Prepared for the

DISTRICT OF OAK BAY

FINAL

The Uplands Combined Sewer Separation Project
Final Report

RFP No. OBMH-02-2015 | September 22, 2016 | Submitted by:

McElhanney

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OQM | Organizational Quality Management Program

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Executive Summary

The District of Oak Bay (the District) is required to comply with Provincial and Regional District requirements for separation of municipal sanitary sewers and storm drains. The CRD's Core Area Liquid Waste Management Plan, authorized under the province's Municipal Wastewater Regulations (MWR), obligates the elimination of combined sewer overflows via the provision of separate stormwater and sanitary sewage systems. Within the Uplands neighbourhood, the original servicing construction, circa 1910, included a single pipe serving both functions. The District has been working toward compliance with the MWR for some years now.

McElhanney Consulting Services Ltd (McElhanney) was retained in May of 2015 to investigate alternatives for sewer separation within the Uplands area of Oak Bay. Six options were developed, broken down into the two CRD pumping station catchments, the Humber catchment and the Rutland catchment. The two catchments comprise a combined total of 391 existing homes. The six options were derived on the basis of design criteria established in conjunction with District technical staff. All of these options will require a number of privately owned pumping systems to service individual dwelling sites. Refinements based on the recent geotechnical information provided by the District (the WSP Canada Inc. geotechnical investigation report August 17), indicate that fewer properties will have to pump under each option with the exception of Option 3 where all households would have to install a sanitary sewer pump. The six options are:

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

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

While the goal of Options 1 and 2 is to minimize the number of pumped connections, additional properties need pumps because the existing easements, required for gravity service, are not being used and 5 metres has been established as the maximum practical and economic depth for trench excavation.

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

Under this option all properties in both catchments would require sanitary sewage pumps.

Option 4 – A new shallow gravity stormwater system with localized areas requiring municipally owned stormwater pumping stations for roadway runoff and existing pipe as a sanitary sewer conveyance.

Option 5 – A hybrid of shallow gravity sanitary sewer system, pumped where necessary, and existing pipe as a stormwater conveyance.

This option would include a shallow depth gravity sanitary sewer system, with smaller, isolated areas of catchment serviced by municipal pressure sewers.

Option 6 – A hybrid shallow gravity sanitary sewer system, with localized community sanitary pumping stations where necessary and the existing system as a storm drain.

This option is a variation of Option 5. More municipally owned pumping stations would be constructed in order to increase the number of dwelling units serviced by gravity sanitary sewer connections compared to Option 5.

BOTH CATCHMENTS COMBINED	Services requiring a pumped connection		Gravity services possible		Total number of services	
	Was	Now	Was	Now	Was	Now
Option 1	85	66	308	325	393	391
Option 2	85	61	308	330	393	391
Option 3	393	391	0	0	393	391
Option 4	179	180	214	204	393	391
Option 5	191	170	202	221	393	391
Option 6	149	152	244	239	393	391

Attached as Appendix A are reduced copies of drawings 1a through 6b, depicting the proposed options.

As an aid in the assessment of relative merits and detractions of the options, an archaeological assessment and a 'desktop' geotechnical assessment were prepared by Golder Associates and Ryzuk Engineering, respectively. Considerable likelihood of encountering bedrock within new sewer pipe trenches was noted by Ryzuk, with two general areas identified as having higher and lower probability of rock at depth, respectively. Areas of higher archeological significance were mapped and reported upon by Golder. It was concluded that all options carry similar risks related to archeological issues.

The District has met with the Songhees Nation and the Esquimalt Nation to inform them of the District's requirement to move forward with the sewer separation project and the District committed to engaging the Nations as the project moved forward.

Technical memos 1 and 2 were prepared and delivered to the District in late 2015. Technical Memo 1 established the project design criteria and study parameters.

Tech Memo 2 covered the development of the 6 options and the modeling needed to assess required pipe sizes and depths for each option. Tech Memo 2 also provided a summary of expected differences in the number of private pumps needed under each option, as well as initial estimates of cost for each of the options. These cost estimates included a 30% contingency reflecting the preliminary nature of the analysis and a further 20% to cover soft costs such as detailed design and project management.

Subsequent to publishing of the technical memos 1 and 2, the District hosted a series of public information meetings, in order to present the material developed thus far and to seek feedback regarding public concerns and preferences. Stemming from that public process, the District requested that McElhanney undertake some additional analysis, prior to an evaluation of the options. This included:

- An assessment of a very deep gravity option that would preclude the need for most, if not all privately owned pumps. This was found to be very costly, and was not pursued further.

An assessment of the surface conditions of easements and statutory rights of way over private properties, within which the existing combined sewers are routed. Existing easements are 5 feet and 10 feet wide - not sufficiently wide to install a second pipe without significant impact on private property. A new wider easement would have to be negotiated with one or both property owners abutting an easement depending on the location of the existing pipe within the easement. The wider easements would have to be cleared to permit construction. The existing easements also contain mature tree, hedges, stone walls, driveways etc. Restoration of the new wider easements could represent a significant cost increase to the District such that construction in the easements would be more expensive than in the roadways.

Various pipe installation techniques were considered, including a number of trenchless technologies. While Horizontal Directional Drilling (HDD) may have some application on private property, HDD is neither a technically nor a financially feasible solution. The District Council resolved (June 2016) not to pursue additional pipes within the existing easements.

In addition, in response to public feedback during the public engagement process:

- Council adopted a resolution that the District work towards providing a sewer separation plan with a phased approach (June 2015)
- A geotechnical investigation was undertaken given the potential cost impact of encountering rock. This report's data increased our understanding of the probability and implications of encountering rock and its influence on cost of the options.

- In August 2016, the District directed McElhanney to incorporate these more recent initiatives and developments into an updated options assessments and revisiting of associated cost estimates. The result was a much clearer assessment of differences between the options, when comparing based on the agreed project assumptions and design criteria outlined later in this report.

Conclusions Summary and Recommendation:

- Present-day combined system operating characteristics clearly indicate that peak flows to the two CRD pumping stations are predominantly stormwater runoff, and these peak flows presently far exceed the capacity of the stations (90 l/s each) during wet weather events.
- Council adopted a resolution not to mandate immediate re-connection of private services to the new system. The public was supportive of the plan that re-construction, or major renovations within private properties, would trigger an obligation to re-connect. (October 2015).
- New storm sewer options will lead to more rapid reduction in combined sewer overflows.
- Options 2 and 4 allow the District to realize environmental benefits immediately as each property connects thereby achieving compliance with the Municipal Wastewater Regulation faster. By comparison, if a new sanitary system was constructed, no diversion of flows away from the CRD pumping stations would occur until all service connections (all homes) were confirmed connected. This could be 20 to 30 years depending on project phasing and available funding.
- Options with deeper sewers will cost considerably more than shallower options, with the degree of cost uncertainty generally increasing with increasing pipe depths. This is due to greater amount of bedrock to be removed and the larger volumes of trench spoil material needed to be trucked to offsite disposal and backfill imported.
- Options 1 and 2 (deep sewers) represent the highest capital costs and the greatest cost uncertainty for the provision of this utility. These options also represent highest risk to mature trees within the Uplands and higher probability of significant disruption within private properties.
- Option 3 is the least expensive to the District however it forces all 391 homes in the Uplands neighbourhood to install a sanitary sewage pump. In order to achieve compliance, 100% of properties must be connected to the new system before coming off the existing combined system. Phased construction of Option 3 is not practical, given the need for achievement of sufficient flushing velocities and the allowable duration of effluent within the system prior to discharge to the CRD pumping stations.

Homes with existing pumps may have to replace these units with higher head (pressure) units.

- Options 4, 5, and 6 are compromise solutions, balancing the overall capital cost and reduced upside project cost risk.
- Of these three options, only Option 4 offers the significant benefits of a new shallow, stormwater network allowing for a phased construction program with resulting gradual reductions in CSOs. Of the 391 homes in the Uplands, approximately 91 have already separated their stormwater and sanitary sewer systems to the property line allowing for immediate environmental benefit as homeowners connect.

CONSULTANT'S RECOMMENDATIONS:

It is recommended that the District:

a. Implement Option 4, a shallower gravity based storm system, including two isolated areas requiring municipal stormwater pump stations.

b. Undertake design by catchment area not by construction phase.

c. Undertake construction on a phased project basis, beginning with the Humber catchment, with contract packages at a minimum of $2 million each.

d. The District should develop a plan for rehabilitation of the existing pipes.

Below is a summary of estimated costs for each of the options, including a 30% contingency allowance and 20% for other soft costs, as reproduced from report section 3.2:

Option No.	Capital cost			Average Annual Operation and Maintenance Costs			Aggregate 50-year duration net present value
	Totals	To the municipality	To the private landowners	Totals	To the municipality	To the private landowners	
	$Millions			$1,000s			$Millions
1	30.9	24.3	6.6	78	65	13	35.9
2	31.9	25.1	6.7	77	64	13	36.8
3	14.2	7.2	7.0	110	9	101	21.3
4	21.5	15.1	6.4	91	46	45	27.4
5	21.4	15.0	6.4	89	48	41	27.2
6	23.4	16.9	6.5	90	54	36	29.2

Option No.	Total Capital Cost (per residential unit, including 50% contingencies)			
	To the Private Landowners ($1,000s)			
	Costs to Landowners with new pumps		Costs to Landowners without new pumps	
	High	Low	High (deep and long)	Low (shallow and short)
1	20	17	38	14
2	20	17	38	14
3	20	17	n/a	n/a
4	20	17	38	14
5	20	17	38	14
6	20	17	38	14

Estimated costs for rehabilitating the existing sewer system, as a separate District maintenance initiative, are in the order of $3 million.

1. Introduction

Under the Capital Regional District (CRD)'s Core Area Liquid Waste Management Plan (CALWMP), and the provincial Municipal Wastewater Regulation (MWR), separation of sanitary and stormwater drainage systems is required within the 'Uplands' area of Oak Bay. The District of Oak Bay (the District) must decide how best to plan for and implement a solution to this complicated and costly infrastructure servicing upgrade issue. To move forward and achieve compliance, the District prepared a request for engineering consulting proposals, in which the following over-arching project goal was indicated:

- Compliance with the CALWMP and MWR, that is, to eliminate combined sewer overflows (CSOs) by eliminating combined sewers in Oak Bay.

Reducing average annual volume—and the peak flow rate—of sewage delivered to the CRD's conveyance system, is a consequential benefit of the project.

McElhanney Consulting Services Ltd. (McElhanney) was retained in May, 2015 to:

- Review the existing combined sewer system function in the Uplands area of the municipality
- Consider and present applicable design criteria that will guide in the development of viable sewer separation options
- Consider and develop, at a preliminary design level of detail, a series of technically feasible options for sewer separation
- Develop defensible estimates of capital costs and longer-term operations and maintenance costs for these options
- Assist with presentation of this material to the public
- Identify key considerations for each of the options
- Compare the options overall, accounting for social, environmental, and project cost factors
- Report on our findings, with a preferred solution indicated

The McElhanney-led team included sub-consultant services covering a desktop geotechnical investigation (Ryzuk Engineering, Victoria) and an archeological overview assessment (Golder, Victoria). The District will engage with First Nations as part of the implementation phase of the project.

This final engineering report follows two technical memoranda submitted to the District dated 02 November, 2015 and 19 November, 2015. It reflects the inclusion of a number of subsequent supplementary documents and investigations requested by the District in response to public feedback captured during the public engagement process.

All of the options developed are technically feasible to construct and to operate. However, when considering public impacts and overall lifecycle costs, there are many constraints and factors requiring consideration. This report is intended to inform the District of pertinent issues and to provide clear direction as to the preferred servicing Option.

2. Background

Presently, sanitary sewage and stormwater runoff are conveyed within the Uplands area of Oak Bay via a combined single pipe network. The District has been investigating how best to comply with the requirements of the CRD CALWMP and provincial MWR for a number of years now. The District decided it was necessary to undertake a more comprehensive assessment of options than had been prepared previously, such that costing could be better understood and a more informed decision could be made. This pre- design options assessment study was commissioned to assist in determining the preferred servicing solution, taking into consideration social and environmental factors as well as expected project lifecycle costs.

The capital costs of the options and the resulting system functionality (MWR compliance) are important factors in selecting a preferred option but there are other factors that must be weighted and considered. These include:

- Impact during construction on the neighbourhood: property access interruption
- Disruption on private property and the cost of services installation to homeowners
- Costs to the District (taxpayers)
- The requirement to install either stormwater or sanitary sewer pump for some properties
- Environmental considerations including how best to utilize the existing sewer network and the timeline associated with addressing the overflows
- Protection of the mature tree canopy
- The long-term operating costs of the differing options to be paid by private property owners and by the District

At the outset of the project, the following key assumptions were agreed upon by the project team:

1. The goal of the project is to eliminate (separate) the combined sewers in Oak Bay (the Minister of Environment's condition for approval of the CALWMP) to eliminate overflows in compliance with the MWR (Section 42).
2. A second pipe would not be installed in existing easements.
3. The existing pipe would continue to be utilized for either sanitary sewer or stormwater conveyance.
4. A maximum practical trench depth is considered to be 5m.
5. Trenchless technology, specifically directional drilling, is not viable for the installation of the new pipe.
6. The District would be responsible for compliance with the Heritage Conservation Act on District property.
7. Property owners would be responsible for compliance with the Heritage Conservation Act on private property.
8. Given the limitation on trench depth, sanitary and / or stormwater pumps would factor in all options.
9. Stormwater would not be treated (decontaminated) prior to discharge to the sea.
10. Based on the statistics on the duration of power outages, the use of pumps on private property is viable.
11. On-site stormwater management would not be an alternative to a storm sewer connection—all properties will need a connection for stormwater.
12. In the absence of detailed geotechnical information, assumptions would be made on the occurrence of rock in generating cost estimates. *(Subsequent to the public engagement process, undertaken in late 2015, the District decided to commission a geotechnical investigation and reporting, in order to better define the impacts of bedrock on each of the options.)*.
13. The cost estimates developed for private property are the average of the total cost to all property owners; that is, cost estimates were not developed on a site-specific basis.
14. At this stage, pre-design, operation, and maintenance costs estimates are based on a percentage of the capital costs.

It is assumed the reader is familiar with the District's original Terms of Reference for this assignment and our proposal dated 17 April, 2015, as well as McElhanney's technical memoranda #1 and #2, dated November 2015. The content of these documents is not repeated here. However, a brief summary of technical memoranda #1 and #2 is provided below, to assist in contextual reference.

2.1. Tech Memo 1 – Dated 19 November, 2015

- Established technical design criteria, hydraulic operating characteristics, etc., to be used in developing and comparing options.
- Considered land use and per capita loading rates, peaking factors to be applied.
- Assessment as to expected system service life, decided upon 50 years, for Net Present Value (NPV) calculation purposes.
- Consideration as to the appropriate design storm events to be modelled.
- Consideration of acceptable infiltration and inflow rates.
- Review of video and survey materials available from the District.

2.2. Tech Memo 2 – Dated 02 November, 2015

Development of six options. Essentially there are two fundamental design solutions, with the six options being variations on these two themes:

- Re-purpose the existing system as a stand-alone storm drainage network.
- Re-purpose the existing system as a stand-alone sanitary sewage conveyance network.

The six options are:

1. Deep new gravity sanitary network
2. Deep new gravity storm drains
3. New pumped sanitary sewer system
4. New shallower storm drainage system, with more pumps
5. New shallower sanitary network, with more pumps
6. Variation on Option 5, with fewer private pumps and more municipal pumping required

For these options:

- Calculations of dwelling units that would require pumping, or not, under each option, based on agreed servicing depths and slopes of service lines and resultant hydraulic grade line
- Pipe routing feasibility assessments under the differing options
- Development of plan / profile drawings for gravity options
- Stormwater and sanitary sewer system modelling scenarios with present day and future loadings applied

- Preliminary 'desktop' geotechnical assessment
- Preliminary archeological issues and impacts assessment
- Initial identification of differing constraints between the options
- Development of unit price cost estimates for capital cost, Operation and maintenance (O&M) costs, and NPV cost estimates

3. Discussion

3.1. Further Effort Since Tech Memo 2

Late in 2015, we received additional data from the District regarding specific dwelling floor elevations. Coupled with excellent feedback via the autumn 2015 public information sessions and the WSP geotechnical report received in August 2016, we have subsequently re-worked the first iteration gravity sewer plan/profiles and associated service connection elevation assumptions for all six options.

The more detailed WSP geotechnical information was utilized by:

- First adding in all suggested rock surfaces to the original plan/profiles drawings
- Reworking of the plan/profiles—adjusting pipe depths and grades—to better optimize each of the overall pipe network options (avoiding bedrock where possible while optimizing the number of possible gravity service connections)
- Confirming the applicable probabilities of encountering rock at differing depths
    - Applying these probabilities to each of the options
    - Assessing volumes of trench rock for each option
    - These volumes were further differentiated by pipe diameter(s) and associated trench width(s)
- Assigning different costs per unit volume of rock, if encountered at differing trench depths
- Reworking the technical memorandum #2 capital cost estimates for all options
- Adding an appropriate cost allowance for encountering rock within private properties

The results of this additional analysis is provided in the form of data tables, as *Appendix B*.

Unit price cost estimates for each option were also updated, attached as *Appendix C*. These new cost estimates reflect the following:

- Updates to suit geotechnical information now in hand
    - Probabilities of more rock than had initially been accounted for
    - More limited opportunity to reuse trench material as backfill; more import fill

- Further breakout of dwelling service connection costing, both within road rights-of-way and across private properties. Increased expected costs for deeper gravity services over private properties
- Refinements in the number of pumped connections expected, whereby most options now indicate a requirement for fewer private pumps
- Allowance for re-connection of all existing roadway catch basins under Options 2 and 4.

Lastly, preliminary design drawings for the six options were also updated, reflecting these refinements. These are provided, in a reduced 11x17 format, as *Appendix A* attached.

3.1.1 Public Engagement Process Outcomes

The District engaged the public through a series of open house meetings held during November and December 2015. These meetings were well attended with the majority of the attendees representing property owners impacted directly by the project in the Uplands neighbourhood.

A number of factors were prevalent, based on public feedback:

- Pumping systems on private property are not preferred
- Costs to the individual homeowners should be minimized
- Disruption of mature trees and screening vegetation needs to be avoided
- The District needs to find the best means of utilizing the existing pipe network

It was stressed during the public engagement process that the preliminary design servicing options undertaken to date have been based on the available information. Further, that the project intent was to understand, generally, the clearly distinguishable differences between the options. It was conveyed to residents that detailed design phase analysis, complete with further survey and topographic detail, would yield refinements in the routing and depth of the District's proposed pipe network and refinement in the number of dwellings that could be serviced by gravity connections. Generally speaking, preference was indicated by residents impacted by the project in the Uplands neighbourhood for deeper gravity sewer options, whereby the need for pumping on private properties could be minimized. For a more detailed summary of the public engagement process and findings, the reader is directed to *Uplands Sewer Separation Public Engagement Overview and Project Survey* (www.okaybay.ca).

Subsequent to the public engagement process, the District instructed McElhanney to undertake supplemental investigations, intended to address specific issues raised by the public. This included the exploration of an Option 7 (a deep gravity system that would eliminate the requirement for pumps entirely) and the utilization of easements for a second pipe installation. Upon further analysis, neither was considered a viable option by the District. Further detail and discussion on these matters is provided as Appendix D.

3.1.1.1 Option Considerations for the Existing Pipe Network

Rehabilitation/lining:

While the lining of the existing century old pipe network is not specifically part of the sewer separation capital project, it is a necessary maintenance activity. District staff intend to address the rehabilitation of the existing system on a phased priority basis, independent of the option chosen for sewer separation. We estimate that pipe lining in the project area will cost in the order of $3 million, at $250/lineal metre.

For Options 1, 3, 5, and 6, (new sanitary network) the existing system will be re-purposed as a storm drainage network. In this case, the existing system can be 'leaky' and still function acceptably.

By contrast, for an option that involves a new storm drain network (Options 2 and 4), lining of the existing system is recommended in order to reduce the potential leakage of sanitary sewage from the pipe. In-stream flow monitoring should be undertaken such that I&I rates can be established. Results of in-stream flow monitoring and calibrated system modelling will assist in confirming the upgrading priorities.

Modeling indicates that diverting only the stormwater from roadway areas, as an interim step, per Options 2 and 4, would not be sufficient to eliminate CSOs. Diversion of stormwater from private properties, in addition to runoff from roadway areas, is required to eliminate CSOs.

3.1.1.2 Easements Over Private Properties – Opportunity to Add a Pipe Within These

The potential for installation of a second pipe within existing easements, via alternative installation methods was evaluated.

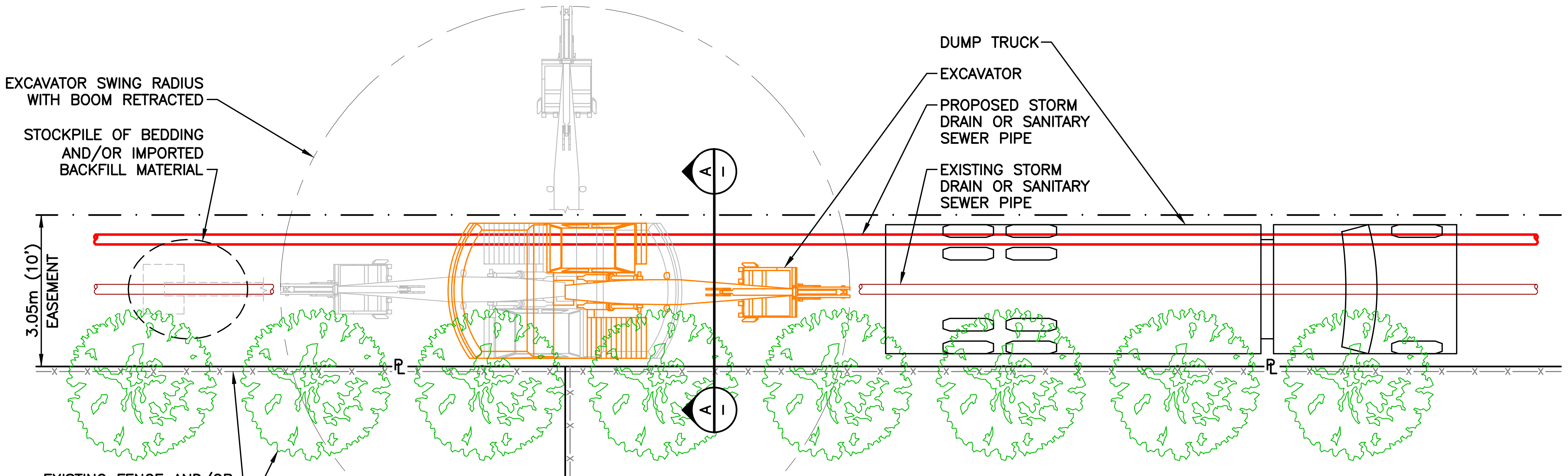
Conventional Trench Excavation Method

The District requested that all existing easements that presently contain a combined sewer pipe be investigated in the field. The intent was a more exhaustive initial assessment of feasibility to construct a second pipe within these easements, and determination of the resulting reduction in the number of private pumps otherwise required. It was concluded that very little realistic opportunity exists, without substantial impacts to abutting property owners.

Attached overleaf is an 8½x11 copy of Figure SK 4, dated 03 December 2015, on which easement construction access considerations are demonstrated.

The use of back lanes (being road dedication in favour of the District) for purposes of twinning sewers would be more feasible than use of the existing easements. The advantage of lanes for alignment of new sewer infrastructure should be investigated in greater detail at the time of detailed design.

SK 4: Construction Access Issues in Narrow Existing Eastments



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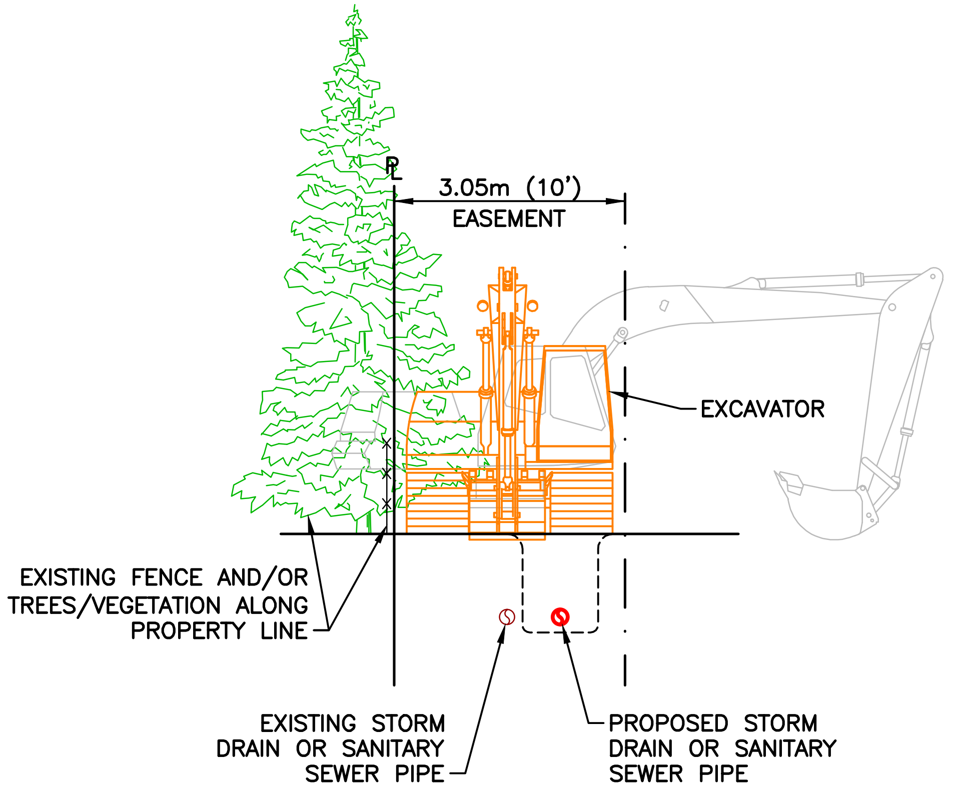

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PIPE INSTALLATION IN 3.05m (10') EASEMENT

SCALE: 1:100
DRAWN BY: MTK
DATE: 2015–12–03
DRAWING No: 15–326–SK.4

P:\15–326 UPLANDS COMBINED SEWER SEPARATION PROJECT PRE–DESIGN\(10) DRAWINGS\SK.4.DWG 1/25/2016 1:31 PM LAYOUT1

Directional Drilling or Other Trenchless Installation Method

We discussed the options of trenchless installation with three contractors who specialize in this field.

Pipe bursting would provide for additional capacity as well as structural integrity improvement and attendance to Inflow and Infiltration (I&I) issues. However, pipe bursting will not provide a second pipe. Good line and grade control can be achieved with this technology and is therefore suitable for replacing sections of existing pipe.

Directional drilling would allow for installation of a second pipe within the 10ft easements or roadways, at least in theory. We have been advised by contractors knowledgeable in this field, however, that the likelihood of success, measured by cost-effective installation with little disruption of immediately affected residents and land owners, is low. An expert in the field of trenchless pipe installation methods, Mr. David O'Sullivan, PW Trenchless Construction Inc., presented to the District Council in May, 2016.

In summary, it was concluded that trenchless installation methods are not viable options within Uplands easement areas for installation of District owned pipes. Privately owned, pumped service connections could be installed by trenchless methods.

Lining via in situ form or equal is a method of rehabilitating existing sewers, adding structural strength and modest improvement in hydraulic characteristics. We note that the District will also need to gain access to some rear yard easement areas, in order to proceed with any such rehabilitation program, particularly where the existing pipes in easements deflect 90 degrees along the routes between adjoining streets.

3.1.1.3 Deeper Gravity Mains – As Needed to Avoid Private Pumps Altogether [OPTION 7]

The costs to install gravity sewers throughout the Uplands area, sufficiently deep so as to avoid private pumps while at the same time avoiding the need to align new sewers within existing easements over private properties, was also investigated. The resulting technical memorandum dated 05 January, 2016, is summarized as follows:

- An approximately 50% increase in the overall capital cost to the District, as compared to deeper gravity sewer Option 1, would result, in order to avoid new private pumps in their entirety, and stay clear of existing easements and rights-of-way over private properties.
    - The increased likelihood of bedrock at greater depths leads to greater financial risk.
    - Increasing pipe depths from 5m will require a benched or stepped excavation at very high cost-per-metre of trench. This is essentially impractical, given the number of other 'live' utilities within the existing roadways that would be exposed or adversely affected.

- Costs incurred by land owners, in reconnecting via a gravity service to a very deep gravity main in the roadway, may be higher than for provision of a private pumped service. This is particularly true along the low side of the road, where deep gravity sewers would result in deep gravity service connections across private properties.

Attached overleaf are reduced 8½x11 copies of Sk5 and Sk6, which illustrate the issues.

There may also be opportunity at some dwelling sites for partial gravity service and partial pumped service, rather than a very deep gravity service. This would apply to both storm and sanitary solutions. Attached double overleaf is a reduced 8½x11 copy of Sk3, illustrating this concept.

3.1.1.4 Timing of Splitting Out Servicing Connections

The operational implications—and incremental benefits—of rapidly achieving private service reconnections differ in some respects, between options involving a new sanitary network versus a new storm drainage network.

The interim benefits of Options 1, 5, and 6 (new sanitary sewer) are less pronounced, if the District does not mandate a timeline for all existing service to be separated, i.e., the existing combined pipe network leading to the CRD pumping stations will need to continue to drain there, because it carries some sanitary sewage. Thus, until all connections are separated and connected to the new sanitary sewer, the District will realize no benefit, in terms of CSO reductions, and no reduction in volumes being conveyed to the CRD system.

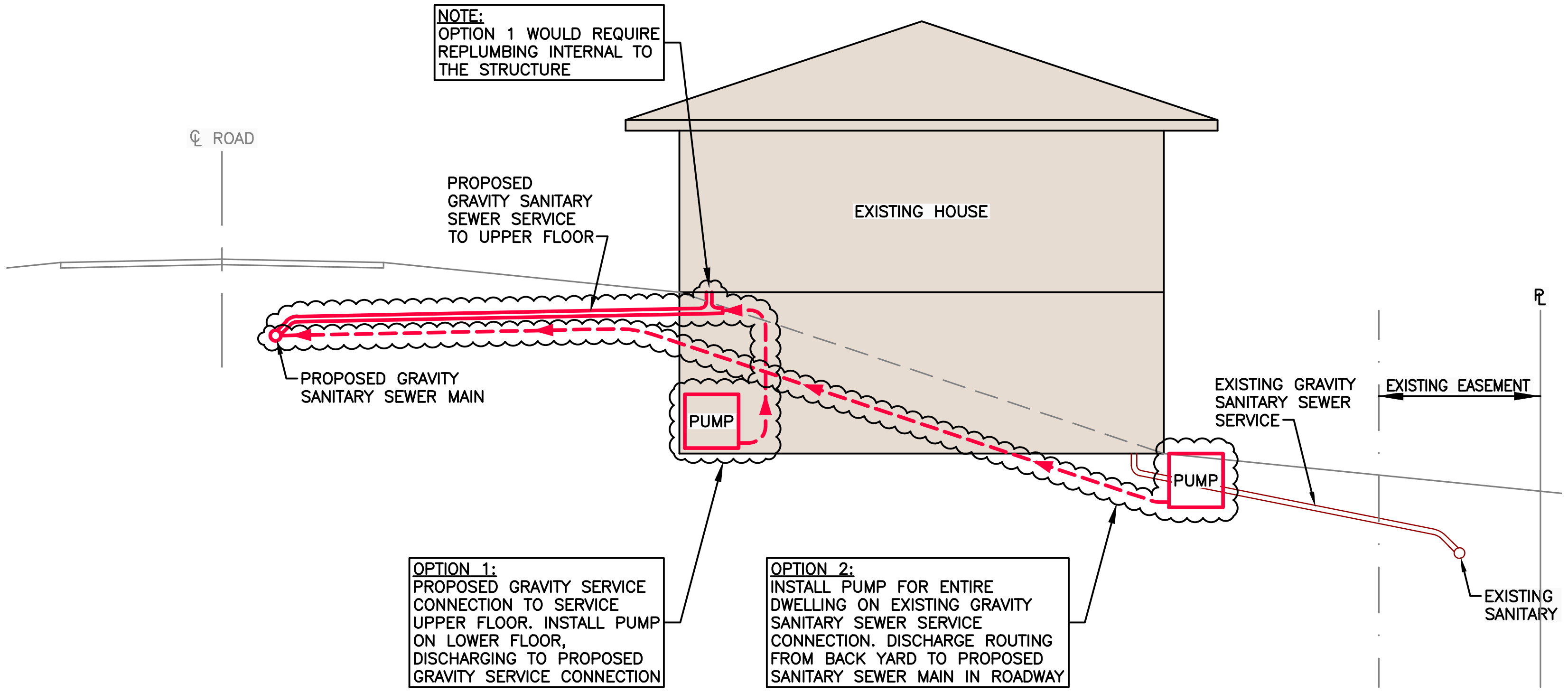
Given the District's decision on the criteria for sewer separation on private property, then the advantages of a new storm network are greater (Options 2 and 4).

Attached are reduced 8½x11 sketches Sk1 and Sk2, overleaf, depicting the hydraulic loading issues that are expected to arise during a phased construction approach, were a new stormwater network or a new sanitary network to be constructed.

3.1.2 Additional Geotechnical Investigation by WSP

Prior to completion of technical memorandum #2, the technical team met to discuss the cost estimates and determined it would be prudent to add monies to the deeper sanitary and storm sewer options to cover remaining uncertainties related to:

- Additional trucking and supply costs for import fill and disposal of trench spoil materials, compared with reuse of excavated material as trench backfill
- Bedrock location uncertainty
- Groundwater uncertainty

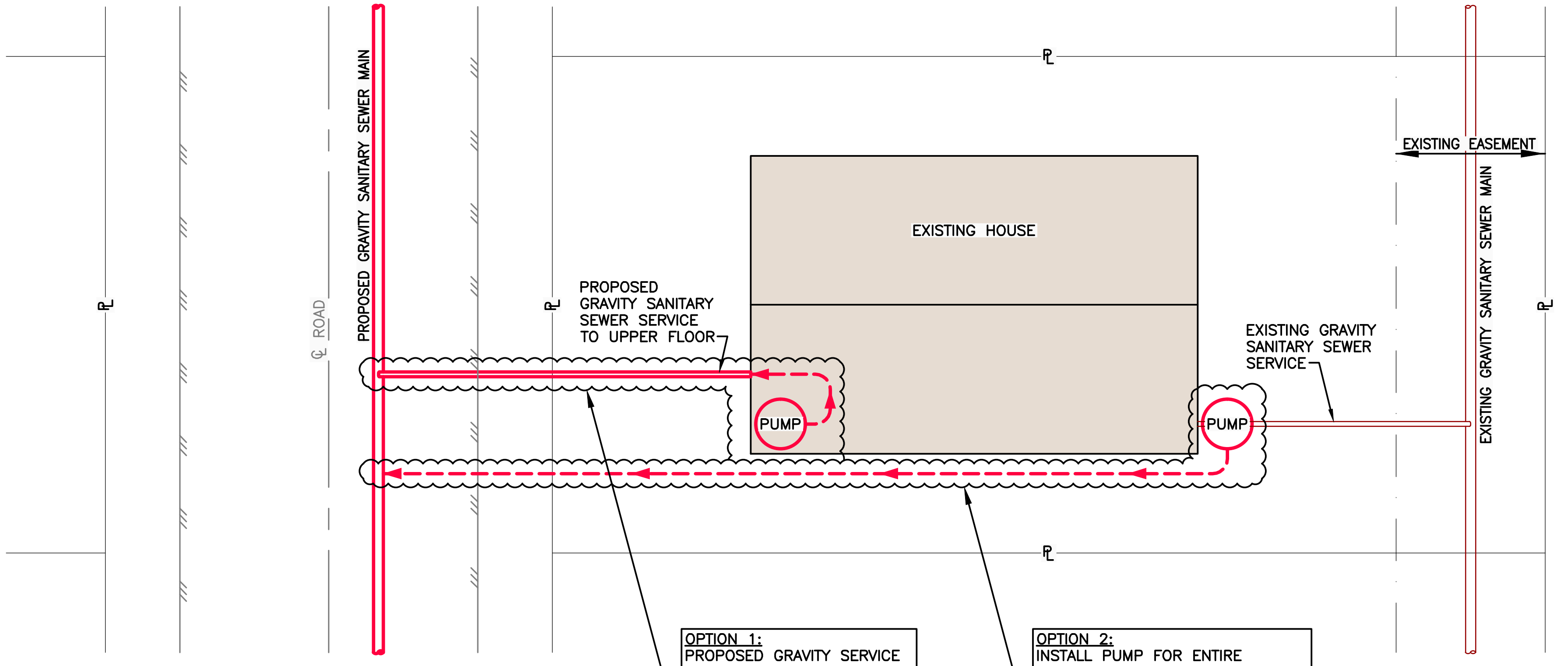


NOTE:
OPTION 1 WOULD REQUIRE REPLUMBING INTERNAL TO THE STRUCTURE

OPTION 1:
PROPOSED GRAVITY SERVICE CONNECTION TO SERVICE UPPER FLOOR. INSTALL PUMP ON LOWER FLOOR, DISCHARGING TO PROPOSED GRAVITY SERVICE CONNECTION

OPTION 2:
INSTALL PUMP FOR ENTIRE DWELLING ON EXISTING GRAVITY SANITARY SEWER SERVICE CONNECTION. DISCHARGE ROUTING FROM BACK YARD TO PROPOSED SANITARY SEWER MAIN IN ROADWAY

PROFILE



OPTION 1:
PROPOSED GRAVITY SERVICE CONNECTION TO SERVICE UPPER FLOOR. INSTALL PUMP ON LOWER FLOOR, DISCHARGING TO PROPOSED GRAVITY SERVICE CONNECTION

OPTION 2:
INSTALL PUMP FOR ENTIRE DWELLING ON EXISTING GRAVITY SANITARY SEWER SERVICE CONNECTION. DISCHARGE ROUTING FROM BACK YARD TO PROPOSED SANITARY SEWER MAIN IN ROADWAY

PLAN

NOTE:
PUBLIC FEEDBACK INDICATES SOME RELUCTANCE OR HESITANCE TOWARD PUMPING. IMPACT DUE TO OPERATIONAL STATUS DURING POWER FAILURE(S).

P:\15-326 UPLANDS COMBINED SEWER SEPARATION PROJECT PRE-DESIGN\(10) DRAWINGS\SK.3.DWG 1/6/2016 8:31 AM SK.3

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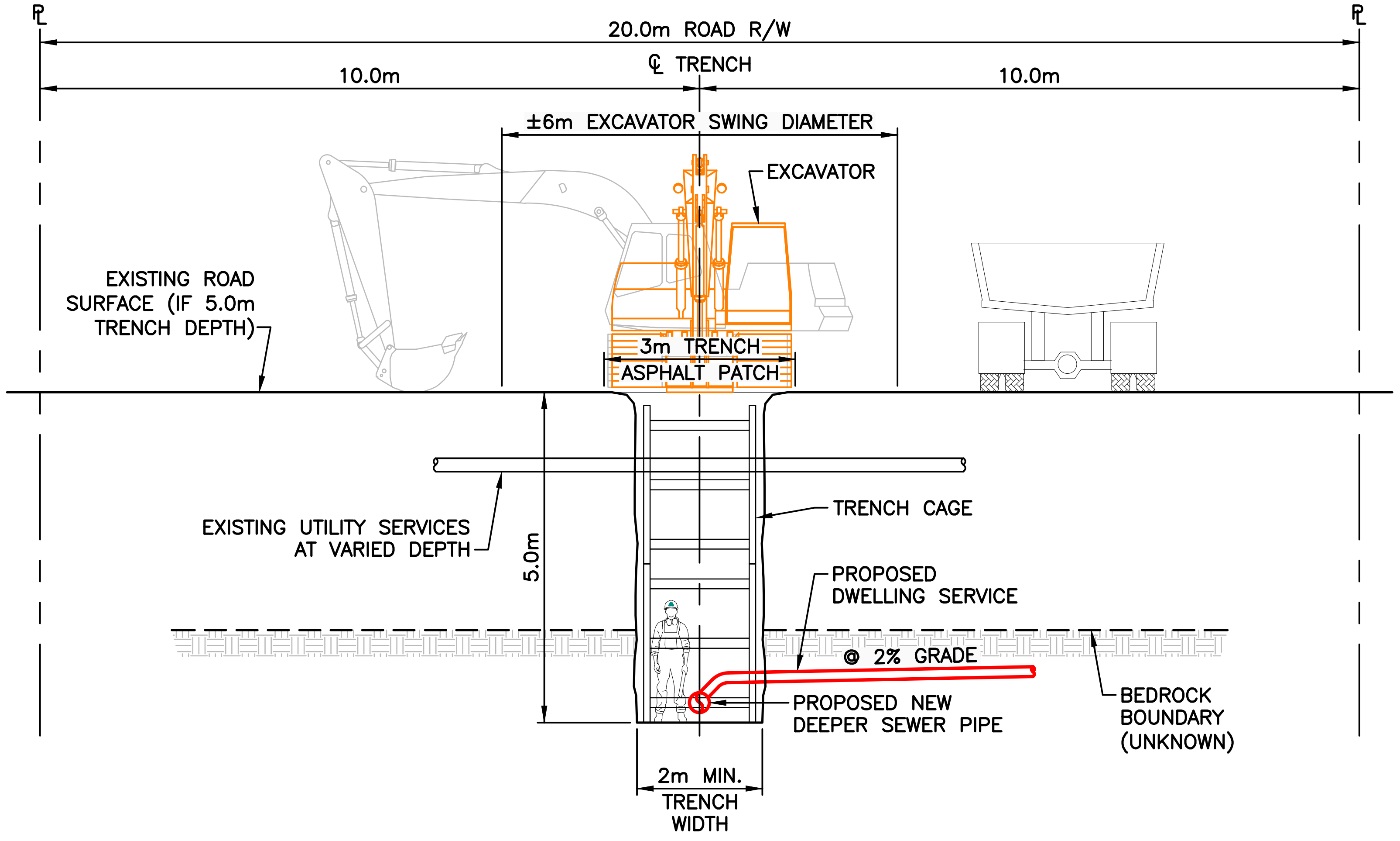
OPTION OF GRAVITY SERVICE TO UPPER FLOOR & PUMP BASEMENT AS OPPOSED TO PUMPING ENTIRE DWELLING

SCALE:	N.T.S.
DRAWN BY:	MTK
DATE:	2016–01–06
DRAWING No:	15–326–SK.3

SK 5: 5 Metre Deep Gravity Sewer Trench Detail



NOTES:
1. TRENCH CAGE(S) ASSUMED.
2. 5.0m MAXIMUM DEPTH BY MODERATELY SIZED EXCAVATION EQUIPMENT.
3. UTILITY CONFLICTS WILL OCCUR. SOME RECONSTRUCTION/REPAIR OF OTHER UTILITIES WILL BE REQUIRED.
4. ONE FULL LANE WILL BE RECONSTRUCTED/REPAIRED (½ OF THE ROAD).
5. BOULEVARDS WILL REMAIN INTACT, FOR THE MOST PART.

1:100 0 2 6m

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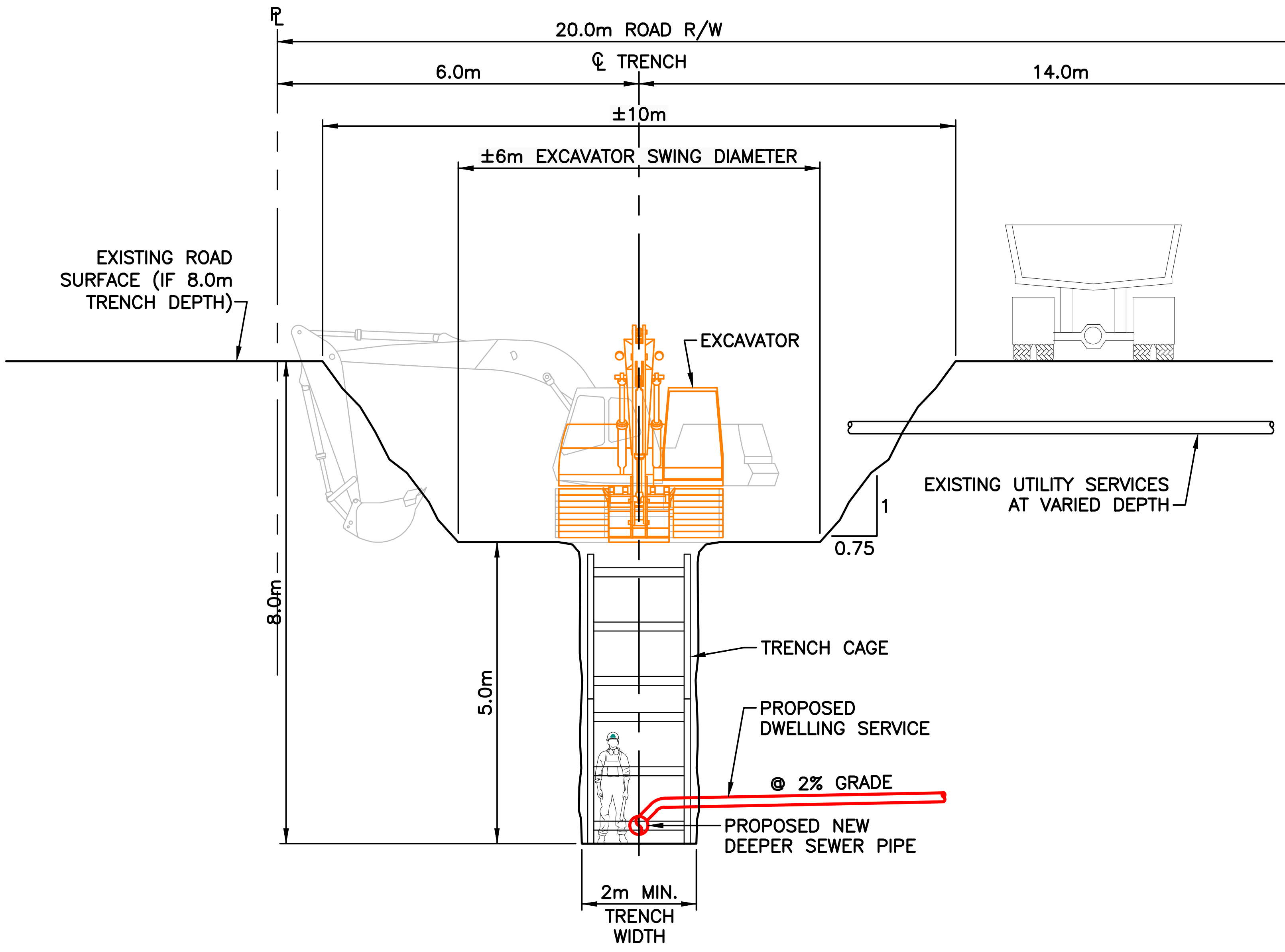
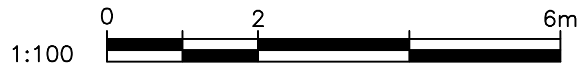
TYPICAL 5m DEEP GRAVITY SEWER TRENCH DETAIL

SCALE:	1:100
DRAWN BY:	PL/MTK
DATE:	2016-02-01
DRAWING No:	15-326-SK.5



NOTES:

1. AT 8m DEPTH, EXCAVATOR MAY NOT BE ABLE TO REACH DUMP TRUCK FOR SPOIL DISPOSAL.
2. PROBABILITY OF TREES & MATURE BOULEVARD VEGETATION DISRUPTION IS HIGH.
3. ENTIRE ROAD RECONSTRUCTION IS LIKELY FOR VERY DEEP SEWERS (>5M DEPTH).
4. WOULD NEED TO SUPPORT OR TEMPORARILY RE–ROUTE/RECONSTRUCT EXISTING UTILITIES & SERVICE CONNECTIONS.
5. TRENCH WILL NEED TO BE OFFSET ±6m FROM ROAD ℄, IN ORDER TO ALLOW ROOM FOR TRUCKS, ETC. WITHIN 20m ROAD R/W.



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TYPICAL 8m DEEP GRAVITY SEWER TRENCH DETAIL

SCALE: 1:100
DRAWN BY: PL/MTK
DATE: 2016–02–01
DRAWING No: 15–326–SK.6

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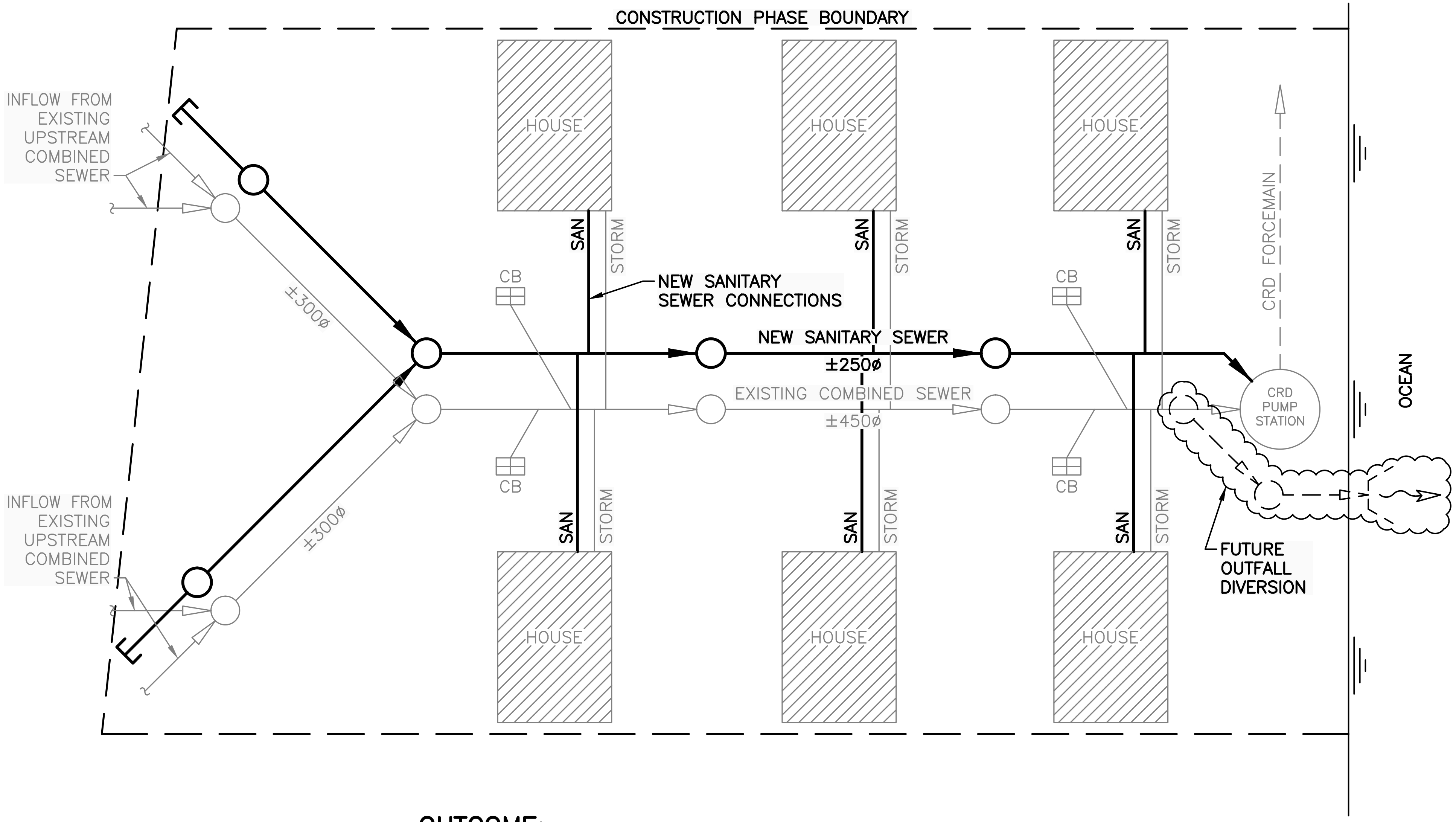
SK1: Schematic Flow Routing if New Sanitary Sewer System



OUTCOME:

1. EXISTING COMBINED 450ø TO REMAIN IN SERVICE (NEW 250ø IS TOO SMALL).
2. NO REDUCTION IN FLOW TO CRD PUMP STATION UNTIL EXISTING CAN BE DIVERTED TO OCEAN OUTFALL. AT THAT TIME = FULL STORMWATER REDUCTION FROM CRD PUMP STATION.
3. FUTURE DIVERSION OUTFALL CANNOT OCCUR UNTIL ALL SANITARY SEWER (FROM SUBSEQUENT PHASES), IN THIS SUBCATCHMENT IS EXTRACTED FROM THE EXISTING SYSTEM.
4. SHORT TERM – LESS IMPACT ON C.S.O. REDUCTION. LONG TERM – GREATER IMPACT.

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SCHEMATIC "PHASE #1" SCOPE
OPTION 1 – NEW SANITARY SEWER

SCALE: N.T.S.
DRAWN BY: MTK
DATE: NOVEMBER 2015
DRAWING No: 15–326–SK.1

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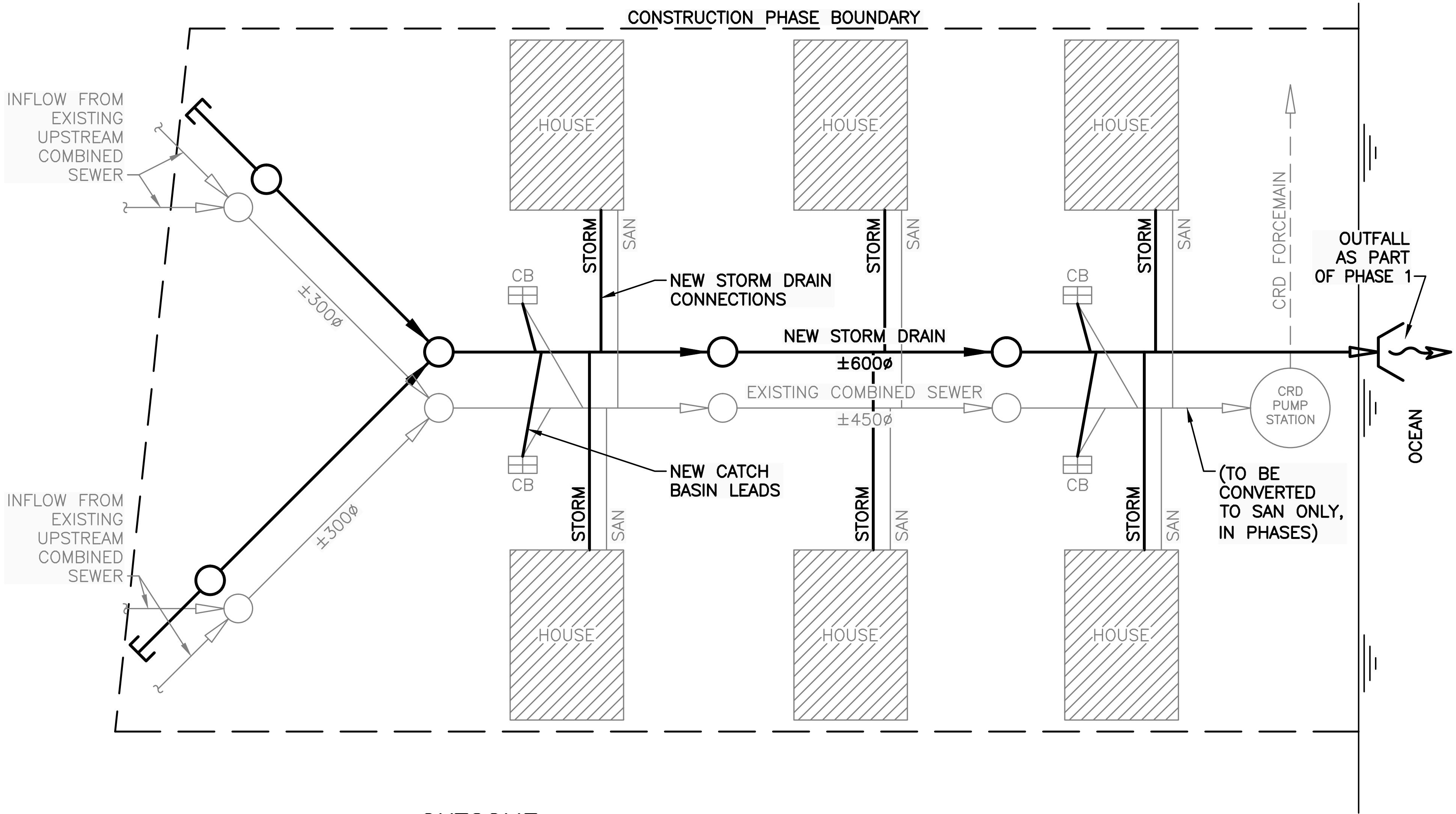
SK2: Schematic Flow Routing if New Storm Drainage System



OUTCOME:

1. FOR THIS SUB-CATCHMENT, THE VOLUME OF STORMWATER ENTERING THE CRD PUP STATION WILL BE REDUCED AT TIME OF PHASE 1 CONSTRUCTION.
2. GROUNDWATER FLOW FROM PHASE 1 SUBCATCHMENT WILL CONTINUE TO REACH CRD PUMP STATION UNTIL LINING/REHAB OF EXISTING PIPES IS COMPLETE.
3. SURFACE RUNOFF WILL BE DIVERTED AWAY FROM CRD PUMP STATION, FROM THIS SUBCATCHMENT.
4. SHORT TERM – GREATER IMPACT ON C.S.O. REDUCTION. LONG TERM – LESS IMPACT.

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SCHEMATIC "PHASE #1" SCOPE
OPTION 2 – NEW STORM DRAIN

SCALE: N.T.S.
DRAWN BY: MTK
DATE: NOVEMBER 2015
DRAWING No: 15–326–SK.2

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These uncertainties led to an interim recommendation that a more detailed geotechnical investigation be undertaken, before a preferred servicing option was selected.

In particular, it was thought imperative, before a sewer separation network option was decided upon by the District, that the probability of encountering bedrock at the proposed depths of new sewers be better established. This work was undertaken during mid-2016 by WSP, a consulting geotechnical engineering firm.

Outcomes of the more detailed geotechnical investigation report, dated July 2016, have been incorporated into this final options assessment report.

The reuse of pipe trench excavated material requires careful consideration at the detailed design stage, with significant input from the District's consulting geotechnical engineers required during construction. We would envision a series of typical cross sections that will guide the installation contractor in the means of maximizing the reuse of existing trench excavation material, while achieving good long-term performance, with issues of trench settlement and groundwater migration being properly attended to.

We can foresee this might be confined to the lower sections of trenches, with import fill placed as the last upper metre of backfill, for example. We expect that scheduling of construction in better weather will greatly impact this potential for existing material reuse. Temporary staging and stockpile areas would need to be identified.

Drilling and blasting will be required where rock is encountered. This will be more extensive and disruptive with the deeper pipe options.

Certainty regarding the overall project cost remains higher for the shallower pipe network options.

3.2. Updated Cost Estimates

The following aspects of the initial estimates were re-evaluated, based on public feedback and via input from the District's technical staff through early 2016.

- Reworked the cost estimates based on improved geotechnical understanding:
  - Incorporated the 'green, orange, and red' zones of differing rock probability, per the WSP report. Utilized the upper bounds of rock probability at differing depths, in an effort toward conservatism at this preliminary design stage.
    - Previous estimates were based on the notion of either rock, or no rock, with an allowance added to the cost estimates.
    - Latest estimates are based on three geographic zones of differing rock probabilities, i.e., now as three differing groupings of probability of encountering rock.

- We confirmed with Western Grater, a local drilling and blasting specialty contractor, that trench rock costs in the range of $100 to $200 per cubic metre are realistic.
- The geotechnical report, quite appropriately, cites relatively broad potential ranges in terms of depths and probability of encountering rock. WSP describes the expected erratic nature of sub-surface rock formations. It is expected that more test drilling will be undertaken as a function of detailed design, along some specific, critical trunk main alignments.
- In our interpretation and cost estimating application of this geotechnical work, we have erred on the conservative side of the rock probability ranges cited by WSP.
- Assumptions are as shown on the attached sketch overleaf, entitled Sk7.

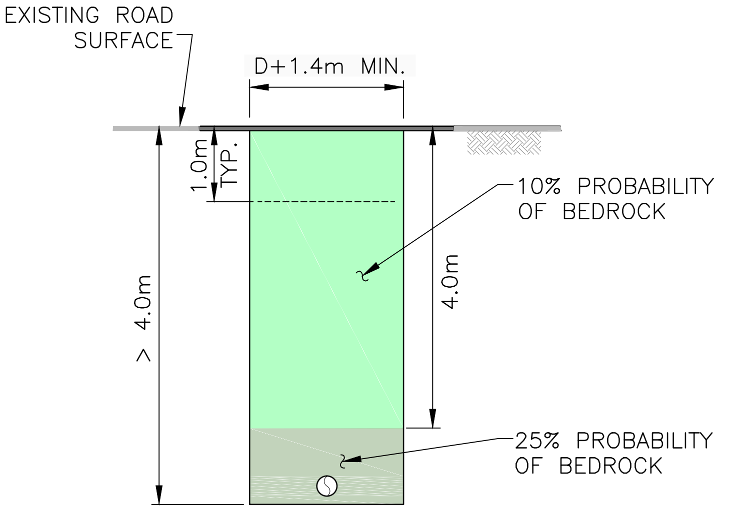
- Reworked the costs estimates based on the total number of pumps, following technical memorandum #2 and subsequent to the public engagement sessions, including refinements undertaken in January 2016, as part of the Option 7 profiles exercise.
  - Reduced the number of pumps for most options. The following tables provide a summary of this effort.

Table 1: Updated Number of Pumps, by Option

BOTH CATCHMENTS COMBINED	Services requiring a pumped connection		Gravity services possible		Total number of services	
	Was	Now	Was	Now	Was	Now
Option 1	85	66	308	325	393	391
Option 2	85	61	308	330	393	391
Option 3	393	391	0	0	393	391
Option 4	179	180	214	204	393	391
Option 5	191	170	202	221	393	391
Option 6	149	152	244	239	393	391

- Reworked the cost estimates for private service connections:
  - Deep versus shallow service depths—increased costs expected for services, based on public feedback and further site reconnaissance.
  - Long and short services are differentiated between now.

SK 7: Interpretation and Application of WSP Geotechnical Investigation

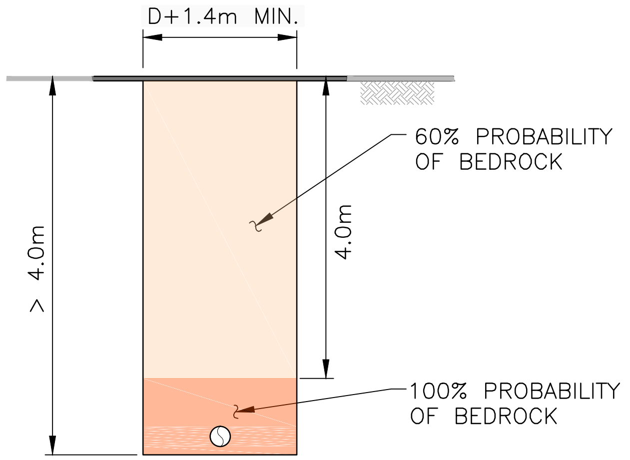


"GREEN" SECTION

1:100

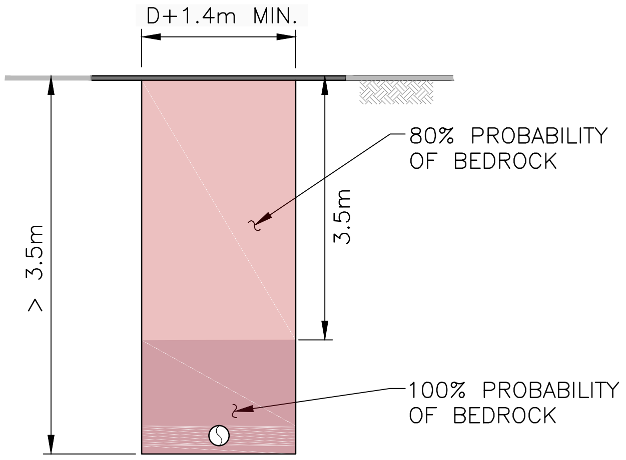
NOTES:

1. MCSL PROBABILITY PERCENTAGES WERE APPLIED BASED ON HIGH SIDE OF WSP GEOTECHNICAL REPORT RANGES.
2. MINIMUM 10% PROBABILITY OF BEDROCK APPLIED DUE TO "ERRATICS" AND INVESTIGATION METHODOLOGY, IE. SPARSE TEST HOLES.
3. TRENCH WIDTH WILL VARY DEPENDANT ON NATIVE MATERIALS ENCOUNTERED.



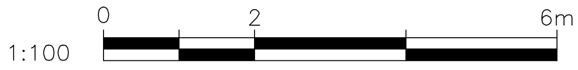
"ORANGE" SECTION

1:100



"RED" SECTION

1:100



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INTERPRETATION AND APPLICATION
OF WSP GEOTECHNICAL REPORT
RESULTS – AUGUST 2016

SCALE: 1:100
DRAWN BY: PL
DATE: 2016.08.30
DRAWING No: SK.7

  - Number of low side and high side services that will be at least partially into bedrock—significant additional cost allowances were added to reflect this.
  - Surface improvement damage and need for restoration within private properties is expected to cost more than previously anticipated, based on public feedback. This is amplified in the case of dwellings proposed to be serviced via deep gravity pipes, due to the size of required trenches.
- Reworked the costs as estimated for trench spoil material reuse versus need for import fill.
  - Per WSP report Section 6.3, there may be savings to be gained here at the time of detailed design. We may have erred on the side of conservatism. Further effort by the geotechnical engineers at the time of detailed design and during the construction phase could save the District considerable costs, if existing spoil material can be effectively reused.
  - We have assumed some trench rock will be reusable as trench backfill, assuming:
    - Suitable handling and design for resistance to unwanted groundwater migration through the trench
    - Fines migration within the trench that could lead to settlement
    - Appropriate weather during construction
    - Appropriate material moisture conditions, etc.

We have added between $100 and $150 per lineal metre to reflect the assumption that roughly half of the trench material will need to be hauled off site, in the interests of conservatism at this stage.

Table 2: Comparison of Costs Per Metre (net of rock removal allowances)

		Cost/m per Tech Memo 2 – Nov. 2015 $	Cost/m per August 2016 report update $
150mm to 200 mm dia	0 to 2 metres depth	450	550
	2 to 3 metres depth	575	700
	3 to 5 metres depth	950	1,100
250mm to 300 mm dia	0 to 2 metres depth	500	600
	2 to 3 metres depth	625	750
	3 to 5 metres depth	1,000	1,150
375mm to 450 mm dia	0 to 2 metres depth	600	700
	2 to 3 metres depth	750	875

		Cost/m per Tech Memo 2 – Nov. 2015 $	Cost/m per August 2016 report update $
	3 to 5 metres depth	1,150	1,300
525mm to 600 mm dia	0 to 2 metres depth	775	875
	2 to 3 metres depth	950	1,075
	3 to 5 metres depth	1,350	1,500

Cost estimates for rock excavation have increased substantially. For example, under Option 1, if we compare the technical memorandum #2 total costs for breakout category 1, 'gravity mains', the total increase of $4.1 million comprises approximately $1.3 million for installed price increases (due to increased import fill allowances, etc.) and $2.8 million due to additional rock allowances.

Similarly, we increased the expected average costs of deeper gravity connections disproportionality, (more than the cost increase applied for shallow gravity services) to reflect the cost of rock excavation, per the attached breakout estimates.

See Appendix E for a more detailed description of the cost estimating update process and the underlying assumptions.

The following are updated overall costing tables, now reflecting the updated costs as derived above. (Detailed unit price breakout cost estimates for each of the options are provided as Appendix C.)

Table 3: Capital and Annual Operation and Maintenance Costs Including Contingencies

Option No.	Capital cost			Average Annual Operation and Maintenance Costs			Aggregate 50-year duration net present value
	Totals	To the municipality	To the private landowners	Totals	To the municipality	To the private landowners	
	$Millions			$1,000s			$Millions
1	30.9	24.3	6.6	78	65	13	35.9
2	31.9	25.1	6.7	77	64	13	36.8
3	14.2	7.2	7.0	110	9	101	21.3
4	21.5	15.1	6.4	91	46	45	27.4
5	21.4	15.0	6.4	89	48	41	27.2
6	23.4	16.9	6.5	90	54	36	29.2

Costs for a higher number of deeper gravity connections in Option 2 is offset by the need for more private pumps in Option 4, leading to an overall cost to the private landowners being very similar under both options.

Table 4: Total Capital Cost Including Contingencies (Per Residential Unit)

Option No.	Total Capital Cost (per residential unit, including 50% contingencies)			
	To the Private Landowners ($1,000s)			
	Costs to Landowners with new pumps		Costs to Landowners without new pumps	
	High	Low	High (deep and long)	Low (shallow and short)
1	20	17	38	14
2	20	17	38	14
3	20	17	n/a	n/a
4	20	17	38	14
5	20	17	38	14
6	20	17	38	14

Costs to land owners in the above table are based on professional, pre-design phase judgement. They are not based on individual private property site assessments or designs. Costs to land owners include allowance for site restoration.

3.3. Options Analysis & Comparison

3.3.1 Advantages and Disadvantages Assessment

Overleaf is a tabulated summary of the relative advantages and detractions of the differing options, *Table 5*.

In summary, the deeper gravity options (Options 1 and 2) afford the opportunity for fewer private pumps, but at much higher overall project capital cost. Risks associated with bedrock encounter are increased with these deeper options. Costs to many residents will also be high for the deeper gravity sewer options, where pumping may prove to be less costly than a deep gravity connection.

Shallower sewer system options (Options 3, 4, 5, and 6) will be much less costly to the District to construct, but will require more private pumps. Shallower pipe systems will pose less risk to existing trees, and represent less disruption of private properties due to construction of service connections.

A new sanitary system (Options 1, 3, 5, and 6) will, when finally constructed and with all private reconnections confirmed, yield lowest overall flows to the CRD pumping stations because of the most effective reduction in the I&I with a new pipe. Lining of the existing system, under Options 2 and 4, will mitigate this, to an extent. However, new sanitary systems will not allow any CSO reductions at the Humber outfall until the last residenroce has separated its service connections and connected to the new sanitary sewer. Similarly, for the Rutland catchment. With a new sanitary system, 100% of the properties must be connected before any CSO reductions take place.

A new storm drain system will allow for immediate reductions in CSOs, as the system is constructed in phases. Thus, a new storm drainage system is the preferred solution from an environmental perspective. A new storm drain system will also allow pipes sized to accommodate higher flows anticipated as a result of climate change. Expected capital costs to private property owners, on average, do not differ considerably between the options. Option 3 represents higher ongoing O&M costs to private property owners.

3.3.2 Decision Criteria

Relevant social, environmental and financial considerations were evaluated, in comparing the options. Individual criteria were established, based on knowledge of past projects, outcome of the public engagement process, and analysis of the advantages and disadvantages applicable to the different options.

Table 5: Advantages and Disadvantages Assessment

	Options	Relative Advantages	Relative Disadvantages
1	NEW DEEPER GRAVITY SANITARY SEWER (EXISTING SYSTEM FOR STORMWATER) - MINIMIZE PRIVATE PUMPING SYSTEMS	New system will be 'tight' with very little stormwater leakage into it. New san system will be 'right sized' for lower sanitary sewer flows. If the system is built as one construction phase, then the reduction in overall stormwater volume to be pumped, over time, at the CRD stations, would be less under this option, than options involving new stormwater systems. Takes advantage of larger existing pipes within easements and rights of way over private properties, for conveyance of stormwater, representing much larger peak flow rates per unit area than does sanitary sewer flows. Less private pumps that the shallower gravity options 5 and 6.	Until the whole system is built [and all services are re-connected] , no flow diversion is possible from the combined system, away from the CRD pump stations. Assuming we are building the lower sections first, working upstream, in phases, either we would need to build oversized san sewers in the lower portions, [to convey diverted upstream portion of combined system], or allow the combined system to continue to drain to the CRD stations, as well as the new pipe. Depending on final phasing decisions, and funding availability, overall volumes to be pumped at the CRD stations will be higher with this option, until the system is completed in full, noting the need to continue to divert combined flows to CRD stations. Deep sewer options will required that the combined sewer is cut and replaced at points of service reconnection crossings - thus adding to the overall project cost. [Options 1 and 2]. Along the low side of the roadway, gravity service reconnections to deeper mains, intended to avoid provide pumping, may be quite disruptive and costly on private properties. Pumping may ultimately be decided in some cases as preferred and the benefit of extra cost of deep mains therefore lost. Higher financial risk, due to bedrock and trench spoil costs. Deep sewers will encounter bedrock. The potential for excavated material from trenches, for re-use as backfill is not yet established.
2	NEW DEEPER GRAVITY STORMWATER SYSTEM (EXISTING SYSTEM FOR SANITARY SEWER) - MINIMIZE PRIVATE PUMPING SYSTEMS	The new storm system would divert drainage from roadway areas and some private properties, as the system is built in phases, thus reducing the overall combined flows reaching the CRD stations [& resultant reduction in periodic CSOs] more significantly than option 1, as the system is built, in phases. Stormwater surface runoff reductions to the CRD pumping stations would be achieved more quickly, in a phased construction program. New storm mains could be built to accommodate shortfalls in long term Q10 capacity, due to climate change. Somewhat less likely that dwelling occupants will inadvertently direct sanitary sewage to the new storm connection provided, as compared to option 1, 3, 5 and 6, where inadvertent stormwater/groundwater could be directed to the new sanitary sewer.	Oversized sanitary system would result, if using combined sewers for this purpose. Periodic flushing frequency and increased O&M costs will be more likely. Odor and solids accumulation might occur in flat grades, larger diameter, re-purposed combined sewers. I & I issues would need to be attended to for leaky, existing system rehab / lining. Requires larger new pipe system. Higher capital cost than Option 1. All catch basins have to be reconnected. Along the low side of the roadway, gravity service reconnections to deeper mains, intended to avoid provide pumping, may be quite disruptive and costly on private properties. Higher financial risk, due to bedrock and trench spoil disposal issues. Deep sewers will encounter bedrock. The potential for excavated material from trenches, for re-use as backfill is not yet established. Unless the existing system is rehabilitated, more I&I flow will be directed to the CRD pumping stations than would for Option 1, upon project completion.
3	LOW PRESSURE MUNICIPAL SYSTEM FOR SANITARY SEWER WITH 100% PRIVATE PUMPING SYSTEMS (EXISTING SYSTEM FOR STORMWATER)	Least cost to the District initially. Shallow trenches. Smaller diameter mains. Likely will be constructed more quickly than deeper gravity sewers, less public disruption due to the installation works out on the roadways. Least disruption of existing roads / boulevard and landscaping. Ease of service reconnection routing and depth, within private properties.	Most costly to private owners, overall, initially, and in ongoing operating costs, long term. All existing dwellings that do not require on-site private pumping now would need to be fitted with pumps. Dwellings with existing pumps may need to replace these with higher head [pressure] units. During power failure, dwelling occupants will need back-up owner or will need to be mindful of pumping chamber capacity limitation. This option does not lend it self as readily to construction in phases. It will require that a large proportion of re-connections occur early on in the process, such that flushing velocities in the mains are achieved and that duration in the system prior to discharge to the CRD pumping station is not excessive. Similar to other new sewer options, all combined sewage will need to be directed to CRD system until this option 3 pipe network is constructed in full and all residences are connected to it. Failure of mechanical or electrical equipment could give rise to flooding or sewage overflows on private properties.

4	Hybrid - SHALLOW GRAVITY STORM MAINS, WITH SOME MUNICIPALLY OWNED PUMPING STATIONS AND SOME PRIVATE PUMPING SYSTEMS AS NEEDED. MORE STORMWATER PUMPS THAN OPTION 2. (EXISTING SYSTEM FOR SANITARY SEWER)	The new storm system would divert drainage from roadway areas and some private properties, as the system is built in phases, thus reducing the overall combined flows reaching the CRD stations [& resultant reduction in periodic CSOs] more significantly than option 1, as the system is built, in phases. Stormwater surface runoff reductions to the CRD pumping stations would be achieved more quickly, in a phased construction program. New storm mains could be built to accommodate shortfalls in long term Q10 capacity, due to climate change. Somewhat less likely that dwelling occupants will inadvertently direct sanitary sewage to the new storm connection provided, as compared to option 1, 3, 5 and 6, where inadvertent stormwater/groundwater could be directed to the new sanitary sewer. Lower capital cost than Option 2.	Would need to pump road runoff drainage from catch basins from two smaller sub-catchments, via municipally owned pumping stations. Same detractions as Option 2, including the accelerated need for rehabilitation, lining or pipe bursting of the existing combined system, so as to reduce stormwater component of flow in the re-purposed pipe network. Storm water road runoff is heavily grit laden, resulting in higher pumping equipment maintenance. Power outages occur generally during storm events, backup power supply would add costs at two municipally owned pumping stations, else, Q100 piped route is needed in these sub-catchments. Pumping stormwater from dwelling sites could necessitate back-up power generators in order to avoid nuisance flooding of lower floors/habituated areas, during power outages; groundwater may enter lower occupied areas. Less opportunity for gravity overflow to the street than with deeper municipal pipes, under Option 2. More pumps than Option 2.
5	Hybrid - SHALLOW GRAVITY SANITARY AND SOME PRIVATE PUMPED SYSTEMS, WITH LOCALIZED AREA OF MUNICIPALLY OWNED PRESSURES SEWERS. MORE SEWER PUMPS THAN OPTION 1. (EXISTING SYSTEM FOR STORMWATER)	Many of the same benefits as Option 1, but shallower trenches and more pumps. Lower overall capital costs than Option 1. Maximizes gravity system advantages at lesser capital cost to the District. Lower operation and maintenance costs, energy costs, than a pure pumping option. During power outages, pumped sanitary flows could be less problematic than pumped stormwater flows, without backup power provision. Shallow depth, gravity fed, service connections will be possible for many residents.	Many of the same detractions as Option 1, related to separation of flows, incrementally, as the system is built in phases, with no CSO reduction possible until completion of the project. Requires more dwellings to pump that the deeper Option 1 and a few more than Option 6. Backup power requirement may exist? This is true of all options involving pumping, and thus, the issue is magnified, as more pumps are required, potentially. Common to all new sewer Options, 1, 3, 5, and 6, the District will need to be vigilant in ensuring that only sanitary sewage is directed from within private properties to the new system, and not a combination of sewage and some storm water.
6	Hybrid - COMBINATION OF LOW PRESSURE PUMPED SANITARY SYSTEM AND SHALLOW GRAVITY SANITARY SYSTEM - LARGER AREAS TRIBUTARY TO MUNICIPALLY OWNED PUMPING STATIONS AND LESS PRIVATE PUMPS THAN OPTION 5, BUT MORE THAN OPTION 1. (EXISTING SYSTEM FOR STORMWATER)	Less private pumped systems that for Option 5, otherwise same as Option 5.	Same detractions as Option 5, and: Higher initial capital costs and ongoing operating costs to the District than Option 5, due to additional municipally owned, pumping stations proposed here. Future housing redevelopment may require more pumps, if the new [future] on-site development plans call for deeper services than existing [this is true of all shallow Options, 3, 4, 5, and 6]. More dwellings on the high side of the road receive different level of service from those situated along the low side of the roadway, typically, than the deeper gravity sewer option. This is true of all shallow gravity Options, 4, 5 and 6. [but less so with Option 6].

In the following sections, the six options are evaluated from a triple bottom line perspective, namely, Environmental, Social and Financial.

ENVIRONMENTAL CRITERIA

1. Most environmentally appropriate use of the existing pipe

Assuming that the existing pipe network will be lined, over time, on a phased priority basis, utilizing the existing system as a sanitary sewer provides the highest environmental benefit, because progress towards compliance with the MWR, specifically elimination of CSO, will be achieved with gradual reductions in the frequency and extent of combined sewer overflows to the ocean.

Lining of the existing pipes will reduce infiltration and inflow within that system, thereby allowing for overall annual flow reductions toward the CRD pumping stations, over time.

The District will need to ensure, as part of the project construction phase scope, that private connections are not 'crossed' in order to maximize the environmental benefits of the project.

A new storm drainage network can be sized to suit longer term expected peak runoff rates resulting due to climate change.

Preferred Option(s): 2 and 4

2. Progressively reduce the frequency and duration of combined sewer overflows

To progressively reduce the frequency and duration of CSO new storm drainage network, is preferred. This criterion is closely tied to the preceding criterion. Compliance with the MWR will be achieved sooner. A total of 91 homes in the Uplands already have separated services

Preferred Option(s): 2 and 4

3. Construction timeframe

Least cost options are favoured, given funding availability and competition for funding from other District infrastructure capital projects. Option 3 represents least capital cost to the District. However, in order for Option 3 to function acceptably, all reconnections must occur at the time of system construction. This implies a change to the existing council resolution.

Preferred Option(s): 3

4. Preserve the mature tree canopy and mature vegetation

Shallow pipe network options are favoured as shallow trenches are less disruptive. Routing that does not destroy mature vegetation on private lands also leads to preference for shallower pipe network options.

Preferred Option(s): 3, 4, 5 and 6

5. Climate change impacts

Storm intensities are predicted to increase in future with resulting potential for shortfalls in storm drainage system capacity. Modelling indicated the potential for surcharging of the existing system in some locations using current design criteria. Repurposing the existing pipes as a storm drainage network heightens this risk. This results in a preference for a new storm pipe.

Preferred Option(s): 2 and 4

SOCIAL CRITERIA

1. Affordability and Fairness

Through the public engagement process we learned that the most important project considerations for residents living throughout Oak Bay were affordability and fairness. These were reflected during the public engagement from two very different perspectives, however.

Many Uplands residents impacted by the project felt that gravity service should be maintained as a priority for the District and that costs related to necessary work on their properties should be minimized.

For property owners living in neighbourhoods outside of the Uplands, minimizing capital costs to the District was the most important consideration recognizing that capital costs for this project would be borne by all Oak Bay residents. Reconciling these disparate desires and viewpoints is an underlying responsibility for Council. Finding a solution that everyone can live with is the goal.

2. Maximize potential for gravity service to private properties and minimize the number of pumps

Uplands residents expressed a preference for gravity service to minimize the number of pumps. Maximizing the potential for gravity service will also minimize the need for pumps, both privately owned and public/municipally owned leading to a preference for deeper gravity sewer options. Given the public concern with private pumps, deeper options are preferred.

Preferred Option(s): 1 and 2.

3. Minimize disruption on private property

The shallower options and pumped options will minimize the disruption on private property. For example, construction of a pumped connection using direction drilling will result in minimal disruption both for duration of construction and effect on the landscape.

Preferred Option(s): 3, 4, 5 and 6

4. Minimize neighbourhood disruption

The duration of disruption during each construction contract will be a factor of the depth of trenches and the presence of rock. The greater the trench depth and amount of rock the longer the construction timeframe. Shallower options are preferred.

Preferred Option(s): 3, 4, 5 and 6

5. Deep private gravity connections versus pumped connections

Uplands residents expressed a preference for gravity service to minimize the need for pumps. However, in areas where rock is present the high cost to property owners of a deep gravity connection may lead to a preference for a pumped service connection. Residents living outside the Uplands area favoured pumped connections (least cost to the District).

Preferred Option(s): 3, 4, 5 and 6

FINANCIAL CRITERIA

1. Geotechnical considerations

Geotechnical investigations indicate three groupings of areas of the Uplands in which differing probabilities of encountering rock are noted. Also note was the irregular profile of the rock surface, increasing the uncertainty surrounding encountering rock. Cost estimates now reflect an increasing cost per cubic metre of rock to be removed, incrementally with increasing depth of expected rock encounter. The quantity of reusable material will also affect project costs. The greater quantity of reusable trench material will reduce costs as less material will have to be disposed off site and less backfill material imported. Geotechnical considerations lead to a preference for shallower options.

Preferred Options 3, 4, 5 and 6

2. Operation, Maintenance and lifecycle costs to the District

These costs will be higher for options with pumping systems that are owned and operated by the District will be higher. (Options 4 and 6).

Overall O&M costs are expected to be slightly higher if the District repurposes the existing combined sewer network as a sanitary sewer system, as some of the pipes would be larger than needed. Periodic flushing may be required or additional capital upgrading may be required, possibly installing smaller pipes inside the older, larger ones.

Preferred Option(s): 3

3. Deep versus shallow pipe alignments

Deep sewers will reduce the number of private pumps, but will increase the cost of construction because of the deeper trenches and greater rock excavation as depth increases, both to be incurred by the District and the private property owners.

Potential for utility conflicts with proposed gravity mains will need to be assessed at the time of detailed design. To avoid conflicts deeper trenches may be necessary at increased costs. The risk of conflict is greater with the shallow gravity options.

Preferred Option(s): 3, 4, 5 and 6

4. Capital costs to the District

The option with the least capital cost to the District is Option 3 followed by options with shallow gravity sewers (Options 4, 5, and 6). The highest cost to the District are for the deep gravity options (Options 1 and 2). Capital costs are slightly higher for new gravity storm network than for gravity sanitary, as the new storm pipes would be larger to convey higher peak design flows.

Preferred Option(s): Option 3

5. Capital costs to Uplands property owners

The cost to property owners depends on the type of service connection, with short shallow connections the least expensive and long, deep connections the most expensive. For pumped service connections the difference between short and long connections is relatively small.

6. Maintenance and lifecycle costs to Uplands property owners

The lowest average O&M costs to property owners is expected under deep gravity sewer Options 1 and 2. The highest annual aggregate operating costs to private owners is expected under Option 3. Shallow gravity Options 4, 5, and 6 will give rise to private owner operating costs, on average, roughly double that of Options 1 and 2, but still much lower than Option 3 because of the differing number of pumps.

Both sanitary and storm pumps will require maintenance and parts replacement over time. Gravity connections and a gravity conveyance system will yield longer service life with less operation and maintenance.

Pumping systems consume hydro power. This is both a cost consideration and one of environmental sustainability.

Preferred Option(s): 1 and 2

3.3.3 Decision Matrix / Balanced Scorecard

The decision criteria described above were grouped into social, environmental and capital cost categories. Relative rankings of the different options were established for each of these decision criteria, based on a scale of zero to two points.

Zero points reflects the least favourable ranking and two points were assigned to the most favourable option(s), under each criterion. The matrix is intended to represent a 'balanced scorecard' approach to comparison of the options. However, the scoring is somewhat subjective. This scorecard aids in the decision making process, but is not the sole determinant.

The outcome of this evaluation is provided in the following table:

Table 6: Decision Matrix / Balanced Scorecard Evaluation

	DECISION CRITERIA	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Notes / Data Source
Social & Environmental Criteria	Most environmentally appropriate use of the existing pipe, that is, should the existing pipe carry sanitary sewage or stormwater. *	○	●	○	●	○	○	A new sanitary sewer network would not be leaky. A new storm network will allow reductions in CSOs on a phased, incremental basis, which is an environmentally superior outcome.
	Progressively reduce the frequency and duration of overflows.	○	●	○	●	○	○	Conclusion that a new phased sanitary sewer system will not allow diversions of stormwater from the existing system until the new system is constructed in full and all private property reconnections are confirmed to be functional.
	Timeframe to completion of the project, based on a phased construction program.	○	○	◑	◑	◑	◑	Assuming the project is competed in phases and overall project capital cost will be a key determiner with respect to total project construction duration. Under Option #3, hookup would be mandatory at time of system construction.
	Preserve the mature tree canopy.	○	○	●	●	●	●	Assumes new shallower pipe systems will be more effectively maintained within alignments under existing pavement areas. Trees over private properties will be least impacted by shallow pressure sewer services. Easements will not be disrupted.
	Minimize disruption on private property.	○	○	◑	◑	◑	◑	Presumption is that pumping systems are disruptive, as is the need for very deep service connections over private properties, and that pumped services will be easier to install than will gravity services, generally speaking.
	Maximize opportunity for gravity service to residents and minimize the number of pumps.	●	●	○	◑	◑	◑	Deeper sewers provide the opportunity to maximize gravity service and minimize the number of pumps.
Project Cost Criteria	Capital costs to Uplands property owners.	◑	◑	◑	◑	◑	◑	Updated Cost Estimates, September, 2016.
	Capital costs to the District.	○	○	●	◑	◑	◑	Updated Cost Estimates, September, 2016.
	Maintenance and lifecycle costs to Uplands property owners.	●	●	○	◑	◑	◑	Updated Cost Estimates, September, 2016.
	Maintenance and lifecycle costs to the District.	○	○	●	◑	◑	○	Updated Cost Estimates, September, 2016.
	Reduce project cost risks.	○	○	●	◑	◑	◑	Most recent geotechnical report, July 2016, by WSP. Notes probability of rock. Risk of encountering rock will increase, generally speaking, with pipe depth.
Total scores, if preferred = 2 points, least preferred = 0 points, intermediate = 1 point		**5**	**9**	**11**	**14**	**10**	**9**	

*Presumes the existing pipe is to be rehabilitated within a reasonable time frame, moving forward.

● Most Favoured ◑ ○ Least favoured

Note: In Table 6, some criteria from the preceding discussion have been combined, reflecting similar themes.

3.4. Preferred Option

Given the existing pipe will be rehabilitated over time, appropriate use of the existing pipe involves re-purposing as a sanitary sewer network. This leads away from Options 1, 3, 5 and 6.

Options 1 and 2 represent very high capital costs and the greatest cost uncertainty for the provision of this utility. These options also represent highest risk to mature trees within the Uplands and higher probability of significant disruption within private properties.

Option 3 is least favored by residents impacted by the project. Construction of Option 3 in phases is not practical, given the need for achievement of sufficient flushing velocities and the allowable duration of effluent within the system prior to discharge to the CRD pumping stations. In addition, Option 3 will not afford an opportunity for CSO reductions until the entirety of the system is constructed and all private services are re-connected.

Options 4, 5, and 6 are compromise solutions, balancing the overall capital cost and reduced upside project cost risk, with the public clear preference for avoidance of pumping systems. Of these three options:

Option 4 provides a clear advantage in allowing for a phased construction program with resulting gradual reductions in CSOs.

Option 4 scores highest based on the balanced score card approach, albeit only marginally higher than Options 3 and 5.

Option 4

The most significant benefit of a new shallow, stormwater network over that of a new shallow sanitary sewer network involves the sequential, phased reduction in CSOs afforded. Present-day system operating characteristics clearly indicate that peak flows to the two CRD pumping stations are predominantly stormwater runoff, and these peak flows presently far exceed the capacity of the stations (90 l/s each) during wet weather events.

3.5. Project Phasing Discussion

The District has indicated an intention to construct the preferred alternative as quickly as budgets will allow. We believe this will be dependent, in part, upon success in acquiring grant monies from senior levels of government.

We understand there is some $7 million in an Oak Bay account reserve for this project currently accumulated by dedicating Gas Tax revenues to the reserve. Given that the District has other infrastructure rehabilitation needs, for example, the existing combined sewer, it is suggested that a new stormwater sewer be installed in stages in the Humber catchment over the next ten years followed by the Rutland catchment over the following twenty years resulting in separate sewers in the Uplands by 2047.

Alternately, the shortest duration project construction scenario, were funding available now, would be to tender the project under the premise that multiple crews will be engaged simultaneously. We can envision a practical limit, in terms of the level of public nuisance, noise, and access disruption that can be tolerated in a given area. We suggest that a crew installing an average of 30 lineal metres of mainline pipe per day, (c/w services and manholes, etc.) over a four-month construction window, would be able to install at most, 2,500 lineal metres of sewer. Thus, it would be possible, with two concurrent installation crews, to undertake the entirety of this project over two successive years. Pursuit of project completion this rapidly is not recommended.

Funding availability aside, a more realistic approach, weighing off the efficiencies of project and construction contract scale, traffic congestion, and public nuisance, would be to expect a single contractor to install roughly 2,500 metres of pipe per year, requiring a total four years (four construction seasons).

As suggested previously, it is recommended that installation of the new storm sewer start in the smaller, Humber catchment so that compliance with the MWR at the Humber pump station will be achieved at the earliest time possible.

4. Conclusions and Recommendations

4.1. Conclusions

a. All options developed to date are technically feasible to design and construct.

b. CSO reductions – compliance with the Municipal Wastewater Regulation
   - Options 2 and 4 featuring a new stormwater sewer will yield immediate/incremental CSO reductions substantially sooner than options involving a new sanitary sewer network.
   - Options 1, 3, 5, and 6 feature a new sanitary system and disconnection of the existing system from the CRD lift stations could only occur after all (100%) dwelling services are proven to be separated.

c. Options 1 and 2 are deeper than the other options and will involve the removal of more bedrock. This adds considerable cost uncertainty, both to the District and to many private home owners, who will, in turn, need to decide if a deep gravity connection is cost effective or even feasible, given on-site improvements within their respective properties.

d. Option 3 has lowest estimated capital cost to the District and highest expected annual operation and maintenance costs to impacted home owners.

e. Options 4, 5, and 6 are comparable in total capital costs to the District and to impacted homeowners.

f. The deeper Options 1 and 2 are expected to be roughly 30% to 45% more costly to construct (private and public costs combined) than shallow gravity options 4, 5, and 6.

g. Operation and maintenance costs are higher for options involving pumping.

h. Very deep sewers (Option 7), which potentially eliminates the need for private pumping systems will be impractical to construct.

i. All options will involve at least some pumped connections.

j. Property owners in the Uplands, impacted by the project, expressed a clear preference for options that reduce the requirement for pumping from private properties and, thus, public preference was expressed for deeper gravity sewers. Detailed design phase analysis, complete with further survey and topographic detail, will yield refinements in the routing and depth of the District's proposed pipe network and in the number of dwellings that could be serviced by gravity connections (as opposed to pumping).

k. Routing / installation of deep gravity service connections could be very disruptive and very costly to some landowners within the Uplands.

l. Lining, or other rehabilitation method, is needed for the existing pipes, in a phased effort.

m. Hydro power interruptions will have differing impacts, depending on the option constructed. Pumps are a feature in all of the options. Backup power generation is recommended for stormwater pumps.

4.2. Recommendations

It is recommended that the District:

a. Implement Option 4, a shallower gravity based storm system, including two isolated areas requiring municipal stormwater pump stations.

b. Undertake design by catchment area not by construction phase;

c. Undertake construction on a phased project basis, beginning with the Humber catchment, with contract packages at a minimum of $2 million each.

d. The District should develop a plan for rehabilitation of the existing pipes.