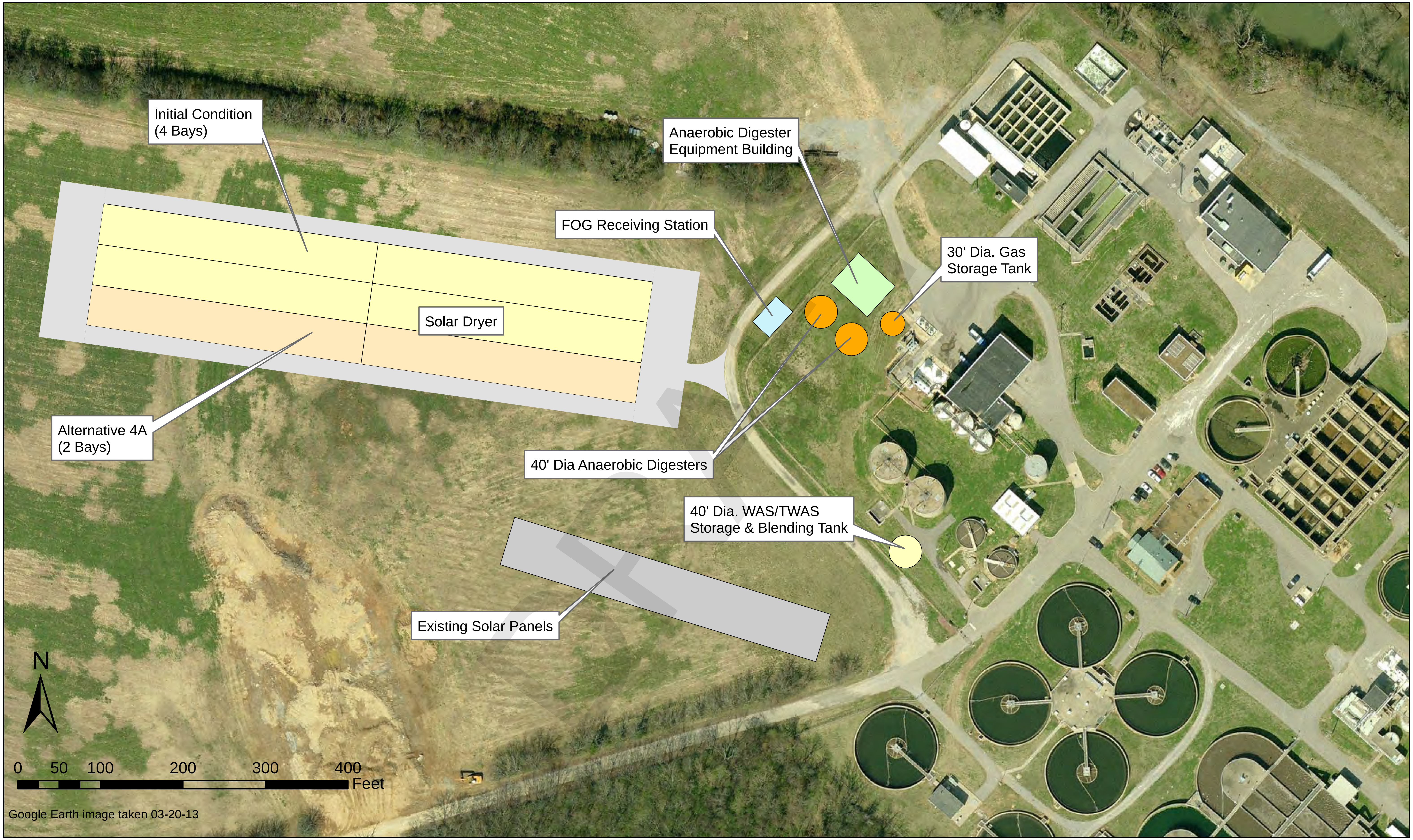

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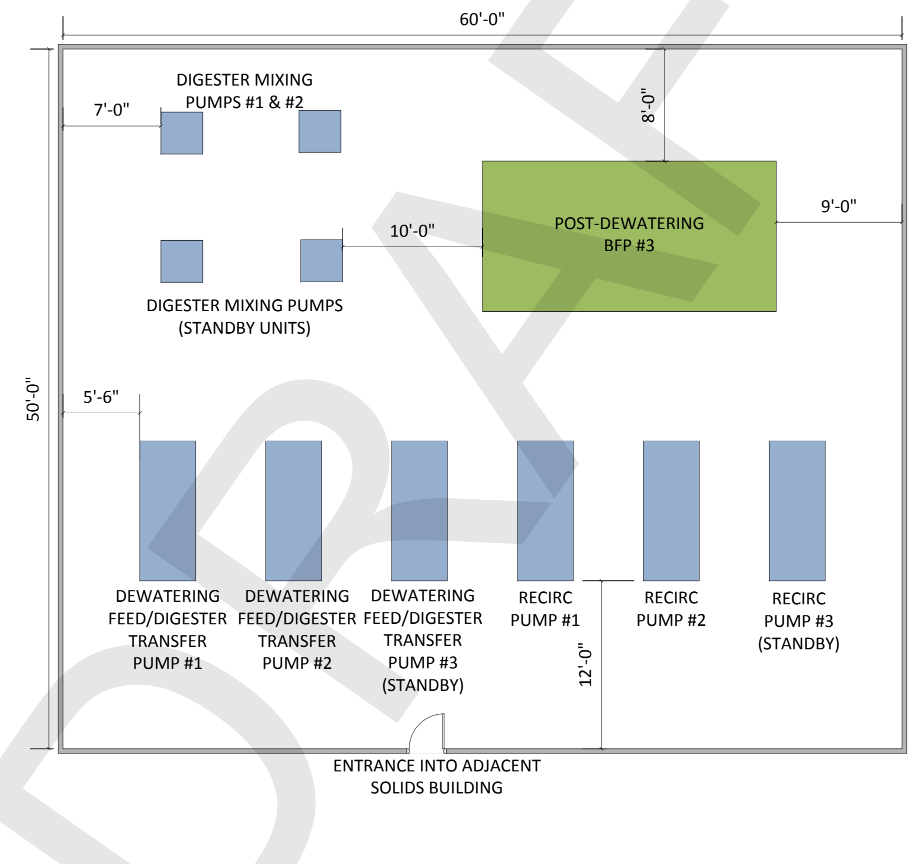
Figure 21
Proposed Site Layout for Alternatives 4 & 4A

PHASE I (CURRENT - 2024)

PHASE II (2024 – 2031)



CDM Smith

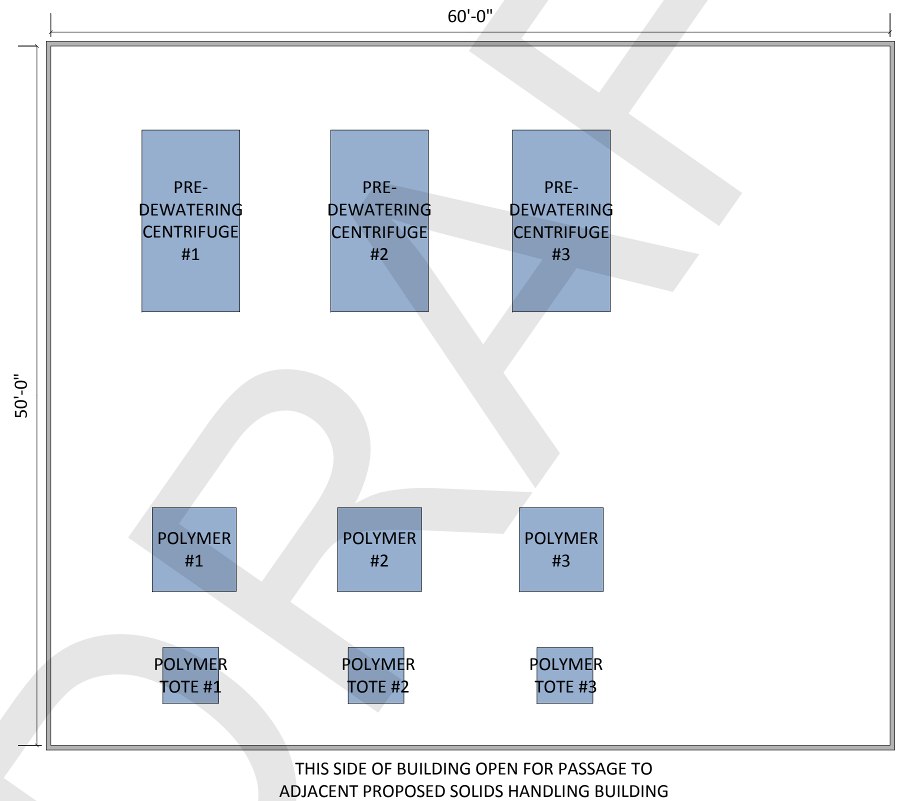
CITY OF FRANKLIN
WATER RECLAMATION FACILITY EXPANSION

PRELIMINARY SOLIDS HANDLING LAYOUT

FIGURE 22

PROPOSED DIGESTER BUILDING LAYOUT FOR ALTERNATIVE 4 & 4A – GROUND FLOOR

PHASE I (CURRENT 2024)



Notes:
1: A minimum of 8 feet is needed for scroll removal.

CDM Smith	CITY OF FRANKLIN WATER RECLAMATION FACILITY EXPANSION PRELIMINARY SOLIDS HANDLING LAYOUT	FIGURE 23 PROPOSED DIGESTER BUILDING LAYOUT FOR ALTERNATIVE 4 & 4A SECOND FLOOR

Evaluation of Alternatives

Economic Analysis

Table 12 provides a summary of each solids process alternative, its phasing, and estimated capital costs.

In Alternatives 3A and 4A, the scope of future expansion of the solar dryer will be determined at a later date after the City has gained first-hand O&M experience with the two Phase I solar dryers. Therefore, the Phase II, Phase III, and total estimated capital costs for these two alternatives do not include the solar dryer expansion.

Table 12 Summary of Project Phasing & Capital Costs

Process Train	Phase	Scope of Work	Estimated Cap. Cost at Each Phase (millions)	Net Present Cost of Three Phases[1] (millions)
Alternative 1: Continue Current Treatment Process	I	• 3 New DAF Systems • WAS & TWAS Storage • New Dewatering Building w/2 New BFPs • Odor Control System • Demolish Existing ATAD System	$18.0	$19.0
	II	• Replace BFPs in Existing Dewatering Building • Replace Odor Control in Existing Building • Truck Unloading for New South WRF TWAS	$3.4	
	III	No Work Anticipated	$0.0	
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	I	• New Thickening Bldg w/3 RDTs • WAS Storage • FOG Receiving & Storage • 2 0.85-MG Anaerobic Digesters w/CHP • Digester Building • Odor Control System • Demolish Existing ATAD & DAF Systems • Convert DAF Tanks into TWAS Storage	$33.0	$38.0
	II	• New Dewatering Bldg w/2 Screw Presses • Extend Odor Control to New Dewatering Bldg. • Retrofit Screw Press into Existing DW Bldg. • Truck Unloading for New South WRF TWAS • Add TWAS Storage	$11.6	
	III	Retrofit 2nd Screw Press into Existing Dewatering Bldg.	$1.6	

[1] 2013 dollars.

Table 12 Summary of Project Phasing & Capital Costs (cont.)

Process Train	Phase	Scope of Work	Estimated Cap. Cost at Each Phase (millions)	Net Present Cost of Three Phases[1] (millions)
<u>Alternative 3:</u> Alternative 2 Plus Solar Drying	I	• New Thickening Bldg w/3 RDTs • WAS Storage • FOG Receiving & Storage • 2 0.85-MG Anaerobic Digesters w/CHP • Digester Building • Odor Control System • 8 Solar Drying Chambers w/Odor Control • Demolish Existing ATAD & DAF Systems • Convert DAF Tanks into TWAS Storage	$66.0	$82.0
	II	• New Dewatering Bldg w/2 Screw Presses • Extend Odor Control to New Dewatering Bldg. • Retrofit Screw Press into Existing DW Bldg. • Truck Unloading for New South WRF TWAS • Add TWAS Storage • 2 Solar Drying Chambers w/Odor Control	$20.0	
	III	• Retrofit 2nd Screw Press into Existing DW Bldg. • 2 Solar Drying Chambers • Refurbish 6 Phase I Solar Drying Chambers	$21.0	
<u>Alternative 3A:</u> Alternative 3 with Partial Solar Drying	I	• New Thickening Bldg w/3 RDTs • WAS Storage • FOG Receiving & Storage • 2 0.85-MG Anaerobic Digesters w/CHP • Digester Building • Odor Control System • 2 Solar Drying Chambers w/Odor Control • Demolish Existing ATAD & DAF Systems • Convert DAF Tanks into TWAS Storage	$41.0	***$47.0***[2]
	II	• New Dewatering Bldg w/2 Screw Presses • Extend Odor Control to New Dewatering Bldg. • Retrofit Screw Press into Existing DW Bldg. • Truck Unloading for New South WRF TWAS • Add TWAS Storage • ***Solar Drying Expansion TBD***	***$12.0***[2]	
	III	• Retrofit 2nd Screw Press into Existing DW Bldg. • ***Solar Drying Expansion TBD*** • Refurbish 2 Phase I Solar Drying Chambers	***$5.0***[2]	

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

Table 12 Summary of Project Phasing & Capital Costs (cont.)

Process Train	Phase	Scope of Work	Estimated Cap. Cost at Each Phase (millions)	Net Present Cost of Three Phases[1] (millions)
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	I	• WAS Storage • FOG Receiving & Storage • 2 0.425-MG Anaerobic Digesters w/THP & CHP • Digester Building • 3 Pre-THP Dewatering Centrifuges • Odor Control System • 4 Solar Drying Chambers w/Odor Control • Demolish Existing ATAD & DAF Systems	$63.0	$69.0
	II	• Replace BFPs in Existing Dewatering Building • Replace Odor Control in Existing Building • 2 Solar Drying Chambers w/Odor Control • Truck Unloading for New South WRF TWAS	$14.0	
	III	• Refurbish 4 Phase I Solar Drying Chambers	$6.0	
Alternative 4A: Alternative 4 with Partial Solar Drying	I	• WAS Storage • FOG Receiving & Storage • 2 0.425-MG Anaerobic Digesters w/THP & CHP • Digester Building • 3 Pre-THP Dewatering Centrifuges • Odor Control System • 2 Solar Drying Chambers w/Odor Control • Demolish Existing ATAD & DAF Systems	$55.0	***$55.0[2]***
	II	• Replace BFPs in Existing Dewatering Building • Replace Odor Control in Existing Building • ***Solar Drying Expansion TBD*** • Truck Unloading for New South WRF TWAS	***$6.0[2]***	
	III	• Refurbish 2 Phase I Solar Drying Chambers	***$3.0[2]***	

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

The estimated Year 2023 (end of Phase I) and 2040 (end of Phase III) annual and per-DT O&M costs are listed below in **Tables 13 and 14.** Similar to the calculation of capital costs, the estimated Year 2040 O&M costs for Alternatives 3A and 4A do not include costs associated with the future expansion of the solar dryer. These costs will be determined when the scope of the future expansion is established.

Table 13 Year 2023 Estimated O&M Costs for Solids Treatment Alternatives

Process Train	Total O&M Cost[1] (millions)	Solids Processed (DT)		Solids Produced	O&M Cost per DT[1]	Rank
		In	Out			
Alternative 1: Continue Current Treatment Process	$1.4	4,100	3,700	Dewatered Sludge for Landfill Disposal	$344	6
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$0.9	4,100	2,800	Class B Biosolids for Agricultural Use	$215	1
Alternative 3: Alternative 2 Plus Solar Drying	$1.1	4,100	2,800	Class A Biosolids[2] for Public Use	$275	3
Alternative 3A: Alternative 3 with Partial Solar Drying	$1.0	4,100	2,800	Dried Class A Biosolids[2], Dewatered Class B Biosolids	$235	2
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$1.4	4,100	2,600	Class A Biosolids for Public Use	$335	5
Alternative 4A: Alternative 4 with Partial Solar Drying	$1.3	4,100	2,600	Dried Class A Biosolids, Dewatered Class A Biosolids	$324	4

[1] 2013 dollars.
[2] Class A status of solar drying process is subject to approval by TDEC.

Table 14 Year 2040 Estimated O&M Costs for Solids Treatment Alternatives

Process Train	Total O&M Cost[1] (millions)	Solids Processed (DT)		Solids Produced	O&M Cost per DT[1]	Rank
		In	Out			
Alternative 1: Continue Current Treatment Process	$1.4	6,100	5,500	Dewatered Sludge for Landfill Disposal	$228	6
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$0.8	6,100	4,200	Class B Biosolids for Agricultural Use	$126	1
Alternative 3: Alternative 2 Plus Solar Drying	$1.0	6,100	4,200	Class A Biosolids[1] for Public Use	$160	3
Alternative 3A: Alternative 3 with Partial Solar Drying	***$0.8***[3]	6,100	4,200	Dried Class A Biosolids[1], Dewatered Class B Biosolids	***$134***[3]	2
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$1.3	6,100	3,900	Class A Biosolids for Public Use	$214	5
Alternative 4A: Alternative 4 with Partial Solar Drying	***$1.2***[3]	6,100	3,900	Dried Class A Biosolids, Dewatered Class A Biosolids	***$204***[3]	4

[1] 2013 dollars.
[2] Class A status of solar drying process is subject to approval by TDEC.
[3] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

With the fewest individual processes, Alternative 1 has the lowest capital cost. However, this alternative's continued dependence on hauling the largest quantity of dewatered sludge to a landfill for disposal results in the highest O&M cost and per-DT O&M cost in 2023 and 2040.

In Alternative 3, the addition of a 12-chamber solar drying facility to Alternative 2 increases the capital cost to the highest of all six alternatives. Because it is assumed that Class A biosolids produced by Alternative 3 would be picked up at the Franklin WRF, the hauling costs are eliminated. However, the resulting per-DT O&M cost is higher than that of Alternative 2 due to the additional electricity and chemicals required to operate the solar dryer.

Alternative 3A, with only two solar dryers installed in Phase I, has a Phase I capital cost that is $25 million lower than Alternative 3. The per-DT O&M cost of Alternative 3A is also lower than that of Alternative 3. Hauling costs incurred in this option and in Alternative 4A are to transport the fraction of dewatered Class B biosolids that cannot be fed to the two solar dryers.

Alternative 4, with the addition of THP and a pre-THP dewatering step, has the second-highest capital cost. Because the addition of THP requires fewer solar dryers in this alternative, the Phase I capital cost reduction in Alternative 4A is not as great as that of Alternative 3A. The supplemental natural gas needed to generate steam for the THP process results in per-DT O&M costs that are second only to Alternative 1.

Overall, Alternatives 2 and 3A have the lowest O&M cost per DT.

Net Present Cost Comparison

Table 15 compares the NPC of the four alternatives. Alternatives 1 and 2 had the lowest NPC, whereas Alternatives 3 and 4 had the highest NPC due to their comparatively high estimated capital cost. Alternatives 3A and 4A do not include costs associated with potential Phase II and III expansions of the solar dryer.

Table 15 NPC of Solids Process Alternatives

Process Train	Total NPC of Estimated Capital Costs[1] (millions)	Total NPC of Est. Annual O&M Costs[1,2] (millions)	Total NPC[1] (millions)	Rank
Alternative 1: Continue Current Treatment Process	$18.5	$27.9	$46.0	1
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$38.1	$16.2	$54.0	2
Alternative 3: Alternative 2 Plus Solar Drying	$82.0	$20.9	$103.0	6
Alternative 3A: Alternative 3 with Partial Solar Drying	***$47.1***[3]	***$17.6***[3]	***$65.0***[3]	3
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$68.7	$27.9	$97.0	5
Alternative 4A: Alternative 4 with Partial Solar Drying	***$55.1***[3]	***$26.4***[3]	***$82.0***[3]	4

[1] 2013 dollars.
[2] Year 1 (2018) to Year 20 (2037).
[3] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

Potential Operating Cost Offsets from Power Generation and Sale of Dried Biosolids

Table 16 presents the potential value of the electricity generated by the CHP systems in Alternatives 2, 3, 3A, 4, and 4A, as well as the potential value of the dried biosolids produced by Alternatives 3, 3A, 4, and 4A over 20 years of operation. These potential values are presented in 2013 dollars.

It was assumed that all of the electricity generated by the CHP systems will be used onsite. Furthermore, the electricity values listed in Table 16 are based on the assumption that electricity pricing will escalate at the rate listed in Table 6.

It was also assumed that a third party will pay the City to haul away all of the available dried biosolids from the Franklin WRF. Values of the dried biosolids listed below were calculated in $5 per wet ton (WT) increments up to $30/WT, based on CDM Smith's understanding of current market pricing for dried biosolids.

Table 16 Potential 20-Year Operating Cost Offsets from Power Generation & Sale of Dried Biosolids

Process Train	20-Year Cost Offset from Power Generation[1] (millions)	20-Year Potential Value of Dried Biosolids (millions)[1]					
		$5/ WT	$10/ WT	$15/ WT	$20/ WT	$25/ WT	$30/ WT
Alternative 1: Continue Current Treatment Process	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$3.4	n/a	n/a	n/a	n/a	n/a	n/a
Alternative 3: Alternative 2 Plus Solar Drying	$4.0	$0.21	$0.41	$0.62	$0.82	$1.03	$1.24
Alternative 3A: Alternative 3 with Partial Solar Drying	$4.0	***$0.06***[2]	***$0.12***[2]	***$0.18***[2]	***$0.24***[2]	***$0.31***[2]	***$0.37***[2]
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$11.2	$0.19	$0.38	$0.57	$0.77	$0.96	$1.15
Alternative 4A: Alternative 4 with Partial Solar Drying	$11.2	***$0.09***[2]	***$0.18***[2]	***$0.28***[2]	***$0.37***[2]	***$0.46***[2]	***$0.55***[2]

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

The CHP systems in Alternatives 2, 3, and 3A are expected to provide an estimated $4 million cost offset over 20 years; because the CHP systems in Alternatives 4 and 4A produce more power, their cost offset is larger.

In **Table 17**, the potential cost offset from power generation is incorporated into the Year 2023 and 2040 annual and per-DT O&M costs. The potential cost offset from the sale of the dried biosolids was not included in the following tables because the actual selling price has not yet been established.

Table 17 Adjusted Year 2023 & 2040 O&M Costs – Power Generation Cost Offset Included

Process Train	Adjusted 2023 Total O&M Cost[1] (millions)	Adjusted 2023 O&M Cost per DT[1]	Adjusted 2040 Total O&M Cost[1] (millions)	Adjusted 2040 O&M Cost per DT[1]	Adjusted Rank
Alternative 1: Continue Current Treatment Process	$1.4 (no change)	$344 (no change)	$1.4 (no change)	$228 (no change)	6
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$0.7 (↓$0.2)	$167 (↓$48)	$0.5 (↓$0.2)	$89 (↓$36)	1
Alternative 3: Alternative 2 Plus Solar Drying	$0.9 (↓$0.2)	$227 (↓$48)	$0.8 (↓$0.2)	$124 (↓$36)	5 (was 3)
Alternative 3A: Alternative 3 with Partial Solar Drying	$0.8 (↓$0.2)	$187 (↓$48)	***$0.6[2] (↓$0.2)***	***$98[2] (↓$36)***	2
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$0.8 (↓$0.5)	$202 (↓$133)	$0.7 (↓$0.6)	$116 (↓$97)	4 (was 5)
Alternative 4A: Alternative 4 with Partial Solar Drying	$0.8 (↓$0.5)	$190 (↓$133)	***$0.7[2] (↓$0.6)***	***$106[2] (↓$97)***	3 (was 4)

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

These results, when compared to Tables 13 and 14, show that the inclusion of the power generation cost offset reduces the Year 2040 O&M cost per DT by about $36/DT (2013 dollars) in Alternatives 2, 3, and 3A. The reduction in O&M cost for Alternatives 4 and 4A is greater, at about $97/DT (2013 dollars), due to the larger quantity of electricity generated; the adjusted O&M costs for Alternatives 4 and 4A thus become more comparable to those of Alternatives 3 and 3A. However, as was the case before the offsets were applied, Alternatives 2 and 3A still have the lowest O&M cost per DT.

The adjusted NPCs are listed below in **Table 18.** Alternatives 3 and 4 remain the highest, and Alternatives 1 and 2 remain the lowest.

Table 18 Adjusted NPC of Solids Process Alternatives – Power Generation Cost Offset Included

Process Train	Total NPC of Estimated Capital Costs[1] (millions)	Adjusted Total NPC of Est. Annual O&M Costs[1,2] (millions)	Adjusted Total NPC[1] (millions)	Revised Rank
Alternative 1: Continue Current Treatment Process	$18.5	$27.9	$46.0 (no change)	1 (no change)
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$38.1	$12.1	$50.0 (↓$4.0)	2 (no change)
Alternative 3: Alternative 2 Plus Solar Drying	$82.0	$16.8	$99.0 (↓$4.0)	6 (no change)
Alternative 3A: Alternative 3 with Partial Solar Drying	***$47.1[1]***	***$13.6[1]***	***$61.0[1] (↓$4.0)***	***3 (no change)***
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$68.7	$16.7	$85.0 (↓$12.0)	5 (no change)
Alternative 4A: Alternative 4 with Partial Solar Drying	***$55.1[1]***	***$15.2[1]***	***$70.0[1] (↓$12.0)***	***4 (no change)***

[1] 2013 dollars.
[2] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

Supplemental tables listing the 20-year total cost of each alternative are included in **Appendix C.**

Greenhouse Gas Emissions

Table 19 lists the estimated 2040 greenhouse gas emissions and per-DT emissions. As the alternative that consumes the greatest amount of diesel fuel while producing dewatered sludge that cannot be beneficially reused, the net carbon emissions for Alternative 1 are positive; in other words, its net GHG impact is to add approximately 3,600 mT CO_2 to the atmosphere in 2040. In contrast, Alternatives 2, 3, 3A, 4, and 4A all produce biosolids and biogas that can be beneficially used; all of these alternatives have negative net carbon emissions (removing CO_2 from the atmosphere) or zero net carbon emissions (neither adding CO_2 to, nor removing CO_2 from, the atmosphere).

Table 19 Greenhouse Gas Impacts of Solids Treatment Alternatives

Process Train	Total Carbon Emissions (mT CO_2/year)	Total Carbon Emissions Reductions (mT CO_2/year)	Net Carbon Emissions (mT CO_2/year)
Alternative 1: Continue Current Treatment Process	7,400	(3,800)	3,600
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	4,200	(6,600)	(2,400)
Alternative 3: Alternative 2 Plus Solar Drying	6,600	(6,600)	0
Alternative 3A: Alternative 3 with Partial Solar Drying	***4,700***[1]	***(6,600)***[1]	***(1,900)***[1]
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	8,400	(12,100)	(3,700)
Alternative 4A: Alternative 4 with Partial Solar Drying	***7,400***[1]	***(12,100)***[1]	***(4,700)***[1]

[1] These calculations do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.
mT = metric ton

Non-Cost Analysis

In addition to the economic analysis described above, each solids process alternative was evaluated according to the following 11 non-cost criteria established by participants at the February 2, 2011, Biosolids Workshop. These criteria were used as the basis for evaluation of alternative solids process during the IWRP project, and they reflect the City's goals for its biosolids management program.

- **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.
- **Reduced 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 land 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 solids 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 WRF 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.

CDM Smith included the following three additional criteria as additional goals of a solids treatment design.

- **Impacts to liquid treatment processes.** Digestion of wastewater sludges in some alternatives releases nitrogen and phosphorus which, when returned to the head of the plant in the dewatering filtrate stream, can impose a considerable loading on the plant. This item is an evaluation of the relative impact of each process on the rest of the treatment plant.
- **Constructability – scheduling.** Of importance to the larger Franklin WRF upgrades project is the impact the solids treatment process has on the overall construction schedule. The more complex the solids treatment process, the greater the impact on the construction schedule.
- **Constructability – maintenance of plant operations (MOPO).** To minimize impact to the Franklin WRF's operations, new facilities should be designed to be constructed alongside the existing ones. All of the alternatives are believed to be relatively equal in terms of their degree of impact to plant operations.

The results of CDM Smith's non-cost scoring evaluation are attached as **Table 20.** A low score in this table indicates an alternative that is most closely aligned with the City's and CDM Smith's goals for biosolids management.

Table 20 Non-Cost Scoring Matrix for Solids Treatment Alternatives

	Non-Cost Criterion	Raw Scoring Criteria 1	Raw Scoring Criteria 3	Raw Scoring Criteria 5	Weight	Alternative 1: Continue Current Treatment Process – Raw Score	Alternative 1 – Comment	Alternative 1 – Weighted Score	Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering – Raw Score	Alternative 2 – Comment	Alternative 2 – Weighted Score	Alternative 3: Alternative 2 Plus Solar Drying – Raw Score	Alternative 3 – Comment	Alternative 3 – Weighted Score
1	Efficiency of operations	High efficiency	Moderate efficiency	Low efficiency	2	1	Lowest energy consumption; least complexity; least potential for impact on treatment process	2	3	Second lowest energy consumption; potential for high impact on treatment process due to phosphorus release in digesters	6	4	Second highest energy consumption; potential for high impact on treatment process due to phosphorus release in digesters	8
2	Reduced energy consumption (per DT solids processed) compared to 105 kWh/DT for current process	Reduced energy consumption	Minimal or no reduction in energy consumption	Increased energy consumption	2	3	Lowest electrical energy consumption (fewest treatment processes); no reduction in consumption compared to current process	6	3	Second lowest energy consumption; no reduction in consumption compared to current process	6	4	Second highest energy consumption; no reduction in consumption compared to current process	8
3	Sustainability	Most sustainable	Somewhat sustainable	Least sustainable	3	5	Least sustainable	15	3	Somewhat sustainable	9	1	Most sustainable	3
4	Diverse portfolio of product use/disposal options	Most options	Some options	Fewest options	3	5	Only option is to dispose of dewatered solids at landfill	15	3	Class B biosolids suitable for agricultural use only	9	1	Expected to produce Class A biosolids (pending TDEC approval) suitable for distribution to the public	3
5	Reliability	High reliability	Moderate reliability	Low reliability	1	1	Highly reliable equipment that is well known to the City	1	1	Blend of highly reliable equipment that is easy to operate and maintain	1	1	Blend of highly reliable equipment that is easy to operate and maintain	1
6	Risk reduction	Greatest reduction	Moderate reduction	Least reduction	3	5	Least reduction of risk due to single disposal option, largest number of truckloads needed for disposal, greatest number of miles driven on public roads	15	4	Some reduction of risk; dewatered biosolids can be land applied or disposed at landfill	12	3	Moderate reduction of risk due to multiple disposal options, no need for disposal by City trucks	9
7	Environmental/public acceptance	Most acceptable	Somewhat acceptable	Least acceptable	5	5	Least acceptable due to expense of landfill disposal with no potential for beneficial reuse	25	3	Dewatered biosolids meet Class B, are suitable for agricultural land application	15	2	Dried product is expected to meet Class A (pending TDEC approval); suitable for public use	10
8	Odor control	Lowest odor potential	Moderate odor potential	Highest odor potential	4	3	Moderate odor potential due to dewatering of undigested solids	12	1	Lower odor potential than Alternative 1 due to dewatering of digested biosolids	4	5	High odor potential due to large area of solar dryer	20
9	Automated processes	Fully automated	Somewhat automated	Least automated	2	2	Can be fully automated, except for disposal	4	2	Can be fully automated, except for disposal	4	2	Can be fully automated, except for disposal	4
10	Class A biosolids	Produces Class A biosolids	n/a	Does not produce Class A biosolids	5	5	Does not produce Class A biosolids	25	5	Does not produce Class A biosolids	25	1	Expected to produce Class A biosolids (pending TDEC approval)	5
11	Expandability strategy for growth	Easily expandable	n/a	Not easily expandable	1	1	Will be designed for easy expansion	1	1	Will be designed for easy expansion	1	1	Will be designed for easy expansion	1
12	Impacts to liquid treatment processes	Low impact	Moderate impact	High impact	3	2	Low impact - no digestion to release phosphorus	6	4	Potential for high impact due to phosphorus release in digesters; chemical application required	12	4	Potential for high impact due to phosphorus release in digesters; chemical application required	12
13	Constructability - Scheduling	Low impact	Moderate impact	High impact	2	1	Smallest scope, lowest impact	2	3	Moderate scope, moderate impact	6	4	Larger scope than Alternative 2, greater impact	8
14	Constructability - MOPO	Minimal effect on MOPO	n/a	Potentially adverse effect on MOPO	2	1	New processes can be constructed alongside existing ones	2	1	New processes can be constructed alongside existing ones	2	1	New processes can be constructed alongside existing ones	2
	Total Non-Cost Evaluation Score (out of 190 points)						**131**			**112**			**94**	
	Rank						**6**			**5**			**1**	

Table 20 Non-Cost Scoring Matrix for Solids Treatment Alternatives (cont.)

Non-Cost Criterion		Raw Scoring Criteria			Weight	Alternative 3A: Alternative 3 with Partial Solar Drying			Alternative 4: Alternative 3 Plus Thermal Hydrolysis			Alternative 4A: Alternative 4 with Partial Solar Drying		
		1	3	5		Raw Score	Comment	Weighted Score	Raw Score	Comment	Weighted Score	Raw Score	Comment	Weighted Score
1	Efficiency of operations	High efficiency	Moderate efficiency	Low efficiency	2	3	Second highest energy consumption, but lower than Alternative 3; potential for high impact on treatment process due to phosphorus release in digesters	6	5	Highest energy consumption; high complexity; potential for high impact on treatment process due to phosphorus release in digesters	10	5	Highest energy consumption; high complexity; potential for high impact on treatment process due to phosphorus release in digesters	10
2	Reduced energy consumption (per DT solids processed) compared to 105 kWh/DT for current process	Reduced energy consumption	Minimal or no reduction in energy consumption	Increased energy consumption	2	4	Second highest energy consumption; no reduction in consumption compared to current process	8	5	Highest energy consumption; no reduction in consumption compared to current process	10	5	Highest energy consumption; no reduction in consumption compared to current process	10
3	Sustainability	Most sustainable	Somewhat sustainable	Least sustainable	3	2	Very sustainable	6	2	Very sustainable	6	2	Very sustainable	6
4	Diverse portfolio of product use/disposal options	Most options	Some options	Fewest options	3	2	Expected to produce Class A biosolids suitable for distribution to the public (pending TDEC approval) & Class B dewatered biosolids for agricultural uses	6	1	Expected to produce Class A biosolids suitable for distribution to the public	3	1	Expected to produce Class A biosolids suitable for distribution to the public & Class A dewatered biosolids suitable for agricultural uses	3
5	Reliability	High reliability	Moderate reliability	Low reliability	1	1	Blend of highly reliable equipment that is easy to operate and maintain	1	2	Highly reliable equipment, but more intensive maintenance is needed	2	2	Highly reliable equipment, but more intensive maintenance is needed	2
6	Risk reduction	Greatest reduction	Moderate reduction	Least reduction	3	4	Moderate reduction of risk due to multiple disposal options, but some City trucks needed to dispose of biosolids that cannot be sent to solar dryer	12	1	Greatest reduction of risk due to multiple disposal options, least number of truckloads needed for disposal	3	2	Greatest reduction of risk due to multiple disposal options, but some City trucks needed to dispose of biosolids that cannot be sent to solar dryer	6
7	Environmental/public acceptance	Most acceptable	Somewhat acceptable	Least acceptable	5	3	Dried product is expected to meet Class A (pending TDEC approval); suitable for public use. Class B dewatered biosolids suitable for agricultural land application	15	1	Dried, hydrolyzed product is expected to meet Class A, has low odor and excellent properties for soil blending/land application. Greatest reduction in solids	5	2	Dried, hydrolyzed product as in Alternative 4, but some dewatered Class A biosolids produced too. Greatest reduction in solids	10
8	Odor control	Lowest odor potential	Moderate odor potential	Highest odor potential	4	3	High odor potential due to large area of solar dryer; lower potential than Alternative 3 due to smaller initial solar dryer installation	12	5	High odor potential due to pre-THP dewatering process, THP; slightly less odor potential at solar dryer compared to Alternative 3	20	4	High odor potential due to pre-THP dewatering process, THP; slightly lower potential than Alternative 4 due to smaller initial dryer installation; slightly less odor potential at solar dryer compared to Alternative 3	16
9	Automated processes	Fully automated	Somewhat automated	Least automated	2	2	Can be fully automated, except for disposal	4	2	Can be fully automated, except for disposal	4	2	Can be fully automated, except for disposal	4
10	Class A biosolids	Produces Class A biosolids	n/a	Does not produce Class A biosolids	5	2	Expected to produce some Class A biosolids (pending TDEC approval)	10	1	Expected to produce Class A biosolids	5	1	Expected to produce Class A biosolids	5
11	Expandability strategy for growth	Easily expandable	n/a	Not easily expandable	1	1	Will be designed for easy expansion	1	1	Will be designed for easy expansion	1	1	Will be designed for easy expansion	1
12	Impacts to liquid treatment processes	Low impact	Moderate impact	High impact	3	4	Potential for high impact due to phosphorus release in digesters; chemical application required	12	5	Potential for high impact due to phosphorus release in digesters, higher VS destruction; chemical application required	15	5	Potential for high impact due to phosphorus release in digesters, higher VS destruction; chemical application required	15
13	Constructability - Scheduling	Low impact	Moderate impact	High impact	2	3	Larger scope than Alternative 2, but smaller scope than Alternative 3 due to smaller solar dryer installation	6	5	Largest scope, greatest impact	10	4	Largest scope, but smaller scope than Alternative 4 due to smaller solar dryer installation	8
14	Constructability - MOPO	Minimal effect on MOPO	n/a	Potentially adverse effect on MOPO	2	1	New processes can be constructed alongside existing ones	2	1	New processes can be constructed alongside existing ones	2	1	New processes can be constructed alongside existing ones	2
Total Non-Cost Evaluation Score (out of 190 points)							**101**			**96**			**98**	
Rank							**4**			**2**			**3**	

The resulting ranking of each alternative, based on cost and non-cost scoring, is as follows.

Table 21 Cost and Non-Cost Scoring of Franklin WRF Solids Process Alternatives

Process Train	Present Cost Ranking	Non-Cost Evaluation Ranking
Alternative 1: Continue Current Treatment Process	1	6
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	2	5
Alternative 3: Alternative 2 Plus Solar Drying	6	1
Alternative 3A: Alternative 3 with Partial Solar Drying	3	4
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	5	2
Alternative 4A: Alternative 4 with Partial Solar Drying	4	3

Recommendations

Based on the results of the economic evaluation and the non-cost scoring, CDM Smith recommends replacement of the Franklin WRF's existing solids treatment process with the systems included in Alternative 3A.

After the two solar dryers are installed and the City demonstrates to TDEC that the process can achieve Class A treatment, Alternative 3A is anticipated to achieve the City's goal of producing Class A dried biosolids that can be distributed to the public, as well as Class B dewatered biosolids that can be land applied for agricultural uses. Class A and B biosolids afford the City multiple disposal options compared to the dewatered sludge currently produced, which can only be disposed in a landfill. The estimated O&M cost for Alternative 3A is also substantially lower than the cost to continue with the current solids treatment practice.

Alternative 3A allows the City to gain real-world experience with solar drying at a Phase I construction cost that is $25 million less than the Phase I construction cost of Alternative 3. The adjusted NPC of Alternative 3A is also $39 million less than that of Alternative 3.

cc: Project File

Appendix A

Capital Cost & Net Present Cost Tables

Appendix A-1
Opinion of Probable Construction Cost for Solids Treatment Improvements - Alternative 1

		Phase I (16 MGD)				Phase II (+4 MGD)				Phase III (+4 MGD)			
		Thickening	Stabilization	Dewatering	Drying	Thickening	Stabilization	Dewatering	Drying	Thickening	Stabilization	Dewatering	Drying
Construction Cost Component	% of Cost	DAF	None	Belt Filter Press	None	DAF	None	Belt Filter Press	None	DAF	None	Belt Filter Press	None
Facilities & Equipment													
Process Equipment	n/a	$1,365,000	$0	$900,000	$0	$15,000	$0	$805,000	$0	$0	$0	$0	$0
Structure (where applicable)	n/a	$791,000	$0	$2,250,000	$0	$0	$0	$75,000	$0	$0	$0	$0	$0
Demolition (where applicable)	n/a	$75,000	$0	$125,000	$0	$0	$0	$75,000	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$409,500	$0	$270,000	$0	$4,500	$0	$241,500	$0	$0	$0	$0	$0
Allowances													
Sitework	5%	$132,025	$0	$177,250	$0	$975	$0	$59,825	$0	$0	$0	$0	$0
Piping	15%	$396,075	$0	$531,750	$0	$2,925	$0	$179,475	$0	$0	$0	$0	$0
Instrumentation & Electrical	25%	$660,125	$0	$886,250	$0	$4,875	$0	$299,125	$0	$0	$0	$0	$0
CONSTRUCTION SUBTOTAL		**$3,828,725**	$0	**$5,140,250**	**$0**	**$28,275**	$0	**$1,734,925**	**$0**	**$0**	$0	**$0**	**$0**
Permits	1.0%	$38,287	$0	$51,403	$0	$283	$0	$17,349	$0	$0	$0	$0	$0
Sales Tax	9.25%	$138,889	$0	$91,575	$0	$1,526	$0	$81,909	$0	$0	$0	$0	$0
Bonds & Insurance													
Builder's Risk	0.5%	$19,144	$0	$25,701	$0	$141	$0	$8,675	$0	$0	$0	$0	$0
General Liability	1.0%	$38,287	$0	$51,403	$0	$283	$0	$17,349	$0	$0	$0	$0	$0
GC Bonds	1.5%	$57,431	$0	$77,104	$0	$424	$0	$26,024	$0	$0	$0	$0	$0
SUBTOTAL #1		**$4,120,763**	$0	**$5,437,435**	**$0**	**$30,932**	$0	**$1,886,231**	**$0**	**$0**	$0	**$0**	**$0**
General Conditions/OH&P													
General Conditions	10%	$412,076	$0	$543,744	$0	$3,093	$0	$188,623	$0	$0	$0	$0	$0
Overhead & Profit	10%	$412,076	$0	$543,744	$0	$3,093	$0	$188,623	$0	$0	$0	$0	$0
SUBTOTAL #2		**$4,944,915**	$0	**$6,524,922**	**$0**	**$37,119**	$0	**$2,263,477**	**$0**	**$0**	$0	**$0**	**$0**
Contingency													
Construction Contingency	30%	$1,210,475	$0	$1,777,477	$0	$8,136	$0	$518,043	$0	$0	$0	$0	$0
SUBTOTAL #3		**$6,155,390**	$0	**$8,302,399**	**$0**	**$45,254**	$0	**$2,781,520**	**$0**	**$0**	$0	**$0**	**$0**
Escalation	0.0%	**$0**	$0	**$0**	**$0**	**$0**	$0	**$0**	**$0**	**$0**	$0	**$0**	**$0**
CONSTRUCTION TOTAL		**$6,155,000**	$0	**$8,302,000**	**$0**	**$45,000**	$0	**$2,782,000**	**$0**	**$0**	$0	**$0**	**$0**
Design & Construction Services	15%	$923,000	$0	$1,245,000	$0	$7,000	$0	$417,000	$0	$0	$0	$0	$0
City Project Administration	2.0%	$123,000	$0	$166,000	$0	$1,000	$0	$56,000	$0	$0	$0	$0	$0
Legal/Finance	3.0%	$185,000	$0	$249,000	$0	$1,000	$0	$83,000	$0	$0	$0	$0	$0
Allowances		**$0**	$0	**$0**	**$0**	**$0**	$0	**$0**	**$0**	**$0**	$0	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$7,386,000**	$0	**$9,962,000**	**$0**	**$54,000**	$0	**$3,338,000**	**$0**	**$0**	$0	**$0**	**$0**
EACH PHASE CAPITAL COST (2013)		**$18,000,000**				**$3,400,000**				**$0**			
YEAR INCURRED		**2015**				**2022**				**2030**			

Appendix A-2
Net Present Cost Calculation for Alternative 1

Calendar Year	Op. Year	Alternative 1 - Continue Current Treatment Process					
		Capital Cost	PC of Capital Cost	Total O&M Cost	PC of O&M Cost	O&M Cost per DT	PC of O&M Cost per DT
2013	-4						
2014	-3						
2015	-2	$18,000,000	$16,300,000				
2016	-1						
2017	0						
2018	1			$1,696,000	$1,329,000	$494	$387
2019	2			$1,803,000	$1,345,000	$506	$378
2020	3			$1,914,000	$1,360,000	$519	$369
2021	4			$2,030,000	$1,374,000	$533	$361
2022	5	$3,400,000	$2,200,000	$2,152,000	$1,387,000	$546	$352
2023	6			$2,278,000	$1,399,000	$561	$344
2024	7			$2,370,000	$1,386,000	$566	$331
2025	8			$2,499,000	$1,392,000	$580	$323
2026	9			$2,634,000	$1,397,000	$595	$315
2027	10			$2,775,000	$1,401,000	$610	$308
2028	11			$2,921,000	$1,405,000	$625	$301
2029	12			$3,073,000	$1,408,000	$641	$294
2030	13	$0		$3,232,000	$1,410,000	$658	$287
2031	14			$3,397,000	$1,412,000	$675	$280
2032	15			$3,569,000	$1,412,000	$692	$274
2033	16			$3,748,000	$1,413,000	$710	$268
2034	17			$3,934,000	$1,412,000	$729	$262
2035	18			$4,128,000	$1,411,000	$748	$256
2036	19			$4,330,000	$1,410,000	$768	$250
2037	20			$4,540,000	$1,408,000	$788	$244
2038	21			$4,758,000	$1,405,000	$809	$239
2039	22			$4,985,000	$1,402,000	$830	$234
2040	23			$5,221,000	$1,398,000	$852	$228
Total NPC of Capital Costs		$18,500,000					
Total NPC of Annual O&M Costs (2018-2037)		$27,900,000					
Total NPC		**$46,000,000**					

Appendix A-3
Opinion of Probable Construction Cost for Solids Treatment Improvements - Alternative 2

Construction Cost Component	% of Cost	Phase I (16 MGD)				Phase II (+4 MGD)				Phase III (+4 MGD)			
		Thickening	Stabilization incl. CHP	Dewatering	Drying	Thickening	Stabilization incl. CHP	Dewatering	Drying	Thickening	Stabilization incl. CHP	Dewatering	Drying
		Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	None	Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	None	Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	None
Facilities & Equipment													
Process Equipment	n/a	$1,015,000	$3,800,000	$0	$0	$40,000	$0	$1,710,000	$0	$0	$0	$385,000	$0
Structure (where applicable)	n/a	$2,565,000	$2,496,394	$0	$0	$72,000	$0	$1,747,500	$0	$0	$0	$37,500	$0
Demolition (where applicable)	n/a	$60,000	$0	$125,000	$0	$0	$0	$37,500	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$304,500	$1,140,000	$0	$0	$12,000	$0	$513,000	$0	$0	$0	$115,500	$0
Allowances													
Sitework	5%	$197,225	$371,820	$6,250	$0	$6,200	$0	$200,400	$0	$0	$0	$26,900	$0
Piping	15%	$591,675	$1,115,459	$18,750	$0	$18,600	$0	$601,200	$0	$0	$0	$80,700	$0
Instrumentation & Electrical	25%	$986,125	$1,859,098	$31,250	$0	$31,000	$0	$1,002,000	$0	$0	$0	$134,500	$0
CONSTRUCTION SUBTOTAL		**$5,719,525**	**$10,782,771**	**$181,250**	**$0**	**$179,800**	**$0**	**$5,811,600**	**$0**	**$0**	**$0**	**$780,100**	**$0**
Permits	1.0%	$57,195	$107,828	$1,813	$0	$1,798	$0	$58,116	$0	$0	$0	$7,801	$0
Sales Tax	9.25%	$103,276	$386,650	$0	$0	$4,070	$0	$173,993	$0	$0	$0	$39,174	$0
Bonds & Insurance													
Builder's Risk	0.5%	$28,598	$53,914	$906	$0	$899	$0	$29,058	$0	$0	$0	$3,901	$0
General Liability	1.0%	$57,195	$107,828	$1,813	$0	$1,798	$0	$58,116	$0	$0	$0	$7,801	$0
GC Bonds	1.5%	$85,793	$161,742	$2,719	$0	$2,697	$0	$87,174	$0	$0	$0	$11,702	$0
SUBTOTAL #1		**$6,051,582**	**$11,600,731**	**$188,500**	**$0**	**$191,062**	**$0**	**$6,218,057**	**$0**	**$0**	**$0**	**$850,478**	**$0**
General Conditions/OH&P													
General Conditions	10%	$605,158	$1,160,073	$18,850	$0	$19,106	$0	$621,806	$0	$0	$0	$85,048	$0
Overhead & Profit	10%	$605,158	$1,160,073	$18,850	$0	$19,106	$0	$621,806	$0	$0	$0	$85,048	$0
SUBTOTAL #2		**$7,261,899**	**$13,920,878**	**$226,200**	**$0**	**$229,274**	**$0**	**$7,461,668**	**$0**	**$0**	**$0**	**$1,020,573**	**$0**
Contingency													
Construction Contingency	30%	$1,975,570	$3,416,263	$67,860	$0	$60,782	$0	$1,896,500	$0	$0	$0	$229,172	$0
SUBTOTAL #3		**$9,237,468**	**$17,337,141**	**$294,060**	**$0**	**$290,057**	**$0**	**$9,358,168**	**$0**	**$0**	**$0**	**$1,249,745**	**$0**
Escalation	0.0%	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CONSTRUCTION TOTAL		**$9,237,000**	**$17,337,000**	**$294,000**	**$0**	**$290,000**	**$0**	**$9,358,000**	**$0**	**$0**	**$0**	**$1,250,000**	**$0**
Design & Construction Services	15%	$1,386,000	$2,601,000	$44,000	$0	$44,000	$0	$1,404,000	$0	$0	$0	$188,000	$0
City Project Administration	2.0%	$185,000	$347,000	$6,000	$0	$6,000	$0	$187,000	$0	$0	$0	$25,000	$0
Legal/Finance	3.0%	$277,000	$520,000	$9,000	$0	$9,000	$0	$281,000	$0	$0	$0	$38,000	$0
Allowances		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$11,085,000**	**$20,805,000**	**$353,000**	**$0**	**$349,000**	**$0**	**$11,230,000**	**$0**	**$0**	**$0**	**$1,501,000**	**$0**
EACH PHASE CAPITAL COST (2013)		**$33,000,000**				**$11,600,000**				**$1,600,000**			
YEAR INCURRED		**2015**				**2022**				**2030**			

Appendix A-4
Net Present Cost Calculation for Alternative 2

Calendar Year	Op. Year	Alternative 2 - Replace Thickening, Add Digestion & Screw Press Dewatering					
		Capital Cost	PC of Capital Cost	Total O&M Cost	PC of O&M Cost	O&M Cost per DT	PC of O&M Cost per DT
2013	-4						
2014	-3						
2015	-2	$33,000,000	$29,900,000				
2016	-1						
2017	0						
2018	1			$1,072,000	$840,000	$312	$244
2019	2			$1,117,000	$834,000	$314	$234
2020	3			$1,164,000	$828,000	$316	$225
2021	4			$1,214,000	$821,000	$318	$216
2022	5	$11,600,000	$7,500,000	$1,265,000	$815,000	$321	$207
2023	6			$1,420,000	$872,000	$349	$215
2024	7			$1,461,000	$854,000	$349	$204
2025	8			$1,518,000	$845,000	$352	$196
2026	9			$1,577,000	$836,000	$356	$189
2027	10			$1,639,000	$828,000	$360	$182
2028	11			$1,702,000	$819,000	$364	$175
2029	12			$1,768,000	$810,000	$369	$169
2030	13	$1,600,000	$700,000	$1,837,000	$802,000	$374	$163
2031	14			$1,908,000	$793,000	$379	$157
2032	15			$1,990,000	$787,000	$386	$153
2033	16			$2,066,000	$779,000	$392	$148
2034	17			$2,146,000	$770,000	$398	$143
2035	18			$2,228,000	$762,000	$404	$138
2036	19			$2,314,000	$753,000	$410	$134
2037	20			$2,403,000	$745,000	$417	$129
2038	21			$2,495,000	$737,000	$424	$125
2039	22			$2,774,000	$780,000	$462	$130
2040	23			$2,878,000	$771,000	$470	$126
Total NPC of Capital Costs		$38,100,000					
Total NPC of Annual O&M Costs (2018-2037)		$16,200,000					
Total NPC		**$54,000,000**					

Appendix A-5
Opinion of Probable Construction Cost for Solids Treatment Improvements - Alternative 3

Construction Cost Component	% of Cost	Phase I (16 MGD)				Phase II (+4 MGD)				Phase III (+4 MGD)			
		Thickening	Stabilization incl. CHP	Dewatering	Drying	Thickening	Stabilization incl. CHP	Dewatering	Drying	Thickening	Stabilization incl. CHP	Dewatering	Drying
		Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	Solar Dryer	Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	Solar Dryer	Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	Solar Dryer
Facilities & Equipment													
Process Equipment	n/a	$1,015,000	$3,800,000	$0	$8,048,000	$40,000	$0	$1,710,000	$2,012,000	$0	$0	$385,000	$4,920,000
Structure (where applicable)	n/a	$2,565,000	$2,496,394	$0	$1,539,200	$72,000	$0	$1,747,500	$384,800	$0	$0	$37,500	$384,800
Demolition (where applicable)	n/a	$60,000	$0	$125,000	$0	$0	$0	$37,500	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$304,500	$1,140,000	$0	$2,414,400	$12,000	$0	$513,000	$603,600	$0	$0	$115,500	$1,476,000
Allowances													
Sitework	5%	$197,225	$371,820	$6,250	$600,080	$6,200	$0	$200,400	$150,020	$0	$0	$26,900	$339,040
Piping	15%	$591,675	$1,115,459	$18,750	$1,800,240	$18,600	$0	$601,200	$450,060	$0	$0	$80,700	$1,017,120
Instrumentation & Electrical	25%	$986,125	$1,859,098	$31,250	$3,000,400	$31,000	$0	$1,002,000	$750,100	$0	$0	$134,500	$1,695,200
CONSTRUCTION SUBTOTAL		**$5,719,525**	**$10,782,771**	**$181,250**	**$17,402,320**	**$179,800**	**$0**	**$5,811,600**	**$4,350,580**	**$0**	**$0**	**$780,100**	**$9,832,160**
Permits	1.0%	$57,195	$107,828	$1,813	$174,023	$1,798	$0	$58,116	$43,506	$0	$0	$7,801	$98,322
Sales Tax	9.25%	$103,276	$386,650	$0	$818,884	$4,070	$0	$173,993	$204,721	$0	$0	$39,174	$500,610
Bonds & Insurance													
Builder's Risk	0.5%	$28,598	$53,914	$906	$87,012	$899	$0	$29,058	$21,753	$0	$0	$3,901	$49,161
General Liability	1.0%	$57,195	$107,828	$1,813	$174,023	$1,798	$0	$58,116	$43,506	$0	$0	$7,801	$98,322
GC Bonds	1.5%	$85,793	$161,742	$2,719	$261,035	$2,697	$0	$87,174	$65,259	$0	$0	$11,702	$147,482
SUBTOTAL #1		**$6,051,582**	**$11,600,731**	**$188,500**	**$18,917,297**	**$191,062**	**$0**	**$6,218,057**	**$4,729,324**	**$0**	**$0**	**$850,478**	**$10,726,056**
General Conditions/OH&P													
General Conditions	10%	$605,158	$1,160,073	$18,850	$1,891,730	$19,106	$0	$621,806	$472,932	$0	$0	$85,048	$1,072,606
Overhead & Profit	10%	$605,158	$1,160,073	$18,850	$1,891,730	$19,106	$0	$621,806	$472,932	$0	$0	$85,048	$1,072,606
SUBTOTAL #2		**$7,261,899**	**$13,920,878**	**$226,200**	**$22,700,756**	**$229,274**	**$0**	**$7,461,668**	**$5,675,189**	**$0**	**$0**	**$1,020,573**	**$12,871,268**
Contingency													
Construction Contingency	30%	$1,975,570	$3,416,263	$67,860	$5,200,627	$60,782	$0	$1,896,500	$1,300,157	$0	$0	$229,172	$2,877,380
SUBTOTAL #3		**$9,237,468**	**$17,337,141**	**$294,060**	**$27,901,383**	**$290,057**	**$0**	**$9,358,168**	**$6,975,346**	**$0**	**$0**	**$1,249,745**	**$15,748,648**
Escalation	0.0%	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CONSTRUCTION TOTAL		**$9,237,000**	**$17,337,000**	**$294,000**	**$27,901,000**	**$290,000**	**$0**	**$9,358,000**	**$6,975,000**	**$0**	**$0**	**$1,250,000**	**$15,749,000**
Design & Construction Services	15%	$1,386,000	$2,601,000	$44,000	$4,185,000	$44,000	$0	$1,404,000	$1,046,000	$0	$0	$188,000	$2,362,000
City Project Administration	2.0%	$185,000	$347,000	$6,000	$558,000	$6,000	$0	$187,000	$140,000	$0	$0	$25,000	$315,000
Legal/Finance	3.0%	$277,000	$520,000	$9,000	$837,000	$9,000	$0	$281,000	$209,000	$0	$0	$38,000	$472,000
Allowances		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$11,085,000**	**$20,805,000**	**$353,000**	**$33,481,000**	**$349,000**	**$0**	**$11,230,000**	**$8,370,000**	**$0**	**$0**	**$1,501,000**	**$18,898,000**
EACH PHASE CAPITAL COST (2013)		**$66,000,000**				**$20,000,000**				**$21,000,000**			
YEAR INCURRED		**2015**				**2022**				**2030**			

Appendix A-6
Net Present Cost Calculation for Alternative 3

Calendar Year	Op. Year	Alternative 3 - Alternative 2 Plus Solar Drying					
		Capital Cost	PC of Capital Cost	Total O&M Cost	PC of O&M Cost	O&M Cost per DT	PC of O&M Cost per DT
2013	-4						
2014	-3						
2015	-2	$66,000,000	$59,900,000				
2016	-1						
2017	0						
2018	1			$1,418,000	$1,111,000	$413	$323
2019	2			$1,459,000	$1,089,000	$410	$306
2020	3			$1,502,000	$1,067,000	$407	$290
2021	4			$1,546,000	$1,046,000	$406	$275
2022	5	$20,000,000	$12,900,000	$1,666,000	$1,074,000	$423	$273
2023	6			$1,818,000	$1,116,000	$447	$275
2024	7			$1,886,000	$1,103,000	$450	$263
2025	8			$1,938,000	$1,079,000	$450	$251
2026	9			$1,993,000	$1,057,000	$450	$239
2027	10			$2,049,000	$1,035,000	$450	$227
2028	11			$2,197,000	$1,057,000	$470	$226
2029	12			$2,260,000	$1,035,000	$472	$216
2030	13	$21,000,000	$9,200,000	$2,325,000	$1,014,000	$473	$206
2031	14			$2,392,000	$994,000	$475	$197
2032	15			$2,568,000	$1,016,000	$498	$197
2033	16			$2,743,000	$1,034,000	$520	$196
2034	17			$2,820,000	$1,012,000	$522	$188
2035	18			$2,900,000	$991,000	$525	$180
2036	19			$2,982,000	$971,000	$529	$172
2037	20			$3,068,000	$951,000	$532	$165
2038	21			$3,276,000	$967,000	$557	$164
2039	22			$3,554,000	$1,000,000	$592	$167
2040	23			$3,658,000	$980,000	$597	$160
Total NPC of Capital Costs		$82,000,000					
Total NPC of Annual O&M Costs (2018-2037)		$20,900,000					
Total NPC		**$103,000,000**					

Appendix A-7
Opinion of Probable Construction Cost for Solids Treatment Improvements - Alternative 3A

Construction Cost Component	% of Cost	Phase I (16 MGD)				Phase II (+4 MGD)				Phase III (+4 MGD)			
		Thickening	Stabilization incl. CHP	Dewatering	Drying	Thickening	Stabilization incl. CHP	Dewatering	Drying	Thickening	Stabilization incl. CHP	Dewatering	Drying
		Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	Solar Dryer	Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	Solar Dryer	Rotary Drum Thickener	Mesophilic Anaerobic Digestion	BFP & Screw Press	Solar Dryer
Facilities & Equipment													
Process Equipment	n/a	$1,015,000	$3,800,000	$0	$2,012,000	$40,000	$0	$1,710,000	$0	$0	$0	$385,000	$727,000
Structure (where applicable)	n/a	$2,565,000	$2,496,394	$0	$384,800	$72,000	$0	$1,747,500	$0	$0	$0	$37,500	$0
Demolition (where applicable)	n/a	$60,000	$0	$125,000	$0	$0	$0	$37,500	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$304,500	$1,140,000	$0	$603,600	$12,000	$0	$513,000	$0	$0	$0	$115,500	$218,100
Allowances													
Sitework	5%	$197,225	$371,820	$6,250	$150,020	$6,200	$0	$200,400	$0	$0	$0	$26,900	$47,255
Piping	15%	$591,675	$1,115,459	$18,750	$450,060	$18,600	$0	$601,200	$0	$0	$0	$80,700	$141,765
Instrumentation & Electrical	25%	$986,125	$1,859,098	$31,250	$750,100	$31,000	$0	$1,002,000	$0	$0	$0	$134,500	$236,275
CONSTRUCTION SUBTOTAL		**$5,719,525**	**$10,782,771**	**$181,250**	**$4,350,580**	**$179,800**	**$0**	**$5,811,600**	**$0**	**$0**	**$0**	**$780,100**	**$1,370,395**
Permits	1.0%	$57,195	$107,828	$1,813	$43,506	$1,798	$0	$58,116	$0	$0	$0	$7,801	$13,704
Sales Tax	9.25%	$103,276	$386,650	$0	$204,721	$4,070	$0	$173,993	$0	$0	$0	$39,174	$73,972
Bonds & Insurance													
Builder's Risk	0.5%	$28,598	$53,914	$906	$21,753	$899	$0	$29,058	$0	$0	$0	$3,901	$6,852
General Liability	1.0%	$57,195	$107,828	$1,813	$43,506	$1,798	$0	$58,116	$0	$0	$0	$7,801	$13,704
GC Bonds	1.5%	$85,793	$161,742	$2,719	$65,259	$2,697	$0	$87,174	$0	$0	$0	$11,702	$20,556
SUBTOTAL #1		**$6,051,582**	**$11,600,731**	**$188,500**	**$4,729,324**	**$191,062**	**$0**	**$6,218,057**	**$0**	**$0**	**$0**	**$850,478**	**$1,499,183**
General Conditions/OH&P													
General Conditions	10%	$605,158	$1,160,073	$18,850	$472,932	$19,106	$0	$621,806	$0	$0	$0	$85,048	$149,918
Overhead & Profit	10%	$605,158	$1,160,073	$18,850	$472,932	$19,106	$0	$621,806	$0	$0	$0	$85,048	$149,918
SUBTOTAL #2		**$7,261,899**	**$13,920,878**	**$226,200**	**$5,675,189**	**$229,274**	**$0**	**$7,461,668**	**$0**	**$0**	**$0**	**$1,020,573**	**$1,799,020**
Contingency													
Construction Contingency	30%	$1,975,570	$3,416,263	$67,860	$1,300,157	$60,782	$0	$1,896,500	$0	$0	$0	$229,172	$394,306
SUBTOTAL #3		**$9,237,468**	**$17,337,141**	**$294,060**	**$6,975,346**	**$290,057**	**$0**	**$9,358,168**	**$0**	**$0**	**$0**	**$1,249,745**	**$2,193,326**
Escalation	0.0%	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CONSTRUCTION TOTAL		**$9,237,000**	**$17,337,000**	**$294,000**	**$6,975,000**	**$290,000**	**$0**	**$9,358,000**	**$0**	**$0**	**$0**	**$1,250,000**	**$2,193,000**
Design & Construction Services	15%	$1,386,000	$2,601,000	$44,000	$1,046,000	$44,000	$0	$1,404,000	$0	$0	$0	$188,000	$329,000
City Project Administration	2.0%	$185,000	$347,000	$6,000	$140,000	$6,000	$0	$187,000	$0	$0	$0	$25,000	$44,000
Legal/Finance	3.0%	$277,000	$520,000	$9,000	$209,000	$9,000	$0	$281,000	$0	$0	$0	$38,000	$66,000
Allowances		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$11,085,000**	**$20,805,000**	**$353,000**	**$8,370,000**	**$349,000**	**$0**	**$11,230,000**	**$0**	**$0**	**$0**	**$1,501,000**	**$2,632,000**
EACH PHASE CAPITAL COST (2013)		**$41,000,000**				**$12,000,000**				**$5,000,000**			
YEAR INCURRED		**2015**				**2022**				**2030**			

Appendix A-8
Net Present Cost Calculation for Alternative 3A

Calendar Year	Op. Year	Alternative 3A - Alternative 3 with Partial Solar Drying					
		Capital Cost	PC of Capital Cost	Total O&M Cost	PC of O&M Cost	O&M Cost per DT	PC of O&M Cost per DT
2013	-4						
2014	-3						
2015	-2	$41,000,000	$37,200,000				
2016	-1						
2017	0						
2018	1			$1,193,000	$935,000	$347	$272
2019	2			$1,241,000	$926,000	$349	$260
2020	3			$1,291,000	$917,000	$350	$249
2021	4			$1,343,000	$909,000	$352	$238
2022	5	$12,000,000	$7,700,000	$1,396,000	$900,000	$355	$229
2023	6			$1,554,000	$954,000	$382	$235
2024	7			$1,588,000	$929,000	$379	$222
2025	8			$1,648,000	$918,000	$382	$213
2026	9			$1,710,000	$907,000	$386	$205
2027	10			$1,774,000	$896,000	$390	$197
2028	11			$1,840,000	$885,000	$394	$190
2029	12			$1,910,000	$875,000	$398	$183
2030	13	$5,000,000	$2,200,000	$1,981,000	$864,000	$403	$176
2031	14			$2,056,000	$854,000	$408	$170
2032	15			$2,155,000	$853,000	$418	$165
2033	16			$2,235,000	$842,000	$424	$160
2034	17			$2,318,000	$832,000	$429	$154
2035	18			$2,405,000	$822,000	$436	$149
2036	19			$2,494,000	$812,000	$442	$144
2037	20			$2,587,000	$802,000	$449	$139
2038	21			$2,683,000	$792,000	$456	$135
2039	22			$2,967,000	$834,000	$494	$139
2040	23			$3,075,000	$824,000	$502	$134
Total NPC of Capital Costs		$47,100,000					
Total NPC of Annual O&M Costs (2018-2037)		$17,600,000					
Total NPC		**$65,000,000**					

Appendix A-9
Opinion of Probable Construction Cost for Solids Treatment Improvements - Alternative 4

Construction Cost Component	% of Cost	Phase I (16 MGD)					Phase II (+4 MGD)					Phase III (+4 MGD)				
		Thickening	Pre-Dewatering	Stabilization incl. THP, CHP	Post-Dewatering	Drying	Thickening	Pre-Dewatering	Stabilization incl. THP, CHP	Post-Dewatering	Drying	Thickening	Pre-Dewatering	Stabilization incl. THP, CHP	Post-Dewatering	Drying
		None	Centrifuge	Mesophilic Anaerobic Digestion	Belt Filter Press	Solar Dryer	None	Centrifuge	Mesophilic Anaerobic Digestion	Belt Filter Press	Solar Dryer	None	Centrifuge	Mesophilic Anaerobic Digestion	Belt Filter Press	Solar Dryer
Facilities & Equipment																
Process Equipment	n/a	$0	$1,665,000	$8,070,000	$0	$4,024,000	$0	$15,000	$0	$1,415,000	$2,012,000	$0	$0	$0	$0	$1,454,000
Structure (where applicable)	n/a	$0	$1,386,000	$2,205,178	$100,000	$769,600	$0	$0	$0	$75,000	$384,800	$0	$0	$0	$0	$0
Demolition (where applicable)	n/a	$0	$60,000	$0	$125,000	$0	$0	$0	$0	$75,000	$0	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$0	$499,500	$2,421,000	$0	$1,207,200	$0	$4,500	$0	$424,500	$603,600	$0	$0	$0	$0	$436,200
Allowances																
Sitework	5%	$0	$180,525	$634,809	$11,250	$300,040	$0	$975	$0	$99,475	$150,020	$0	$0	$0	$0	$94,510
Piping	15%	$0	$541,575	$1,904,427	$33,750	$900,120	$0	$2,925	$0	$298,425	$450,060	$0	$0	$0	$0	$283,530
Instrumentation & Electrical	25%	$0	$902,625	$3,174,044	$56,250	$1,500,200	$0	$4,875	$0	$497,375	$750,100	$0	$0	$0	$0	$472,550
CONSTRUCTION SUBTOTAL		**$0**	**$5,235,225**	**$18,409,458**	**$326,250**	**$8,701,160**	**$0**	**$28,275**	**$0**	**$2,884,775**	**$4,350,580**	**$0**	**$0**	**$0**	**$0**	**$2,740,790**
Permits	1.0%	$0	$52,352	$184,095	$3,263	$87,012	$0	$283	$0	$28,848	$43,506	$0	$0	$0	$0	$27,408
Sales Tax	9.25%	$0	$169,414	$821,123	$0	$409,442	$0	$1,526	$0	$143,976	$204,721	$0	$0	$0	$0	$147,945
Bonds & Insurance																
Builder's Risk	0.5%	$0	$26,176	$92,047	$1,631	$43,506	$0	$141	$0	$14,424	$21,753	$0	$0	$0	$0	$13,704
General Liability	1.0%	$0	$52,352	$184,095	$3,263	$87,012	$0	$283	$0	$28,848	$43,506	$0	$0	$0	$0	$27,408
GC Bonds	1.5%	$0	$78,528	$276,142	$4,894	$130,517	$0	$424	$0	$43,272	$65,259	$0	$0	$0	$0	$41,112
SUBTOTAL #1		**$0**	**$5,614,048**	**$19,966,958**	**$339,300**	**$9,458,648**	**$0**	**$30,932**	**$0**	**$3,144,142**	**$4,729,324**	**$0**	**$0**	**$0**	**$0**	**$2,998,366**
General Conditions/OH&P																
General Conditions	10%	$0	$561,405	$1,996,696	$33,930	$945,865	$0	$3,093	$0	$314,414	$472,932	$0	$0	$0	$0	$299,837
Overhead & Profit	10%	$0	$561,405	$1,996,696	$33,930	$945,865	$0	$3,093	$0	$314,414	$472,932	$0	$0	$0	$0	$299,837
SUBTOTAL #2		**$0**	**$6,736,857**	**$23,960,350**	**$407,160**	**$11,350,378**	**$0**	**$37,119**	**$0**	**$3,772,971**	**$5,675,189**	**$0**	**$0**	**$0**	**$0**	**$3,598,039**
Contingency																
Construction Contingency	30%	$0	$1,688,057	$5,574,105	$122,148	$2,600,313	$0	$8,136	$0	$848,891	$1,300,157	$0	$0	$0	$0	$788,612
SUBTOTAL #3		**$0**	**$8,424,914**	**$29,534,455**	**$529,308**	**$13,950,692**	**$0**	**$45,254**	**$0**	**$4,621,862**	**$6,975,346**	**$0**	**$0**	**$0**	**$0**	**$4,386,651**
Escalation	0.0%	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CONSTRUCTION TOTAL		**$0**	**$8,425,000**	**$29,534,000**	**$529,000**	**$13,951,000**	**$0**	**$45,000**	**$0**	**$4,622,000**	**$6,975,000**	**$0**	**$0**	**$0**	**$0**	**$4,387,000**
Design & Construction Services	15%	$0	$1,264,000	$4,430,000	$79,000	$2,093,000	$0	$7,000	$0	$693,000	$1,046,000	$0	$0	$0	$0	$658,000
City Project Administration	2.0%	$0	$169,000	$591,000	$11,000	$279,000	$0	$1,000	$0	$92,000	$140,000	$0	$0	$0	$0	$88,000
Legal/Finance	3.0%	$0	$253,000	$886,000	$16,000	$419,000	$0	$1,000	$0	$139,000	$209,000	$0	$0	$0	$0	$132,000
Allowances		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$0**	**$10,111,000**	**$35,441,000**	**$635,000**	**$16,742,000**	**$0**	**$54,000**	**$0**	**$5,546,000**	**$8,370,000**	**$0**	**$0**	**$0**	**$0**	**$5,265,000**
EACH PHASE CAPITAL COST (2013)		**$63,000,000**					**$14,000,000**					**$6,000,000**				
YEAR INCURRED		**2015**					**2022**					**2030**				

Appendix A-10
Net Present Cost Calculation for Alternative 4

Calendar Year	Op. Year	Alternative 4 - Alternative 3 Plus Thermal Hydrolysis					
		Capital Cost	PC of Capital Cost	Total O&M Cost	PC of O&M Cost	O&M Cost per DT	PC of O&M Cost per DT
2013	-4						
2014	-3						
2015	-2	$63,000,000	$57,100,000				
2016	-1						
2017	0						
2018	1			$1,857,000	$1,455,000	$541	$424
2019	2			$1,923,000	$1,435,000	$540	$403
2020	3			$1,992,000	$1,416,000	$540	$384
2021	4			$2,063,000	$1,396,000	$541	$366
2022	5	$14,000,000	$9,000,000	$2,137,000	$1,378,000	$543	$350
2023	6			$2,216,000	$1,361,000	$545	$335
2024	7			$2,409,000	$1,409,000	$575	$336
2025	8			$2,576,000	$1,434,000	$598	$333
2026	9			$2,666,000	$1,414,000	$602	$319
2027	10			$2,759,000	$1,393,000	$606	$306
2028	11			$2,855,000	$1,373,000	$611	$294
2029	12			$2,955,000	$1,354,000	$617	$282
2030	13	$6,000,000	$2,600,000	$3,058,000	$1,334,000	$622	$272
2031	14			$3,165,000	$1,315,000	$629	$261
2032	15			$3,583,000	$1,418,000	$695	$275
2033	16			$3,708,000	$1,398,000	$703	$265
2034	17			$3,944,000	$1,416,000	$731	$262
2035	18			$4,122,000	$1,409,000	$747	$255
2036	19			$4,265,000	$1,389,000	$756	$246
2037	20			$4,412,000	$1,368,000	$766	$237
2038	21			$4,564,000	$1,348,000	$776	$229
2039	22			$4,721,000	$1,328,000	$786	$221
2040	23			$4,884,000	$1,308,000	$797	$214
Total NPC of Capital Costs		$68,700,000					
Total NPC of Annual O&M Costs (2018-2037)		$27,900,000					
Total NPC		**$97,000,000**					

Appendix A-11
Opinion of Probable Construction Cost for Solids Treatment Improvements - Alternative 4A

Construction Cost Component	% of Cost	Phase I (16 MGD)					Phase II (+4 MGD)					Phase III (+4 MGD)				
		Thickening	Pre-Dewatering	Stabilization incl. THP, CHP	Post-Dewatering	Drying	Thickening	Pre-Dewatering	Stabilization incl. THP, CHP	Post-Dewatering	Drying	Thickening	Pre-Dewatering	Stabilization incl. THP, CHP	Post-Dewatering	Drying
		None	Centrifuge	Mesophilic Anaerobic Digestion	Belt Filter Press	Solar Dryer	None	Centrifuge	Mesophilic Anaerobic Digestion	Belt Filter Press	Solar Dryer	None	Centrifuge	Mesophilic Anaerobic Digestion	Belt Filter Press	Solar Dryer
Facilities & Equipment																
Process Equipment	n/a	$0	$1,665,000	$8,070,000	$0	$2,012,000	$0	$15,000	$0	$1,415,000	$0	$0	$0	$0	$0	$727,000
Structure (where applicable)	n/a	$0	$1,386,000	$2,205,178	$100,000	$384,800	$0	$0	$0	$75,000	$0	$0	$0	$0	$0	$0
Demolition (where applicable)	n/a	$0	$60,000	$0	$125,000	$0	$0	$0	$0	$75,000	$0	$0	$0	$0	$0	$0
Labor, Construction Equipment & Misc Material	30%	$0	$499,500	$2,421,000	$0	$603,600	$0	$4,500	$0	$424,500	$0	$0	$0	$0	$0	$218,100
Allowances																
Sitework	5%	$0	$180,525	$634,809	$11,250	$150,020	$0	$975	$0	$99,475	$0	$0	$0	$0	$0	$47,255
Piping	15%	$0	$541,575	$1,904,427	$33,750	$450,060	$0	$2,925	$0	$298,425	$0	$0	$0	$0	$0	$141,765
Instrumentation & Electrical	25%	$0	$902,625	$3,174,044	$56,250	$750,100	$0	$4,875	$0	$497,375	$0	$0	$0	$0	$0	$236,275
CONSTRUCTION SUBTOTAL		**$0**	**$5,235,225**	**$18,409,458**	**$326,250**	**$4,350,580**	**$0**	**$28,275**	**$0**	**$2,884,775**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1,370,395**
Permits	1.0%	$0	$52,352	$184,095	$3,263	$43,506	$0	$283	$0	$28,848	$0	$0	$0	$0	$0	$13,704
Sales Tax	9.25%	$0	$169,414	$821,123	$0	$204,721	$0	$1,526	$0	$143,976	$0	$0	$0	$0	$0	$73,972
Bonds & Insurance																
Builder's Risk	0.5%	$0	$26,176	$92,047	$1,631	$21,753	$0	$141	$0	$14,424	$0	$0	$0	$0	$0	$6,852
General Liability	1.0%	$0	$52,352	$184,095	$3,263	$43,506	$0	$283	$0	$28,848	$0	$0	$0	$0	$0	$13,704
GC Bonds	1.5%	$0	$78,528	$276,142	$4,894	$65,259	$0	$424	$0	$43,272	$0	$0	$0	$0	$0	$20,556
SUBTOTAL #1		**$0**	**$5,614,048**	**$19,966,958**	**$339,300**	**$4,729,324**	**$0**	**$30,932**	**$0**	**$3,144,142**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1,499,183**
General Conditions/OH&P																
General Conditions	10%	$0	$561,405	$1,996,696	$33,930	$472,932	$0	$3,093	$0	$314,414	$0	$0	$0	$0	$0	$149,918
Overhead & Profit	10%	$0	$561,405	$1,996,696	$33,930	$472,932	$0	$3,093	$0	$314,414	$0	$0	$0	$0	$0	$149,918
SUBTOTAL #2		**$0**	**$6,736,857**	**$23,960,350**	**$407,160**	**$5,675,189**	**$0**	**$37,119**	**$0**	**$3,772,971**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1,799,020**
Contingency																
Construction Contingency	30%	$0	$1,688,057	$5,574,105	$122,148	$1,300,157	$0	$8,136	$0	$848,891	$0	$0	$0	$0	$0	$394,306
SUBTOTAL #3		**$0**	**$8,424,914**	**$29,534,455**	**$529,308**	**$6,975,346**	**$0**	**$45,254**	**$0**	**$4,621,862**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2,193,326**
Escalation	0.0%	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CONSTRUCTION TOTAL		**$0**	**$8,425,000**	**$29,534,000**	**$529,000**	**$6,975,000**	**$0**	**$45,000**	**$0**	**$4,622,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2,193,000**
Design & Construction Services	15%	$0	$1,264,000	$4,430,000	$79,000	$1,046,000	$0	$7,000	$0	$693,000	$0	$0	$0	$0	$0	$329,000
City Project Administration	2.0%	$0	$169,000	$591,000	$11,000	$140,000	$0	$1,000	$0	$92,000	$0	$0	$0	$0	$0	$44,000
Legal/Finance	3.0%	$0	$253,000	$886,000	$16,000	$209,000	$0	$1,000	$0	$139,000	$0	$0	$0	$0	$0	$66,000
Allowances		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
CAPITAL COST - EACH TECHNOLOGY		**$0**	**$10,111,000**	**$35,441,000**	**$635,000**	**$8,370,000**	**$0**	**$54,000**	**$0**	**$5,546,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2,632,000**
EACH PHASE CAPITAL COST (2013)		**$55,000,000**					**$6,000,000**					**$3,000,000**				
YEAR INCURRED		**2015**					**2022**					**2030**				

Appendix A-12
Net Present Cost Calculation for Alternative 4A

Calendar Year	Op. Year	Alternative 4A - Alternative 4 with Partial Solar Drying					
		Capital Cost	PC of Capital Cost	Total O&M Cost	PC of O&M Cost	O&M Cost per DT	PC of O&M Cost per DT
2013	-4						
2014	-3						
2015	-2	$55,000,000	$49,900,000				
2016	-1						
2017	0						
2018	1			$1,756,000	$1,376,000	$511	$401
2019	2			$1,827,000	$1,363,000	$513	$383
2020	3			$1,901,000	$1,351,000	$516	$366
2021	4			$1,977,000	$1,338,000	$519	$351
2022	5	$6,000,000	$3,900,000	$2,057,000	$1,326,000	$522	$337
2023	6			$2,142,000	$1,315,000	$527	$324
2024	7			$2,301,000	$1,345,000	$550	$321
2025	8			$2,391,000	$1,332,000	$555	$309
2026	9			$2,485,000	$1,318,000	$561	$298
2027	10			$2,583,000	$1,305,000	$568	$287
2028	11			$2,684,000	$1,291,000	$575	$276
2029	12			$2,789,000	$1,278,000	$582	$267
2030	13	$3,000,000	$1,300,000	$2,897,000	$1,264,000	$590	$257
2031	14			$3,009,000	$1,251,000	$598	$248
2032	15			$3,420,000	$1,353,000	$663	$262
2033	16			$3,551,000	$1,338,000	$673	$254
2034	17			$3,687,000	$1,323,000	$683	$245
2035	18			$3,869,000	$1,323,000	$701	$240
2036	19			$4,016,000	$1,308,000	$712	$232
2037	20			$4,169,000	$1,293,000	$724	$224
2038	21			$4,326,000	$1,277,000	$735	$217
2039	22			$4,489,000	$1,262,000	$748	$210
2040	23			$4,657,000	$1,247,000	$760	$204
Total NPC of Capital Costs		$55,100,000					
Total NPC of Annual O&M Costs (2018-2037)		$26,400,000					
Total NPC		**$82,000,000**					

Appendix B

Combined Heat & Power (CHP) System Conceptual Design

Memorandum

To: *CDM Smith Project Team*

From: *Scott E. Henriques, P.E., LEED AP O&M, CDM Smith*

Date: *June 14, 2013*

Subject: *Franklin WRF Modifications & Expansion Project*
Biosolids Management Preliminary Engineering TM
Appendix B – Conceptual Design of Combined Heat & Power (CHP) Systems

1.0 Overview

The objective of this memorandum is to provide preliminary sizing, basic equipment requirements, consumption, generation and costing data to provide Combined Heat and Power (CHP, aka cogeneration or CHP) for two anaerobic digester scenarios for this project. In each scenario, the CHP plant will use methane biogas produced by the anaerobic digestion process as a main source of fuel. The CHP plant will generate both electricity and heat. The electricity will be used to displace electricity that would typically be purchased from the local utility, and the heat will be used to provide for the needs of the anaerobic digestion process.

2.0 Conventional Anaerobic Digester CHP Plant (Alternatives 2, 3 & 3A)

2.1 Concept and Rationale

The base scenario in Alternatives 2, 3 and 3A is a conventional mesophilic anaerobic digestion (MAD) process where sludge is heated to approximately 96 to 100 degrees F and deprived of oxygen. In this environment, anaerobic microbes will convert a portion of the complex organic compounds contained in the sludge to methane gas. The methane gas is then collected and burned in a similar fashion to natural gas by the CHP plant, which in turn produces useful electricity and the heat necessary to heat the incoming sludge as well as keep the process warm in cooler weather.

2.2 Sizing Considerations

The goal in sizing the CHP plant for a conventional anaerobic digester process is to use as much of the free (of commodity costs) biogas to do as much useful work for the plant as possible in the form of electricity and heat. The amount of digester biogas generated by the anaerobic process is typically sufficient to provide for all the heating needs of the process with an abundant surplus. However, the electricity generated by the same amount of biogas will not be sufficient to provide the needs for the remainder of the WRF. Therefore, it is assumed that the entire electrical production capacity of the CHP plant will be able to do useful work, consuming all the biogas produced and displacing the cost of purchasing electricity from the local utility. Furthermore, sizing of the CHP plant for the conventional anaerobic digester is based on the amount of biogas the process will generate.

Another important factor that affects the sizing of the CHP plant is the amount of fluctuation there will be in the rate of biogas production. If the amount of fluctuation is high and frequent, and the CHP plant is sized for the absolute peak anticipated rate of biogas production, the capacity of the CHP plant's capability will not be realized for much of the year, as there will be insufficient biogas to run the CHP at full capacity much of the time. This effectively dilutes the value of the capital investment's return. An amount of biogas storage can be balanced with the size of the CHP plant, much like the heat rate and storage capacity of a domestic hot water heater. Since actual CHP equipment comes in incremental sizes, some amount of storage will be required if the majority of biogas is to be usefully consumed. It is therefore assumed that sufficient biogas storage capacity will be provided to make up for the capacity differences between incremental CHP sizes.

The average biogas production rate for the Alternatives 2, 3, and 3A solids treatment trains is estimated to be 58 standard cubic feet per minute (scfm), starting in 2018, with peak production as high as 73 scfm. This production rate is expected to gradually increase to approximately 110 scfm average and 136 scfm peak in the year 2040. Based on the anticipated rate of increase in biogas production, we would recommend a first CHP plant consisting of two engines sized at about 1.2 times the average biogas production for 2018. The first year will result in approximately 16 percent of the annualized capacity of the CHP plant unutilized. However, in 2019, this underutilization drops to 13 percent, 8 percent in 2020, 5 percent in 2021, and 1 percent in 2022. Additional capacity is expected to be required before 2023 if all of the biogas is to be usefully consumed.

Using this strategy, the final recommended build-out of the CHP system would include two CHP machines. The units considered for this initial analysis are each rated for 70 scfm of biogas input, 270 kW electrical output, and 1,090 BTU/hr thermal output. It is assumed that the biogas contains 600 BTU per cubic foot (BTU/CF).

This plant would also require a 1,900 thousand BTU per hour (MBH) of boiler capacity as a backup in the event that the CHP plant fails. It is recommended that one CHP plant and the backup boiler be installed for operation in 2018, with addition of the second CHP plant in 2020 when further biogas is projected to be available for use. Alternatively, both CHP plants may be installed as part of the Phase I solids treatment upgrades. The estimated capital cost of one CHP plant and backup boiler is $420,000.

By comparison, addition of the MAD system in Alternatives 2, 3, and 3A without a CHP system would require three 950 MBH boilers for digester heating. These boilers are the equivalent of 1,900 MBH N+1 installed for operation in year 2018.

2.3 Energy Model

The energy model assumes that the CHP plant will be available during 95 percent of annual operating hours when one CHP unit is installed, and 97.5 percent of operating hours when two units are installed. All electrical output displaces retail electricity purchased from the local utility, and all of the heat necessary to heat the digester plant is from the CHP plant (except during the 5 percent down time). The heat, although usefully employed, has no economic value as it is assumed that biogas would be consumed in a traditional boiler to obtain the heat. The remaining heat will be dumped via radiator, and a small amount (less than 4 percent) of the biogas is expected to be flared.

It was assumed that natural gas would be used to heat the digesters during CHP system downtime. This cost is captured in the annual operation and maintenance (O&M) cost calculations.

2.4 Typical Equipment Requirements

The analysis for Alternatives 2, 3, and 3A is based on two Tech 3 G946-270 engine driven CHP plants. The plant would be packaged complete with engine, dual fuel (digester gas and natural gas backup) gas trains, generator, heat dump radiators, heat recovery heat exchangers, controls, and controls interface.

The plant would also require an emergency flare for biogas in the event the CHP plant is down or not capable of consuming the biogas produced. This flare would be required for all alternatives in which anaerobic digestion is included. The cost of the emergency flare is included in the capital cost calculations under gas handling equipment.

Digester gas is typically contaminated with high moisture content, hydrogen sulfide (H_2S), and siloxanes. These contaminants are detrimental to combustion equipment and need to be removed from the biogas prior to its use. The cost of this gas conditioning equipment is included in the capital cost calculations under gas handling equipment.

2.4.1 Thermal and Electrical Tie-In

In order to gain beneficial use of the CHP plant, it will be necessary to provide both electrical and thermal tie-ins to the Franklin WRF. From an electrical standpoint, the tie-ins will consist of synchronization equipment as well as power lines. Thermal tie-in would include a hot water glycol loop to transfer the heat to the digester heat exchangers.

2.5 Economics

Based upon the assumptions and scenarios described above and an annual electricity rate inflation of 3 percent per year, the CHP system performance and project estimated comparative economics are presented below in **Table B-1.** The total 20-year value of the electricity generated is estimated to be $4.0 million (2013 dollars).

Table B-1 Anticipated CHP System Performance & Economic Analysis – Alternatives 2, 3, and 3A

Calendar Year	Operating Year	Biogas Generated/ Consumed (MMBTU)	Electricity Generated (kWh)	Useful Heat Generated (MMBTU)	Value of Electricity Produced (2013)
2018	1	18,000	2,000,000	5,500	$176,000
2019	2	19,000	2,000,000	5,700	$179,000
2020	3	20,000	2,200,000	5,900	$186,000
2021	4	20,000	2,300,000	6,000	$189,000
2022	5	21,000	2,300,000	6,200	$192,000
2023	6	22,000	2,400,000	6,400	$195,000
2024	7	22,000	2,500,000	6,500	$197,000
2025	8	23,000	2,600,000	6,700	$199,000
2026	9	24,000	2,600,000	6,800	$202,000
2027	10	25,000	2,700,000	7,000	$204,000
2028	11	25,000	2,800,000	7,200	$206,000
2029	12	26,000	2,900,000	7,300	$207,000
2030	13	27,000	3,000,000	7,500	$209,000
2031	14	28,000	3,000,000	7,700	$211,000
2032	15	28,000	3,100,000	7,800	$213,000
2033	16	29,000	3,200,000	8,000	$214,000
2034	17	30,000	3,300,000	8,200	$216,000
2035	18	31,000	3,400,000	8,300	$217,000
2036	19	31,000	3,500,000	8,500	$218,000
2037	20	32,000	3,600,000	8,700	$220,000

3.0 Thermally Hydrolyzed Anaerobic Digester CHP Plant (Alternatives 4 & 4A)

3.1 Concept and Rationale

The thermal hydrolysis pretreatment (THP) scenario in Alternatives 4 and 4A is an enhanced MAD process where 220 PSIG saturated steam is injected into the sludge to break down the sludge to a more readily digestible state. This process allows more sludge to be digested in a smaller footprint more quickly, with a higher biogas yield compared to traditional anaerobic digestion.

For the purposes of this analysis, the process needs of the Exelys THP system by Krüger were used as the design basis.

3.2 Sizing Considerations

Since the THP process requires steam to function and the anaerobic digestion process produces useful methane gas, the goal for sizing the CHP plant is to provide all of the steam requirements for the process via cogeneration. With this goal in mind, the sizing of this scenario is greatly simplified and entirely driven by steam demand requirements. The CHP plant will be sized for the thermal output to provide 220 PSIG steam at 2,500 PPH. No additional digester heating is anticipated when the THP process is included.

Using this strategy, the final recommended build-out would include two CHP machines, each rated for 8,100 MBH of gas input, 975 kW electrical output, and 1,700 PPH of 220 PSIG steam output. This plant would also require a 4,100 MBH, 220 PSIG steam boiler as a backup in the event the CHP plant fails. Due to these loads, it is recommended that the entire plant be constructed and ready for operation in year 2018. The estimated capital cost of the two CHP machines and backup boiler is $2,150,000.

The base case comparison is three (3) 2,100 MBH boilers, which is approximately the equivalent of 4,100 MBH N+1 installed for operation in year 2018.

3.3 Energy Model

The energy model for this scenario assumes that all of the electricity generated by the CHP system while it is supplying the steam load of the THP process will be utilized to meet the plant electrical needs. The quantity of biogas produced is estimated to be insufficient to meet the needs of the THP process. Natural gas will be necessary to supplement the biogas for this scenario. The heat, although usefully employed, has no economic value as it is assumed that biogas would be consumed in a traditional boiler to obtain the heat. The remaining heat will be dumped via radiator, and a small amount (less than 4 percent) of the biogas is expected to be flared.

3.4 Typical Equipment Requirements

The analysis is based on two Dresser-Rand SFGLD 480 engine driven CHP plants. The plant would be packaged complete with engine, dual fuel (digester gas and natural gas backup) gas trains, generator, heat dump radiators, heat recovery heat exchangers, controls and controls interface. An emergency flare and biogas conditioning equipment, similar to those described in Section 2.4, would be required. These costs are included in the capital cost calculations.

Because the process requires direct injection of steam into the sludge, the majority of the steam will be consumed by the process. A very large (for a traditional steam boiler plant) amount of new feed water will need to be supplied to the system at the rate of about 26.4 gallons per hour, or 231,000 gallons per year. It would typically be recommended that this feed water be treated sanitary effluent, which would require further conditioning via reverse osmosis to provide a boiler feed water with a minimum 3600 PPM TDS, 700 PPM alkalinity and 20 PPM hardness. Better feed water quality is desirable, and potable water would be used as a backup water supply.

3.4.1 Thermal and Electrical Tie-In

In order to gain beneficial use of the CHP plant, it will be necessary to provide both electrical and thermal tie-ins. Electrically, these tie-ins will consist of synchronization equipment and power lines. Thermal connections would require steam piping to the THP process, as well as some means of returning a small amount of steam main condensate to the heat recovery steam generators.

3.5 Economics

Based upon the assumptions and scenarios described above and annual electricity and natural gas cost inflation of 3 percent per year, the project estimated comparative economics are presented below in **Table B-2.** The total 20-year value of the electricity generated is estimated to be $11.2 million (2013 dollars).

Table B-2 Anticipated CHP System Performance & Economic Analysis – Alternatives 4 & 4A

Calendar Year	Operating Year	Biogas Generated/ Consumed (MMBTU)	Natural Gas Consumed (therms)	Electricity Generated (kWh)	Cost of Natural Gas Consumed	Value of Electricity Produced (2013)
2018	1	24,000	255,000	5,700,000	($305,000)	$504,000
2019	2	25,000	260,000	5,900,000	($320,000)	$512,000
2020	3	26,000	266,000	6,100,000	($336,000)	$520,000
2021	4	27,000	270,000	6,300,000	($353,000)	$528,000
2022	5	28,000	276,000	6,500,000	($370,000)	$535,000
2023	6	29,000	282,000	6,700,000	($390,000)	$541,000
2024	7	30,000	289,000	6,900,000	($411,000)	$547,000
2025	8	31,000	295,000	7,100,000	($434,000)	$553,000
2026	9	32,000	302,000	7,300,000	($456,000)	$558,000
2027	10	32,000	308,000	7,500,000	($480,000)	$563,000
2028	11	33,000	314,000	7,700,000	($504,000)	$568,000
2029	12	34,000	320,000	7,900,000	($529,000)	$572,000
2030	13	35,000	326,000	8,200,000	($555,000)	$576,000
2031	14	36,000	331,000	8,400,000	($581,000)	$579,000
2032	15	37,000	425,000	8,600,000	($768,000)	$582,000
2033	16	38,000	432,000	8,800,000	($803,000)	$585,000
2034	17	39,000	438,000	9,000,000	($839,000)	$587,000
2035	18	40,000	444,000	9,200,000	($876,000)	$589,000
2036	19	41,000	450,000	9,400,000	($915,000)	$591,000
2037	20	42,000	456,000	9,600,000	($954,000)	$593,000

cc: Project File

Appendix C

Supplemental Cost Tables

Table C-1 presents the 20-year total cost of each alternative. This total cost represents the combination of capital and O&M costs over the life of each project.

Table C-1 Total 20-Year Cost

Process Train	Phase I Const. Cost (millions)[1]	Phase II Const. Cost (millions)[2]	Phase III Const. Cost (millions)[3]	20-Year O&M Cost[4] (millions)	Total Cost (millions)	Rank
Alternative 1: Continue Current Treatment Process	$18.0	$3.4	$0.0	$59.0	$80.4	2
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$33.0	$11.6	$1.6	$34.0	$80.2	1
Alternative 3: Alternative 2 Plus Solar Drying	$66.0	$20.0	$21.0	$44.0	$151.0	6
Alternative 3A: Alternative 3 with Partial Solar Drying	$41.0	***$12.0***[5]	***$5.0***[5]	***$37.0***[5]	***$95.0***[5]	3
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$63.0	$14.0	$6.0	$59.0	$142.0	5
Alternative 4A: Alternative 4 with Partial Solar Drying	$55.0	***$6.0***[5]	***$3.0***[5]	***$56.0***[5]	***$120.0***[5]	4

[1] 2015 dollars.
[2] 2022 dollars.
[3] 2030 dollars.
[4] Year 1 (2018) to Year 20 (2037).
[5] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.

Table C-2 presents the adjusted 20-year total cost of each alternative. The cost adjustment is based on the value of the power generated by the CHP system where applicable. Proceeds from the sale of dried biosolids are not included.

Table C-2 Adjusted Total 20-Year Cost – Power Generation Cost Offset Included

Process Train	Phase I Const. Cost (millions)[1]	Phase II Const. Cost (millions)[2]	Phase III Const. Cost (millions)[3]	Adjusted 20-Year O&M Cost[4] (millions)	Adjusted Total Cost (millions)	Adjusted Rank
Alternative 1: Continue Current Treatment Process	$18.0	$3.4	$0.0	$59.0	$80.4 (no change)	2 (no change)
Alternative 2: Replace Thickening, Add Digestion & Screw Press Dewatering	$33.0	$11.6	$1.6	$25.0	$71.2 (↓$9.0)	1 (no change)
Alternative 3: Alternative 2 Plus Solar Drying	$66.0	$20.0	$21.0	$35.0	$142.0 (↓$9.0)	6 (no change)
Alternative 3A: Alternative 3 with Partial Solar Drying	$41.0	***$12.0[5]***	***$5.0[5]***	***$28.0[5]***	***$86.0[5] (↓$9.0)***	***3 (no change)***
Alternative 4: Alternative 3 Plus Thermal Hydrolysis	$63.0	$14.0	$6.0	$35.0	$118.0 (↓$24.0)	5 (no change)
Alternative 4A: Alternative 4 with Partial Solar Drying	$55.0	***$6.0[5]***	***$3.0[5]***	***$32.0[5]***	***$96.0[5] (↓$24.0)***	***4 (no change)***

[1] 2015 dollars.
[2] 2022 dollars.
[3] 2030 dollars.
[4] Year 1 (2018) to Year 20 (2037).
[5] These costs do not include future expansion of the solar dryer. Future expansion will be determined by the City during Phase I.