Stormwater Master Plan

District of Hope

July 2022

Project No. 1239-271

ENGINEERING ■ PLANNING ■ URBAN DESIGN ■ LAND SURVEYING

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List of Acronyms

AES	Atmosphere Environmental Service
DEM	Digital Elevation Model
District	District of Hope
GCM	Global Circulation Model
GIS	Geographic Information System
ICI	Industrial, Commercial, and Institutional
IDF	Intensity-Duration-Frequency
IOCP	Integrated Official Community Plan
LiDAR	Light Detection and Ranging
PCIC	Pacific Climate Impacts Consortium
PCSWMM	Personal Computer Stormwater Management Model
SWMP	Stormwater Master Plan
TRUE	TRUE Consulting

Units of Measure

km	kilometre
L/d	Litres per day
L/s	Litres per second
lpcd	Litres per capita per day
m	metre
mg/L	milligrams per Litre
mm	millimetre
NTU	Nephelometric Turbidity Units
psi	pounds per square inch

Executive Summary

The Stormwater Master Plan (SWMP) has been produced by TRUE Consulting (TRUE) at request of the District of Hope (District) to provide description and evaluation of the stormwater conveyance systems within the District's boundaries.

Responsible stormwater planning must be recognized as an on-going and evolving process, instead of a singular static deliverable. This SWMP has been produced as a **living document.**

TRUE has utilized PCSWMM Professional to develop a working model of the District's watershed and conveyance systems. The results of modelled scenarios have been used to lead discussion on existing deficiencies in conveyance infrastructure, recommend areas where future deficiencies may develop with community growth, and identify where future data collection may be useful to expanding the detail and confidence of the model.

In November 2021, an atmospheric river event was experienced by the coast mountains around Hope and caused extensive flooding in the Coquihalla River. The November event was more than a 10-year 24hr rain event and was timely in that it provided a unique opportunity to calibrate the PCSWMM model to actual conditions as experienced during this event. Formal monitoring or recording infrastructure would provide opportunity to further calibrate the computational model.

The 2021 Census of Population data presents that Hope experienced a significant population increase between 2016 and 2021. This is beyond what was anticipated by the District of Hope Integrated Official Community Plan (IOCP) and is presently within the IOCP 2035-2040 range. Inadequate stormwater infrastructure with a growing population has the potential to exacerbate flooding and property damage from major rainstorm events. Several examples of vacant or under-utilized land areas are included in this report. Commentary and guidance is provided for the benefit of the District of Hope as to how to approach these land areas from a high-level stormwater management perspective as prospective development opportunities are brought forward by developers. Section 3.2 of the report will be a valuable resource for District staff when reviewing development applications.

The standard practice of using historical data to predict future events has been shown to be inadequate. As a result, incorporating climate change into predictions is becoming an increasingly important factor in the planning of stormwater management systems. The science of climate change progressed in recent years and there are now tools available to adapt historical rainfall data to account for various scenarios of climate change. By updating its Subdivision and Development Servicing Bylaw Design Criteria Manual to account for climate change, the District can reduce the risk of current development creating future impacts to the overall drainage system, including both public and private property. Additional improvements to the District's Design Criteria Manual are identified for consideration.

The computational model predicts that the municipal stormwater infrastructure generally performs adequately during the 10 year with climate change storm. This is confirmed when compared to anecdotal observations made during the November 2021 atmospheric river event.

As expected, during the 100 year with climate change storm, the minor system is generally overwhelmed by runoff in many areas and the major system is engaged. This typically begins with ponding of stormwater around catch basins and culverts. As the storm peaks, flooding and overland flow occurs. Major stormwater channels where runoff concentrates are overwhelmed, potentially resulting in road washouts, migrating streams, and property damage. Many of Hope's streets allow for the passive drainage of this excessive runoff but some low-lying areas have no overland flow path. These low-lying areas flood until the storm event diminishes and the stormwater infrastructure carries away the excessive runoff or infiltration occurs. It is important that the District recognize these trapped low areas as possible hazards in the review of development applications within the community. Flood hazard maps should be updated to include the findings of this study.

Several structural and non-structural recommendations are provided in this report. Non-structural recommendations include items such as bylaw development, bylaw update, maintenance practices and asset management. Structural recommendations include the identification of twelve prioritized capital projects to address known deficiencies within the District boundaries. Project sheets for each of the capital projects providing description and order of magnitude cost are provided within the report Appendices.

1.0 Introduction

The Stormwater Master Plan (SWMP) has been produced by TRUE Consulting (TRUE) at request of the District of Hope (District) to provide description and evaluation of the stormwater conveyance systems within the District's boundaries.

Responsible stormwater planning must be recognized as an on-going and evolving process, instead of a singular static deliverable. This SWMP has been produced as a **living document**. The purpose of this approach is that the report itself will not require replacement or superseding in the future, but rather, a continual on-going update as goals, resources, inputs, and regulations to it change. The content of this document is not intended to remain static.

TRUE has utilized PCSWMM Professional to develop a working model of the District's watershed and conveyance systems. At the time of writing, TRUE was not aware of any flow monitoring within the study area, as such, the model remains uncalibrated. However, this report will discuss the limitations of the calibration and present recommendations on validating the results.

Utilizing the PCSWMM model, TRUE has produced results for several design storm events in current day conditions and future estimated conditions. Current day conditions were evaluated using a combination of freely available provincial and federal datasets, topographic survey, and orthographic photography.

The results of the modelled scenarios have been used to lead discussion on existing deficiencies in conveyance infrastructure, recommend areas where future deficiencies may develop with community growth, and identify where future data collection may be useful to expanding the detail and confidence of the model.

1.1 Limitations

The scope of this study is limited to the conveyance of storm events through and over the District's developed boundary. This study does not look at the effects of flooding or backwater events related to the major water bodies within and surrounding the District such as the Fraser River, Silverhope Creek and the Coquihalla River. Those water bodies are the subject of various other related studies, some of which are discussed following.

Specific model limitations are noteworthy. These include:

1. The exclusion of minor drainage components of the District's stormwater management system. These minor drainage components are likely to have no impact on the modelling of major storms. Examples of these include residential driveway crossing, catch basins, and minor storm piping.
2. The limited inclusion of MOTI infrastructure impacting the District's watershed. It is assumed this infrastructure conveys flows across MOTI corridors but is not strictly modelled.
3. The exclusions of areas which do not include major stormwater management systems. This includes the Landstrom/Haig area North of the Fraser River, and the Airport/Floods area at the west end of the District.

As with any other computational model, the results are only as good as the inputs. The model and results are based on the District's current GIS database. As part of the work, some of the GIS elements have been updated with survey information and field confirmation. It will be recommended that the District make efforts to maintain the currency of their GIS database and periodically update the PCSWMM model to ensure that information used by community staff and leaders utilizes the most up-to-date information. The base information of any recommendations or projects as a result of this study should be field confirmed early in the implementation stages.

1.2 Background

This study aims to provide District staff with:

- Guidance while reviewing development proposals
- Identification of existing system deficiencies
- Understanding of challenges associated with population growth and climate change
- Illustration of the impact of climate change over time
- Recommendations for long-term upkeep and improvement of the related stormwater model and master plan

1.2.1 Integrated Official Community Plan

The District's Integrated Official Community Plan (IOCP) lays out goals, objectives, and policies for the growth and management of the community. Included in the IOCP are several statements and goals directly related to the development and upkeep of the SWMP. These statements are summarized here:

Goal 9: Hope has a healthy, dependable source of water and a community sanitary sewer and stormwater system that: is responsibly managed; and protects the natural environment

Policy 1.4.2: Where feasible, ensure that Urban/Suburban development provides for paved road access, management of stormwater, potable water supply, sanitary sewage collection and treatment, solid waste collection, street lighting, and underground utilities, in an ecologically responsible manner.

Policy 6.4.2: Encourage, where appropriate, the use of wetlands for stormwater detention or retention purposes.

Objective 9.7: To prevent impacts to water quality in creeks, stream, rivers, and other bodies of water that may receive stormwater discharge.

Policy 9.7.1: Identify drainage basins, necessary infrastructure improvements, capital costs, and environmental protection requirements.

Policy 9.7.2: Encourage new developments to incorporate stormwater management best practices that are appropriate for site conditions.

Policy 9.7.3: Ensure drainage to the ground is maintained at pre-development levels and flow paths are provided for major storm events that cannot be returned to the ground or accommodated by the storm sewer system. The storm sewer system should continue to be upgraded to reduce flooding potential.

Policy 9.7.4: Encourage the use of parks and open space for stormwater detention areas and conveyance corridors where space and programs permit.

Policy 9.7.5: Encourage the use of surface drainage systems as amenities or open space corridors.

Policy 9.7.6: Encourage the use of natural systems like wetlands to capture, slow down, store, filter, and infiltrate stormwater discharge in existing and new developments. Such systems should be design by a Qualified Professional with expertise in this field.

Policy 9.7.7: Encourage new subdivisions to include Integrated Stormwater Management Plans to mitigate the negative impacts of downstream runoff and discharge entering watercourse and streams.

Policy 9.7.8: Prepare a Stormwater Management Master Plan for the community to reduce negative impacts from direct discharge into rivers, creeks, and streams.

1.2.2 Subdivision and Development Servicing Bylaw and Design Criteria Manual

The District's Subdivision and Development Servicing Bylaw and Design Criteria Manual provides a thorough and comprehensive guidance for the handling of stormwater conveyance and detention in new developments within the District's jurisdiction. Analysis and recommendation performed in this SWMP have considered the guidance of the Design Criteria Manual, as well as provides recommended advancements of the same. The overall documentation as it relates to stormwater management is fairly comprehensive and includes most of the major topics considered in industry standard design. Notably missing from the Design Criteria Manual is discussion and inclusion of climate change, specifically in selecting and utilizing design storms for sizing infrastructure.

1.3 Previous Related Studies

The District and other related governing bodies have commissioned various studies related to the District's overall stormwater environment. Key conclusions from these reports are summarized in point form in the following sections.

1.3.1 East Kawkawa Lake

The East Kawkawa Lake Drainage Study was written in 1987 by Stanley Associates Engineering Ltd. for the Regional District of Fraser-Cheam.

The Regional District of Fraser-Cheam was dissolved and incorporated into the Fraser Valley Regional District in 1995.

- The study looked at flooding and erosion from Camilos Creek, east of Kawkawa Lake
- Concluded that "critical weather conditions" causes flooding of the alluvial fan where the residential community is built
- Concluded that culverts and stream channel capacities within lower alluvial fan can accommodate 2-year return flows
- Concluded that >2-year events will create flooding up to 1.5m
- Recommended redirection of Camilos Creek debris flows between Johnson and Kereluk roads (200-year return event)

1.3.2 Silverhope Creek Flood Hazard

The Silverhope Creek Flood Hazard Assessment was written in 1999 by Northwest Hydraulic Consultants for the District of Hope.

- Floods of the creek and surrounding area occurred in 1980, 1984, 1989, 1990, and 1995, all between November and February (winter)
- HEC-RAS model built to study backwater conditions
- Creek was estimated to convey 300cms before breaching its banks

1.3.3 Johnson Road Flood Hazard

The Johnson Road Flood Hazard Assessment was written in 2002 by Northwest Hydraulic Consultants for the District of Hope.

- Written in response to flooding caused by January and February rain-on-snow events
- Floods illustrated deficient capacity of culverts along Johnson Road
- Recommended upgrading the culverts along the road and below Kawkawa Lake Road and adding a sediment trap to reduce sediment accumulation in ditches.

1.3.4 Lower Coquihalla Flood Hazard

An assessment of the flooding hazard for the lower portion of the Coquihalla River through the District was begun in 2017 and reported to council in 2019 by LCI Engineering Consultants. This report discussed the potential impacts of flooding from the river. That report made recommendations on protecting riverbanks with the intention of protecting riverside lots.

An atmospheric river event occurred in Hope in November 2021 (see following section). Following that event that induced extreme flows in area streams and rivers, including the Coquihalla River, the District of Hope retained Ally Emergency Management Inc. to conduct an After Action Report. This report reviewed the timeline of events and actions that took place during the November storm and summarized the pros and cons of how the overall situation was handled. The report makes recommendations on which practices to retain, and which may need to be refined for future potential events.

1.4 2021 Flooding Events

In November 2021, an atmospheric river event was experienced by the coast mountains around Hope and caused extensive flooding in the Coquihalla River as well as the Coldwater and Tulameen Rivers

This event caused extensive damage in those watersheds, which is well covered in the media.

An atmospheric river is a band of warm, moisture-laden air many hundreds of kilometers long and hundreds of kilometers wide. The result of which can be extended periods of heavy rain fall

Specific to the District and this SWMP, the size of the November event and performance of the storm system is of particular interest. This section will review the event in the context of urban drainage rather than the flooding and damage caused by river processes.

The November event was more than a 10-year 24hr rain event. The major event spanned over two days (November 14th and 15th) for a total estimated rainfall of 275 mm. Later in the month (November 28th) another significant event occurred with a total rainfall of 115 mm. Table 1-1 summarizes the events while Figure 1-1 provides a graphical representation of the rainfall for the entire month of November.

TABLE 1-1: SUMMARY OF NOVEMBER 2021 RAINFALL EVENTS

Date	24-hour Rainfall	Return Period
November 14th, 2021	178 mm	50-year
November 15th, 2021	97 mm	2 to 5-year
November 28th, 2021	115 mm	5-year
November 30th, 2021	77 mm	2-year
December 1, 2021	66 mm	1 to 2-year

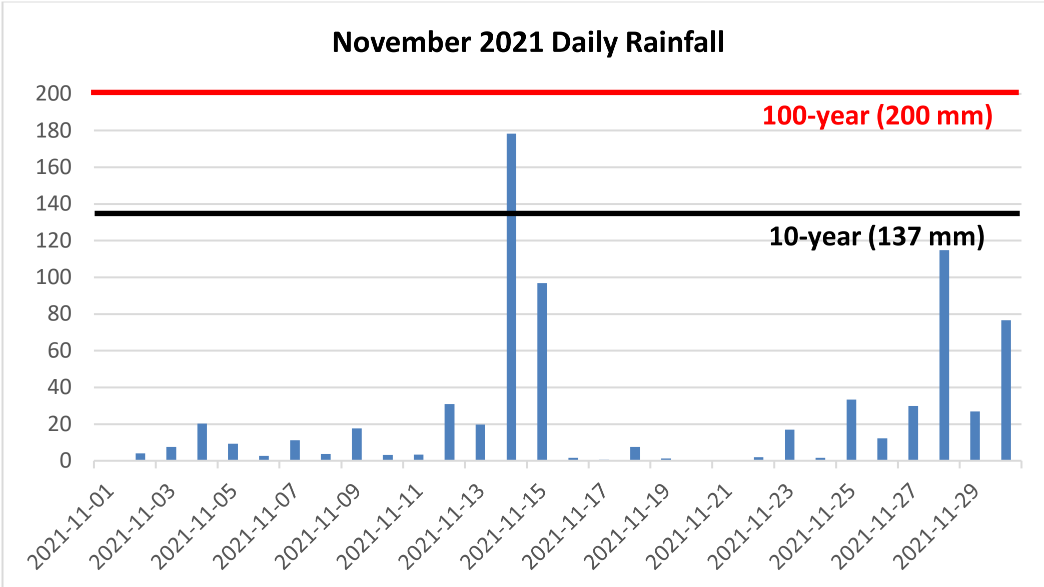


FIGURE 1-1: TOTAL DAILY RAINFALL IN NOVEMBER 2021

Under this significant event, the District's internal drainage system performed relatively well compared to the riverine impacts in the region. Figures A1 and A2 in Appendix A provides a general overview of the impacts and performance of the storm system. The figures also highlight areas of the District which saw minimal impacts with areas of no evidence of flooding or flooding area despite relatively large catchment areas.

The following points summarize the general performance aspects of the District's drainage system:

- The Kawkawa Lake residential area was the worst performing area with overtopping culverts, debris impacts and creek avulsion. The areas most impacted by this 2021 event are effectively the same as those areas reviewed in the *East Kawakawa Lake* Study (see previous section) and the *Jonson Road Flood Hazard* Study (see previous section).
- Kawakawa Lake had elevated water levels inducing minor impacts to property.
- Thacker Creek (Forrest Cres.) was at capacity and is suspected to have slightly overtopped with overland flows travelling down Glenaire Drive.
- Southern portions of Kettle Valley Rd experienced overland flows resulting in a partial road washout.
- Overland flows from Kettle Valley traveled to Dr Frost Rd contaminating a private well
- The Hope Creek Debris Basin filled and overtopped with overland flows travelling north on Highway 1/Water Ave.
- The urban core of Hope, with the most piped infrastructure, experience minimal flooding with no indications of surcharged sewers.
- Old Yale and Owl Rd did not see any signs of flow or flooding despite a large catchment from Hope Mountain.

1.5 Watershed

The District of Hope is located at the eastern end of the Fraser Valley, at the confluence of the Coquihalla and Fraser Rivers, amongst the steep slopes of the Coastal Mountain Range. Development of the District is generally focused to the lower areas adjacent to and south of the rivers, and near Lake Kawkawa, with outer limits boarding the slopes of the mountains. Areas of low development and agriculture exist north of the Fraser River, and at the west and east ends of the District boundaries.

The District is situated within the Pacific Maritime Ecozone, which is described as lying between the Pacific Ocean and the province's western mountain ranges. This bounding between ocean and mountains results in the characteristics of the zone being strongly influenced by the ocean.

The District's rainfall patterns are largely dictated by orographic conditions, in which airflows heavy with moisture from the ocean are forced to higher elevations by air currents, which are driven up by steep mountain slopes (see Figure 1-2). The result is extensive rainfall on the ocean-side of the mountains. At higher elevations, it is common for moisture to manifest as snowfall.

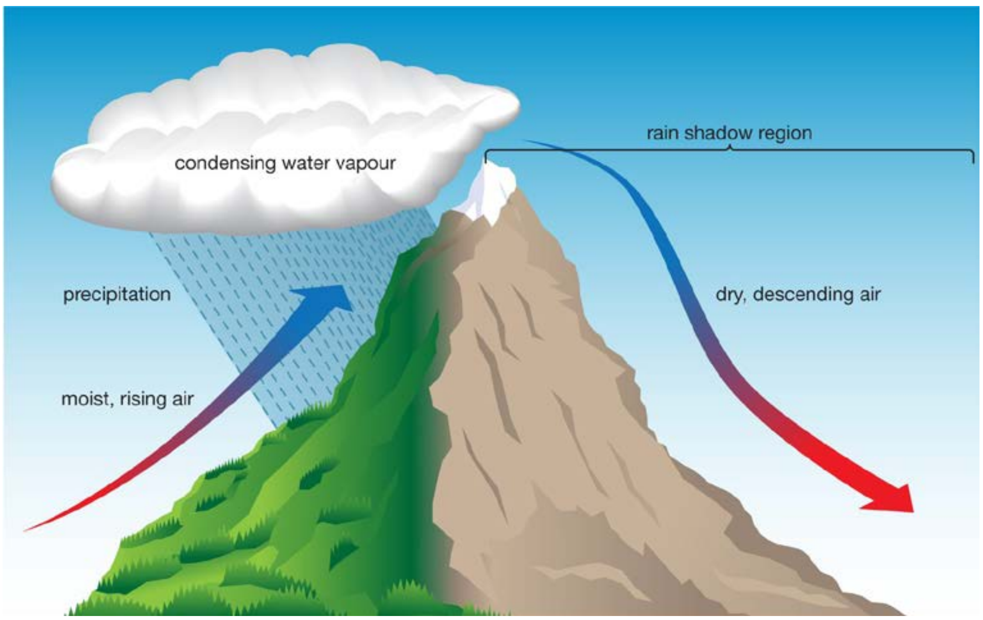


FIGURE 1-2: GRAPHICAL DESCRIPTION OF OROGRAPHIC RAINFALL

The persistent rainfall provided by the ocean and mountain bound conditions results in the District's watershed being occupied by dense vegetation.

The Coquihalla River flows into the Fraser River at the north end of the District's downtown area and continues west to the final terminus at in the Straight of Georgia. Many creeks and streams flow from the mountains, through the District, and terminate in the major rivers.

Stormwater from catchment areas in the mountains south and east of the District generally flow north and west overland until they are either discharged into water bodies or picked up by the District's conveyance infrastructure.

To the south of the District, along BC Highway #1, provincially owned infrastructure conveys flows from the south mountain catchments towards the District's downtown area.

Appendix B contains figures which show the major watercourses and major flow paths within the study area. The watercourse alignments have been updated from Provincial datasets based available LiDAR.

2.0 Hydrologic and Hydrologic Model

The analysis for the SWMP was performed with a computational model, built using PCSWMM Professional.

PCSWMM Professional is an industry-standard GIS-based computational software suite designed to handle all aspects of stormwater modelling, including catchment delineation and description, flow path determination, and design storm development. The “two-dimensional” aspect of the model describes the function of evaluating both overland flow and infiltration (the first dimension) and engineered collection and conveyance infrastructure (the second dimension).

The general development of the model, described herein, involves:

- Selection of calibration records
- Delineation of subcatchments
- Determination of subcatchment parameters
    - Impervious Area / Land use
    - Soil conditions
    - Slope
- Inputting Stormwater infrastructure
- Selection and development of design storms
    - Current and Future (Climate Change)

The model itself has been provided to the District on a USB drive with the original submission of this document.

2.1 Calibration Records

Monitoring of flow in key elements of the storm infrastructure and measurement of real-world storm events are crucial in calibrating a computational model. These measured variables provide a higher level of confidence to model developers and decision makers when reviewing the results of design storms intended to mimic future extreme events (such as 1-in-100 year storms).

The District does not currently have any monitoring or recording infrastructure to provide these variables for calibration. TRUE held discussions with District staff to collect anecdotal evidence of deficiencies (ponding, surcharging, etc) during past storm events. This evidence was used as approximate indicators of calibration during model development. Most notable and recent of these events was the November 2021 Atmospheric River. That event was used to produce a design storm (see later sections) and the results of which were found to be reasonably consistent with the anecdotal records of what occurred along with field review completed by TRUE.

2.2 Subcatchments

The study area for the model has been broken into 2618 subcatchments. Each subcatchment defines a localized area of stormwater collection that discharges to a single point via overland flow. Subcatchments are the basic building blocks of the model, to which attributes such as slope, vegetative cover, infiltration, etc., are applied.

2.2.1 Delineation

Subcatchments and overland flow paths are delineated from a high-resolution digital elevation model (DEM) using GIS software (see Figure 2-1). The DEM used for this study was obtained from the Government of Canada High Resolution Digital Elevation Model – CanElevation Series. This data set has been collected by the federal government over the series of several projects using airborne LiDAR equipment. The dataset provided gives a 1m² resolution for much of the study area. This data can be sourced here:

https://open.canada.ca/data/en/dataset/957782bf-847c-4644-a757-e383c0057995

Once delineated by the software, the resulting mapping of subcatchments was reviewed and manually adjusted to fill in holes and identify missing overland paths.

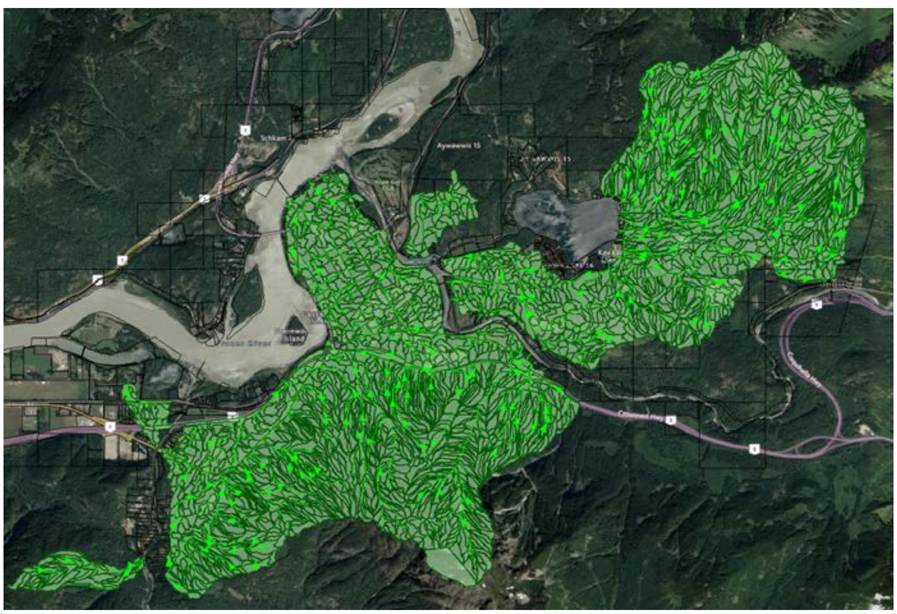


FIGURE 2-1: MODEL CATCHMENT AREA

Two areas are excluded from the model, including the Landstrom/Haig area North of the Fraser River, and the Airport/Floods area at the west end of the District as there is minimal drainage infrastructure in those regions and limited growth potential. The MOTI infrastructure impacting the District's stormwater management is also idealized. These limitations are further discussed in Section 1.1 above.

2.2.2 Soil parameters

Soils parameters are an attribute of subcatchments that defines how pervious areas handle overland flow. This data is typically sourced from the Government of BC Soil Mapping Data Packages. However, most of the Hope area soils have not been mapped by the Government of BC. Data is available for the Hope-Flood area and further westward along the Fraser Valley. This data presents that the valley soils are generally well drained sandy loam until the river begins to widen, 10-15km west of Hope. It is assumed that the soils in the Hope area are generally sandy loam.

2.2.3 Impervious Areas and Vegetative Cover

Determination of the percentage of area covered by impervious surfaces and vegetative cover impacts the nature of overland flow through subcatchments and is used by the model alongside soil parameters to determine properties for overland flow, storage, and infiltration.

A machine learning process was used within GIS software to evaluate high resolution orthographic imagery. This algorithm extracts building outlines, impervious areas (such as pavements), and identifies vegetative cover. A typical output of this algorithm is presented in Figure 2-2.

FIGURE 2-2: TYPICAL OUTPUT OF GIS SOFTWARE IMPERVIOUS AREA ALGORITHM – RED = IMPERVIOUS, GREEN = PERVIOUS

2.2.4 Land uses

Land use is used as an estimate of future subcatchment conditions, given growth of the community. The District's IOCP provides the framework for land use zoning.

Appendix C provides figures which show the Districts current IOCP land use designations.

2.3 Minor System

The minor system describes the built conveyance infrastructure, such as manhole, pipes, catchbasins, culverts, storage, infiltration, outfalls, etc. The entirety of this system was surveyed by TRUE in 2019. That survey aimed to collect the location of all manholes, along with photos, inverts, and pipe sizes. TRUE estimates that the survey was successful in picking up over 98% of existing manholes. District and TRUE construction records, as well as high resolution orthographic photos, were reviewed in comparison to the surveyed information to identify any missed information.

The District's built storm infrastructure consists of several hundred manholes, many hundred catchbasins, approximately 50 discharge locations (outfalls, rockpits, infiltration points), and nearly 37km of pipe of various size, material, and age.

Much of the District's built storm infrastructure was developed before incorporation, development guidelines, or engineering standards were enforced. As such, a large portion of the conveyance assets do not meet any level of industry standard for capacity, design, or materials of construction. Accounting for this, and the overall age of most assets, the District is carrying a considerable infrastructure deficit for the existing storm system. As noted in the 2016 Asset Management Investment Plan, written by Urban Systems Ltd, the District carried up to $6.5 million in storm system infrastructure deficit. TRUE notes that the District should be planning for the regular upkeep and renewal of all asset groups, budgeting for the total lifecycle costs.

Most of the infrastructure listed above is located within the downtown core and the neighborhood immediately to its north. Additional infrastructure is found within the newer neighborhoods bordering Kawkawa Lake Rd, between the Coquihalla River and Kawkawa Lake Park. Some infrastructure is found within the neighborhoods surrounding the Silverhope Rd and Flood Hope Rd intersection. The neighborhoods east of Kawkawa have the least amount of municipal stormwater infrastructure. As expected, the District of Hope's stormwater infrastructure is found where the land is well developed, populated, and flat.

Highways 1 and 3 contain culverts which are maintained by the MOTI. The location and physical properties of these culverts were gathered from the Ministry of Transportation (MOT) Culvert database accessed through BC iMap. This data can also be accessed here:

https://catalogue.data.gov.bc.ca/dataset/89d44ba6-7236-48ed-afab-f25a98c846ef

2.4 Growth Scenarios

The 2021 Census of Population data presents that Hope experienced an 8.2% population increase between 2016 and 2021 (see Figure 2-3). This is beyond what was anticipated by the District of Hope Integrated Official Community Plan (IOCP) and is presently within the IOCP 2035-2040 range. Inadequate stormwater infrastructure with a growing population has the potential to exacerbate flooding and property damage from major rainstorm events.

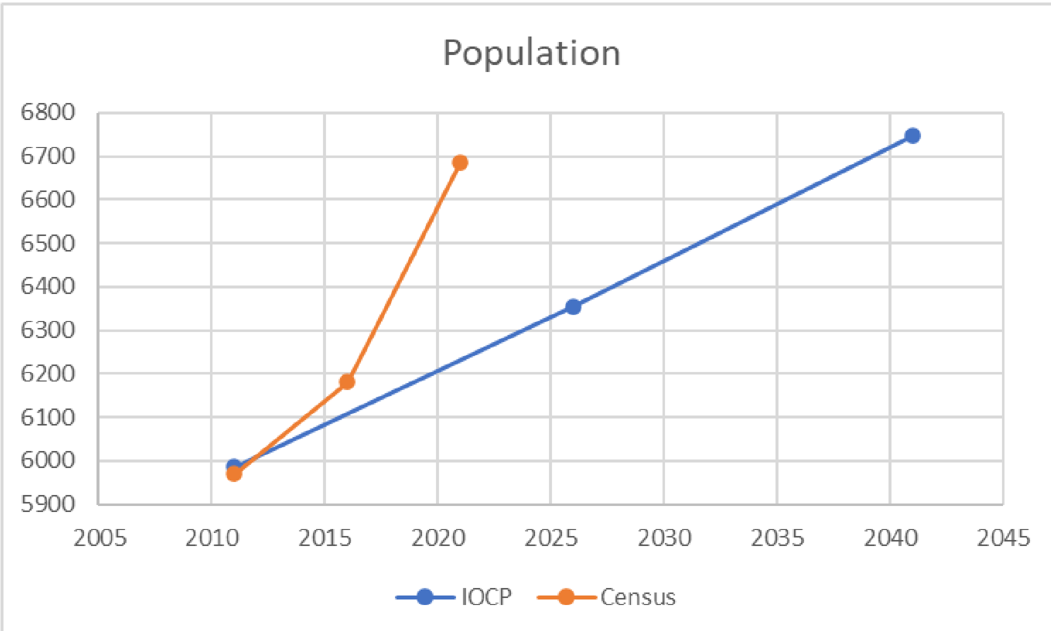


FIGURE 2-3: POPULATION BY GOVERNMENT OF CANADA CENSUS OF POPULATION AND DISTRICT OF HOPE INTEGRATED OFFICIAL COMMUNITY PLAN

2.5 Rainfall

Environment Canada monitors and records climate data throughout the country. This information is used to produce Intensity-Duration-Frequency (IDF) Curves. These curves provide the basis for design storms for return periods of 2, 5, 10, 25, 50, and 100 years.

Environment Canada produces a curve specifically for the District of Hope, as shown in Figure 2-4 below.

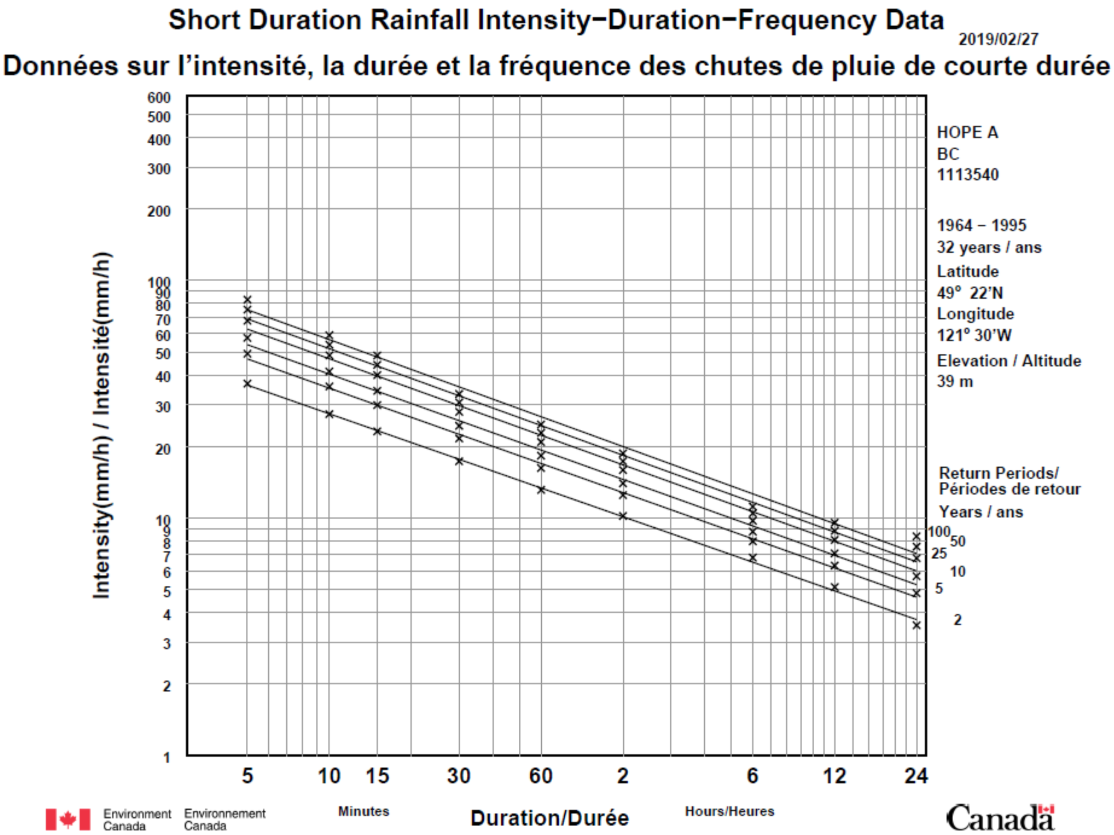


FIGURE 2-4: DISTRICT OF HOPE IDF CURVE FROM ENVIRONMENT CANADA

2.5.1 Climate Change

The natural limitation of IDF Curves is that they are only based on historic data. This use of historic data has been shown to inadequately predict future events, due to the effects of climate change. The science of climate change progressed in recent years and there are now tools available to adapt IDF curves to account for various scenarios of climate change.

For the purposes of this study, the results of two tools have been evaluated and utilized:

- IDF CC Tool: https://www.idf-cc-uwo.ca/
- IDF Temperature Scaling: https://climatedata.ca/resource/idf-curves-and-climate-change/

For both tools the highest emissions scenarios for Global Circulation Models (GCM) have been used generally referred to as SSP5.85 (Shared Socio-Economic Pathway). This climate scenario is characterized by rapid and fossil-fueled development with high socio-economic challenges to mitigation and low socio-economic challenges to adaptation.

The IDF_CC tool is designed as a simple and generic decision support system to generate local IDF curve information that accounts for the possible impacts of climate change. It applies a user-friendly GIS interface and provides precipitation accumulation depths for a variety of return periods (2, 5, 10, 25, 50 and 100 years) and durations (5, 10, 15 and 30 minutes and 1, 2, 6, 12 and 24 hours), and allows users to generate IDF curve information based on historical data, as well as future climate conditions that can inform infrastructure decisions. The tools utilize the outputs of multiple Global Circulation Models, precipitation data, and statistically downscales the data to user selected site.

IDF Temperature scaling provides a simple and robust way to update IDF curves for climate change. The capacity of air to hold moisture is governed by the Clausius-Clapeyron (CC) relation, approximately 7% per 1°C. The scaling method relies on the Clausius-Clapeyron moisture capacity-temperature relationship of air to project rainfall into the future using temperature outputs of climate models. For the Hope area the estimated increase in temperature by the end of the century is 5.2 °C.

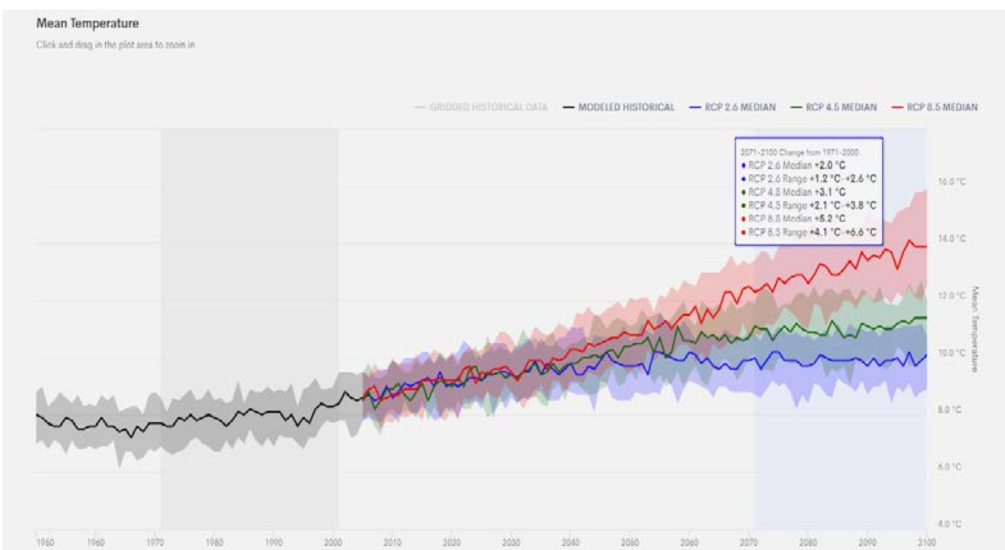


FIGURE 2-5: IDF TEMPERATURE SCALING OUTPUT

TABLE 2-1: SUMMARY OF RAINFALL INCREASES BY CLIMATE CHANGE PREDICTION METHOD

Method	10 – Year Storm		100 – Year Storm	
	Increase	Climate Adjusted 24hr Rainfall	Increase	Climate Adjusted 24hr Rainfall
IDF CC	+24%	170 mm	+40%	280 mm
Temperature Scaling	+42%	193 mm	+42%	284 mm

Table 2-1 summarizes estimate increase in rainfall based on the two tools. The two methods match very well for the 100-year storm while differ on the 10-year storm. The results of the IDF CC Tool were adopted for modelling purposes as this tool is more widely used and adopted in the BC context. The Temperature Scaling is a more simplified method and has been recently introduced but shows uncertainty in climate change modelling as the science continues to evolve.

Figure 2-6 shows the climate adjust values in relation to the November rainfall recorded at Hope airport rain gauge.

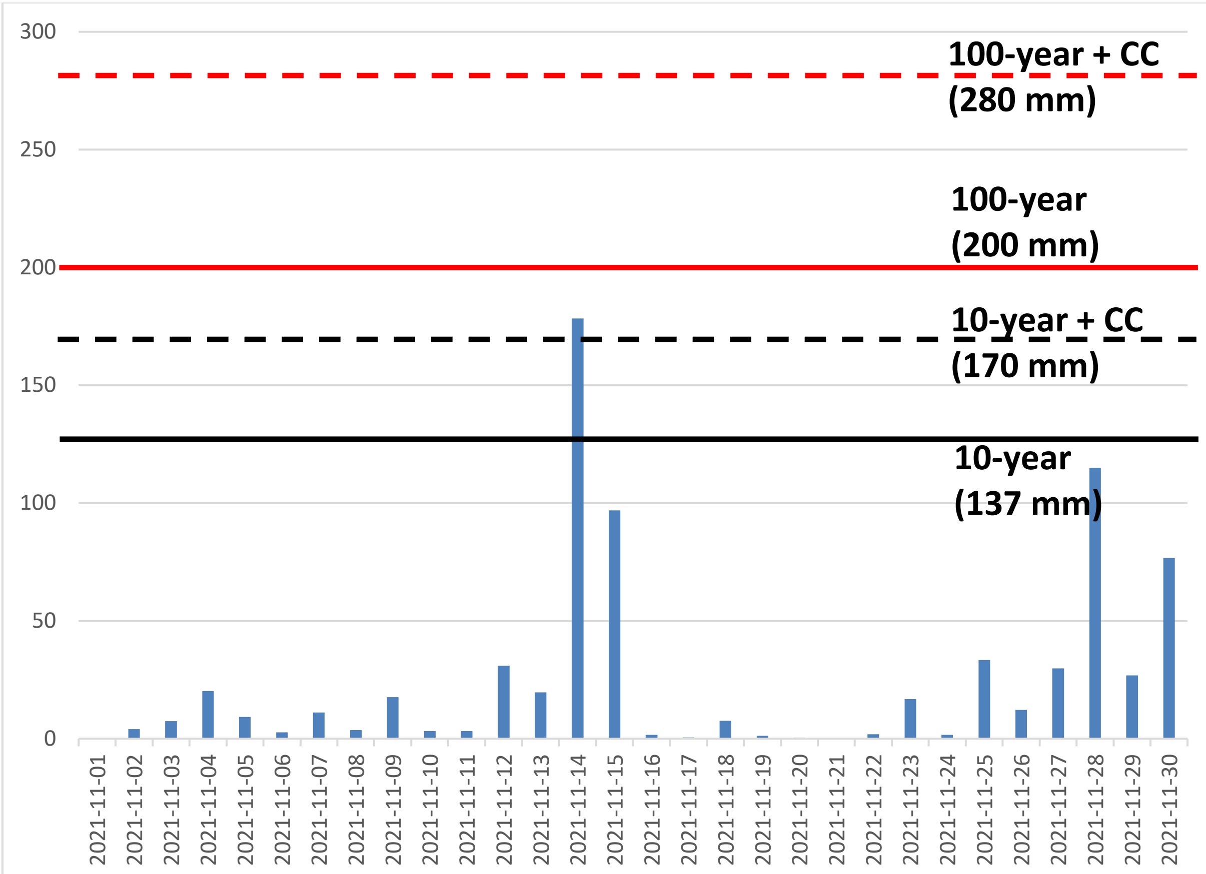


FIGURE 2-6: HOPE AREA NOVEMBER 2021 RAINFALL AND ESTIMATED CLIMATE CHANGE RAINFALL

Climate Change modelling for the region is indicating that both the frequency and magnitude of atmospheric events are going to increase. Essentially, the November event is going to become a relatively common occurrence that the District should expect.

2.5.2 Design Storms

Traditionally, the stormwater modelling in the Lower Mainland would use the SCS Type-IA rainfall distribution, which is primarily used for Northern pacific coastal areas of North America (NRCS, 1986). Other jurisdictions in the Lower Mainland have been finding the peak of the SCS 1A synthetic design storm too conservative and have been modifying/ decreasing the peak intensity.

The project modelling was first completed with the SCS 1A synthetic design storm. However, the preliminary results suggested widespread flooding would occur in areas of the District during a 10-Year Storm Event and the flooding was exacerbated when the impacts of climate change were included. However, during the November event many parts of the District performed relatively well (particularly the urban core) and there has not been a history of surcharged infrastructure except for select locations.

In comparison, the modelling of the recorded November storm, adjusted for climate change, provides a conservative, yet more reasonable result, in the opinion of TRUE. The November atmospheric river was in the order of a 10-year-24hr event (climate adjusted). This storm event had a lower peak than the traditional SCS Type 1A storm and instead prolonged heavy rainfall for longer. This storm event was observed locally, whereas the SCS Type 1A is a regional generalization. It is believed that the November storm rainfall distribution is likely the best available representation of major storm events for the District of Hope and will be used for the basis of this modelling exercise.

A hyetograph is a graphical representation of the distribution of rainfall intensity over time.

For design and analysis purposes, the peak of this recorded local storm hyetograph was increased by 20% to improve the conservativeness of the model. Figure 2-7 presents this modified storm profile applied to the predicted 10-year + climate change storm event alongside the traditional 10-year + climate change SCS Type 1A storm.

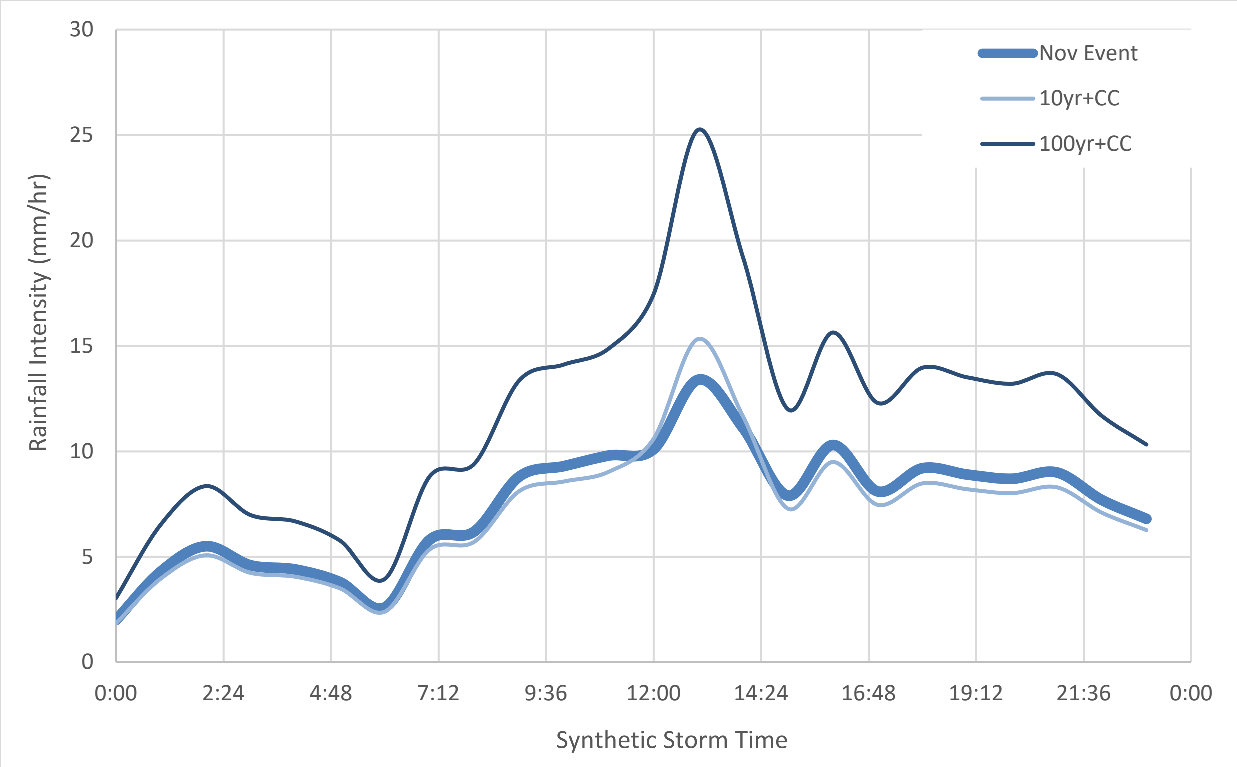


FIGURE 2-7: OBSERVED NOVEMBER 2021 HYETOGRAPH, APPLIED TO 10YEAR + CC STORM, COMPARED WITH 10YR+CC SCS TYPE 1A STORM

The November based design storm provides an overall higher average flowrate over a longer period. The general result of using the November based design storm is a longer period required to overwhelm the drainage systems, followed by a longer period during which those systems are fully utilized. The use of this design storm more closely reflects what TRUE suggests to be a more likely long-term, and practical design event.

The November 2021 storm data is the most current available data. However, as climate change occurs, the impact on future storms will be better understood. Therefore, it would be prudent to re-assess this design storm's validity following major storm events such as the one in November 2021. At the very minimum, this validity must be reassessed during the preliminary or detailed design process of major stormwater infrastructure upgrades.

3.0 Results

The following are presented and discussed within this section:

- Model Results during 10 year and 100 year return events.
- Proposed System Upgrades to Manage 10 year and 100 year return events.
- Future Development Considerations with regional and site specific recommendations.

3.1 Model Scenarios

Existing infrastructure was modelled in PCSWMM and the effects of a 10 year with climate change and 100 year with climate change storm were simulated. All culverts were modelled as clean, although the field review noted culverts with 10 – 50% debris. Results from both modelled storm events are presented with potential mitigation projects and costs within Appendix H Project Sheets.

3.1.1 10 Year Return Event (Including Climate Change)

The municipal stormwater infrastructure generally performs adequately during the 10 year with climate change storm. As the simulated storm applied the modified November 2021 rainfall distribution with a similar total rainfall, model flooding results are consistent with what was observed during the November 2021 storm event. Figures for the10-year scenario can be found in Appendix D.

Notable results include:

1. Flooding of Kawkawa Lake Rd. crossing at 66657 Kawkawa Lake Rd.
2. Flooding of Kawkawa Lake Rd. crossing at 66597 Kawkawa Lake Rd.
3. Flooding of Thacker Creek along Forrest Cres.
4. Flooding at 65617 Kawkawa Lake Rd.

Beyond the areas identified above, the figures present other piped system components that are technically overcapacity. However, the resulting surcharge is not significant which rarely surcharges to surface and generally perform adequately and do not require specific upgrades.

3.1.2 100 Year Return Event (Including Climate Change)

As expected, the minor system (pipes and catchbasins) is generally overwhelmed by runoff in many areas and the major system (overland flow and major culverts) is engaged. This typically begins with ponding of stormwater around catch basins and culverts. As the storm peaks, flooding and overland flow occurs. Figures for the 100-year scenario can be found in Appendix E.

Major stormwater channels where runoff concentrates are overwhelmed, potentially resulting in road washouts, migrating streams, and property damage.

Notable results of overwhelmed stormwater infrastructure during the 100-year event include:

1. Intersection of Kawkawa Lake Rd. and Johnson Rd.
2. Kawkawa Lake Rd. crossing at 66657 Kawkawa Lake Rd.
3. Kawkawa Lake Rd. crossing at 66597 Kawkawa Lake Rd.
4. Thacker Creek along Forrest Cres.
5. Kettle Valley Rd. crossing, 250m South of Kawkawa Lake Rd.

Many of Hope's streets allow for the passive drainage of this excessive runoff but some low-lying areas have no overland flow path. These low-lying areas flood until the storm event diminishes and the stormwater infrastructure carries away the excessive runoff or infiltration occurs.

Notable results of flooding due to insufficient or no defined overland drainage:

1. Flooding at 65617 Kawkawa Lake Rd.
2. Flooding of low lying area along Coquihalla St.
3. Potential flooding flooding of low lying area east of Owl St.

District of Hope infrastructure interfaces with MOTI infrastructure along HWY 1 and HWY 3 in several locations. Notable flooding of these interfaces includes:

1. Storage between HWY 3 eastbound and westbound lanes, 500m east of HWY 1 overpass.
2. Storage south of HWY 3 eastbound lanes, 200m west of HWY 1/Flood Hope Road exit.
3. Intersection of HWY 1/Flood Hope Road Exit and HWY 1/Flood Hope Road.
4. Potential Flooding Of Thacker Creek at HWY3.

3.2 Future Development Considerations

The recent census data suggests the District of Hope is undergoing a rapid growth period. Poor stormwater planning may exacerbate problems already experienced or create new ones. This section identifies large land areas that are presently vacant or under-utilized and for which development may have impact on adjacent lands. Typical impacts on stormwater caused by development along with a discussion of potential mitigation strategies is presented. Several examples are discussed to highlight the site specific or regional stormwater challenges and potential design solutions.

3.2.1 Development Impact on Stormwater

Development typically increases the runoff from the land by adding impervious surfaces. The District's bylaws and design guidelines require developments to match pre- to post- runoff performance by the application of communal and private onsite infiltration structures.

Some areas within the District contain existing depressions which trap and infiltrate stormwater runoff. These areas should be protected by the District and accommodated for during development. Trap low storage designs trap and infiltration water to reduce post-development stormwater runoff. The recently developed service station along Flood Hope Rd. is a good example of applying trap low storage design at site containing existing depressions. This depression flooded following the November/December 2021 events, but the flooded area appears to be limited to the south end of the parking lot, while the site buildings remained safely above the ponding water (see Figure 3-1).

FIGURE 3-1: FLOODED SOUTH END OF FLOOD HOPE RD SERVICE CENTER., DECEMBER 3RD, 2021

Ideal trap low storage can retain and infiltrate runoff from minor and major storm events. However, trap storage generally accommodates minor events well and can be overwhelmed during major storms. This flooding stormwater must be carried away from buildings to prevent damage. Therefore, a safe overland flow route is necessary in the event trap low storage is overwhelmed.

Properly constructed roadways and ditches convey stormwater away from structures even while flooded. This is often not appreciated by the public and privately owned ditches are often undesirable by the homeowner. These unfortunately suffer encroachment by retaining walls, driveways, alleyway, and other private structures. Maintaining privately owned overland flow routes within urban/suburban residential and ICI is made more difficult as the routes may span across two, or several, privately owned properties (see Figure 3-2). This highlights the importance of maintaining overland flow routes within the control of the District.

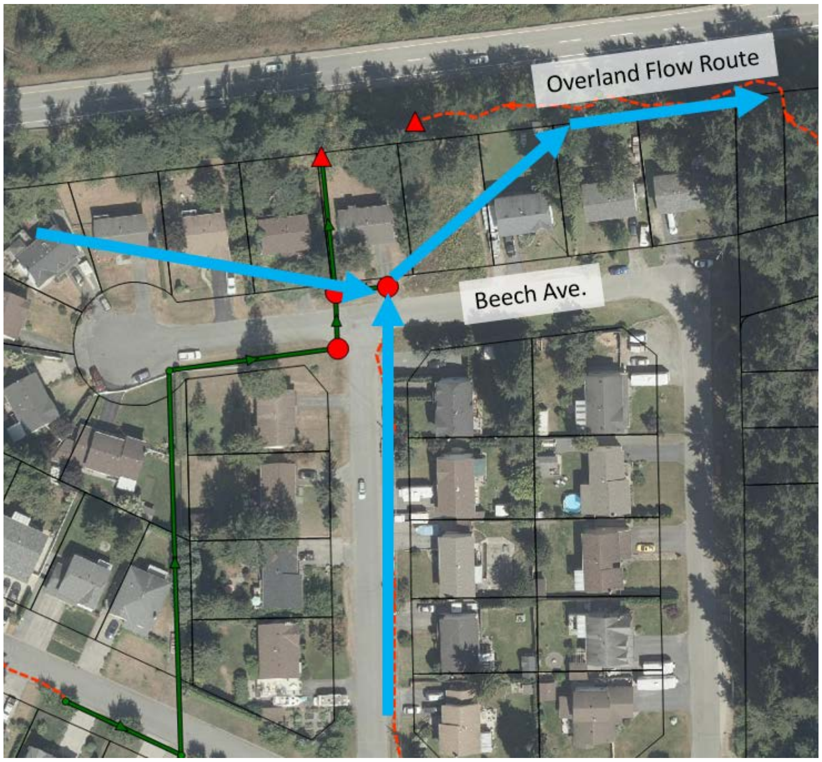


FIGURE 3-2: SUBURB OVERLAND FLOW THROUGH PRIVATE RESIDENTIAL LOTS ALONG BEECH AVE.

The most sustainable and economical way to maintain overland flow routes within the control of the District is to require the routes be part of roadway rights-of-way or park land/recreationally designated lots. The District's Integrated Official Community Plan Policy 9.7.3 identifies that overland flow paths must be provided for major storms. It is recommended that, at the subdivision stage of development, the District require the proponent to identify the proposed overland flow routes with sufficient capacity for major storm events that are outside private property and within the District control.

3.2.2 Urban/Suburban Residential and Country Residential

This section includes several examples of large vacant land areas that are zoned for residential development in order to highlight the site specific or regional stormwater challenges and discuss potential design solutions. This section should be referenced during design reviews of prospective land development projects and can be communicated to landowners early in the development process. Only examples which are sufficiently large are included. Within the included figures below, the subject area is highlighted in blue, while critical existing depression storage areas are cross hatched and outlined in black.

3.2.2.1 21392 Union Bar Rd, Vacant Lot East of Kettle Valley Rd

The vacant lot east of Kettle Valley Rd. with PID 011-015-446 is identified as Urban/Suburban Residential in the OCP (see Figure 3-3). This area does not receive stormwater from the surrounding lots and presently drains to the north into Kawkawa Lake or Sucker Creek, or west onto Kettle Valley Rd. Available Lidar data presents that there are no large depressions within the lot. Development proponents should be made to prove that overland flow routes exist and have capacity to convey runoff to the existing discharge points during major storm events. Development proponents should also be encouraged to redirect drainage to the north and into Sucker Creek where possible.

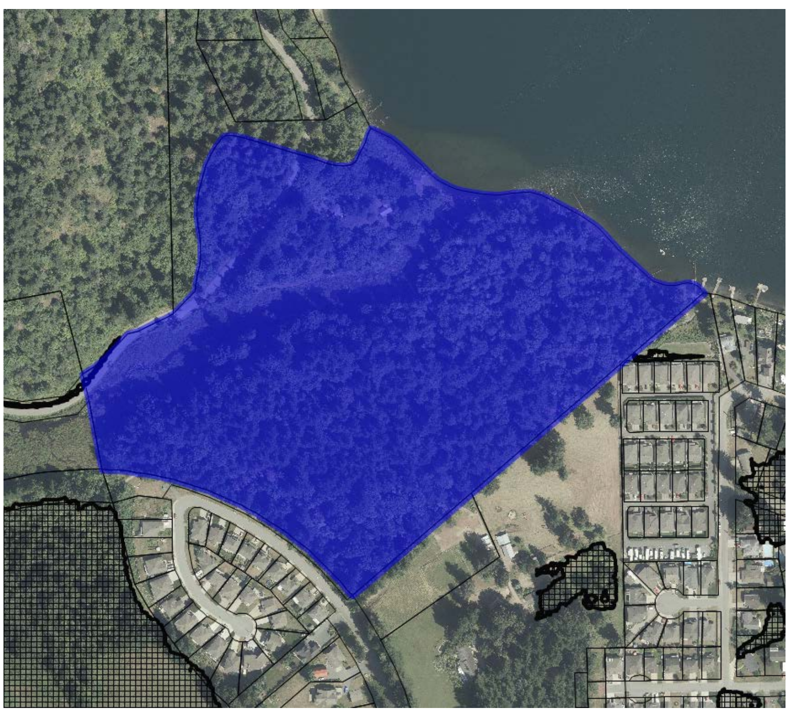


FIGURE 3-3: 21392 UNION BAR RD. (PID 011-015-446)

3.2.2.2 20600 Riverview Dr., Vacant Lot at South end of Riverview Dr

The vacant lot at the south end of Riverview Dr. with PID 001-502-883 is identified as Urban/Suburban Residential in the OCP (see Figure 3-4). This area receives a marginal amount of stormwater from the small lots to it's northeast. It presently drains to the northwest into the Coquihalla River. Available Lidar data presents that there is only a minor depression in this area (0.2 hectares). Appropriate drainage design could likely prevent major storm events from causing damage to structures within this existing depression. Development proponents should be made to prove that overland flow routes exist and have capacity to convey runoff to the existing discharge points during major storm events. The proponents would also need to show how the structures within this depression area would not be affected by flooding.

FIGURE 3-4: 20600 RIVERVIEW DR., (PID 001-502-883)

3.2.2.3 20935 Park St., Vacant Municipal Lot South of Golf Course Rd.

The vacant municipally owned lot south of Golf Course Rd. with PID 023-676-248 is identified as Urban/Suburban Residential in the OCP (see Figure 3-5). This area receives stormwater from 8 hectares of urban/suburban development to the south along 7th Avenue. It presently drains to the northeast into the Coquihalla River. Available Lidar data presents that there is a 1.2 hectare depression in this area which is primarily within this municipal lot. This depression is likely filled during a major storm event. Some of this depressed area is only marginally above the adjacent Coquihalla, and therefore draining the lot by ditching could expose it to flooding during high river water periods. If the District of Hope intends to develop this municipal property, the existing stormwater mains draining 7th Avenue may need to be upgraded. Additional preliminary design would also be needed to fully understand the risks presented by modifying the existing stormwater storage and creating overland drainage to the Coquihalla River.

FIGURE 3-5: 20935 PARK ST., (PID 023-676-248)

3.2.2.4 21176 Kettle Valley Rd., Lot East of Kettle Valley Rd

The lot east of Kettle Valley Rd. with PID 001-643-177, is identified as Urban/Suburban Residential in the OCP (see Figure 3-6). This area receives a marginal amount of stormwater from the small lots to it's northeast. It presently drains to the north towards Kawkawa Lake, or west onto Kettle Valley Rd. Available Lidar data presents that there is small depression in this area (0.3 hectares). Development proponents should be made to prove that overland flow routes exist and have capacity to convey runoff to the existing discharge points during major storm events. The proponent would also need to show how structures within this depression area would not be affected by flooding. The proponent should be encouraged to provide overland drainage northward, through the adjacent lot with the owner's permission, into Kawkawa Lake. This would help reduce the overland flow along Kettle Valley Rd. during major storm events.

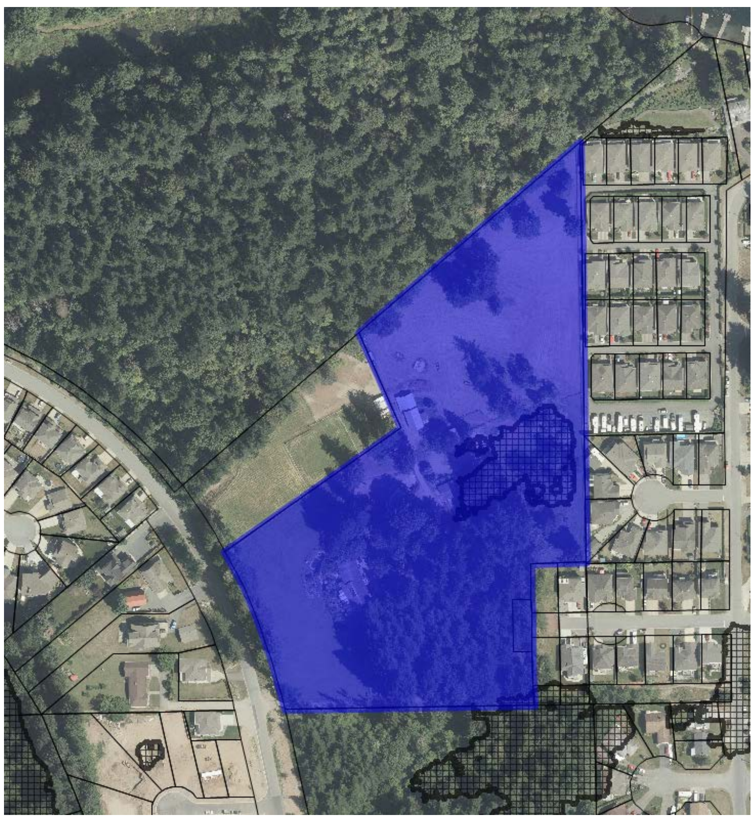


FIGURE 3-6: 21176 KETTLE VALLEY RD., (PID 001-643-177)

3.2.2.5 65823 Kawkawa Lake Rd., Municipal Lot East of Kettle Valley Rd

The vacant municipal lot east of Kettle Valley Rd. with PID 010-363-769 is identified as Urban/Suburban Residential and Parks, Recreation and Open Space in the OCP (see Figure 3-7). This area receives stormwater from 3 hectares of urban/suburban development to the east within the Lakeview Cres. area. It presently drains to the northwest along Kettle Valley Rd. and ultimately into the Coquihalla River. Available Lidar data presents that there is a 0.7 hectare depression in this area which is primarily within this municipal lot. If the District of Hope intends to develop this municipal property, the overland drainage from the Lakeview Cres. area will need to be accommodated. Additional preliminary design would also be needed to fully understand the risk presented by modifying the existing stormwater storage.

FIGURE 3-7: 65823 KAWKAWA LAKE RD., (PID 010-363-769)

3.2.2.6 65617 Kawkawa Lake Rd., Vacant Lot North of Kawkawa Lake Rd.

The vacant lot north of Kawkawa Lake Rd. with PID 002-858-959 is identified as Urban/Suburban Residential in the OCP (see Figure 3-8). This area receives stormwater from approximately 55 hectares of land and presently has no clear drainage outlet. Available Lidar data presents that there is a large 13 hectare depression, most of which is located within this lot. This depression likely detains and infiltrates runoff from major storms. Development proponents should be made to prove that overland flow routes exist or establish drainage with capacity to convey runoff to Sucker Creek during major storm events. The proponents would also need to show how structures within this depression area would not be affected by flooding. Potentially some of this lot is undevelopable as a result of this large depression.

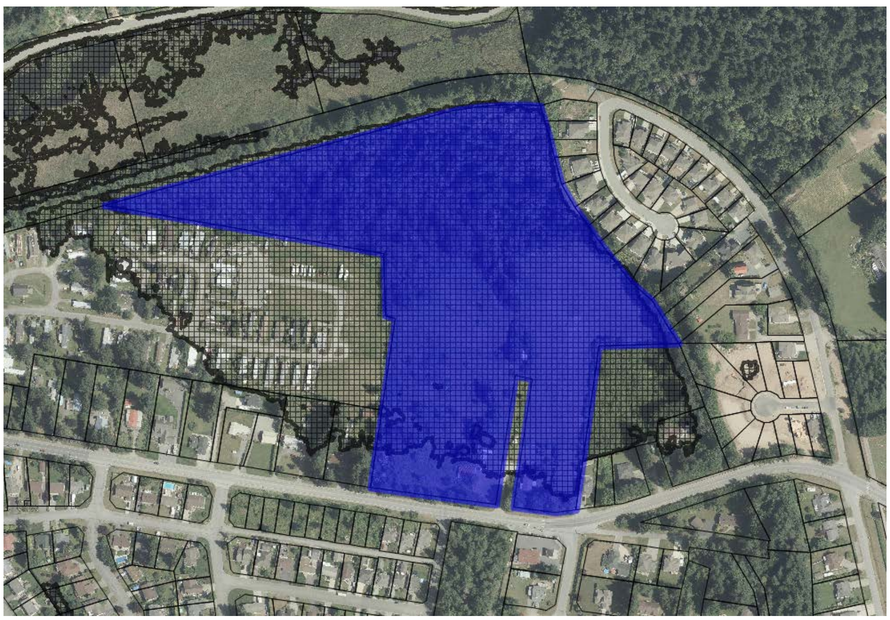


FIGURE 3-8: 65617 KAWKAWA LAKE RD, (PID 002-858-959)

3.2.2.7 66657 Kawkawa Lake Rd., Lot Spanning of Kawkawa Lake Rd

The lot spanning Kawkawa Lake Rd. with PID 010-433-775 is identified as Urban/Suburban Residential in the OCP (see Figure 3-9). This area receives stormwater from over 200 hectares of land to the east and the Camilos Creek flows through it. The lot presently drains eastward through the Kawkawa Lake Rd. by an undersized culvert crossing and then reaches the lakeshore by a private channel. This creek broke it's banks east of Kawkawa Lake Rd. and attempted to realign itself during the November 2021 major storm event. The high flows experienced by this creek have the potential to quickly convey debris, which could result in the creek realigning itself again. Careful attention must be paid to this debris flow hazard and the stormwater capacity of this creek. Development proponents should be made to prove how they will protect this overland flow route and appropriately accommodate drainage through this area. The District should also require any development proponents surrender the creek along with a reasonable setback to allow expansion and prevent encroachment. A section of this lot is assigned the high to severe flood hazard rating caution within the IOCP Hazard Mapping and may be undevelopable.

FIGURE 3-9: 66657 KAWKAWA LAKE RD., (PID 010-433-775)

3.2.2.8 66556 Kawkawa Lake Rd., Lot East of Kawkawa Lake Rd

The lot east of Kawkawa Lake Rd. with PID 030-485-851 is identified as Urban/Suburban Residential in the OCP (see Figure 3-10). This area receives stormwater from over 80 hectares of land to the east and the Sucker Creek flows through it. The lot presently drains eastward through the Kawkawa Lake Rd. at an undersized culvert crossing. Careful attention must be paid to the stormwater capacity of this creek. Development proponents should be made to prove how they will protect this overland flow route and appropriately accommodate drainage through this area. A section of this lot is assigned the moderate to high flood hazard rating caution within the IOCP Hazard Mapping and may be undevelopable.

FIGURE 3-10: 66556 KAWKAWA LAKE RD., (PID 030-485-851)

3.2.2.9 65936 Kawkawa Lake Rd., Lot South of Kawkawa Lake Rd.

The lot south of Kawkawa Lake Rd. with PID 010-353-548 is identifies as Urban/Suburban Residential in the OCP (see Figure 3-11). This lot does not receive stormwater from the surrounding area. Some of the lot drains to the north into the Kawkawa Lakeview Crescent subdivision while some drains into the vacant municipal lot with PID 001-643-117. Available Lidar data presents that there are no large depressions within the lot. Development proponents should be made to prove that downstream overland flow routes can accommodate this lot's runoff.

FIGURE 3-11: 65936 KAWKAWA LAKE RD., (PID 010-363-548)

3.2.2.10 64295 Flood Hope Rd., Vacant Lot North of Flood Hope Rd.

The vacant lot north of Flood Hope Rd. with PID 014-646-986 is identified as Urban/Suburban Residential (see Figure 3-12). This lot does not receive stormwater from the surrounding area. This lot drains in all directions as the highest point is near the center of the lot. Available Lidar data presents that this lot borders a 4.6 hectare depression along HWY 3 to the north. Development proponents should be made to prove how they will protect this depression area from encroachment. They would also need to prove how structures nearby to this depressed area will be protected from flooding. Proponents should be encouraged to redirect drainage northward towards the large existing depression.

FIGURE 3-12: 64295 FLOOD HOPE RD., (PID 014-646-986)

3.2.2.11 20060 Hockin Rd., Vacant Lot North of Flood Hope Rd.

The lot north of Flood Hope Rd. with PID 010-320-512 is identified as Urban/Suburban Residential (see Figure 3-13). This lot receives stormwater from over 90 hectares of land to the south. This lot generally drains northward. Available Lidar data presents that this lot borders a 4.6 hectare depression along HWY 3 to the north, approximately 0.5 hectares of which is within the lot. Development proponents should be made to prove how they will protect the overland flow route for the 90 hectares upstream and this large depression from encroachment. They would also need to prove how structures within the depressed area will be protected from flooding. Proponents should be encouraged to accommodate potential drainage infrastructure across Flood Hope Rd., which would convey runoff northward through the property, and into the large existing depression.

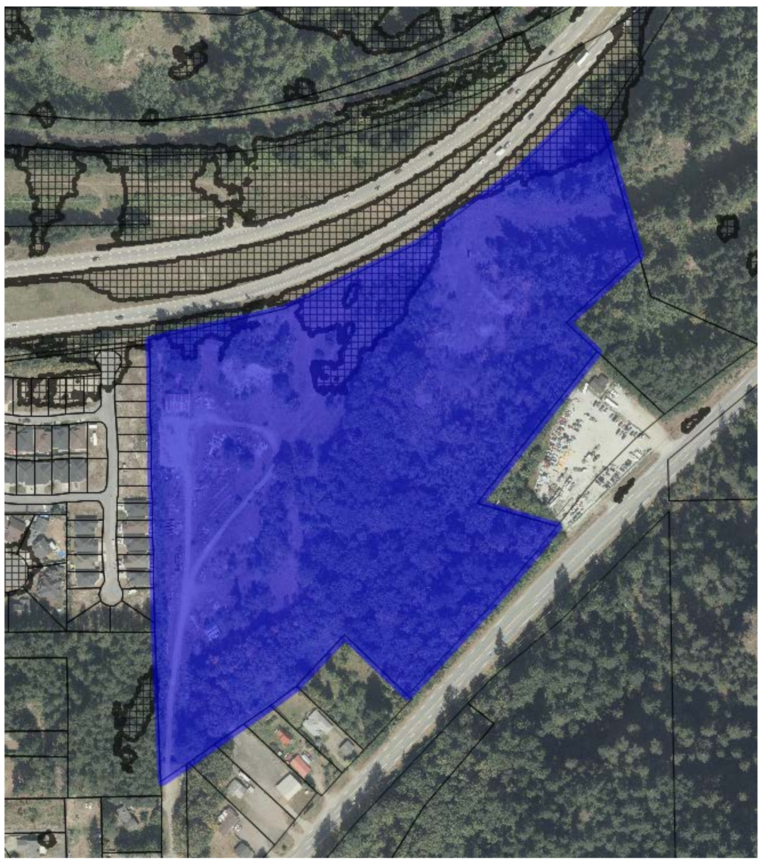


FIGURE 3-13: 20060 HOCKIN RD., (PID 010-320-512)

3.2.2.12 Lots South of Tum Tum Rd.

The lots at the south end of Tum Tum Rd. are identified as Urban/Suburban Residential and Limited Use in the OCP (see Figure 3-14). The southeast corners of these properties are designed as Limited Use and contain a drainage gulley that receive runoff from over 80 hectares of land. This existing gulley will need to be protected from development. Available Lidar data presents that there is also a depression within the lots. These lots generally drain toward the north/northeast or westward. Careful attention must be paid to the stormwater capacity of this gulley. Development proponents should be made to prove how they would protect this gulley from encroachment as well as any structures within the depression area from flooding damage.

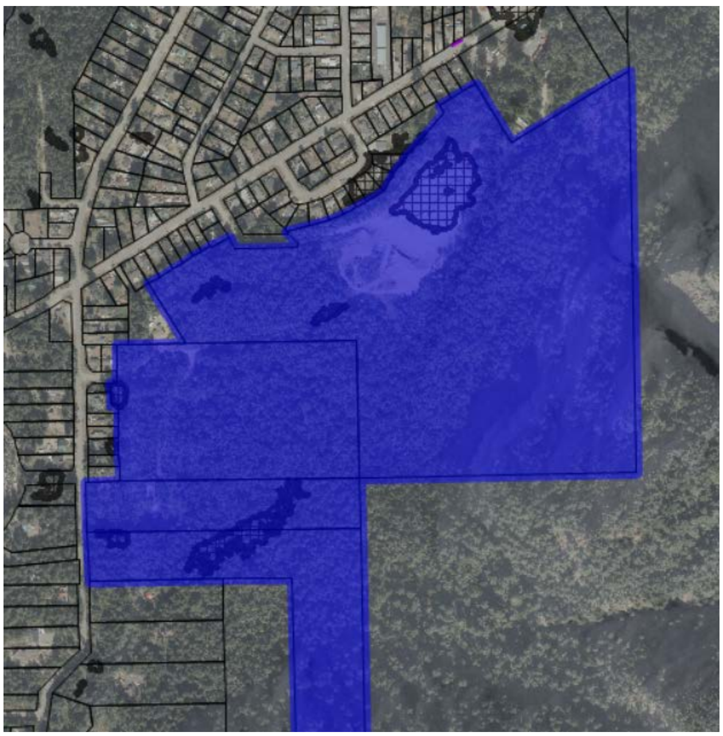


FIGURE 3-14: 4.3.2.12: LOTS SOUTH OF TUM TUM RD.

3.2.2.13 1275 7th Ave., Vacant Lot North of Hospital

The vacant lot east of 7th Ave, with PID 001-891-740 is identified as Urban/Suburban Residential in the OCP (see Figure 3-15). This lot does not receive runoff from adjacent properties and generally drains to 7th Ave or to the northeast towards the Coquihalla through an undeveloped municipal park lot. Available Lidar data presents that there are no large depressions within the lot. The lot is generally flat so the development proponent should be encouraged to apply trap low storage design to eliminate runoff during minor and major storm events. Development proponents should be made to prove that downstream overland flow routes can accommodate any runoff.

FIGURE 3-15: 1275 7TH AVE., (PID 001-891-740)

3.2.2.14 Vacant Lots East of Kettle Valley Rd. and South of Kawkawa Lake Rd.

The vacant lots east of Kettle Valley Rd. and South of Kawkawa Lake Road are identified as Country Residential or Urban/Suburban (see Figure 3-16). These lots generally receive runoff from the lots to their immediate east and drain westward. Lidar data presents that there are no large depressions within the lot but several minor depressions. The District should consider requiring the developer to require a comprehensive neighborhood plan with drainage to the south. This approach would redirect stormwater directly to the Coquihalla River and away from the Kawkawa Lake Rd./Kettle Valley Rd. area. The Development proponents should be made to prove that overland flow routes are provided which can accommodate the existing overland flows. They should also be required to maintain the depressed areas or equivalent to limit the impact of development.

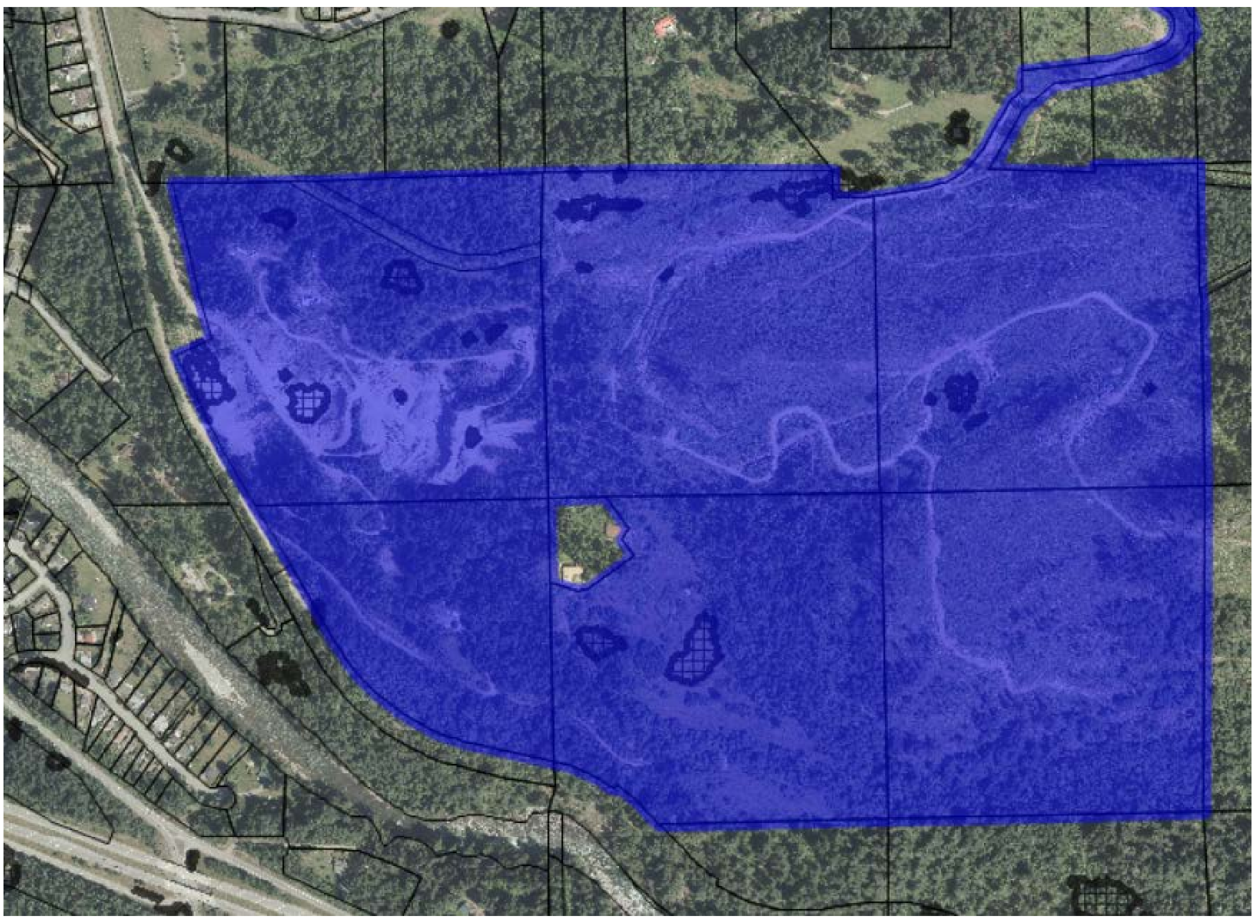


FIGURE 3-16: VACANT LOTS EAST OF KETTLE VALLEY RD. AND SOUTH OF KAWKAWA LAKE RD.

3.2.3 Industrial, Commercial, and Institutional

This section includes several examples of large vacant or under-utilized land areas that are zoned for ICI development in order to highlight the site specific or regional stormwater challenges and discuss potential design solutions. This section should be referenced during design reviews of prospective land development projects and can be communicated to land owners early in the development process. Only examples which are sufficiently large are included. Within the included figures below, the subject area is highlighted in blue, while depression storages are cross hatched and outlined in black.

3.2.3.1 Existing Developed Lots Around Raab St. from 3rd Ave to 5th Ave.

The existing developed commercial lots around Raab St. From 3rd Ave to 5th Ave are identified as Light Service Industry or Highway Commercial within the OCP (see Figure 3-17). This area receives runoff from the east and south and generally drains through an existing storm main system at it’s west. Available Lidar data presents that there is a 7.7 hectare depression in this area, which includes most of the existing development. Therefore, these is no overland flow route for most of the development. Stormwater modelling suggests that the existing storm mains are adequate to keep the depression from flooding more than 100mm during the 100-Year storm event. Redevelopment proponents should be made aware of this hazard so they may accommodate it with a suitable building design. The District should also consider adapting the IOCP to add a minor flooding hazard to this area.

FIGURE 3-17: EXISTING RAAB ST. DEPRESSION

3.2.3.2 910 Old Hope Princeton Way, Commercial Lot South of Old Hope Princeton Way

The existing development within the lot south of Old Hope Princeton Way with PID 011-014-971 is identified as Light Service Industry within the OCP (see Figure 3-18). This lot does not receive runoff from the surrounding area, and it generally drains northwards through a culvert across Old Hope Princeton Way, along roadside ditching, and ultimately into the Coquihalla River. Available Lidar data presents that there is small 0.4 hectare depression in this area. The lot is generally flat so the development proponent should be encouraged to apply trap low storage design to eliminate runoff during minor and major storm events. Redevelopment proponents should be made to prove that the existing stormwater infrastructure can support redevelopment or modify it if required. They should also be required to demonstrate how structures within the depression area will be protected.

FIGURE 3-18: 910 OLD HOPE PRINCETON WAY, (PID 011-014-971)

3.2.3.3 19743 Foster Rd., Vacant Lot South of Flood Hope Rd

The vacant lot south of Flood Hope Rd. with PID 031-036-597 is identified as Comprehensive Development in the OCP (see Figure 3-19). This lot receives some runoff from the neighborhood to it's immediate south and generally drains northward into the adjacent Silverhope Creek. Available Lidar data presents that there is a depression storage where the lot borders the adjacent eastern neighbor. Development proponents should be required to maintain overland flow between this depression and the Silverhope Creek, as well as overland flow routes from the south. There are also several small depressions with a combined area of 0.2 hectares. There are potentially more small depressions which are not accurately measured by Lidar through the existing forest canopy. The development proponent should be encouraged to apply trap low storage design to eliminate runoff during minor and major storm events. Note that the IOCP identifies the west side of the lot is floodway, therefore there may be limited development potential.

FIGURE 3-19: 19743 FOSTER RD., (PID 031-036-597)

3.2.3.4 20079 Klassen Rd., Vacant Lot South of Flood Hope Rd

The vacant lot south of Flood Hope Rd. with PID 014-665-387 is identified as Light Service Industry in the OCP (see Figure 3-20). This lot contains a relatively large gulley at it's west end and it receives runoff from approximately 15 hectares of surrounding area. This lot drains to the northwest. Available Lidar data presents that there are no large depressions within the lot but several small depressions with a combined area of 0.4 hectares. There are potentially more small depressions which are not accurate measured by Lidar through the existing forest canopy. The development proponent should be encouraged to apply trap low storage design to eliminate runoff during minor and major storm events. Development proponents should also be made to prove that the development will accommodate the existing overland flow route.

FIGURE 3-20: 20079 KLASSEN RD., (PID 014-665-387)

3.2.3.5 63370 Flood Hope Rd., Commercial Lot South of Flood Hope Rd

The existing commercial lot south of Flood Hope Rd. with PID 018-085-695 is identified as Light Service Industry in the OCP (see Figure 3-21). This lot receives runoff from approximately 9 hectares of surrounding area. This lot drains to the developed lot to it's west which has a large depression at it's south end which floods during large events. Available Lidar data presents that there are no large depressions within the lot but small depressions with a combined area of 0.2 hectares. The redevelopment proponent should be encouraged to apply trap low storage design to eliminate runoff during minor and major storm events and prevent impact on the adjacent low lying lot. Redevelopment proponents should also be made to prove that the development will accommodate the existing overland flow route.

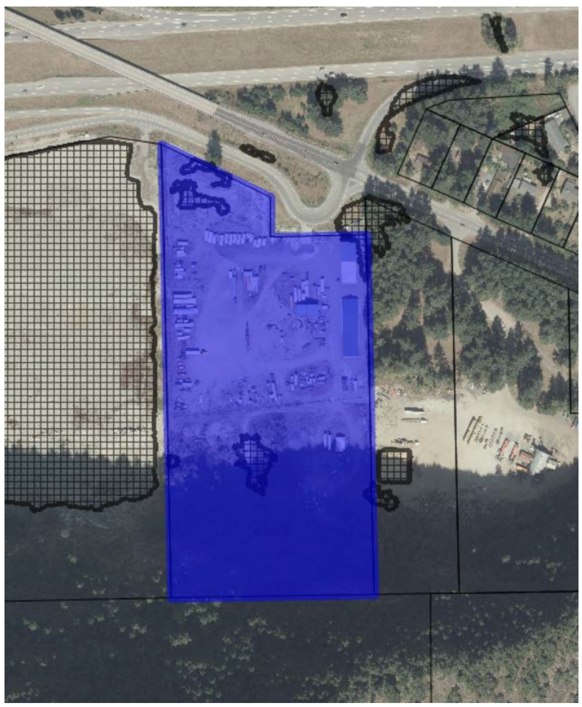


FIGURE 3-21: 63370 FLOOD HOPE RD., (PID 018-085-695)

3.2.3.6 63071 Flood Hope Rd., Mobile Home Park North of Flood Hope Rd, and 63170 Flood Hope Rd., Vacant Lot North of Tobena Rd

The existing mobile home park north of Flood Hope Rd with PID 026-771-306 and adjacent vacant lot with PID 026-771-292, are identified as Light Service Industry in the OCP (see Figure 3-22). These lots do not appear to receive runoff from the surrounding area; however, they contain a 4.8 hectare depression that is at risk of flooding during major storm events. The drainage mechanism for these lots is unclear but it may be through an existing culvert in the railbed along it's north border. The development proponent must confirm sufficient drainage exists for these lots and should be encouraged to apply trap low storage design to eliminate runoff during minor and major storm events

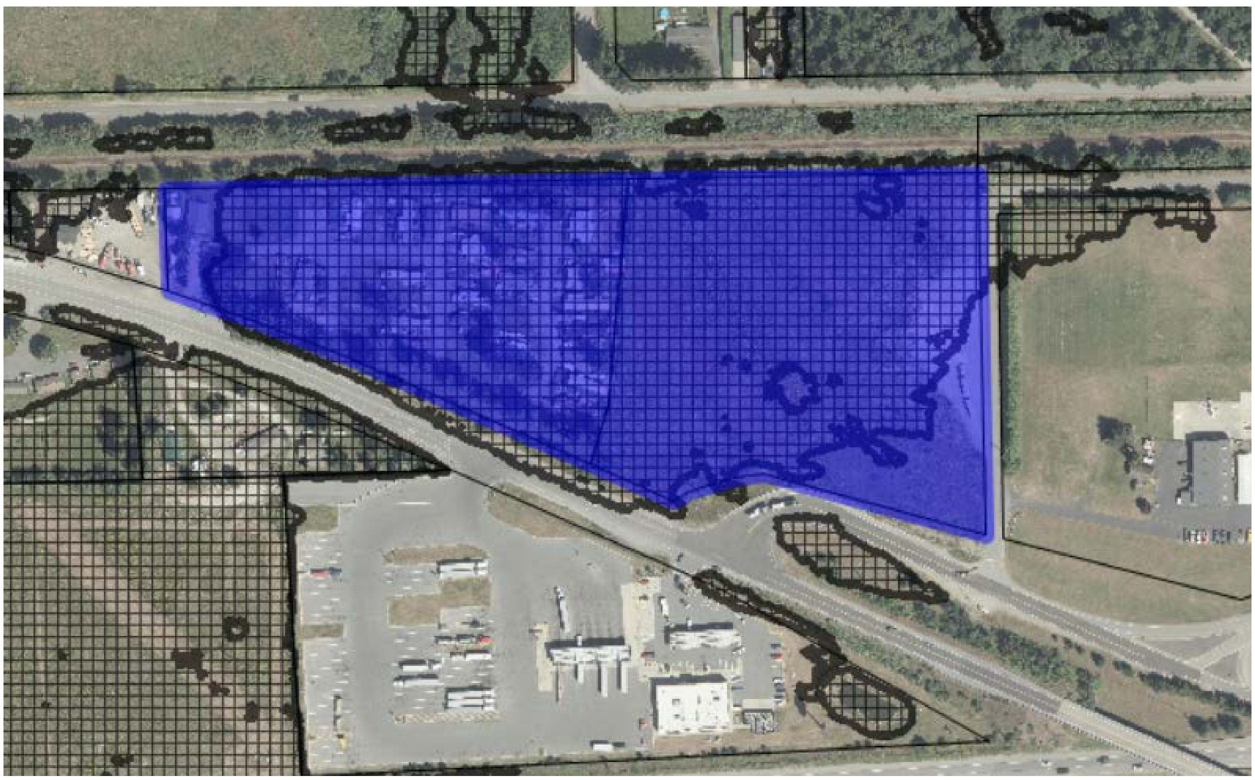


FIGURE 3-22: 63071 FLOOD HOPE RD., (PID 026-771-306), AND 63170 FLOOD HOPE RD., (PID 026-771-292)

3.2.4 Agricultural Land

The land designated as agricultural land in the District generally surrounds the airport. This area is near the river and likely has a relatively high water table. Many of these Rural/Agricultural zoned lots also contain large natural depressions (see Figure 3-23). These depressions likely accumulate stormwater during major events and return regional runoff by retaining and infiltrating it. Stormwater accumulation has even been visible following during past major events (see Figure 3-24). It is recommended that these lots remain zoned as Agricultural/Rural and that these natural infiltration features be protected.

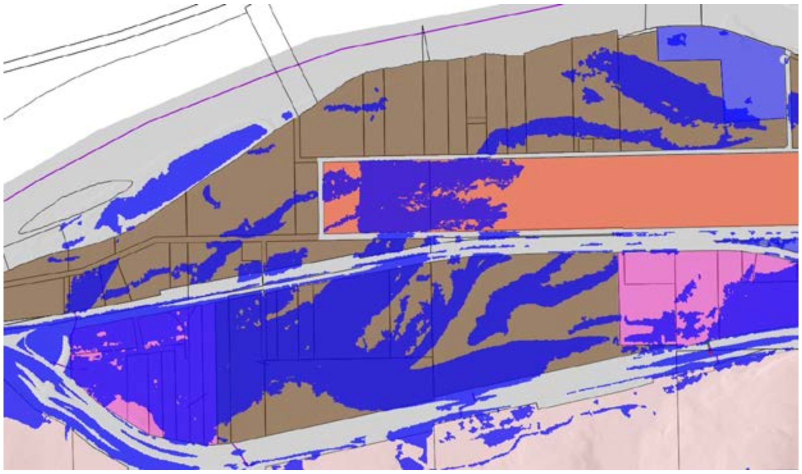


FIGURE 3-23: AGRICULTURAL ZONING (BROWN LOTS) WITH EXISTING LAND DEPRESSIONS (BLUE POLYGONS)

FIGURE 3-24: FLOODED DEPRESSION WITHIN AGRICULTURAL AREA ON DECEMBER 3RD, 2021

4.0 Recommended Improvements

This section builds from the future development discussion in Section 3.2 and provides a greater level of detail in terms of specific recommendations for consideration of the District of Hope.

4.1 Model Improvements

4.1.1 Calibration

As noted in earlier sections of this report, the computational model developed as part of this SWMP is not analytically calibrated due to lack of measured flows and depths during real-world events. Model outputs were compared to anecdotal records of the November 2021 event and found to be reasonably similar. However, this level of comparison does not constitute an accurate calibration.

Gauge height (also known as stage) is the height of the water in the stream above a reference point.

TRUE recommends that the District consider installing flow and rainfall monitoring in Thacker Creek. A typical installation would include an engineered weir structure with gauge monitoring connected a data collector and power source. An alternative would be to install a system that can connect either to an online server, or the District's existing SCADA. Parallel to the weir and gauge would be a rainfall monitor connected to the same data collector. The data collected by this system can later be used to calibrate and improve or confirm the computational model and provide improved confidence in results.

4.1.2 Database and Model Upkeep

Following the concepts of good asset management, the District should continue to upkeep and improve its database of asset information. As previously noted, TRUE is confident that the current database contains over 98% of existing manholes. However, it is generally believed that the inventory of minor items such as culverts is largely incomplete. It is recommended that as drainage system elements are inspected, improved, installed, removed, or abandoned, that the GIS database and the PCSWMM model inputs are updated accordingly. Small updates over time can be made very efficiently, whereas bulk wholesale updates to models and datasets are often more costly and not as accurate.

4.2 Policy and Operational Recommendations

4.2.1 Update IOCP Flood Hazard Map

As noted early in this plan, the District's IOCP contains many Goals, Objectives, and Policies that directly relate to the management of the stormwater conveyance and discharge systems. The District should consider implementing the following the guidance during the creation of development bylaws, and design criteria.

4.2.1.1 Protect Old Yale South Flow Path/Infiltration Area

The Old Yale South Flow Path, as identified in Figure 4-1, is a major conveyance path for a large catchment area along the south end of the District's boundary. Previous mapping based on the topographic data area suggested that there should be an overland flow path/stream to convey flows towards Silver Creek. However, LiDAR analysis determined no such flow path to Silver Creek exists and catchment areas from Hope Mountain are directed to the north to Old Yale and Owl Rd.

Initial, model runs indicated this are had substantial flow in both the 10-year and 100-year events. However, field inspection of the area found no evidence of major overland flow. Instead, field inspection determined this area is dominated by rockfall and talus at the base of the mountain, followed by a gravel/sand upper bench, with a natural gulley in between. This natural gulley directs flow towards the north, instead of towards Silver Creek as previously mapped. The field review also suggests that mountain runoff from minor and medium storms is primarily received by the talus region, where it is then infiltrated to the ground water table. The model was updated to reflect this behaviour.

TRUE recommends that the District protects this overland flow path and associated natural infiltration from development, due to its proximity to the talus (which mostly aligns with the District's existing High Geotechnical Hazard Area identified in the IOCP). While no historic drainage issues have arisen in this area, it is currently not understood if or how climate change may impact this area hydrologically and if the receiving talus will reach carrying capacity. Currently the model is estimating no flows during the 10-year event with substantial flows in the 100-year event with the estimated infiltration capacity being overwhelmed. Consequently, it is recommended this are be protected from development.

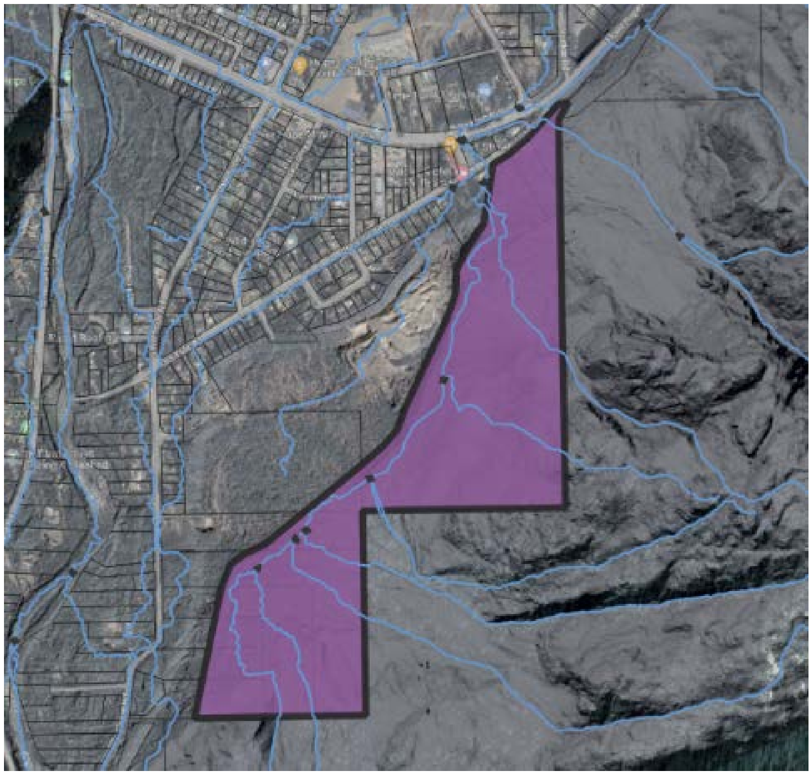


FIGURE 4-1: OLD YALE SOUTH FLOW PATH

4.2.1.2 Update Streams and Associated Flood Ratings From Improved Lidar Data

Developing the model included estimating stream locations from high quality Lidar data using a GIS software watershed delineation tool. This process has identified discrepancies between the creek locations shown on the District's IOCP Hazards Maps and the estimated creek location identified from the Lidar data. This is particularly evident within the east end of the Kawkawa Lake subdivision, shown in Figure 4-2. The District should consider updating these IOCP Hazards Maps based on the Lidar data stream location.

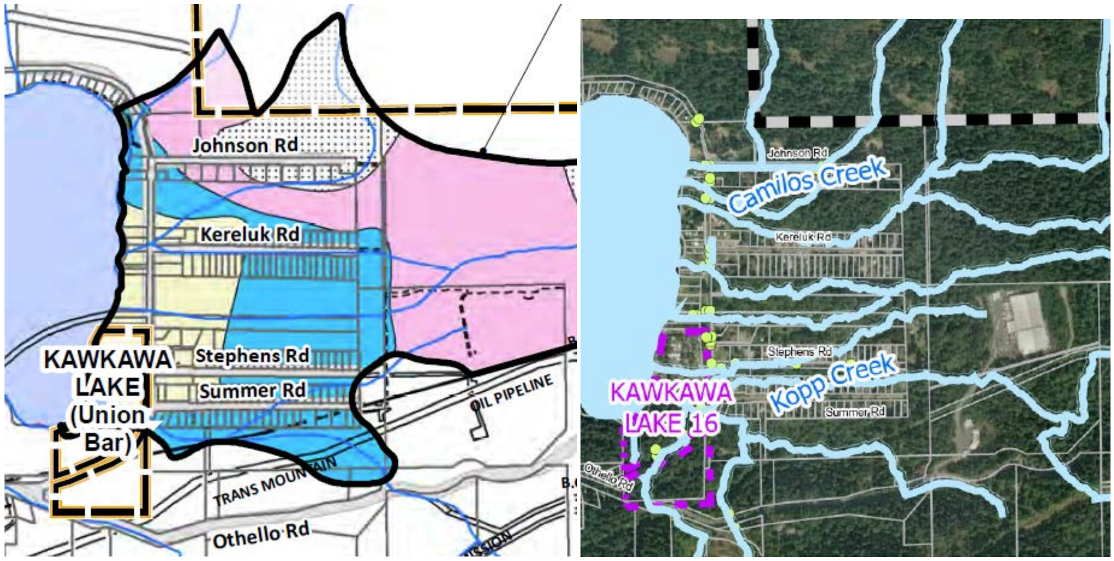


FIGURE 4-2: COMPARISON OF CREEK LOCATION ON DISTRICT IOCP HAZARD MAP (LEFT) AND ESTIMATED CREEK LOCATION FROM LIDAR DATA (RIGHT)

4.2.1.3 Add Sink Areas with Corresponding Flood Ratings

Regional and local low points were identified from the LiDAR data during the model development. Notable low points include the agricultural areas surrounding the airport, the Raab St. commercial area, and 65617 Kawkawa Lake Rd, each of which are discussed in Section 3.2 above. The District should consider updating their IOCP Hazards Maps to include these low points and the surface flow hazard that exists within these areas. Additional low points are presented within the Major Potential Ponding figures found in Appendix F.

4.2.2 Development Review Process

The rapidly growing population of the District suggests that development is going to continue at accelerated rates. It is recommended that the District utilize the SWMP and its recommendations, alongside the computational model while making reviews for development proposals. As outlined in several documents (Subdivision Bylaw, IOCP, etc.), the District's goals and objectives for drainage center around ensuring that development does not create negative impacts to the existing systems.

The District's current process of review of development applications generally only involves a site-wide analysis of the stormwater system, without consideration of impact to adjacent or downstream discharge or conveyance infrastructure. Utilizing this plan and the related model, it is possible, and recommended, to consider a development's overall impact on the entire stormwater system. Notably, it is recommended the District review all downstream impacts to overland flow paths. TRUE encourages the District to engage engineering support familiar with the stormwater model during this process.

4.2.3 Develop a Watercourse Bylaw

During development of the model, and field review of site impacted by the November 2021 event, TRUE made note of several watercourses on private land with historic encroachments. Many of these encroachments into the watercourses restrict the natural capacity of the stream. This capacity issue has been noted several times in the reports and studies listed in Section 1 of this report, and during the November 2021 event. Current climate change modelling suggests that these flows will increase year over year increasing flood risk. In many cases, the observed capacity issues are exacerbated by poor maintenance of infrastructure encroaching on the watercourse (damaged, filled in, obstructed, etc.).

The Local Government Act maintains provisions for municipal governments to assign a watercourse as part of the municipality's drainage system:

LOCAL GOVERNMENT ACT

Part 9 — Regional Districts: Specific Service Powers

Division 3 — Drainage, Sewerage and Related Matters

Watercourse may be included in drainage system

307 A board may, by bylaw, make a watercourse part of the regional district drainage system, whether the watercourse is on private land, on regional district land or on a highway.

Requirements respecting drainage works

312 (1)In this section and section 313, "stream" has the same meaning as in section 1 (1) of the Water Sustainability Act.

(2)A board may, by bylaw,

(a)establish requirements that must be met by owners of dikes, and

(b)establish requirements that must be met by persons undertaking the construction of

(i)dikes,

(ii)works to maintain the proper flow of water in a stream, ditch, drain or sewer in the regional district, or

(iii)works to reclaim or to protect part of the land mass of the regional district from erosion by action of the sea or a stream or from any other cause.

Utilizing the provisions of the act, it is recommended that the District look to develop a bylaw outlining:

- the inclusion of key watercourses as part of the District's drainage system
- definition of requirements and limitations to development and modifications that can be made to watercourses on private property
- District responsibilities to approve development and modifications to watercourses on private property

- Penalties related to unauthorized development and modifications to watercourses on private property

The primary benefits to the proposed bylaw are:

- Public and staff awareness of the critical role played by these watercourses
- Expand the definition of watercourses to include ditches, culverts, other conveyance elements that are not covered under the Water Sustainability Act
- Supports the protection of natural watercourses in conjunction Water Sustainability Act
- Allows the ability of the District to remove unapproved obstructions or changes to watercourses with the ability to recover associated costs.

4.2.4 Update Storm Design Guidelines

As previously stated, TRUE's review of Section D of the Subdivision Bylaw Design Criteria Manual found the content to be thorough and comprehensive. However, upon completion of the SWMP efforts, TRUE has several recommendations for update and expansion of the Manual.

Climate Change

The current version of the manual is consolidated as of October 2005. The manual recommended the use of design storm data as provided by the Atmosphere Environmental Service, which is an industry standard practice. This information is built from historical records of rainfall in a given area and provides an estimated model of storms *as they would have occurred in the past*. Industry standards are now moving towards estimating models of storms *as they may occur in the future*. This practice involves considering the estimated impacts of climate change, which generally intensifies the design storms.

As was done in the analysis for this SWMP, TRUE recommends that the District add requirements and reference to tools for altering design storms for climate change. At this time, TRUE recommends the District adopts the IDF CC Tool (https://www.idf-cc-uwo.ca/). This tool has become widely used in BC and provides a user-friendly GIS based interface. As parameters of the tool, it is recommended the District adopt the following:

- 2070 – 2100 Timeframe
- CMIP6 – Pacific Climate Impacts Consortium (PCIC) Bias Corrected Data Set
- All Model Ensemble
- SSP5.85 Emission Scenario

By including requirements to consider the impact of climate change, the District can reduce the risk of current development creating future impacts to the overall drainage system, including both public and private property.

Infiltration Pre-treatment

Infiltration is an effective and encouraged method of discharging drainage flows to the environment. It is recommended that the District add requirement for pre-treatment prior to infiltration discharge in the design criteria. Pre-treatment requirements should include:

- Settlement of suspended fine materials
  - Extends the service life of infiltration infrastructure
  - Minimizes maintenance needs
- Storm Pollutants Removal
  - Oils and grease can be removed
  - Removal of heavy metals and other pollutants
  - Protects groundwater aquifers to a higher level (over mechanical means)

It is recommended that primary treatment be completed through vegetative processes (swales, rain gardens, bio-retention. These provide the highest level of treatment and are best aligned with the ICOP policies and goals. Discharging to "green" then ground is preferred over mechanical separation devices (oil grit separators, hydrodynamic separators, etc.) as they don't perform to the same level.

Low Impact Design / Best Management Practice

The current ICOP contains policy statements (9.7.2 and 9.7.3) regarding the encouragement of Low Impact and Best Management Design practices for new development. It is recommended the design manual should be expanded to include details and references to the practices that the District desires to be implemented. The District should consider referencing similar design guidelines from the region, such as:

- City of Vancouver's Best Management Practice Toolkit Volume II
  - https://vancouver.ca/files/cov/integrated-stormwater-management-best-practice-toolkit-volume-2.pdf
- Capital Regional District's Green Stormwater Infrastructure Common Design Guidelines
  - https://www.crd.bc.ca/docs/default-source/es-watersheds-pdf/green-stormwater-infrastructure-crd/mainreport-gsi-commondesignguidelines-spring2019-final.pdf?sfvrsn=2c8ed0ca_2
- Low Impact Development Technical Guidance Manual for Puget Sound
  - https://kingcounty.gov/~/media/depts/dnrp/solid-waste/green-building/documents/Low_Impact_Development-manual.ashx?la=en
- Eastern Washington Low Impact Development Guidance Manual
  - https://apps.ecology.wa.gov/publications/documents/1310036.pdf

The District could reference an example manual or could create their own manual to suit the specific needs and desires of the District.

Overland Flow Routes

Overland flow routes represent a large portion of the District's drainage conveyance infrastructure. In low lying areas with little or no grade, the use of buried conveyance systems (pipes and manholes) can be ineffective or prohibitively deep / expensive. The District's design guidelines for the drainage systems should contain guidance for developers to build and maintain suitable overland flow paths with appropriate design storms.

Supplemental Details

The current set of supplemental details for sewer (sanitary and storm), drawings SDS-1 through SDS-24, are dated 1999 and would benefit from adjustment and updating. Apart from an overall review and update to meet modern approaches and construction methods, the District would benefit from making a detailed review of how infiltration galleries are constructed and how many clean-outs they require.

4.2.5 Infiltration Infrastructure Maintenance

Much of the District's discharge of conveyed drainage flows is executed with the use of infiltration infrastructure. The effective implementation of infiltration within the District is critical for minimizing the risk of flooding and ponding during extreme events. The effectiveness of this infrastructure is contingent on execution of good maintenance.

TRUE noted considerable sedimentation in and around much of the District's infiltration infrastructure (see Figure 4-3). The build-up directly impacts and reduces the effective capacity of the systems and creates risk during storm events.

TRUE recommends that the District develop an annual maintenance program for infiltration infrastructure and appurtenances. Items for consideration in such a plan should include

- *Increased maintenance of hydrodynamic separators*
- *Increased maintenance of sumps*
- *Increased flushing/inspection of perforated pipes*
- *Potential installation of additional cleanouts*
- *Considered increased pre-treatment on existing infiltration infrastructure*

FIGURE 4-3: EXAMPLE OF INFRASTRUCTURE REQUIRING MAINTENANCE

4.2.6 Culvert and Ditch Maintenance

Culverts and ditches make up a large portion of the District's conveyance infrastructure. The use of these developments is common in low lying areas with little slope, such as the central developed area of the District. The capacity and overall effectiveness of these flow paths is contingent upon good maintenance practices. The build up of sediment, overgrowth of foliage, and obstruction by debris increases the risk of over-topping of these systems, and potential flooding or ponding on public and private property, including damaging or obstructing roadways.

TRUE's field inspection of the drainage system revealed several areas of considerable deficiency in terms of culvert and ditch maintenance. Notably, most culverts and ditches were found to be no less than 50% filled with sediment, several ditches were overgrown, and many culvert inlets and outlets were obstructed with natural and human generated debris (see Figure 4-4).

TRUE recommends that the District develop an annual inspection and maintenance program for these conveyance systems to ensure that build up and debris do not reach detrimental levels. As part of this program, the District should evaluate what levels of service are and are not acceptable for ditches and culverts and use that evaluation as a benchmark for allocating resources to annual maintenance.

FIGURE 4-4: EXAMPLE OF CULVERT REQUIRING MAINTENANCE TO INCREASE CAPACITY

4.2.7 Protect Boulevard Swales and Ditches

Many of the District's residential neighbourhoods utilize a rural cross-section for road rights-of-way. This cross-section is typically comprised of a paved roadway, with gravel or grassed shoulders, and swales or ditches up to property line. This approach is a very sustainable drainage practice and is directly inline with the IOCP goals, objectives, and policies.

There is a common tendency for the community to fill in the swales or ditches to create additional parking, landscaping, wider driveways and developing urban cross sections of roads (see Figure 4-5 and Figure 4-6). In some cases, individuals have been conscious of the swales purpose and attempted to install culverts or extend existing driveway culverts, in other cases, swales may have simply been backfilled. The general result of this practice is a reduced capacity for drainage conveyance (see Figure 4-7), reduced opportunity for infiltration, and often the installation of disjointed, poorly graded, or undersized culverts. Overall, the result is a negative impact on the drainage conveyance network.

This reduction in capacity and effectiveness of the swales and ditches creates an increased risk for ponding or flooding of private property and roadways during storm events. The impacted conveyance infrastructure also creates risk for roadways, as paved edges exposed to additional standing water decreases the expected service life and level of service for the pavement.

TRUE recommends that the District investigates methods or policies related to enforcing protection of roadway swales and the maintenance of driveway culverts.

TRUE's review of the Subdivision and Development Servicing Design Criteria Manual notes that there is a minimum width for driveways, but no stated maximum. It is recommended that the District look into updating this detail to include an enforceable maximum width to protect frontage drainage.

The replacement of rural to urban cross-sections, involving the replacement of swales and ditches with engineered curb and gutter, and direct discharge to underground infrastructure, is a shift away from the IOCP's goal, policies, and objectives. Removal of swales and ditches reduces the volume of pre-treatment provided to infiltrated flows and will generally result in the shortened lifespan of buried infrastructure, such as rockpits.

TRUE recommends that the District encourage the development of modified urban cross-sections that include "natural assets", such as bioswales or rain gardens, to improve the quality and effectiveness of the stormwater conveyance system.

When considering the enhancement of stormwater collection and treatment, it is best to go green before going underground

FIGURE 4-5: ENCOURAGEMENT OF VEGETATION IN DRAINAGE DITCHES REDUCES VOLUME AND FLOW CAPACITY

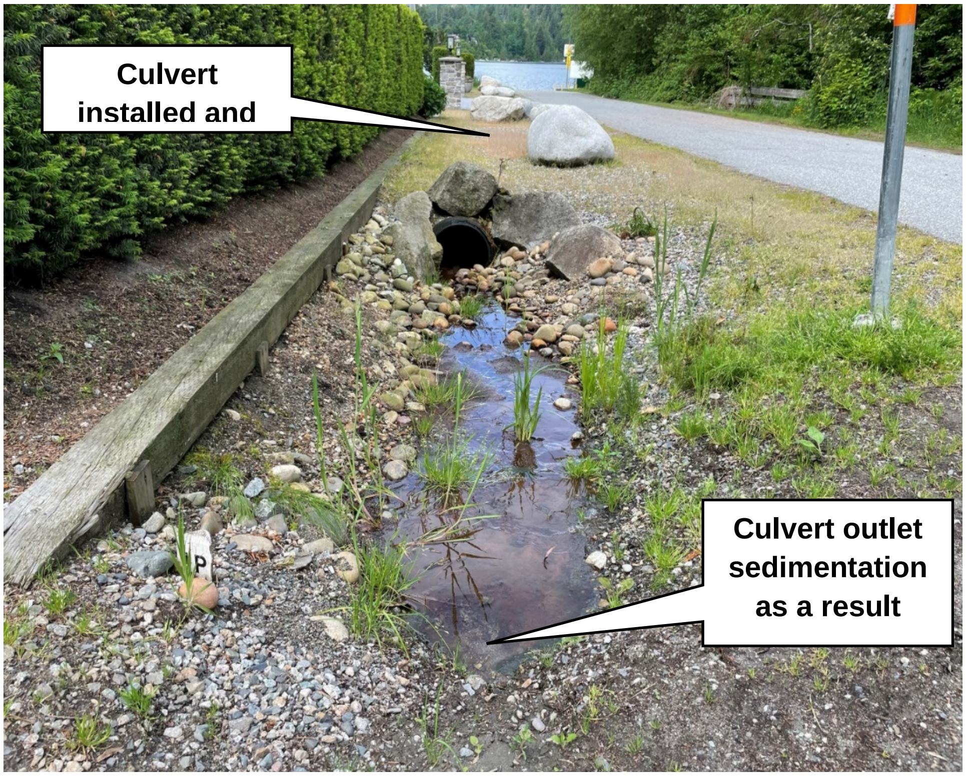


FIGURE 4-6: INFILLED AND LANDSCAPED DITCH/SWALE RESULTING IN SEDIMENTATION AT CULVERT OUTLET

FIGURE 4-7: DITCH HAS BEEN INFILLED OVERTIME WITH SEDIMENT AND ROCK, REDUCING CAPACITY AND INFILTRATION CAPABILITIES

4.2.8 SWMP and Model Upkeep

This document has been produced with the intention of becoming a **living document.** It is to the District's benefit to upkeep this SWMP. Recommended ongoing updates to the document include:

A living document, is not static and is adaptable to changing conditions. It is a document that is continually edited and updated

- Updating the model to include development on a periodic basis
- Reevaluate the impacts of future development as plans and timelines update
- Record when recommendations are completed (infrastructure improved / constructed, bylaws implemented, plans created, etc.)
- Update sections / content impacted by the evolving goals and resources of the District
- Record the impacts of future major storm events, such as the November 2021 event, either as additional sections to this plan, or Appendices

As an absolute minimum, the District should plan to perform a complete review of this document every 5 to 10-years, to ensure current information, current policies, and regulatory changes are reflected in the content.

4.2.9 Update Development Cost Charge Bylaw to include Stormwater Planning

As population growth and development continue within the District, it will be important for the District to budget and plan for stormwater planning accordingly. As previously recommended the SWMP should be updated every 5-10 years. To fund this planning work, the District should consider expanding its Development Cost Charge (DCC) Bylaw to include provision for stormwater planning. A general guideline for the cost breakdown of this planning work may be 75% DCC and 25% taxes, as the planning work will undoubtedly benefit existing users. The District should expect to budget $150,000 to fully update the SWMP.

In addition, other municipalities have utilized stormwater planning DCCs to fund development reviews of the proposed stormwater servicing to ensure individual developments are adhering to the SWMP while also allowing the SWMP to be adapted on a case by case basis while maintain a global perspective.

4.3 Capital and Operational Upgrades

Model results for the 10- and 100-Year storms events were reviewed to provide a list of capital upgrades to mitigate infrastructure surcharging, flooding, and unacceptably high flowrates or velocities. These are summarized by priority in Table 4-1 and further described in the Appendix A Project Sheets.

TABLE 4-1: CAPITAL UPGRADES SUMMARY

Project #	Description	Priority	Order of Magnitude Cost
SW-1	Upgrade Culvert At 66657 Kawkawa Lake Rd.	High	$1.2M
SW-1a	Debris Basin and Channel Upgrades At 66657 Kawkawa Lake Rd.	High	$600K
SW-2	Upgrade Thacker Creek along Forrest Cres.	High	$1.5M
SW-3	Upgrade Coquihalla St. Storm Mains	High	$1.7M
SW-4	Upgrade Drainage South of Kettle Valley Rd. and Kawkawa Lake Rd. Intersection	Moderate	$1.0M
SW-5	Overland Drainage for 65617 Kawkawa Lake Rd. Low Point	Moderate	$300K
SW-6	Upgrade Kawkawa Lake Rd. / Johnson Rd. Intersection Culvert	Moderate	$250K
SW-6a	Debris Basins Upstream of Kawkawa Lake Rd. / Johnson Rd. Intersection	Moderate	$800K
SW-7	Upgrade Culvert at 66597 Kawkawa Lake Rd.	Moderate	$250K
SW-8	Additional Culvert At Kawkawa Lake IR#16	Moderate	$650K
SW-9	Stormwater Retention Pond to Prevent Owl St. Depression Flooding.	Low	$600K
SW-10	Overland Route for Drywell Network Along Lakeview Cres.	Low	$70K

Model results also identified potential flooding of stormwater features within the MOTI highway corridors (see Table 4-2). These areas were not assessed in detail but are areas of concern. This infrastructure is outside the District's jurisdiction but could impact District like some of these areas did during the November event. It is recommended that District open a dialogue with the MOTI to ensure future MOTI projects to mitigate flooding includes collaboration between the District and MOTI.

TABLE 4-2: NOTABLE MODEL RESULTS WITHIN MOTI HIGHWAY CORRIDORS

Project #	Description
MOTI-1	Flooding of storage basin between HWY 3 eastbound and westbound lanes, 500m east of HWY 1 overpass. The outlet of this storage basin is unknown.
MOTI-2	Flooding of storage basin south of HWY 3 eastbound lanes, 200m west of HWY 1/Flood Hope Road exit.
MOTI-3	Flooding of intersection between HWY 1/Flood Hope Road Exit and HWY 1/Flood Hope Road.
MOTI-4	Flooding of Thacker Creek at HWY3, along the Old Hope Princeton Way exit.

5.0 Conclusions

This Stormwater Management Plan has been produced by TRUE Consulting at the request of the District of Hope. This plan, along with the accompanying computations PCSWMM model, is developed with the intention of being a living document that is to be periodically and regularly updated as the process of stormwater management continues and evolves within the District. Key triggers for revisiting the plan and model are:

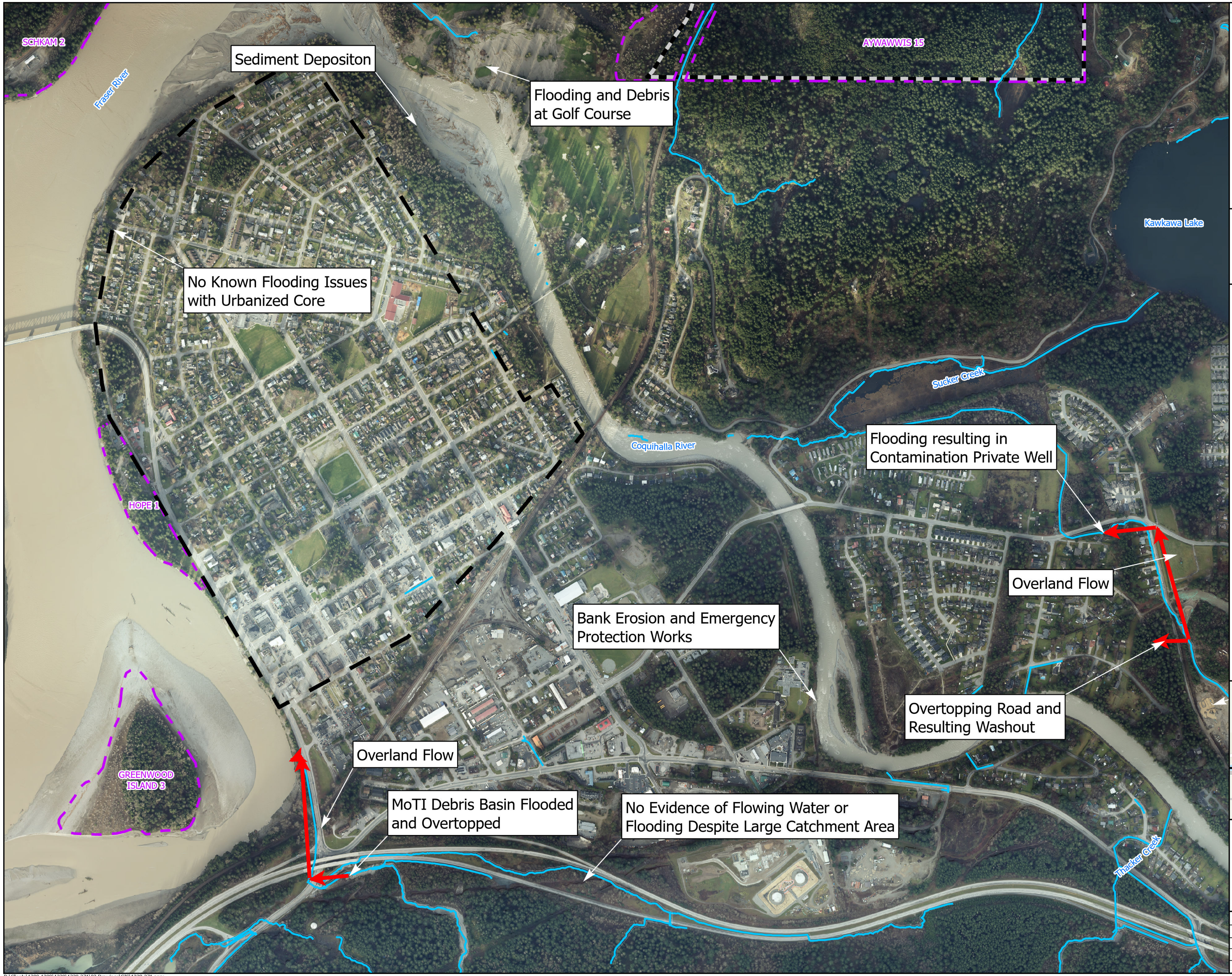
- As recommendations are completed
- The minimum 5–10 year review timeframe has passed
- Related municipal goals, resources, or directions are changed
- Related or supporting documentation is updated or created (IOCP, similar studies, etc.)
- Major Events occur (similar to the November 2021 event)
- Sufficient calibration data has been collected

The document has been originally provided to the District in pdf and hardcopy format in 2022. The hardcopy format was accompanied with a USB drive containing the PCSWMM computational model. Additional copies of the report or model can be obtained from TRUE at the request of the District. It is the responsibility of the District to keep the PCSWMM model up-to-date, or to retain the services of a modelling professional to do so.

The November 2021 event was an unfortunately well-timed event (occurred while the District was studying its systems) that highlighted the impact and importance of the stormwater discharge and conveyance systems. This document has outlined many projects and recommendations for addressing current and potential future deficiencies to minimize the impact related to future similar events. It is the responsibility of the District to consider their resource availability and the District's acceptable levels of service and risk when considering the recommendations within this plan.

APPENDIX A

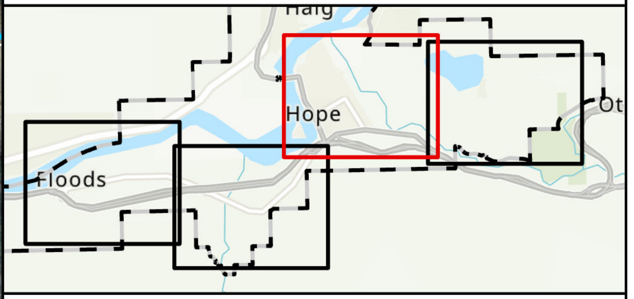
November 2021 Storm Overview Figures



DISTRICT OF HOPE

November Flooding Overview

Major Flow Paths
Flow Direction
Flooding Areas
First Nation Reserve
Municipal Boundary



0 100 200 300 400 500 m

N

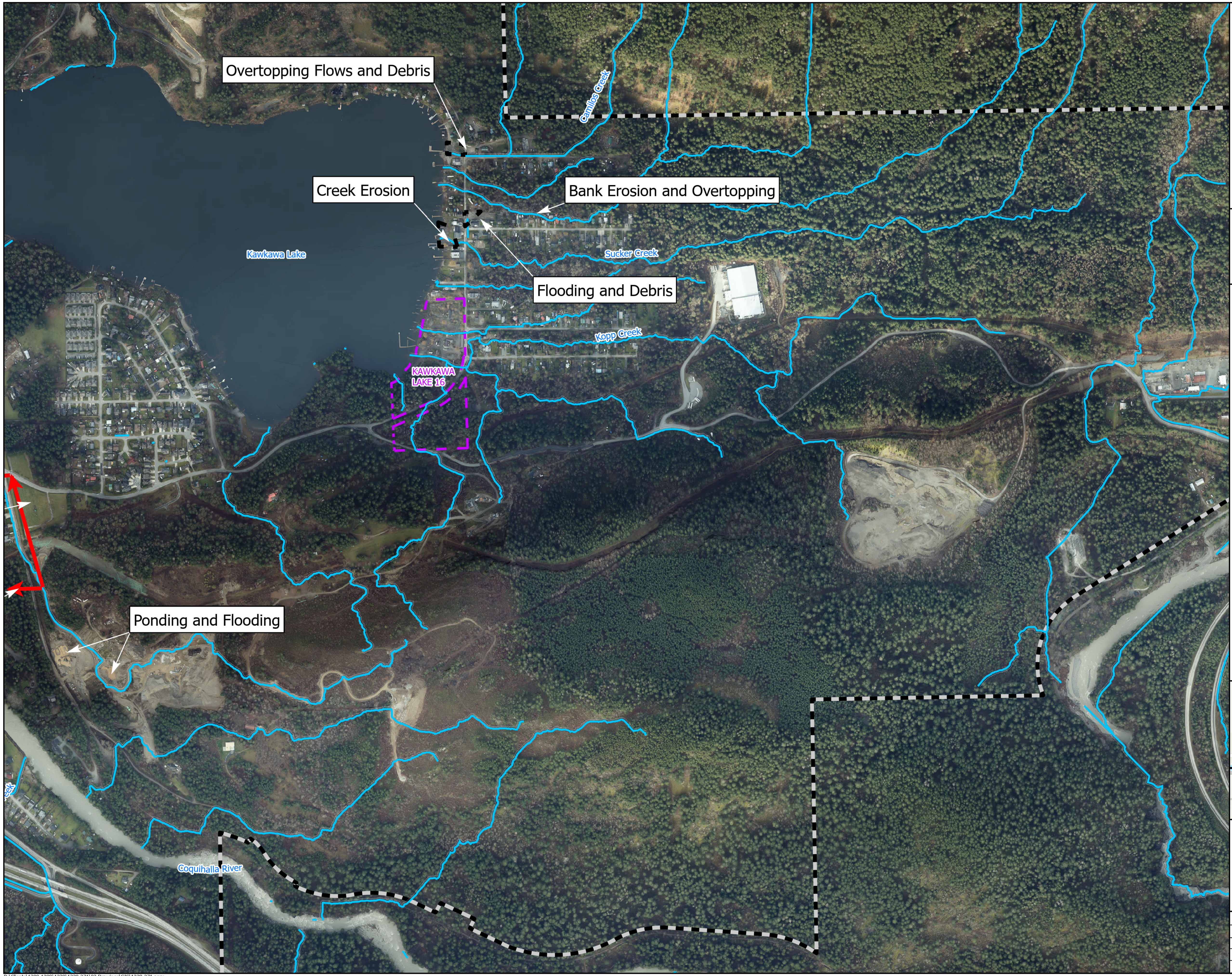
Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure A1

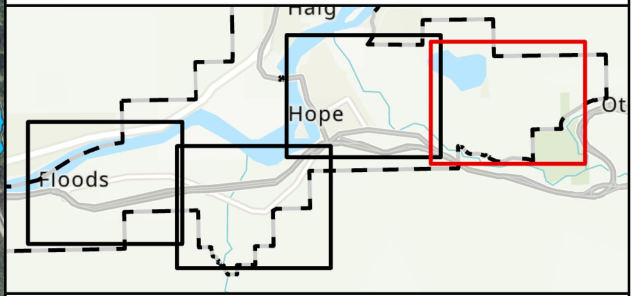
R:\Clients\1200-1299\1239\1239-271\03 Drawings\GIS\1239-271.aprx



DISTRICT OF HOPE

November Flooding Overview

- Major Flow Paths
- Flow Direction
- Flooding Areas
- First Nation Reserve
- Municipal Boundary



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

Figure A2

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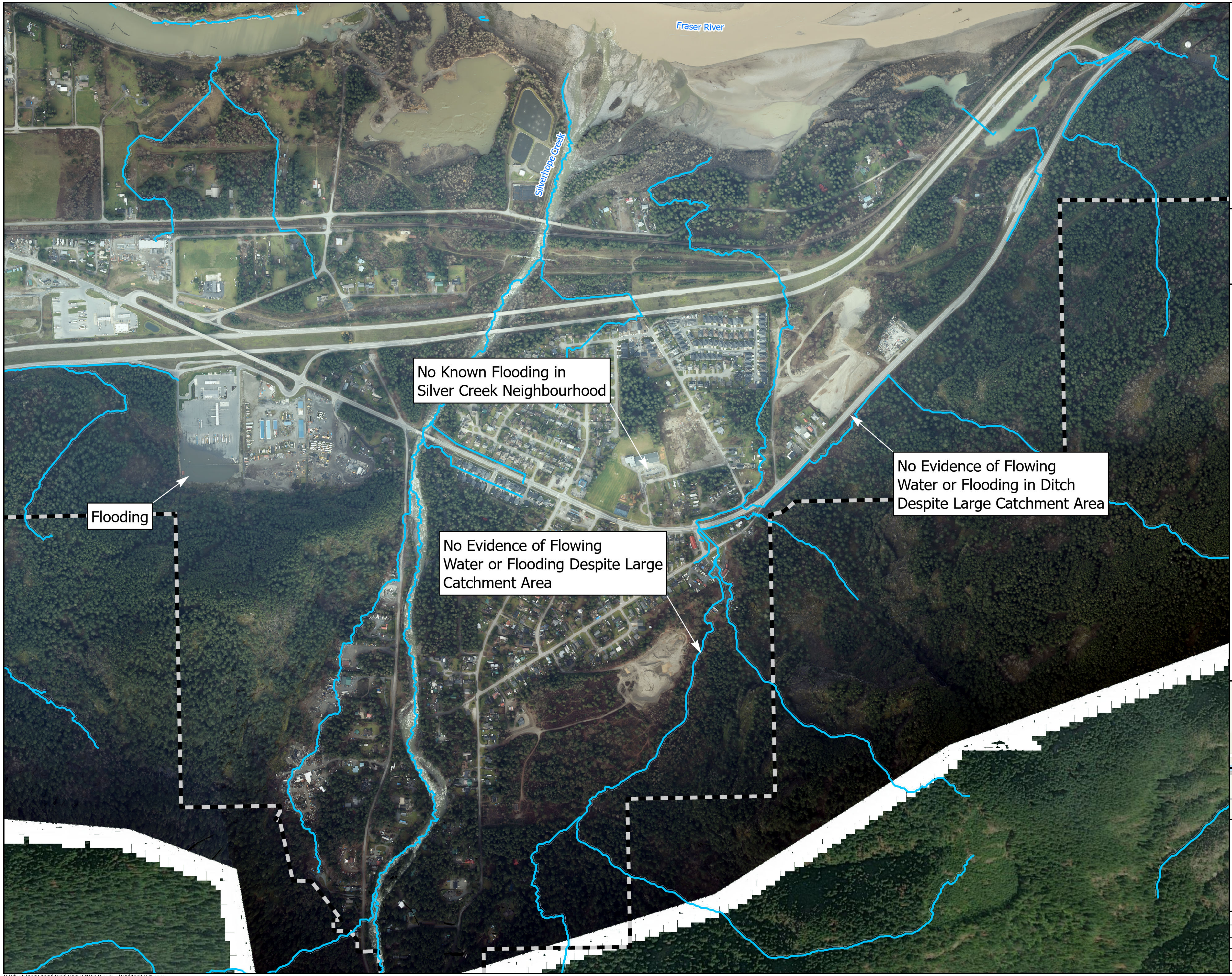
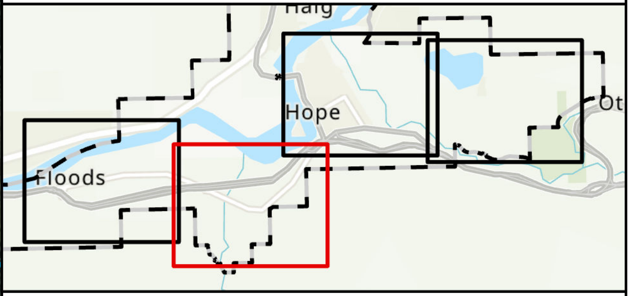


DISTRICT OF HOPE

November Flooding Overview

Major Flow Paths
Flow Direction
Flooding Areas
First Nation Reserve
Municipal Boundary



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

Figure A3

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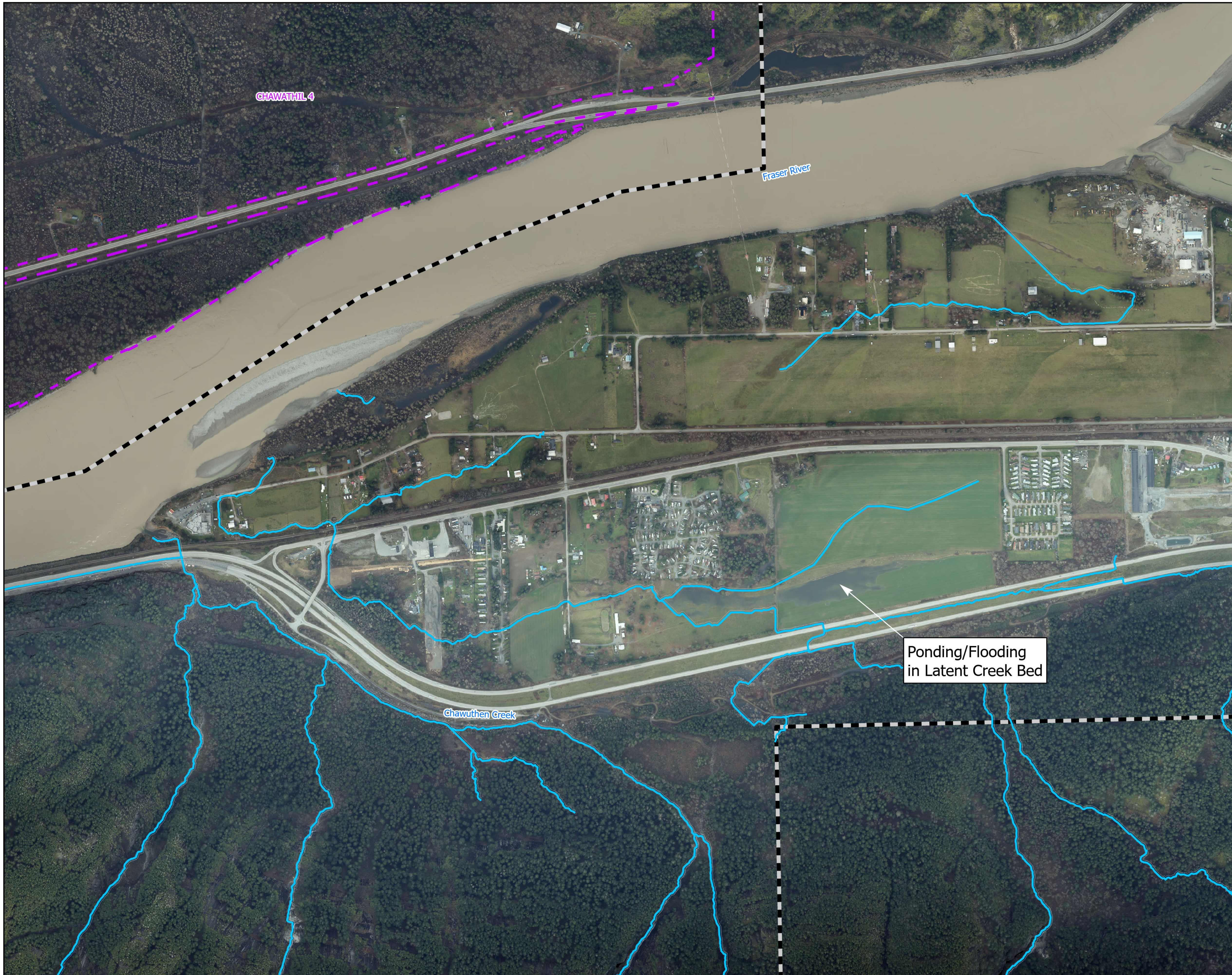
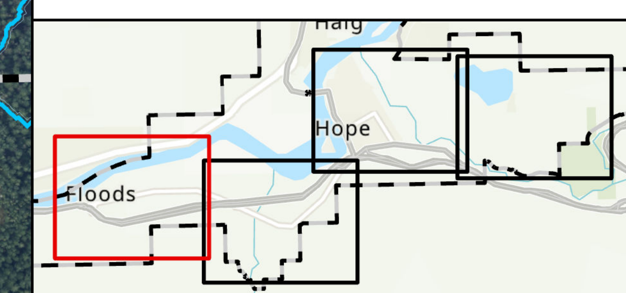
DISTRICT OF HOPE



November Flooding Overview

- Major Flow Paths
- Flow Direction
- Flooding Areas
- First Nation Reserve
- Municipal Boundary



0 100 200 300 400 500 m

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Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

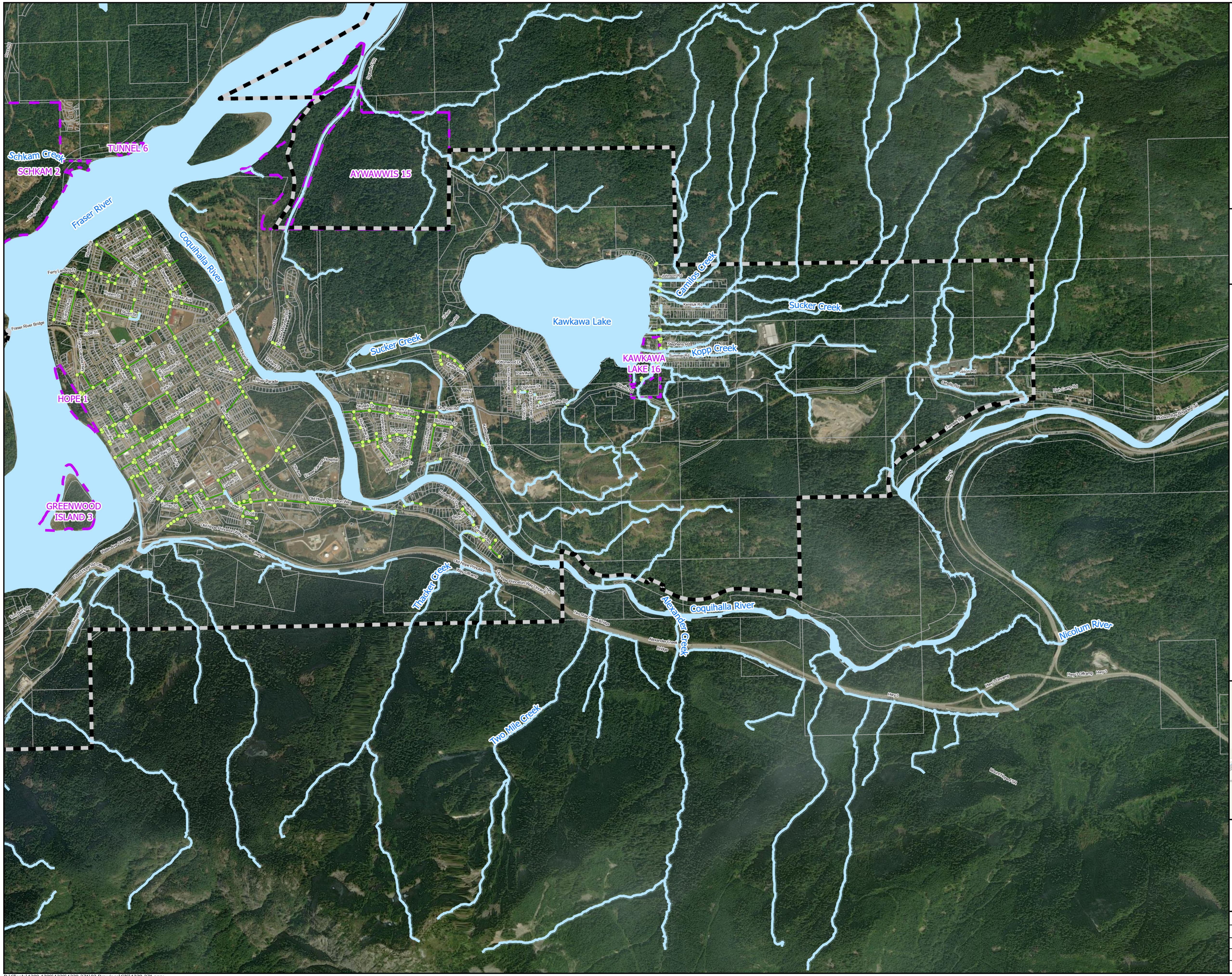
Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure A4

APPENDIX B

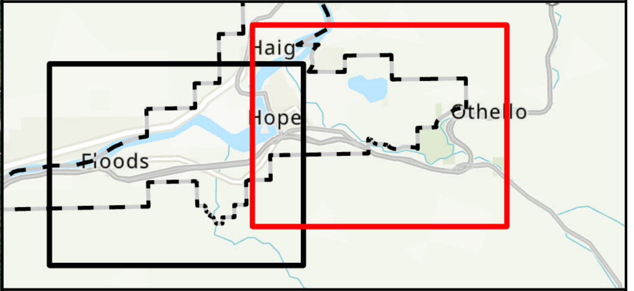
Drainage System Overview Figures



DISTRICT OF HOPE

Drainage System Overview

- Storm Manhole
- Storm Mains
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths



0 250 500 750 1,000 m

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Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:25,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure B1

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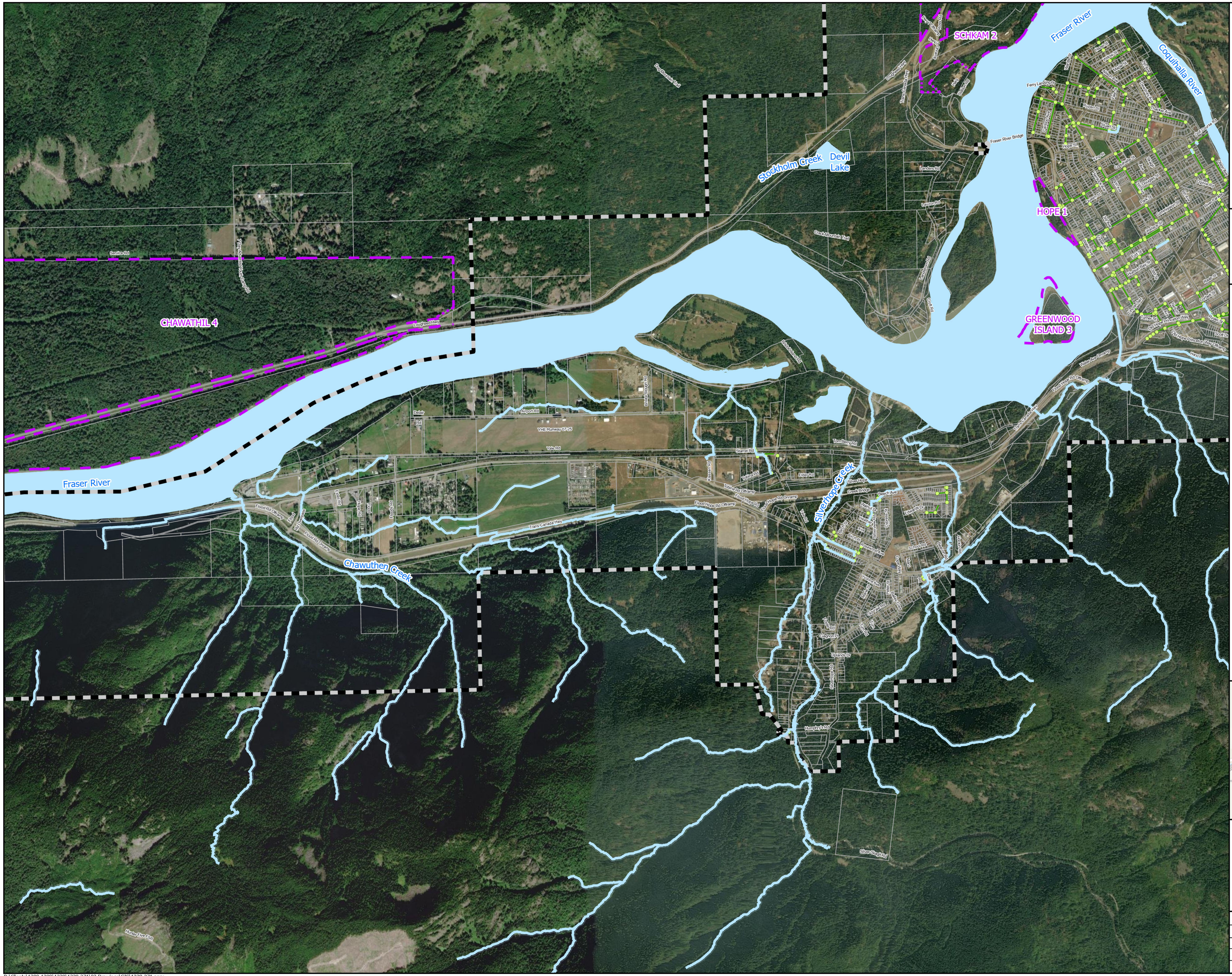
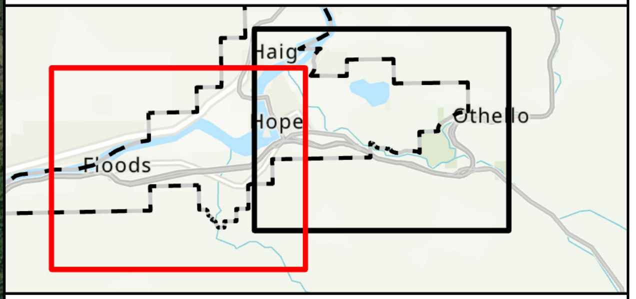


DISTRICT OF HOPE

Drainage System Overview

- Storm Manhole
- Storm Mains
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths



0 250 500 750 1,000 m

N

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Projection: Transverse Mercator (Zone 10)

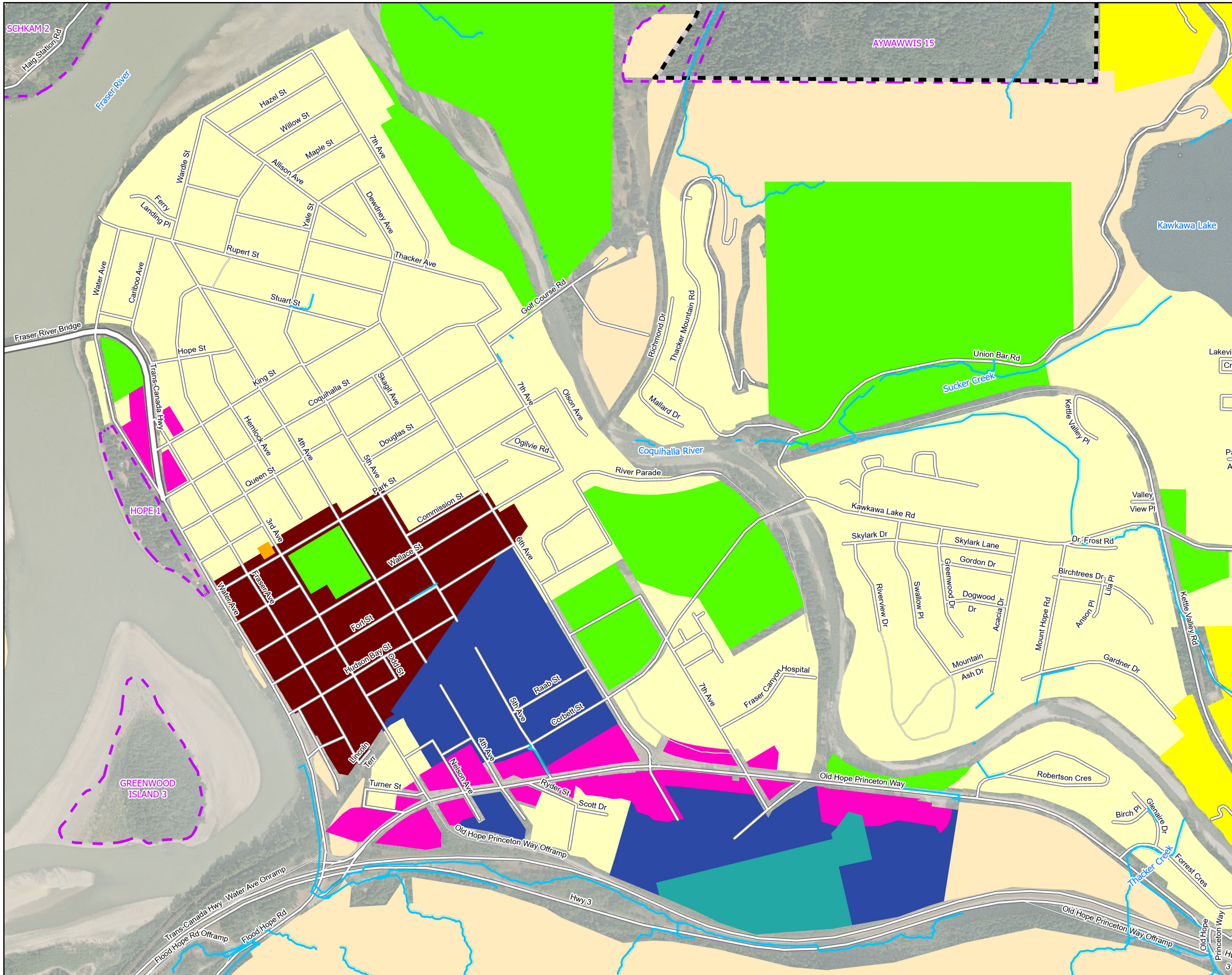
Scale:	1:25,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure B2

APPENDIX C

IOCP Land Use Figures



DISTRICT OF HOPE

OCP Future Landuse

- Airport
- Comprehensive Development
- Country Residential
- Downtown Hope
- Heavy Industry
- Highway Commercial
- Light Service Industry
- Limited Use
- Parks, Recreation and Open Space
- Rural/Agricultural
- Urban/Suburban Residential
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths

Haig
Hope
Othello
ods

0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure C1

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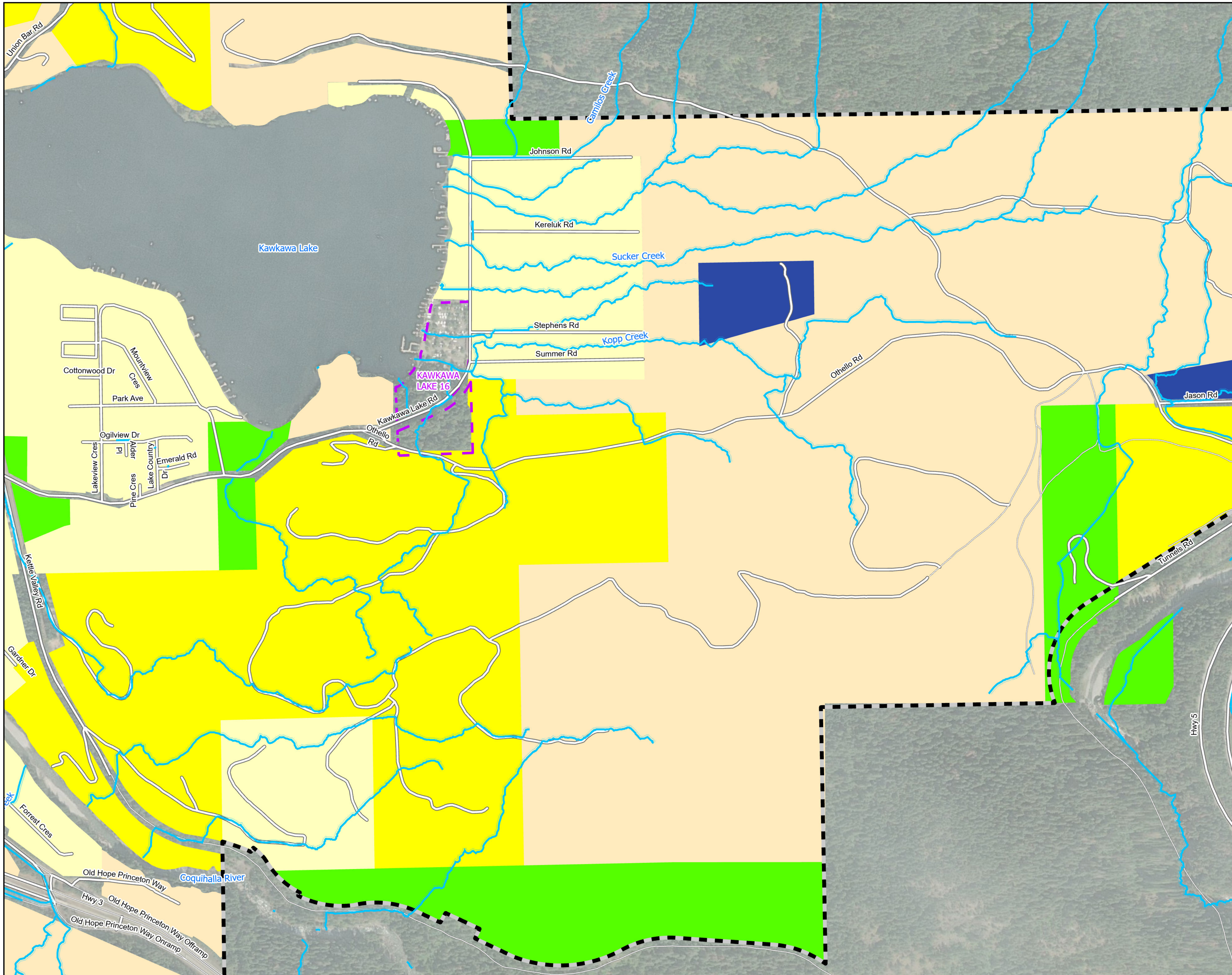
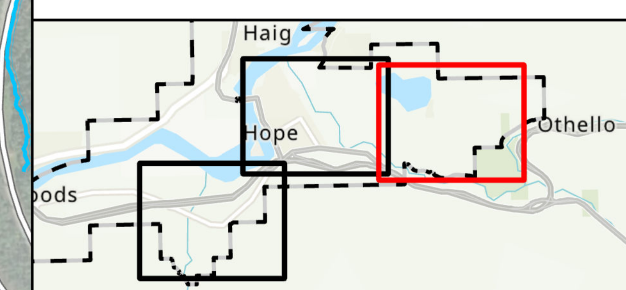


DISTRICT OF HOPE

OCP Future Landuse

- Airport
- Comprehensive Development
- Country Residential
- Downtown Hope
- Heavy Industry
- Highway Commercial
- Light Service Industry
- Limited Use
- Parks, Recreation and Open Space
- Rural/Agricultural
- Urban/Suburban Residential
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths



0 100 200 300 400 500 m

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Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

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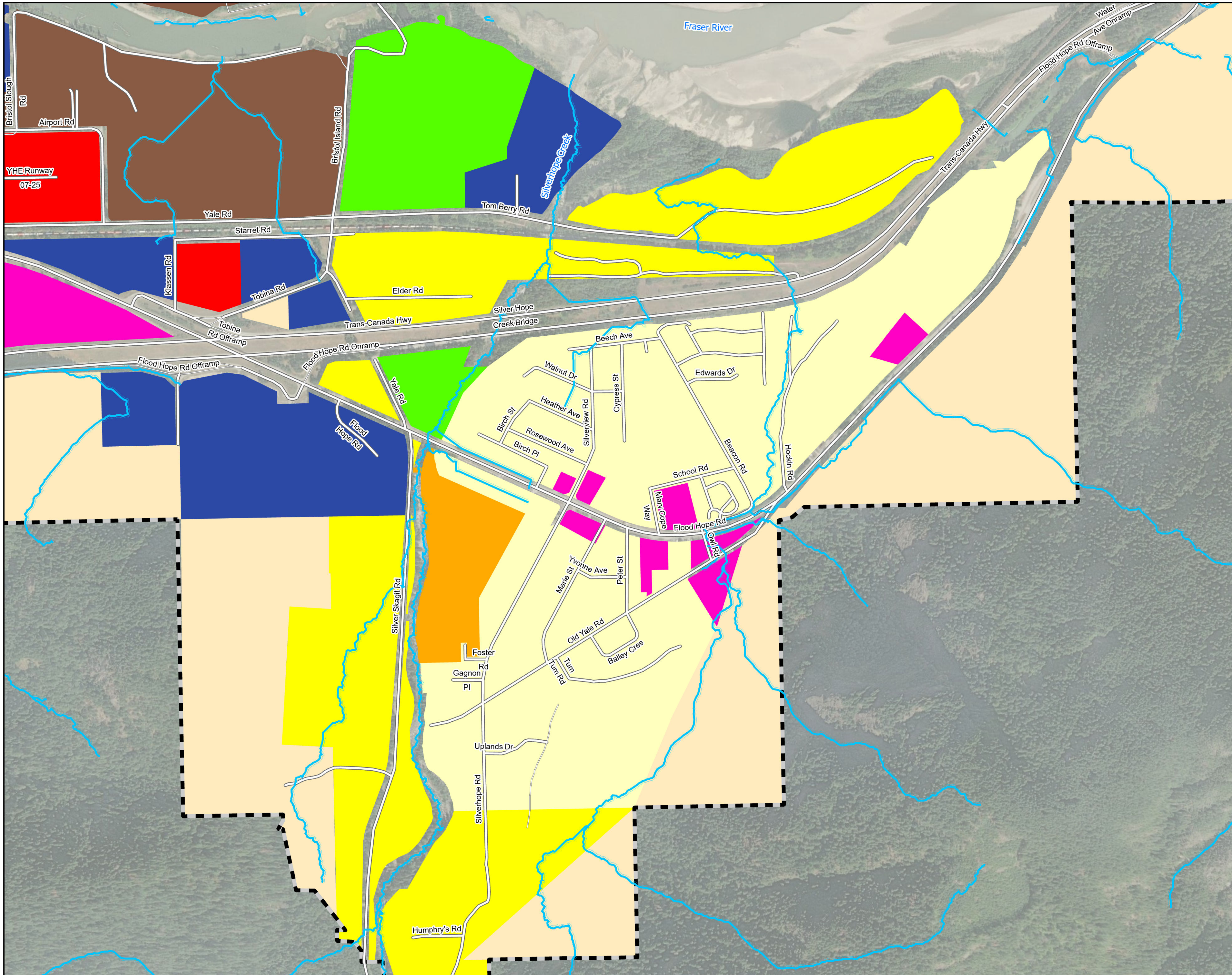
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

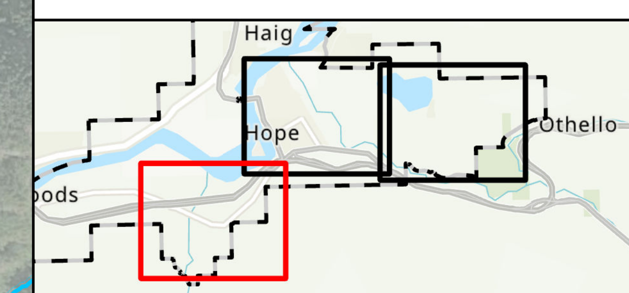
Figure C2



DISTRICT OF HOPE

OCP Future Landuse

- Airport
- Comprehensive Development
- Country Residential
- Downtown Hope
- Heavy Industry
- Highway Commercial
- Light Service Industry
- Limited Use
- Parks, Recreation and Open Space
- Rural/Agricultural
- Urban/Suburban Residential
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths



0 100 200 300 400 500 m

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Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

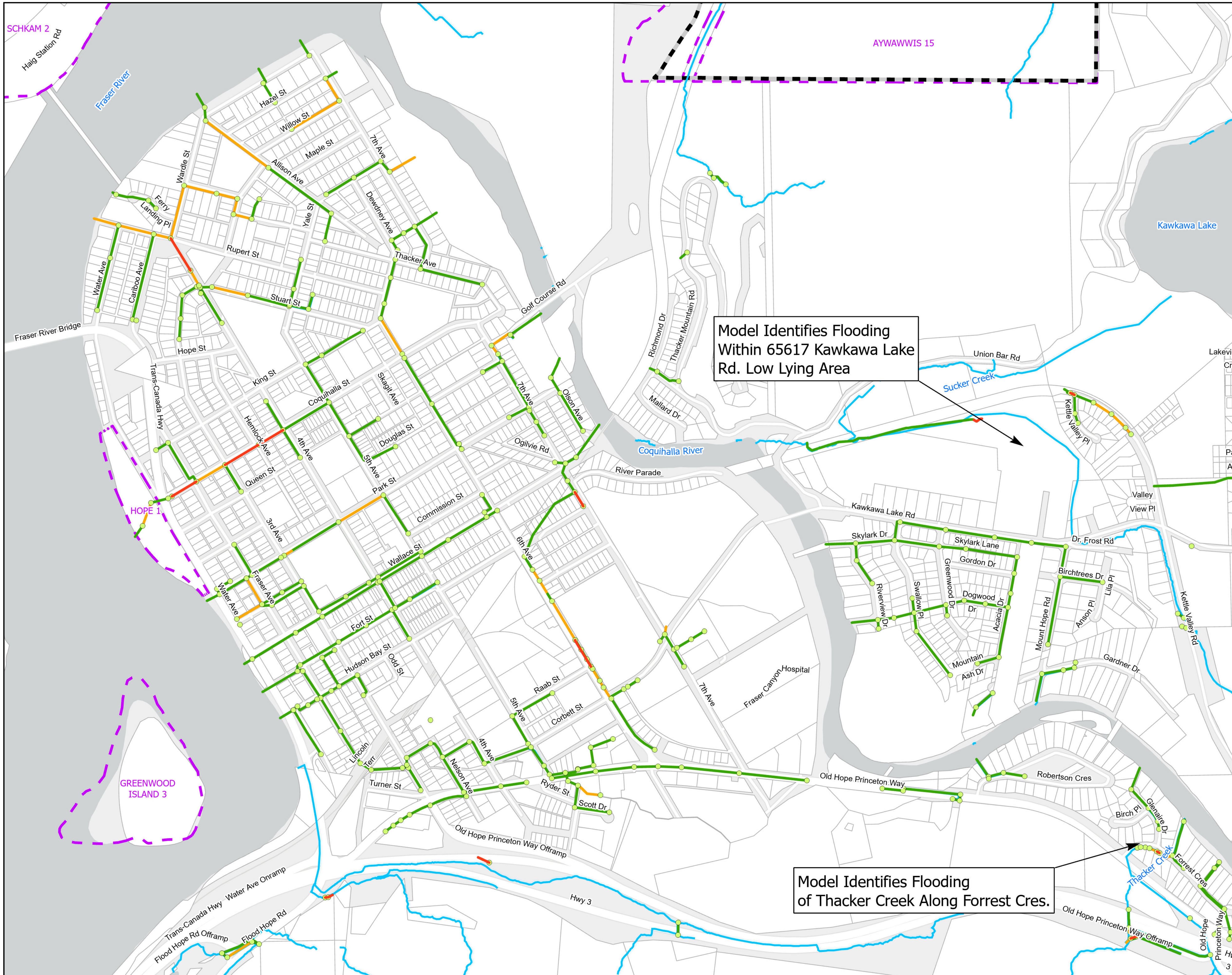
Figure C3

APPENDIX D

10 Year Storm Sewer Assessment Figures

DISTRICT OF HOPE

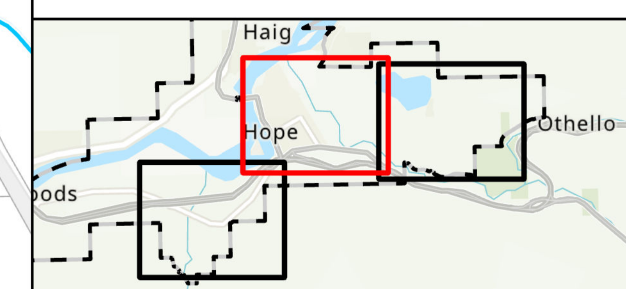
10-Year Storm Sewer Assessment



- Storm Manhole

Flow Depth vs Pipe Diameter

- No Surcharging
- Pipes > 100 % Capacity
- Pipes > 150 % Capacity
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths



0 100 200 300 400 500 m

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Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

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Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure D1

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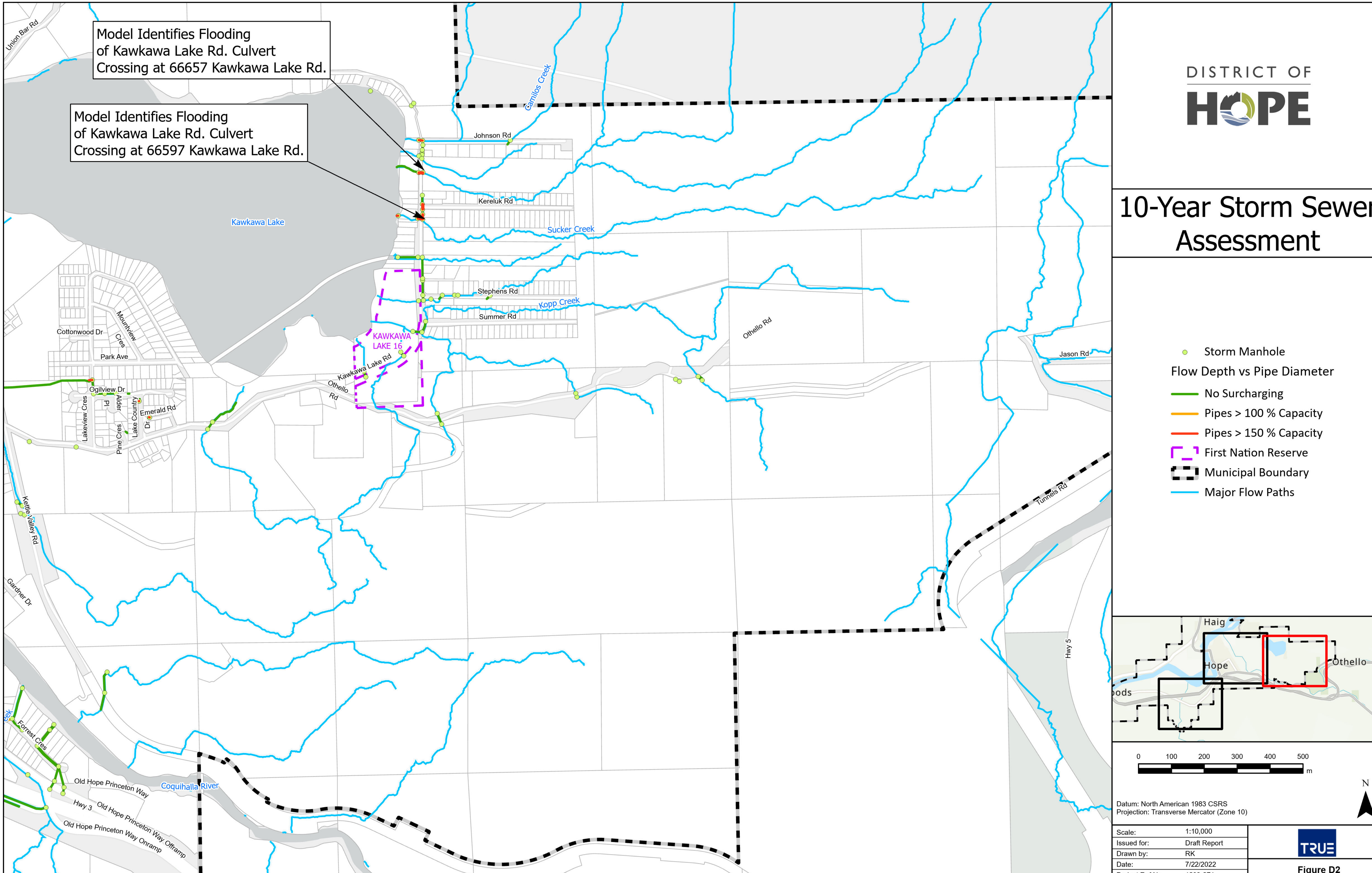

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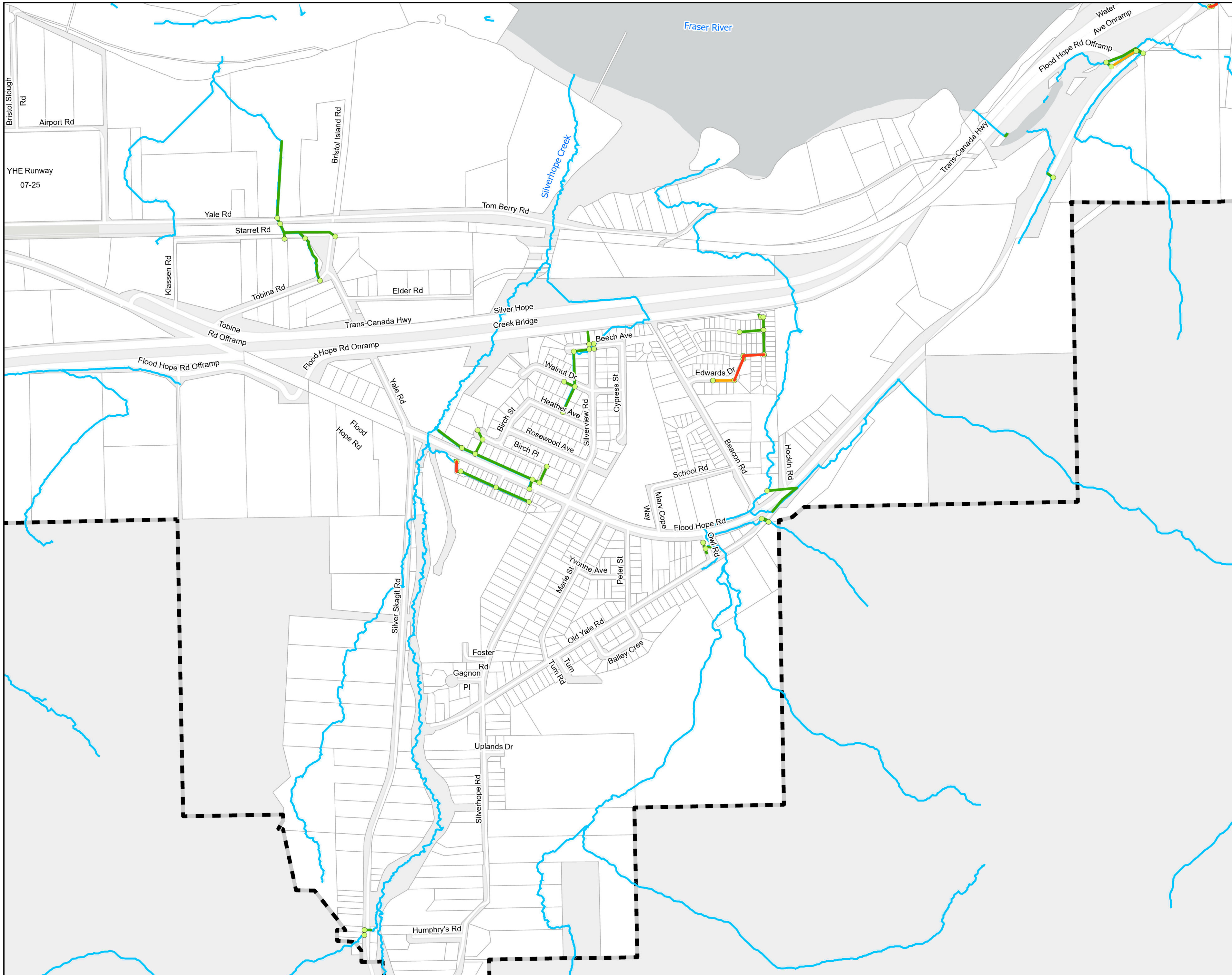


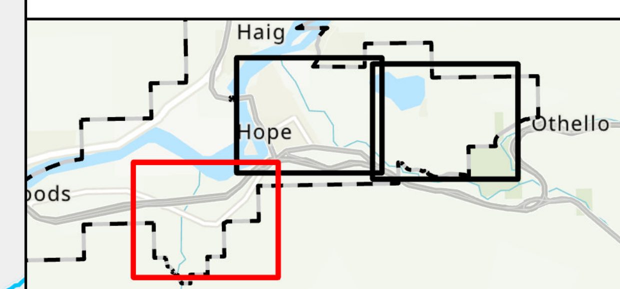
DISTRICT OF HOPE

10-Year Storm Sewer Assessment

Storm Manhole

Flow Depth vs Pipe Diameter

- No Surcharging
- Pipes > 100 % Capacity
- Pipes > 150 % Capacity
- First Nation Reserve
- Municipal Boundary
- Major Flow Paths



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

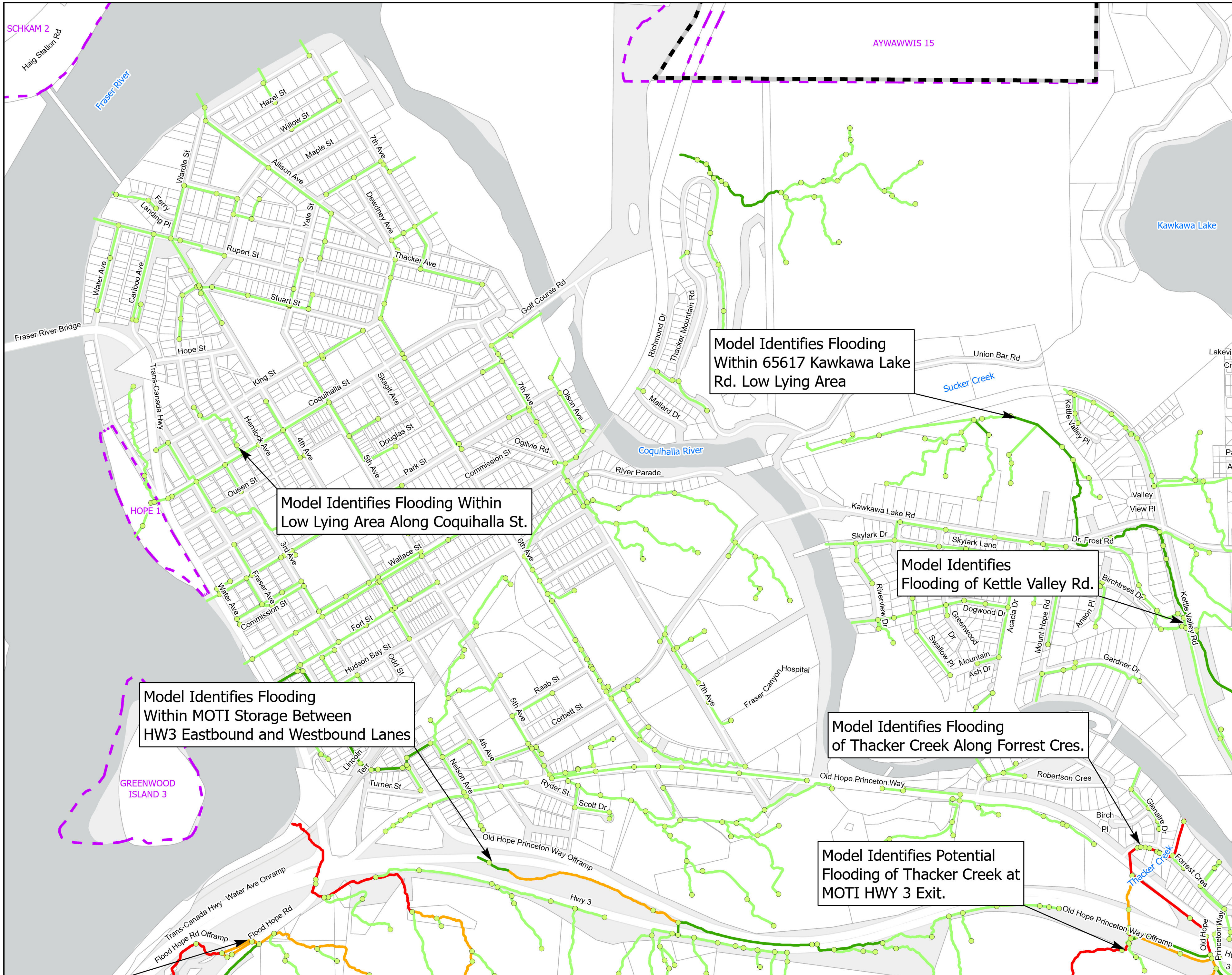
TRUE

Figure D3

R:\Clients\1200-1299\1239\1239-271\03 Drawings\GIS\1239-271.aprx

APPENDIX E

100 Year Model Results



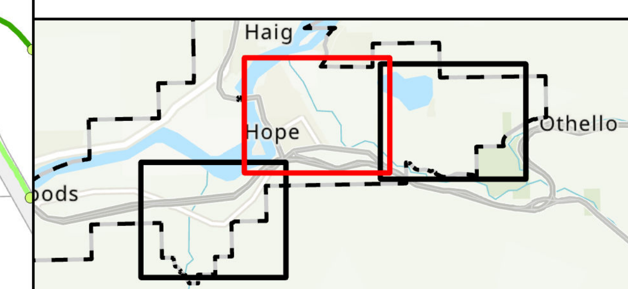
DISTRICT OF HOPE

100-Year Model Results

- Storm Manhole

Max Flow (L/s)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0
- First Nation Reserve
- Municipal Boundary



0 100 200 300 400 500 m

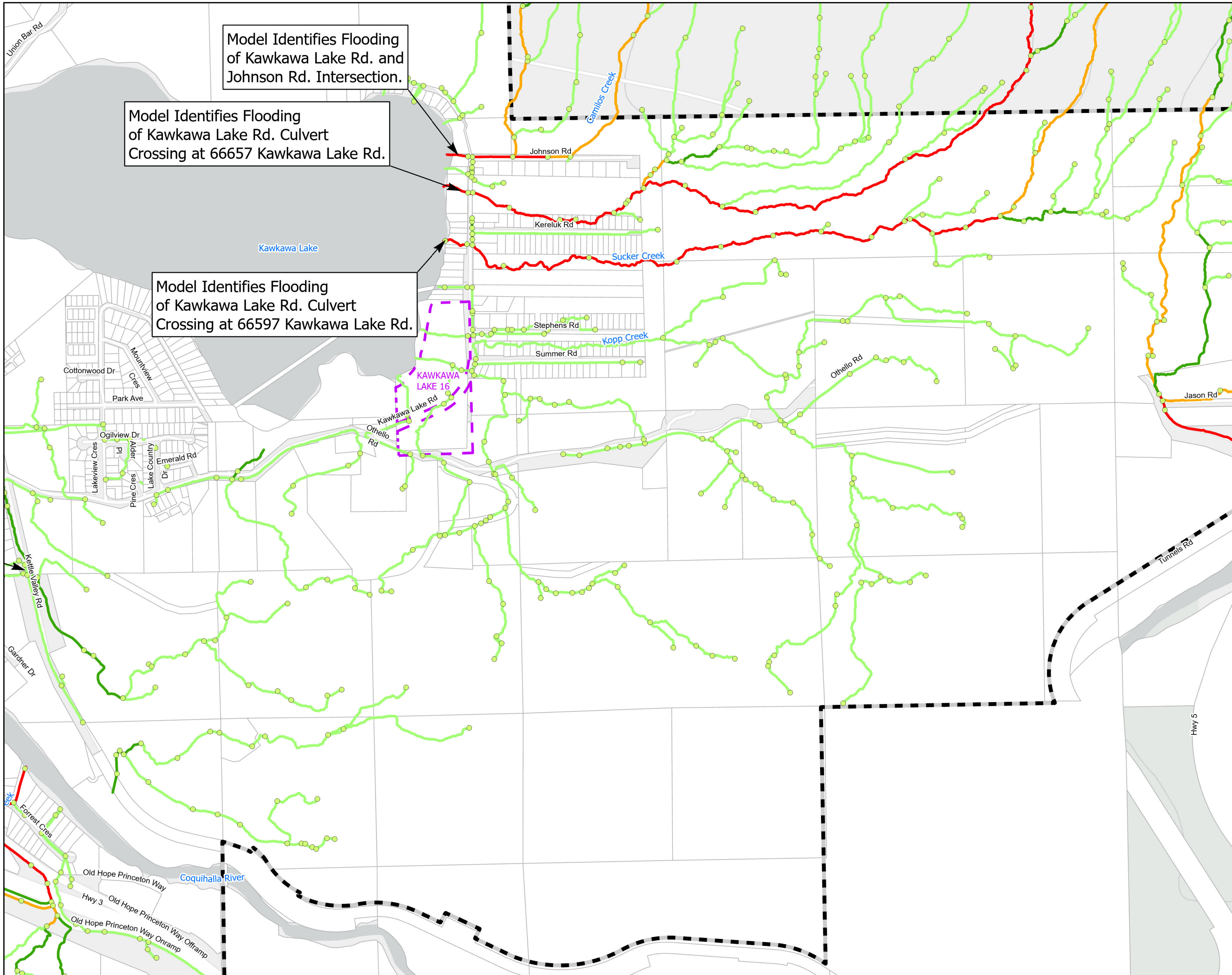
N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure E1



DISTRICT OF HOPE

100-Year Model Results

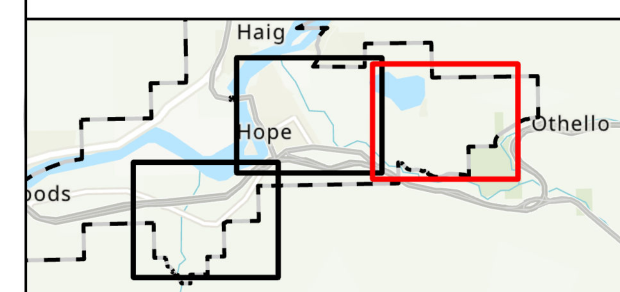
Storm Manhole

Max Flow (L/s)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

First Nation Reserve

Municipal Boundary



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

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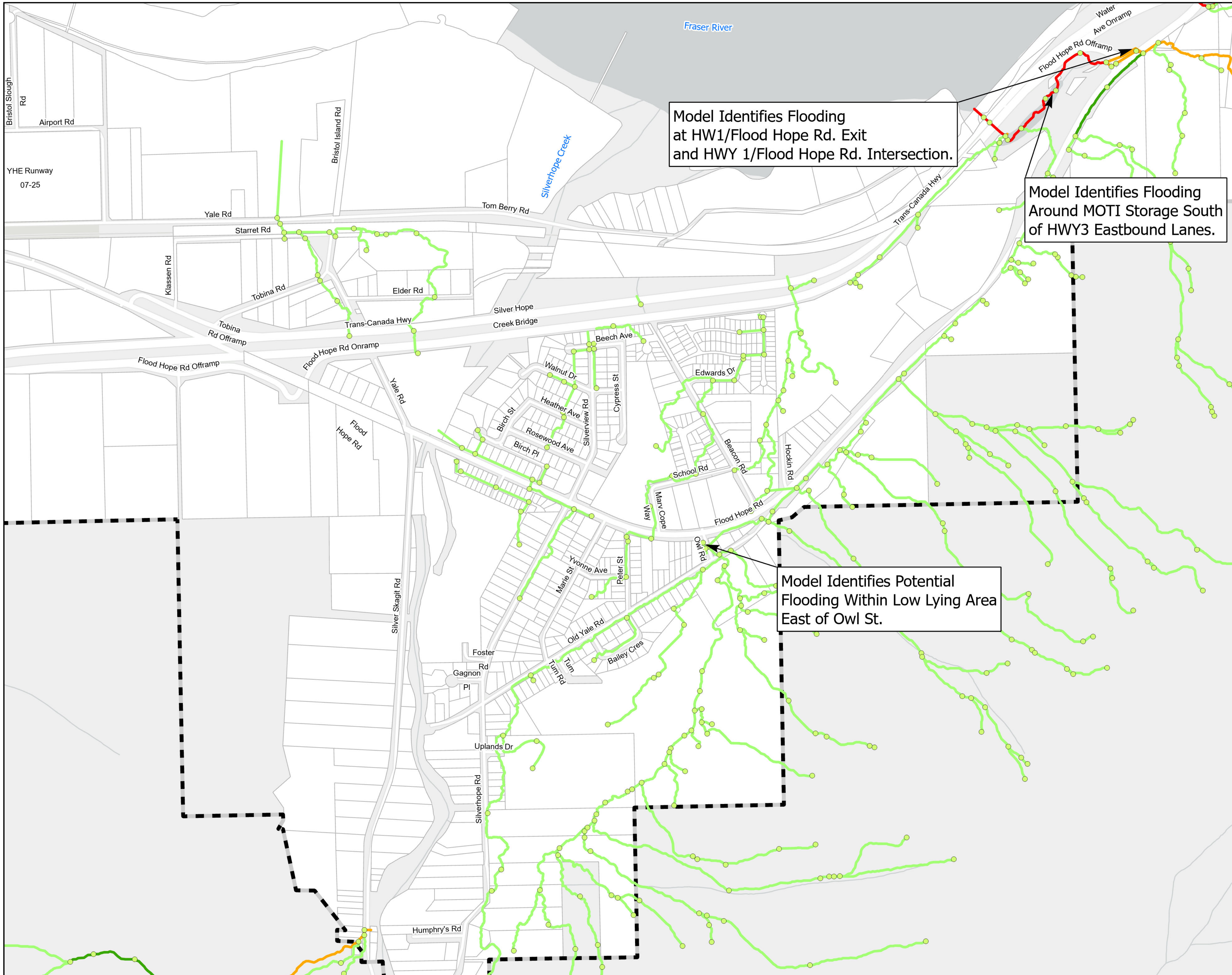
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

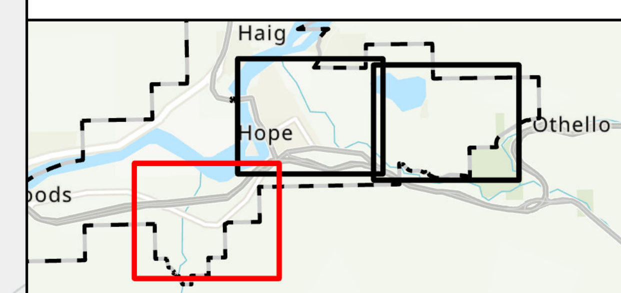
Figure E2



DISTRICT OF HOPE

100-Year Model Results

- Storm Manhole
- Max Flow (L/s)
  - 0 - 0.5
  - 0.5 - 1.0
  - 1.0 - 2.0
  - > 2.0
- First Nation Reserve
- Municipal Boundary



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

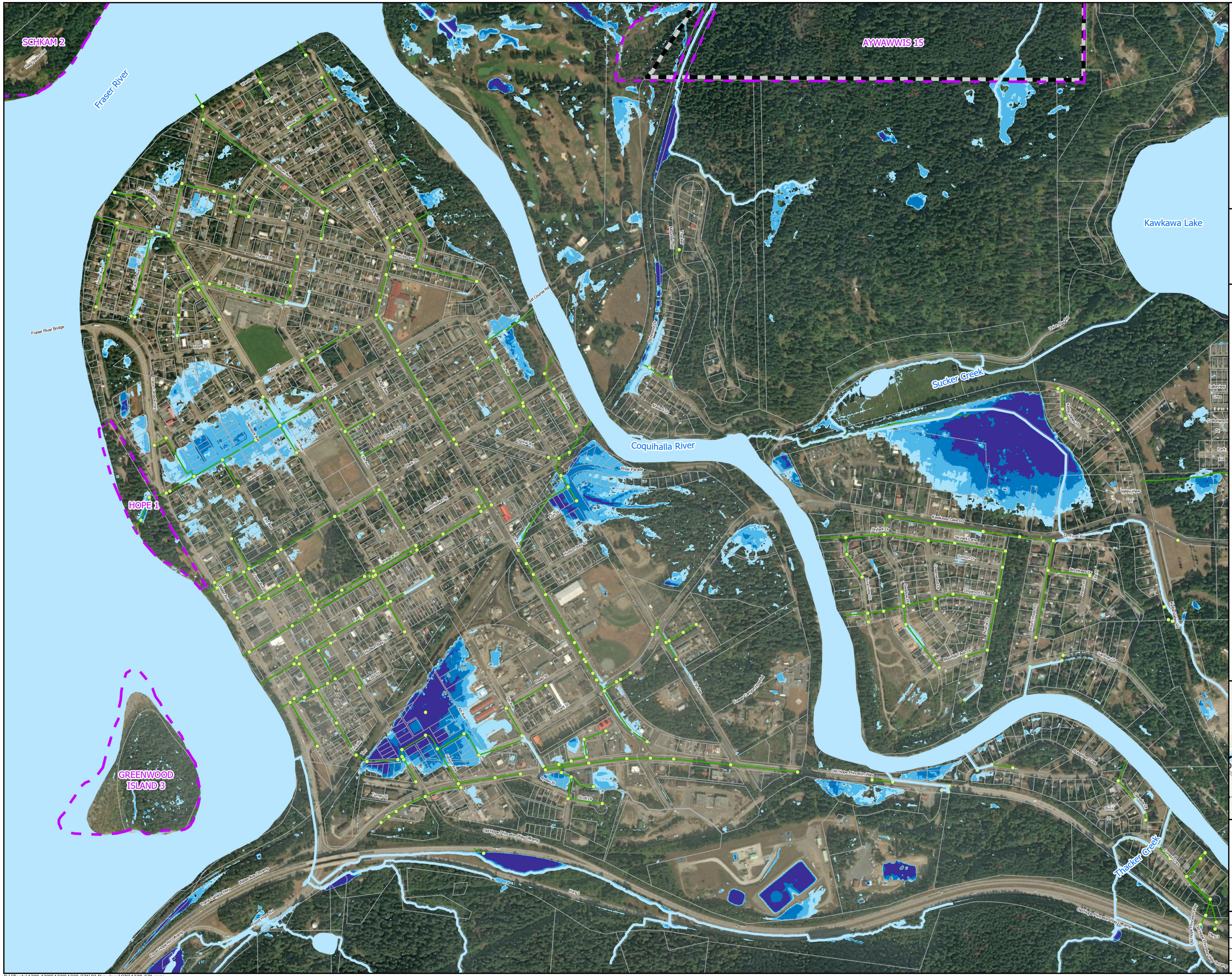
TRUE

Figure E3

R:\Clients\1200-1299\1239\1239-271\03 Drawings\GIS\1239-271.aprx

APPENDIX F

Major Potential Ponding Locations Figures



DISTRICT OF HOPE

Major Potential Ponding

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure F1

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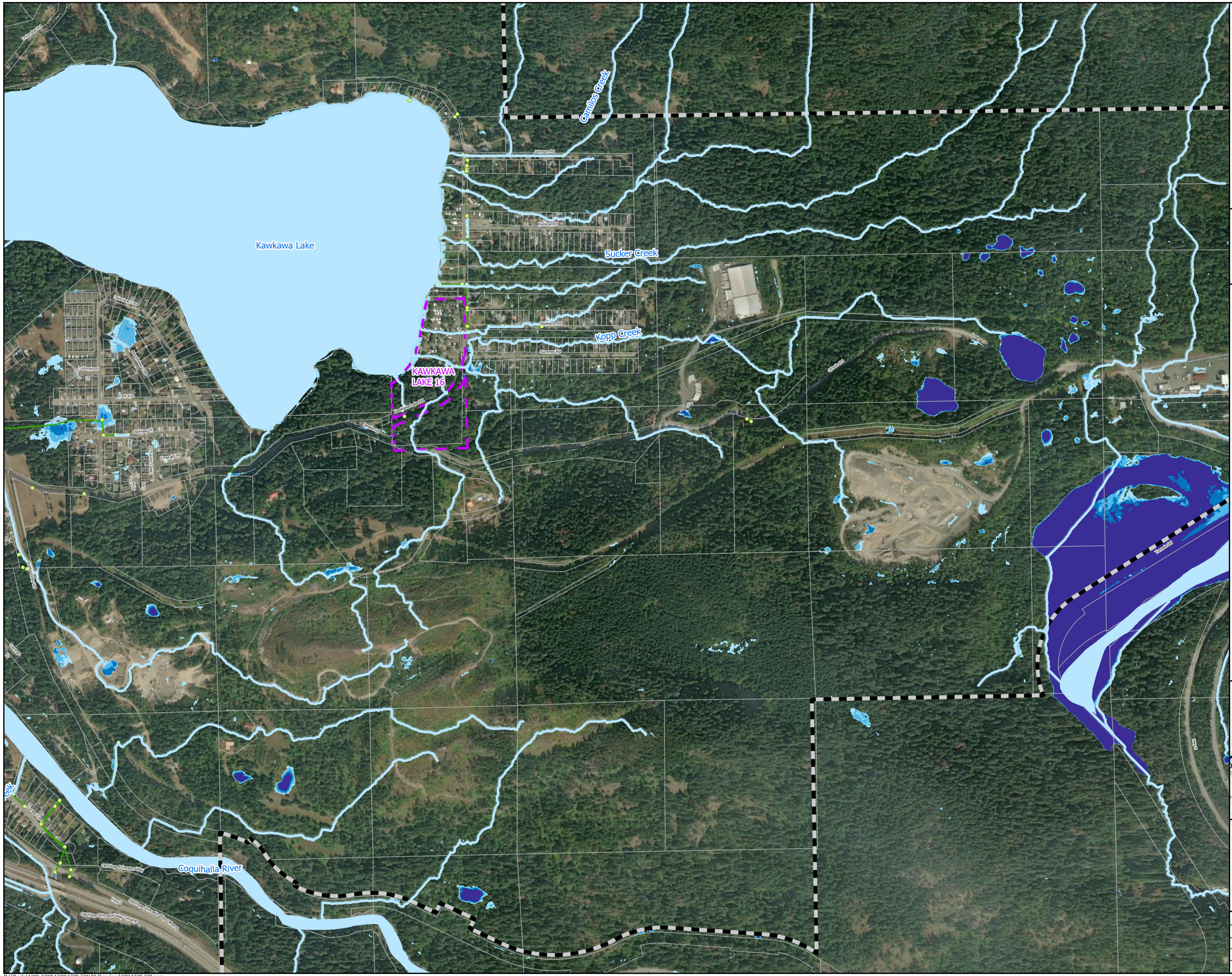


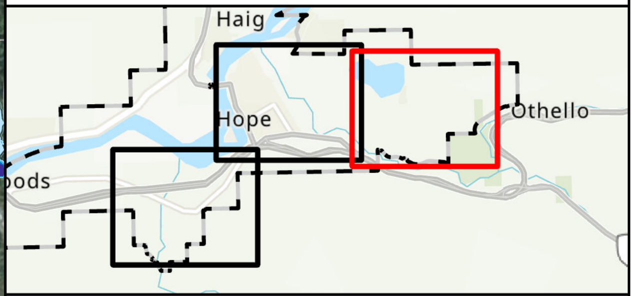
DISTRICT OF HOPE

Major Potential Ponding

- Storm Manhole
- Storm Mains
- Major Flow Paths
- First Nation Reserve
- Municipal Boundary

Max Depth (m)

- 0.15 - 0.5
- 0.5 - 1
- 1 - 1.5
- > 1.5



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure F2

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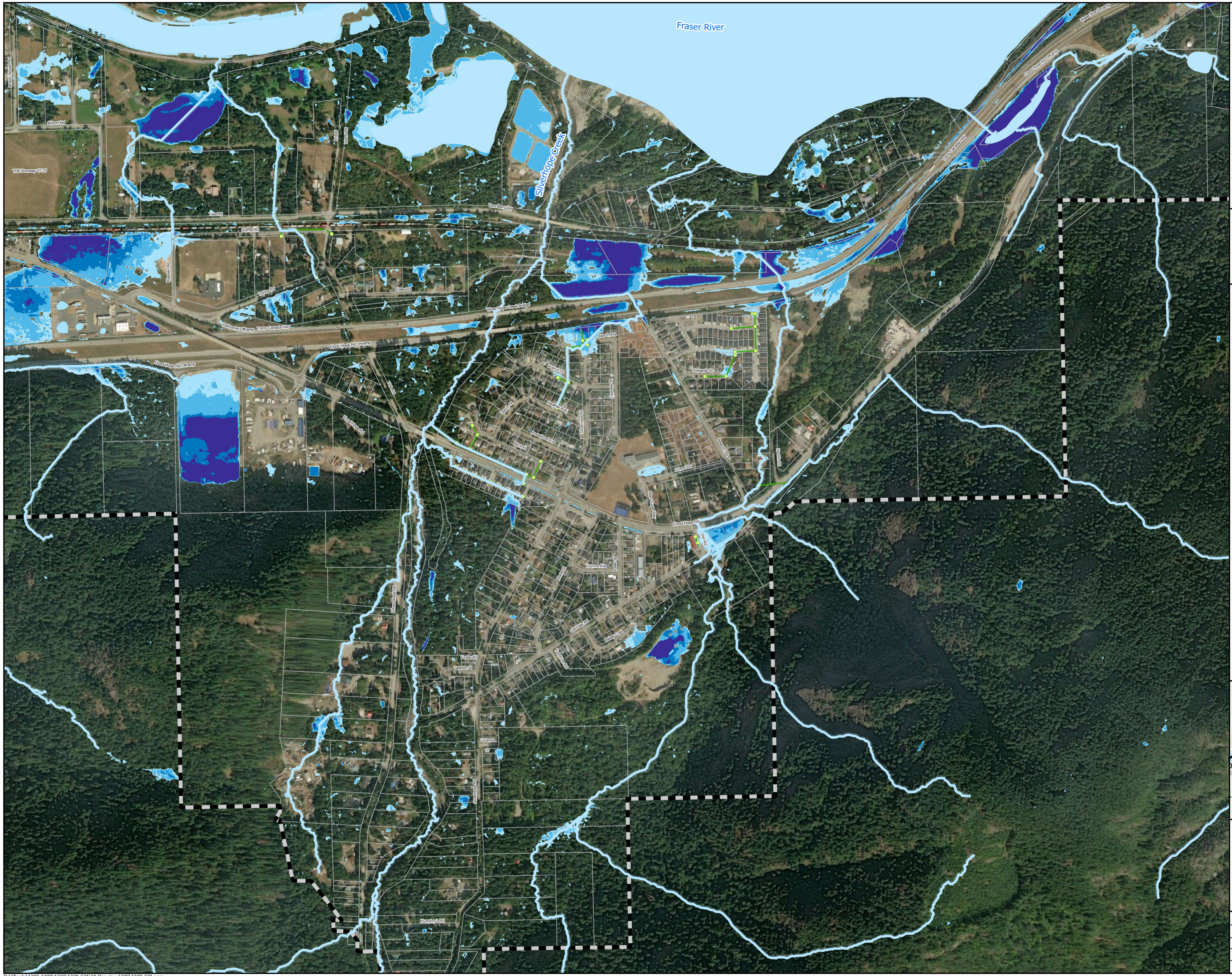


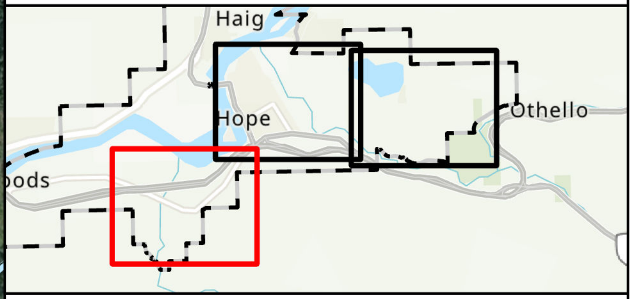
DISTRICT OF HOPE

Major Potential Ponding

- Storm Manhole
- Storm Mains
- Major Flow Paths
- First Nation Reserve
- Municipal Boundary

Max Depth (m)

- 0.15 - 0.5
- 0.5 - 1
- 1 - 1.5
- > 1.5



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

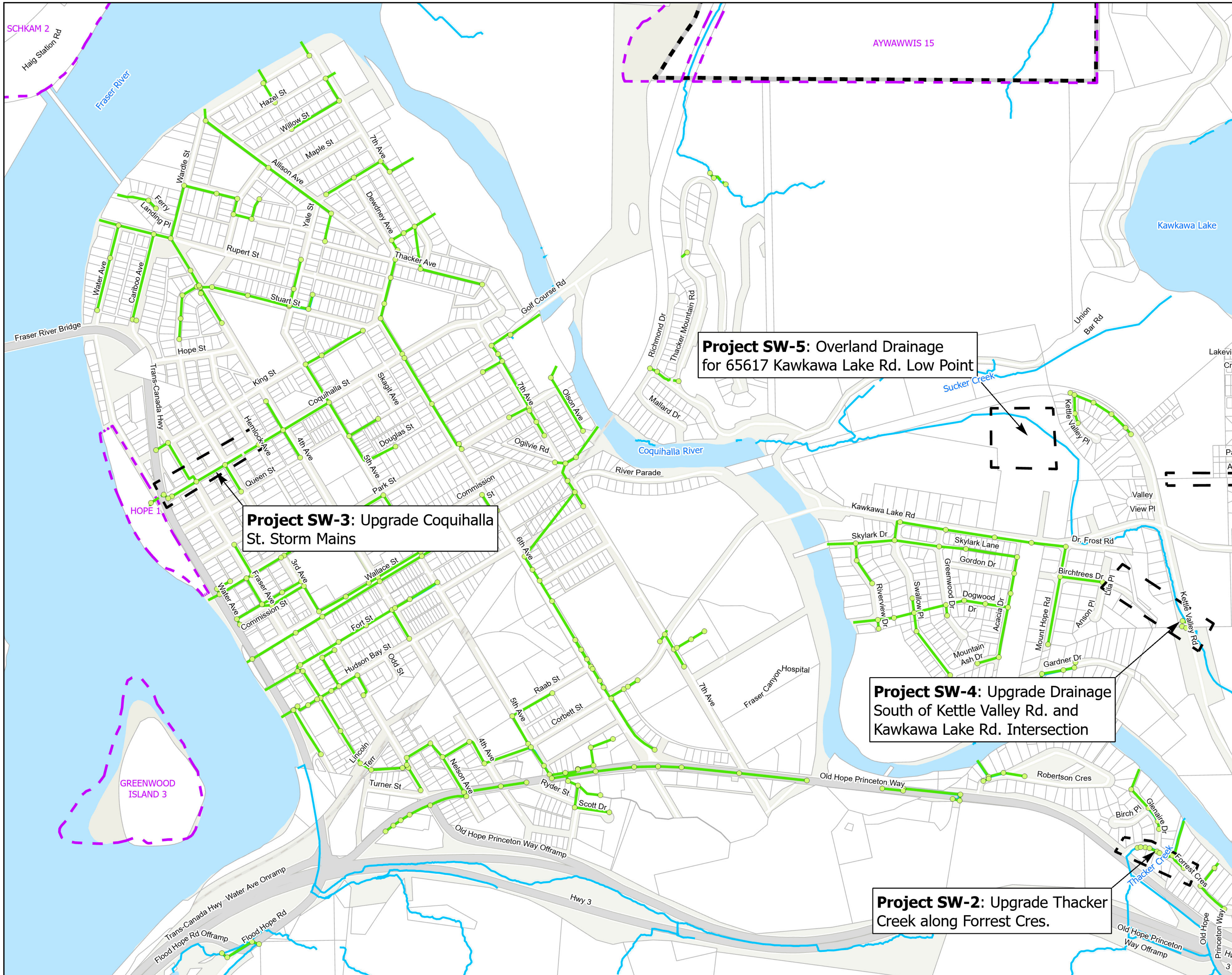
Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

Figure F3

R:\Clients\1200-1299\1239\1239-271\03 Drawings\GIS\1239-271.aprx

APPENDIX G

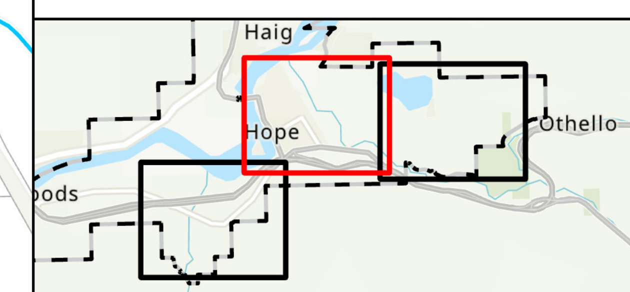
Prioritized Upgrades Locations Figures



DISTRICT OF HOPE

Prioritized Upgrades

- Storm Manhole
- Storm Mains
- Municipal Boundary
- First Nation Reserve
- Major Flow Paths
- Project Area



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Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

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Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure G1

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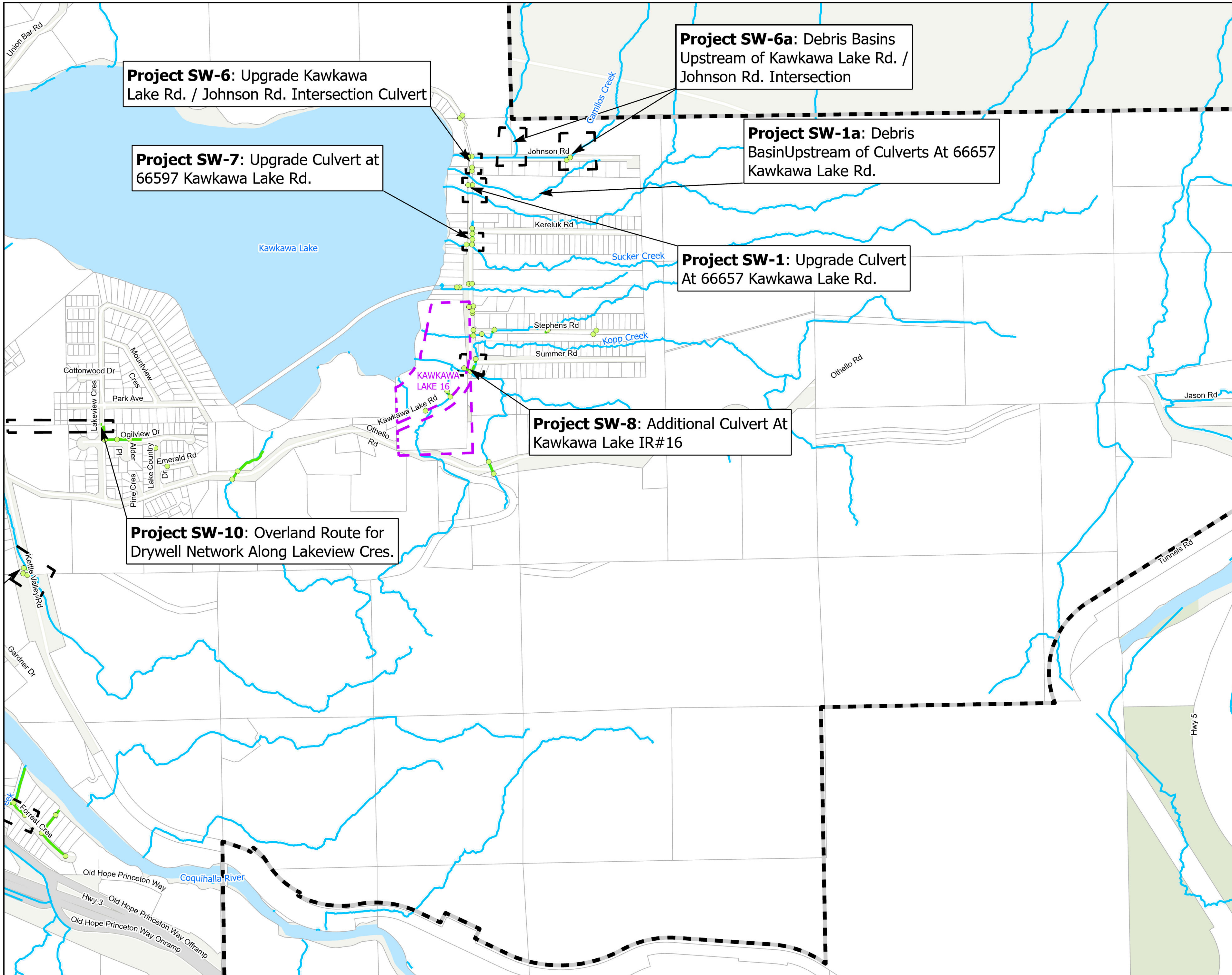
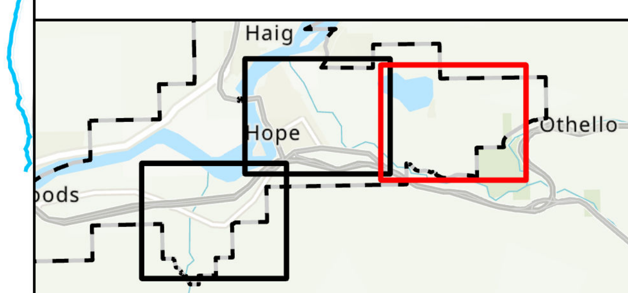


DISTRICT OF HOPE

Prioritized Upgrades

- Storm Manhole
- Storm Mains
- Municipal Boundary
- First Nation Reserve
- Major Flow Paths
- Project Area



0 100 200 300 400 500 m

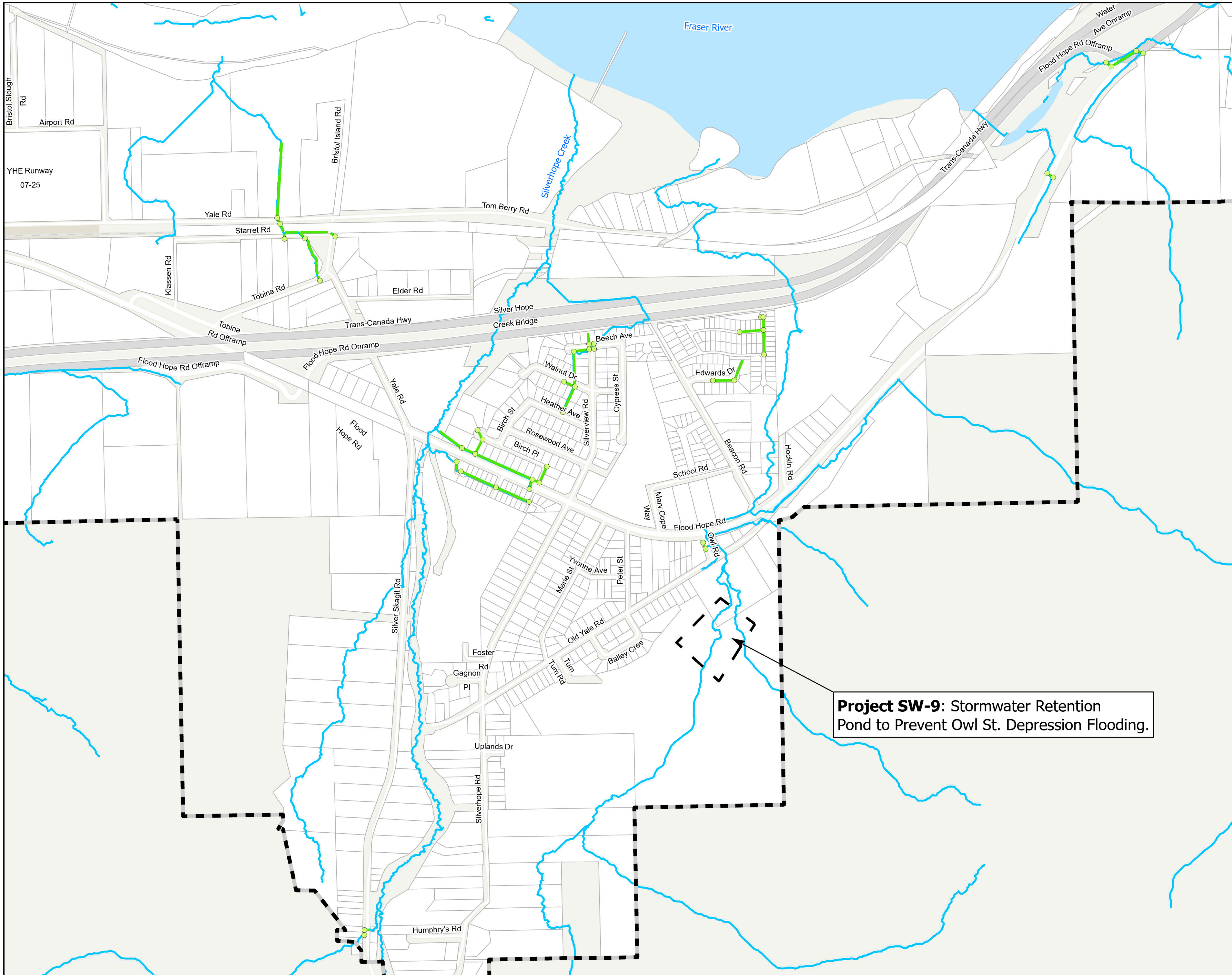
N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

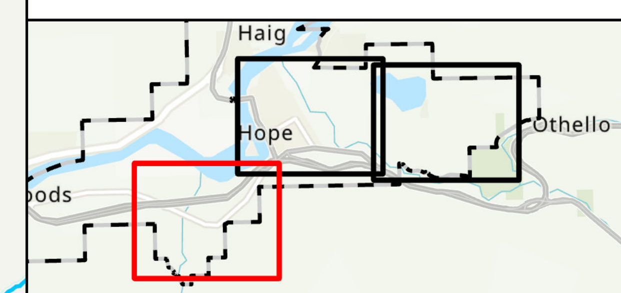
Figure G2



DISTRICT OF HOPE

Prioritized Upgrades

- Storm Manhole
- Storm Mains
- Municipal Boundary
- First Nation Reserve
- Major Flow Paths
- Project Area



0 100 200 300 400 500 m

N

Datum: North American 1983 CSRS
Projection: Transverse Mercator (Zone 10)

Scale:	1:10,000
Issued for:	Draft Report
Drawn by:	RK
Date:	7/22/2022
Project Ref No.	1239-271

TRUE

Figure G3

APPENDIX H

Project Sheets

SW-1a Project:

Debris Basin Upstream of Culverts At 66657 Kawkawa Lake Rd.

Priority: High

Trigger: Mitigate Debris Flows and Stream Migration Major Storm Events

Performance During November 2021 Major Storm Event

Debris and stormwater flow overwhelmed creek bed north of Kereluk Rd. Creek breaks banks and realigns to cross Kawkawa Lake Rd. south of existing crossing. Desired creek flow maintained by emergency resources efforts.

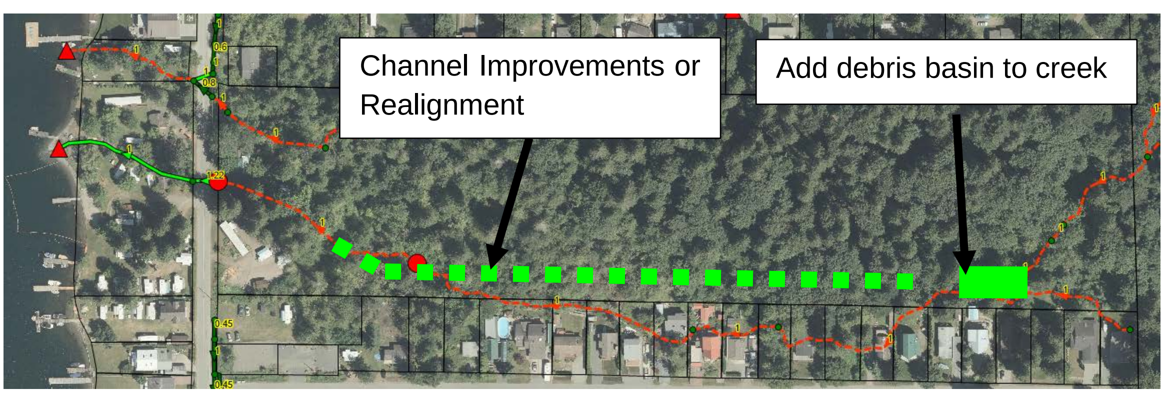
Mitigation Solutions

A debris basin for catching migrating creek debris would help limit the stream avulsion processed migration during major storm events.

The existing creek channel is extremely confined with historic encroachments and has insufficient capacity even the recent areas rebuilt after the November storm. Improvements and even realignment of the channel is warrant to reduce risk to existing residences and potential downstream overtopping toward Kawkawa Lake Rd.

Creek crosses private land which is identified in OCP as Urban/Suburban residential. Negotiation with landowner during future subdivision or development could acquire necessary land for debris basin.

Proposed Solution Figure



Cost Estimate

Estimate Value: $1,200,000

SW-1 Project:

Upgrade Culvert At 66657 Kawkawa Lake Rd.

Priority: High

Trigger: Mitigate Flooding During 10- and 100-Year Events

Performance During 10 Year Return Period Storm with Climate Change

Culvert overwhelmed with notable surcharging leading to flooding of roadway. Very high flows in private channel west of road.

Performance During 100 Year Return Period Storm with Climate Change

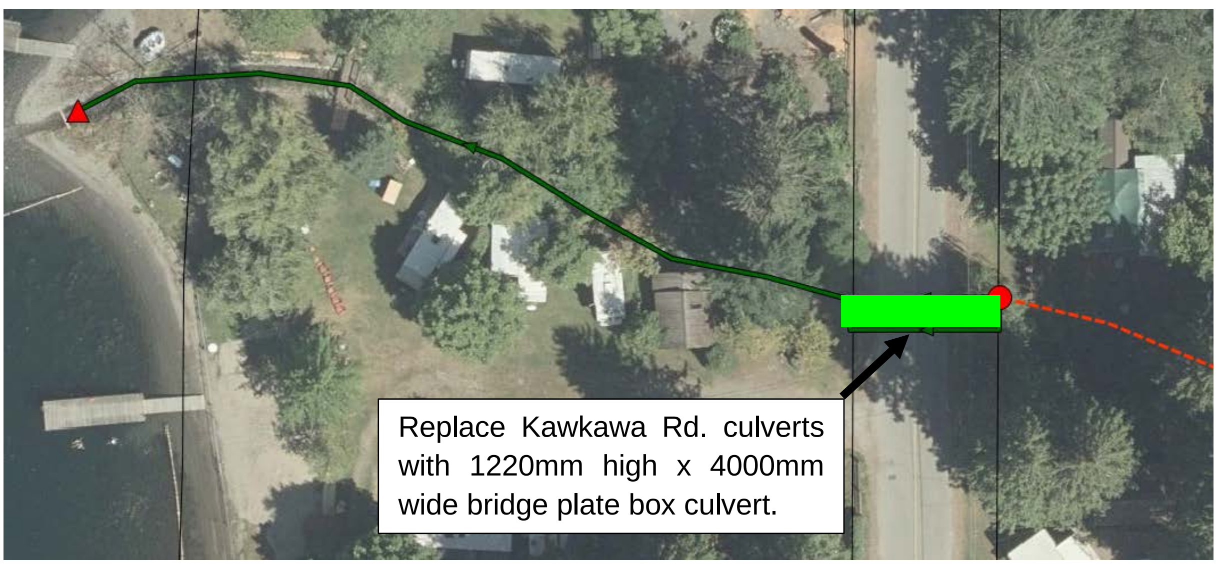
Culvert overwhelmed and roadway flooded.

Mitigation Solutions

Increase culvert capacity by replacing existing culvert with a with 1220mm high x 4000mm wide bridge plate box culvert.

Establish bylaw to protect overland flow paths from encroachment and regrading.

Proposed Solution Figure



Cost Estimate

Estimate Value: $600,000

SW-2 Project:

Upgrade Thacker Creek along Forrest Cres.

Priority: High

Trigger: Mitigate Flooding During 10- and 100-Year Events

Performance During 10 Year Return Period Storm with Climate Change

High flows overwhelm south side ditching and culverts. Overland flow occurs, likely to spill down Glenaire Dr.

Performance During 100 Year Return Period Storm with Climate Change

Very high flows overwhelm south side ditching and culverts. Overland flow occurs, likely to spill down Glenaire Dr.

Existing Driveway Crossing 1

Existing Driveway Crossing 2

Existing Driveway Crossing 3

Existing RoadwayCrossing 2

Mitigation Solutions

Confirm major storm event stormwater flows in existing channel by monitoring.

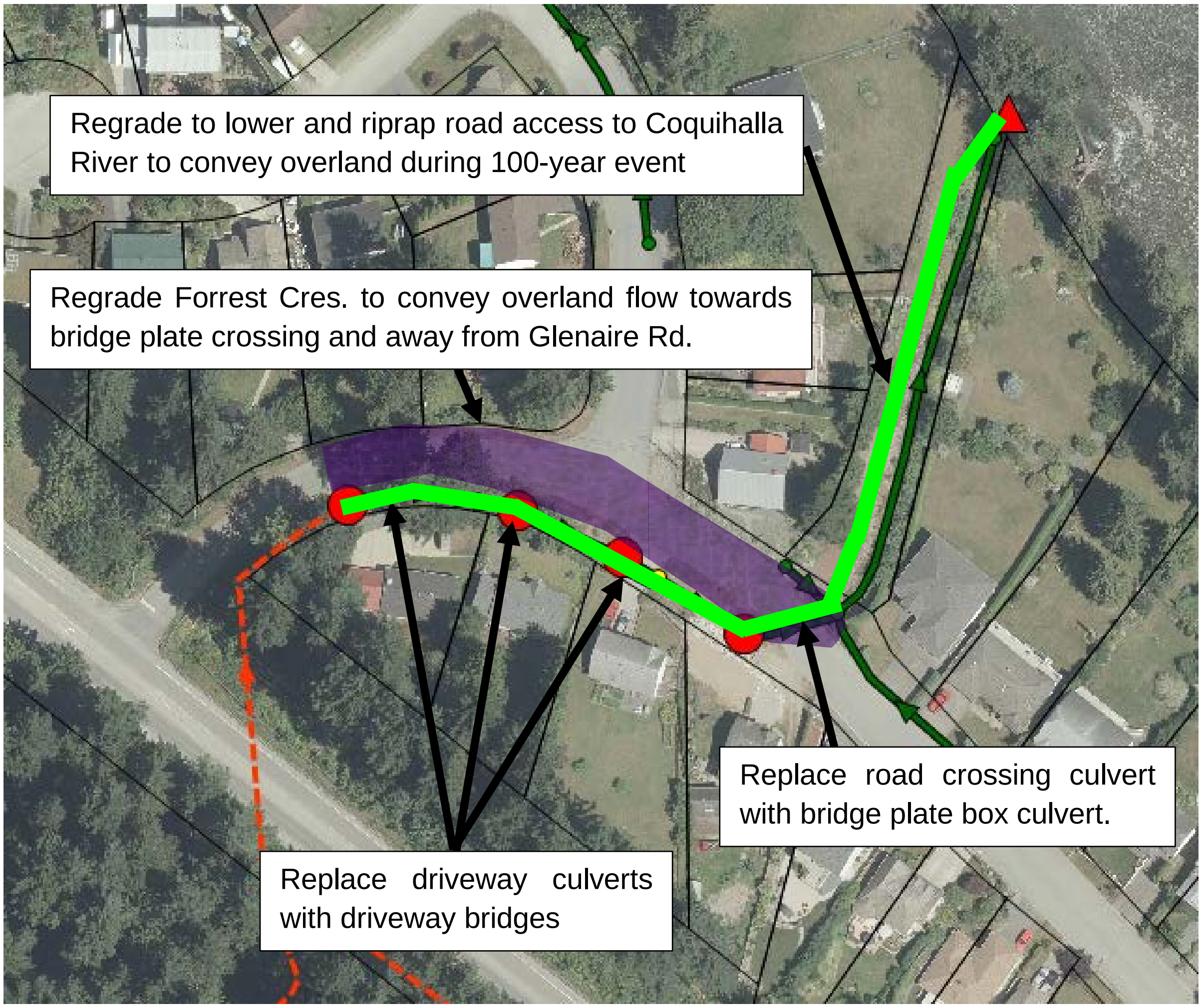
Replace driveway culverts with driveway bridges to maintain wide ditch channel along south side of Forrest Cres.

Replace road crossing culvert with 1400mm high x 4500mm wide bridge plate box culvert.

Regrade to lower and riprap gravel road access to Coquihalla River to convey overland flow.

Regrade Forrest Cres. to convey flooding water towards bridge plate box culvert. Superelevate road to prevent flood from spilling onto Glenaire.

Proposed Solution Figure



Cost Estimate

Estimate Value: $1,500,000

SW-3 Project:

Upgrade Coquihalla St. Storm Mains

Priority: High

Trigger: Mitigate Flooding During 10- and 100-Year Events

Performance During 10 Year Return Period Storm with Climate Change

Underground piping at capacity from runoff. Minor surface ponding.

Performance During 100 Year Return Period Storm with Climate Change

Storm sewers overwhelmed. Low lying area has no outlet. Flooding to occur.

Mitigation Solutions

Replace existing 600mm clay and corrugated steel pipe storm mains with 900mm.

Add high capacity inlet at low points and connect to upgraded storm mains.

Proposed Solution Figure

Cost Estimate

Estimate Value: $1,700,000

SW-4 Project:

Upgrade Drainage South of Kettle Valley Rd. and Kawkawa Lake Rd. Intersection

Priority: Moderate

Trigger: Mitigate Roadway Washout Risk and 100-Year Storm Event Flooding.

Background

High side ditching along Kettle Valley Rd. has filled in with sediment, resulting in overtopping and washout of roadway.

Performance During 100 Year Return Period Storm with Climate Change

Very high flows through road crossing, likely to result in overtopping and flooding of roadway. Very high flows through undefined overland routes at base of steep slope.

Mitigation Solutions

Monitor and confirm flows from industrial lot to east and through culverts.

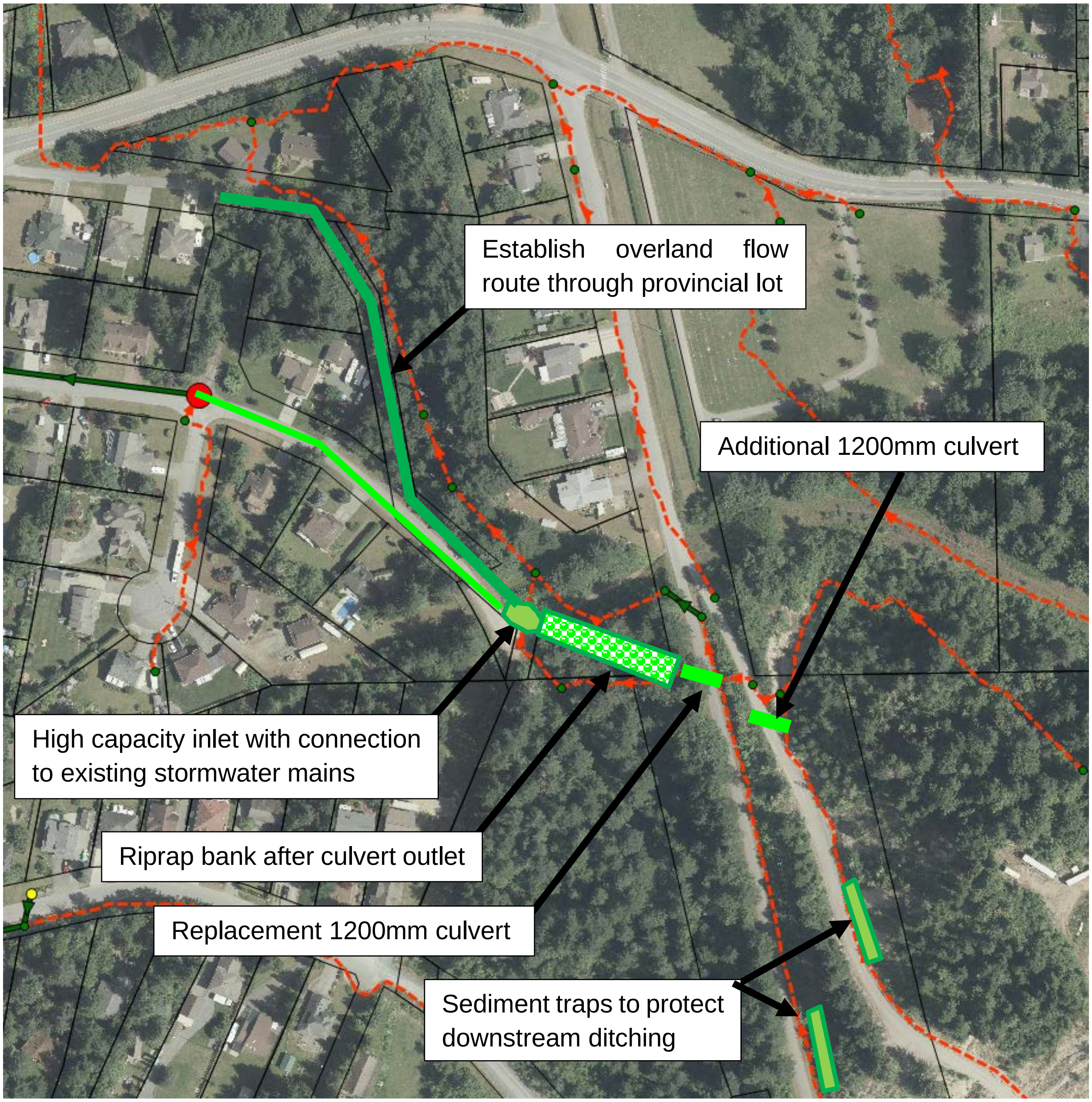
Protect ditching from upstream sediment by adding sediment trap along stormwater ditching from industrial lot to east.

Replace culvert crossing to prevent overtopping of road. Riprap culvert outlet to safely convey runoff down slope. This proposed riprap is on land which is currently privately owned but likely undevelopable.

High capacity inlet at base of riprap into 200m of stormwater main leading to existing stormwater main beneath Birchtrees Dr.

Stormwater ditching along provincial lot to convey overland major storm event runoff toward Dr. Frost Rd.

Proposed Solution Figure



Cost Estimate

Estimate Value: $1,000,000

SW-5 Project:

Overland Drainage for 65617 Kawkawa Lake Rd. Low Point

Priority: Moderate

Trigger: Subdivision Application or Building Permit for 65617 Kawkawa Lake Rd

Performance During 10 Year Return Period Storm with Climate Change

Low lying area overwhelmed by incoming runoff. Area is without overland drainage path and volume is infiltrated.

Performance During 100 Year Return Period Storm with Climate Change

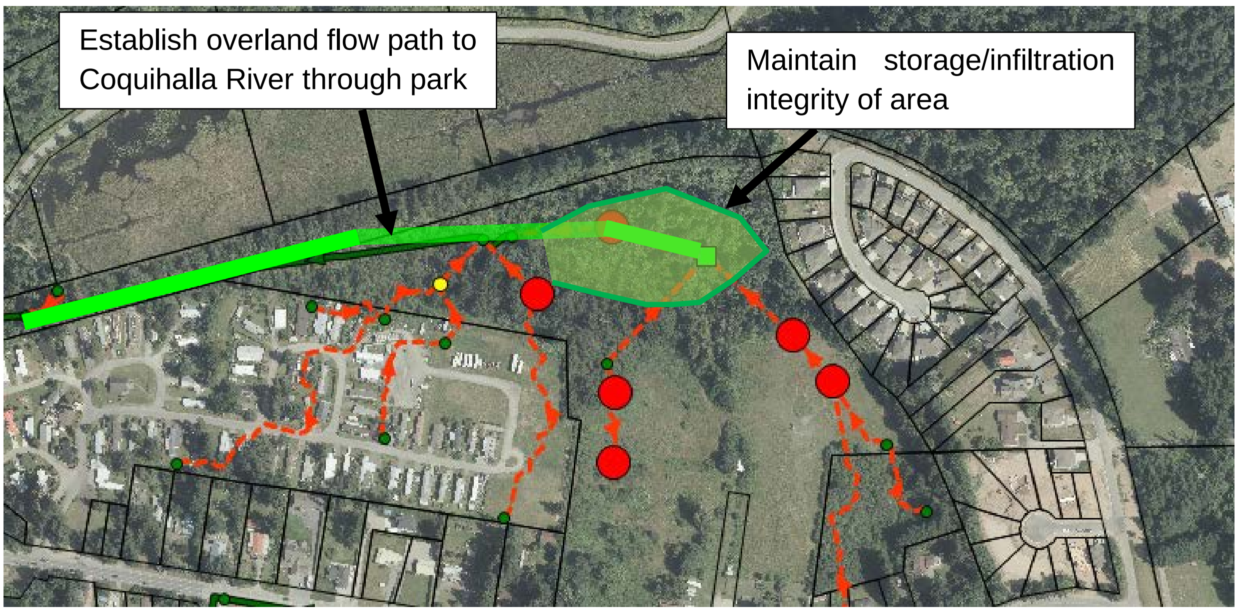
Low lying area floods until overland flow path to northwest begins to flow. Remaining volume is infiltrated.

Mitigation Solutions

Establish drainage to Coquihalla through park area.

Significant runoff storage offered by this low point. Must be retained regardless of development.

Proposed Solution Figure



Cost Estimate

Estimate Value: $300,000

SW-6a Project:

Debris Basins Upstream of Kawkawa Lake Rd. / Johnson Rd. Intersection

Priority: Moderate

Trigger: Mitigate Debris Flows and Stream Migration Major Storm Events

Background

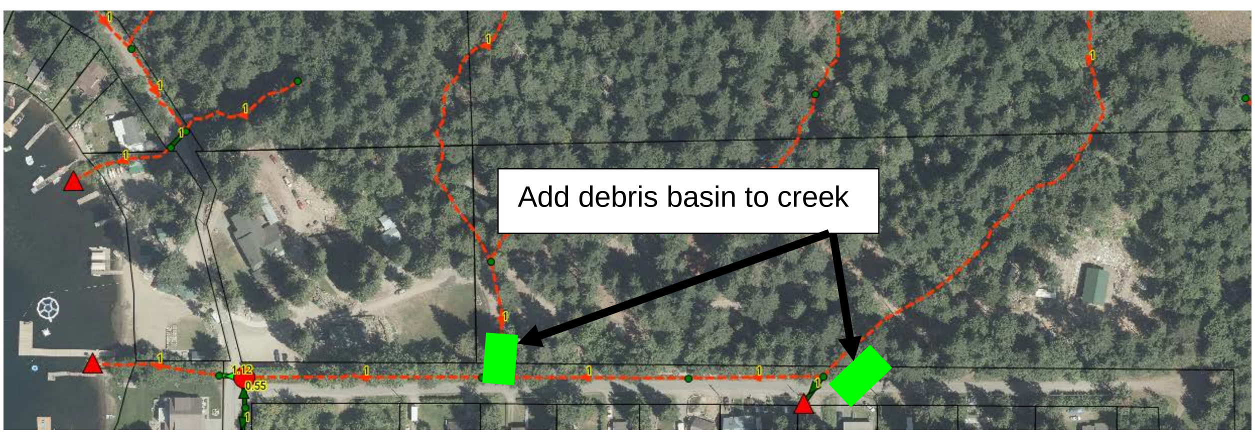
Creek leading to Kawkawa Lake Rd./Johnson Rd. intersection carries debris from the nearby mountainside. Northwest Hydraulics Consultants (nhc) reported in their April 25, 2002 Johnson Road Flood Hazard Assessment report that an estimated 2000m3 of debris was trucked away following the January 6 – 8, 2002 rain on snow event. This previous nhc work recommended a sediment trap to capture stream sediment before it is deposited in roadside ditches.

Mitigation Solutions

Add debris basins for catching migrating sediment and debris to help limit ditch infill and stream migration during major storm events.

The contributing creeks cross private land which is identified in OCP as Urban/Suburban residential. Negotiation with landowner during future subdivision or development could acquire necessary land for debris basin.

Proposed Solution Figure



Cost Estimate

Estimate Value: $800,000

SW-6 Project:

Upgrade Kawkawa Lake Rd. / Johnson Rd. Intersection Culvert

Priority: Moderate

Trigger: Mitigate Flooding During 10- and 100-Year Events

Performance During 10 Year Return Period Storm with Climate Change

Surcharging present at intersection northwest corner, resulting in some flooding of intersection. High flows in private channel west of road

Performance During 100 Year Return Period Storm with Climate Change

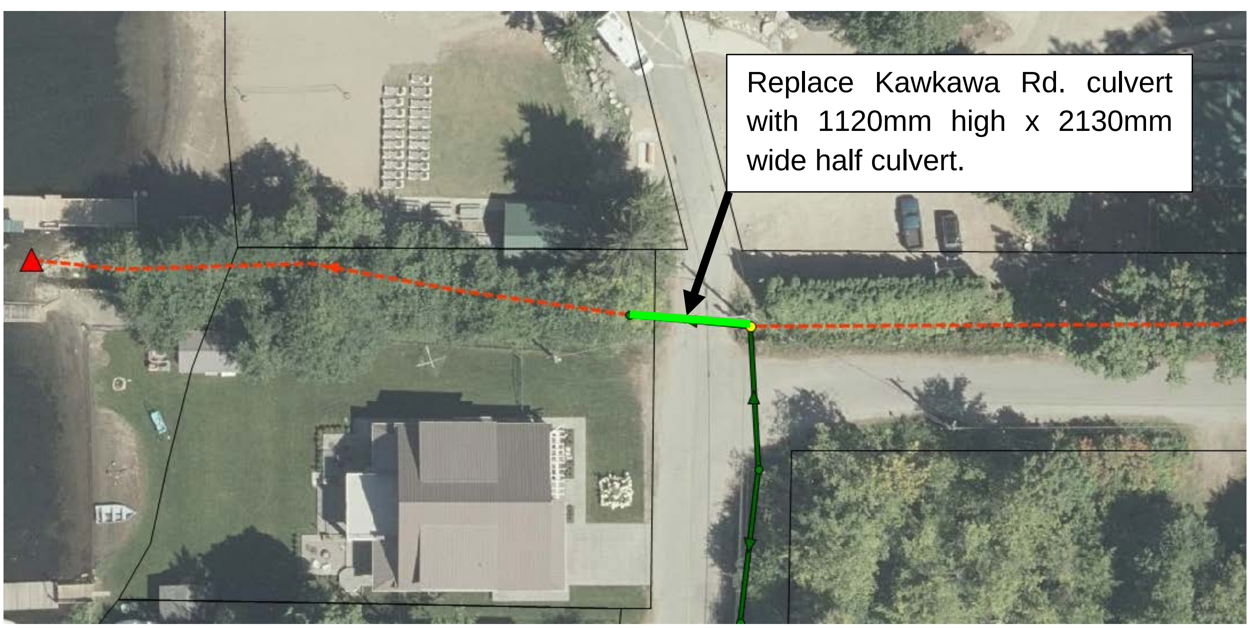
Intersection flooded by flow from east. Very high flows in private channel west of road.

Mitigation Solutions

Increase culvert capacity by replacing existing culvert with 1120mm high x 2130mm wide half culvert.

Establish bylaw to protect overland flow paths from encroachment and regrading.

Proposed Solution Figure



Cost Estimate

Estimate Value: $250,000

SW-7 Project:

Upgrade Culvert At 66597 Kawkawa Lake Rd.

Priority: Moderate

Trigger: Mitigate Flooding During 10- and 100-Year Events

Performance During 10 Year Return Period Storm with Climate Change

Flow from east causing surcharging and overflowing of road. High flows in private channel west of road.

Performance During 100 Year Return Period Storm with Climate Change

Culvert overwhelmed and roadway flooded. Very high flows in private channel west of road.

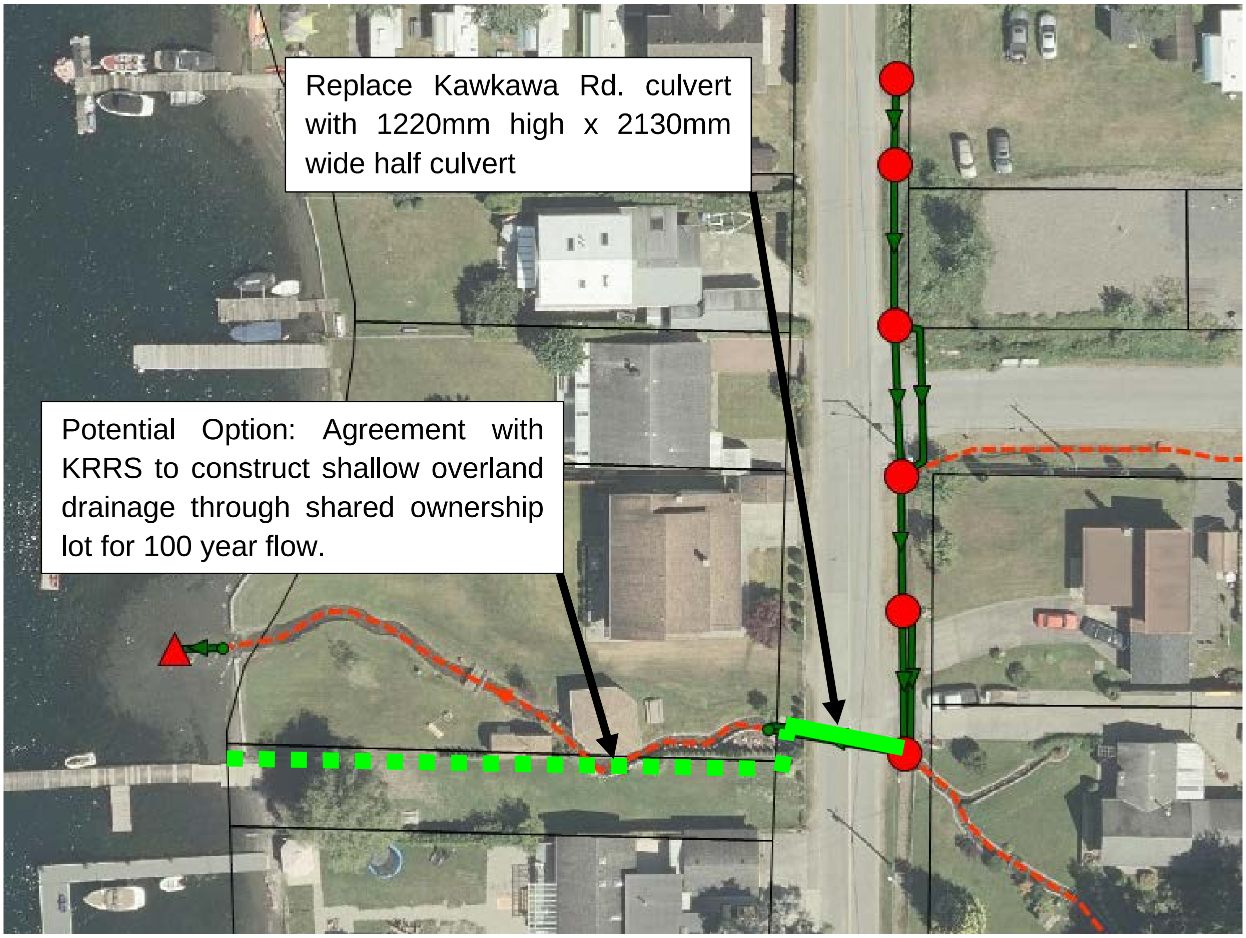
Mitigation Solutions

Increase culvert capacity by replacing existing culverts with 1220mm high x 2130mm wide half culvert.

Establish bylaw to protect overland flow paths from encroachment and regrading.

Potential option to reroute 100 year flow through KRRS shared ownership lot if agreement can be made with KRRS.

Proposed Solution Figure



Cost Estimate

Estimate Value: $250,000

DISTRICT OF HOPE

TRUE

SW-8 Project:

Additional Culvert At Kawkawa Lake IR#16

Priority: Moderate

Trigger: Mitigate Flooding during 100-Year Event

Performance During 10 Year Return Period Storm with Climate Change

Flow from east causing surcharging and ponding back towards Summer road intersection. High flows in channel west of road within Kawkawa Lake IR#16.

Performance During 100 Year Return Period Storm with Climate Change

Culvert overwhelmed. Additional ponding at Summer Road intersection and potential overtopping at IR entrance. Very high flows in the downstream channel within Kawkawa Lake IR#16.

Mitigation Solutions

Add additional 1800mm culvert to road crossing.

Highlight importance of overland flow route to Kawkawa Lake IR#16

Proposed Solution Figure

Cost Estimate

Estimate Value: $650,000

DISTRICT OF HOPE

TRUE

SW-9 Project:

Stormwater Retention Pond to Prevent Owl St. Depression Flooding

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Priority: Low

Trigger: Subdivision and Development of PID 014-665-336

Performance During 10 Year Return Period Storm with Climate Change

Concentrated runoff from south and east collect in depression east of Owl St. Some flooding to occur. No overland outlet identified.

Performance During 100 Year Return Period Storm with Climate Change

Increased runoff from south and east collect in depression east of Owl St. Flooding to occur.

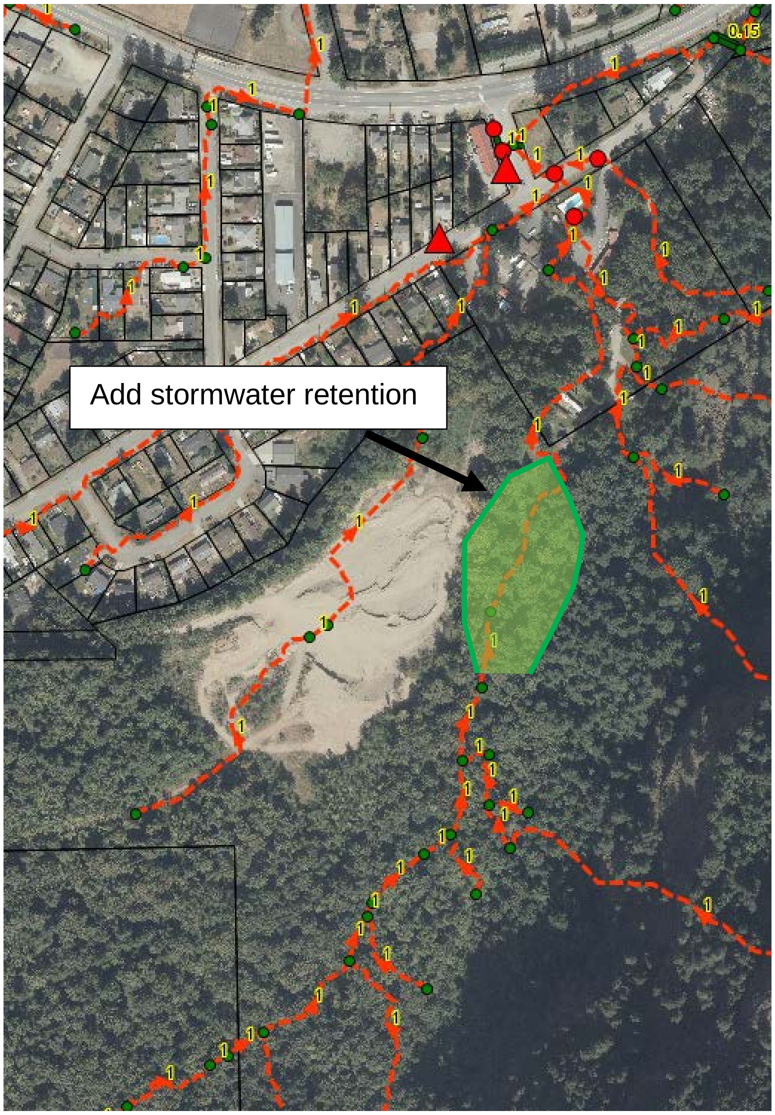
Mitigation Solutions

Confirm major storm event stormwater flows in existing channel by monitoring.

Construct pond for stormwater detention.

Creek crosses private land in area identified in OCP as Limited Use. Private land also designated Urban/Suburban Residential. Negotiation with landowner during future subdivision or development could acquire necessary land for debris basin with.

Proposed Figure



Cost Estimate

Estimate Value: $600,000

SW-10 Project:

Overland Route for Drywell Network Along Lakeview Cres.

Priority: Low

Trigger: Mitigate Flooding During 100-Year Event

Performance During 10 Year Return Period Storm with Climate Change

Underground infiltration basins managing and infiltrating runoff. Some ponding to occur at storm peak.

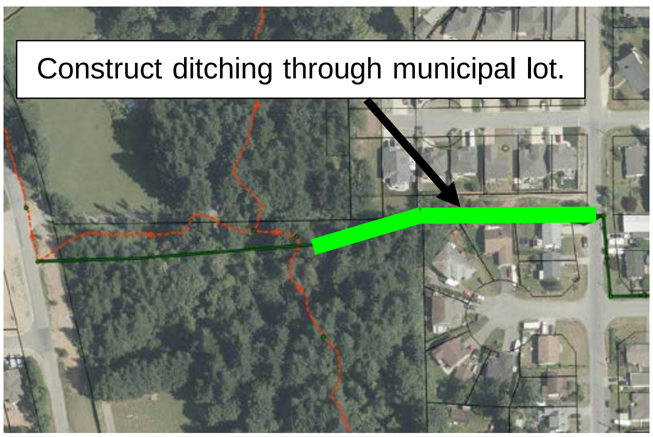
Performance During 100 Year Return Period Storm with Climate Change

Underground infiltration basins overwhelmed. Ponding to occur with overland flow westward through private property.

Mitigation Solutions

Establish ditching through municipal lot.

Proposed Solution Figure



Cost Estimate

Estimate Value: $70,000