Appendix C
Anaerobic Digestion and Waste Gas Burner Capacity Assessment

Anaerobic Digestion and Waste Gas Burner Capacity Assessment

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DATE: May 22, 2013

PROJECT NUMBER: 436645

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Executive Summary

ES.1 Introduction

Over the last 10 years, The City of Toronto has been working toward the development and implementation of a Biosolids Management Strategy that meets their overall economic, environmental and social objectives. In a continuation of this program, in 2012, The City retained CH2M HILL Canada Limited (CH2M HILL) to prepare a conceptual design for a biosolids Truck Loading Facility and accompanying odour control features at the Highland Creek Treatment Plant.

The project aims to achieve the following objectives:

1. Develop four conceptual layout options for the Truck Loading Facility, all of which incorporate odour control systems. The three potential options advanced by the City early in the project for the Truck Loading Facility include:
    a. Utilize the existing Biosolids Management Building to locate the Truck Loading Facility.
    b. Expand the existing Biosolids Management Building to accommodate a new Truck Loading Facility.
    c. Construct a new Truck Loading Facility on site, and close to the existing Biosolids Management Building.
    d. Construct a new Truck Loading Facility and dewatering facility at a central location, east of the new Dechlorination Building.
2. Assess the capacity requirements associated with the Truck Loading Facility in terms of biosolids handling capabilities as well as the needs of major ancillary systems.
3. Considering the differences in biosolids treatment requirements for beneficial use of biosolids rather than thermal reduction, assess the capacity of the existing four anaerobic digesters and associated ancillaries (gas handling system, waste gas burners, etc) based on the updated mass balance and the current waste activated sludge (WAS) thickening project. Identify expansion requirements and develop alternatives, with conceptual layout plans for these alternatives.
4. Recommend a preferred conceptual design that best meets the City's requirements for the Truck Loading Facility and for the existing anaerobic digestion system.

This Technical Memorandum 3 will focus on the review and evaluation of anaerobic sludge digestion requirements needed to stabilize biosolids to the degree necessary for land application. Further, changes to digestion will be compared with the predicted capacity requirements from a previous study (CH2M HILL 2012, Engineering Study for Various Process Systems in the Digester Facility at the Highland Creek Treatment Plant)

ES.2 Design Basis

Primary sludge and waste activated sludge (WAS) quantities have been predicted in TM 1. The sludge quantities critical to the sizing of anaerobic digestion facilities are summarized in Table ES-1.

TABLE ES-1
Design Basis for Anaerobic Digestion Facllity

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	**Average**	**Maximum Month Load**	**Maximum Week Load**	**Average**	**Maximum Month Load**	**Maximum Week Load**
Primary Sludge						
Flow, m^3/d	1,160	1,690	2,000	1,420	2,110	2,460
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
TWAS						
Flow, m^3/d	410	560	630	500	690	780
TS Load, kg/d	20,275	28,130	31,470	25,170	34,470	39,025
VS Load, kg/d	14,820	19,800	22,050	18,335	24,280	27,325
Total Sludge to Digestion						
Flow, m^3/d	1,570	2,260	2,630	1,930	2,800	3,240
TS Load, kg/d	58,715	83,990	97,625	72,115	104,145	120,060
VS Load, kg/d	42,990	60,880	70,505	52,720	75,290	86,585

The biogas quantities associated with various operating conditions are summarized in Table ES-2.

TABLE ES- 2
Design Basis for Biogas Management

Parameter	2032	Ultimate Plant Capacity
Biogas Generation Rate		
Average, m^3/d	21,000	25,235
Maximum Month[1], m^3/d	28,715	35,425
Maximum Week[2], m^3/d	32,830	38,820
Peak Diurnal	45,960	54,350
Methane Fraction (at condition noted)		
Average, percent	0.58	0.58
Maximum Month[1], percent	0.58	0.58
Maximum Week[2], percent	0.58	0.58

Notes:
1. Maximum month' projections are based on the maximum 30 day running average during a specific annual period.
2. Maximum week projections are based on digestion of the maximum week sludge loads with a minimum digestion SRT of 12 days.

The design of anaerobic digestion facilities to stabilize biosolids to the degree necessary for land application requires that the solids retention time (SRT) in the digester be greater than 15 days on the basis of maximum month loads to the process. This criterion allows for some accumulation of debris, grit and scum in the digester.

The existing digesters do not have sufficient volumetric capacity to handle the predicted sludge loads for the design year of 2032 or beyond.

ES.3 Conventional Digester Expansion

The digesters could be expanded by building new tankage similar to that currently employed (volume = 6,610 m^3 per digester). Adopting this approach would involve constructing three new digesters before 2032 and one thereafter to handle the anticipated load from the ultimate capacity of the plant.

Larger digester sizes could be employed to reduce the final number of additional digesters.

ES.4 Digester Expansion Coupled with Primary Sludge Thickening

A large fraction of the sludge load to the digestion facility is primary sludge, anticipated to be withdrawn from the primary treatment process at a solids concentration of about 3.3 percent. The previous history of co-thickening has resulted in minimal data being available that might justify somewhat higher primary sludge concentrations; however, the assumed value is reasonable. Regardless, mechanical thickening of primary sludge would realistically increase the solids concentration to a minimum of 5.5 percent and an average solids concentration over 6 percent.

Mechanical primary sludge dewatering can be accomplished using one of several processes including centrifuges, gravity belt thickeners, or rotary drum thickeners. The gravity belt thickening option was selected as a generic option because it can be designed to include an enclosure to capture odorous gas emissions, it is compatible with fibrous materials (such as primary sludge) and it is available in reasonable sizes compatible with the range of flows that would be experienced at the Highland Creek TP. Rotary drum thickeners could also be used – the necessary infrastructure and costs would be similar to those of gravity belt thickeners. Centrifuges, such as are being incorporated in the new WAS thickening facility, are more costly for primary sludge thickening and are subject to accelerated abrasive wear due to the amount of grit normally present in primary sludge. Hence, centrifuge thickening is generally only used for primary sludge thickening in larger wastewater treatment plants and only after incorporating primary sludge screening and grit removal.

With the implementation of primary sludge thickening, the number of additional digesters needed to handle the plant flow can be reduced to one in the short term, with the addition of one more after 2032 to handle ultimate plant flows and loads.

ES.5 Digester Expansion Coupled with Enhanced Digestion

There are a large number of processes available that enhance digestion, in many cases allowing for the tankage to be designed on the basis of lower SRTs than generally employed for conventional anaerobic digestion. Available options include:

- Thermophilic Digestion
- Staged Digestion
- Mechanical, Chemical, or Mechanical/Chemical Homogenization
- Thermal Hydrolysis
- Recuperative Thickening

Of these options, acid/gas digestion was selected for further examination. This process configuration has been proven in other similar plant applications and allows the main digestion process (the gas phase) to be designed at a lower SRT.

ES.6 Comparison of Digestion Expansion Scenarios

Five expansion scenarios were developed in the sections of the main TM as are summarized and compared in the following Table ES-3.

TABLE ES-3
Digestion Expansion Scenarios

Description	**Conventional**		**Conventional, Larger Digesters Option 1**		**Conventional, Larger Digesters Option 2**		**Conventional with Primary Sludge Thickening**		**Acid Gas Digestion, Existing Digester Size, with Primary Sludge Thickening**	
Design Condition	2032	Ultimate	2032	Ultimate	2032	Ultimate	2032	Ultimate	2032	Ultimate
Max Month Primary Sludge Flow, m^3/d	1,690	2,110	1,690	2,110	1,690	2,110	1,015	1,270	1,015	1,270
Max Month WAS Flow, m^3/d	560	690	560	690	560	690	560	690	560	690
Max Month Blended Sludge Flow, m^3/d	2,260	2,800	2,260	2,800	2,260	2,800	1,575	1,960	1,575	1,960
Acid Reactor Minimum SRT, d	-	-	-	-	-	-	-	-	2	2
Digester Minimum SRT, d	15	15	15	15	15	15	15	15	12.5	12.5
Acid Reactors										
Number, Duty/ Standby	-	-	-	-	-	-	-	-	2/1	3/1
Volume per reactor, m^3									1,575	1,575

TABLE ES-3
Digestion Expansion Scenarios

Description	Conventional		Conventional, Larger Digesters Option 1		Conventional, Larger Digesters Option 2		Conventional with Primary Sludge Thickening		Acid Gas Digestion, Existing Digester Size, with Primary Sludge Thickening	
Digesters, Existing	**2032**	**Ultimate**	**2032**	**Ultimate**	**2032**	**Ultimate**	**2032**	**Ultimate**	**2032**	**Ultimate**
Number	4	4	4	4	4	4	4	4	4	4
Volume per reactor, m^3	6,610	6,610	6,610	6,610	6,610	6,610	6,610	6,610	6,610	6,610
Digesters, New										
Number	3	4	2	3	2	2	1	2	0	1
Volume per reactor, m^3	6,610	6,610	7,780	7,780	15,560	15,560	6,610	6,610	-	6,610
Total Digester Volume, m^3	46,270	52,880	42,000	49,780	57,560	57,560	33,050	39,660	26,440	39,660
Firm Digester Volume, m^3	39,660	46,270	34,220	42,000	42,000	42,000	26,440	33,050	19,830	33,050
Capital Costs (000's)										
Primary Sludge Thickening[1]	-	-	-	-	-	-	$18,015	$0	$18,015	$0
Acid Reactors[2]	-	-	-	-	-	-	-	-	$38,410	$12,470
Digesters	$82,000	$26,670	$59,990	$28,050	$74,630	$0	$32,670	$26,700	$0	$30,670
Total Capital Cost (000's)	$82,000	$26,670	$59,990	$28,050	$74,630	$0	$50,685	$26,700	$56,425	$43,140
Present Value of Capital Cost (000's)[3]	$94,730		$74,290		$74,630		$64,520		$79,670	
Present Value of O&M Costs (000's)	$54,850		$50,710		$52,450		$54,110		$56,920	
Total NPV	$149,580		$125,000		$127,080		$118,630		$136,590	
Non Monetary										
Number of processes	1		1		1		2		3	
Polymer required, T/y	0		0		0		35.1/42.8		35.1/42.8	
Digester Mixing Power, kW[5]	325/370		295/350		405/405		295/355		280/355	

TABLE ES-3
Digestion Expansion Scenarios

Description	Conventional	Conventional, Larger Digesters Option 1	Conventional, Larger Digesters Option 2	Conventional with Primary Sludge Thickening	Acid Gas Digestion, Existing Digester Size, with Primary Sludge Thickening
More biogas/ Higher VSr	Neutral	Neutral	Neutral	Neutral	Yes
Foam resistant	No	No	No	No	Yes

Notes: 1. Primary sludge thickening based on provision of four gravity belt thickeners in initial installation and no additional units for ultimate plant capacity.

2. Acid reactors would each be 12 m in diameter with a 14.0 m SWD

3. Present value of capital cost based on Stage 1 expansion being completed between 2013 and 2015 while the Stage 2 Expansion would occur between 2030 and 2032. Discount rate is 3 percent.

4. Present value of O&M costs based on the following:

- Power costs at $0.09/kWh, power usage based on 9 W/m^3 of input for digesters with no primary sludge thickening and 10 W/m3 for digesters with primary sludge thickening. Includes recirculation pumping. Primary sludge thickening power consumption based on 0.006 kWh/kg of sludge thickened.
- Labour costs based on staff required to operate and maintain all digesters, sludge thickening and ancillaries.
- Polymer costs based on 2.5 kg

5. Power for digester mixing based on 7 W/m^3 for digesters without primary sludge thickening and 8 W/m^3 for digesters with primary sludge thickening. Total power for digesters included 2 W/m^3 for recirculation pumping.

6. Labour costs are based on $75/h and are meant to include salary burdens, supervision, overeheads, and other related payroll costs.

ES.7 Recommended Digestion Expansion Scenario

Primary Sludge Thickening

Given the costs associated with constructing new digesters, it is recommended that the option that minimizes this requirement be adopted – primary sludge thickening with limited expansion of the digesters. Primary sludge thickening would be incorporated using gravity belt thickeners (although rotary drum thickening might be considered as the project is developed further). Four gravity belt thickeners would be installed in a new facility located near the main entrance to the plant on the north side of the main access road.

Anaerobic Digestion

The recommended option entails the construction of one new digester. A second new digester would be required after 2032 to handle the ultimate capacity of the plant. The new digesters would be identical to the existing units and would be constructed with the improvements to the mixing system, as recommended in a previous study, incorporated in the initial construction.

Waste Gas Burners

The previous study (CH2M HILL, 2012) of the Waste Gas Burners and other digestion related systems recommended the installation of three new units, each with a capacity of 1,500 m^3/h. This capacity should be sufficient for one unit to handle the predicted maximum week waste biogas. As noted in Section 2, the peak diurnal biogas production estimate at plant capacity is 54,000 m^3/d or about 2,250 m^3/h. Two of the WGBs could handle that peak load. Given that waste biogas is generally directed to the plant boilers for energy recovery, the sizing appears sufficient.

Waste Gas Burners

Class 4 capital cost estimates have been prepared for the preferred option considered for the anaerobic digester upgrade. These estimates are based on vendor proposals for major equipment, unit prices for structural portions of the work and similar elements constructed at other wastewater treatment plants, and allowances for various components based on complexity and scope. The cost estimate at this point in project development is $ 53,376,000 excluding HST.

TABLE ES-4

Capital Cost Estimates[1] of Preferred Option (Includes Digestion Upgrades, Primary Sludge Thickening and Waste Gas Burners upgrades. Excludes cost related to the Truck Loading Facility and associated Odour Control)

Description	Digestion Upgrades, Primary Sludge Thickening and Waste Gas Burners upgrades Detailed Cost[1]
Digestion Upgrades and Primary Sludge Thickening Direct Cost	
Civil work (sitework, excavation, demolition, Tie-ins, underground utilities, etc)	$ 2,011,000
Structural (substructures, superstructures, supports, architectural elements, etc)	8,170,000
Process Mechanical (process equipment, process piping, conveyance elements, process ancillaries)	7,541,000
Building Mechanical (Heating, Ventilation and Air Conditioning (HVAC), plumbing, utility piping, etc)	1,885,000
Electrical (Power supply and distribution, wiring, power monitoring, transient protection, etc).	3,017,000
Instrumentation and Control (monitoring devices, local equipment controls, SCADA, life protection and safety systems, control wiring and networks)	2,514,000
Subtotal Digestion Upgrades and Primary Sludge Thickening Direct Cost[1,2]	$ 25,138,000
Indirect Cost (Contractor's profit, bonds, insurance, etc)	6,584,000
Subtotal Direct + Indirect Cost	$ 31,722,000
Contingency (30%)	9,517,000
Escalation[1]- 2016 dollars	4,017,000
Total Construction Cost (Excluding Engineering and HST)	$ 45,255,000
Engineering Cost (12 % of Total Construction Cost)	5,430,000
Total Estimated Capital Cost, Including Construction, Engineering and excluding HST	**$ 50,685,000**

Note:

[1] Estimates are shown in 2012 dollars (Direct Cost), with escalation to midpoint in construction indicated separately (2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017. Some totals may be appear incorrect; when compared to cost presented in Appendices B; due to rounding errors.

[2] Direct Cost includes DIVs-2, 3, 4, 11, 14, 15 A and B, 13, 16A. Details are presented in Appendix B.

1. Introduction

1.1 Project Background

Over the last 10 years, The City of Toronto has been working toward the development and implementation of a Biosolids Management Strategy that meets their overall economic, environmental and social objectives. Key milestones during this period include the following:

- Biosolids and Residuals Master Plan (BRMP), 2002. The City initiated this project to assess options and determine a direction for the future management of biosolids and water residuals generated by the City's water and wastewater treatment plants to the year 2025. This report was released for public comment in 2004.
- BRMP Peer Review, 2005. The results of the BRMP were subjected to a peer review, specifically to assess the decision making model and methodology.
- BRMP Update, 2008. The BRMP was updated to incorporate the recommendations of the peer review and to revise projected quantities and quality to reflect trends since the implementation of the Biosolids and Residuals Master Plan. The consideration of water treatment residuals were dropped from this exercise; hence, the project became known as the Biosolids Master Plan (BMP). The BMP was completed in draft and issued for public review in 2009. The recommended alternative for the HCTP remained thermal reduction.
- Council Directive, 2010. The Council did not approve the recommended thermal reduction alternative for HCTP, directing City staff to implement a beneficial use biosolids management strategy for HCTP, with landfilling as a contingent option.
- Staff Report, 2011. A report was forwarded to Council in 2011 outlining the findings of the BMP for HCTP and outlining the implications of proceeding with either fluidized bed incineration (thermal reduction technology) or a truck loading facility as needed for a beneficial use program. Council voted to proceed with the biosolids Truck Loading Facility.

In 2012, The City retained CH2M HILL Canada Limited (CH2M HILL) to prepare a conceptual design for a biosolids Truck Loading Facility and accompanying odour control and ancillary features at the Highland Creek Treatment Plant.

1.2 Project Objectives

The project aims to achieve the following objectives:

1. Develop four conceptual layout options for the Truck Loading Facility, all of which incorporate odour control systems. The three potential options advanced by the City early in the project for the Truck Loading Facility include:

a. Utilize the existing Biosolids Management Building to locate the Truck Loading Facility.

b. Expand the existing Biosolids Management Building to accommodate a new Truck Loading Facility.

c. Construct a new Truck Loading Facility on site, and close to the existing Biosolids Management Building.

d. Construct a new Truck Loading Facility and dewatering facility at a central location, east of the new Dechlorination Building.

2. Assess the capacity requirements associated with the Truck Loading Facility in terms of biosolids handling capabilities as well as the needs of major ancillary systems.

3. Considering the differences in biosolids treatment requirements for beneficial use rather than thermal reduction, assess the capacity of the existing four anaerobic digesters and associated ancillaries (gas handling system, waste gas burners, etc) based on the updated mass balance and the current waste activated sludge (WAS) thickening project. Identify expansion requirements and develop alternatives, with conceptual layout plans for these alternatives.

4. Recommend a preferred conceptual design that best meets the City's requirements for the Truck Loading Facility and for the existing anaerobic digestion system.

1.3 Project Deliverables

The project work has been segregated into a series of logical steps that allows review of progress as the project team arrives at specific milestones where major decisions are finalized. The deliverables associated with these work elements are as follows:

- Technical Memorandum (TM) 1: Truck Loading Facility- Assessment of Capacity Requirements
- TM 2: Truck Loading Facility- Siting and Configuration
- TM 3: Anaerobic Digestion and Waste Gas Burner Capacity Assessment

These Technical Memoranda will be compiled and attached to the final Truck Loading Facility Conceptual Design Report. This report will also include the evaluation of options for silos/hoppers, odour control requirements and alternatives, and logistical demands of the recommended Truck Loading Facility. Further, the Report will consider the changes necessary to other biosolids management processes on the site necessitated by the change to the biosolids management

1.4 Scope of TM 3 – Digester and Waste Gas Burner Assessment

This Technical Memorandum 3 (TM 3) will review the capacity of the existing digesters and waste gas burners within the context of the basic design parameters established in TM 1 – Assessment of

Capacity Requirements. Various upgrade scenarios will be developed for the digesters and the waste gas burners that will meet the demands of growth in catchment's population to 2032 and beyond. These upgrade scenarios must satisfy the needs of the City of Toronto with regard to the following considerations:

- Compatibility with the existing plant infrastructure
- Operability and maintainability
- Impact on the neighbouring areas due to visibility, traffic, noise, etc.
- Costs

A plant that incorporates thermal oxidation (incineration) of waste biosolids is able to optimize operation of its digesters by bypassing raw sludge to thermal oxidation during times of peak solids loads or when maintenance requires the wasting of significant quantities of sludge over the short term. Without the ability to bypass anaerobic digestion in the future as the mode of biosolids disposal changes to land application, the design of the digesters will have to become much more robust.

This technical memorandum outlines the assessment of existing digester capacity considering the change to biosolids management at the Highland Creek TP. Further, it considers the potential need to expand the digestion facilities to reliably handle the sludge fed to the process such that land application criteria are satisfied, to change upstream biosolids management techniques so that digestion expansion can be prevented or deferred, or to modify the digestion process so that it could achieve treatment goals in shorter process detention times, again reducing or eliminating the need to further expand digestion.

As a corollary of this investigation, the waste gas burners will be assessed and various configurations for new digesters will be examined.

1.5 Reference Documents

The following background information and reference documents provided information that was used to develop TM 3:

- Plant historical operating data between 2009 and 2011;
- City of Toronto (2009 to 2011). HCTP Annual Reports;
- TSH Consultants (2005). HCTP Facilities Forecast;
- AECOM (2009). HCTP NFPA Code review and Assessment, (TM 14);
- HCTP Record Drawings from various contracts;
- AECOM (2011). City of Toronto Biosolids Master Plan;

- AECOM (2012). HCTP WAS Thickening and Sludge Storage Upgrades Design Report
- CH2M HILL (2012). Engineering Study for Various Process Systems in the Digester Facility at the Highland Creek Treatment Plant
- Technical Memorandum 1: Truck Loading Facility – Assessment of Capacity Requirements
- Technical Memorandum 2: Truck Loading Facility – Siting and Configuration

1.6 Organization of Document

Following this introduction, Technical Memorandum 3 has been arranged to logically present the material and evaluations undertaken to this point in the project. The following sections are as follows:

- Section 2: Review of Design Basis
- Section 3: Conventional Digestion Expansion
- Section 4: Digestion Expansion Coupled with Primary Sludge Thickening
- Section 5: Digestion Expansion Coupled with Enhanced Digestion
- Section 6: Digestion Expansion Scenario Comparison
- Section 7: Recommended Digester Expansion Scenario
- Section 8: Waste Gas Burner Assessment

2. Review of Design Basis

2.1 Raw Sludge Loads to Digestion

Technical Memorandum 1 outlined the design basis for the various elements of the biosolids management system at the Highland Creek Treatment Plant (HCTP). The important criteria for the Anaerobic Digestion Facility are summarized in Table 1.

TABLE 1
Design Basis for Anaerobic Digestion Facllity

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	Average	Maximum Month Load	Maximum Week Load	Average	Maximum Month Load	Maximum Week Load
Primary Sludge						
Flow, m^3/d	1,160	1,690	2,000	1,420	2,110	2,460
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
TWAS						
Flow, m^3/d	410	560	630	500	690	780
TS Load, kg/d	20,275	28,130	31,470	25,170	34,470	39,025
VS Load, kg/d	14,820	19,800	22,050	18,335	24,280	27,325
Total Sludge to Digestion						
Flow, m^3/d	1,570	2,260	2,630	1,930	2,800	3,240
TS Load, kg/d	58,715	83,990	97,625	72,115	104,145	120,060
VS Load, kg/d	42,990	60,880	70,505	52,720	75,290	86,585

2.2 Design Standard for Digestion

The acceptance of land application of digested biosolids in Ontario mandates some pathogen removal through treatment. The standard applied is based on achieving residual *E. Coli* densities of 2,000,000 per gram of biosolids (Ministry of Environment, (2002). *Nutrient Management Act*). Generally, the Ministry of the Environment recommends that digestion provide a minimum of 15 days of solids retention time at mesophilic temperatures (35°C to 37°C, Ministry of Environment (2008), *Design Guidelines for Sewage Works*). Given that most digesters are once through processes, the solids retention time (SRT) equals the hydraulic retention time (HRT). In practice, this recommendation translates into the following design basis:

> Provide 15 days solids retention time (SRT) at a maximum month influent load, with one of the largest units out of service.

In theory, 15 days is significantly more than necessary; however, this value accounts for the fact that some of the digestion facility's volume is unavailable because of the deposition of debris and the accumulation of scum and because mixing is not 'perfect', so some of the volume must be accounted as unavailable. Generally, CH2M HILL's standard for digester design expands on the above recommendation as follows:

> Provide solids retention time (SRT) in a digestion facility handling secondary sludge or a combination of primary and secondary sludge, according to the following:
>
> a. 15 days at a maximum month influent sludge load, with one of the largest units out of service, or
>
> b. 12.5 days at a maximum month influent sludge load with one of the largest units out of service when accounting for debris and scum accumulations in the digester volume, and
>
> c. 12 days at a maximum week influent sludge load (or some other maximum load defined by maintenance activities) with one of the largest units out of service, when accounting for debris and scum accumulations in the digester volume.

This standard is based on the premise that digestion begins to fail at an SRT below 8 or 9 days as the hydrolysis of secondary sludge biomass begins to falter. Primary sludge fermentation and digestion remains active; however, the complex compounds of which cellular material is comprised are more difficult to degrade. Exhibit 1 illustrates the predicted impact of reducing digestion SRTs. This graph was generated using the Pro2D model for the Highland Creek plant and varying the digester volume to obtain the range of SRT values investigated.

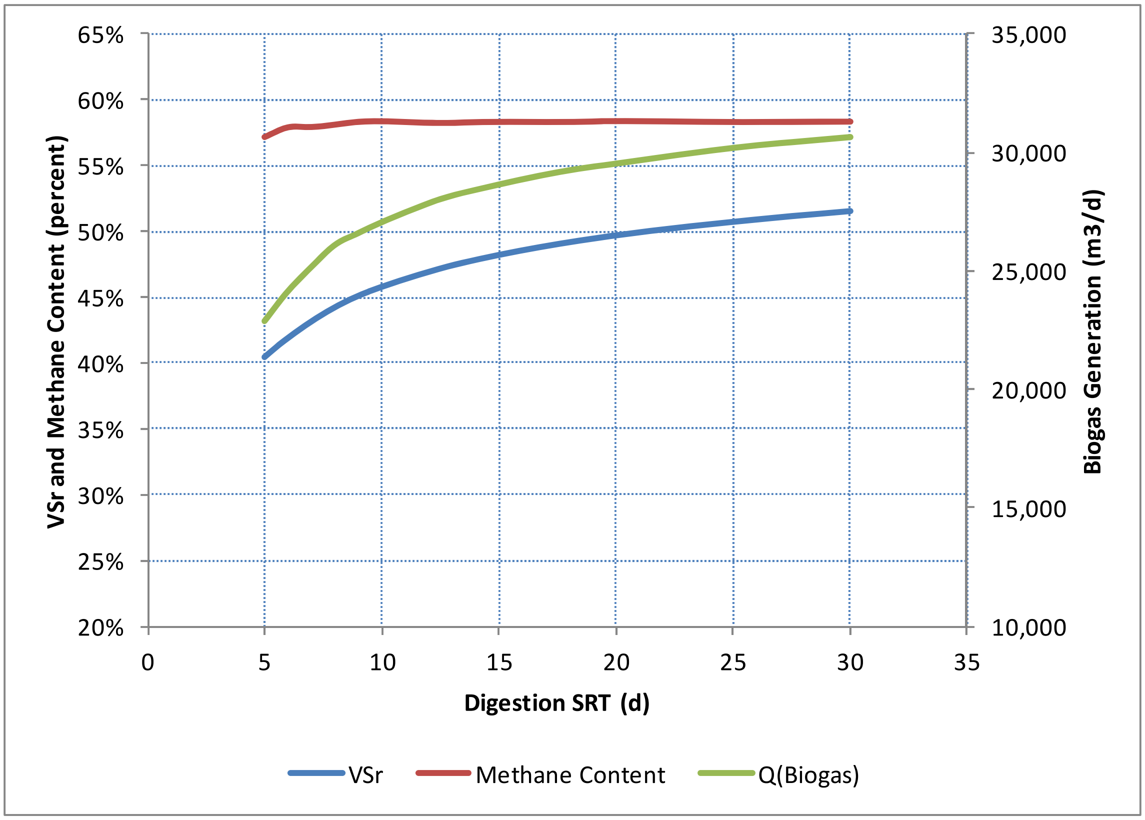


EXHIBIT 1
Anaerobic Digestion Performance Through Range of SRT Values

As is apparent from the modeling work, when the anaerobic digestion SRT drops below 10 days, volatile solids reduction (VSr) and biogas generation rates begin to decrease exponentially.

In addition to the SRT in a anaerobic digestion system, the loading rate is a critical design parameter. Generally loading rates for anaerobic digestion are expressed in terms of kg of volatile solids applied per m^3 of volume per day ($kgVS/m^3/d$). Conventional digesters are typically limited to sustained loading rates of about 3.2 $kgVS/m^3/d$ (WEF (2009). **MOP8, Design of Municipal Wastewater Treatment Plants**, McGraw Hill), although this value can vary depending upon the ratio between primary and secondary sludge. At higher VS loading rates, foaming can become an issue and it is possible that ammonia toxicity can create problems, especially if there is a low primary sludge to secondary sludge mass ratio.

2.3 Predicted Biogas Quantities

The Pro2D model was used to predict biogas quantities under various plant operating conditions. The predicted quantities are summarized in Table 2.

TABLE 2
Design Basis for Biogas Management

Parameter	2032	Ultimate Plant Capacity
Biogas Generation Rate		
Average, m^3/d	21,000	25,235
Maximum Month[1], m^3/d	28,715	35,425
Maximum Week[2], m^3/d	32,830	38,820
Peak Diurnal	45,960	54,350
Methane Fraction (at condition noted)		
Average, percent	0.58	0.58
Maximum Month[1], percent	0.58	0.58
Maximum Week[2], percent	0.58	0.58

Notes: 1. Maximum month projections are based on the maximum 30 day running average during a specific annual period.
2. Maximum week projections are based on digestion of the maximum week sludge loads with a minimum digestion SRT of 12 days.

3. Conventional Digestion Expansion

3.1 Existing Digester Description

There are four existing anaerobic digesters at the Highland Creek TP, all put into service in approximately 2003 and numbered Digester 5 to Digester 8. The digesters are relatively conventional 'pancake' shaped units, each with a total volume of 6,610 m^3. They are mixed with a gas mixing system as was described in a previous study (CH2M HILL 2012, Engineering Study for Various Process Systems in the Digester Facility at the Highland Creek Treatment Plant). Design data for the existing digesters is summarized in Table 3.

TABLE 3
Summary of Existing Digesters and Associated Major Process Components

Item	Description
Total number of digesters	4 (all primary anaerobic digesters)
Digester Dimensions	33.5 m diameter 7.5 m sidewater depth Volume per digester, 6,610 m^3, not including the bottom cone
Total Digester Volume	26,440 m^3, (6,610 m^3 x 4 digesters)
Digester covers	Fixed fabricated steel covers with safety relief valves
Raw Sludge Feed	16 raw sludge pumps (8 in Old Plant, 4 in Phase I, and 4 in Phase IV) 2 flow meters (1 for Old Plant, and 1 for Phases I&IV Plants) 4 automated main sludge feed control valves (1 per digester)
Digested Sludge Removal and Transfer	4 variable speed sludge transfer pumps and associated automated inlet valves (1 per digester)
Sludge Heating System	4 dual pass sludge heat exchangers (1 per digester) 4 sludge recirculation pumps (1 per digester)
Digester Gas – Mixing System	5 gas mixing compressors (4 duty 1 standby) Digester gas mixing draft tubes
Waste Gas Burners (WBGs)	3 WGBs, each with a rated capacity of 513 m^3/hr
<u>Digester Gas Utilization Systems</u>	
High pressure boosters	3 High Pressure booster compressors, each with a rated capacity of 480 Nm^3/hr
Boilers	5 boilers, each sized to handle 870 Nm^3 /hr biogas.

Digester 5 was inspected in early 2012. Although it was found in relatively good condition after nine years of operation, grit and debris accumulations in the bottom of the tank accounted for about 18 percent of the total volume.

3.2 Future Digestion Capacity Requirements

The projected raw sludge volumes for the year 2032 and for the ultimate plant capacity have been presented in Section 2.1 and the design approach to digestion, outlined in Section 2.2. Based on the values contained in those sections, the existing digesters will have substantial capacity shortfalls as shown in Table 4.

TABLE 4
Design Basis for Anaerobic Digestion Facllity

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	**Average**	**Maximum Month Load**	**Maximum Week Load**	**Average**	**Maximum Month Load**	**Maximum Week Load**
Primary Sludge						
Flow, m^3/d	1,160	1,690	2,000	1,420	2,110	2,460
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
TWAS						
Flow, m^3/d	410	560	630	500	690	780
TS Load, kg/d	20,275	28,130	31,470	25,170	34,470	39,025
VS Load, kg/d	14,820	19,800	22,050	18,335	24,280	27,325
Total Sludge to Digestion						
Flow, m^3/d	1,570	2,260	2,630	1,930	2,800	3,240
TS Load, kg/d	58,715	83,990	97,625	72,115	104,145	120,060
VS Load, kg/d	42,990	60,880	70,505	52,720	75,290	86,585
Volume Requirements						
15 day SRT		33,900			42,000	

The existing four digesters provide a firm (largest unit out of service) process volume of 19,830 m^3, well below the volume requirements noted in Table 4. Without varying plant operation in any manner, the digesters could be expanded in two ways. The first would entail maintaining the existing digester geometry and size while the second would be to use somewhat larger digesters to minimize the number of units required. In the first scenario for the ultimate plant capacity, seven duty digesters would be needed to provide the requisite SRT; hence, eight total units would be installed. For the design year of 2032, six duty units and seven total digesters would be necessary to meet the volumetric requirements. The resulting total and firm volumes would be as follows:

Option 1A - Conventional Expansion, Existing Digester Size for New Units

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Digesters		
Number	3	4
Volume, m^3	6,610	6,610
Total Volume, m^3	46,270	52,880
Firm Capacity, m^3	39,660	46,270

The second approach would employ larger digesters that better fit the projected capacity requirements. It would be possible to reduce the ultimate number of additional digesters. Either the digesters could be increased in size to result in either three new digesters ultimately or two new digesters ultimately. The possible designs would be approximately as follows:

Option 1B - Conventional Expansion, Larger New Digester, Three Total

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Digesters		
Number	2	3
Volume, m^3	7,780	7,780
Total Volume, m^3	42,000	49,780
Firm Capacity, m^3	34,220	42,000

Option 1C - Conventional Expansion, Larger New Digester Size, Two Total

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Digesters		
Number	2	2
Volume, m^3	15,560	15,560
Total Volume, m^3	57,560	57,560
Firm Capacity, m^3	42,000	42,000

The latter approach would result in much larger digesters and substantial over-building in the short term, although a much smaller digester footprint in the long term.

4. Digestion Expansion Coupled with Primary Sludge Thickening

4.1 Primary Sludge Thickening

The predicted primary sludge quantities are high because the anticipated thickened sludge concentrations are relatively low – 3.3 percent. This estimate of thickened sludge concentrations is conservative given that the plant has no recent experience with in situ thickening of primary sludge in the primary clarifiers. For the last number of years, primary sludge and WAS has been co-thickened in these units. Currently, a WAS Thickening Project is underway where WAS will be re-directed to a series of six thickening centrifuges and then the thickened WAS (TWAS) will be re-blended with the thickened primary sludge prior to digestion. When sludge loads are very high or a digester is out of service, a portion of the TWAS will bypass the digestion process and be blended with digested sludge prior to incineration. Although discontinuing co-thickening will alter how primary sludge thickens in the existing primary clarifiers, the selected concentration of 3.3 percent has been retained for analysis of downstream processes.

Primary sludge thickening can be accomplished in much the same manner as WAS thickening, using rotary drum thickeners, gravity belt thickeners, or centrifuges. A newly commissioned primary sludge thickening facility at Hamilton's Woodward Avenue WWTP has shown the ability to consistently achieve thickened primary sludge solids concentrations above 6 percent. If a similar upgrade was implemented at the Highland Creek TP, using one of the available mechanical thickening processes in parallel with the centrifuge thickening equipment currently being installed for WAS thickening, it is believed that a minimum solids concentration of 5.5 percent would be achievable for the primary sludge. Gravity belt thickeners have been tentatively selected for primary sludge thickening for several reasons, as follows:

- Gravity belt thickeners can handle higher hydraulic loads than rotary drum thickeners, so fewer units would be required.
- Gravity belt thickeners can be enclosed, so odours are contained.
- Gravity belt thickener power consumption is much less than that of centrifuges.
- Gravity belt thickening does not require pre-screening of sludge as is the case when thickening primary sludge with centrifuges.
- Gravity belt thickeners are able to achieve 6 percent or greater thickened primary sludge concentrations with reasonable polymer dosages.

Most of the benefits noted above for gravity belt thickeners in comparison to centrifuges are shared with rotary drum thickeners. The selection should be revisited at a future date prior to finalizing the design. It is unlikely that costs will be the deciding factor when chosing between gravity belt thickeners and rotary drum thickeners - experience has shown that the cost difference between rotary drum thickening and gravity belt thickening is minimal.

If primary sludge thickening was implemented, it is presumed that primary sludge would be withdrawn from the clarifiers at a solids concentration of about 1.5 percent. Withdrawing the sludge at lower concentrations than currently practiced will enhance primary treatment performance, especially during peak flow events. When the inventory of solids in the clarifier is lowered, solids scouring from highly loaded primary clarifiers is less of an issue. Given that the sludge would be withdrawn in more dilute form than is presently the case, the design of the primary sludge thickening facility would be as summarized in Table 5.

TABLE 5
Design Basis for Primary Sludge Thickening

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	**Average**	**Maximum Month Load**	**Maximum Week Load**	**Average**	**Maximum Month Load**	**Maximum Week Load**
Primary Sludge						
Flow, m^3/d	2,160	3,460	4,320	3,460	3,460	4,320
Solids Concentration, percent	1.78	1.62	1.53	1.36	2.00	1.88
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
Gravity Belt Thickening						
Maximum Loading Rate, $m^3/m/h$	45			45		
Belt Width, m	2.0			2.0		
Number of Units (duty/standby)	2/2			2/2		
Thickened Primary Sludge						
Flow, m^3/d	640	1,015	1,200	785	1,270	1,475
Solids Concentration, percent	6.0	5.5	5.5	6.0	5.5	5.5
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260

The primary sludge flows are based on operating the two duty GBTs at about 80 percent of the rated loading rate under average conditions and increasing the flows to nearer the rated capacity when primary sludge loads exceed the maximum month capacity. The primary sludge will concentrate in the primary clarifiers to at least 2 percent solids concentrations without causing deterioration in primary treatment efficiency.

The assumed capture through gravity belt thickeners used to prepare this table was 100 percent. Actually, the capture rate would be about 95 percent, so solids loads through the entire treatment system would increase to account for the internal recycle of primary sludge solids. For the purpose of this analysis, this recycle has been ignored as it will have minimal impact on process sizing.

4.2 Digester Capacity Requirements with Primary Sludge Thickening

Digester expansion requirements would be substantially reduced with the addition of primary sludge thickening because of the reduced sludge quantities, on a volumetric basis. The modified design basis for sizing the digesters would be as shown in Table 6.

TABLE 6
Design Basis for Anaerobic Digestion Facility, with Primary Sludge Thickening

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	**Average**	**Maximum Month Load**	**Maximum Week Load**	**Average**	**Maximum Month Load**	**Maximum Week Load**
Thickened Primary Sludge						
Flow, m^3/d	640	1,015	1,200	785	1,270	1,475
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
TWAS						
Flow, m^3/d	410	560	630	500	690	780
TS Load, kg/d	20,275	28,130	31,470	25,170	34,470	39,025
VS Load, kg/d	14,820	19,800	22,050	18,335	24,280	27,325
Total Sludge to Digestion						
Flow, m^3/d	1,050	1,575	1,830	1,285	1,950	2,255
TS Load, kg/d	58,715	83,990	97,625	72,115	104,145	120,060
VS Load, kg/d	42,990	60,880	70,505	52,720	75,290	86,585
Volume Requirements						
15 day SRT		23,625			29,250	
Loading Rates, kgVS/m^3/d		2.6	3.2		2.6	3.2

The expansion needs for 2032 and for the ultimate plant expansion would be as follows:

Option 2 – Digester Expansion with Primary Sludge Thickening, Existing Digester Size for New Units

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Digesters		
Number	1	2
Volume, m^3	6,610	6,610
Total Volume, m^3	33,050	39,660
Firm Capacity, m^3	26,440	33,050

The new digesters could even be slightly smaller than the existing; however, there would be minimal savings involved over the long term. There would be no advantage to using larger digesters as was explored for conventional expansion of the facility.

5. Digestion Expansion Coupled with Enhanced Digestion

5.1 Enhanced Digestion

There are many approaches to enhancing digestion, almost all with the intent of hydrolyzing the complex organics (found mostly in the TWAS) prior to digestion so that either better VS removals and biogas production can be accomplished through existing digesters or to allow a reduction in the SRT that a digester expansion needs to be designed to achieve. Further, there are many types of enhanced digestion processes that achieve much better pathogen removal. The basic reason to consider enhanced digestion at the Highland Creek TP is to allow a reduction of the necessary SRT, hence digester volume, which would be required to achieve reasonable biosolids stabilization.

The following paragraphs summarize five basic types of enhanced digestion, with a discussion of the ability of each to facilitate reduced SRTs in the digestion process.

- **Thermophilic Digestion**: Changing the operating temperature of the anaerobic digesters from 35°C to 55°C enables the digesters to be sized at an SRT of 12.0 to 13.0 days versus the conventional mesophilic digestion SRT of 15 days. The additional heat required is substantial and other changes would be necessary in the system to ensure process stability – changes to ensure consistent feed rates to the digesters, improved condensate removal, and added insulation to retain heat. Further, the hotter product will have an impact on dewatering performance. A major advantage of this process is that it substantially improves pathogen deactivation. However, to get a ‘Class A’ biosolids product (similar to the CP1 NASM product defined in the Nutrient Management Act, 2002), the digestion facility would have to incorporate some series operation (termed Extended Thermophilic Digestion).

- **Staged Digestion**: There are many types of staged digestion that enhance stabilization. The most commonly applied is acid/gas digestion in which small reactors are employed to provide about 2 days SRT prior to conventional digestion. The ‘gas’ digesters can be sized for lower SRTs than conventional units – typically 12 days. Although it is possible to operate one or both of the stages at thermophilic temperatures, it is more common to operate both at mesophilic temperatures when improving VSr and biogas production are the major objectives. Pathogen removal is not improved through normal acid/gas digestion configurations; however, there is a proprietary system that involves an acid stage comprised of six small tanks in series that purports to achieve much better pathogen removal.

  Temperature phased anaerobic digestion (TPAD) is a type of staged digestion that is comprised of a 3 to 5 day thermophilic anaerobic reactor followed by an 8 to 10 day mesophilic anaerobic reactor. This proprietary arrangement achieves some pathogen removal due to the thermophilic stage; however, it has not proven pathogen removal to the degree necessary for Class A validation.

- **Mechanical, Chemical, or Mechanical/Chemical Homogenization**: There are numerous processes in use that employ various processes to disrupt protoplasm so that it is much easier to digest. These processes include ultra-sound, electric pulsations, mechanical homogenization, and chemically enhanced mechanical homogenization. They claim to enhance VSr and biogas production; however, their effectiveness is minimal at longer SRTs (over 20 days).
- **Thermal Hydrolysis**: In this process, sludge is dewatered to approximately 16 percent TS and pretreated by heating to 160°C at a pressure of about 4 bar. The pretreated sludge is diluted to between 10 and 12 percent with effluent water to lower the temperature and ammonia content prior to conventional digestion. Typically, the digesters are sized for an SRT of 15 day; although 12 days appears sufficient in most cases. Because of the high sludge concentrations, the volume requirement for digestion is generally 30 to 50 percent of the norm. VSr improves, even for longer digestion SRTs and dewaterability is substantially enhanced. Further, the treated biosolids are pathogen free due to the high temperatures used in the process. However, thermal hydrolysis is complex and energy requirements are significant. In cases where cogeneration is not practiced, the energy balance generally is not favourable toward thermal hydrolysis. The biggest benefit would be that no digestion capacity expansion would be necessary within the lifetime of the plant should this process be implemented as a pretreatment step. Further, the centrifuges presently being installed for WAS thickening could be modified and used for pre-dewatering. Additional units would still be required to handle the primary sludge as well.
- **Recuperative Thickening**: In this process, a portion of the digested sludge is dewatered and recycled to the inlet of the anaerobic digesters. Effectively, recuperative thickening un-couples the hydraulic retention time and solids retention time so that the digesters can achieve greater SRTs without added volume. Generally, the anaerobic digestion SRT can be increased by 25 to 50 percent without having an impact on stabilization performance. In many cases, this process is implemented by returning a dedicated solids stream from dewatering. However in the case of Highland Creek, the separation distance would prevent the use of the existing dewatering centrifuges for recuperative thickening.

For the purposes of assessing existing digester capacity, acid/gas digestion has been selected for consideration. This process would reduce digester tankage requirements by 20 percent, although requiring three or four acid reactors be installed upstream. This process illustrates the impact of a moderate change to digestion, although it is recognized that further analysis would be needed to select the most appropriate process for implementation.

5.2 Digester Capacity Requirements in Acid/Gas Configuration

Acid/gas digester capacity requirements have been derived with and without allowing for primary sludge thickening. The SRT in the digesters would be reduced to 12.5 days, so without primary sludge thickening the digester firm capacity would need to be at least 28,250 m^3 for the design year of 2032 and 35,000 m^3 for the plant's ultimate capacity. Without primary sludge thickening, the design configuration would be as follows:

Digester Expansion with Acid/Gas Modification, without Primary Sludge Thickening, Existing Digester Size for New Units

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Acid Reactors		
Number	3	4
Reactor Volume, m^3	2,260	2,260
New Digesters		
Number	2	3
Volume, m^3	6,610	6,610
Total Volume, m^3	39,660	46,270
Firm Capacity, m^3	33,050	39,660

If modified sizes were selected for the new digesters to reduce the total of new units for the ultimate plant capacity, the design configuration would be as follows:

Digester Expansion with Acid/Gas Modification, without Primary Sludge Thickening, Larger Digester Size for New Units

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Acid Reactors		
Number	3	4
Reactor Volume, m^3	2,260	2,260
New Digesters		
Number	2	2
Volume, m^3	8,560	8,560
Total Volume, m^3	43,560	43,560
Firm Capacity, m^3	35,000	35,000

In the short term, this option would be over-sized because the existing digesters and one new digester are marginally too small for the existing sludge loads.

If primary sludge thickening was incorporated at the same time as an acid/gas reconfiguration of the digestion system, the digester firm capacity would be reduced to 19,700 m^3 for the design year of 2032 and 24,400 m^3 for the plant's ultimate capacity. The design would be as follows:

Digester Expansion with Acid/Gas Modification, with Primary Sludge Thickening, Existing Digester Size for New Units

	2032	Ultimate Cap'y (219 ML/d)
Existing Digesters		
Number	4	4
Volume, m^3	6,610	6,610
New Acid Reactors		
Number	3	4
Reactor Volume, m^3	1,575	1,575
New Digesters		
Number	0	1
Volume, m^3	-	6,610
Total Volume, m^3	26,440	33,050
Firm Capacity, m^3	19,830	26,440

This scenario, because it negates the need for a digester in the short term and requires only one new digester in the long term, will exhibit much better economics than the previous two acid-gas digestion options. For this reason, comparison of the other options to acid-gas conversion will be limited to this option, which has been termed Option 3 through the remainder of this Technical Memorandum.

6. Digestion Expansion Scenario Comparison

6.1 General

The preceding sections have established a number of potential digester expansion scenarios with and without primary sludge thickening and with and without enhanced digestion (acid/gas reactors). Table 7 summarizes those scenarios and lists the estimated capital costs for each scenario as well as identifying a number of non-monetary considerations for each.

6.2 Discussion

The least cost option in terms of capital cost is the implementation of primary sludge thickening. This option requires the least additional digester volume. The relatively low cost for primary sludge thickening is more than offset by the savings in digester construction.

TABLE 7
Digestion Expansion Scenarios

Description	Conventional Option 1A		Conventional, Larger Digesters Option 1B		Conventional, Larger Digesters Option 1C		Conventional with Primary Sludge Thickening Option 2		Acid Gas Digestion, Existing Digester Size, with Primary Sludge Thickening Option 3	
Design Condition	**2032**	**Ultimate**	**2032**	**Ultimate**	**2032**	**Ultimate**	**2032**	**Ultimate**	**2032**	**Ultimate**
Max Month Primary Sludge Flow, m^3/d	1,690	2,110	1,690	2,110	1,690	2,110	1,015	1,270	1,015	1,270
Max Month WAS Flow, m^3/d	560	690	560	690	560	690	560	690	560	690
Max Month Blended Sludge Flow, m^3/d	2,260	2,800	2,260	2,800	2,260	2,800	1,575	1,960	1,575	1,960
Acid Reactor Minimum SRT, d	-	-	-	-	-	-	-	-	2	2
Digester Minimum SRT, d	15	15	15	15	15	15	15	15	12.5	12.5
Acid Reactors										
Number, Duty/Standby	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2/1**	**3/1**
Volume per reactor, m^3	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	1,575	1,575
Digesters, Existing										
Number	4	4	4	4	4	4	4	4	4	4
Volume per reactor, m^3	6,610	6,610	6,610	6,610	6,610	6,610	6,610	6,610	6,610	6,610
Digesters, New										
Number	3	4	2	3	2	2	1	2	0	1
Volume per reactor, m^3	6,610	6,610	7,780	7,780	15,560	15,560	6,610	6,610	-	6,610
Total Digester Volume, m^3	46,270	52,880	42,000	49,780	57,560	57,560	33,050	39,660	26,440	39,660
Firm Digester Volume, m^3	39,660	46,270	34,220	42,000	42,000	42,000	26,440	33,050	19,830	33,050
Capital Costs (000's)										
Primary Sludge Thickening[1]	**-**	**-**	**-**	**-**	**-**	**-**	$ 18,015	$ 0	$ 18,015	$ 0
Acid Reactors[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	$ 38,410	$ 12,470
Digesters	$ 82,000	$ 26,670	$ 59,990	$ 28,050	$ 74,630	$ 0	$ 32,670	$ 26,700	$ 0	$ 30,670
Total Capital Cost (000's)	$ 82,000	$ 26,670	$ 59,990	$ 28,050	$ 74,630	$ 0	$ 50,685	$ 26,700	$ 56,425	$ 43,140
Present Value of Capital Cost (000's)[3]	$ 94,730		$ 74,290		$ 74,630		$ 64,520		$ 79,670	
Present Value of O&M Costs (000's)	$ 54,850		$ 50,710		$ 52,450		$ 54,110		$ 56,920	
Total NPV	$ 149,580		$ 125,000		$ 127,080		$ 118,630		$ 136,590	
Non Monetary										
Number of processes	1		1		1		2		3	
Polymer required, T/y	0		0		0		35.1/42.8		35.1/42.8	
Digester Mixing Power, kW[5]	325/370		295/350		405/405		295/355		280/355	
More biogas / Higher VSr	Neutral		Neutral		Neutral		Neutral		Yes	
Foam resistant	No		No		No		No		Yes	

Notes:
1. Primary sludge thickening based on provision of four gravity belt thickeners in initial installation and no additional units for ultimate plant capacity.
2. Acid reactors would each be 12 m in diameter with a 14.0 m SWD
3. Present value of capital cost based on Stage 1 expansion being completed between 2013 and 2015 while the Stage 2 Expansion would occur between 2030 and 2032. Discount rate is 3 percent.
4. Present value of O&M costs based on the following:
   - Power costs at $0.09/kWh, power usage based on 9 W/m^3 of input for digesters with no primary sludge thickening and 10 W/m3 for digesters with primary sludge thickening. Includes recirculation pumping. Primary sludge thickening power consumption based on 0.006 kWh/kg of sludge thickened.
   - Labour costs based on staff required to operate and maintain all digesters, sludge thickening and ancillaries.
   - Polymer costs based on 2.5 kg
5. Power for digester mixing based on 7 W/m^3 for digesters without primary sludge thickening and 8 W/m^3 for digesters with primary sludge thickening. Total power for digesters included 2 W/m^3 for recirculation pumping.
6. Labour costs are based on $75/h and are meant to include salary burdens, supervision, overeheads, and other related payroll costs.

Primary sludge thickening would incur some operating costs for polymer addition. Based on the predicted 2032 sludge quantities, a dosage of 2.5 kg/tonne dry solids, and a polymer cost of $6/kg, the annual cost would be about 210,000. However, there are some offsetting mixing costs. For mixing without primary sludge thickening, it has been assumed that the energy input would need to be 6.5 W/m^3. For mixing with primary sludge thickening, because of the more viscous material, the average energy input would be 7.5 W/m^3. However, the volumes that require mixing are substantially different. Based on the 2032 requirements, the total energy required for the base case option would be about 300 kW versus 229 kW for digestion with primary sludge thickening. The differential 71 kW would incur an annual energy consumption differential worth about $56,000. Regardless, the present value of the option with primary sludge thickening would be substantially below the cost of the options with no primary sludge thickening.

The savings in digester construction associated with acid gas digestion do not compensate for the cost that would be incurred for acid reactor construction. Since the plant does not have cogeneration, the additional biogas that might be generated is of minimal value and the reduction in biosolids (due to greater VSr) would not offset the capital cost disadvantage.

7. Recommended Digestion Expansion Scenario

7.1 Introduction

Given the costs associated with constructing new digesters, it is recommended that the option that minimizes this requirement be adopted – primary sludge thickening with limited expansion of the digesters. This option entails the construction of a new primary sludge thickening facility and the construction of one new digester. A second new digester would be required after 2032 to handle the ultimate capacity of the plant. The new digesters would be identical to the existing units and would be constructed with the improvements to the mixing system, as recommended in a previous study, incorporated in the initial construction.

7.2 Primary Sludge Thickening Facility

The primary sludge thickening facility would be designed to handle the primary sludge generated by the predicted 2032 tributary population. There are minimal upgrades envisioned for the expansion of the facility to serve the ultimate tributary population. More mass of primary sludge would be pumped from the primary clarifiers, but at greater solids concentrations. The primary sludge thickening facility would be based on the key design criteria that are summarized in Table 8.

TABLE 8
Design Basis for Primary Sludge Thickening

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	**Average**	**Maximum Month Load**	**Maximum Week Load**	**Average**	**Maximum Month Load**	**Maximum Week Load**
Primary Sludge						
Flow, m^3/d	2,160	3,460	4,320	3,460	3,460	4,320
Solids Concentration, percent	1.78	1.62	1.53	1.36	2.00	1.88
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
Gravity Belt Thickening						
Maximum Loading Rate, m^3/m/h	45	45	45	45	45	45
Belt Width, m	2.0	2.0	2.0	2.0	2.0	2.0
Number of Duty Units			2			2
Number of Standby/Maint Units			2			2
Washwater rate, m^3/h/GBT			12			12
Thickened Primary Sludge						
Flow, m^3/d	640	1,015	1,200	785	1,270	1,475
Solids Concentration, percent	6.0	5.5	5.5	6.0	5.5	5.5
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
Primary Sludge Feed Tank						
Number	2			2		
HRT, h	6			6		
Volume per tank, m^3	540			540		
Mixing type	Intermittent Aeration			Intermittent Aeration		
Mixing input, W/m^3	10			10		
TPS Holding Tank						
Number	1			1		
HRT, h	4			4		
Volume per tank, m^3	200			200		
Mixing type	Intermittent Aeration			Intermittent Aeration		
Mixing input, W/m^3	20			20		
TPS Pumps						
Number	3			4		
Type	Progressive Cavity			Progressive Cavity		
Capacity, m^3/h	25			25		
Head	60			60		

A layout and cost estimate for the new primary sludge thickening facility is included in Appendix A of this TM.

7.3 Anaerobic Digestion Expansion

Four existing anaerobic digesters will be expanded by the addition of one more similarly sized unit built west of the existing Waste Gas Burner installation. Ultimately, one further digester would be constructed south of the one new unit. These two new digesters would be designed as indicated in the following Table 9.

TABLE 9
Design Basis for Primary Sludge Thickening

Parameter	2032			Ultimate Capacity (219 ML/d)		
Condition	**Average**	**Maximum Month Load**	**Maximum Week Load**	**Average**	**Maximum Month Load**	**Maximum Week Load**
Thickened Primary Sludge						
Flow, m^3/d	640	1,015	1,200	785	1,270	1,475
Solids Concentration, percent	6.0	5.5	5.5	6.0	5.5	5.5
TS Load, kg/d	38,440	55,860	66,155	46,945	69,675	81,035
VS Load, kg/d	28,170	40,890	48,465	34,385	51,010	59,260
Thickened WAS						
Flow, m^3/d	410	560	630	500	690	780
Solids Concentration, percent	5.0	5.0	5.0	5.0	5.0	5.0
TS Load, kg/d	20,275	28,130	31,470	25,170	34,470	39,025
VS Load, kg/d	14,820	19,800	22,050	18,335	24,280	27,325
Blended Sludge						
Flow, m^3/d	1,570	2,260	2,630	1,930	2,800	3,240
Solids Concentration, percent	5.6	5.3	5.3	5.6	5.3	5.3
TS Load, kg/d	58,715	83,990	97,625	72,115	104,145	120,060
VS Load, kg/d	42,990	60,880	70,505	52,720	75,290	86,585
Existing Digesters						
Number	4			4		
Volume per tank, m^3	6,610			6,610		
Mixing type	Hydraulic			Hydraulic		
Mixing input, W/m^3	8			8		
Recirculation pumping, L/s	25			25		
HEX Capacity, MW	1.0			1.0		
New Digesters						
Number	1			2		
Volume per tank, m^3	6,610			6,610		
Mixing type	Hydraulic			Hydraulic		
Mixing input, W/m^3	8			8		
Recirculation pumping, L/s	25			25		
HEX Capacity, MW	1.0			1.0		

A layout and cost estimate for the existing and new anaerobic digesters and pumphouse is included in Appendix A of this TM.

7.4 Waste Gas Burners Assessment

The previous study (CH2M HILL, 2012) of the Waste Gas Burners (WGBs) and other digestion related systems recommended the installation of three new units, each with a capacity of 1,500 m^3/h. This capacity should be sufficient for one unit to handle the predicted maximum week waste biogas. As noted in Section 2, the peak diurnal biogas production estimate at plant capacity is 54,000 m^3/d or about 2,250 m^3/h. Two of the WGBs could handle that peak load. Given that waste biogas is generally directed to the plant boilers for energy recovery, the sizing appears sufficient.

The cost estimate for WGBs was developed as part of the previous study and slightly for this study, was modified to include escalation and engineering. The updated estimate totals $3,905,000 and is summarized in Table 10 for the recommended option (Option 1) and another option that was developed as part of the work of the previous study.

Table 1
Summary of Capital Cost Estimates[1] for Waste Gas Burner Options, Sized for 2032 Requirements

Description	Option 1[2]	Option 2[3]
Waste Gas Burners Direct Cost		
Civil work (sitework, excavation, demolition, Tie-ins, underground utilities, etc)	$ 60,000	$ 80,000
Structural (substructures, superstructures, supports, architectural elements, etc)	99,500	198,300
Process Mechanical (process equipment, process piping, conveyance elements, process ancillaries)	1,858,200	1,203,000
Building Mechanical (Heating, Ventilation and Air Conditioning (HVAC), plumbing, utility piping, etc)	5,500	5,700
Electrical (Power supply and distribution, wiring, power monitoring, transient protection, etc).	6,600	106,600
Instrumentation and Control (monitoring devices, local equipment controls, SCADA, life protection and safety systems, control wiring and networks)	30,000	50,000
Subtotal Direct Cost[1]	2,090,000	1,643,000
Indirect Cost (Contractor's profit, bonds, insurance, etc.)	355,300	279,300
Subtotal Direct + Indirect Cost	2,445,000	1,922,000
Contingency (30%)	733,500	576,600
Escalation[1] - 2016 dollars	308,500	243,000
Total Construction Cost (Excluding Engineering and HST)	**$ 3,487,000**	**$ 2,742,000**
Engineering Cost (12 % of Total Construction Cost)	416,000	329,000
Total Estimated Capital Cost, Including Construction, Engineering and excluding HST	**$ 3,905,000**	**$ 3,071,000**

Note:

1. Estimates are shown in 2012 dollars (Direct Cost), with no escalation to midpoint in construction. Some totals may be appear incorrect; when compared to cost presented in Appendices 2,4,6, 8; due to rounding errors.
2. Option 1 – Replace the three WGBs with new larger WGBs.
3. Option 2 – Add two new larger WGBs to the existing three WGBs.

7.5 Detailed Capital Cost Estimate of Recommended Digestion Expansion Scenario

Class 4 capital cost estimates have been prepared for the preferred option considered for the anaerobic digester upgrade. These estimates are based on vendor proposals for major equipment, unit prices for structural portions of the work and similar elements constructed at other wastewater treatment plants, and allowances for various components based on complexity and scope. The cost estimate for the digester upgrades and the primary sludge thickeners the at this point in project development is $ 50,685,000 excluding HST (detailed are presented in Table 10 and in Appendix B).

TABLE 10
Capital Cost Estimates[1] of Preferred Option (Includes Digestion Upgrades, Primary Sludge Thickening and Waste Gas Burners upgrades. Excludes cost related to the Truck Loading Facility and associated Odour Control)

Description	Digestion Upgrades, Primary Sludge Thickening and Waste Gas Burners upgrades Detailed Cost[1]
Digestion Upgrades and Primary Sludge Thickening Direct Cost	
Civil work (sitework, excavation, demolition, Tie-ins, underground utilities, etc)	$ 885,000
Structural (substructures, superstructures, supports, architectural elements, etc)	13,711,000
Process Mechanical (process equipment, process piping, conveyance elements, process ancillaries)	6,194,000
Building Mechanical (Heating, Ventilation and Air Conditioning (HVAC), plumbing, utility piping, etc)	1,679,000
Electrical (Power supply and distribution, wiring, power monitoring, transient protection, etc).	1,268,000
Instrumentation and Control (monitoring devices, local equipment controls, SCADA, life protection and safety systems, control wiring and networks)	1,162,000
Subtotal Digestion Upgrades, Primary Sludge Thickening Direct Cost[1,2]	$ 24,900,000
Indirect Cost (Contractor's profit, bonds, insurance, etc)	$ 6,821,000
Subtotal Direct + Indirect Cost	$ 31,721,000
Contingency (30%)	$ 9,516,000
Escalation[1]- 2016 dollars	$ 4,017,000
Total Construction Cost (Excluding Engineering and HST)	**$ 45,255,000**
Engineering Cost (12 % of Total Construction Cost)	$ 5,430,000
Total Estimated Capital Cost, Including Construction, Engineering and excluding HST	**$ 50,685,000**

Note:

[1] Estimates are shown in 2012 dollars (Direct Cost), with escalation to midpoint in construction indicated separately (2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017. Some totals may be appear incorrect; when compared to cost presented in Appendices B; due to rounding errors.

[2] Direct Cost includes DIVs-2, 3, 4, 11, 14, 15 A and B, 13, 16A. Details are presented in Appendix B.

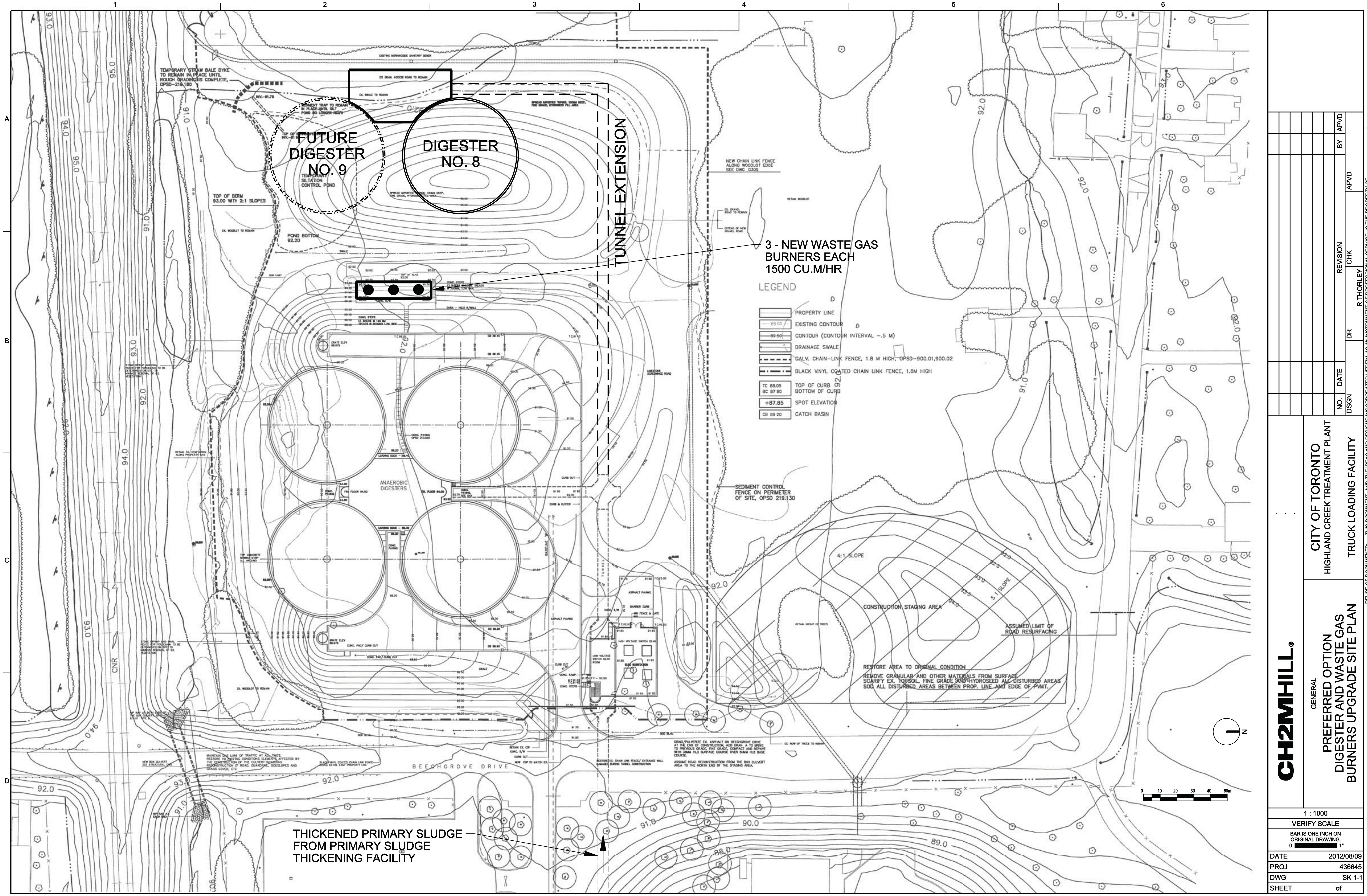
7.6 Summary of Capital Costs

Two elements of the digestion upgrades are included in the above discussion – waste gas burners and digester upgrades (including primary sludge thickening). Both elements require an expansion of capacity because when the beneficial use of biosolids from the plant is initiated, all of the waste primary and secondary solids streams will need to be directed to the digestion complex, exceeding current capacities. The estimated cost of these two elements is as follows:

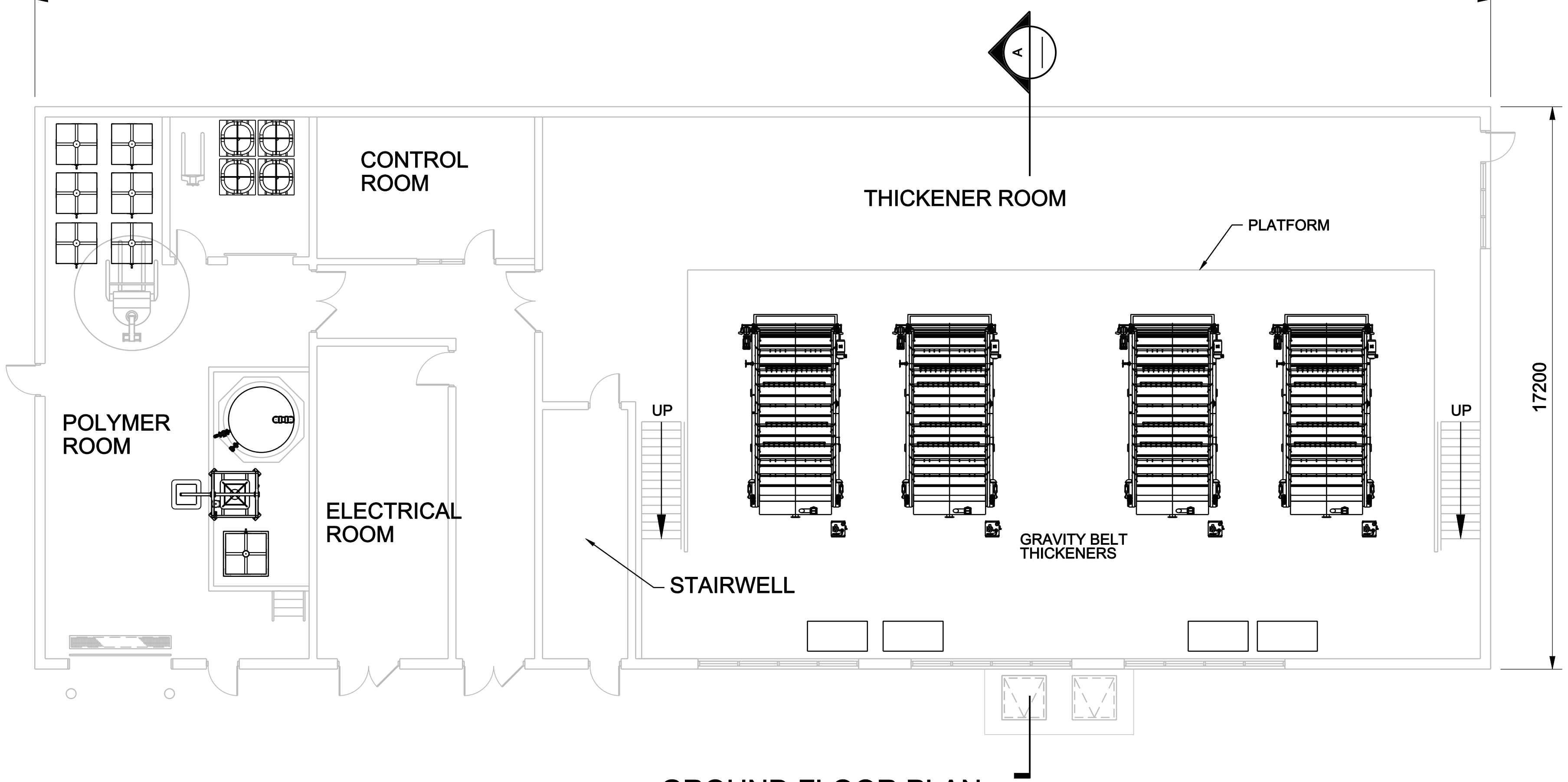
Waste Gas Burner Upgrade	$ 3,905,000
Digester Upgrades and Primary Sludge Thickening	50,685,000
Total	**$ 54,590,000**

These cost estimates do not include any allowances for upgrades to the existing digestion system or primary sludge system. For instance, the costs associated with converting the mixing systems in the existing digesters from gas mixing to hydraulic mixing systems has not been included because that change is related to maintenance issues and is not related to a change in the biosolids management systems.

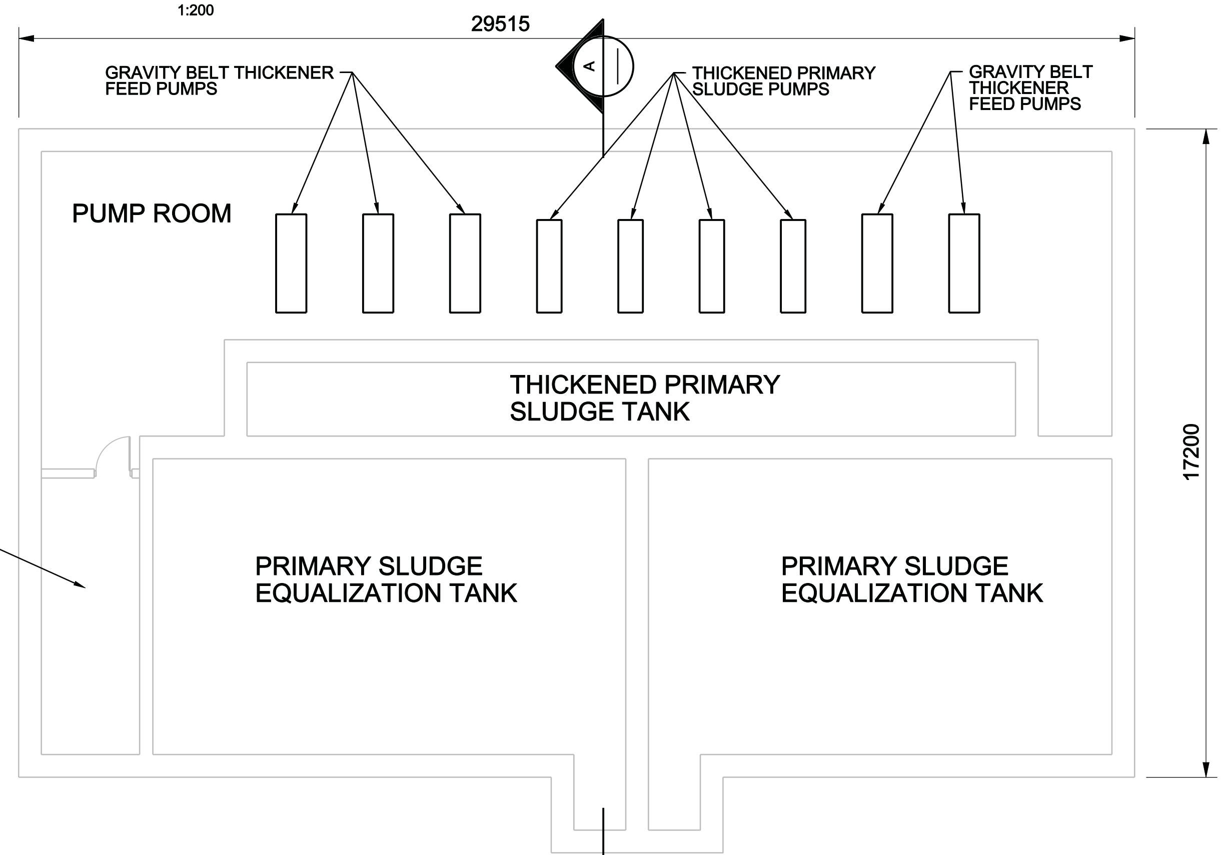
Appendix A
Anaerobic Digestion, Primary Sludge Thickening Facility and Waste Gas Burner Site Plan



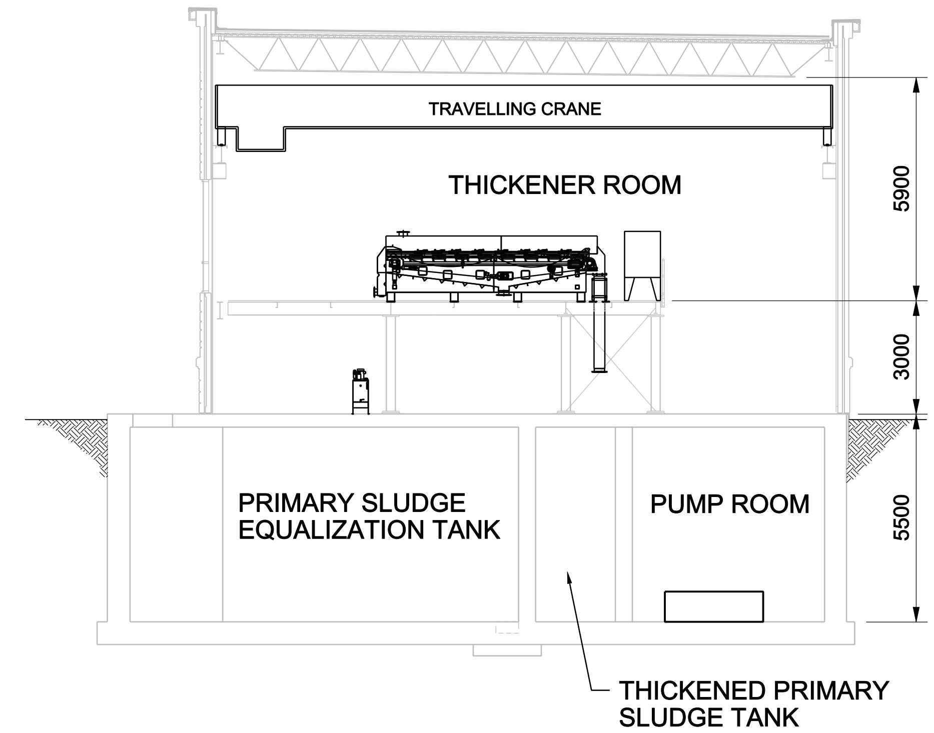
FILENAME: DIGESTER-SITE.dgn PLOT DATE: 2012\10\24 PLOT TIME: 3:09:23 PM



GROUND FLOOR PLAN
1:200



BASEMENT FLOOR PLAN
1:200



A SECTION
1:200

0 1000 2000 3000 4000 5000

NO.	DATE	REVISION	BY	APVD
DSGN	DR R THORLEY	CHK	APVD	

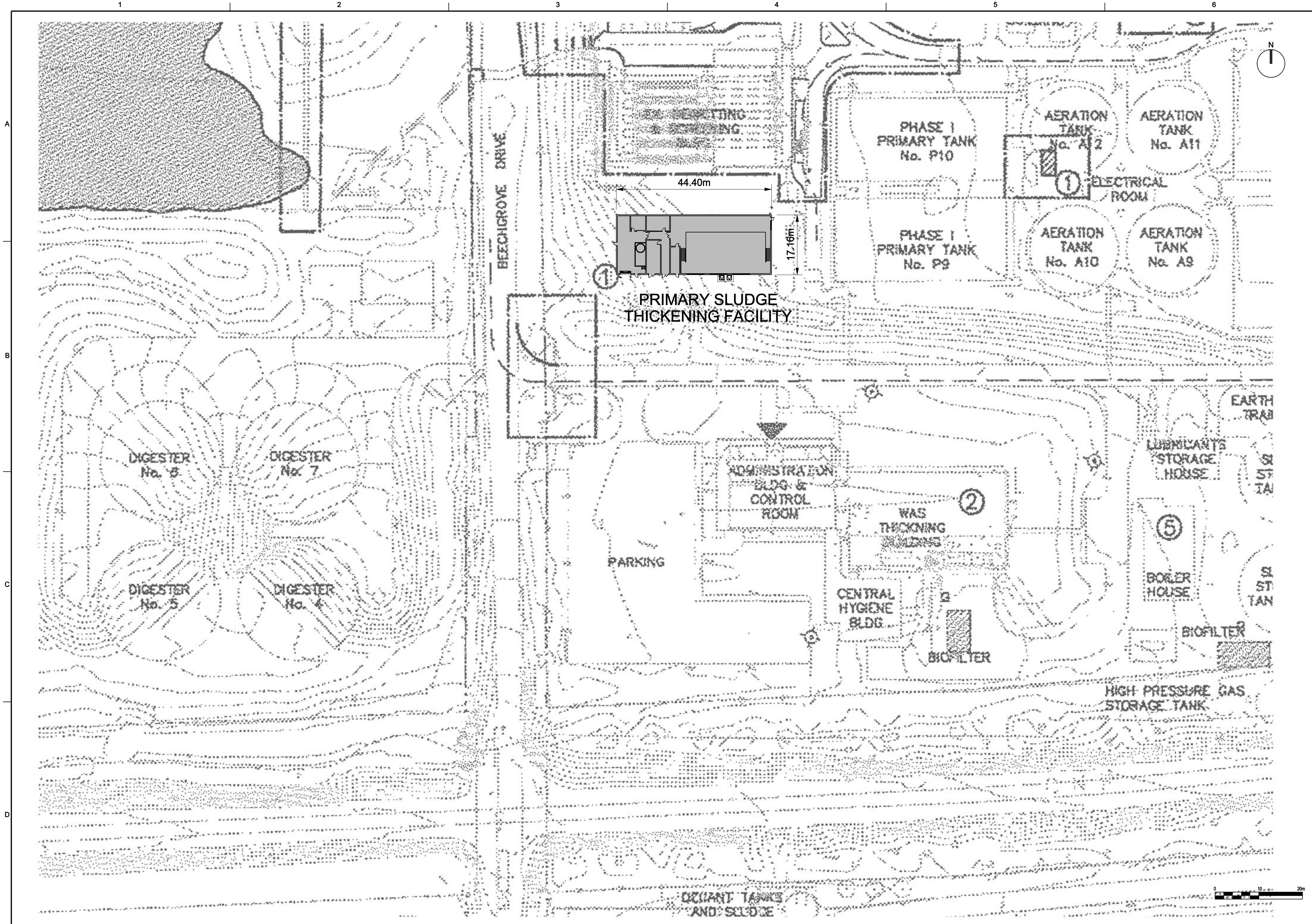
CITY OF TORONTO
HIGHLAND CREEK TREATMENT PLANT
TRUCK LOADING FACILITY

CH2MHILL®

GENERAL
PREFERRED OPTION
PRIMARY SLUDGE THICKENING
FACILITY PLANS AND SECTION

1 : 200	
VERIFY SCALE	
BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"	
DATE	2012/08/09
PROJ	436645
DWG	FIG 1-2
SHEET	of

FILENAME: THICKENING-PLAN.dgn PLOT DATE: 2012\10\24 PLOT TIME: 2:54:00 PM



NO.	DATE	REVISION	BY	APVD

DSGN | DR R THORLEY | CHK | APVD

CITY OF TORONTO
HIGHLAND CREEK TREATMENT PLANT

TRUCK LOADING FACILITY

CH2MHILL

GENERAL

PREFERRED OPTION PRIMARY SLUDGE THICKENING FACILITY SITE PLAN

1 : 1000
VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	2012/08/09
PROJ	436645
DWG	FIG 1-1
SHEET	of

Appendix B
Anaerobic Digestion, Primary Sludge Thickening Facility and Waste Gas Burner – Capital Cost Details

Option 1A - Three New Digesters, Each 6,610 m^3

Cost Estimate [1]

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation % of Matl	Installation Cost	Total Cost
Div 1 - General Requirements							
General Requirements- Covers the general contractor's site cost such as office trailer, site staff, small tools and equipment, permits, cleanup, testing & start-up.		Included in General Conditions Below					
Sub-Total Division 1 - General Requirements							**$ -**
Div 2 - Building Sitework	Costs Scaled from the estimate prepared for Option 2						$ 1,431,800
Sub-Total Division 2 - Building Sitework							**$ 1,431,800**
Div 3 - Concrete	Costs Scaled from the estimate prepared for Option 2						$ 22,181,600
Sub-Total Division 3 - Concrete							**$ 22,181,600**
Div 4 - Masonry							
Masonry- **INCLUDED IN DIV 3**							
Sub-Total Division 4 - Masonry							**$ -**
Div 5 - Metals							
Metals - **INCLUDED IN DIV 3**							$ -
Sub-Total Division 5 - Metals							**$ -**
Div 6 - Wood & Plastics							
Wood and Plastics- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 6 - Wood & Plastics							**$ -**
Div 7 - Thermal and Moisture Protection							
Thermal and Moisture Protection- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 7 - Thermal and Moisture Protection							**$ -**
Div 8 - Doors and Windows							
Doors and Windows- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 8 - Doors and Windows							**$ -**
Div 9 - Finishes							
Finishes- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 9 - Finishes							**$ -**
Div 10 - Specialties	Costs Scaled from the estimate prepared for Option 2						$ -
Sub-Total Division 10 - Specialties							**$ -**
Div 11 - Equipment	Costs Scaled from the estimate prepared for Option 2						$ 6,838,700
Sub-Total Division 11 - Equipment							**$ 6,838,700**
Div 13 - Special Construction I&C	Costs Scaled from the estimate prepared for Option 2						$ 1,880,000
Sub-Total Division 13 - Special Construction I&C							**$ 1,880,000**
Div 14 - Conveying Systems	Costs Scaled from the estimate prepared for Option 2						$ 485,400
Sub-Total Division 14 - Conveying Systems							**$ 485,400**
Div 15A - Building Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 2,716,400
Sub-Total Division 15A - Building Mechanical							**$ 2,716,400**
Div 15B - Process Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 2,697,000
Sub-Total Division 15B - Process Mechanical							**$ 2,697,000**
Div 16A - Electrical	Costs Scaled from the estimate prepared for Option 2						$ 2,051,500
Sub-Total Division 16A - Electrical							**$ 2,051,500**
Sub-Total Basic Facility Costs (Direct Cost)							**$ 40,282,400**

	Option 1A - Three New Digesters, Each 6,610 m^3				Cost Estimate (1)		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Indirect Cost							
Contract Staff & Home Office OH					8.00%		$ 3,223,000
							$ 43,505,400
General Conditions					7.00%		$ 3,045,000
							$ 46,550,400
Mobilization/Demobilization					2.00%		$ 931,000
Insurance					1.00%		$ 465,500
Bond					1.00%		$ 465,500
							$ 48,412,400
Profit					6.00%		$ 2,904,700
							$ 51,317,000
Subtotal Indirect Cost							$ 11,034,700
Contingency					30.00%		$ 15,395,000
							$ 66,712,000
Escalation To Mid Point of Construction[3] (March 2015)					9.74%		$ 6,498,000
Total Construction Cost (Excluding Engineering and HST)							**$ 73,210,000**
Engineering Cost (12% of Total Construction Cost)					12.00%		**$ 8,785,000**
HST 13%							$ 9,517,300
Total Estimated Captital Cost, Including Construction, Engineering and Excluding HST							**$ 81,995,000**
Total Estimated Captital Cost, Including HST							**$ 91,512,300**

(1) The Cost Estimate have been prepared for guidance in project evaluation and implementation from the information available at the time the estimate was prepared. These estimates are considered Order of Magnitude Estimates by the American Association of Cost Engineers (AACE). This level of estimate is expected to be accuate to within plus 50% to minus 30% of the costs prepared.

(2) Highland Creek wwtp Waste Gas Burner and Drain Trap Chamber Study, CH2M HILL January 2012

(3) Estimates are shown in 2012 dollars, with escalation to midpoint in construction indicated separately (March 2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017.

Option 1B -
Two New Digesters, Each 7,800 m^3

Cost Estimate [1]

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		Total Cost
					% of Matl	Cost	
Div 1 - General Requirements							
General Requirements- Covers the general contractor's site cost such as office trailer, site staff, small tools and equipment, permits, cleanup, testing & start-up.		Included in General Conditions Below					
Sub-Total Division 1 - General Requirements							**$ -**
Div 2 - Building Sitework	Costs Scaled from the estimate prepared for Option 2						$ 1,047,500
Sub-Total Division 2 - Building Sitework							**$ 1,047,500**
Div 3 - Concrete	Costs Scaled from the estimate prepared for Option 2						$ 16,228,500
Sub-Total Division 3 - Concrete							**$ 16,228,500**
Div 4 - Masonry							
Masonry- **INCLUDED IN DIV 3**							
Sub-Total Division 4 - Masonry							**$ -**
Div 5 - Metals							
Metals - **INCLUDED IN DIV 3**							$ -
Sub-Total Division 5 - Metals							**$ -**
Div 6 - Wood & Plastics							
Wood and Plastics- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 6 - Wood & Plastics							**$ -**
Div 7 - Thermal and Moisture Protection							
Thermal and Moisture Protection- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 7 - Thermal and Moisture Protection							**$ -**
Div 8 - Doors and Windows							
Doors and Windows- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 8 - Doors and Windows							**$ -**
Div 9 - Finishes							
Finishes- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 9 - Finishes							**$ -**
Div 10 - Specialties	Costs Scaled from the estimate prepared for Option 2						$ -
Sub-Total Division 10 - Specialties							**$ -**
Div 11 - Equipment	Costs Scaled from the estimate prepared for Option 2						$ 5,003,100
Sub-Total Division 11 - Equipment							**$ 5,003,100**
Div 13 - Special Construction I&C	Costs Scaled from the estimate prepared for Option 2						$ 1,375,400
Sub-Total Division 13 - Special Construction I&C							**$ 1,375,400**
Div 14 - Conveying Systems	Costs Scaled from the estimate prepared for Option 2						$ 355,100
Sub-Total Division 14 - Conveying Systems							**$ 355,100**
Div 15A - Building Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 1,987,300
Sub-Total Division 15A - Building Mechanical							**$ 1,987,300**
Div 15B - Process Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 1,973,100
Sub-Total Division 15B - Process Mechanical							**$ 1,973,100**
Div 16A - Electrical	Costs Scaled from the estimate prepared for Option 2						$ 1,500,800
Sub-Total Division 16A - Electrical							**$ 1,500,800**
Sub-Total Basic Facility Costs (Direct Cost)							**$ 29,470,800**

	Option 1B - Two New Digesters, Each 7,800 m^3				Cost Estimate (1)		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Indirect Cost							
Contract Staff & Home Office OH					8.00%		$ 2,358,000
							$ 31,828,800
General Conditions					7.00%		$ 2,228,000
							$ 34,056,800
Mobilization/Demobilization					2.00%		$ 681,100
Insurance					1.00%		$ 340,600
Bond					1.00%		$ 340,600
							$ 35,419,100
Profit					6.00%		$ 2,125,100
							$ 37,544,000
Subtotal Indirect Cost							$ 8,073,400
Contingency					30.00%		$ 11,263,100
							$ 48,807,100
Escalation To Mid Point of Construction[3] (March 2015)					9.74%		$ 4,754,000
Total Construction Cost (Excluding Engineering and HST)							**$ 53,561,100**
Engineering Cost (12% of Total Construction Cost)					12.00%		**$ 6,427,000**
HST 13%							$ 6,962,943
Total Estimated Captital Cost, Including Construction, Engineering and Excluding HST							**$ 59,988,000**
Total Estimated Captital Cost, Including HST							**$ 66,951,043**

(1) The Cost Estimate have been prepared for guidance in project evaluation and implementation from the information available at the time the estimate was prepared. These estimates are considered Order of Magnitude Estimates by the American Association of Cost Engineers (AACE). This level of estimate is expected to be accuate to within plus 50% to minus 30% of the costs prepared.

(2) Highland Creek wwtp Waste Gas Burner and Drain Trap Chamber Study, CH2M HILL January 2012

(3) Estimates are shown in 2012 dollars, with escalation to midpoint in construction indicated separately (March 2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017.

Option 1C -
Two New Digesters, Each 15,560 m^3

Cost Estimate [1]

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		Total Cost
					% of Matl	Cost	
Div 1 - General Requirements							
General Requirements- Covers the general contractor's site cost such as office trailer, site staff, small tools and equipment, permits, cleanup, testing & start-up.		Included in General Conditions Below					
Sub-Total Division 1 - General Requirements							**$ -**
Div 2 - Building Sitework	Costs Scaled from the estimate prepared for Option 2						$ 1,303,100
Sub-Total Division 2 - Building Sitework							**$ 1,303,100**
Div 3 - Concrete	Costs Scaled from the estimate prepared for Option 2						$ 20,188,800
Sub-Total Division 3 - Concrete							**$ 20,188,800**
Div 4 - Masonry							
Masonry- **INCLUDED IN DIV 3**							
Sub-Total Division 4 - Masonry							**$ -**
Div 5 - Metals							
Metals - **INCLUDED IN DIV 3**							$ -
Sub-Total Division 5 - Metals							**$ -**
Div 6 - Wood & Plastics							
Wood and Plastics- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 6 - Wood & Plastics							**$ -**
Div 7 - Thermal and Moisture Protection							
Thermal and Moisture Protection- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 7 - Thermal and Moisture Protection							**$ -**
Div 8 - Doors and Windows							
Doors and Windows- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 8 - Doors and Windows							**$ -**
Div 9 - Finishes							
Finishes- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 9 - Finishes							**$ -**
Div 10 - Specialties	Costs Scaled from the estimate prepared for Option 2						$ -
Sub-Total Division 10 - Specialties							**$ -**
Div 11 - Equipment	Costs Scaled from the estimate prepared for Option 2						$ 6,224,000
Sub-Total Division 11 - Equipment							**$ 6,224,000**
Div 13 - Special Construction I&C	Costs Scaled from the estimate prepared for Option 2						$ 1,711,000
Sub-Total Division 13 - Special Construction I&C							**$ 1,711,000**
Div 14 - Conveying Systems	Costs Scaled from the estimate prepared for Option 2						$ 441,700
Sub-Total Division 14 - Conveying Systems							**$ 441,700**
Div 15A - Building Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 2,472,200
Sub-Total Division 15A - Building Mechanical							**$ 2,472,200**
Div 15B - Process Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 2,454,600
Sub-Total Division 15B - Process Mechanical							**$ 2,454,600**
Div 16A - Electrical	Costs Scaled from the estimate prepared for Option 2						$ 1,867,100
Sub-Total Division 16A - Electrical							**$ 1,867,100**
Sub-Total Basic Facility Costs (Direct Cost)							**$ 36,662,500**

	Option 1C - Two New Digesters, Each 15,560 m^3				Cost Estimate (1)		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Indirect Cost							
Contract Staff & Home Office OH					8.00%		$ 2,933,000
							$ 39,595,500
General Conditions					7.00%		$ 2,772,000
							$ 42,367,500
Mobilization/Demobilization					2.00%		$ 847,400
Insurance					1.00%		$ 423,700
Bond					1.00%		$ 423,700
							$ 44,062,300
Profit					6.00%		$ 2,643,700
							$ 46,706,000
Subtotal Indirect Cost							$ 10,043,500
Contingency					30.00%		$ 14,011,700
							$ 60,717,700
Escalation To Mid Point of Construction[3] (March 2015)					9.74%		$ 5,914,000
Total Construction Cost (Excluding Engineering and HST)							**$ 66,631,700**
Engineering Cost (12% of Total Construction Cost)					12.00%		**$ 7,996,000**
HST 13%							$ 8,662,121
Total Estimated Captital Cost, Including Construction, Engineering and Excluding HST							**$ 74,628,000**
Total Estimated Captital Cost, Including HST							**$ 83,289,821**

(1) The Cost Estimate have been prepared for guidance in project evaluation and implementation from the information available at the time the estimate was prepared. These estimates are considered Order of Magnitude Estimates by the American Association of Cost Engineers (AACE). This level of estimate is expected to be accuate to within plus 50% to minus 30% of the costs prepared.

(2) Highland Creek wwtp Waste Gas Burner and Drain Trap Chamber Study, CH2M HILL January 2012

(3) Estimates are shown in 2012 dollars, with escalation to midpoint in construction indicated separately (March 2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017.

Preffered Option	**One New Digester; Waste Gas Burner Upgrades and a Primary Sludge Thickening Facility**				**Cost Estimate [(1)]**		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Div 1 - General Requirements							
General Requirements- Covers the general contractor's site cost such as office trailer, site staff, small tools and equipment, permits, cleanup, testing & start-up.		Included in General Conditions Below					
Sub-Total Division 1 - General Requirements							**$ -**
Div 2 - Building Sitework							
Civil Work -Digester Excavation and Rough Grading	1	sum	$ 435,000.00	$ -	$ -	incl.	$ 435,000
Civil Work- Access Road	1	sum	$ 200,000.00	$ -	$ -	incl.	$ 200,000
Minor Demolition and Tie-In with Tunnel	1	sum	$ 200,000.00	$ -	$ -	incl.	$ 200,000
Civil Work- Primary Sludge Thickening Facility	1	sum	$ 50,000.00	$ -	$ -	incl.	$ 50,000
Sub-Total Division 2 - Building Sitework							**$ 885,000**
Div 3 - Concrete							
Building Digester - (Architectural, Structural)	1	sum	$ 3,000,000.00	$ -	$ -	incl	$ 3,000,000
Building Primary Sludge Thickening- (Architectural, Structural)	2,291	m^2	$ 1,620.00	$ 3,711,484.80	$ -	incl	$ 3,711,485
Tunnel Extension	1	sum	$ 2,000,000.00	$ -	$ -	incl.	$ 2,000,000
Digester Concrete(walls, roof slab, columns)	1	sum	$ 5,000,000.00	$ -	$ -	incl.	$ 5,000,000.00
Sub-Total Division 3 - Concrete							**$ 13,711,500**
Div 4 - Masonry							
Masonry- **INCLUDED IN DIV 3**							
Sub-Total Division 4 - Masonry							**$ -**
Div 5 - Metals							
Metals - **INCLUDED IN DIV 3**							$ -
Sub-Total Division 5 - Metals							**$ -**
Div 6 - Wood & Plastics							
Wood and Plastics- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 6 - Wood & Plastics							**$ -**
Div 7 - Thermal and Moisture Protection							
Thermal and Moisture Protection- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 7 - Thermal and Moisture Protection							**$ -**
Div 8 - Doors and Windows							
Doors and Windows- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 8 - Doors and Windows							**$ -**
Div 9 - Finishes							
Finishes- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 9 - Finishes							**$ -**
Div 10 - Specialties							
Specialties- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 10 - Specialties							**$ -**
Div 11 - Equipment							
-Primary Sludge Thickening Facility							
Gravity Belt Thickeners (GBT)	4	each	$ 190,000.00	$ 760,000.00	30%	$ 57,000	$ 817,000
Primary Sludge Pumps	5	each	$ 40,000.00	$ 200,000	50%	$ 100,000	$ 300,000
Polymer System	1	sum	$ 1,000,000.00	$ -	$ -	incl.	$ 1,000,000
Odour Control	1	sum	$ 250,000.00	$ -	$ -	incl.	$ 250,000
Thickening Sludge Pumps	4	each	$ 40,000.00	$ 160,000	50%	$ 80,000	$ 240,000
Blower- Tank Intermittent Aeration	2	each	$ 10,000.00	$ 20,000	50%	$ 10,000	$ 30,000
-Subtotal Primary Sludge Thickening Facility							$ 2,637,000
-Digester Upgrades							
Sludge Recirculation Pumps incl VFD	2	each	$ 30,000.00	$ 60,000.00	50%	$ 30,000	$ 90,000
Heat Exchangers	2	each	$ 100,000.00	$ 200,000	50%	$ 100,000	$ 300,000
Mixing Equipment(Rotamix System)	1	each	$ 650,000.00	incl.	50%	$ 325,000	$ 975,000
Grinder	2	each	$ 45,000.00	$ 90,000	50%	$ 45,000	$ 135,000
Digester Drain Pumps	2	each	$ 30,000.00	$ 60,000	50%	$ 30,000	$ 90,000
-Subtotal Digesters							$ 1,590,000
Sub-Total Division 11 - Equipment							**$ 4,227,000**

Preffered Option	One New Digester; Waste Gas Burner Upgrades and a Primary Sludge Thickening Facility				Cost Estimate [1]		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Div 13 - Special Construction I&C							
Instrument Control Panel (ICP), PLC System - Software and Hardware	1	sum	$ 1,162,425.00	$ -	$ -	Incl.	$ 1,162,425
-Estimated as 25% of Equipment cost(DIV 11)							
Sub-Total Division 13 - Special Construction I&C							**$ 1,162,400**
Div 14 - Conveying Systems							
Bridge Crane- Digester	1	sum	$ 200,000.00	$ -	$ -	incl	$ 200,000
Monorail- Primary Sludge Thickening Facility	1	sum	$ 100,000.00	$ -	$ -	incl.	$ 100,000
Sub-Total Division 14 - Conveying Systems							**$ 300,000**
Div 15A - Building Mechanical							
-Digester Building and Tunnel							
Building Exhaust Fans/ Heaters	1	sum	$ 149,000	$ -	$ -	incl	$ 149,000
Sump Pump Allowances	1	sum	$ 30,000	$ -	$ -	incl	$ 30,000
Make Up Air Units/Dehumidication Units	1	sum	$ 350,000	$ -	$ -	incl	$ 350,000
Building Duct Work	1	sum	$ 200,000	$ -	$ -	incl	$ 200,000
-Subtotal Digester Building and Tunnel							$ 729,000
-Primary Sludge Thickening Facility							
Building Exhaust Fans/ Heaters	1	sum	$ 150,000	$ -	$ -	incl	$ 150,000
Sump pump allowances	1	sum	$ 50,000	$ -	$ -	incl	$ 50,000
Make Up Air Units/Dehumidication Units	1	sum	$ 450,000	$ -	$ -	incl	$ 450,000
Building Duct Work	1	sum	$ 300,000	$ -	$ -	incl	$ 300,000
-Subtotal Primary Sludge Thickening Facility							$ 950,000
Sub-Total Division 15A - Building Mechanical							**$ 1,679,000**
Div 15B - Process Mechanical							
-Digester Building							
500 mm Check valves	2	each	$ 13,000.00	$ 26,000	50%	$ 13,000	$ 39,000
350 mm Knife Gate Valves	4	each	$ 15,000.00	$ 60,000	50%	$ 30,000	$ 90,000
500 mm Discharge pipe	60	m	$ 500.00	$ 30,000	50%	$ 15,000	$ 45,000
600 mm Suction pipe	60	m	$ 700.00	$ 42,000	50%	$ 21,000	$ 63,000
Miscellenaus Piping (Gas Piping, Hot Water)	1	sum	$ 380,000.00	$ -	$ -	Incl.	$ 380,000
Safety Devices	1	sum	$ 200,000.00	$ -	50%	$ 100,000	$ 300,000
-Subtotal Digester Building							$ 917,000
-Primary Sludge Thickening Facility							
Primary Sludge to GBT	1	sum	$ 300,000.00	$ -	50%	$ 150,000	$ 450,000
Filtrate Pipes	1	sum	$ 100,000.00	$ -	50%	$ 50,000	$ 150,000
Miscellaneous Piping (polymer, flush water lines)	1	sum	$ 100,000.00	$ -	50%	$ 50,000	$ 150,000
-Subtotal Primary Sludge Tickening Facility							$ 750,000
Sub-Total Division 15B - Process Mechanical							**$ 1,667,000**
Div 16A - Electrical							
Electrical - Supply and Install	1	sum	$ 1,268,100.00	$ 1,268,100	incl	$ -	$ 1,268,100
-Estimated as 30% of Equipment Cost (DIV 11)							
Sub-Total Division 16A - Electrical							**$ 1,268,100**
Sub-Total Basic Facility Costs (Direct Cost)							**$ 24,900,000**
Indirect Cost							
Contract Staff & Home Office OH					8.00%		$ 1,992,000
							$ 26,892,000
General Conditions					7.00%		$ 1,882,000
							$ 28,774,000
Mobilization/Demobilization					2.00%		$ 576,200
Insurance					1.00%		$ 287,700
Bond					1.00%		$ 287,700
							$ 29,925,600
Profit					6.00%		$ 1,795,800
							$ 31,721,000
Subtotal Indirect Cost							$ 6,821,400
Contingency					30.00%		$ 9,516,200
							$ 41,237,200
Escalation To Mid Point of Construction[3] (March 2015)					9.74%		$ 4,017,000

Preffered Option	One New Digester; Waste Gas Burner Upgrades and a Primary Sludge Thickening Facility				Cost Estimate (1)		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Total Construction Cost (Excluding Engineering and HST)							**$ 45,254,200**
Engineering Cost (12% of Total Construction Cost)					12.00%		**$ 5,431,000**
HST 13%							$ 5,883,046
Total Estimated Captital Cost, Including Construction, Engineering and Excluding HST							**$ 50,685,000**
Total Estimated Captital Cost, Including HST							**$ 56,568,246**

(1) The Cost Estimate have been prepared for guidance in project evaluation and implementation from the information available at the time the estimate was prepared. These estimates are considered Order of Magnitude Estimates by the American Association of Cost Engineers (AACE). This level of estimate is expected to be accuate to within plus 50% to minus 30% of the costs prepared.

(2) Highland Creek wwtp Waste Gas Burner and Drain Trap Chamber Study, CH2M HILL January 2012

(3) Estimates are shown in 2012 dollars, with escalation to midpoint in construction indicated separately (March 2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017.

	Option 1C - Two New Digesters, Each 15,560 m^3				Cost Estimate [1]		
Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		**Total Cost**
					% of Matl	Cost	
Div 1 - General Requirements							
General Requirements- Covers the general contractor's site cost such as office trailer, site staff, small tools and equipment, permits, cleanup, testing & start-up.		Included in General Conditions Below					
Sub-Total Division 1 - General Requirements							**$ -**
Div 2 - Building Sitework	Costs Scaled from the estimate prepared for Option 2						$ 985,200
Sub-Total Division 2 - Building Sitework							**$ 985,200**
Div 3 - Concrete	Costs Scaled from the estimate prepared for Option 2						$ 15,263,800
Sub-Total Division 3 - Concrete							**$ 15,263,800**
Div 4 - Masonry							
Masonry- **INCLUDED IN DIV 3**							
Sub-Total Division 4 - Masonry							**$ -**
Div 5 - Metals							
Metals - **INCLUDED IN DIV 3**							$ -
Sub-Total Division 5 - Metals							**$ -**
Div 6 - Wood & Plastics							
Wood and Plastics- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 6 - Wood & Plastics							**$ -**
Div 7 - Thermal and Moisture Protection							
Thermal and Moisture Protection- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 7 - Thermal and Moisture Protection							**$ -**
Div 8 - Doors and Windows							
Doors and Windows- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 8 - Doors and Windows							**$ -**
Div 9 - Finishes							
Finishes- **INCLUDED IN DIV 3**							$ -
Sub-Total Division 9 - Finishes							**$ -**
Div 10 - Specialties	Costs Scaled from the estimate prepared for Option 2						$ -
Sub-Total Division 10 - Specialties							**$ -**
Div 11 - Equipment	Costs Scaled from the estimate prepared for Option 2						$ 4,705,700
Sub-Total Division 11 - Equipment							**$ 4,705,700**
Div 13 - Special Construction I&C	Costs Scaled from the estimate prepared for Option 2						$ 1,293,600
Sub-Total Division 13 - Special Construction I&C							**$ 1,293,600**
Div 14 - Conveying Systems	Costs Scaled from the estimate prepared for Option 2						$ 334,000
Sub-Total Division 14 - Conveying Systems							**$ 334,000**
Div 15A - Building Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 1,869,200
Sub-Total Division 15A - Building Mechanical							**$ 1,869,200**
Div 15B - Process Mechanical	Costs Scaled from the estimate prepared for Option 2						$ 1,855,800
Sub-Total Division 15B - Process Mechanical							**$ 1,855,800**
Div 16A - Electrical	Costs Scaled from the estimate prepared for Option 2						$ 1,411,600
Sub-Total Division 16A - Electrical							**$ 1,411,600**
Sub-Total Basic Facility Costs (Direct Cost)							**$ 27,718,900**

Option 1C -
Two New Digesters, Each 15,560 m^3

Cost Estimate [1]

Component Description	Quantity	Unit	Unit Cost	Material Cost	Installation		Total Cost
					% of Matl	Cost	
Indirect Cost							
Contract Staff & Home Office OH					8.00%		$ 2,218,000
							$ 29,936,900
General Conditions					7.00%		$ 2,096,000
							$ 32,032,900
Mobilization/Demobilization					2.00%		$ 640,700
Insurance					1.00%		$ 320,300
Bond					1.00%		$ 320,300
							$ 33,314,200
Profit					6.00%		$ 1,998,900
							$ 35,313,000
Subtotal Indirect Cost							$ 7,594,200
Contingency					30.00%		$ 10,593,800
							$ 45,906,800
Escalation To Mid Point of Construction[3] (March 2015)					9.74%		$ 4,471,000
Total Construction Cost (Excluding Engineering and HST)							**$ 50,377,800**
Engineering Cost (12% of Total Construction Cost)					12.00%		**$ 6,045,000**
HST 13%							$ 6,549,114
Total Estimated Captital Cost, Including Construction, Engineering and Excluding HST							**$ 56,423,000**
Total Estimated Captital Cost, Including HST							**$ 62,971,914**

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(2) Highland Creek wwtp Waste Gas Burner and Drain Trap Chamber Study, CH2M HILL January 2012

(3) Estimates are shown in 2012 dollars, with escalation to midpoint in construction indicated separately (March 2016). It has been assumed that projects would be tendered in 2015 and constructed by 2017.