Appendix C
Basis of Estimate Technical Memorandum

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CSO Master Plan

Basis of Estimate
Technical Memorandum

August 2019

City of Winnipeg

CSO Master Plan

Project No:	470010CH
Document Title:	Basis of Estimate Technical Memorandum
Revision:	02
Date:	August 2019
Client Name:	City of Winnipeg
Project Manager:	John Berry
File Name:	CSO_MP_BasisofEstimate_Final_08012019.docx

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Document History and Status

Revision	Date	Description	By	Review	Approved
0	02-2019	DRAFT	SG	ES	
1	04-2019	2nd DRAFT	VN	SG, PP	
2	08-2019	Final	SG	JB	DJT

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Acronyms and Abbreviations

AACE	Association for the Advancement of Cost Engineering
CS	combined sewer
CSO	Combined Sewer Overflow
GI	green infrastructure
LBIS	land-based information system
LDS	land drainage sewer
ML/d	megalitre(s) per day
MSD	Manitoba Sustainable Development
MRST	Manitoba Retail Sales Tax
NSWL	normal summer water level
O&M	operations and maintenance
PACC	Program Alternative Cost Calculator – costing tool
PV	present value
SCADA	supervisory control and data acquisition
SRS	storm relief sewer
STP	sewage treatment plant
TBM	tunnel boring machine
WWF	wet weather flow
WWS	wastewater sewer

1. Introduction

The objective of this document is to summarize the basis for the cost estimates developed for the Combined Sewer Overflow (CSO) Master Plan. As part of the Master Plan, it was necessary to develop a clear framework to support the capital investment required to control the release of untreated wastewater discharged from combined sewer infrastructure in the City of Winnipeg (City) in accordance with Environment Act No. 3042 (EA No. 3042) issued by Manitoba Sustainable Development (MSD).

The cost estimates for the CSO Master Plan were initially developed during the Preliminary Proposal phase when the alternative plans and control limits were being assessed. The submission of the Preliminary Proposal led to the selection of one of the alternative plans which was subsequently further refined as part of the CSO Master Plan development.

As part of the Preliminary Proposal phase, five alternative limits for CSO control were identified as follows:

- Control Option No. 1: 85 Percent Capture in a Representative Year
- Control Option No. 2: Four Overflows in a Representative Year
- Control Option No. 3: Zero Overflows in a Representative Year
- Control Option No. 4: No More Than Four Overflows per Year
- Control Option No. 5: Complete Sewer Separation

The Preliminary Proposal included a cost estimate for each of the alternative control plans as identified in Table 1-1. The estimated cost of the program ranged from $1.2 billion to $4.1 billion in 2014 dollars including a plus 50 percent estimating allowance for budget review purposes.

Table 1-1. Preliminary Proposal Alternative Plan Cost Estimates (2014 Dollars)

Description	Capital Cost	Capital Cost + 50% Allowance	Present Value Lifecycle Cost
Control Option No. 1: 85% Capture in a Representative Year	$ 830,000,000	$1,245,000,000	$ 970,000,000
Control Option No. 2: Four Overflows in a Representative Year	$1,720,000,000	$2,580,000,000	$1,850,000,000
Control Option No. 3: Zero Overflows in a Representative Year	$2,170,000,000	$3,255,000,000	$2,310,000,000
Control Option No. 4: No More than Four Overflows per Year [a]	$2,300,000,000	$3,450,000,000	$2,450,000,000
Control Option No. 5: Complete Sewer Separation	$2,760,000,000	$4,140,000,000	$2,790,000,000

[a] Control Option No. 4 is extrapolated from Control Option No. 3.

In December 2015, the City submitted the Preliminary Proposal to MSD recommending Control Option No. 1. The City received written approval dated November 17, 2017 from MSD to proceed with Control Option No. 1. The approval stated the program should be implemented before the end of 2045 or as otherwise agreed by the Director. The 2045 date would mean the timeline for the complete implementation of all the CSO Master Plan upgrades spans approximately 25 years.

2. CSO Master Plan Cost Update

The Preliminary Proposal recommendation of Control Option No. 1 was the starting point for the CSO Master Plan. Identifiable differences between the Preliminary Proposal and the Master Plan cost estimates account for the progression from an initial estimate used to compare a series of alternative plans for the entire system, to an estimate focusing on a specific level of CSO control for each sewer district.

The estimates reflect changes to the control option selection since the Preliminary Proposal, updated construction costs, and the addition of Green Infrastructure (GI) enhancements. The calculation of the CSO Master Plan and Preliminary Proposal cost estimate were based on the following assumptions:

- Capital costs and O&M costs are reported in terms of present value.
- The CSO Master Plan includes a fixed allowance of 10 percent for GI which was not included in the Preliminary Proposal.
- The Preliminary Proposal capital cost is in 2014 dollar values whereas the Master Plan capital cost is based on the control options configurations for each sewer district engineering plan and in 2019 dollar values.

A comparison of the Preliminary Proposal and CSO Master Plan cost estimates for Control Option No. 1 is provided in Table 2-1.

Table 2-1. Preliminary Proposal and Master Plan Capital Cost Comparison

Item	2014 Preliminary Proposal Cost Estimate (2014 Dollars)	2014 Preliminary Proposal Cost Estimate (2019 Dollars) [a]	2019 Master Plan Cost Estimate (2019 Dollars)
Class 5 Estimated Capital Cost	$ 830,000,000	$ 963,000,000	$1,045,800,000
Green Infrastructure Allowance (10%)	Not Included	Not Included	$ 104,600,000
Subtotal – Capital Cost	**$ 830,000,000**	**$ 963,000,000**	**$1,150,400,000**
Class 5 Estimate Range: (-50% to + 100%)	($415,000,000 to $1,660,000,000)	($481,500,000 to $1,926,100,000)	($575,200,000 to $2,300,800,000)
Capital Cost + 50% Estimating Allowance	$1,245,000,000 [b]	$1,445,500,000	$1,725,600,000
Capital Cost for Budgeting Purposes	**$1,660,000,000**	**$1,926,100,000**	**$2,300,800,000**

[a] 2019 dollar value is based on 3% inflation per year
[b] Cost as identified in the Preliminary Proposal

As agreed with the City, the upper range of the Class 5 estimate (+$100%) is used for budgeting purposes giving a total capital cost of $2,3 Billion for the CSO Master Plan. In the Preliminary Proposal, a different approach was used whereby the total capital cost was reported as $1,2 Million using +50% of the base estimate. Using the same approach and removing the GI allowance would equate to $1,569 Million which is approximately 26 percent higher than that reported for the Preliminary Proposal and this increase in estimated cost is attributed to the following:

- Construction cost escalation from 2014 to 2019 equating to about 16 percent.
- An increase in the amount of sewer separation projects selected for control options, which have a higher capital cost, but lower operating costs.

3. Definition of Project Costs

Conceptual level Class 5 capital cost estimates were developed for the control solutions proposed for each sewer district as follows:

- Local costs were applied where local estimates were readily available for items such as sewer and chamber installations.
  - Local unit rates based on typical local values were used to estimate the value of sewer separation work.
- A cost estimation tool was used for generating costs for other technologies that have not been previously applied in the City. This tool utilized projects completed in other cities and applied correction factors to adjust to expected Winnipeg conditions.

Cost estimates were developed in conjunction with Jacobs' internal tool, Program Alternative Cost Calculator (PACC), and later adjusted for economic factors local to the City. The PACC is a spreadsheet tool created to assist in the developing Class 5 estimates for linear infrastructure programs. The unit costs within the PACC are derived from broad-based historical pricing data from other markets for materials, equipment and labour. The unit costs from the PACC were adjusted to align with local costs for Winnipeg. Labour and material costs, competitive market conditions, final project details, implementation schedule, and other factors were applied.

The objective of the CSO Master Plan cost estimates is to compare control options at a district level and to serve as a basis to guide the City's annual capital budget allocations for program implementation.

The CSO Master Plan cost estimates are reported in terms of Present Value (PV) costs comprised of the following two components:

(i) Capital Cost – This represents the one-time, fixed expense to construct the sewer system control upgrades and is estimated in current dollar values (2019); and

(ii) Lifecycle Cost – This represents the annual operations and maintenance (O&M) investment derived in current dollars then projected over the life of the asset at an annual escalation factor. This is explained further in Section 3.2 Lifecycle Cost Assumptions

The CSO Master Plan has assumed construction costs are based on a conventional design-bid-build project delivery method. Hence allowances have been made for project administration, engineering and construction. It was also assumed that the control options implemented at each sewer district would consist of conventional sewer system infrastructure.

A base construction cost for each control technology proposed within a sewer district was established using outputs from the hydraulic model evaluations and applying parametric cost curves and localized unit costs. The parametric cost curves are based on local historical cost data for control options when available and supplemented with information from the Jacobs' PACC tool where limited local experience is available. The control technology estimating assumptions are included in Section 4. The estimated capital cost for each sewer district includes the addition of the following components which have been added to the base construction cost:

- Engineering Design: 13 percent
- Project Design Contingency: 30 percent
- Program Management: 2 percent
- Manitoba Retail Sales Tax (MRST): 8 percent
  - MRST applies only to tangible personal property. It has been included for all CSO Master Plan components to remain conservative. It will be applicable to some projects or parts of projects and not

others, which is subject to interpretation, and may require tax department clarification at the time of construction.

- Green Infrastructure (GI) has been accounted for by applying a 10 percent markup to the capital cost and assumes that some GI will be completed in every sewer district. Additional unit costs are available from the *Green Infrastructure* (CH2M et al., 2014) technical memorandum.

3.1 Capital Cost Exclusions

There are a number of items outside of what is included in the cost estimates, but which are assumed to be covered as part of the estimating contingency and allowances. These include items such as stakeholder consultations, traffic management and utility relocations. Additionally, there are other items that may impact the overall cost of the CSO Master Plan but are not included within the cost estimates provided. These items are described as follows:

Finance and Administration

A finance and administration allowance of 3.25 percent.

Federal Goods and Services Tax (GST)

GST is currently 5 percent but is not included because of municipal exemptions.

Sewage Treatment Plant Upgrading

Additional combined sewage captured under the CSO program will be routed to the sewage treatment plants for wet weather flow (WWF) treatment. Upgrades have been completed or are underway for WWF treatment at the sewage treatment plants. The capital and operating costs of all WWF treatment has not been included in the CSO program estimates.

Land Acquisition

At the planning level, the details of sewer system upgrade components within each CSO district are not entirely defined. The broad-based nature of the various upgrade options means that some of the CSO controls may be retrofitted into existing infrastructure (e.g. in-line storage), whereas other control options may require additional land for off-line storage or treatment. In either case, there may be a need for additional land to serve as permanent or temporary workspace for construction, maintenance, staging, materials handling, or to house the final works.

In built-up urban environments, the availability of sufficient workspace to carry out the work is limited. Although the need to acquire large parcels of land to perform Sewer system improvements can be mitigated somewhat using trenchless installation methods, there will always be a need for temporary workspace for contractor staging.

The cost for staging areas, lane rentals on city streets, rental of vacant parcels, and/or expropriation was excluded. Typically, only at the concept-level can the extent of land acquisition be identified. Then it can be further defined through the preliminary design stage, prior to be ultimately being delineated during detailed design. Hence it could not be included at the current stage.

Geotechnical Investigations

While many of the CSO control installations will occur at the same site as currently installed sewer infrastructure, there are locations where additional storage is to be provided in a new location where the subsurface ground conditions need to be characterized. This is particularly true where deep excavations are necessary or where a trenchless methodology is being considered. In these situations, detailed site investigations are recommended to capture special geotechnical considerations. At other locations for other control options such as sewer separation, the level of investigation will be identified on a case by case basis.

Trenchless methods for installation of new works is preferred by the City for sewer replacement and sewer relief projects to minimize disruption to adjacent neighbourhoods and minimize surface restoration.

The application of trenchless methods is highly contingent upon geotechnical suitability of the underlying soil conditions for it to be feasible. The CSO program is likely to require the construction of larger diameter sewers installed at greater depths. At the planning stage, a cost for geotechnical investigations was excluded due to the variability at each site and the variability of the type of trenchless methods used.

Program Support Services

The capital cost does not include field services by internal resources, consulting services, and contracts for carrying out or supporting the engineering evaluations, pilot testing, and real time control works in support of program management.

Operations and Maintenance

Operations and Maintenance (O&M) is not included in the capital cost estimate prepared for the CSO Master Plan but has been included in the lifecycle analysis and program implementation planning. Lifecycle cost assumptions for O&M are described in Section 3.2.

3.2 Lifecycle Cost Assumptions

The lifecycle cost estimates were developed based on assumptions about O&M requirements for each control technology. The main assumptions used for the lifecycle cost analysis included the following:

- The estimating process uses a PV approach for annual O&M costs, assuming a 35-year lifecycle with a 3 percent discount rate.
- O&M costs were determined on an individual asset basis and account for annual expenses such as energy, materials, and chemicals, as well as periodic replacement maintenance. Periodic replacement maintenance costs were derived based on a percent of capital cost applied at 10, 20 and 30 year intervals.

More specific assumptions relating to each control technology are applied in the estimates as follows:

Labour

- The cost of labour, including benefits, for all asset maintenance was assumed to be $35 per hour. This value is based on the high end of the 2016 to 2021 collective agreement with an allowance for future increases. A crew of three individuals with a maintenance vehicle has an assumed costing rate of $150 per hour.

Control Option Maintenance

- Sewer and Tunnel
  - $4 per linear metre per year.
- In-line Storage
  - 3 hours of labour per week, or 156 hours per year.
  - An additional 2 hours of labour were included per wet weather event.
- Screens
  - 3 hours of labour per week, or 156 hours per year.
  - An additional 8 hours were added per wet weather event.
  - For mechanical screens, an average operational duration is 4 hours per event.
- Off-line Storage Tank and Tunnel
  - 8 hours of labour per week, or 416 hours per year.
  - An additional 8 hours for a tank were added per wet weather event.

- An additional 4 hours for a tunnel were added per wet weather event.

- Pumping Station
  - 4 hours of labour per week, or 208 hours per year.
  - An additional 4 hours were added per wet weather event.
  - An average pumping duration is 24 hours per event.
- Gravity Flow Controllers
  - 4 hours per week, or 208 hours annually.

Utilities

- Energy costs were based on annual volume and total dynamic head pumped, assuming a pump efficiency of 75%, a motor efficiency of 95%, and variable frequency drive efficiency of 98%. Electricity costs were estimated to be $0.05 per kilowatt-hour.

The life span of each asset type (conveyance or facility) or part of a facility (such as superstructure, foundation, tankage, mechanical, or electrical) has been taken into consideration. Periodic equipment replacement costs have been added over the program duration as required on a percentage of capital cost basis as shown in **Table 3-1**. Remaining residual value for assets at the end of the analysis period was not considered in the estimates.

Table 3-1. Periodic Equipment Replacement Cost

Design Item	Periodic Percentage of Capital Cost Replaced		
	10 Years	20 Years	30 Years
Off-line Storage	5%	14%	5%
Control Gate	5%	14%	5%
Screens	0%	10%	0%
Submersible Pump Stations	20%	25%	0%
Tunnel	10%	15%	5%
Flow Control	0%	10%	0%

4. Control Options Cost Assumptions

A parametric costing tool was used to provide the initial cost curves for a wide range of control options. All construction costs include the general requirements for contracting, as well as the contractor's labour, materials, overhead, and profit. Therefore, the construction costs are equivalent to prices received for design-bid-build tenders and exclude markups for contract contingency, engineering, and taxes.

To apply the parametric costing tool, costs were converted to Winnipeg conditions based on the *Engineering News-Record Construction Cost Index* (ENRCCI) for November 2018 (ENR, 2018). Since there is no ENRCCI for Winnipeg, a current ENRCCI was adjusted using the RS Means Index of 99.7; this adjustment sets the ENRCCI index used in the tool for Winnipeg, Manitoba, Canada in November of 2018 at 11150.

The approach and assumptions for costing each type of control option are summarized in the following subsections.

4.1 Gravity Sewers and Tunnels

Construction costs for gravity sewers and tunnels are sensitive to the installation method, pipe size, and depth. In the City, there is a high level of experience using pipe diameters smaller than 2100 mm. 2100 mm is the representative diameter assumed for a tunnel. A large dataset of local costs is available for smaller diameter sewers, so these unit costs were applied directly to the proposed CSO Master Plan work. The unit costs used for sewer and tunnel construction are shown on Figure 4-1.

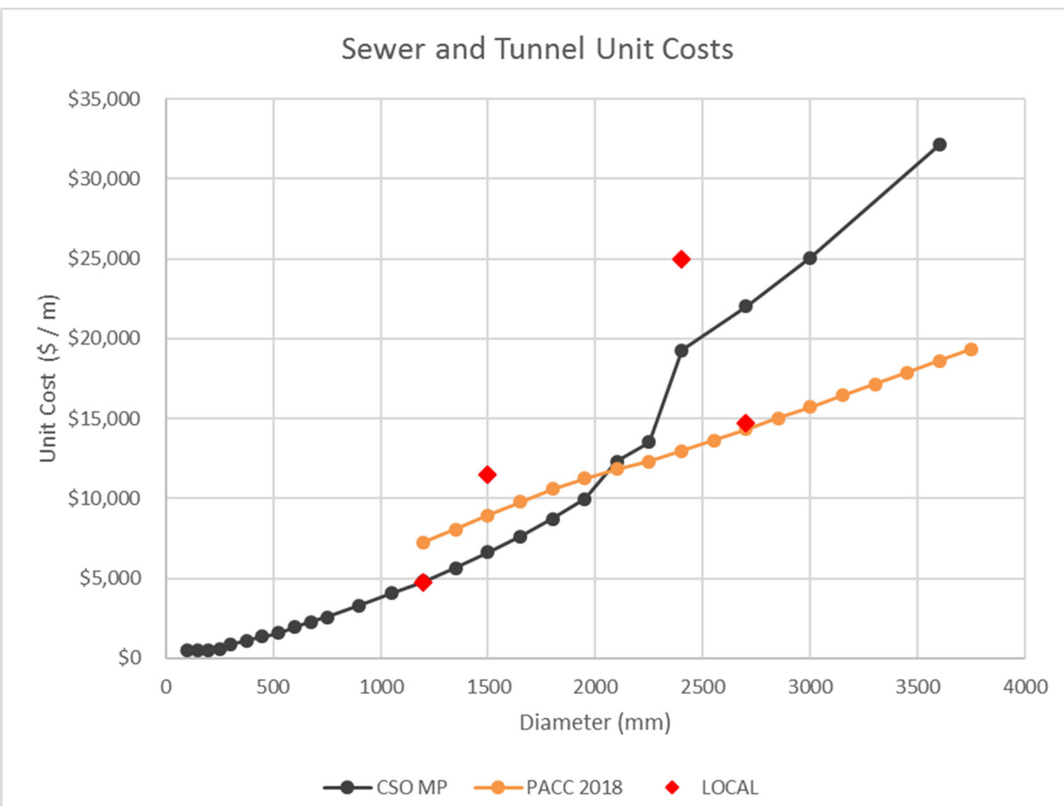

Figure 4-1. Sewer and Tunnel Unit Cost Curves

The majority of sewer installation in the City has been carried out using a horizontal coring method. This coring technique has been successful for pipe diameters up to about 900 mm. Alternative local methods have been used to install up to a 1500 mm diameter pipe. Unit costs for larger diameter pipes were extrapolated where insufficient historical pricing data was available; above 2100 mm. Although there are a few recent examples, tunnelling projects in the City are limited over the last few decades. A comparison of recent local costs to the parametric cost tool was completed. As shown in Figure 4-1, the PACC unit costs are higher than the CSO Master Plan cost at the smaller diameters and lower for larger diameter sewers. Some recent local pipe installation costs for larger diameter pipe are included as a diamond on Figure 4-1as a comparison. The CSO Master Plan costs were applied for the entire range of diameters and are assumed to be conservative at the larger diameters to include the appropriate assumptions and unknowns.

The unit costs associated with the parametric costing tool include following assumptions:

- Tunnel boring machine (TBM) for pipe diameters > 2100 mm diameter;
- Use of micro-TBM for ≤ 2100 mm diameter;
- All tunneling methods assume mixed-face tunneling that accounts for handling both soil and rock along the length of the tunnel construction

Parametric unit costs include the following:

- Mobilization and demobilization
- Purchase or rental of tunneling equipment
- Pipe supply and installation by tunneling
- Launching and receiving shafts, quantities based on the following assumptions:
  - Micro-TBM: 300 m drive
  - TBM: 300 m drive
- A 10% multiplier for dewatering during construction
- A 30% multiplier for mixed-face tunneling for either micro-tunneling or TBM
- Reinstatement or restoration costs for pavement or boulevards at shaft locations

The localized unit costs for sewer installation include the following:

- Local installation methods
- Shoring and dewatering
- Manholes/Shafts
- Restoration

Items not included in the unit costs are as follows:

- Sewer and service connections
- Utility relocations
- Capital cost markups – included on top of base construction cost within the contingency
- O&M – included with the lifecycle cost and program evaluations

4.2 Sewer Separation

The City has previously completed sewer separation on an opportunistic basis under the Basement Flooding Relief program, and any previously committed projects continuing through the CSO Master Plan. Sewer separation reduces the volume of combined sewage collected, thereby reducing the CSO program storage volumes required, the conveyance requirements to the treatment plants, and the size and operating costs of treatment facilities. Two approaches were reviewed in the development of cost estimates for sewer separation as follows:

1) Installation of a new dedicated land drainage sewer (LDS) in Combined Sewer (CS) districts to collect road drainage and discharge it directly to the river. The existing CSs are reserved strictly for conveyance of domestic wastewater and rainfall derived inflow and infiltration. Foundation drainage would continue to flow to the CS system.

2) Convert the existing CS to serve strictly as an LDS. This requires construction of a new wastewater sewer trunk to accept domestic wastewater and flows from reconnected foundation connections. This method was only applied in the estimate in special cases where specific benefits were identified. However, this method of separation should be considered any time a sewer district is being assessed for separation.

Costs for sewer separation were estimated using sewer data exported from the City's land-based information system (LBIS) database. In order to approximate the amount of separation required to achieve complete separation of a sewer district, the existing amount of separation completed within a sewer district must be determined. A length of pipe installation to separate the remainder of the district is then calculated based on the existing amount of separation.

The basis of the approach is to assume a new LDS system equal in length to the original CS system servicing that same area would be required to complete the LDS separation. A number of steps were used to determine an approximate length of new sewer required as follows:

1) The length of the different types of sewer within a sewer district were taken from the LBIS.

2) The length of sewer within a range of diameters was totaled for each type (CS, WSS, SRS, LDS).

3) The following calculation was then applied to determine the length of remaining unseparated combined sewer:

$$\text{Total Length Unseparated} = \text{Total CS Length} * \left[1 - \frac{(\text{Total LDS Length} + \text{Total SRS Length})}{(\text{Total CS Length} + \text{Total WWS Length})}\right]$$

The following assumptions were applied to calculate the separation length remaining in a sewer district:

- Combined sewers: All sewers with a CS flow type within a district were used to calculate the separation lengths.
- Land drainage sewers: All LDSs were assumed to represent separate areas.
- Storm relief sewers: Relief sewers present a special situation, since they do not directly receive wastewater flows and could be converted to LDS. Relief sewers would typically be undersized as a separate LDS on their own, but they are large enough to significantly contribute to a new separate LDS system. They have been assumed as separate when present.
- Wastewater sewers: All WWSs were assumed to represent a separate area.
- Areas identified as separate were assumed to be adequate without any further modifications.

Once an unseparated length was determined for each sewer district, this was verified with a secondary check of the LBIS network. A percent reduction of total length was applied if any differences are found or if known sewer separation has taken place that is not accounted for in the LBIS. An example would be the ongoing separation work in the Cockburn, Jefferson East, or Ferry Road sewer districts, which is not represented in the LBIS. Once the unseparated length is manually validated, a ratio of typical pipe sizes installed in a sewer district is applied to this length. The corresponding ratios and applicable median unit costs for the size range are listed in Table 4-1.

Table 4-1. Separation Pipe Unit Costs and Ratios

Size (mm)	% of Unseparated CS Length	Unit Cost
Size (mm)	% of Unseparated CS Length	Unit Cost
<500	44%	$ 984
500-900	20%	$ 2,122
900-1200	14%	$ 4,059
1200-1800	12%	$ 7,133

An example calculation for the Dumoulin sewer district is shown below.

Table 4-2. Separation Length Summary - Example

Sewer District	Total CS Length (m)	Total WWS Length (m)	Total LDS Length (m)	Total SRS Length (m)	Total Sanitary Length (m)	Separate or Relieved (%)	Separation Remaining (%)	Total Length not Separated (m)
Dumoulin	5971	320	2318	344	6291	42.3	57.7	3444

$$\text{Total Length Unseparated} = \text{Total CS Length} * \left[1 - \frac{(\text{Total LDS Length} + \text{Total SRS Length})}{(\text{Total CS Length} + \text{Total WWS Length})}\right]$$

$$\text{Total Length Unseparated} = 5971 * \left[1 - \frac{(2318 + 344)}{(5971 + 320)}\right]$$

$$\text{Total Length Unseparated} = 5971 * \left[1 - \frac{(2662)}{(6291)}\right]$$

$$\text{Total Length Unseparated} = 3444\ \text{m}$$

Table 4-3. Separation Cost Summary - Example

Size (mm)	% of Unseparated CS Length	Length	Unit Cost	Cost
<500	44%	1515	$ 984	$1,490,760
500-900	20%	689	$ 2,122	$1,462,058
900-1200	14%	482	$ 4,059	$1,956,438
1200-1800	12%	413	$ 7,133	$2,945,929
>1800	10%	344	$19,277	$6,631,288
			Dumoulin Cost to Separate	**$14,486,473**

4.3 In-line Storage

In-line storage is created by increasing the control elevation at the primary weir in the CS system. To facilitate the in-line storage, control gates are proposed at the primary CS diversions near the outfall. Control gates may also serve to divert flows into adjacent screening chambers for capture of floatables as discussed in Section 4.4.

The in-line storage concept assumes the following:

- Control gates were limited to a maximum height of half the trunk diameter to mitigate back-water effects upstream of the gate location. The basement flood risk for pre and post control option installation was evaluated to maintain the same level of protection (i.e. – no increase in HGL was allowed).
- Where normal summer river levels are higher than the in-line storage depth, control gate configuration will need to be reconsidered, since the discharge is inherently controlled by the river backwater pressure on the flap gate.
- The Grande Water Management Systems TRU-BEND gate was selected as the “representative product” because it meets the general intent and has been manufactured for use in CSs. The gate is hinged at its base, which allows it to completely lower for high flows, and is operated by a counterweight mechanism which minimizes mechanical and electrical malfunctions.
- The TRU-BEND gates, for most locations, can be manufactured and applied to meet the half pipe height requirements. Only for trunk sewers that are greater than three metres will there potentially be a restriction of control gate construction for this half pipe diameter height. The control gate has a maximum standard height of 1.5 m, so any sewer with a diameter greater than 3.0 m and a gate installed from invert would not meet the half pipe height without modification.

The cost estimates assume that control gates would be installed in a newly constructed chamber along the existing sewer alignment where possible. Dry weather flow would continue to be diverted by the existing primary weir upstream of the control gate. The control gate would be installed as close to the primary weir and off-take as possible and may be integrated in a single chamber. This will be reassessed for each installation during preliminary design. The control gate would activate, rise up and begin to capture flow when the level in the sewer increased above the primary weir elevation.

Installation of the chamber and gate is similar to existing gate chambers installed along the riverbank; therefore, the unit cost can be developed and compared to existing local installation costs. A unit cost approach based on the existing trunk size was used so that variance in costs could be shown. The unit cost curve for the installation of a control gate is shown in Figure 4-2.

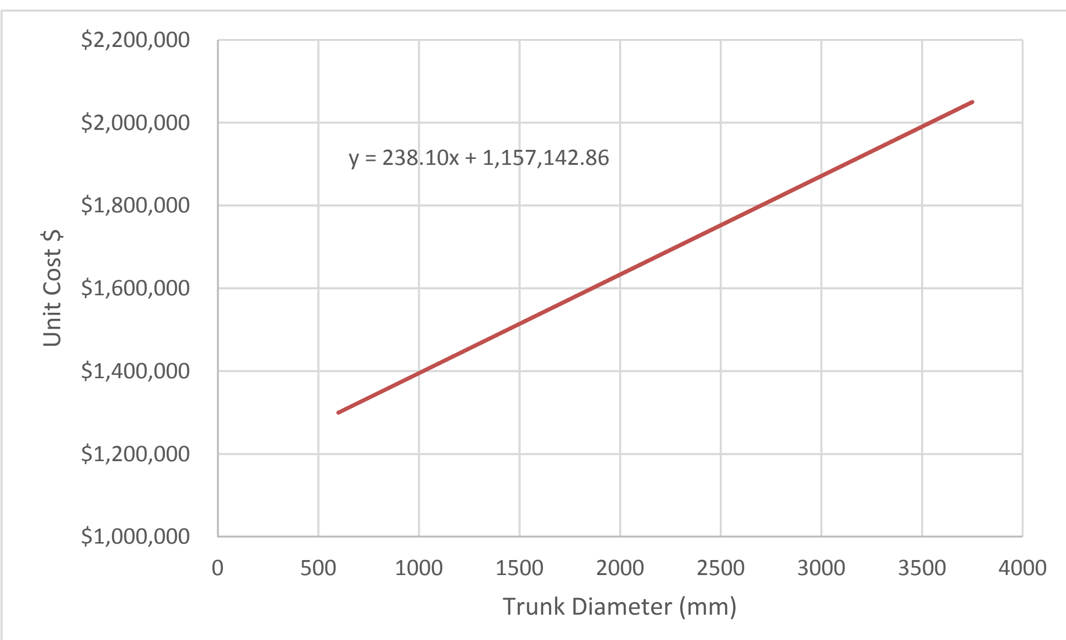

Figure 4-2. In-line Storage Control Gate Cost Curve

The base construction costs include the following:

- Gate chamber construction
- Gate and ancillary equipment

The base construction costs do not include the following:

- Instrumentation
- Capital cost markups – included on top of base construction cost within the contingency
- O&M – included with the lifecycle cost and program evaluations

4.4 Screens

Where hydraulic capacity allows, it is recommended that a portion of the overflow at each district's primary outfall be screened. The partial screening approach achieves the following objectives:

- Preserves the hydraulic capacity under high flows to avoid basement flooding;
- Captures a higher percentage of the first flush (and corresponding floatables).

Screening typically requires the presence of a control gate or increase in static weir height to provide the necessary head. A side-weir would be installed in the control gate chamber immediately upstream of the control gate. When the in-line depth of storage reaches the screen side weir, the bypass will flow to the screen and only the screened flow will discharge to the river. All CSO will be screened until the control gate drops to its lowered position. After lowering, the control gate will no longer provide additional CS capture beyond that already provided by the primary weir. This will allow the combined sewage to discharge to the receiving stream without screening, as a permitted CSO.

The off-line screening concept assumes the following:

- An extension to the control gate chamber will be used to house the screens and ancillary equipment, with a channel or pipe installed to return the screened flow to the outfall and into the river.
- The Grande ACU-SCREEN has been used as the "representative product". It is a mechanically cleaned screen that has been widely used for CSO screening applications.
- The maximum flow through the screen has been calculated with the InfoWorks hydraulic model. An engineering evaluation is required to determine the optimal flow rate and screen sizing.
- The screenings collected will be diverted back to the lift station or gravity interceptor connection and transferred to a sewage treatment plant. Pumps will be required to transfer the screenings where sufficient hydraulic capacity is not available.

As the design screened flow rate increases, a larger screen area is required. Additionally, a decrease in available hydraulic head also increases the screen area required. The required screen area dictates the chamber size to house the screening equipment. Screening unit cost rates are shown on Figure 4-3.

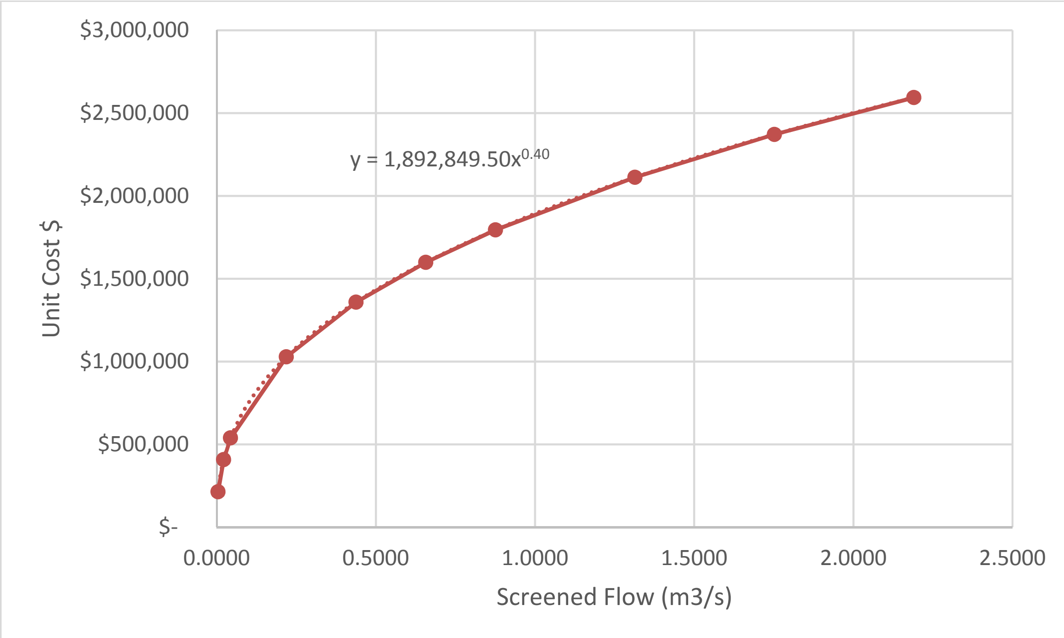

Figure 4-3. Screening Unit Cost Curve

The base construction costs include the following:

- Screening chamber construction
- Screens

The base construction costs do not include the following:

- Instrumentation
- Screening pumps or piping
- Odour control
- Cost related to additional floatable material collection transferred to plant
- Capital cost markups – included on top of base construction cost within the contingency
- O&M – included with the lifecycle cost and program evaluations

4.5 Latent Storage

Latent storage utilizes available capacity in the existing SRS system. The latent component is the volume that would normally be full to the river level elevation. The river level provides force on the flap gate to allow sewer levels to rise and equalize. During wet weather, when the system level increases above the river, the flap gate opens, and flow is released. A lift station is proposed to be installed to dewater the latent storage and pump it to the CS system. The dewatered volume acts as available storage for the next wet weather event.

Flap gate control can be added to the SRS outfall, which allows this latent volume to be trapped behind the flap gate even under low river level conditions. As part of the latent storage design, each location was evaluated based on the representative year river level conditions to confirm if the required latent storage volume capture is provided without flap gate control added. If the latent storage volume potential was high, but not realized during NSWL river conditions, flap gate control was recommended. Flap gate control uses a latch to hold the gate closed until a high level set point is reached and the flap gate is signaled to release. The latch is not sold as a separate product; therefore, it was assumed that new gates equipped with the latch would be installed in all locations where flap gate control is required.

The cost estimates for latent storage without flap gate control are based on pumping station costs as discussed in Section 4.7. The latent dewatering rate assumes that the storage will be dewatered within 24 hours and has an appropriately sized pump to allow this. The costs for construction of a new chamber or modifications to the existing chamber for the flap gate control are based on similar work completed in the City

The latent storage concept assumes the following:

- A new lift station and latent storage force main piping for dewatering the latent storage is required to transfer the stored flows back to the collection system.
- Where applicable, a controllable flap gate is installed to replace the existing flap gate within the existing gate chambers, with only minor modifications.
- The Grande Acu-Gate was selected as the "representative product" for flap gate control.

The base construction cost includes the following:

- Modification of the gate chamber and installation of the ACU-GATE
- Installation of a submersible lift station
- Piping
- Instrumentation

The base construction costs do not include the following:

- Capital cost markups – included on top of base construction cost within the contingency
- O&M – included with the lifecycle cost and program evaluations
- Odour control

4.6 Off-line Storage Tank

The CSO Master Plan includes construction of new, off-line storage tanks for temporary storage of wastewater flows from combined sewers. The tanks would be deep, buried concrete tanks with minimal superstructure. Near surface off-line storage tanks have been used unless otherwise stated.

A feature of the near surface storage tanks is the requirement for the sewage to be lifted from the CSs where it is collected into the tanks. This can be accomplished by construction of new low lift pumping stations or, in some cases, by retrofitting existing flood pumping stations with piping to the storage basins. The near surface position minimizes the excavation and cost of construction and the uncertainty in working near riverbanks with poor soil conditions.

The storage tanks have been assumed to be constructed of concrete and sized in terms of 2,500 m^3 modules measuring approximately 20 m x 50 m x 2.5 m depth.

Following a peer review process completed during the development of the Preliminary Proposal, it was found that the parametric cost estimates were low relative to experience elsewhere. As such, a unit cost of $3500 per m^3 of off-line storage provided during the peer review was used. This unit rate was adjusted to 2019 dollars using 3 percent inflation per year equating to approximately $4000 per m^3 for a 2500 m^3 tank. The dollar per volume decreases as the amount of storage increases. The cost curve in Figure 4-4 shows both the PACC cost range (dashed) and the alternative curve based on the peer review value of $4000 per m^3. The alternative curve was ultimately adopted to estimate costs for off-line storage tanks.

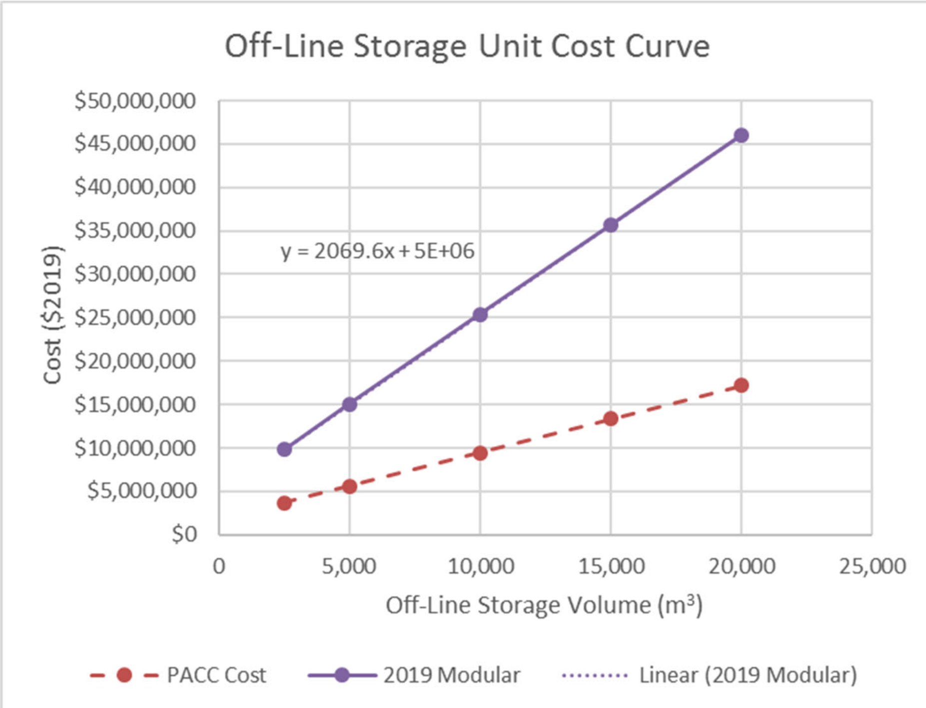

Figure 4-4. Off-line Storage Unit Cost Curve

The cost curve was adjusted for local conditions as shown on Figure 4-4. Local conditions will require storage tanks to be built independently for several CS districts and will not benefit from economies of scale. It is, therefore, more appropriate to consider them on a module basis, assuming the construction of a series of modules rather than one large storage tank.

The base construction cost for off-line storage tanks includes the following:

- Construction of cast-in-place concrete tanks
- Dewatering pumps
- Automated flushing system
- Odour control (Assumed as 2% of total off-line tank construction costs)
- Instrumentation

The base construction costs do not include the following:

- Diversion structures
- High lift transfer pumps for filling the storage basins
- Capital cost markups – included on top of base construction cost within the contingency
- O&M – included with the lifecycle cost and program evaluations

4.7 Pumping Stations

The addition of dewatering pumping and control is required for implementation of the proposed CSO control technologies. Pumps are sized to empty the storage elements within a 24 hour period following a wet weather event. The range of pumping configurations is described in the following list:

- Latent Storage – Pumping is required to dewater combined sewage from the SRS system. Standalone lift stations located adjacent to the relief pipes will be installed for this. It is assumed that lift stations with submersible pumps and force main piping to the existing CS will be used.
- Lift Stations – The current system has several dry well lift stations that discharge to the interceptor system. These would continue to operate in the same manner with the CSO program for dry weather flow. Existing lift stations will have to be reassessed as part of an overall real time control strategy to determine the suitability to meet future needs.
- Gravity Discharges – The 16 CS districts which drain by gravity may need to be upgraded with an added level of control, such as flow control valves and flow recorders. The level and type of flow control required would be assessed as part of the overall real time control strategy. .
- Screening Discharge – The floatables collected by the screens would either be manually lifted out or pumped to the lift stations. Screening pumps, if required, will be included with the screen installations.
- Transfer Pumps – Near surface off-line storage tanks require that the combined sewage be pumped into the storage tanks. High rate low-lift pumping stations will be required for this. In some cases, existing flood pumping stations located in districts where off-line storage is planned, may be retrofitted for this use.

There will be opportunities to combine pumping systems to avoid the selection and use of several pumps within each district. The PACC pumping station costs are based on construction of a pump station with below ground submersible or dry well configuration, coarse bar screens, a super structure, valves, piping, controls, and a backup generator.

The base construction cost for pump stations include the following:

- Excavation and construction of a pumping station
- Internal piping and valves
- Pumps, motors, and variable speed drives
- Instrumentation
- Standby generator

The base construction costs do not include the following:

- Odour control
- Capital cost markups – included on top of base construction cost within the contingency
- O&M – included with the lifecycle cost and program evaluations

A cost curve as shown in Figure 4-5 has been developed to estimate construction cost for various sizes of pumping stations. The cost increases based on flow rate with a direct correlation to larger structures, piping and pumps. The cost flattens out in relation to a maximum size of structure and the pumps sizes continue to increase.

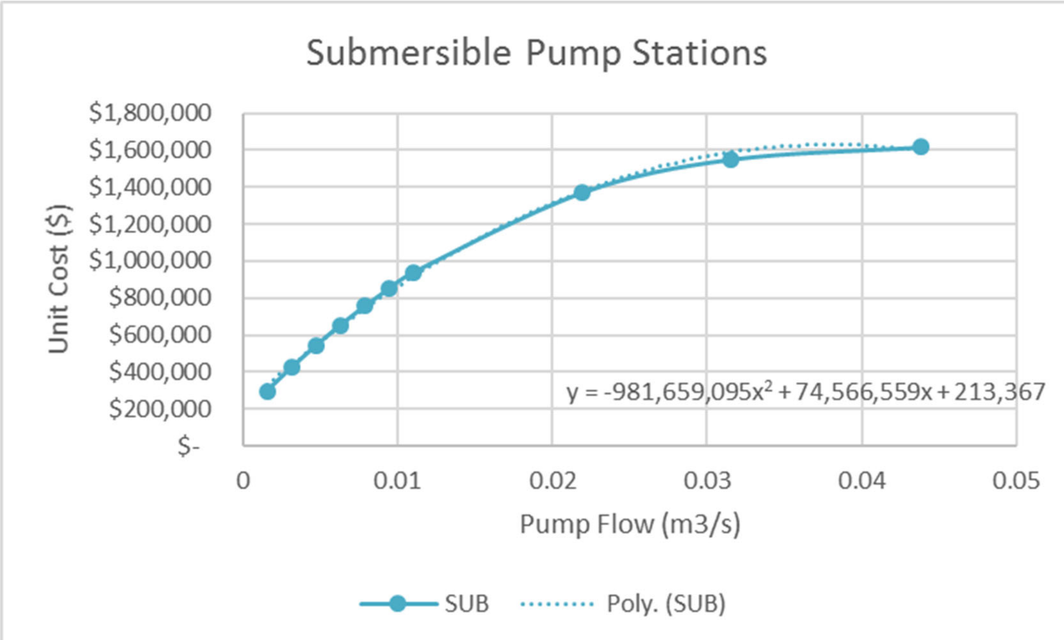

Figure 4-5. Pump Station Unit Cost Curves

The cost for pumping stations will increase with greater installation depths, because of increased excavation and larger pumps to overcome the static head. For this analysis, the pumping stations were assumed to each be relatively shallow, not requiring a depth adjustment. Further reasoning for this assumption for pump station depth is listed below:

- Majority of sewer pipes are located less than 10 m deep;

Force main costs have been estimated based on the pipe unit cost identified in Section 4.2. It is assumed that they would be installed with local methods. There is the potential for a force main cost to increase above what may be expected of a typical sewer installation cost where there are difficult connections or additional appurtenances such as air release / vacuum valves are required. Each force main would be refined for specifics during preliminary and detailed design.

5. Future Cost Estimate Update Considerations

During the development and refinement of the cost estimates, several items were identified for consideration during future cost updates.

- **Type of Sewer Separation**: An independent LDS installation was the primary approach used to estimate the sewer separation costs. Further analysis should be completed to determine additional benefit by partially converting the existing CS and SRS systems to LDS.
- **Proof of Concept:** The CSO Master Plan includes a 10-year period for technology evaluations and pilot studies, intended to validate and gain comfort in the control option selections. This implies that there is a possibility of rejection, which may lead to the need for more costly substitutes.
- **Consequential Upgrades:** The project development process for the CSO Master Plan assumed the works would be carried out independent of existing or other asset condition or upgrading needs. In practice, there may be needs or pressures to integrate indirect upgrades, such as lift station upgrades, water mains, integration of other BFR works, street repairs, or rehabilitation of existing sewers to support the CSO program upgrades.
- **Market Demand Price Changes:** The rapid growth in work and the long-term implementation period increase the risk of construction cost increases. Local engineering and contracting resources are currently not in place to deal with the volume of work projected in the Master Plan. The usual market response to increased demand is an increase in costs. , which may be exacerbated because of the need for specialized skills and limited resources for much of the work.
- **Ancillary Costs:** Labour and utility costs will change throughout the implementation of program. For the CSO Master Plan the main objective was to determine relative cost comparisons between different control option selections. Additional scrutiny should be placed on costs related to these types of items for the purpose of developing O&M budgets.

6. References

Association for the Advancement of Cost Engineering (AACE). 2016. *AACE International Recommended Practice No. 18R-97. Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries. TCM Framework: 7.3 – Cost Estimating and Budgeting*. March 1, 2016.

Engineering News-Record (ENR). 2018. "ENR Cost Indexes in 20 Cities 1978-2018". *Construction Economics.* Accessed February 11, 2019. https://www.enr.com/economics.

University of Manitoba. 1983. *Geological Engineering Report for Urban Development Winnipeg.* Prepared by the Department of Geological Engineering, University of Manitoba. Accessed February 11, 2019. http://link.lib.umanitoba.ca/portal/Geological-engineering-report-for-urban/GL7umYSGzCE/.

Note:
The PACC costs referenced in this document have been developed from the sources defined in the following bullets and have been updated to local conditions:

- R.S. Means. 2018. Construction Cost Data. Unpublished data accessed online. https://www.rsmeans.com/.
- Richardson 2018. Richardson Process Plant Estimating Standards. CostDataOnLine.com.
- Mechanical Contractors Association of America, Inc. (MCAA) 2018. Web-Based Labor Estimating Manual (WebLEM). http://www.weblem.org/.
- National Electrical Contractors Association (NECA). 2018. 2017-2018 NECA Manual of Labor Units (MLU).
- United States Environmental Protection Agency. Various References and Standards
- Costs from various municipalities' facilities
- CH2M HILL Canada Limited historical data
- Vendor quotes on equipment and materials, where appropriate
- Estimator judgment