Prepared for the

DISTRICT OF OAK BAY

FINAL

The Uplands Combined Sewer Separation Project

Technical Memo 2 – Activity 2, Options Development

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OQM | Organizational Quality Management Program

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Contents

1. INTRODUCTION

This technical memorandum is intended to convey the results of sewer system separation options development; Activity 2, per our engineering services proposal dated April 17th, 2015. The following provides a summary description of options developed, together with accompanying maps and figures. A description of the underlying assumptions and limitations specific to each option is also provided, if this varies from that contained in technical memo #1 presented previously. Lastly, capital and lifecycle cost estimates for each option are presented.

2. SIX COMBINED SEWER SEPARATION OPTIONS: DERIVATION AND DESCRIPTIONS

2.1 DISTRICT'S STATED PROJECT OBJECTIVES

- Achieve compliance with the CRD's core area LWMP
- Avoid / reduce the risk of combined sewage overflows in the most effective and expeditious manner possible.
- Take advantage of realistic and advantageous stormwater management enhancement opportunities
- Cost effective I&I reduction
- Save money on pumping costs, environmental benefits in reduced power consumption
- Minimize disruption of the public during construction
- Minimize impact to existing trees and landscaping, both on private property and public right-of-way
- Maintain the existing system as either sanitary or stormwater sewers
- Achieve a design standard consistent with the rest of the community, but reflective of on-going changes in stormwater management
- Be in a position to make an informed decision, based on agreed criteria, including defensible cost estimates, inclusive of O&M – full lifecycle costs

2.2 OPTIONS DERIVATION - IN ORDER TO MEET THESE OBJECTIVES.

2.2.1 Options Descriptions

Options 1 to 4 were identified in the District's original RFP. These we as follows:

Option 1 – New gravity sewer system and existing combined system to remain for stormwater conveyance.

Option 2 – New gravity storm drainage system and existing combined system to remain for sanitary sewer conveyance.

Option 3 – New pumped low pressure system for sanitary sewer collection and existing system to remain for stormwater conveyance.

Option 4 – New pumped low pressure storm drainage system and existing combined system to remain for sanitary sewer conveyance.

In our original project proposal, we added options 5 and 6 as a combination of ideas from options 1 to 4, these being:

Option 5 – A hybrid of gravity and pumped systems that would lead to least overall project lifecycle cost.

Option 6 - A hybrid of gravity and pumped systems that would least impact private properties.

2.2.2 Options 1 and 2

We developed relatively detailed plan/profile designs for the whole of the two sub-catchments, [Humber and Rutland] noting service point elevations of existing dwellings, where this information was available to us. We tabulated service connection elevations for all dwellings within the study area, and established proposed sewer and storm utility grades that would maximize the servicing by gravity connections. Reduced copies of these plan profiles and tabulations are attached as appendices hereto.

In order to generate the most cost effective system configurations that maximize gravity connections (options 1 and 2), we developed the following decision criteria:

- Individual private pumping station, complete with all installation costs and appurtenances, for service to a typical existing dwelling, is estimated to cost approximately $9,000 each. This is comprised of the following components:
  - Supply of the pumping and controls equipment, wet well tankage
  - Electrical connections and electrical upgrading
  - Excavation and backfilling for the pumping equipment
  - Restoration of the landscaping or surface improvements in the vicinity of the station
  - Portable power generator.

  Note: pipe connection to the municipal sewer is not included in this pumping equipment total.

- Assume a typical road frontage width per property of 30 metres.

- Increasing the depth of gravity sewer main within the road r/w from 3 metres to 4 metres would likely cost in the order of $100/lineal metre of pipeline.

  - Similarly, increasing the depth of a gravity main from 4 to 5 metres, would cost an additional roughly $150 per lineal metre of pipeline length.
- Premium cost per lot frontage for additional sewer main depth [from 3 to 5 metres] would therefore be between $3,000 and $7,500.

- Private pumps, otherwise needed if municipal sewer mains are shallower, would be situated on the low side of the roadway typically. Thus, only one side of the street is affected by this sewer deepening advantage assessment. [Dwellings on the high side of the road can typically connect to a relatively shallow depth gravity main].

- Assuming every other dwelling along the low side of a given section of road can, on average, avoid the need for private pumping, then a depth increase from 3 to 4 metres represents a definite <u>overall</u> cost savings, when considering combined costs for municipal and private components of the system. The incremental cost of a deeper municipal sewer pipe is less than the cost of additional private pump[s], in this case.

- Similarly, if all dwellings along a given stretch of roadway were to require individual sewage pumping systems, given a 3 m deep sanitary sewer, while increasing this depth to at most 5 metres precludes pumping need; then, again, the <u>overall</u> combined private and public initial capital costs are reduced.

- The above assumes increased depth of the pipe network needed to achieve gravity servicing, does not extend any considerable distance beyond the area directly abutting the houses that would otherwise need to pump.

- The above does not account for on-going operation and maintenance of private pumping stations, nor electrical costs, nor periodic pumping equipment replacement costs, all of which would only serve to increase the overall combined public/private cost benefit, or advantage, of a deeper gravity main.

Options 1 and 2 are predicated on the intention to reduce the number of pumped connections to a new sanitary sewer system or a new storm drainage system, respectively.

For option 1, given the topography and existing dwelling service points with the Uplands area, a number of proposed sanitary sewers were designed as considerably deeper than the existing combined system.

This deepening of the new system will also enable ease of service re-connection to the new sanitary or storm gravity mains, under options 1 and 2 respectively.

There is a practical limit as to construction feasibility and resulting cost of proposed gravity sewer depth. As such, we have sought to maximize the number of proposed gravity sanitary sewer connections, but have not achieved 100% connections by gravity, under options 1 and 2.

There remain, per the attached drawings, a number of dwellings for which pumping is the only realistic option under this deeper gravity sewer system scenario, noting that it has been determined infeasible to "twin" sewers within existing rights of way over private properties, as discussed in more detail in section 3.1 below. Portions of development within the Uplands exist on a relatively steep side slope. Servicing these properties entirely by gravity would necessitate very deep pipes within the road rights of way [to capture gravity service connections from dwellings along the low side of the roadway].

Alternately, what is referred to as 'double servicing' could theoretically be pursued within these areas. Double servicing refers to a design that includes a pair of parallel, relatively shallow mains, on a side hill development, rather than a single deeper sewer. One shallow main would be aligned within the road right of way, servicing the higher side lots. The other would be located within an easement along the back of the lower side lots.

Double servicing is a relatively costly initial capital cost solution, and one that is not feasibly available to the District in the case of the existing Upland development. Again, one of the over-arching constraints agreed upon with the District early on in the project evolution was the realization that it will not be feasible, given the narrow existing rights of way and/or easements [typically 10 feet wide] and mature landscaping within these areas, to twin existing sewers within these existing utility corridors on private property.

2.2.3 Option 3

The concept is that of a low pressure sanitary sewer network, complete with relatively shallow graded, smaller diameter, municipally owned pressure sanitary sewers. Under this scenario, all properties within the study area would need to be fitted with individual pumping stations on each dwelling site.

As we investigated the practicalities of an Option 4 layout, it became clear that the notion of pumping of storm drainage from the entirety of the catchment would not be a cost effective initial capital exercise, nor at all cost effective from an on-going operation and maintenance perspective. Under this scenario, either a large number of municipal pumping stations would need to be constructed, to capture and convey roadway runoff, or a parallel shallow gravity network would need to be installed, with fewer, but larger municipally owned stormwater pumping stations. This concept was decided to be fatally flawed and preliminary design was not pursued further, nor costed out.

2.2.4 Hybrid option 4

A hybrid Option 4, very similar to Option 5, [as described below], was then derived instead. The concept here would include a relatively shallow new gravity stormwater system to be constructed, with smaller, localized areas requiring municipally owned stormwater pumping stations for roadway runoff. The number of dwellings requiring on-site individual pumping systems [so as to provide for known approximate foundation drain elevations] far exceeds that of Option 2 above, under this hybrid Option 4 scenario. However, the initial capital cost of shallow depth storm drains is significantly lower than Option 2.

2.2.5 Option 5

Option 5 would be the reverse of the revised Option 4, per above. Thus, Option 5 would include a shallow depth gravity sanitary sewer system, with smaller, isolated areas of the catchment serviced by municipal pressure sewers, [similar to Option 3]. Option 5 would require individual pumping of sewage from a larger number of dwellings than would Option1, but at a lower initial capital cost for the municipality's portion of the system.

2.2.6 Option 6

Option 6 is a variation on Option 5, wherein the difference involves a number of smaller municipally owned pumping stations to be constructed, in order to increase the number of individual dwelling units serviced by gravity sanitary sewer connections(i.e.: less private pumps), as compared to Option 5. These municipally owned pumping stations could vary considerably in complexity and cost, depending on the District's preference regarding pumping equipment supplier and backup power generation equipment.

At this stage, we have assumed backup power for municipal pumping stations will be by means of a portable genset, trailer mounted, rather than permanent facilities. We have made other assumptions as to the level of service the District would expect to be afforded from these municipal pumping stations, but we would expect to discuss this in more detail, prior to finalizing the resulting cost estimates.

3. PRE-DESIGN ISSUES COMMON TO ALL OPTIONS

3.1 CONSTRUCTION FEASIBILITY AND DESIGN LIMITATIONS

3.1.1 Known design constraints common to all options

- New mains on private property would require a new or widened SRW. The existing 3 metre wide SRWs are too narrow and too constricted by surface improvements to accommodate 2 pipes.
- Depth and location of existing combined sewers – new systems will need to be built and connections made, without conflicting with existing pipe grades.
- Locations of existing SRWs and easements – need to find suitable gravity pipe routing which bypasses these alignments over private properties.
- Location of existing watermains.
- Location of mature trees and landscaping.
- Location of third party, private utilities.
- Main floor and basement elevation of dwellings.
- Existing dwellings with individual:

    - sanitary (14 pumps) or
    - storm (10 pumps), or
    - both services pumped (at 3 dwellings),

  Vs those serviced via gravity presently
  (With two possible exceptions, these will remain pumped services, even for Options 1 and 2).
- Existing dwellings with two separated sewer services to property line [= 80 as of September, 2015].

3.1.2 Constraints for which information is not available or remains unclear

- Detailed geotechnical information and rock profile, as no drilling or test pitting has been undertaken to date. Information to date based on general knowledge and experience in the project area.
- Detailed locations or Telus and Shaw infrastructure.
- Detailed locations of municipal streetlight underground cables.
- Information as to the location of buried original concrete road structure.
- Detailed information on archeological sites within the road right-of-way. We are only aware of areas of known archeological potential.

3.1.3 Proposed Pipe Depth

- Maximum realistic depth 5.0 metres to pipe invert
- Depth of new pipes needs to differ sufficiently from existing pipes in parallel alignments, so as to allow for service reconnections.
- Increasing depth equates to less cost certainty, due to increased probability of encountering bedrock along proposed sewer alignments.

Attached as an appendix hereto are detailed calculation tables outlining the means by which service connection types and sewer main depths were derived. Effort needed to assess potential for gravity services was considerable, noting the number of existing connections approaching 400 and the need for multiple iterations of plan/profile drawing generation, in order to optimize (reduce the number of required pumped connections).

Also attached are 11x17 reductions of plan/profile drawings, having been prepared for the deeper gravity sewer options 1 and 2. These are to be referred to in conjunction with the tabulations, per above.

3.1.4 Construction of new municipal pipes within (or across) private properties

As described above, we have determined the construction of new "twinned" sewer utilities within existing sewer rights of way, and easements over private property, to be infeasible. The rationale for this determination is as follows:

- Open cut excavation to install new pipe on private property is not feasible. A number of potential locations for installation of new pipe on private property were identified. In all locations, there were significant trees or landscaping that would have to be removed to allow trenching for the new pipe. Photos of existing SRWs are shown in Figures D and E, attached.
- Directional drilling [trenchless technology] may be a feasible alternative for installation of new pipe on private property. Excavation of a pit would be required at each end of the drilled pipe. Removal of landscaping along the route of the pipe would not be required.
- Pipe bursting would be the preferred method for upgrading the existing pipe, as needed, within/across private properties, assuming existing rights of way, or easements, are in place.
- Minimum SRW requirement for a single pipe = 4.0 metres. Existing SRWs are 3 metres.
- Minimum SRW width required for two pipes = 5.0 metres. Adding a second pipe adjacent to an existing pipe, would require a 2.0 M wide addition to the existing SRW.
- Due to the challenges in obtaining new SRWs or additional width on existing SRWs, all options have been developed with a goal of eliminating the requirement for new mains on private property.
- The function and condition of existing combined sewer pipe alignments over existing private properties have been reviewed. The majority of the pipes are municipal mains that convey sewage from multiple upstream properties. In some locations, the pipes over private property are individual services that just service one property. Photos of these alignments are shown on Figures D and E.
    - With one exception, municipal mains on private property are located within right of ways, or easements, registered on title. The one exception is the main running diagonally across 3225 and 3245 Norfolk Rd. There is an easement plan having been registered in this case, but no accompanying right of way or easement document, stipulating the nature of the intended rights. Thus, we believe there may be no rights conveyed here.
    - There are at least 10 locations where an individual service crosses an adjacent private property. We have not fully investigated all locations but we have identified locations where there does not appear to be any easement for the service pipe. This is not the responsibility of Oak Bay, but an issue for neighbours to resolve.
    - In all options developed, the existing pipes are to remain in service as either a sanitary sewer or stormwater system. For the existing system to remain in service, mains on private property must remain functional. Repair or

replacement of these mains through traditional open cut methods would typically require removal of significant trees, landscaping and fencing. It would also require the work to be contained within the existing 3 metre SRW which would be challenging.

- None of the pipes in easements have recent video inspection records. All mains in easements should have video inspection and condition assessment completed. As the consequence of failure for these mains is high, their rehabilitation by lining or pipe bursting should be prioritized over other mains in the network in the same condition.

3.1.5 Other constrains/opportunities

- Existing utilities within municipal road rights of way are to be protected and are to remain in service during sewer separation construction.
- Cured-In-Place Pipe lining would likely be suitable for rehabilitation of the existing mains.
  - Existing combined sewer system is at end of design life, therefore replacement/rehabilitation will be required regardless of future use as sanitary or storm.
  - Lining of existing pipes will yield a 50 year design life extension
  - Lining of pipes will reduce the interior diameter by approximately 5 mm while decreasing the roughness coefficient and eliminating root intrusions. The net effect will not significantly impact the hydraulic capacity.
  - Cost per meter of lining in the Victoria market is typically significantly less costly than conventional remove and replacement. As mobilization costs are a significant factor, it is most cost effective for larger projects or when the timing of work can be coordinated with other work in the region. Replacement of a clay tile pipe is typically only required when the size is no longer appropriate, or the pipe has completely failed. In this case, pipe bursting is likely the preferred solution.
  - With the exception of localized upgrading of the existing system, to suit a new sanitary network and existing combined network as a storm system, (Option 1), we have not carried a substantial extent of existing system rehab costs in our estimates thus far. This was as agreed to with the District's project manager.
- Sanitary sewer I&I reduction is critical to suit the LWMP expected outcomes.
- Allowing services to remain 'combined', and therefore entering the new sanitary sewer system for the foreseeable future, could give rise to a need for larger sanitary sewers mains than otherwise warranted.
- Phasing of planned system construction requires careful consideration.

  Storm rain gardens, bio-swales, retention or detention storage provision needs to be considered. However, protection of the abutting pavement structure from saturation is critical to pavement design life. In addition, we need to consider if the storage volume obtainable at reasonable cost will have any material effect on pipe sizing requirements, or ability to continue to utilize existing pipes, under climate change rainfall intensity models.

3.2 GEOTECHNICAL CONSIDERATIONS

REPORT OUTCOMES AND IMPLICATIONS

A desktop geotechnical study was completed by Ryzuk engineering, attached as an appendix hereto. This is a very high level overview of the geotechnical issues, but the following salient points of relevance to the options are as follows:

- Considerable variation in soil stratigraphy is expected. The report includes mapping of generalized areas where deeper soils are expected to be encountered vs areas where bedrock is expected closer to the surface. We have made allowances in the cost estimates for the differing options, based on proposed pipe depth and expected soil stratigraphy – likelihood of encountering bedrock in pipe trenches.

- Considerable variation in the existing soil's capability to receive and transport groundwater is noted. There are areas of the Uplands more conducive to the notion of rainwater infiltration back to ground. Generally speaking, the Uplands area is not thought to be an ideal candidate for this practise.

- It is recommended that no stormwater infiltration be undertaken within dwelling sites along the waterfront, owing to concerns regarding the increased probability of waterfront bank erosion resulting.

3.3 EXISTING LANDSCAPING ISSUES/CONSIDERATIONS

The Uplands development was initiated almost 100 years ago. These residential lots are much larger than typical lots in Oak Bay and have extensive mature trees and landscaping. By contrast, the roads are relatively narrow with wide boulevards. The boulevards are well maintained and contain mature trees, typically on both sides. In many locations, large shrubs, hedges or trees from private property extend into the public right-of-way. While there is plenty of width in the boulevard on most roads, installation of new sewer mains would require the removal of the boulevard trees. It is unlikely that the residents would support an alignment that had such a significant impact on the tree canopy. It is therefore assumed that the alignment of any proposed systems will be primarily located under the paved roadway. Cost estimates reflect this assumption.

3.4 INITIAL ARCHEOLOGICAL ASSESSMENT

Summarize the initial Golder sub-consultant draft report, once this is agreed to as completed, with the District.

- Initial AIA report
- Adjunct report regarding options available to the District and to land owners, complete with estimates of probable cost which are expected in order to attend to the archeological process.
    - Accompanying flowchart.

4. PCSWMM MODELING EXERCISE

4.1 DESCRIPTION OF THE SWMM MODELS CREATED

Computer models were created in order to simulate existing conditions in the combined sewer system. These models were generated from existing geometric data provided to us in the form of cadd drawing files. Entirely new models were needed, due to the considerable number of simplifying assumptions having been made by the authors of past modeling for the District.

Notwithstanding, the new pre-design models were calibrated against past results having been prepared by KWL, as a 1st iteration check. Model results were then confirmed, to the extent possible, against CRD pump station records. Unfortunately, the CRD only captures flow out of the Humber and Rutland pumping stations, they do not collect data regarding flows influent to these stations. Thus, only generalized checks as to average daily flows could be made, based on pumping station records. This said, the combined flow models do correspond reasonably closely to inferred inflows to the two CRD pumping stations and past published CRD system design flows.

In future, we strongly recommend the District undertake instream flow monitoring, initially at two sites within each of the two CRD pump station catchments, in order to allow a better understanding of peak flows and base flows carried under present day conditions. This data, when combined with analysis of rainfall records from the nearest reliable data source, would allow for better model calibration and, thus, more certainty as to existing system conveyance capacities.

Model calibration to this level of accuracy would be ideally available now, but is not essential for overall pre-design options comparisons. However, this exercise should be completed prior to detailed design of the preferred option.

From the completed model of existing combined sanitary and stormwater runoff flows, we then created a series of sanitary and stormwater flow models, as follows:

- **Existing pipe network conditions** with a 5 year return period, SCS Type 1, 24 hour storm applied. This is representative of conditions expected under overall Option 1, with a new sanitary sewer system to be constructed.

We believe the existing network was deigned to convey something in this range of storm water flows. The 5 year event represents a reasonable level of service threshold which residents in the District might expect to receive from an existing aging stormwater conveyance system. This model indicates small areas of minor flooding. Thus, only minor localized segments of the existing network are recommended for replacement, in order to convey the 5 year storm event, under Options 1, 3, 5 and 6 (new sanitary system).

- **Same as above, but with a 10 year return period design storm event applied**. Loadings derived from this model are useful for Option 2, wherein we would want to be sure we construct a new storm system capable of conveying the commonly accepted 'minor' storm event, being the 10 year return period storm. Under existing system geometry, the Q10 storm causes large scale widespread existing system capacity shortfalls.

- **Existing pipe network, were it to convey only sanitary sewer flows**, complete with a considerable infiltration and inflow allowance, I&I, representative of older clay tile pipe network. This is also representative of overall Option 2.

  We decided upon adoption of 0.5 l/s/ha as an I&I allowance. [As noted above, we would have ideally been in a position to extract from pumping station influent data the dry weather winter base flow, and, in turn, extract from that a proportion assumed as base infiltration flow. Unfortunately, this data was not available to us. We are reasonably confident the 0.5 l/s/ha allowance is representative of existing conditions. By comparison, new pipe would typically be designed to accommodate an I&I component of flow between 0.06 and 0.17 l/s/ha, being considerably lower values.

- **Existing pipe network used to convey only stormwater flows (with storage)**. Calculations as to total overall stormwater storage needed, at various nodes in the system, such that, if extracted from the system and stored temporarily, or put back to ground via infiltration, existing pipe network upgrades would not be necessary.

  It was found, not unexpectedly, that the volume of storage or extraction/infiltration to allow the design ten year return period storm event to be conveyed without significant surcharging, would be significant. It is not thought practical to plan for this. Rather, we recommend [if it is decided that the existing system should be used for stormwater runoff conveyance] the District plan to convey the 5 year event within the existing system in the short term. Over the longer term, as system replacement is warranted due to deterioration or otherwise, it is recommended that the network be incrementally upgraded to suit the un-attenuated 10 year return period event.

Attachment No. 4 contains a series of model output graphics, including indications as to expected system capacity shortfalls and overflow stormwater volumes.

In order to convey the 5 year return period design storm, only very minor upgrading of the existing combined sewer system and of the isolated segments of stand-alone storm mains along Lansdowne would be required. We have accounted for a portion of this in the following cost estimates, but, it is recommended that in-stream monitoring and better model calibration be completed before detailed design phase. Projected positive impacts of on-site storage, over time, should also be considered.

It is also recommended that the District proceed with a rainfall management strategy, which we presume would include on-site, individual dwelling lot scale, stormwater management features. Based on our past experience, a target on-site storage volume in the order of 3.0 cubic metres per dwelling unit should be considered. These on-site units [rain gardens, or storage infiltration pits, etc.] would be designed to assist in reducing the overall peak flows, albeit expected only modestly, and would assist in groundwater recharge within the two catchments, thereby more closely mimicking pre-development conditions. On-site source control measures would also serve to improve overall stormwater runoff quality to the receiving environment.

- **Proposed new deeper gravity storm system**, modeled to convey the ten year return period design storm without surcharge and without material reductions in peak flows, as might result from an on-going rainwater management program (Option 2).

- **Proposed new deeper gravity sanitary sewer system**, modeled to convey peak dry weather flows and a vastly reduced overall I&I component of sanitary system flow (Option 1). We note that MMCD suggests flows as low as 0.06 l/s/ha be used for new systems, and 0.12 l/s/ha for older systems. Our experience modeling older systems indicates typical I&I flows to be substantially higher. We recommend the District apply 0.17 l/s/ha, for purposes of sizing new sanitary system pipes. This provides some long term insurance against capacity issues, at very little, if any additional initial capital cost.

- **Modeling for System upgrading Option 3**, this being the concept of pumping from all dwellings into a municipally owned and operated pressure sewer network. This was prepared by a third party vendor, and checked by MCSL for reasonability and completeness.

- **Modeling of Options 4, 5 and 6** was not specifically undertaken, noting the similarities with Options 1 and 2. We note that the depths of proposed pipelines in Options 4, 5 and 6 is reduced, and thus the available gravity gradients are similarly reduced. However, it has been assumed that pipe diameters will not be materially affected here, and that cost estimates for the capital construction will not be affected significantly by isolated sections of pipe size change required at the time of detailed design.

Rather, the largest factors differentiating Options 1 and 2 from 4, 5 and 6, are in the pipe depths, and costs related to trench excavation/backfilling, and in the cost of additional on-site private pumping systems in these latter, shallow gravity pipe network options.

Municipal pumping station input flows to the networks, under Options 4, 5 and 6 have not yet been added as discrete pumped elements. Rather, the peak wet weather flow from the aggregate of dwelling units tributary to each node has been carried for these models. **Option 6 should be updated to suit proposed pumping station output [discharge rates], and checked for downstream pipe diameters**, and spare downstream capacities. We will undertake this during the 'assignment Activity 3', comparative analysis of the six options.

4.2 MODEL OUTPUT SUMMARY

Below we have summarized outcome of the modeling exercise:

	HUMBER CATCHMENT	RUTLAND CATCHMENT
Catchment area [ha]	40	69
Impervious % under <u>future conditions</u>, with all services connected	30	30
Number of service connections	158	235
Peak wet weather combined flows under existing conditions, with 5 year rainfall event [l/s]	565*	480*
Inferred existing Peak I&I rates [l/s/ha]	0.50	0.50
Peak existing dry weather sanitary sewer component of flow [l/s]	5	8
Sanitary flow peaking factor inferred from data	3.8	3.8
Peak 5 year return period stormwater runoff rates 50 year horizon, net of sanitary sewer component [l/s]	357*	561*
Peak 10 year return period stormwater runoff rates 50 year horizon, net of sanitary sewer component [l/s]	647*	1,058*
Proposed peak wet weather flow, PWWF, for existing network, if used as a sanitary sewer system [l/s]	25	40
Proposed peak wet weather flow for new sanitary sewer system [l/s] I & I = 0.17 l/s/ha.	12	19

*Relative differences are attributable to less impervious areas, concluded from past work by others, in the Rutland catchment under existing conditions (46% vs 28%). This is expected to be corrected in future, as new services are constructed and connected to the new municipal system.

4.3 FURTHER MODELING DETAILS AND RESULTS

4.3.1. Separated Storm Drainage Models

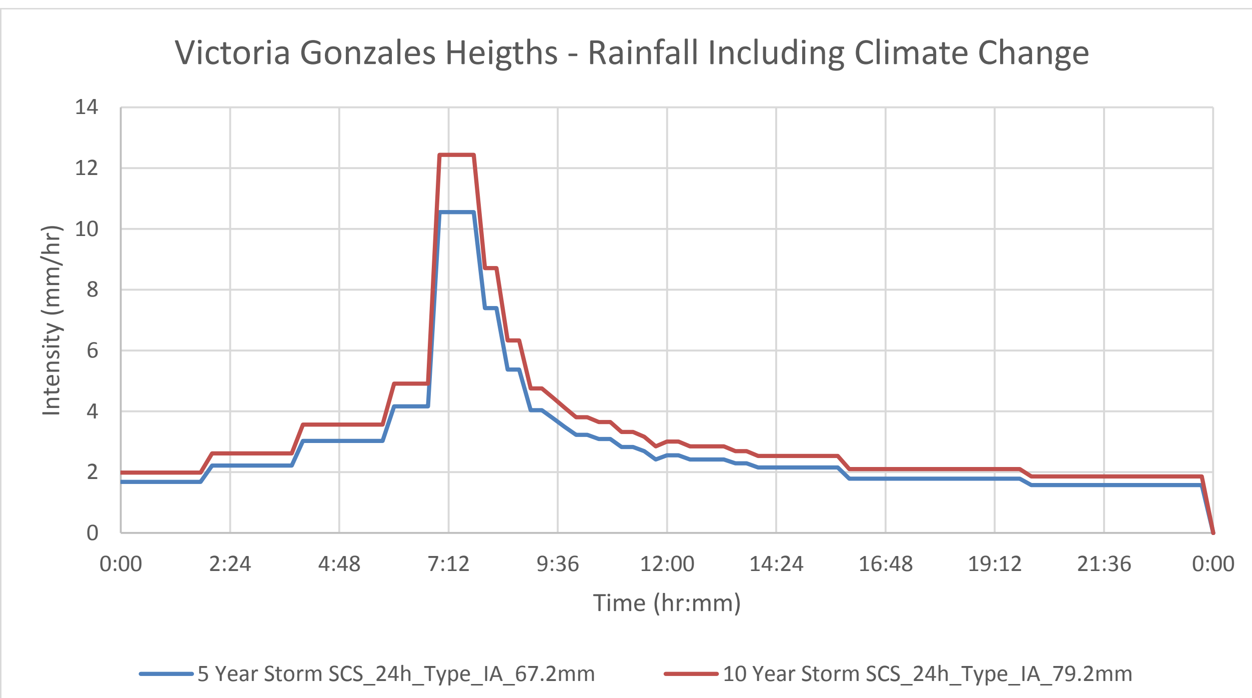
KWL had created "lumped" models, calibrated to pumped outflow records at each CRD pumping station. For purposes of preliminary system design, we could not utilize this past effort.

KWL used the 5 year storm (SCS Type1A), subsequent to CRD pump station flow calibration.

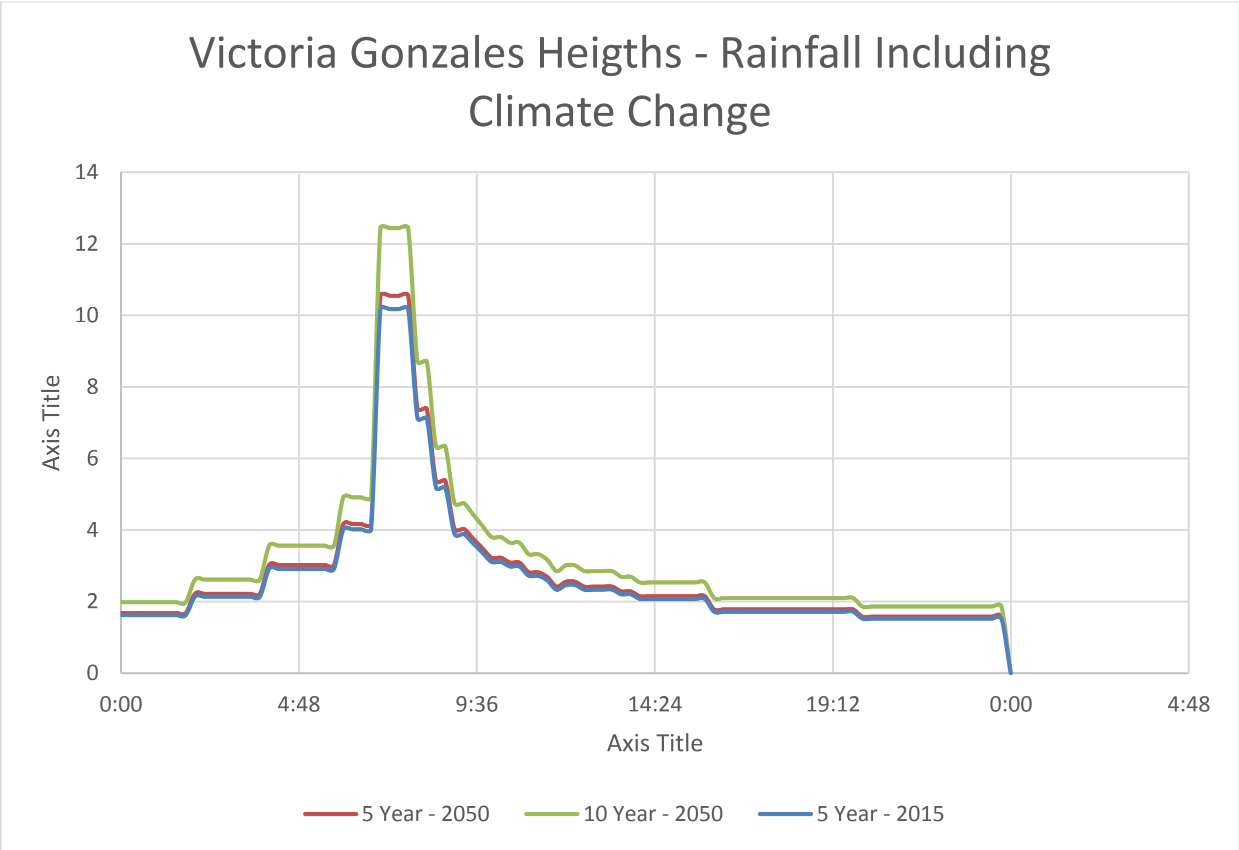
We initially constructed SWMM models of the combined system in both catchments, based on existing conditions, adjusting the inferred percent impervious value in order to obtain results consistent with past efforts. The 5 year (year 2050 - 5 yr. 10% Monthly Rainfall Increase), 24 hr rainfall event for was used to complete this calibration. Once the impervious values were matched, the 10 year (2050. 10 yr. 10% Monthly Rainfall Increase), 24 hr Victoria Gonzales Heights IDF curve was applied.

Present Day Peak 5 year rainfall intensity was determined to be 10.17 mm/hr, while the 10 year storm generated a result of 11.68 mm/hr. Similarly, the future peak 5 year and 10 year storm intensities were calculated as 10.55 and 12.43 mm/hr respectively.

The existing, present day 5 and 10 year storms generate total rainfall of 67.2 and 79.2mm respectively. Storm hyetographs are as follows:



For future, +/- 50 year models, the % impervious area assumptions were adjusted, better reflecting expected future conditions, wherein all dwellings are expected to be directly connected to a stormwater conveyance network and where the runoff volumes per unit area are expected to be relatively consistent between the two catchments (given the very similar land use and topography). We also adjusted the storm intensities, to reflect future climate change expectations. The following curves reflect this future scenario modeling adjustment.



The 'Green-Ampt' method was utilized in order to determine present day infiltration rates in pervious areas of each subcatchment. The subcatchment data is as follows:

Catchment	% Impervious – to suit CRD pumping station outflow calibration – per existing conditions	Total Area (ha)	Green-Ampt Parameters		
			Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit
Humber	46.2	40	178	2	0.3
Rutland	23.5	69			

Where:

- <u>Suction head</u> is defined as the average value of soil capillary suction along the wetting front (mm)
- <u>Conductivity</u> is intended to model the soil saturated hydraulic conductivity (mm/hr)

- Initial deficit can be defined as the fraction of soil volume that is initially dry (i.e., difference between soil porosity and initial moisture content).

The large difference between % impervious values for the two catchments was assumed (in the past) to be due to differences in the connectivity of roof leaders. Past KWL effort determined that the percent of roof tops in the Humber and Rutland catchments connected with the existing system are 89% and 30% respectively. This past report explains that the "surprisingly low connection rate in the Rutland catchment may be attributable to the more permeable soil conditions in the area."

This said, in future, we expect this anomaly will be corrected, with all dwellings being connected to the new systems, at least as an overflow pipe.

For the future conditions models, the input parameters were adjusted as follows:

Catchment	% Impervious	Total Area (ha)	Green-Ampt Parameters		
			Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit
Humber	30	40	178	2	0.3
Rutland	30	69			

The following nodes are expected to flood [i.e.: overtop the ground surface] during the 5 year storm; were the existing combined system used as a storm drainage network alone, and all connections to dwellings made, given a 2015 year storm intensity (i.e.: 30% impervious area in both catchments):

Catchment	Node	Location	Max Flood Rate (L/s)	Max Flood Volume (m^3)
Rutland	6860	2525 Lansdowne	4.57	11
	5359	Lansdowne & Weald	16.61	19

We have accounted for upgrading only a portion of these pipes in the short term, under the Options where a new sanitary system will be constructed. This assumes it will be decided, at time of detailed design, that some stormwater pipe surcharging can be tolerated, at least in the short term. The attenuating impact of rainfall runoff storage within private properties, over time, may also improve the existing system capability, to a limited degree. Further recommended model calibration, based on instream monitoring, will confirm this.

As a result of the 50 year future event, with climate change storm intensity increase added, the following existing system nodes are shown to be under capacity, again, given the 5 year return period storm:

Catchment	Node	Location	Max Flood Rate (L/s)	Max Flood Volume (m^3)
Rutland	6860	2525 Lansdowne	4.91	14
	5359	Lansdowne & Weald	17.6	24
	5300A	3130 Uplands	9.24	7

As described above, the existing pipe network response to the design 10 year storm event is considerably less ideal. It was shown that nodes would flood to the ground surface, during the 50 year future, 10 year return period, event, as tabulated below:

Catchment	Node	Location	Max Flood Rate (L/s)	Max Flood Volume (m^3)
Humber	5145	3490 Beach Dr.	38.17	18
	5204	W MH @ Beach & Ripon	16.63	3
	5212	S MH @ Beach & Ripon	10.84	3
	5241	3295 Midland Rd	10.37	2
	5306	3185 Norfolk Rd	11.69	3
Rutland	5257	Uplands Pl & Uplands Rd	3.43	1
	5300A	3130 Uplands	20.94	45
	5337	Lansdowne & Uplands	9.81	14
	5359	Lansdowne & Weald	12.62	20
	6860	2525 Lansdowne	21.87	46

We then revised the "storm only" models to reflect necessary pipe upgrades. It was shown that the following existing conduit would need to be upgraded to accommodate the long term future 5 year storm event, if existing system remains as a storm drain network:

Catchment	Node	Location	Existing Size (mm)	Recommended Size (mm)	Length (m)
Rutland	5300A - 5337	Upland Rd – Lansdowne Rd	200	250	87
	5337 - 6860	Lansdowne Rd	200	250	60
	6860 - 5359	Lansdowne Rd	200	250	182
	5359 - 5365	Lansdowne Rd	200	250	60

By contrast, the following existing pipe segments would need to be upgraded in the respective catchments, in order to convey the long term 10 year storm [again, net of sanitary sewer component of flow], (i.e.: Option numbers 1, 3, 5, 6):

Catchment	Node	Location	Existing Size (mm)	Recommended Size (mm)	Length (m)
Humber	5145 - 5181	Beach Dr.	200	250	222
	5210 - HUMBER_OUT	Beach Dr. – Humber Rd	525	600	302
	5211 - 5215	Midland Rd - Ripon Rd	200	250	181
	5212 - 5210	Exeter Rd	375	525	12
Rutland	COT1 - 5272	Cotswold Rd	200	250	62
	5272 - 5300A	Cotswold – Uplands	200	250	172
	5300A - 5337	Upland Rd – Lansdowne Rd	200	300	87
	5337 - 6860	Lansdowne Rd	200	300	60
	6860 - 5359	Lansdowne Rd	200	300	182
	5359 - 5365	Lansdowne Rd	200	300	60
	5356 - 5375	Lansdowne Rd	250	375	86
	5375 - 5381	Lansdowne Rd	450	525	86
	5381 - 5390	Lansdowne Rd	450	525	69
	5138 - 5173	Upper Terrace	200	250	138
	5173 - 5208	Upper Terrace	200	375	161
	5208 - 5254	Upper Terrace	300	375	184
	5290 - 5375	Midland	375	450	299
	5288 - 7016	Cotswold	200	250	104
	5257 - 5201	Uplands	200	250	264
	5201 - 5208	Cardigan	200	250	65

Based on the above, we conclude that the District would be best served if the following action plan were to be adopted to accommodate stormwater:

- Undertake instream monitoring – so as to confirm model calibrations. Confirm or refute with better certainty the past observations and conclusions as to differing stormwater runoff flows per unit area, and effective impervious percentages, from the two catchments.
- Plan to accommodate the 5 year return period storm for the short term.
- Plan on modest stormwater capacity upgrading in the short term, to suit 5 year runoff flows. Before detailed design of any such stormwater conveyance upgrading is undertaken, confirm the preliminarily modeled extent of pipe surcharges and desired operating characteristics.
- Note that this is an existing developed neighbourhood, and the opportunity for community based, municipally owned stormwater detention/retention facilities is quite limited.

- Coordinate between the engineering, building and planning departments at Oak Bay to establish planning targets for on-site, private property stormwater runoff attenuation [we suggest roughly 3.0 cubic metres per dwelling unit is achievable at reasonable cost], and source control measures, as re-development occurs. Assume, for purposes of stormwater pipe sizing, that overall resulting reductions in peak flows to be carried by the municipal systems will be modest, but not negligible.
- Design all new stormwater pipes to suit a 10 year return period storm.

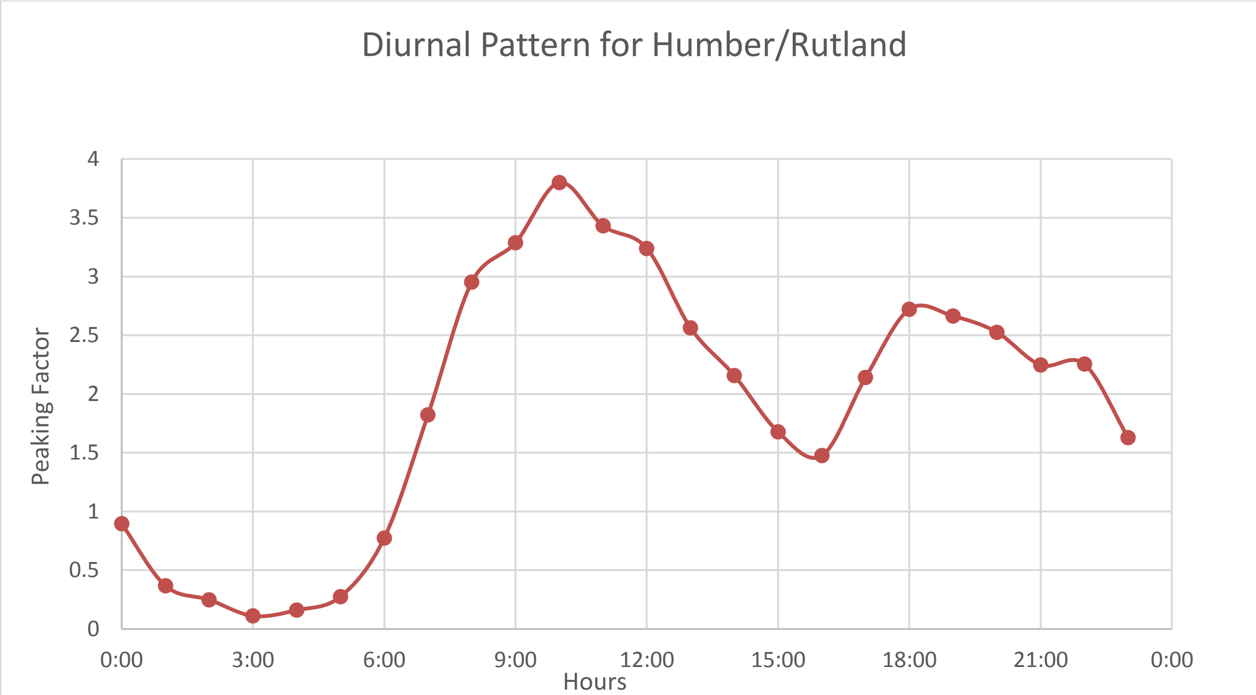
4.3.2 Separated Sanitary Sewer Models

For the Sanitary Models, MMCD design parameters were utilized in order to determine sewerage loading, as follows:

		Purposed Sanitary – Option 1	Existing Sanitary – Option 2	
# Connections	Humber	161		
	Rutland	240		
Capita Factor		2.5		Cap/Connection
DWF		300		L/cap/day
I&I		0.17	0.50	L/s/ha

The 0.50 L/s/ha I&I allowance corresponds to the leak prone existing system. Since definitive I&I data does not exist for these lift station catchments, this I&I allowance was arrived at based on CRD pumping station output data and engineering judgement. The base outflow for the Humber Catchment is approximately 20 L/s. This number, divided by the catchment area resulted in the 0.50 L/s/ha I&I component. This value was also used for the Rutland catchment, barring available data to suggest otherwise. 0.50 L/s/ha corresponds to about 3 times the "older system" MMCD allowance, but we believe is reflective of the clay tile combined system within the Uplands area.

A diurnal sewerage demand curve was used to determine the peaking factors for the system. Both catchments were determined to experience a maximum peaking factor of 3.8. This curve is displayed in the following figure:



Using the existing system as a sanitary sewer network, may, over time, give rise to operational issues, as the pipe network will be larger than needed to suit sanitary flows in isolation. Thus, more frequent flushing of mains may be required, to effectively control odour issues.

5. PRELIMINARY DESIGN DRAWINGS

- 6 pairs of drawings, depicting each of the six system configuration options, are appended hereto, one for each of the two CRD pumping station catchments, Humber and Rutland, respectively.

- Additional drawings have been prepared, including:
    - 11x17 reductions of plan / profiles in support of the deeper gravity sewer options 1 and 2,
    - miscellaneous details,
    - noting the existing system conditions c/w photo inlays,
    - Stormwater overland flood routing; noting three locations where either a municipal pumped system or a new storm main across private proprieties may be needed, in order to safely convey Q100 overland flood water.
    - Possible community based, publically owned stormwater storage locations [based on constraints related to limited geotech information and surface landscaping details received thus far].

- Attachment 4 includes graphics of SWMM modeling output, including the following:
  - Drawings R2 and H2, noting expected pipe overflows in the option 1 concept, wherein the existing system will continue to be used for 5 year return period stormwater conveyance.
  - Drawings R3 and H3, noting the same outcomes with a ten year return storm applied, no changes to existing system.
  - Drawings R4 and H4 indicate the upgrades needed to the existing system, in order to convey the 10 year return period storm, over time, under Option 1.
  - Drawings R7 and H7 indicate the pipe diameters needed for a new stormwater system, i.e.: Option 2.

If the District deems it of benefit, we could include proposed pipe depths and pipe diameters on the drawings, as a public display addition, and for purposes of the final assignment deliverable.

6. COST ESTIMATES

6.1 CAPITAL COSTS

Capital cost breakdowns for each of the preliminary design options are included as an appendix hereto.

Also attached are net present value calculation tables for each of the six options, inclusive of estimated operation and maintenance costs over a 50 year design horizon. Discussion is needed regarding the anticipated rates of interest and inflation, and if variations in these assumptions will materially affect the relative ranking of overall option costing.

For purposes of capital cost estimating, it has been assumed that new or upgraded sanitary sewers and/or storm drains, to be located within municipal road rights of way [or rights of way/easements over private properties], would be paid for by the 'project', [i.e.: would be publically funded]. A council decision is pending on this issue, and regarding the timing of requirement of private land owners to 'hook up' to the system, as it is made available. If need be, we will amend the cost estimate breakouts to reflect this decision, at a later point in the assignment execution.

By contrast, it has been tentatively agreed that all works required within individual private properties, including within easements in favour of one or more private parcels over another, would be funded by the benefitting land owners.

This notwithstanding, we have compiled the capital and O&M cost estimates as aggregate values for each of the options, inclusive of both expected costs to service individual private properties and within lands under the municipality's control. In so doing, we have sought to demonstrate the overall project costs, for comparison in the planned triple bottom line evaluation context.

In addition, the following assumptions or clarifications pertain to the cost estimates as complied thus far.

1. Lining or rehab of the existing system is NOT included as yet. Explicitly excluded, except notionally per options 2 & 4 as noted in the estimate breakouts.

2. We will assume the District's stated annual capital budget allocation will be accumulated and expended every 5 years as construction projects, in 2015 dollars - indexed to inflation. Initially, however, we have combined, for simplicity of initial options comparison, such that capital works are expected to be completed for each option as a single contract unit in year one, for each option.

3. Annual O&M costs [including periodic equipment replacement] have been added as estimated %'s of initial capital costs, for both private and public initial capital works. These %'s have been varied to reflect estimates of the relative degree of anticipated on-going operational system costs.

4. Commonly, for planning study purposes, operation and maintenance for gravity sewer systems is expected to cost in the order of one to two percent of initial capital construction value. This can vary considerably, based on parameters such as the age of the system, the complexity of system components, the degree of labour intensive maintenance required, power consumption expectations for pumping systems, etc.

   For comparative purposes, we arrived at the following O&M percentages:

   - 0.5% of capital cost for gravity pipe network
   - 0.25% of capital cost for municipally owned pressure sewers
   - 2.5% of capital costs for municipally owned pumping equipment
   - 3.0% of capital costs for privately owned pumping equipment

   These percentages reflect the expected 'economies of scale' afforded to the municipality, particularly as related to on-going pumping equipment costs. Longer term net present value of the options are sensitive to, and are affected to a material degree (over a 50 year design life) by the cost of on-going operation and maintenance.

5. Private property capital and O&M costs/dwelling unit will be broken out to the extent possible, noting dwellings with existing twin services and existing pumps, relative lengths of proposed services, etc. However, these will be aggregated for purposes of overall options assessment and comparison.

6. We have applied a 30% capital cost contingency, to account for preliminary design phases uncertainties, such as location of other utilities, etc.

7. Soft costs, such as engineering, project management fees, permitting fees/costs, District administration costs, and tan allowance carried in anticipation of archeological issues assistance, are included, in aggregate, as a further 20% of capital construction costs estimated.

8. Net present value calculations will assume the discount [interest] rate and inflation rate will offset, with inflation projected to outstrip interest accumulated over the project duration.

9. This is a relative cost comparison exercise. Absolute costs are estimated at preliminary design phase to at best +/- 30%, but relative costing comparison remains valid, assuming consistent application of assumptions.

10. Manholes are included in the per lineal metre pipe prices, at a between $50 and $100 per lineal metre, depending upon pipe diameter and depth.

11. Road restoration is estimated in a range of $150 to $250 per l.m. of trench.

12. We note this is a relatively congested existing road r/w with many existing utilities, with moderate traffic expected.

13. Uncertainties as to existence of concrete pavement structure to be excavated through, street lighting and shallow utility conflict potential, street tree and landscaping remediation, all are to be accounted for in the 30% contingency amount at this stage.

14. Probability of encountering bedrock is per Ryzuk report dated Sept, 2015, increasing with depth, in specific areas, a premium of between $150 and $300 per l.m. has been added.

15. Service connection assumptions: short = 20 m or less, long are greater than 20 m.

16. Costs estimated for private, on-site pumping stations include the following allowances: pumping equipment/tankage, controls equipment, plumbing connection, electrical connections/new sub-panels, site excavation and restoration and a small, portable power generator.

    [Costs for private pipes, connecting the dwelling to the municipally owned sewers, is not included in the $9,000 pumping system aggregate cost per unit. Costs for service connection pipes are broken out separately].

    Costs for municipal pumping stations allow for a portable, trailer mounted back-up power generator, rather than permanent on-site gen-set facilities at each station.

17. 393 total services to be provided. 80 existing sanitary services are expected to be reused for the #1 and #2 options, for the onsite portion of works. For options 4, 5 and 6, we have assumed ½ of these 80 dwellings will need a new pumped service to be re-laid, due to proposed shallow gravity mains in the roadway. I.e.: the existing service on private property will be too deep.

18. 17 existing sanitary pumps and 13 existing storm pumps have been accounted for. The number of existing pumped connections could be reduced, for options 1, 2, 3, & 6, depending on final design grades. Assumed here that all will be reused.

19. Sites with two existing onsite services will cost less to reconnect for options 3, 4, 5, & 6, due to reduction in separation cost at the existing buildings.

20. Service connections in the roadway are expected to require 1 production day for short services and 2 production days for longer services. Complications are expected to potentially include attending to existing:
    - Buried lighting wires
    - Buried hydro/tel/cable
    - Buried gas mains
    - Former concrete pavement structure

21. The cost estimate for service connections within road rights of way is representative of an average cost for services constructed concurrent with installation of the mains and services constructed at a later date by others.

22. Archeological risk has not been differentiated between areas of probable higher and lower risk. It is assumed that all six options will impose similar risks, given the proposed depths of the infrastructure to be installed.

23. Capital costs cited include expected contractor profit and overhead.

24. Operation and maintenance costs for on-site private service connection pipes are considered to be very low and have been ignored in this analysis.

25. Operation and maintenance costs related to the maintenance and upgrading of the existing combined system – in order to render it useful to continue in service for another 50 years, is explicitly not included herein.

26. Capital Costs to the municipality include the portions of proposed individual service connections located within lands under the municipality's ownership or control.

27. No seismic impact considerations have been accounted for in the cost estimates, thus far. Similarly, the impact of sea level rise on the gravity network, and on the CRD's pumping stations has not been factored into the long term costing for this project scope.

28. Annual Operation and maintenance costs are cited based on percentages of capital costs, <u>net</u> of contingency allowances.

29. For option 4, the existing storm main along Lansdown is not sufficiently deep to pick up adjoining services, now connected to the deeper combined sewer. Therefore, these dwellings would need to be pumped.

30. Production rates are estimated at 40 m/day for shallow sewers and 20 m/day for deep sewers.
31. On-site service connection costs and pumping equipment installation costs will vary considerably, depending on site specific circumstances.

6.2 O&M COSTS

POSSIBLE COSTS TO BE INCURRED BY THE MUNICIPALITY

- flushing requirements
- pressure sewer pigging/cleaning
- pumping power costs (not including existing CRD pump stations)
- pumping system maintenance/inspections (not including existing CRD pump stations)
- pumping equipment replacement
- stormwater erosion protection requirements
- stormwater detention /retention facility maintenance
- I&I planning and flow reduction costs on-going

POSSIBLE COSTS TO BE INCURRED BY PRIVATE LAND OWNERS

- annual pumping power costs per unit
- Stormwater rainfall management system maintenance?
- new pumps at year 25
- new services at 50 years
- root cleaning

O&M costs, including allowances for the above elements, have been summarized as percentages of capital value, for purposes of preliminary design estimating.

6.3 SUMMARY OF COST ESTIMATES

Option No.	Capital cost			Annual operation and maintenance costs			Aggregate 50 year duration net present value
	Totals	To the municipality	To the private land owners	Totals	To the municipality	To the private land owners	
	$Millions			$1,000's			$Millions
1	19.9	16.4	3.6	63	44	19	24.0
2	20.7	17.1	3.6	66	47	19	25.0
3	13.9	6.9	7.0	111	9	102	21.0
4	14.4	10.1	4.2	82	38	45	19.7
5	14.6	10.3	4.3	75	28	47	19.5
6	15.4	11.6	3.8	77	42	36	20.4

CAPITAL COST BREAKDOWN

Option No.	Total Capital Cost (per residential unit, including contingencies)					
	$1,000's	To the Private Landowners ($1,000's)				
	Average to the Municipality	Average Aggregate Costs to Private Landowners	Average Costs to Landowners with new pumps		Average Costs to Landowners without new pumps	
			High	Low	High	Low
1	42	9	20	17	11	8
2	44	9	20	17	11	8
3	18	18	20	17	N/A	N/A
4	26	11	20	17	8	5
5	26	11	20	17	8	5
6	30	10	20	17	8	5

Note that the average cost to landowners, where new pumps are required, is based on $9,000 per dwelling unit for supply and installation of pumping equipment and plumbing/electrical connections, $2,200 per unit for new service connection pipe to the roadway, and a total of 50% contingency allowances then added, as described above. It is likely the actual costs to homeowners will be considerably less. However, for overall system option comparison purposes, this average cost per pumped unit is appropriate.

7. CLOSURE/ NEXT STEPS

Assignment 'Activity 3' will focus on a comparison of the relative advantages and detractions of the six technically feasible options having been developed. This will include further derivation of distinguishing features of each option and an assessment of the operational issues that are anticipated to arise, as the optional system configurations are built out [and connected to] in phases or stages, sequentially.

We expect the District will be taking a summary of the 6 options to the public shortly, advising as to the derivation of these options and seeking initial feedback as to public preference between the differing scenarios.

We expect to discuss in more detail with the District's technical team the implications regarding timing of a requirement (or triggers as to the obligation) for owners of private properties to install and connect new separate services to a newly upgraded system.

As agreed with the District, we have assumed the existing system rehabilitation, in-situ lining or pipe replacement, owing to system age and condition will not be factored into the options costing. Expressed another way, we have not included costs for upgrading of the existing pipe network to suit another 50 years of service life, other than a notional allowance for some initial manhole rehabilitation and I&I engineering assessment effort, or localized storm drain capacity shortfall. The suitability of the existing combined system as a stand-alone sanitary sewer system needs further consideration, in our view.

Condition assessment video records should be reviewed with the District and some reasonably conservative estimate of annual pipe rehabilitation budgeting established. While technically feasible to utilize the existing system 'as-is', [and thus a viable option at this stage], for a sanitary sewer network, the long term costs of rehabilitation of this system, for this use requires further discussion with the District.

Further discussion is expected regarding geotechnical and archeological implications.

Further consideration as to costs for stormwater storage feasibility and advantages is needed, as compared to, or in addition to, proposed pipe network upgrading.

Some refinement of capital and operating costs is expected to result, updating the values having been preliminarily prepared under Option 2.

Anticipated issues regarding the scheduling of a phased construction program will also be considered and cost estimates adjusted to suit.

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Attachments:

1. Preliminary design options and misc. details drawings – full size sheets
2. Plan/profile drawings for deeper gravity options – reduced 11x17 sample sheets
3. Tabulations of proposed pipe sizing and grade calculations
4. SWMM model output graphics – R1 through R7 and H1 through H7, inclusive.
5. Detailed unit price cost estimates and net present value calculations for each option.
6. Sub-consultant reports:
    - Ryzuk Geotechnical
    - Golder Archeology Assessment
    - 'E1' pressure sewer system design report – relevant to Option 3.