

### **Township of Esquimalt Stormwater System Modeling**

### **Final Report**

#### **Prepared for:**

Township of Esquimalt 1229 Esquimalt Road Esquimalt, BC V9A 3P1

### Prepared by:

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### **Document History and Version Control**

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#### Introduction 1.0

The Township of Esquimalt, BC (Township) retained GeoAdvice Engineering Inc. (GeoAdvice) to develop a hydraulic model of their stormwater system. The scope of work for GeoAdvice was to develop a hydrologic and hydraulic model of the Township's stormwater system and to assess system performance under varying storm events and land use conditions. The scope of work did not include the development of system improvement recommendations.

The model was developed using InfoSWMM. InfoSWMM is a fully dynamic stormwater management modeling software package from Innovyze Inc.

The key objective of this study was to develop a preliminary model of the Township's stormwater system. Following that, performance was assessed under the following conditions:

- · Existing system under existing land use; and
- Existing system under future land use with climate change.

The stormwater system, as modeled, is presented in **Figure 1.1**.

The main components of the stormwater system model are summarized in **Table 1.1**.

Table 1.1: Model Statistics of Current System

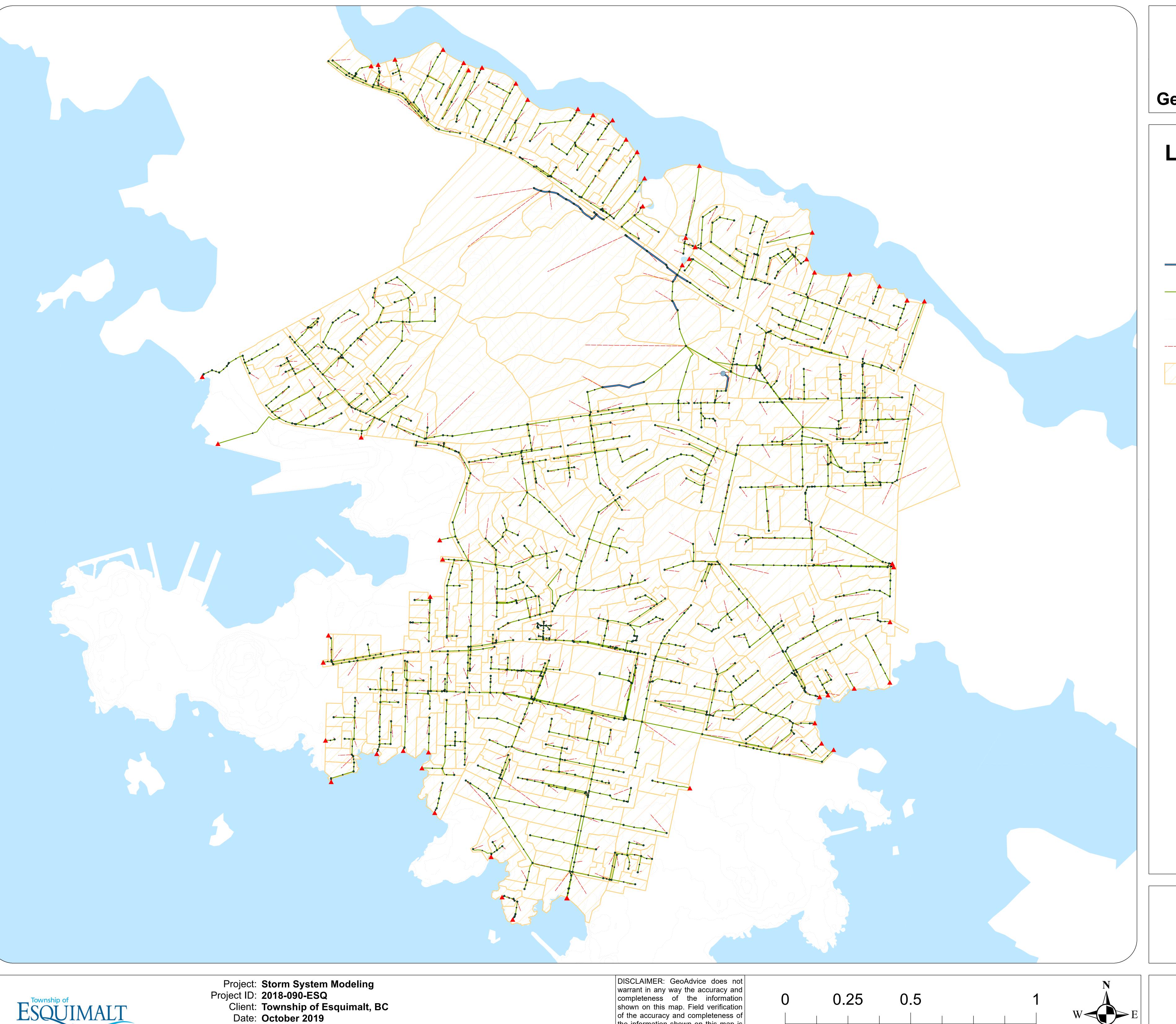
Component	Total
Study Area	542 ha
Subcatchments	557
	Ditches:
Charma Canadailea	• 20 (0.98 km)
Storm Conduits	Gravity Mains:
	• 1,126 (62.66 km)
Junctions	1,131
Outfalls	60
	Study Area Subcatchments Storm Conduits Junctions

In the preparation of this report, GeoAdvice would like to acknowledge the support of the following Township Staff:

- Mr. Brad Daly
- Mr. Jeff Miller









- **Detention Pond**
- Outfall
- Junction
- Ditch
- **Gravity Main** 
  - Contour (5 meter)
- Allocation Line
- Subcatchment

**Existing Stormwater System** Overview

Created by: **SG** Reviewed by: **WdS** 

of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

Kilometers

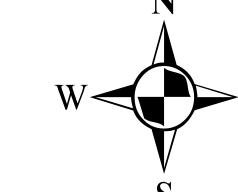


Figure 1.1



### 2.0 Stormwater Model Build

#### 2.1 Data Collection and Review

At the outset of the project, the Township provided all available GIS data, as-built drawings, and operational data related to their stormwater system. The following data was provided:

- Township of Esquimalt LiDAR data (January 8, 2019);
- Stormwater system Mylar drawing scans 70 drawings (January 22, 2019);
- Orthophotos (January 22, 2019); and
- Stormwater system GIS data (Updated on April 3, 2019).

All data was reviewed and critical questions were posed to the Township on February 5, 2019. The Township provided responses on February 11, 2019 and updated their GIS data accordingly. Their responses were incorporated into the model build.

### 2.2 Hydraulic Model Development

The existing Township GIS dataset was used to define the stormwater system network model. It was understood that this dataset was not complete and lacked key information for the development of an all-pipe model. As such, pipes were added to the model to the extent that data was available. Where GIS data was not available, extraction or interpolation of pipe characteristics was attempted from older Mylar as-built drawings or parallel sanitary sewer mains. Due to variations in data completeness, some areas of the model are more detailed than others; furthermore, some areas required the assumption invert elevations for critical connectivity purposes. These changes, omissions, and assumptions were tracked during the model build process.

Culverts were defined in model in accordance with the Township GIS. Manning's "n" roughness coefficients were assigned to the gravity mains and culverts according to **Table 2.1**.

**Table 2.1: Gravity Main and Culvert Roughness Coefficients** 

Material Type	Manning's Roughness Coefficient*
Culvert	0.013
Gravity Main	0.013

<sup>\*</sup>Roughness coefficients based on average value for a range of materials and ages.

Modeled gravity mains and culverts with an inlet or outlet were assigned an entrance loss coefficient of 0.5 (averaged from typical entrance loss values) and a theoretical exit loss coefficient of 1.0. Specific details on each inlet and outlet structure were not confirmed.

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Ditch locations, transects and invert elevations were extracted from a digital elevation model (DEM) developed from LiDAR data (wherever possible) which tends to provide accurate geometry above the water level, but will leave uncertainty below the water level. It should also be understood that, in many instances, the Township's ditch network was excluded from their GIS data and had to be inferred from LiDAR data and Township sketches. We recommend that ditches be accounted for in the Township GIS for future modeling endeavors.

When reasonable transect profiles could not be generated using the available LiDAR data, standard ditch geometries were used as summarized in **Table 2.2.** 

**Table 2.2: Standard Open Channel Geometry** 

Storm System Component	Bed Width (m)	Maximum Depth (m)	Left Bank Slope	Right Bank Slope	Manning's Roughness Coefficient*
Ditch	1.0	0.1	1:5	1:5	0.025

<sup>\*</sup>Roughness coefficients based on standard values for a manmade ditch.

Manning's "n" roughness coefficients vary and should be updated over time through site assessment and model calibration.

Junctions were added in the model to provide connectivity where transitions between different physical attributes, such as size and slope, occur and to represent outfalls and catchment load points. Missing rim elevations for junctions were extracted from LiDAR data. For critical junctions with missing invert elevations and no other supporting data, a bury depth of 1.5 m was assigned.

It should be understood that only one storage structure (GA-DP1) and no control structures have been included in the model at this time due to a lack of supporting data. As the Township's data is updated through site investigation, detention and control structures should be included in the hydraulic model and GIS.

### 2.3 Hydrologic Model Development

Model subcatchments were delineated based on surface topography and the configuration of conveyance features. The granularity of the delineation was determined in a manner such that no dry pipes would exist during a storm event.

Subcatchment widths were estimated using the following formula:

$$Width = 1.7 \times \sqrt{Area}$$

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These subcatchment width calculations should be viewed as a starting-point only. The subcatchment width parameter is variable and must be calibrated. Subcatchment slopes, the average slope over each catchment area, were determined using the DEM.

The hydrologic parameters that were uniformly applied to all the subcatchments are summarized in **Table 2.4**. These values were selected based on industry standards and previous experience with similar topography.

**Table 2.4: Subcatchment Hydrologic Modeling Parameters** 

Hydrologic Parameter	Value
Depression Storage	
Pervious Area	5.0 mm (developed)
	12.0 mm (undeveloped)
Impervious Area	2.0 mm
Manning's "n" Overland Roughness Coefficient	
Pervious Area "n"	0.100
Impervious Area "n"	0.013

The impervious percentage for each subcatchment was estimated based on existing zoning coverage. Each landuse designation was sorted into high-level categories that generally maintain similar properties. The impervious percentage for each existing zoning category is defined in **Table 2.5**.

Table 2.5: Subcatchment Imperviousness and Routing Estimates (Existing Zoning)\*

Landuse Category	Total Imperviousness (%)	Runoff Routed to Pervious Area (%)
Residential	55	25
Commercial Centre/Industrial	80	15
Parks, Recreation and Culture	10	85
Institutional	70	55
Comprehensive Development	50	55
Road	70	25
Marine	0	100

<sup>\*</sup>Adopted values generally in line with Master Municipal Construction Documents (MMCD) recommendations, but tailored to suit our understanding of the Township's zoning descriptions.







The Modified Horton infiltration process was used to characterize soil infiltration characteristics in the model. The Modified Horton infiltration parameters are summarized in **Table 2.6**.

**Table 2.6: Modified Horton Infiltration Parameters** 

Minimum Infiltration Rate (mm/hr)	Maximum Infiltration Rate (mm/hr)	Decay Constant (1/hr)	Drying Time (days)
2.5	18.0	4.14	7

Decay Constant: Decay constant for the Horton infiltration curve. Drying Time: Time for a fully saturated soil to completely dry (days).

Groundwater was not modeled under this scope of work. A significant groundwater presence was not observed at the two flow monitoring locations (**Section 3.1**); however, other locations within the Township or different times of year may observe stronger groundwater influence. The need for groundwater modeling should be revisited after completing additional flow monitoring.







### 3.0 Flow Monitoring & Model Validation

### 3.1 Flow Monitoring Program

GeoAdvice retained Bot Corp to conduct a small stormwater system flow monitoring program in the spring of 2019. The flow monitoring program included the installation of flow monitors at two (2) sites for a duration of about three months (from March 10, 2019 to June 1, 2019). The purpose of the flow monitoring program was to obtain some field data for a high-level model validation as the Township had not previously collected flow data for their stormwater system.

The two (2) flow monitoring sites are identified in **Table 3.1**.

**Table 3.1: Flow Monitoring Sites** 

Station	Site Location	GIS ID	Approx. Catchment Area
F1	Greenwood Ave. @ Kinver St.	DGM0407	12.0 hectares
F2	897 Admirals Rd.	DGM1155	11.5 hectares

Flow data was correlated against rainfall data collected at a rain gauge maintained by Macaulay Elementary School on the school's grounds. This tipping-bucket style rain gauge records cumulative rainfall and resets on a daily basis. Data is reported from the rain gauge in one minute increments; however the actual recording frequency is dependent on bucket tips and may not always correspond with the recording interval. As such, smaller storm events and peak intensities may be missed or underreported.

Flow statistics from the monitoring period have been summarized in **Table 3.2**.

**Table 3.2: Flow Monitoring Statistics** 

Station	Duration of Record*	Average Flow (L/s)	Peak Flow (L/s)
F1	March 2019 – April 2019	0.4	29.8
F2	March 2019 – April 2019	2.1	91.0

<sup>\*</sup>Statistics limited to the selected validation period (**Section 3.2**)

It should be noted that the recorded data for the Admirals Rd. site (F2) is somewhat suspicious. While there is nothing in the flow data that stands out immediately, the velocity and level data appear to be recording somewhat significant system response even when no rainfall is recorded. Additionally, given the slightly smaller catchment area than the Greenwood site, the significantly larger peak flows (typically at least three times larger) are also questionable. The scatter graph plot of depth vs. velocity at the Greenwood location does not provide any additional insight.

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Additional monitoring should be conducted in the vicinity of the Greenwood site to understand the validity of the observed response.

The flow monitoring and rain gauge data were used to identify storm events, and the associated system response, to select an appropriate validation period. Due to the general lack of storm events in the month of May 2019, it was decided to use the March – April 2019 rainfall data in the model validation.

### 3.2 Model Validation

As the flow monitoring program was limited and full model calibration was not included in the scope of this project, the recorded flow data were compared to model predictions in an attempt to validate the model results or identify significant discrepancies that may require further investigation. Detailed model calibration was not completed.

To conduct the validation, model simulations were run for a period of two months, simulating the entire period of March – April, 2019. The input for these simulations was the processed rainfall data generated by the Macaulay rain gauge. The model results for the entire duration of the simulation were then compared against the flow monitoring data. The results of these simulations are provided in **Figure 3.1** and **Figure 3.2**.

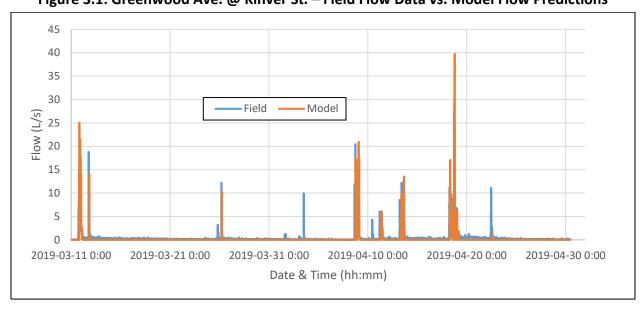


Figure 3.1: Greenwood Ave. @ Kinver St. – Field Flow Data vs. Model Flow Predictions







Overall, the model shows good agreement with the field observations at the Greenwood Ave. monitoring site. There are obvious discrepancies and missing flow responses; however, many of these discrepancies are likely due to poor resolution and low accuracy in the rainfall data.

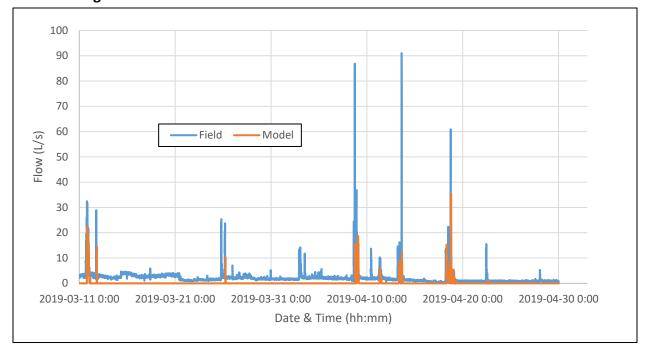


Figure 3.2: 897 Admirals Rd. – Field Flow Data vs. Model Flow Predictions

Regarding the Admirals Rd. monitoring location, the model shows a poor agreement with the field observations. Observed peak flows are often more than three times greater than model predictions (peak model = 30 L/s vs. peak field = 90 L/s), numerous flow responses are missing from the model predictions, and the peak response pattern does not match (model does not peak when field observations peak). This cannot be explained by rainfall data errors or inaccuracies (unless this area is prone to exaggerated pockets of severe weather compare to the rest of the Township). Numerous simulations were run in the model to test the impact of various changes to soil infiltration parameters and even at 100% impervious and 0% infiltration the observed flow response could not be replicated. While it is possible that the model and GIS are missing a part of this catchment, it is more likely that there is an unexpected (and significant) cross connection or there was something wrong with the flow monitor. Without further investigation, we would not recommend using this location to interpret the model's performance.







### 4.0 Future Scenarios

The modeled future scenarios differ from the existing scenarios only in the design storms, which account for climate change (refer to **Section 5.1**), and subcatchment impervious percentage estimates, which are based on OCP Land Use data (provided by the Township).

The future impervious percentage for each subcatchment was estimated based on the Township's OCP land use plan. As with the existing landuse data, each OCP landuse designation was sorted into high-level categories that generally maintain similar properties. A few additional categories were created for the OCP landuse to better reflect the expected zoning changes. The impervious percentage for each OCP land use category is defined in **Table 4.1**.

Table 4.1: Subcatchment Imperviousness and Routing Estimates (OCP Landuse)\*

Landuse Category	Total Imperviousness (%)	Runoff Routed to Pervious Area (%)
Low Density/General Residential	55	25
Medium Density/Townhouse Residential	70	50
High Density Residential	80	20
Commercial Centre/Industrial	80	15
Parks, Recreation and Culture	10	85
Institutional	70	55
Comprehensive Development	50	55
Road	70	25
Marine	0	100

<sup>\*</sup>Adopted values generally in line with MMCD recommendations but tailored to suit our understanding of the Township's OCP landuse descriptions.

Imperviousness and routing parameters were only updated for subcatchments in which parcels were identified as undergoing a landuse change at the OCP horizon. For consistency, the parcels undergoing changes were extracted from previous work done by GeoAdvice for the Township's sanitary sewer model and master plan.







#### 5.0 **System Capacity Analysis**

This section summarizes the Township stormwater system capacity analysis under existing and future conditions.

### 5.1 Design Storms

IDF curves for use in the model were developed using the IDF-CC tool (https://www.idf-ccuwo.ca/) for an ungauged (no official Environment Canada weather station) location at Macaulay Elementary School (for consistency with the rain gauge used in the flow monitoring program). The IDF-CC tool utilizes historical data from nearby Environment Canada rain gauge locations to extrapolate historical IDF curves for areas without defined IDF data.

The IDF-CC tool was also used to develop climate-change adjusted IDF curves. GeoAdvice assumed a planning horizon of +50 years, developing climate change projections for 2070 assuming the median climate change scenario<sup>1</sup>. All available bias-corrected climate data were used to develop the projections.

As the Township does not have a specific design storm distribution defined, GeoAdvice chose to utilize two separate design storm distributions for analysis. Though this was not required under the existing scope of work for this project, GeoAdvice felt that the information was critical to the Township making an informed decision about the modeling results. As such, we provided the additional distribution and modeling results at no extra cost.

The Modified Chicago design storm and the SCS Type 1A design storm were both selected for the different stresses they place on a stormwater system. The SCS Type 1A storm tends to result in a greater average rainfall intensity applied over the 24-hour period, but a lower peak intensity. The Modified Chicago storm results in a significantly higher peak rainfall intensity (corresponding to a 5-minute event) and, typically, a lower average rainfall intensity.

An example of these design storms are provided in Figure 5.1 and Figure 5.2.

<sup>&</sup>lt;sup>1</sup> The median climate change scenario is defined herein as the Representative Concentration Pathway (RCP) 4.5 climate change scenario as defined by the Intergovernmental Panel on Climate Change (IPCC). For more information, please refer to the IDF-CC tool (https://www.idf-cc-uwo.ca/Faq) or the IPCC (https://www.ipccdata.org/guidelines/pages/glossary/glossary r.html)









Figure 5.1: 2-Year, 24-hour Modified Chicago Design Storm (Without Climate Change)

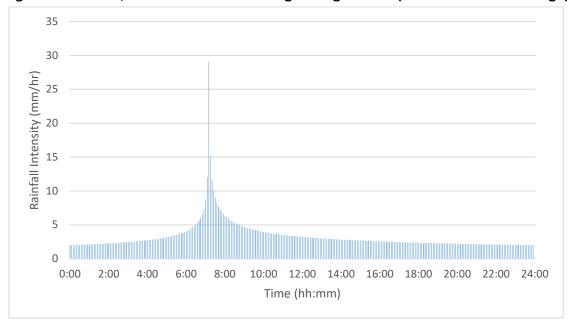
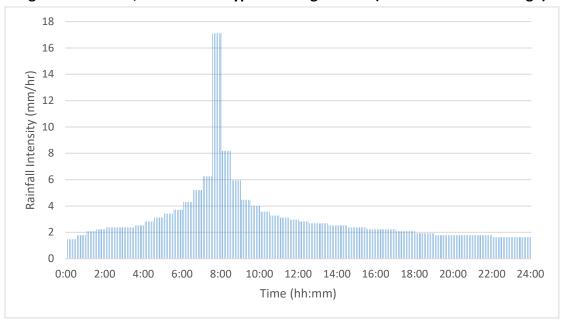


Figure 5.2: 2-Year, 24-hour SCS Type 1A Design Storm (Without Climate Change)



The design storms used in the model are summarized in **Table 5.1**.







**Table 5.1: Town of Esquimalt Design Storms** 

Return Period	Distribution	Climate Change	Total Rainfall (mm)	Average Intensity (mm/hr)	Peak Rainfall Intensity (mm/hr)
	SCS Type 1A	No	74.40	3.10	17.11
2-Year	Chicago	No	77.97	3.25	29.02
2-1Eal	SCS Type 1A	Yes	79.01	3.29	18.17
	Chicago	Yes	82.74	3.45	30.8
	SCS Type 1A	No	108.00	4.50	24.84
10 Voor	Chicago	No	104.98	4.37	44.53
10-Year	SCS Type 1A	Yes	116.90	4.87	26.89
	Chicago	Yes	114.34	4.76	48.77
	SCS Type 1A	No	144.00	6.00	33.12
100 //	Chicago	No	136.02	5.67	73.46
100-Year	SCS Type 1A	Yes	158.90	6.62	36.55
	Chicago	Yes	150.58	6.27	81.34

### 5.2 Hydraulic Level of Service (HLoS) Criteria

Capacity HLoS was determined using the hydraulic capacity (q/Q), hydraulic grade line (HGL), surcharge time and flood time model results under peak conditions. **Tables 5.2** – **5.4** summarize the criteria used to define the capacity HLoS ratings.

Table 5.2: Gravity Main Hydraulic Level of Service Criteria Scoring

Criteria	Score
Hydraulic Capacity (q/Q*)	
q/Q < 1.0	1
q/Q ≥ 1.0	2
Hydraulic Grade Line (HGL)	
HGL < Crown	1
Crown ≤ HGL < Rim Elevation	2
HGL ≥ Rim Elevation	3
Surcharge	
Surcharge Time <= 15 minutes	1
Surcharge Time > 15 minutes	2
Flood	
Flood Time <= 15 minutes	1
Flood Time > 15 minutes	2

<sup>\*</sup>q/Q = peak flow/full pipe flow.







The 15-minute cutoff time for surcharge and flood events was chosen to differentiate between deficiencies caused by short-duration, high-intensity events (5, 10 and 15-minute storms) and those resulting from longer duration events (longer than 15 minutes). Addressing deficiencies identified under short-duration events through pipe capacity upgrades may not always be the most practical or cost-effective solution.

**Table 5.3: Gravity Main Hydraulic Level of Service Ratings** 

HLoS Rating	Capacity	HGL	Surcharge	Flood
Α	1	. 1 1		1
В	1	2	1	1
	1	3	1	1
С	1	2	2	1
	1	3	2	1
	1	3	2	2
D	2	1	1	1
	2	2	1	1
	2	3	1	1
E	2	2	2	1
	2	3	2	1
F	2	3	2	2

Detailed descriptions of how each HLoS category relates, in practical terms, to the performance of the Township stormwater system are presented in **Table 5.4**.







**Table 5.4: Gravity Main Hydraulic Level of Service Descriptions** 

HLoS Rating	Code	Description			
Α	1-1-1-1	Gravity main performing as designed			
В	1-2-1-1	Adequate capacity; Minimal backwater caused by downstream condition			
	1-3-1-1	Adequate capacity; Minimal backwater caused by downstream condition (potential for < 15 minute flood event)			
С	1-2-2-1	Adequate capacity; Significant backwater caused by downstream condition			
	1-3-2-1 Adequate capacity; Significant backwater caused by downstream condition (potential for < 15 minute flood event)				
	1-3-2-2	Adequate capacity; Significant backwater caused by downstream condition (potential for > 15 minute flood event)			
2-1-1-1		Marginal capacity			
D	2-2-1-1	Marginal capacity; Surcharge event < 15 minutes			
	2-3-1-1	1 Marginal capacity; Surcharge event < 15 minutes (potential for < 15 minute flood event)			
E	2-2-2-1	Capacity exceeded; Significant surcharge (> 15 minute) event likely			
	2-3-2-1	Capacity exceeded; Significant surcharge (> 15 minute) event likely (potential for < 15 minute flood event)			
F	2-3-2-2	Capacity exceeded; Large (> 15 minute) flood event likely			

When conducting the capacity analysis, ditches and detention structures were not assessed.

### **5.3 Gravity Main Capacity Analysis**

To provide the Township with the clearest possible understanding of their stormwater system performance, a number of different scenarios were simulated to depict the impact of various design storm distributions, storm return periods and land use arrangements.

#### **Existing Landuse without Climate Change:**

- 2-Year Existing System Performance with Existing Land Use (SCS Type 1A)
- 2-Year Existing System Performance with Existing Land Use (Chicago)
- 10-Year Existing System Performance with Existing Land Use (SCS Type 1A)
- 10-Year Existing System Performance with Existing Land Use (Chicago)
- 100-Year Existing System Performance with Existing Land Use (SCS Type 1A)
- 100-Year Existing System Performance with Existing Land Use (Chicago)

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#### **OCP Landuse with Climate Change:**

- 2-Year Existing System Performance with OCP Land Use + Climate Change (SCS Type 1A)
- 2-Year Existing System Performance with OCP Land Use + Climate Change (Chicago)
- 10-Year Existing System Performance with OCP Land Use + Climate Change (SCS Type 1A)
- 10-Year Existing System Performance with OCP Land Use + Climate Change (Chicago)
- 100-Year Existing System Performance with OCP Land Use + Climate Change (SCS Type 1A)
- 100-Year Existing System Performance with OCP Land Use + Climate Change (Chicago)

The existing and future gravity main HLoS results under each scenario are summarized in **Table 5.5** and **Table 5.6**.

Table 5.5: Gravity Main HLoS Results (Number of Mains) – Existing Landuse

HLoS Rating	2 Yr. SCS 1A	2 Yr. Chicago	10 yr. SCS 1A	10 Yr. Chicago	100 Yr. SCS 1A	100 Yr. Chicago
Α	570	472	432	330	338	248
В	5	41	3	44	4	23
С	191	158	217	204	253	248
D	22	81	22	63	22	37
E	177	263	216	304	215	319
F	161	111	236	181	294	251
Total	1,126	1,126	1,126	1,126	1,126	1,126

Table 5.6: Gravity Main HLoS Results (Number of Mains) – OCP Landuse + Climate Change

HLoS Rating	2 Yr. SCS 1A	2 Yr. Chicago	10 yr. SCS 1A	10 Yr. Chicago	100 Yr. SCS 1A	100 Yr. Chicago
Α	546	453	404	311	313	230
В	3	32	4	45	4	29
С	193	169	224	208	259	251
D	24	64	23	50	18	37
E	186	284	222	308	218	305
F	174	124	249	204	314	274
Total	1,126	1,126	1,126	1,126	1,126	1,126

**Please Note:** Ditches have been excluded from this analysis.

Maps depicting model results for existing landuse scenarios have been provided in **Appendix A**. Please refer to **Appendix B** for maps of results under OCP landuse with climate change.







For the Township's stormwater network, we would not recommend pipe upgrades for HLoS ratings of 'A', 'B', 'C' and 'D' as there is capacity available in the gravity main to convey flows or the capacity deficiency is not predicted to be detrimental to overall system operation. Gravity mains receiving an HLoS rating of 'B', 'C' or 'D' may show surcharging or flooding on connected nodes; however, these cases would indicate that the surcharged condition is due to downstream hydraulic deficiencies (case 'B' or 'C') or not significant enough to be of concern (case 'D').

For 2 and 10-year return period storms, we would recommend that only gravity mains receiving a HLoS rating of 'E' and 'F' are considered for upgrade. A gravity main receiving an 'E' rating requires an upgrade as the hydraulic capacity has been exceeded and is likely causing surcharging to occur. A gravity main receiving an 'F' rating indicates that significant flooding is likely, increasing the priority of the upgrade.

**Please Note:** When flooding occurs, a portion of the storm flow is lost. This results in reduced flow reaching downstream conduits. As such, if deficiencies were resolved to eliminate flood losses, the performance of downstream links would change. As shown in the figures, there is significant flooding predicted under all storm events.

With respect to the results, the Township will find that a significant number of 'E' and 'F' rankings are predicted under all storm events, with the most surprising results occurring under the 2-year storms. In investigating these results, two key factors stand out:

- The Township's stormwater system includes a large number of 150 mm and 200 mm storm mains, which are quickly overwhelmed by typical runoff volumes. In reality, some additional storage would be available in the unmodeled catch basins and catch basin leads; it is also possible that modeled subcatchments have been directed into small diameter mains when, in reality, flow would route overland into catch basins located further downstream.
  - The Township should investigate these areas to determine if flooding is typical under 2-year storm events. If flooding does not typically occur under these events, the modeled subcatchment discretization and allocation may require additional refinement during future model updates.
- The golf course subcatchments are modeled with the same subcatchment parameters as all other model subcatchments and it is assumed that runoff from the golf course is routed north into the Township stormwater system. This assumption appears to result in significant flood volumes that are not likely to be present. Should on-site stormwater management be present for the golf course, or if more detailed soils information is available, this should be incorporated into the model during future model updates.







### 6.0 Conclusions and Recommendations

GeoAdvice Engineering was retained by the Township of Esquimalt to build and analyze a hydraulic model of the Township's stormwater water system using InfoSWMM. As discussed with the Township at the project kickoff, this model should be considered as a good basis for further study and refinement. Before using the model to inform any significant capital works, we have provided a few recommendations for further studies and model improvements that should be undertaken as the Township's time and budget allow.

### 1. Develop System Improvement Recommendations

As improvement recommendations were not included in this scope of work, we recommend that the Township use the model to develop initial improvement recommendations and develop a preliminary estimate of future capital projects and budget requirements. However, before developing the upgrade recommendations, we strongly advise the Township to undertake additional flow monitoring (Item #3, below) and conduct a detailed model calibration.

#### 2. Field Verification of Stormwater System Information

Using the flagged GIS data as a starting point, the Township should verify any noted discrepancies and work to fill any missing system data. Additionally, it would be good to consolidate all known stormwater system data into the Township's GIS data as there is still significant information contained in older Mylar drawings.

#### 3. Additional Flow Monitoring

The Township should undertake additional flow monitoring to capture a wider-range of catchment parameters and to further verify model operation. While one flow monitoring location seems to show good agreement with model predictions, the other showed poor correlation – additional flow data will be required to undertake the model calibration.

#### 4. Soil Properties

Based on orthophotos and old soil maps, it appears that soil properties across the Township may vary more than expected when first undertaking the model build (e.g. golf course vs. rocky hillsides vs. Gorge inlet). As such, the Township would likely benefit from developing GIS-based basic soil maps that could then be used to inform more varied soil and infiltration parameters in the stormwater model.

#### 5. Detention and Control Structures

At the kickoff meeting it was noted that no significant detention and/or control structures exist in the Township's system. Based on orthophotos, and later Township notes, at least one detention structure was identified in the golf course area and photos imply that there may

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be more. Additionally, while the one detention structure was modeled, there appears to be no way to drain the pond other than through infiltration. It would be good to again confirm the presence of all detention and control structures (weirs, detention structure outlets, etc.) in the system.

#### 6. Climate Change and Design Storms

The Township should carefully review and confirm the climate change predictions utilised in this study and should further determine which design storm distribution they are most comfortable with using in assessing system performance.

#### 7. Permanent Township-Owned Rain Gauge

The Township should consider installing their own, permanent, high-accuracy rain gauge for use in ongoing stormwater system modeling and analysis. Without reliable, high-resolution rain data, stormwater model calibration can be a difficult or misleading exercise. Especially on Vancouver Island, rainfall patterns and intensities can vary significantly from municipality to municipality and even within a municipality. As such, the Environment Canada weather stations in Victoria are not reliable enough for model calibration purposes in Esquimalt.

#### 8. Extended Modeling Support Services

We will assist the Township in maintaining and operating the updated model for a period of one (1) year from the date of completion of this assignment and update the Township of its operational status on a quarterly basis via a written status report. It is understood that during this period, we will have to respond to specific queries to model scenarios from the Township for capital planning and operational needs.

#### 9. Maintenance of Stormwater System Model

Ongoing development, zoning and infrastructure changes dictate that updates should be completed every year. Piping capacities should be updated where investigations indicate discrepancies from assumptions used in the model development.







### **Submission**

Prepared by:

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Reviewed and Approved by:

Werner de Schaetzen, Ph.D., P.Eng.

Project Manager

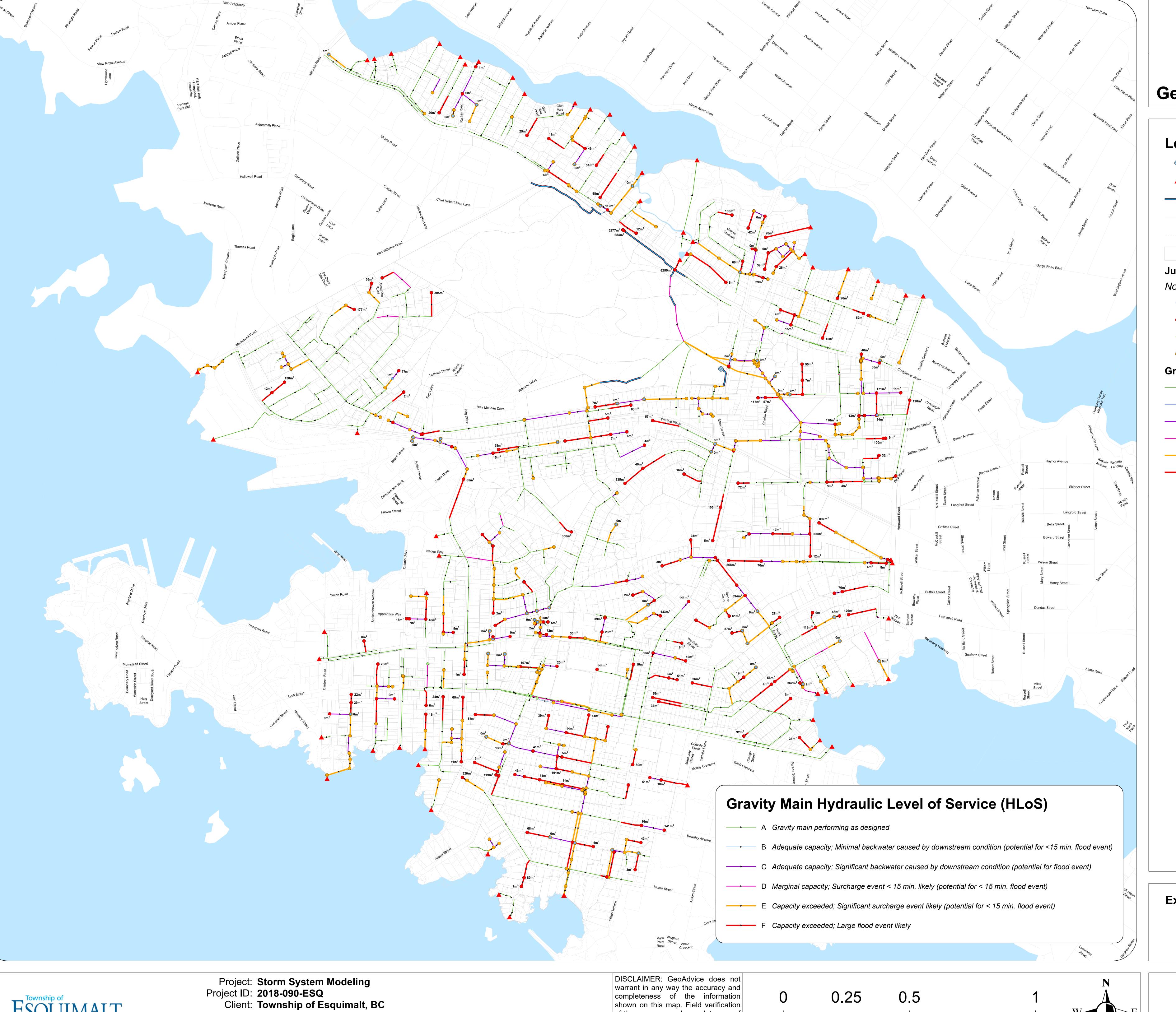




### Appendix A HLoS Results – Existing Landuse, No Climate Change









- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (52)
- Flooding > 15 min (202)
- Surcharged < 15 min No Flooding (7)
- Surcharged > 15 min No Flooding (271)

## **Gravity Main HLoS**

- → A (570)

- F (161)

Existing Landuse: 2-Year 24-Hour SCS Type 1A Design Storm **Historical IDF** Hydraulic Level of Service Results

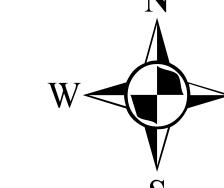


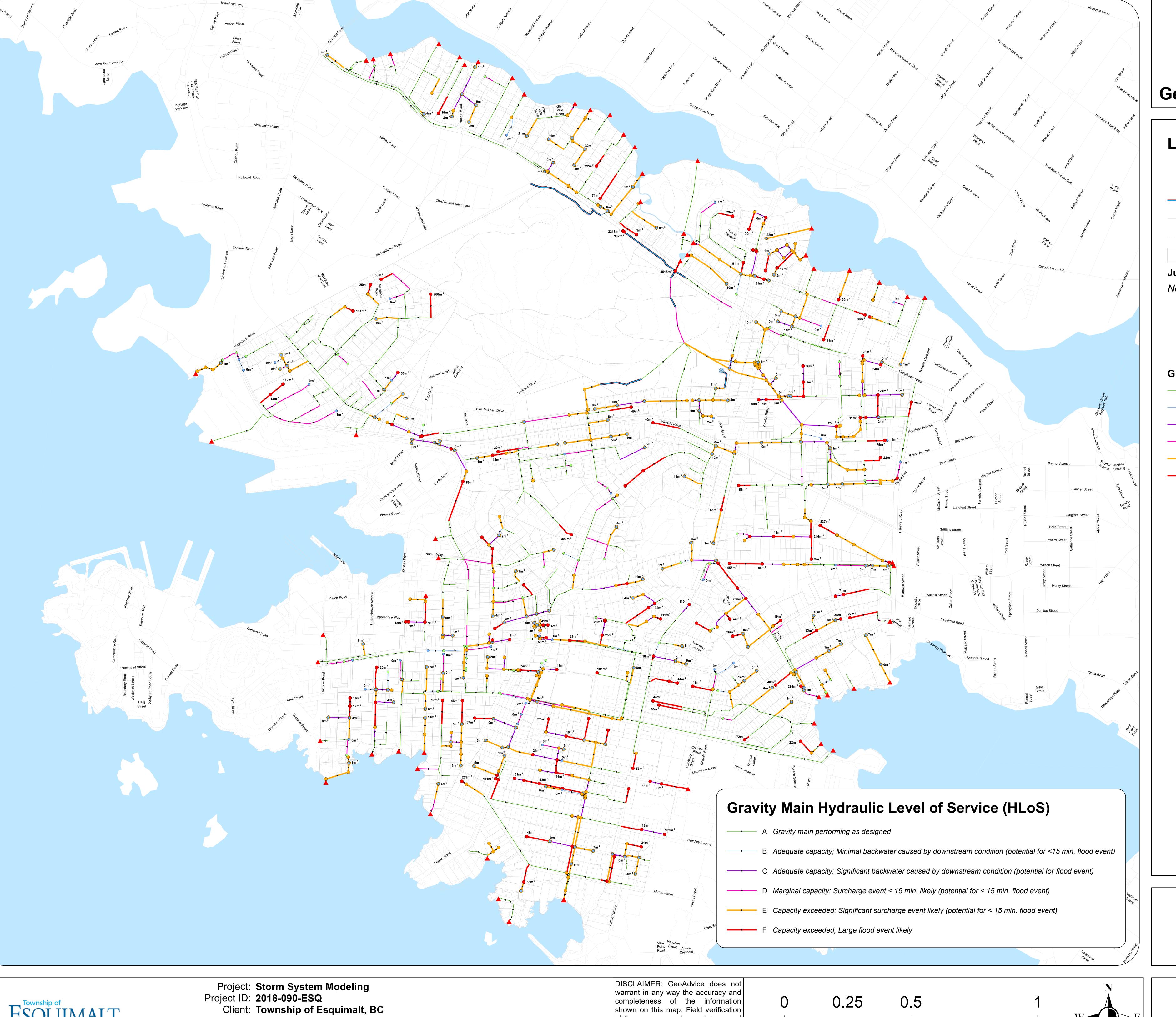
Date: October 2019 Created by: **SG** 

Reviewed by: WdS

of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (206)
- Flooding > 15 min (144)
- Surcharged < 15 min No Flooding (61)
- Surcharged > 15 min No Flooding (211)

## **Gravity Main HLoS**

- → A (472)

- F (111)

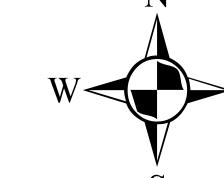
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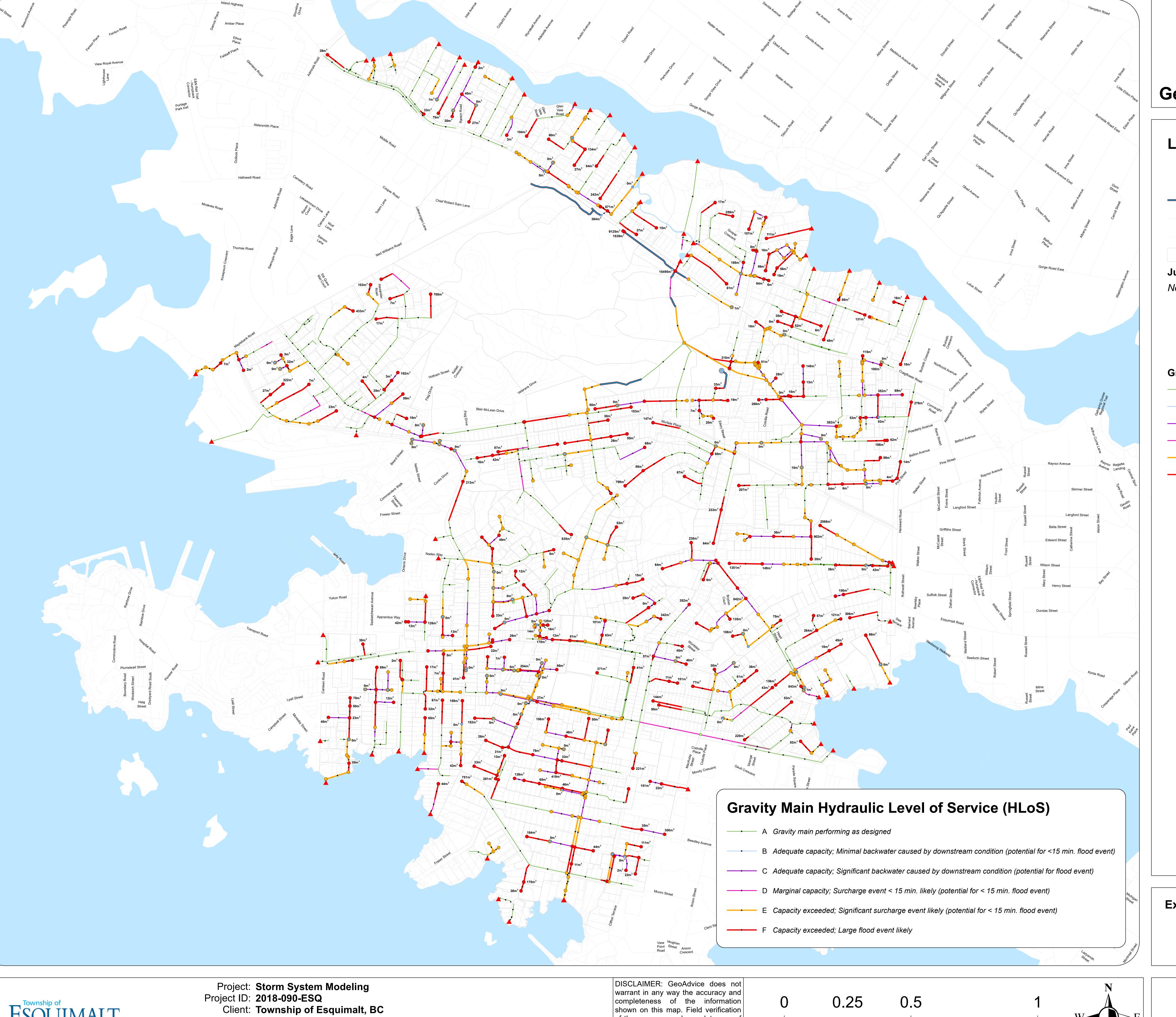


Date: October 2019 Created by: **SG** Reviewed by: WdS

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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (73)
- Flooding > 15 min (296)
- Surcharged < 15 min No Flooding (3)
- Surcharged > 15 min No Flooding (296)

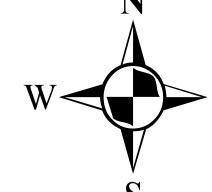
## **Gravity Main HLoS**

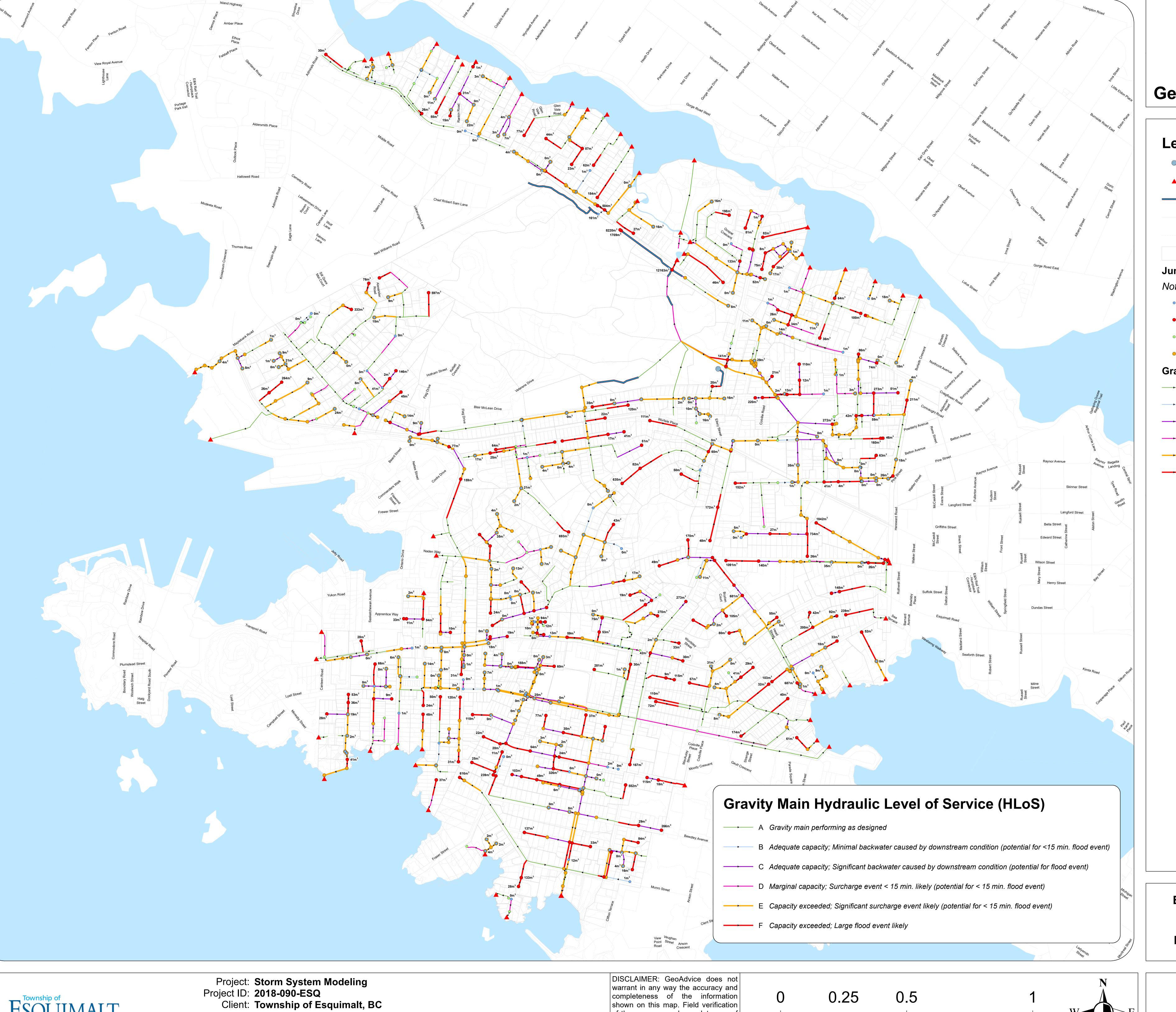
Existing Landuse: 10-Year 24-Hour SCS Type 1A Design Storm Historical IDF Hydraulic Level of Service Results

Date: October 2019 Created by: **SG** Reviewed by: WdS

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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (259)
- Flooding > 15 min (229)
- Surcharged < 15 min No Flooding (49)
- Surcharged > 15 min No Flooding (231)

## **Gravity Main HLoS**

- → A (330)

- F (181)

**Existing Landuse: 10-Year 24-Hour** Chicago Design Storm **Historical IDF** Hydraulic Level of Service Results

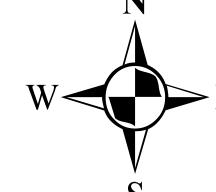


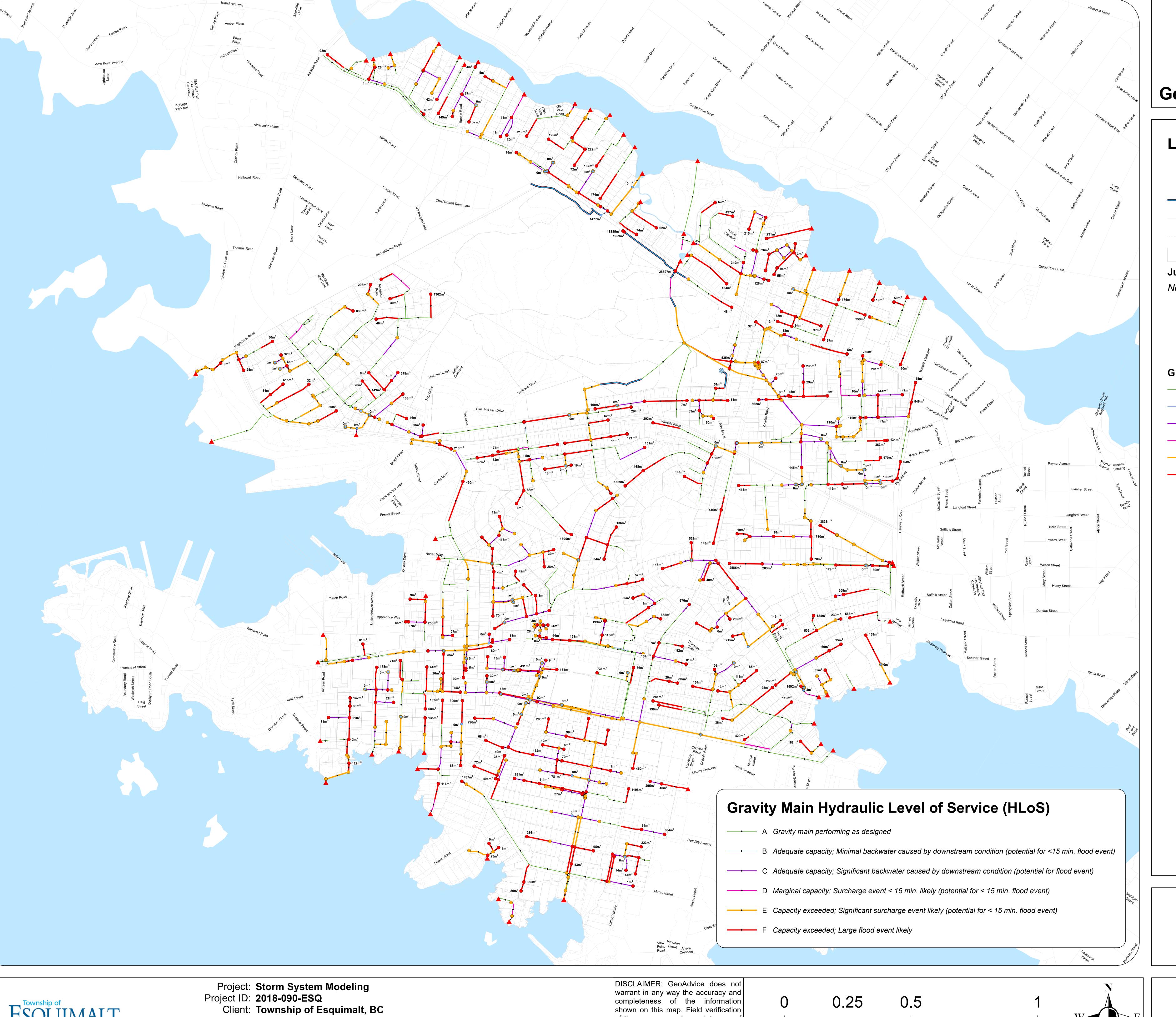
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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (71)
- Flooding > 15 min (375)
- Surcharged < 15 min No Flooding (2)
- Surcharged > 15 min No Flooding (313)

## **Gravity Main HLoS**

- → A (338)

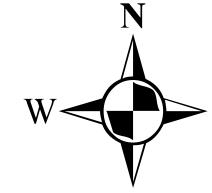
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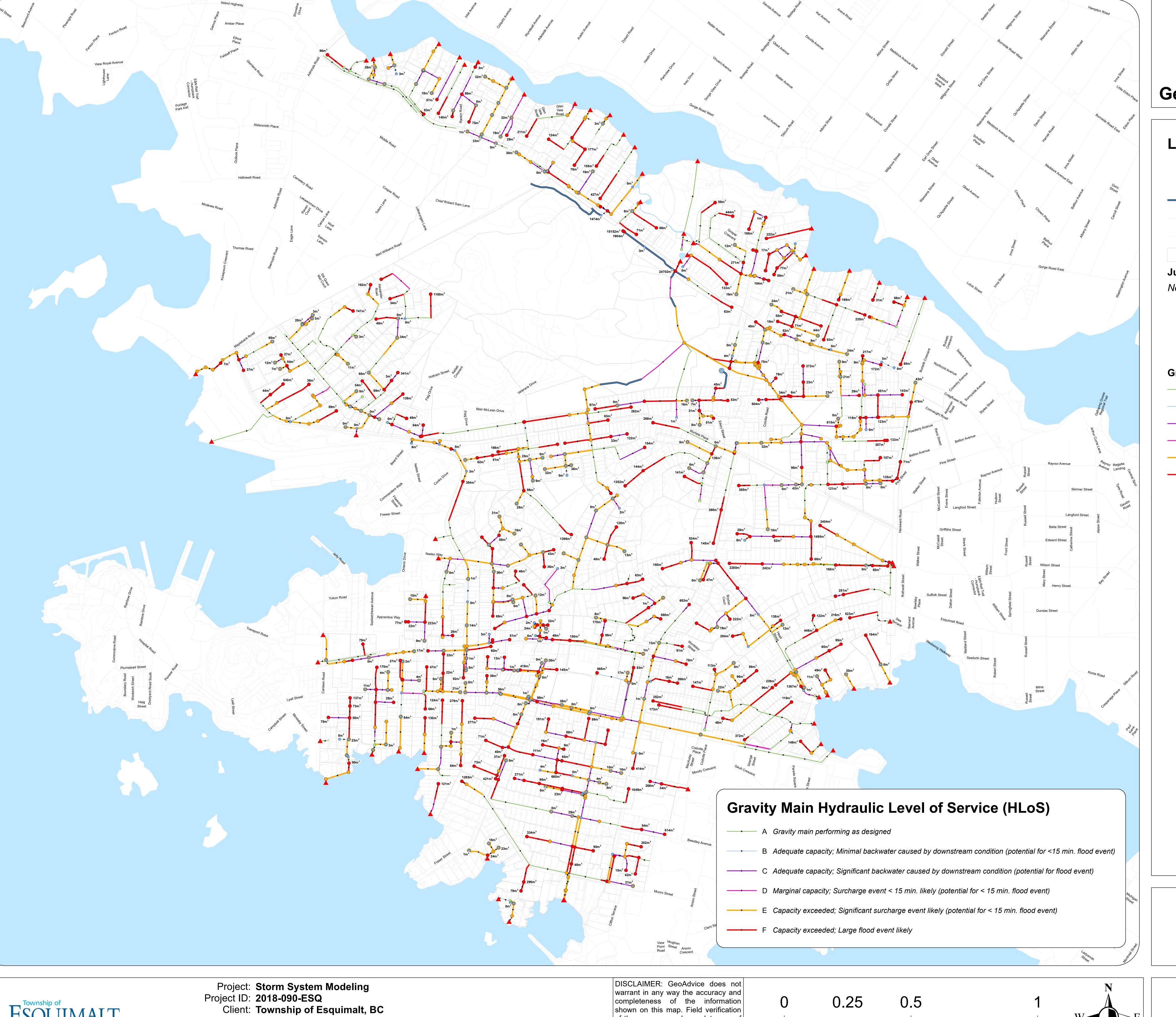
Date: October 2019 Created by: **SG** 

Reviewed by: WdS

of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (244)
- Flooding > 15 min (322)
- Surcharged < 15 min No Flooding (24)
- Surcharged > 15 min No Flooding (266)

## **Gravity Main HLoS**

- → A (248)

- **─** E (319)
- F (251)

Existing Landuse: 100-Year 24-Hour Chicago Design Storm **Historical IDF** Hydraulic Level of Service Results

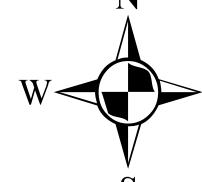


Date: October 2019 Created by: **SG** 

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Kilometers

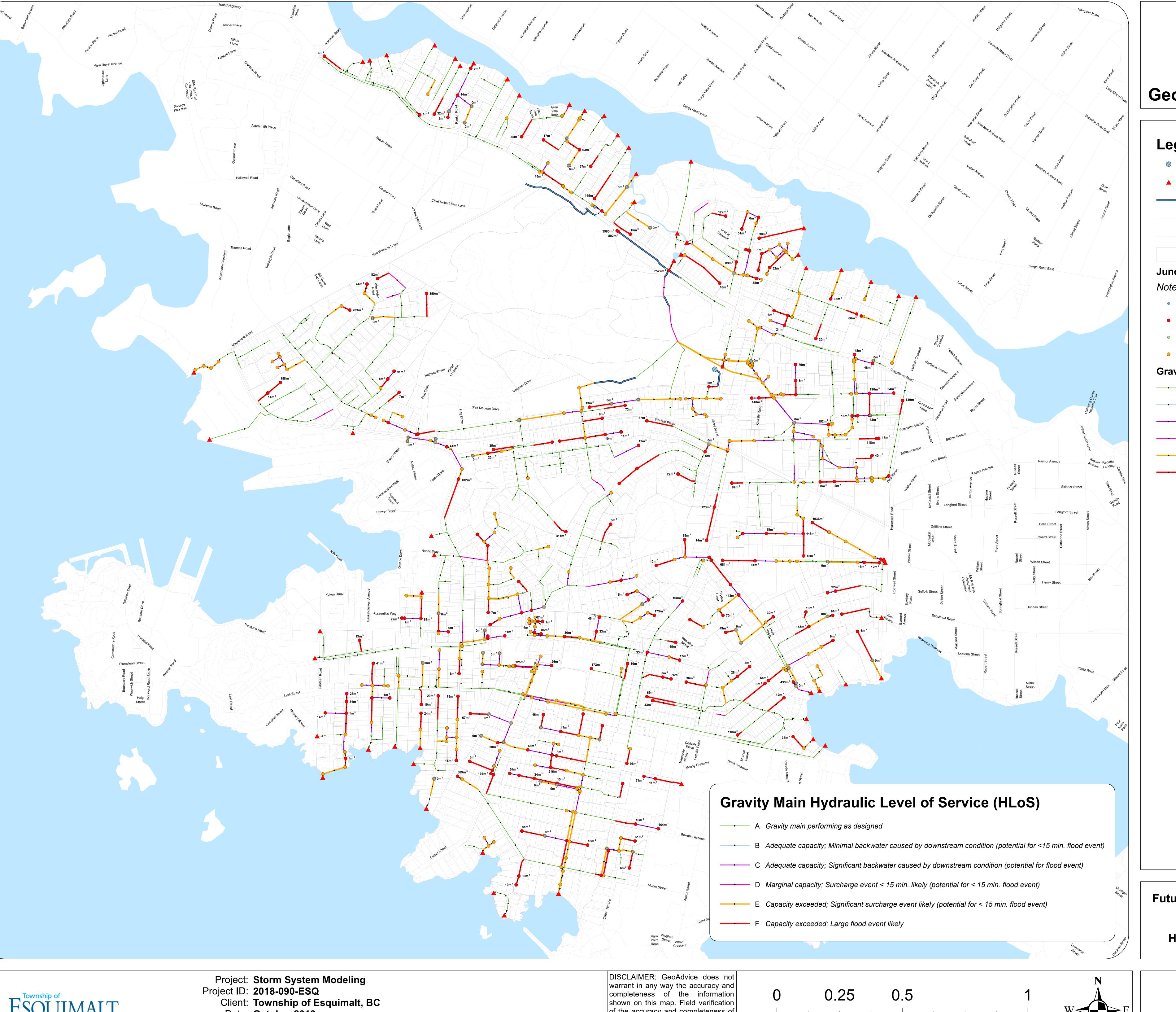




### Appendix B HLoS Results – OCP Landuse, With Climate Change









- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (55)
- Flooding > 15 min (218)
- Surcharged < 15 min No Flooding (2)
- Surcharged > 15 min No Flooding (277)

## **Gravity Main HLoS**

- → A (546)

Future Landuse: 2-Year 24-Hour SCS-1A Design Storm 2070 RCP 4.5 IDF Hydraulic Level of Service Results

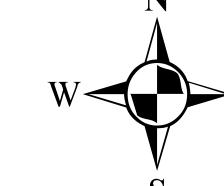


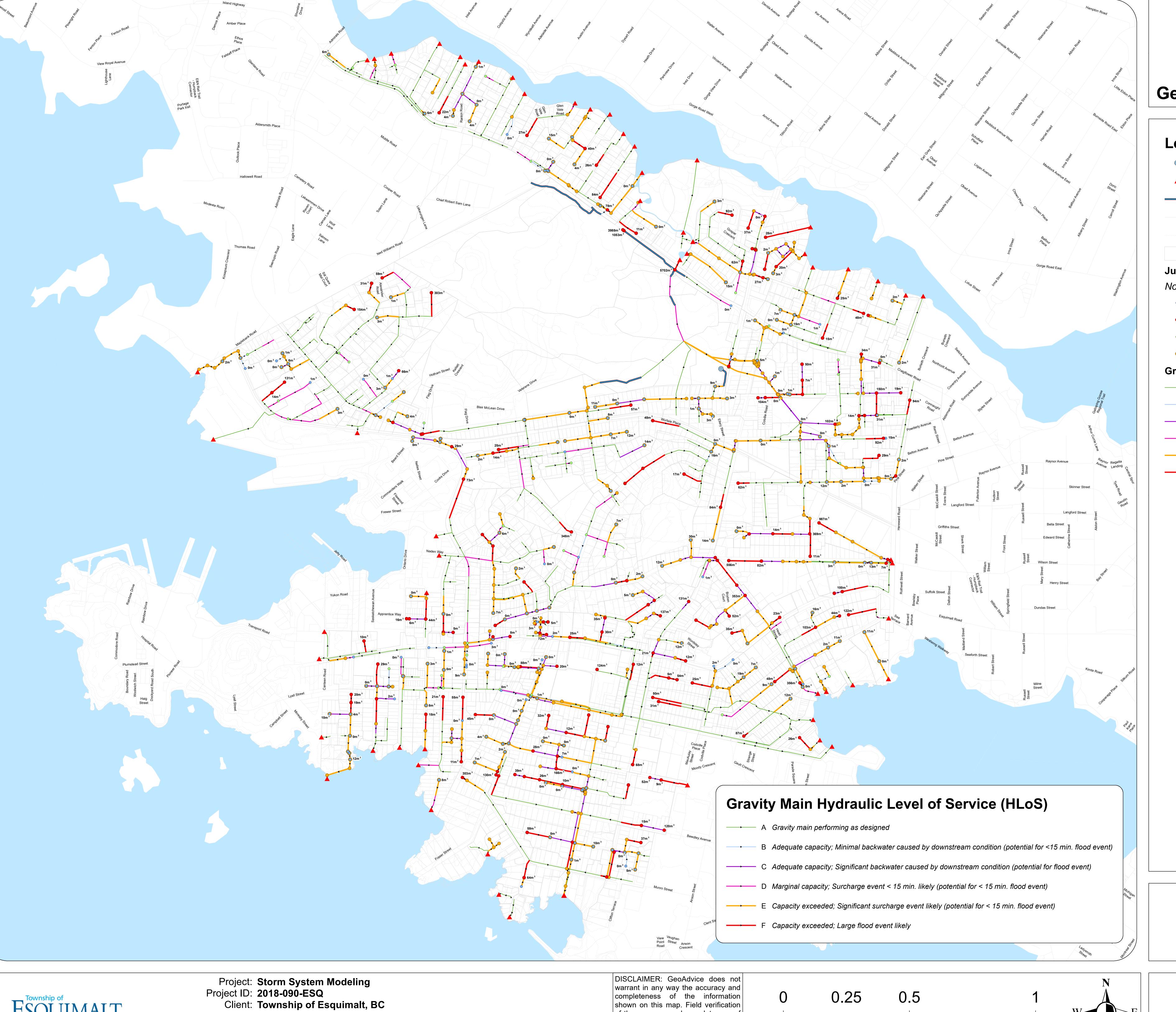
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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (209)
- Flooding > 15 min (162)
- Surcharged < 15 min No Flooding (37)
- Surcharged > 15 min No Flooding (228)

## **Gravity Main HLoS**

- → A (453)

- F (124)

Future Landuse: 2-Year 24-Hour Chicago Design Storm 2070 RCP 4.5 IDF Hydraulic Level of Service Results

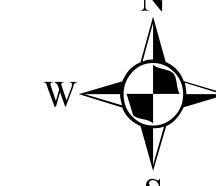


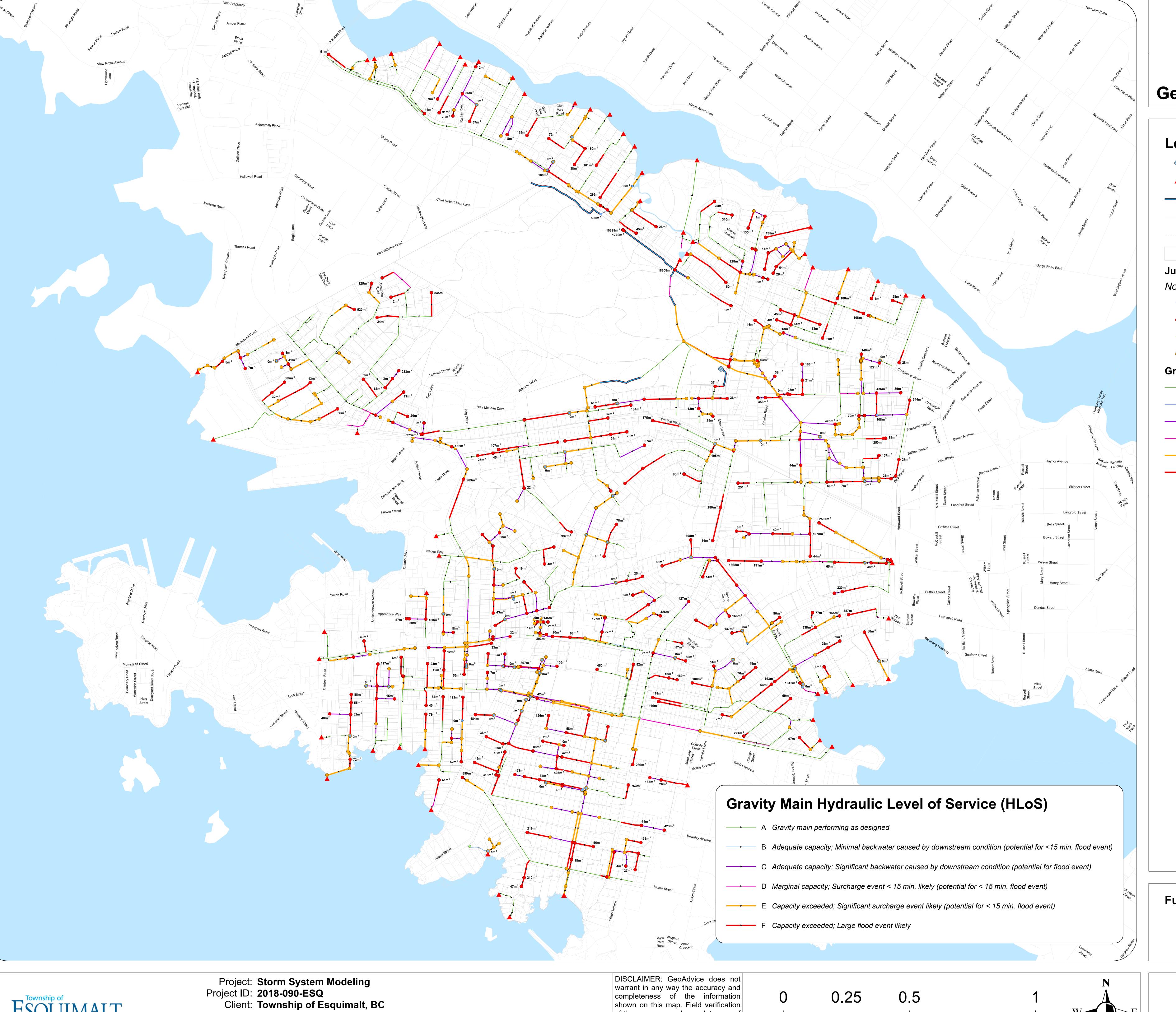
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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (62)
- Flooding > 15 min (317)
- Surcharged < 15 min No Flooding (3)
- Surcharged > 15 min No Flooding (313)

## **Gravity Main HLoS**

- → A (404)

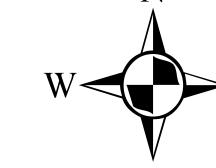
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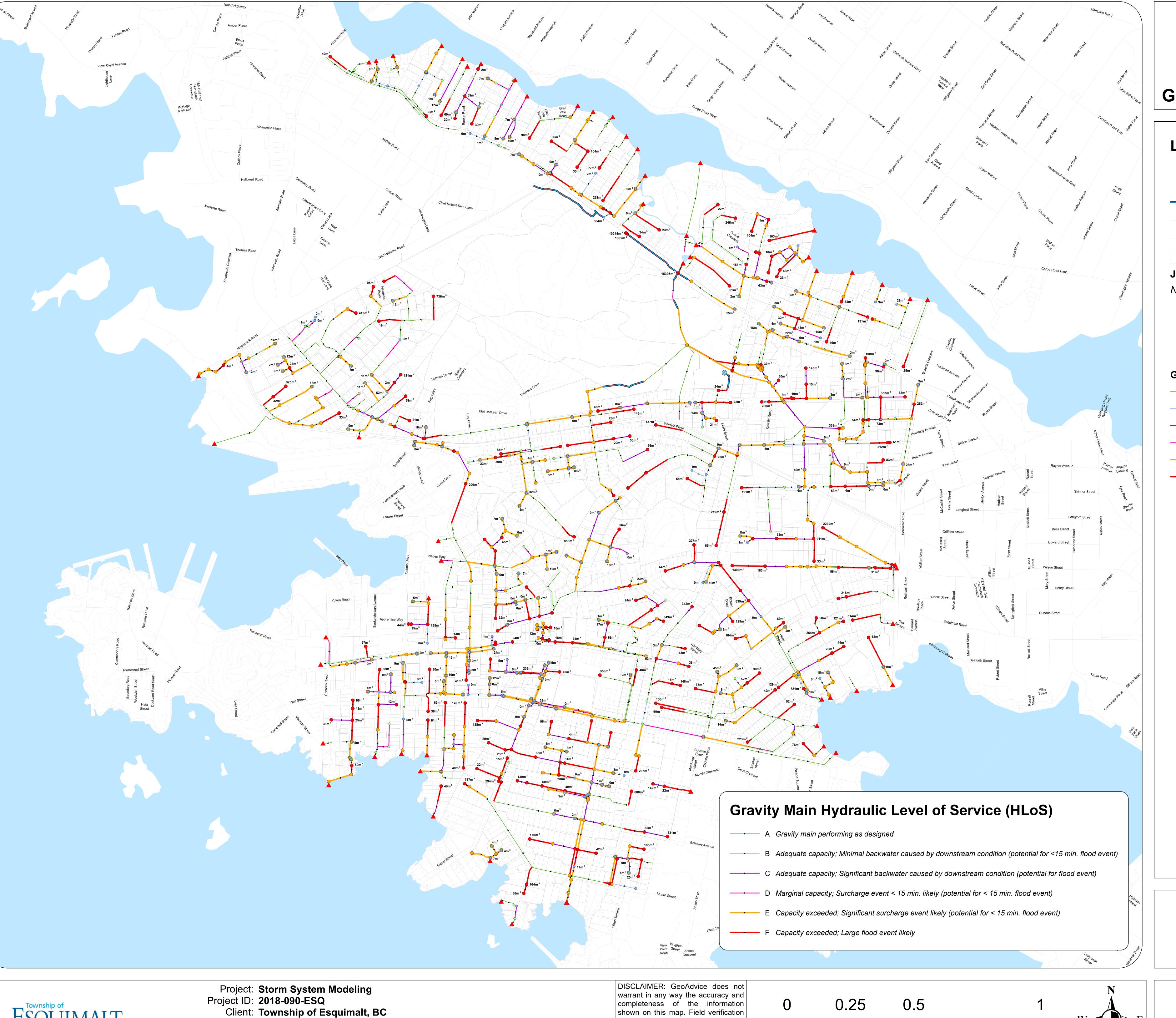


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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (250)
- Flooding > 15 min (255)
- Surcharged < 15 min No Flooding (47)
- Surcharged > 15 min No Flooding (240)

## **Gravity Main HLoS**

- → A (311)

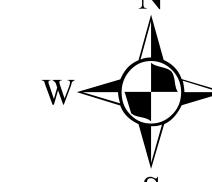
Future Landuse: 10-Year 24-Hour Chicago Design Storm 2070 RCP 4.5 IDF Hydraulic Level of Service Results

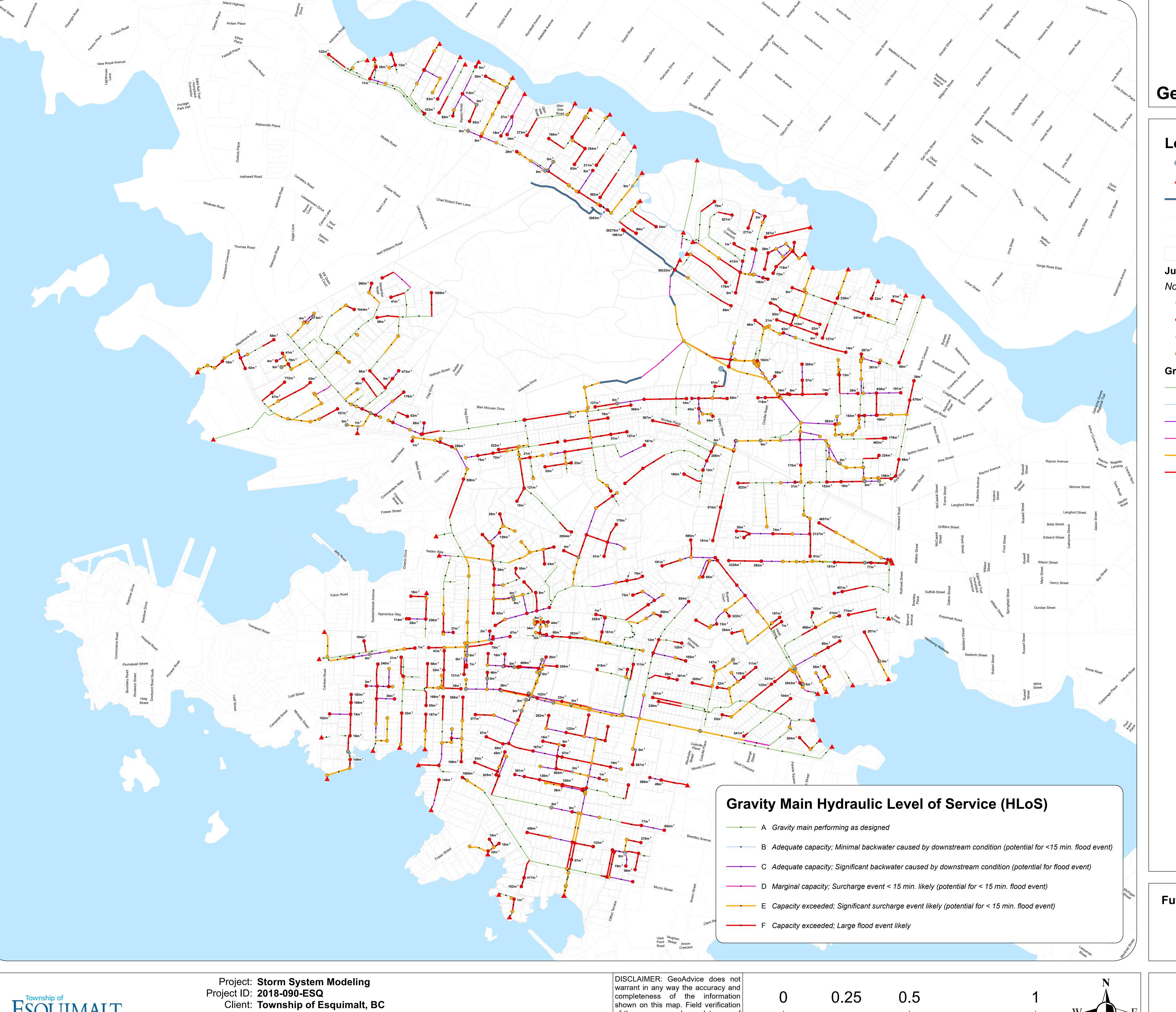


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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (61)
- Flooding > 15 min (405)
- Surcharged < 15 min No Flooding (2)
- Surcharged > 15 min No Flooding (322)

## **Gravity Main HLoS**

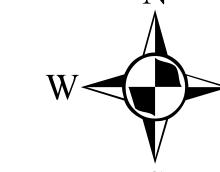
- → A (313)

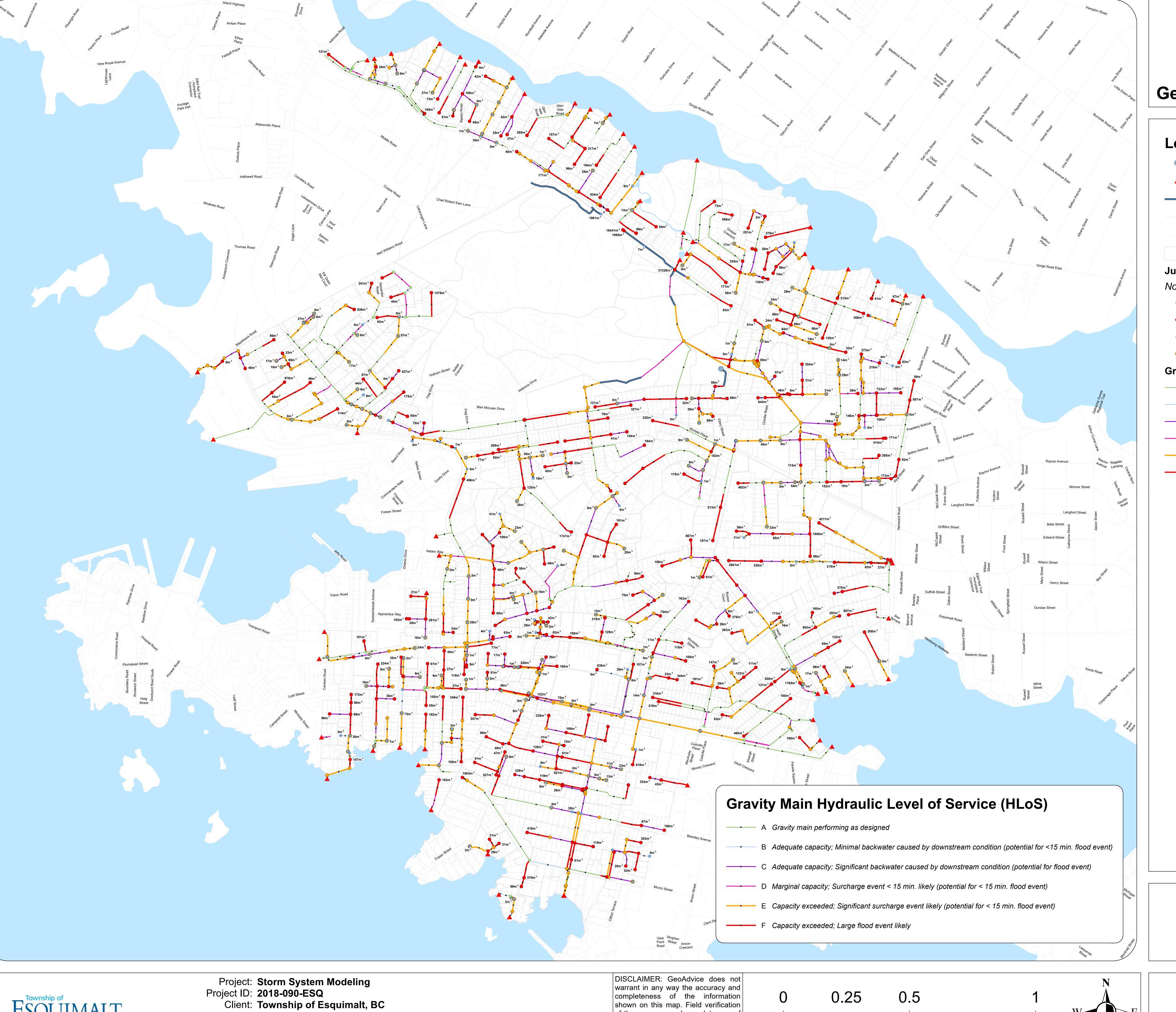
Future Landuse: 100-Year 24-Hour SCS-1A Design Storm 2070 RCP 4.5 IDF Hydraulic Level of Service Results

Date: October 2019

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Kilometers







- **Detention Pond**
- Outfall
- Road
- Contour (5 meter)
- Subcatchment

### **Junction**

Note: Predicted flood volume defined on map

- Flooding < 15 min (221)
- Flooding > 15 min (355)
- Surcharged < 15 min No Flooding (33)
- Surcharged > 15 min No Flooding (264)

## **Gravity Main HLoS**

- → A (230)

Future Landuse: 100-Year 24-Hour Chicago Design Storm 2070 RCP 4.5 IDF Hydraulic Level of Service Results



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of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

Kilometers

