LAKE COUNTRY
Life. The Okanagan Way.

Integrated Stormwater Management Plan:

Phase 1 Report

DISTRICT OF LAKE COUNTRY

November 2023

URBAN SYSTEMS

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1. INTRODUCTION

1.1. Background

The District of Lake Country (the District) has been working to prepare an Integrated Stormwater Management Plan (ISMP) for several years. This has included developing a GIS-based infrastructure inventory and documenting stormwater management issues. A master drainage plan was prepared in 2015 (Richardson), which provided a broad overview of stormwater management within the District. This ISMP is an update to and expansion of that plan. In July 2022, the District engaged Urban Systems Ltd. to prepare the first phase of the ISMP.

1.2. Objectives

The objectives listed below reflect the drivers for the ISMP, which include increased development pressure, existing drainage issues, fiscal responsibility, and enhanced quality of life.

1. Protect People, Property, and Infrastructure – Develop solutions that provide the level of protection deemed appropriate for each service area.
2. Manage Development Impacts – Development of all types disrupts the natural hydrology of a watershed – almost always generating increased runoff rates, volumes, and pollutants. Minimize these impacts to an acceptable level.
3. Improve Stormwater Quality - Improve water quality of point and non-point source discharge and rainwater runoff to District receiving waters.
4. Protect, Preserve, and Restore Natural Resources – Wetlands, natural streams and gullies, and lake foreshores are especially vulnerable to poorly designed and implemented stormwater management infrastructure. Identify and protect these natural resources where new infrastructure is proposed and implement restoration where existing infrastructure has already caused damage.
5. Adapt To a Changing Climate – Ensure that strategies and new / upgraded infrastructure reflect the realities of climate change and incorporate appropriate adaptive measures to increase resiliency.
6. Develop Strategic Capital Investment Plan – Develop a prioritized list of capital works that address identified stormwater management issues.
7. Optimize Operations and Maintenance – Account for ongoing operational and maintenance requirements for any proposed designs, with the aim of selecting the optimal solutions considering all factors.

1.3. Guiding Principles

The ISMP is a comprehensive document that is intended to reflect and support the District's vision for the community, but with a focus on stormwater management. It is called an *integrated* plan because it identifies and considers the linkages between drainage servicing, land use planning, and environmental protection. Its purpose is to support the growth of the District in a way that maintains or ideally, enhances the overall health of the subject watersheds.

1. Respect and Celebrate Water - Respect water for its life-giving properties. Prioritize opportunities to retain and filter water on-site, celebrating its place in the landscape and minimizing discharge into buried, "grey"[1] infrastructure.
2. Consider Natural Hazards – Identify and consider the impacts of stormwater management on natural hazards such as unstable or steep slopes and erodible soils.
3. Consider and Manage Risk – Given the uncertainty associated with rainstorm severity and frequency, employ risk management to inform decision making.
4. Integrate Stormwater Management - Fulfill multiple shared District and community objectives through an integrated planning process focused on achieving the greatest public benefit. Look for or create opportunities with co-benefits.
5. Work With Nature – Identify and respect natural drainage paths. Minimize solutions that deviate significantly from these.
6. Align stormwater management with other District Strategic Initiatives – The following documents also provide vision and guidance for stormwater management. The ISMP is to reflect and support these where feasible and identify misalignments where found.
   - Subdivision Development and Servicing (SDDS) Bylaw,
   - Official Community Plan (OCP), and
   - Liquid Waste Management Plan (LWMP)
   - Building Regulation Bylaw
   - Soil Regulation Bylaw
   - Stormwater Management Bylaw
   - Zoning Bylaw
7. Follow Federal and Provincial Regulations – Key federal and provincial regulations that impact stormwater management include:
   - Local Government Act
   - Canadian Navigable Waters Act
   - Canada Wildlife Act
   - Fisheries Act
   - Migratory Birds Convention Act
   - Water Sustainability Act
   - Riparian Areas Protection Regulation
   - Dike Maintenance Act

[1] To differentiate between traditional, manufactured infrastructure and stormwater management solutions that rely more on natural hydrologic processes, the terms "grey" and "green" infrastructure are used respectively.

1.4. Plan Development

The ISMP is intended to be a "living" plan – one that is used and updated on a regular basis. To facilitate this, the ISMP is being developed in phases as presented in this sub-section. Phase 1 (embodied in the current document) was completed under the District's 2022 budget for the ISMP. Subsequent phases will require further planning and capital funding from Council.

1.4.1. Phase 1 - Framework

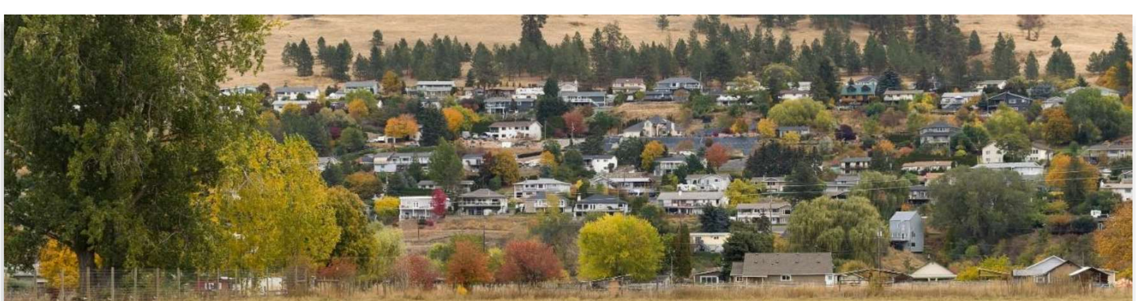
Phase 1 provides the context and framework for the ISMP. The information gathered and prepared is applicable to the entire District. It details what the District has (existing conditions) and summarizes the current understanding of what might be (future conditions). It also presents the District's philosophy for stormwater management within the broader context of community vision and goals.

Part of understanding both existing and future conditions is identifying, assessing, and prioritizing existing and potential stormwater management challenges. Existing challenges are caused by conditions that already exist – lack of infrastructure, undersized or degraded infrastructure, or on-going damage to natural resources for example. Potential stormwater management challenges are those which are likely to occur during or after future land use and/or climate changes. In both cases, Phase 1 identifies these challenges, assesses risk associated with each, and prioritizes them for further work in Phase 2. Section 1.6 of this document provides additional details regarding the Phase 1 scope.

1.4.2. Phase 2 - Catchment-Specific Plans

Once the ISMP framework has been developed and a clear understanding of the stormwater management challenges facing the District have been identified, assessed, and prioritized, Phase 2 focuses on identifying, assessing, and selecting opportunities to address these issues. Since drainage systems are typically dendritic, it is beneficial to address challenges within the context of the whole drainage catchment. Therefore, potential opportunities and solutions are identified and assessed catchment-by-catchment. This approach results in catchment-specific plans that include a list of recommended capital works, operations and maintenance (O&M) enhancements, and potential non-structural improvements (service levels, policies, etc.). O&M enhancements and non-structural improvements are more typically recommended catchment or even District wide.

Since the Phase 2 work is completed catchment-by-catchment, it is feasible to spread the work over a more manageable period (two or more years) if funding is limited. Catchments with high priority challenges would be addressed first, with lower-priority catchments addressed as time and funding permit. A more detailed scope for the Phase 2 portion of the ISMP is presented in Section 6.



1.4.3. Phase 3 - Implementation

Phases 1 and 2 comprise development of the ISMP itself. However, unless the plan is implemented, it has little value. Typical implementation would include the following:

- inform the annual capital plan,
- inform the annual operational and maintenance plans and programs,
- guide development planning, reviews, and approvals, and
- inform District policy reviews and updates.

1.4.4. Phase 4 - On-Going Management

Much of the information collated and developed for the ISMP reflects a "snapshot in time". This includes land use assumptions, infrastructure inventory, priorities, analyses results, and sometimes even policies. It is important to track changes as they occur so that the ISMP recommendations can be assessed for relevancy. Phase 4 consists of updating the ISMP periodically and assessing the implications on the recommendations.

1.5. Document Organization

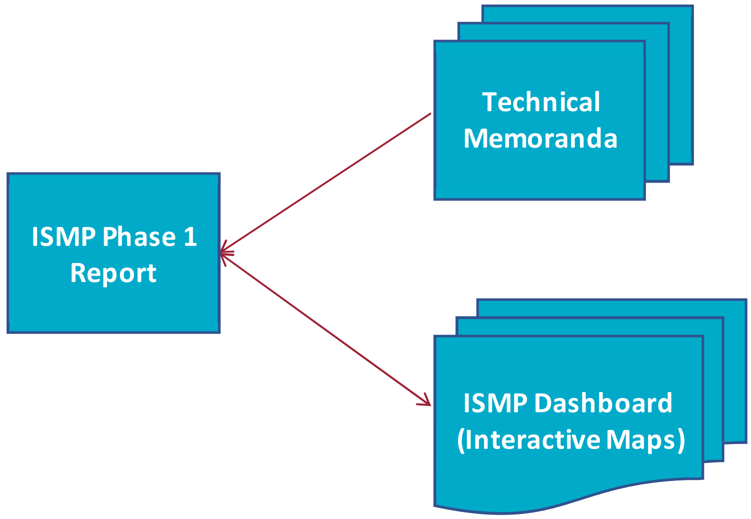
Traditionally, ISMPs were substantial written reports which included detailed content about each facet of the ISMP – written sections, maps, tables, and appendices. ISMPs are used by a variety of people for different purposes. This includes:

- District Senior Staff and Council for high-level guidance,
- Planning and Engineering Staff for capital planning and implementation as well as for the development approvals process,
- Developers for informed planning and design,
- Operations and Maintenance Staff for context when addressing stormwater-related issues, and
- the public for community engagement.

The information and corresponding level of detail required by each of these groups differs, so the traditional ISMP report was typically comprehensive even though a reader might access only a portion of it.

The current ISMP is organized to simplify access to the information that different user groups may require. It is comprised of the following components and utilizes online tools where appropriate as illustrated in Figure 1.1. The current document is the ISMP Phase 1 Report – an enhanced executive summary of key information from the ISMP. The ISMP Dashboard is a set of online, interactive maps that are grouped into themes and allows the user to view information with or without significant detail. The Technical Memoranda detail assumptions and analyses used to inform the ISMP – information that would be useful to only a small group of people. Appendices A to G contains the Technical Memoranda and Appendix H contains more information about, and a link to, the ISMP Dashboard.

Figure 1.1: ISMP Document Organization



1.6. Phase 1 Scope

Phase 1 of the ISMP (current document) consists of the following tasks/deliverables:

- Gather and review background information. This included GIS data, previous reports and studies, and operational information. The corresponding deliverable was the Data Gap Memorandum located in Appendix A.
- Define existing drainage routes and catchments. Advanced GIS tools were used to develop highly detailed data sets which show surface flow paths, depressions, and corresponding drainage catchments as deliverables. These were provided to the District for their use and can be viewed in the Dashboard.
- Define and characterize the study area hydrogeology. This work was completed by Waterline Resources Inc., which prepared the report found in Appendix B. Waterline also provided GIS data sets which can be viewed in the online interactive maps.
- Develop/confirm analysis and evaluation criteria. This information guided the analysis and assessment work completed during Phase 1. Criteria not explicitly stated in the District SDDS bylaw, Schedule M (DLC, 2022), were presented in the draft Stormwater Management Design Guidelines in Appendix C.
- Confirm lake level boundary conditions. Since some infrastructure discharges into the lakes within District boundaries, it is necessary to define appropriate water levels where backwater can impact hydraulic performance. A technical memorandum, located in Appendix D, details how these values were developed.
- Confirm current understanding of future land use. OCP and zoning designations for each parcel were compared to identify potential land use changes. This was supplemented by a discussion with Planning Staff regarding anticipated developments and corresponding timing. Deliverables were GIS data sets which can be viewed in the Dashboard.

- Develop a hydrologic and hydraulic computer model for the entire District. A PCSWMM model was developed based on existing infrastructure and was tuned to reflect observed field conditions. A technical memo describing how the model was developed and "calibrated" is in Appendix F. Note that modeling for the ISMP excludes hydraulic modeling and detailed analysis of Vernon and Winfield creeks. This work was completed under a separate flood risk assessment and mapping project.
- Assess the status of the receiving waters' quality. This was a high-level assessment which is outlined in Section 2.7 of this document. Map-based information can be viewed in the Dashboard.
- Conduct a Risk Assessment to identify and categorize drainage issues to be addressed in Phase 2 (developing recommendations to address identified issues). The risk assessment technical memorandum is in Appendix G – assessed risks and model results for defined scenarios can be viewed in the Dashboard.

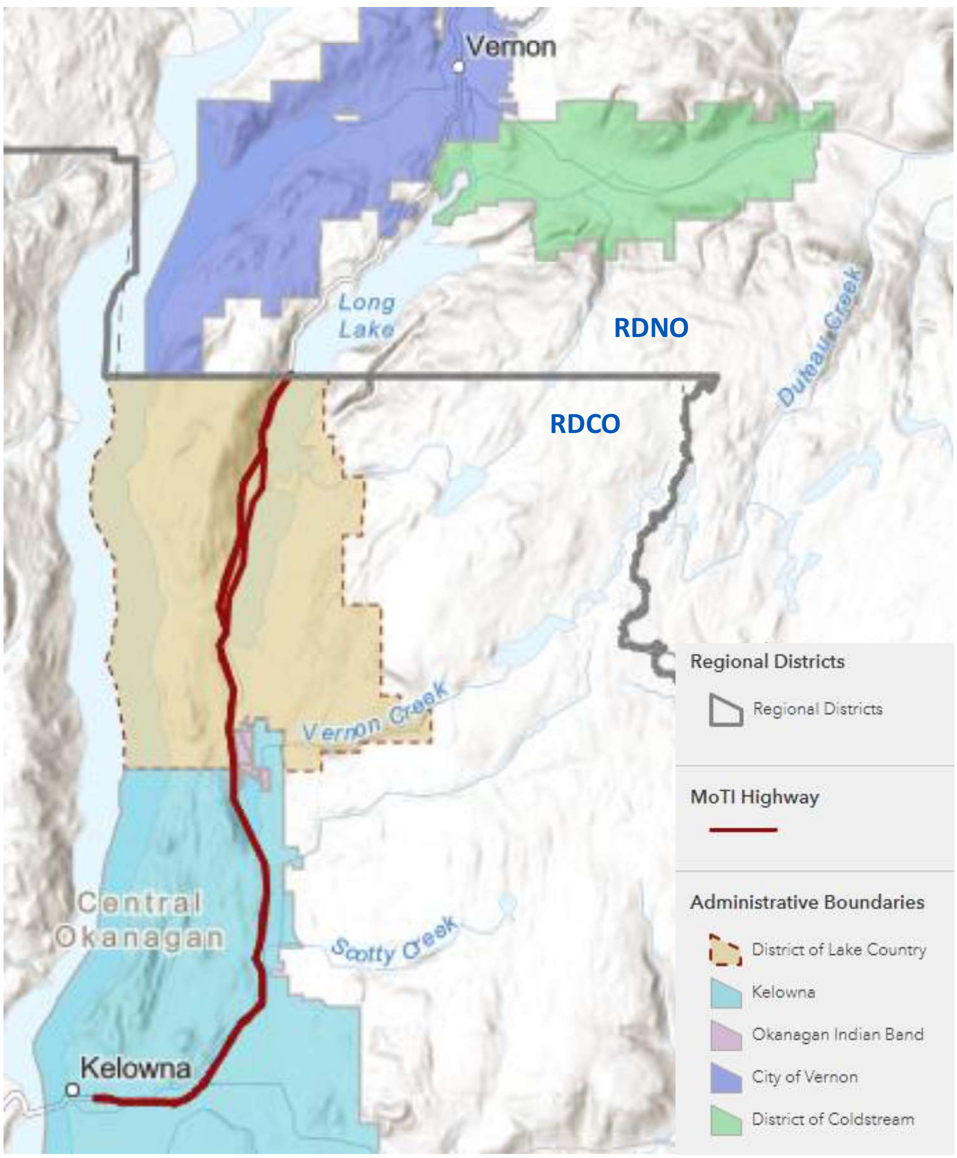
1.7. Key Stakeholders

While the District is funding and preparing this ISMP independently, other stakeholders may be impacted by the ISMP recommendations. Conversely, stormwater management policies, infrastructure, and procedures within adjacent jurisdictions may also impact stormwater management efforts within the District. It is therefore important to be aware of these potential impacts and to engage with the affected stakeholders to ensure that stormwater management occurs cooperatively. Referring to Figure 1.2, the key stakeholders within this context are as follows:

- **BC Ministry of Transportation and Infrastructure (MoTI)** – owns and operates roads within District boundaries. The primary road is Highway 97, which has its own stormwater management infrastructure that discharges onto both public and private properties, and in some cases, to receiving waters or to District infrastructure which ultimately discharges to a receiving water. While MoTI also owns Pelmewash Parkway, the District has an agreement with them for operations and maintenance of this recreational stretch of road. Runoff from catchments within the District has the potential to flow onto MoTI roads, necessitating a cooperative relationship between the District and MoTI.
- **Okanagan Indian Band (OKIB)** – Duck Lake IR#7 is located at the north end of Ellison (Duck) Lake. The outlet from the lake to Middle Vernon Creek is located within OKIB territory.
- **City of Kelowna (Kelowna)** – a significant portion of the industrial land accessed from Beaver Lake Road, all of Ellison Lake, and the lower reaches of Upper Vernon Creek are located within Kelowna's boundaries.

- **Regional District of Central Okanagan (RDCO)** – the upper portion of catchments draining into the District of Lake Country from the east are located within RDCO boundaries. Land use decisions within RDCO can impact runoff generated within these catchments.
- **Regional District of North Okanagan (RDNO)** – borders the District of Lake Country along its northern boundary. This boundary crosses Kalamalka Lake as well as several small catchments on both sides of Kalamalka Lake. Runoff crosses the terrestrial boundary from both jurisdictions.
- **City of Vernon (Vernon)** – the boundary between the District and Vernon is relatively short, and crosses only a few small catchments west of Commonage Road. Runoff crosses this boundary from both jurisdictions.

Figure 1.2: Key Stakeholders



1.8. Acknowledgements

Development and preparation of the ISMP was the work of many. Key guidance, information, and review was provided on behalf of the District from Matthew Salmon, Scott Unser, Mark Laudon, Sid Smith, Aron Chatten, Patti Meger, Jared Kassel, and Tamera Cameron. Hydro-geotechnical assessment and support was provided by Simon Wing and Collen Middleton of Waterline Resources. In addition to this report's author, key Urban Systems staff included Taylor Swailes, Marliese von Huene, Justin Wilkes, Justin Larratt, Ryan Periana, Ricky Banga, Taylor Shewchuck, and Thomas Simkins.

1.9. Disclaimer

Although this document contains drawings and illustrations showing existing drainage works, they are not intended to be relied upon as as-constructed information. Most of the data contained on these drawings has been gathered from many different sources that span several years. There is no assurance that the obtained documents were, in fact, the most up-to-date. Nor is there any assurance that works shown have not been abandoned nor upgraded. Some field reconnaissance was conducted to verify key drainage routes, but it was beyond the scope of this project to confirm every system component within the study area. Therefore, prior to implementing any of the works recommended in this document, field information should be confirmed in greater detail; hydraulic analyses should be updated; and appropriate detailed designs should be prepared.

This document also contains information about soil and groundwater conditions. This data was compiled on a very general basis to provide an indication of potential conditions. Final stormwater management works or decisions contingent upon groundwater and / or soil conditions should be based upon site-specific assessment by a qualified professional.

Finally, the analyses presented in this document were conducted for general assessment, planning, and development management purposes only. Detailed analyses are still required to inform the design of any recommended works.

2. OVERVIEW

2.1. Study Area

The District and its drainage catchments are part of the Okanagan Basin, which ultimately drains into the Columbia River and the Pacific Ocean. The study area is located primarily within the south-eastern tip of the Fraser Plateau hydrologic zone[2] (iMap BC). Given its very close proximity to the defined hydrologic zone boundary, we have assumed that the study area catchments have more in common with the Southern Thompson Plateau rather than with the Fraser Plateau hydrologic zone.

Referring to Figure 1.2, the District boundaries encompass portions of several lakes and streams. These waters collectively function as the receiving waters for stormwater runoff generated both within and upstream of the District. These include:

- Okanagan Lake
- Ellison Lake[3]
- Wood Lake
- Kalamalka Lake
- Upper Vernon Creek (and its tributaries such as Clark Creek)
- Middle Vernon Creek
- Winfield Creek

All the water bodies are connected, starting with Upper Vernon Creek which drains into Ellison Lake. Flow from Ellison Lake is northward, ultimately reaching Okanagan Lake via Wood Lake, Kalamalka Lake, and Vernon Creek through the City of Vernon. Drainage within the District is therefore divided into two primary basins – Vernon Creek and Okanagan Lake. Within these two primary basins are many smaller streams that discharge into one of the identified receiving waters – Oyama Creek and Ribbleworth Creek for example. Some of these may function as receiving waters for runoff from District facilities, but for the purpose of defining primary drainage catchments, outlets into only the identified primary receiving waters have been used.

The north-south linear orientation of the District along lake shores and streams means that drainage is delineated over many relatively small catchments instead of only a few large watersheds. It also means that drainage occurs, for the most part, in one of three directions:

- east to west into Okanagan Lake,
- west to east into the Vernon Creek valley[4], and
- east to west into the Vernon Creek valley.

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2 A hydrologic zone is an area with homogenous runoff characteristics where data can be reasonably extrapolated to estimate the characteristics at ungauged sites with an acceptable degree of accuracy.

3 Ellison Lake is not within the District boundaries, but it significantly influences flows through Middle Vernon Creek.

4 The "Vernon Creek Valley" is used in this document to refer to the valley which extends from south to north, starting at Elli son Lake, and ultimately drains to Okanagan Lake via Vernon Creek.

2.2. Climate

2.2.1. Existing Climate

In the broadest sense, the District is located within a temperate zone and has a cold, semi-arid climate. This is characterized by:

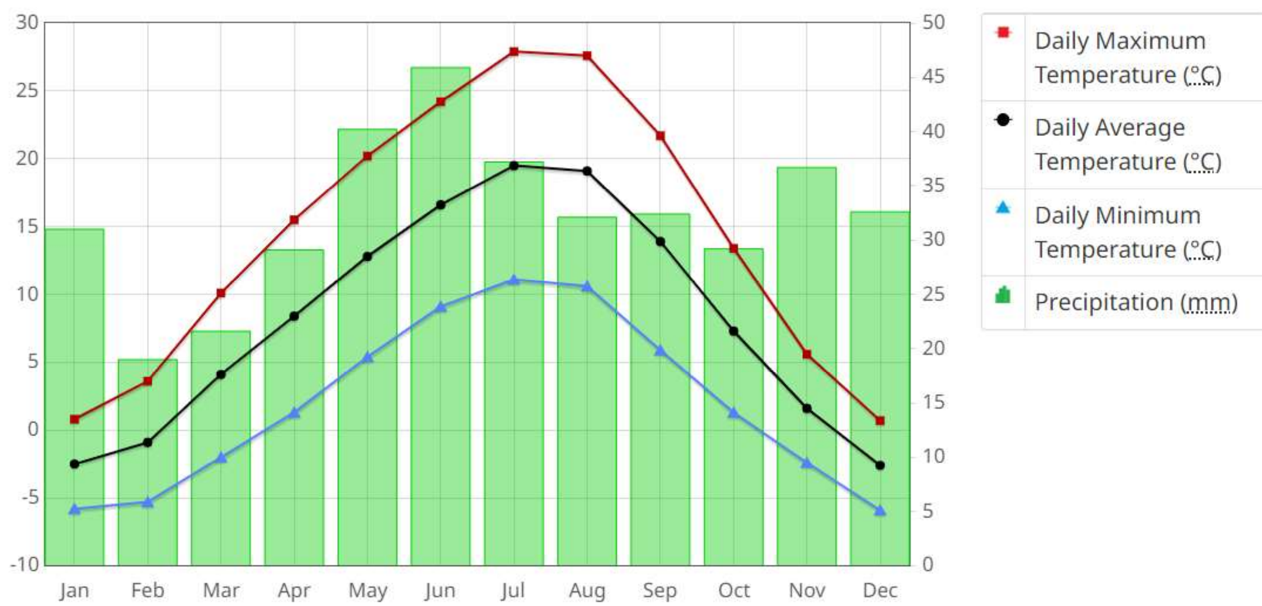
- warm and dry summers,
- relatively cold winters,
- temperature variations between day and night, and
- between 250-500 mm annual precipitation, some of which falls as snow.

The Environment and Climate Change Canada (ECCC) climate station with published climate normals that is closest to the District is Kelowna A (1123970), located at the Kelowna Airport. The normals for the 30-year period 1981-2010 indicate the following key metrics:

- average annual temperature range is -2.5 to 19.5 degrees Celsius
- average daily temperature variation is 7.4 °C in winter and 16.3 °C in summer
- average annual precipitation is 387 mm, with approximately 76 mm of this falling as snow

Figure 2.1 shows the monthly values for temperature and precipitation.

Figure 2.1: Kelowna A Climate Normals (1981-2010)



2.2.2. Existing Rainfall/Design Storms

For the purposes of this ISMP, we are interested in a storm's total rainfall, duration, frequency, and pattern. To a lesser degree, we are also interested in antecedent conditions – the amount of rainfall that occurred shortly before a design rainfall event – which impacts soil infiltration capacity, depression storage, and storage available in retention and detention facilities.

Intensity-Duration-Frequency (IDF) curves inform the first three types of information required. These curves are generated through statistical analysis of recorded rainfall and reflect historical rainfall conditions. Given the proximity to the Kelowna Airport, the District uses IDF curves generated from the Kelowna A climate station for analysis and design purposes. Determining the type of rainfall pattern to use, however, is more subjective.

A rainstorm is relatively unique in terms of how much rain falls every few minutes during its duration – it's pattern. Assuming a uniform time interval - say five minutes - some intervals will exhibit more rainfall than others. This usually occurs in random patterns, hence the storm's uniqueness. High intensity rainfall (a large rainfall amount over a given period) has the potential to overwhelm drainage infrastructure for which capacity is expressed as a flow rate (storm sewers for example). Storms which bring a large amount of total rainfall, even at a low intensity, have the potential to overwhelm stormwater infrastructure dependent on storage volume (water treatment or detention facilities for example). In general, most rainstorms within the District have relatively short durations and less than 5mm of rain. Less frequent storms typically have longer durations, higher rainfall amounts, or both.

For the purposes of this ISMP:

a) historical storms were used to calibrate the computer model under existing conditions, and
b) synthetic rainstorms were used to assess system capacities and to size proposed infrastructure.

To ensure that analyses were conducted using the full range of potential rainfall intensities and amounts for a given frequency, the Chicago Storm pattern over a 24 hour duration was used a the "design" storm. Hydrographs generated from this storm simultaneously test flow rate and volume-based infrastructure during modeling.

The selected frequency, expressed as a return period, reflects the design service level. The SDDS bylaw specifies that minor and major drainage systems be designed using return periods of 10 and 100 years respectively. Note that these return periods represent the following probabilities that the event's total rainfall will be exceeded in any given year:

- 10% for the 10 year event, and
- 1% for the 100 year event.

Appendix E contains a technical memorandum detailing the historical and design storms used for this ISMP. Twenty-four hour rainfall values are presented in Table 2.1.

2.2.3. Future Climate

The District accepts that climate patterns are changing, and that its residents may be impacted by runoff from more extreme rainfall events. As per SDDS Bylaw Schedule M, the District requires that stormwater infrastructure designs for new developments reflect potential future precipitation. For non-development related drainage infrastructure, projected precipitation should also be considered - particularly in components where critical and long-term design decisions are being made, or in areas where the consequences of failure are high.

The technical memorandum in Appendix E also presents the design storms based on projected future rainfall. The storms used to analyze future conditions are based on the same existing conditions patterns presented in Section 2.6.2 of the current report. For future conditions, however, each storm's total rainfall was calculated using the IDF_CC Tool methodology presented in the technical memorandum. The values reflect the following assumptions:

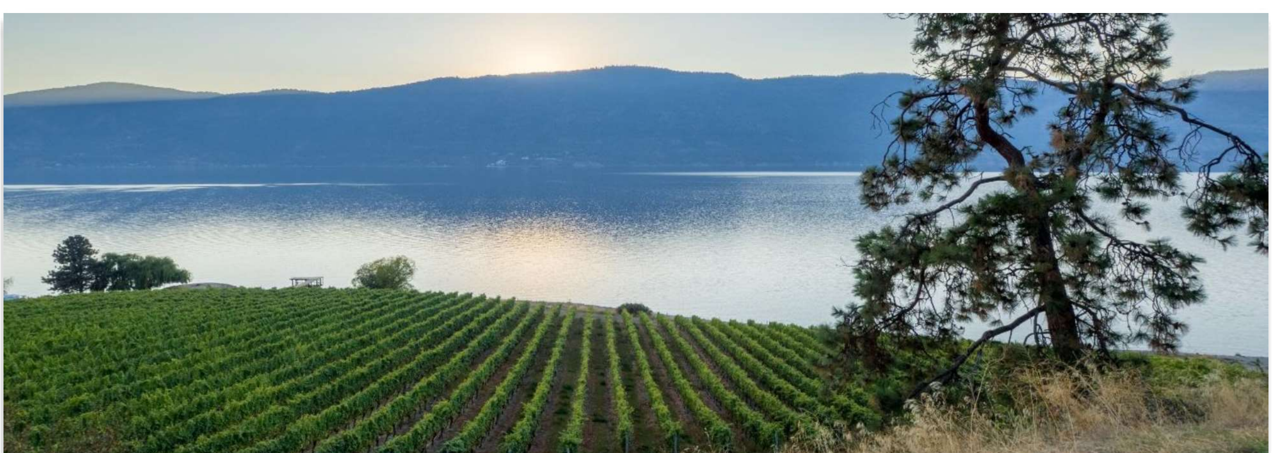
- Future periods from 2041 to 2070 and from 2071 to 2100
- Pacific Climate Impacts Consortium (PCIC) bias-corrected ensemble of down-scaled CMIP6 GCMs based on SSP5.85 (median values)
- GEV frequency distribution

Table 2.1 summarizes the existing and future rainfall depths as well as the projected amount of change.

Table 2.1: 24-Hour Design Rainfall (mm)

Condition	10-Yr	100-Yr
Existing Climate	31.4	42.0
Future Climate	37.1	47.7
Change	+19%	+16%

The technical memo also shows that the projected amount of change in rainfall intensities varies for each combination of storm duration and frequency (return period). These changes range from +8% to +53%, with the highest amounts of change occurring for sub-hour durations with lower frequencies (longer return periods). The Chicago Storm pattern reflects all these changes.



2.3. Geology / Hydro-Geology

The geology and hydro-geology within the District plays a critical role in how rainfall is transformed into surface runoff. The combination of soils, bedrock, and groundwater directly impact the rate at which rainfall can infiltrate into the ground, and the volume of rainfall which can be absorbed during a rainfall event. The combination of these characteristics also informs how well collected stormwater can be infiltrated into the sub-surface soils. Infiltration potential is a function of soil hydraulic conductivity, depth to an impermeable layer (bedrock or soil with extremely low hydraulic conductivity), and the presence of groundwater. This information was developed, mapped, and assessed for the ISMP by Waterline Resources Inc. (Waterline), and is detailed in their full report (see References). More detailed information is also available via the Interactive Maps.

Figures 2.2 and 2.3 summarize key results of Waterline's assessment – a map of sub-surface infiltration potential and unconsolidated aquifers respectively. Figure 2.2 shows the locations where the combination of soil infiltration capacity, depth to bedrock or an impermeable layer, and depth to groundwater supports infiltration of stormwater to ground. The pie chart shows the percentage of the District land which falls into each infiltration potential category (High, Moderate, or Low). It shows that only 2% of the land within the District has conditions that may be suitable for use of infiltration systems.

The study also indicates that there are four unconsolidated aquifers within the Vernon Creek valley. These aquifers are composed of sands and gravels that allow groundwater to move freely through the soil matrix. Two of the aquifers are confined and two are unconfined. Aquifers 344 and 345 are confined, meaning that they are separated from the ground surface by an impermeable layer. This usually precludes any significant, long-term infiltration of surface water into the sub-soils, but not always. Aquifers 1238 and 1239 are unconfined, which means that surface water can infiltrate down into them. These areas have greater infiltration potential, subject to soil drainage characteristics and unsaturated zone thickness.

The Waterline study also provided values for use in the hydrologic model developed for the ISMP. This included hydraulic conductivity and storage capacity values for the soils within the District.

Figure 2.2: Sub-Surface Infiltration Potential

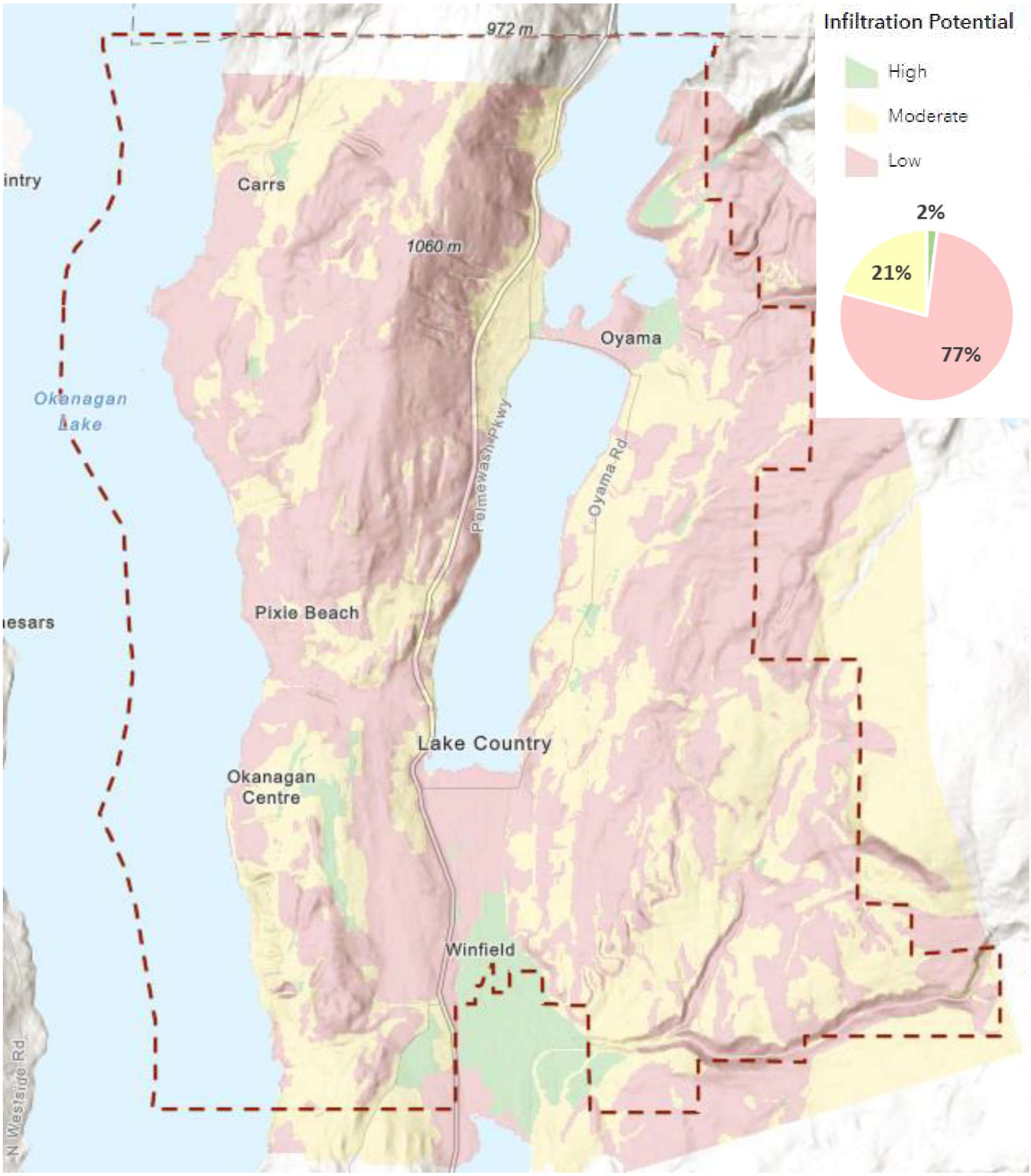
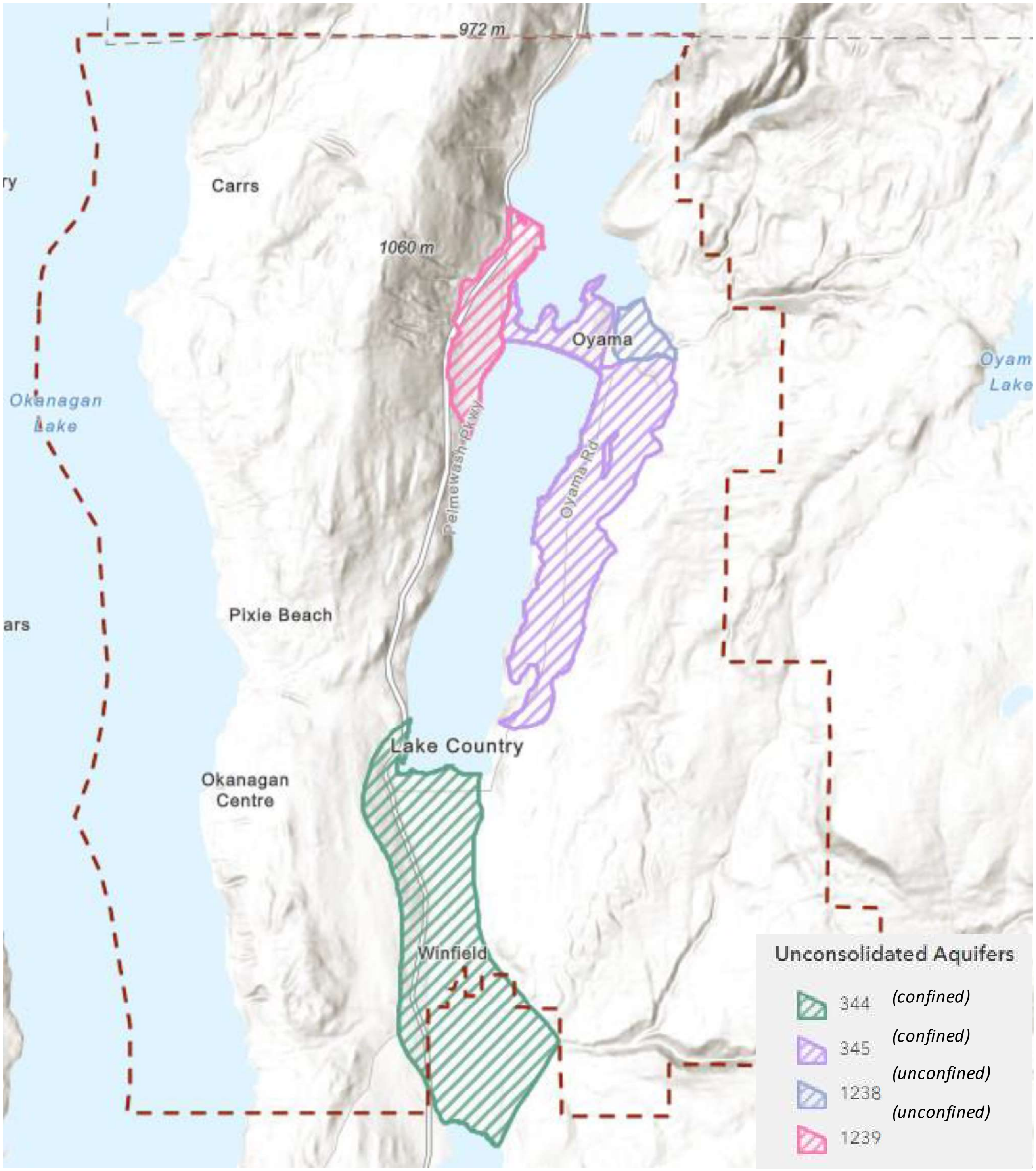


Figure 2.3: Unconsolidated Aquifers



2.4. Land Cover / Land Use

2.4.1. Existing Land Use

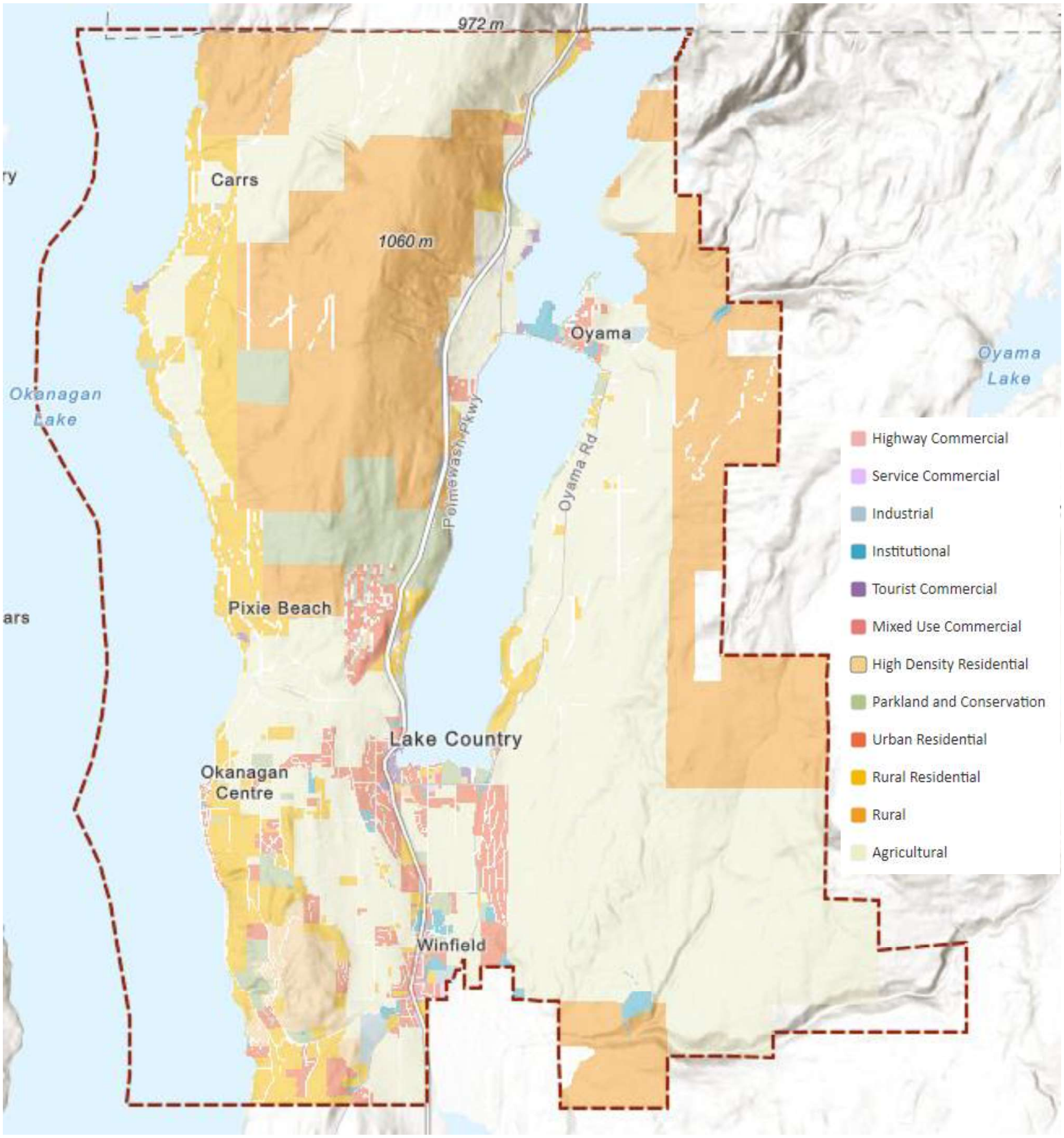
Land cover and land use has a significant impact on how much and how quickly rain is transformed into surface runoff. Impervious (hard) surfaces directly connected to a piped drainage system converts most of the rainfall into runoff very quickly. Natural ground cover – trees, grasses, shrubs – tends to hold a significant portion of the rainfall until it evaporates or infiltrates into the ground, generating lower runoff volumes and peak flows.

Most of the District is rural – comprised of natural areas, agriculture, and rural-residential holdings. Urban development is located in clusters throughout the District. These include the following key neighbourhoods:

- the Highway 97 corridor,
- Downtown along Main Street
- the south end of Bottom Woodlake Road
- the area east of Lodge Road
- Woodsdale Road
- Davidson / Pretty Roads
- The Lakes development
- portions of Oyama
- portions of Okanagan Centre
- Lakestone / Tyndall Road
- small developments off Reed Road and Chase Road

Figure 2.4 shows existing zoning in terms of OCP land use designations since they are more generalized and easier to understand within the context of this ISMP. This approach also provides the opportunity to compare existing and proposed land uses using the same terminology.

Figure 2.4: Unconsolidated Aquifers



For the purposes of this ISMP, land use parameters (surface depression storage, percent impervious, rainfall interception, roughness coefficient) reflect a set of hydrologic conditions which are created by combinations of surface treatments. For example, cemeteries, parks, and school grounds denote different land uses from a planning perspective but reflect similar hydrological conditions. While buildings are usually classified by their use (residential, commercial, etc...), they all have roofs which direct rainfall to roof drains in a similar fashion.

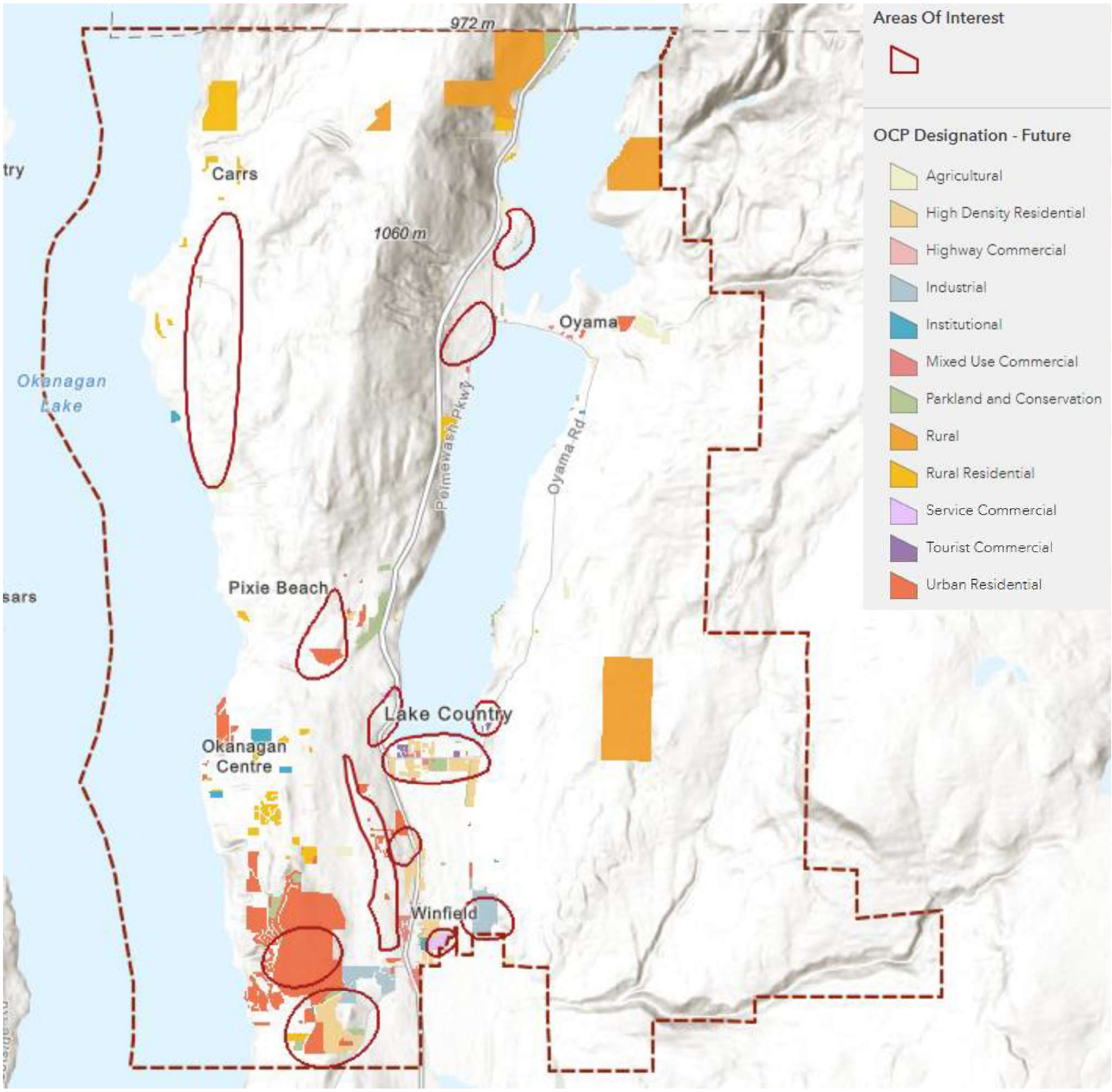
Building footprint mapping was provided by the District, which was used to help determine the amount of impervious area in each catchment. This was further supplemented by GIS analysis of orthophotographs to identify other hard surfaces such as roads, sidewalks, and parking lots. Pervious areas were classified using a combination of land use zoning and manual visual interpretation. For example, pervious areas within residential areas were assumed to be a mix of lawn, trees, and shrubs. Undeveloped areas were classified as forest, grassland, or a mix of both. Assumed parameter values used for the PCSWMM model and based on this information are presented in Appendix F.

2.4.2. Future Land Use

Future land use is expressed through the Official Community Plan (OCP). It is not a detailed document, but it does provide insight into the location and type of land use changes anticipated by the District. Figure 2.5 shows the location of parcels where the future OCP designation differs from the current zoning expressed as an equivalent OCP designation. Figure 2.5 also shows the general locations where the District has high confidence that development will occur within the current planning horizon, or at least where interest in some level of development has been expressed to the District Planning Department.

Only some of the defined primary drainage catchments will be impacted by future development, and to varying degrees. The most significant change will be the amount of total additional impervious area that will be created. This has the potential to increase storm runoff in terms of peak flow and total volume unless adequately managed during the development process. Based on projected land use changes and new/upgraded roads, the study area imperviousness is anticipated to increase by almost 10%. This varies from catchment to catchment, with some catchments have zero anticipated increase while the imperviousness of others could double.

Figure 2.5: Projected Land Use Changes and Areas of Development Interest



2.4.3. Roads and Paths

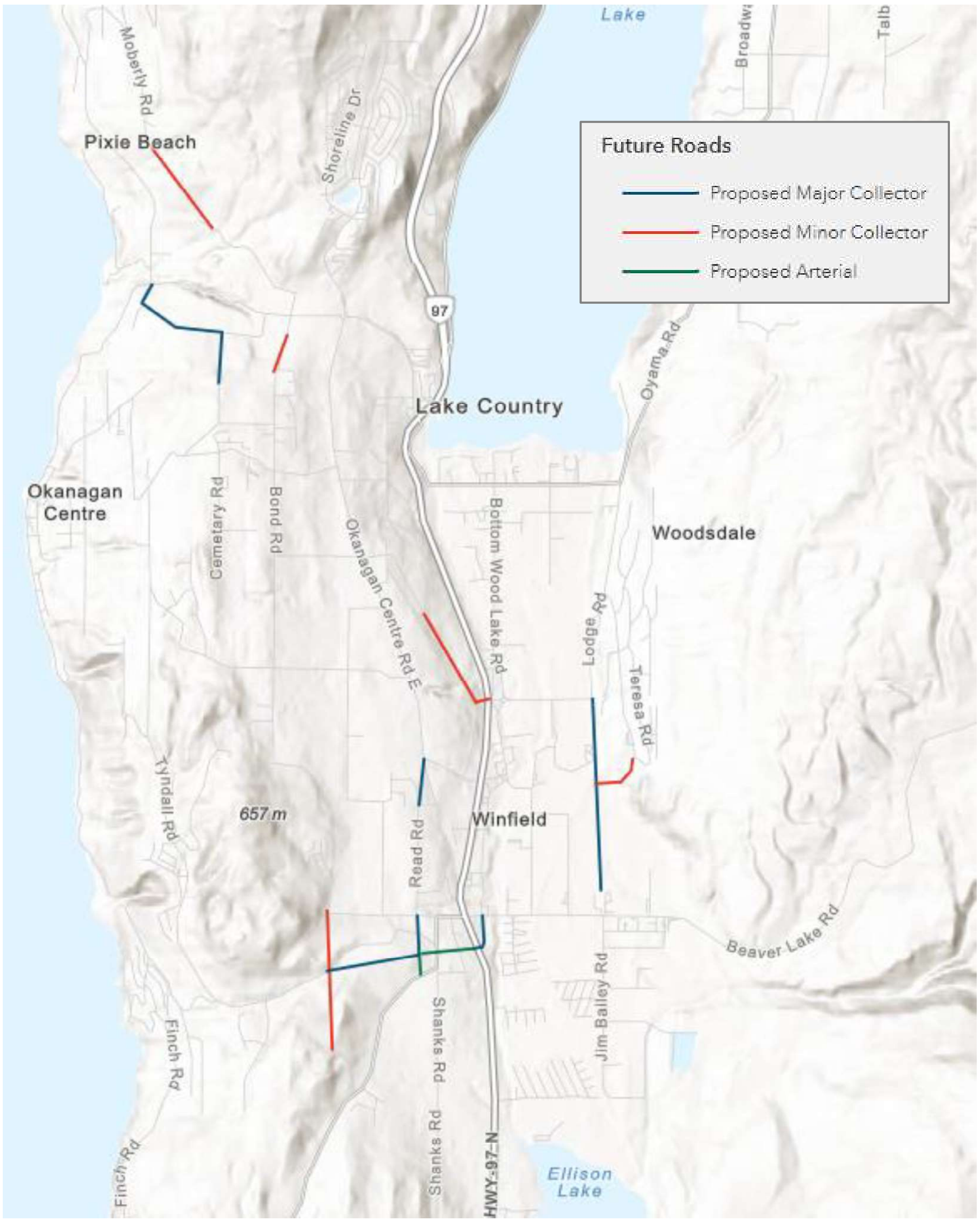
While most roads within the District have a rural cross-section, the District does have plans to improve some over the next 20 years or so. Improvements may include:

- widening for safety or increased carrying capacity,
- urbanizing (adding curb, gutter, and storm) to increase servicing levels, and
- adding sidewalks, bicycle paths, or multi-use paths to increase mobility.

Plans also include new roads or road extensions to improve connectivity. This is in addition to internal roads associated with development presented in Section 2.4.2. All these improvements will result in additional impervious surfaces and have the potential to increase runoff peaks and volumes unless adequately managed.

The Mobility Master Plan (All North, 2019) recommends several new streets, roads, and multimodal paths over the next 20 years. Many of these are located within anticipated developments, but some are located off-site. They are shown in Figure 2.6.

Figure 2.6: Projected (Non-Development) Road Changes



2.5. Stormwater Management Systems

2.5.1. Collection / Conveyance

The District uses a dual drainage system approach to managing storm runoff. The "minor" drainage system is comprised of storm sewers, swales, channels, culverts, and flow control facilities designed to prevent flooding and property damage, and to minimize public inconvenience caused by frequent storm events. Runoff from the minor storm is referred to as the "minor flow". The "major" drainage system comprises surface flood paths and depressions, drainage outlets (i.e., designated storm sewers that convey the major flow), ditches, roadways, watercourses, and flow control facilities designed to accommodate runoff from less frequent, more intense storms. Runoff from these storm events is referred to as the "major flow".

Drainage within most of the District is provided by roadside ditches and culverts, which function as both the minor and major systems. This is true even in some areas consisting of non-rural land uses. Figure 2.7 shows the location of storm sewers (gravity mains), culverts, and outfall locations. The storm sewers have been likely sized to function as the minor system, typically designed to convey runoff from design storms with a 10-year return period. Ditches and culverts may convey minor system flows in rural areas, but they also are intended to function as the major system, typically for runoff from design storms with a 100-year return period.

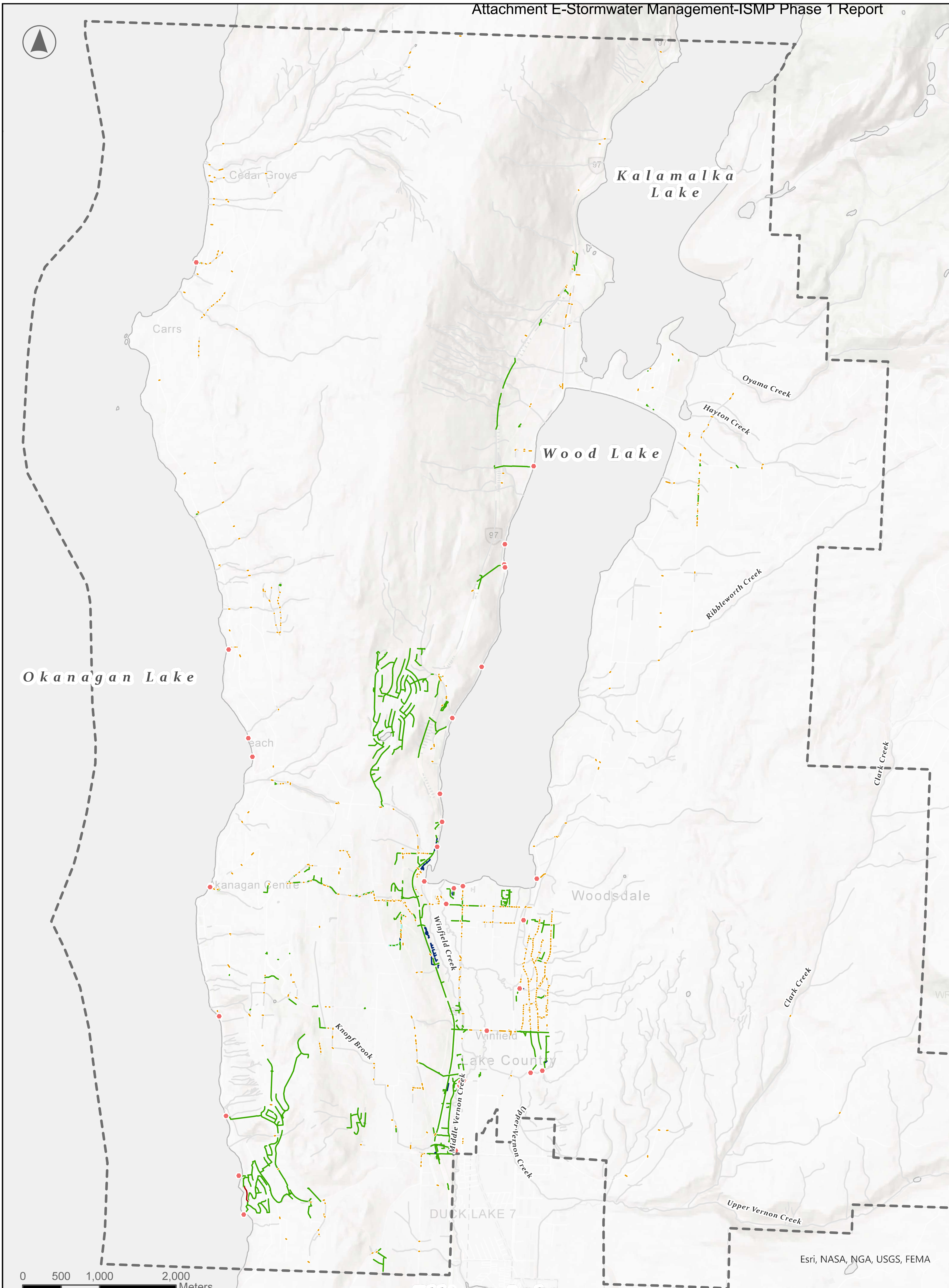
Based on the GIS inventory, Table 2.2 summarizes existing stormwater management assets currently owned and maintained by the District. This excludes infrastructure on private property (mostly stratas) and that owned by MoTI.

Table 2.2: Existing Stormwater Management Assets

Asset Type	Units	Value
Gravity Main - Solid	km	30.7
Gravity Main - Perforated	km	8.1
Forcemain	km	0.2
Culvert (Road)	km	4.3
Culvert (Driveway)	km	4.7
Culvert (Road)	count	248
Culvert (Driveway)	count	415
Manhole	count	442
Drywell	count	373
Catch Basin	count	1155
Catch Basin Lead (lateral)	km	12.5

Gravity main materials are distributed as follows:

- 72.8% Polyvinylchloride (PVC - including perforated pipe)
- 14.7% Corrugated Metal (CMP)
- 11.3% unknown
- 1.1% High Density Polyethylene (HDPE)
- 0.1% Reinforced Concrete (RCP)



Legend

- Outfalls
- Culvert
- Forcemain
- Gravity Main
- Minor Drainage Course
- Perforated Drain Gravity
- District of Lake Country Boundary

LAKE COUNTRY

Life. The Okanagan Way.

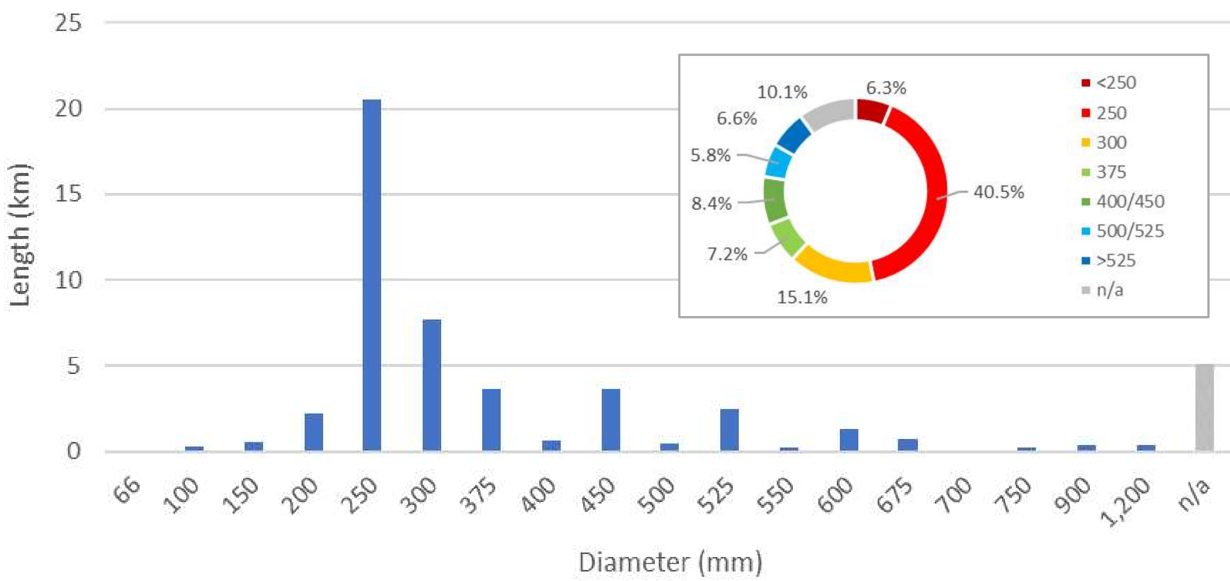
Master Drainage Plan

Existing Drainage Infrastructure

Figure 2.7

Figure 2.8 summarizes the lengths of existing gravity mains by diameter (excluding culverts).

Figure 2.8: Existing Storm Gravity Mains by Diameter



2.5.2. Infiltration

Infiltration systems (drywells and/or perforated storm sewers) are used throughout the District. In some cases, drywells were installed to address localized ponding at locations where surface or piped conveyance systems do not exist. Examples of this include locations along Camp Road and Ivy Court. In other cases, infiltration was designed and installed in developments to minimize discharge to downstream systems. Examples include the Lakestone and Lakes developments. As shown in Table 2.2, there are approximately 420 drywells and 10 km of perforated storm sewer in the District.

Where infiltration is appropriate (soils are well drained, sufficiently deep, and free of groundwater limitations) infiltration can be a useful tool for managing runoff volumes and addressing stormwater quality. Staff have indicated that some of the infiltration systems currently installed are not functioning as anticipated. Challenges include:

- Drywells with reduced infiltration capacity – they work sufficiently well for small rainfall events where internal storage volume is sufficient to temporarily hold runoff until it can be infiltrated, but overflow to the surface during events with greater rainfall / runoff.
- Seepage discharge on hillsides – drywells located on hillsides where soils are shallow and lay on bedrock can cause infiltrated runoff to surface downstream. This can impact downstream properties, infrastructure, and potentially hillside or road stability.

Specific issues will be identified and addressed in Phase 2 of the ISMP.

2.5.3. Flow Control / Detention Storage

As presented in Section 3, flow control is used protect downstream systems (natural and built). It has typically been implemented as part of the drainage system for new development, and usually consists of an orifice-based control structure within a manhole and detention storage just upstream of the control structure. Detention storage accumulates runoff in excess of the controlled discharge rate and temporarily holds it until it can be released into the downstream system.

Currently, the District has only a few such systems – most of which are part of the Lakestone development off Okanagan Centre Road West. Facilities in that development include a three of concrete tanks (one above ground and two below ground) and an open, surface dry pond. The Lakes development also has a buried tank and a surface wet pond for detention storage.

2.5.4. Stormwater Quality Treatment

Section 2.7 discusses receiving water quality, which can be impacted by pollutants collected and conveyed by stormwater. Most of the stormwater treatment which occurs within the District is through infiltration – primarily because most roads have a rural cross section and runoff infiltrates as it flows through ditches or across vegetated surfaces. Within older developments serviced by storm sewer systems, the primary method of removing suspended solids from stormwater within the District is by catch basin sumps. Most catch basins are quipped with a storage sump approximately 0.5 m below the outlet pipe invert.

Newer developments, which do not solely rely on stormwater infiltration, typically include at least one stormwater treatment device in its system. These are usually vortex-based facilities which remove debris and suspended sediments from the collected runoff. The current understanding is that many pollutants (some hydro-carbons and biological constituents) are attached to the suspended sediments, and therefore are also removed when the sediments are removed. Free-floating Hydro-carbons (oils and greases) can also be removed from stormwater by oil-water separators or by specialty devises installed in the vortex unit.

The District GIS currently does not include data on installed treatment facilities. This data gap should be addressed to ensure that the facilities can be adequately inspected and maintained to assure continued performance.

2.5.5. Outfalls

For the purposes of this section, an outfall is defined as the point where a piped system, including select culverts, discharges to a receiving water. The District GIS currently has no data on these outfalls – whether they are simply exposed pipe, protected by an outlet structure, have energy dissipation, have a grate, or are submerged. Based on these criteria, there are approximately 35 outfalls within the District. Additional information should be collected and added to the GIS to facilitate inspection and maintenance going forward.

2.6. Environment

2.6.1. General

Given the semi-arid conditions within the District, the environment is sensitive to changes in surface and ground water quantity and quality. The purpose of this section is to provide context and awareness for plans and decisions regarding stormwater management.

2.6.2. Biogeoclimatic Ecosystem Classification (BEC) Zones

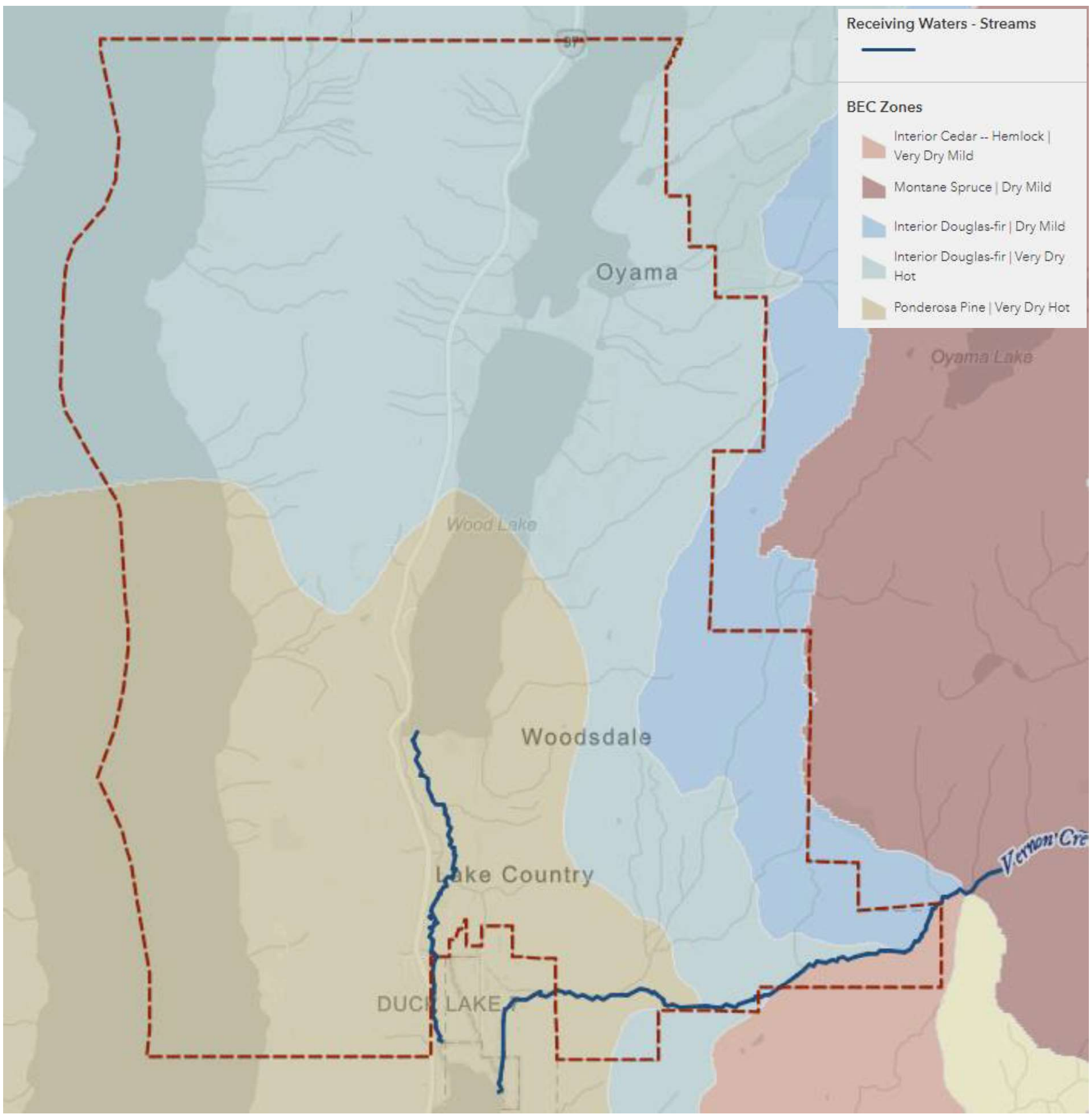
The Biogeoclimatic Ecosystem Classification system was first developed at the University of BC and then adopted by the BC Ministry of Forests in the 1970's. It combines the biological, soils, and climatic characteristics of an area in terms of predominant vegetation, temperature, and water availability. The classification process is detailed and involved, but the resulting classifications provide a useful description of these combined characteristics. Referring to Figure 2.9, we see that the District is predominantly within two primary zones – Interior Douglas Fir to the north and east, and Ponderosa Pine to the south. Both zones are further classified as "Very Dry Hot", which corresponds to the lower elevations in the valley. At higher elevations to the east, tree species include Interior Cedar, Hemlock, and Montane Spruce. Climatic conditions transition to Dry and Mild. Distribution of these zones within the District are summarized in Table 2.3.

Note that the "dry" classification is common throughout. This indicates that plants present in these zones have adapted to limited water availability. However, even within these general zones, microclimates within the riparian areas along streams, lakes, and wetlands do exist which support more water-loving species. The key point is that stormwater management works which divert significant amounts of rainwater away from or to an area are likely to impact the environmental characteristics of that area over the long term. More detailed information about BEC zones can be found online (Marcoux, 2004 and BC MFLNRO).

Table 2.3: BEC Zone Distribution Within the District

Zone and Sub-Zone	Distribution
Interior Cedar-Hemlock, Very Dry Mild	0.8%
Interior Douglas Fir, Dry Mild	6.9%
Interior Douglas Fir, Very Dry Hot	56.0%
Montane Spruce, Dry Mild	0.2%
Ponderosa Pine, Very Dry Hot	36.1%

Figure 2.9: BEC Zones



2.6.3. Aquatic and Foreshore

Four of the primary streams which flow through the District – Upper Vernon Creek, Middle Vernon Creek, Winfield Creek, and Oyama Creek - are considered fish bearing. In addition, the lake shore at the mouths of these streams is classified as "very high" value fish habitat. Figure 2.10 shows the foreshore Aquatic Habitat Index ratings for the three primary lakes within the District and Table 2.4 summarizes the percentage of shoreline for each of these lakes by index classification. Figure 2.11 shows the streams where fish have been observed and reported, indicating that these are fish-bearing streams.

Figure 2.10: FIM Aquatic Habitat Rating (Current and Potential)

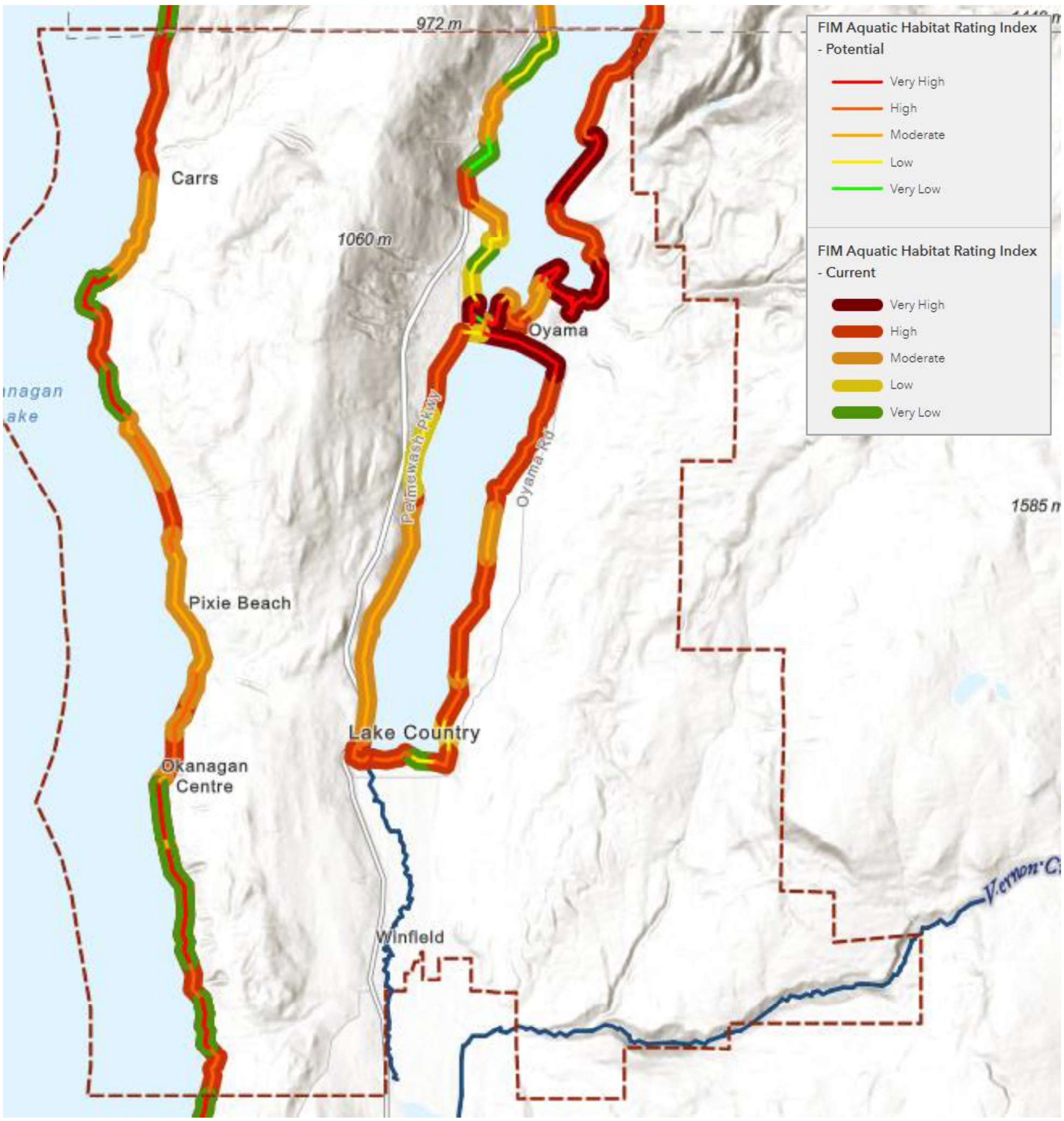
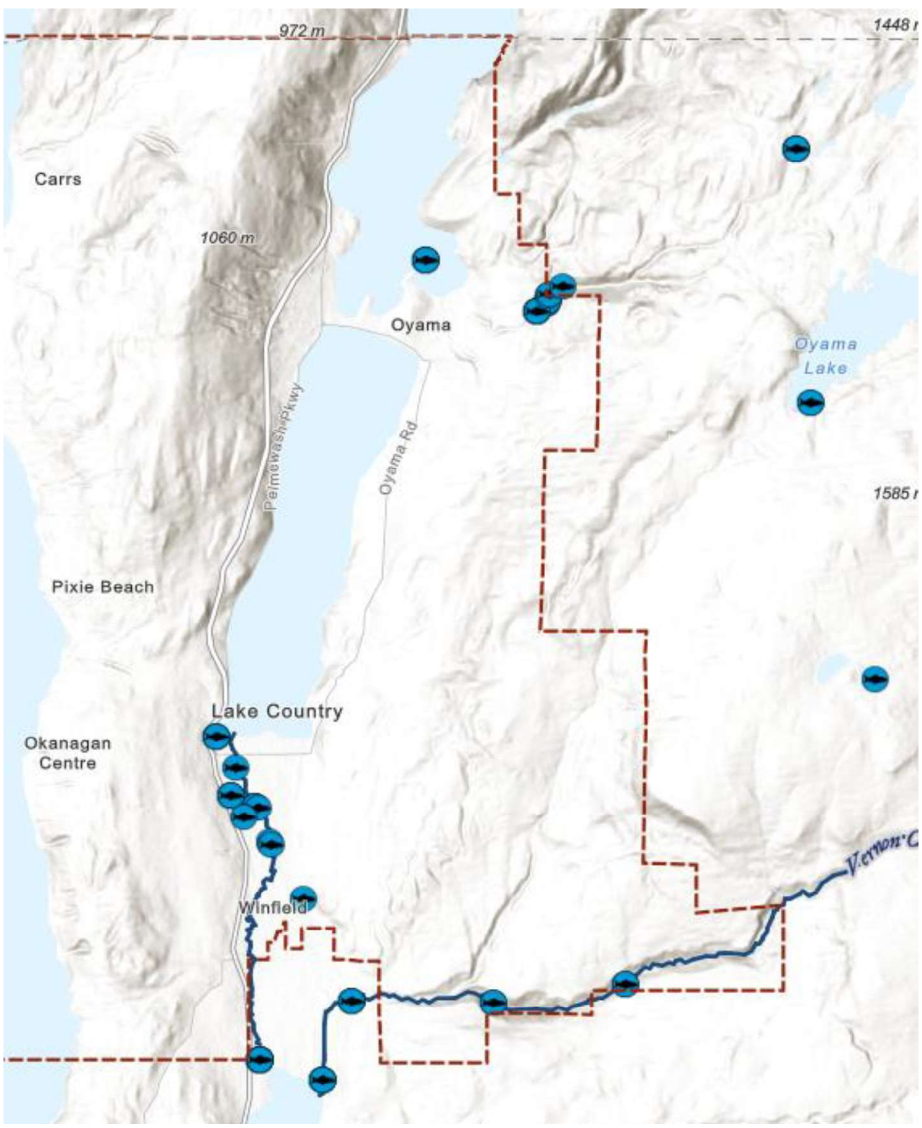


Table 2.4: FIM Aquatic Habitat Rating Distribution

FIM Aquatic Habitat Rating	Total Length (m)					
	Wood Lake		Kalamalka Lake		Okanagan Lake	
	Current	Potential	Current	Potential	Current	Potential
Very High	1,545	1,545	5,448	5,448	-	5,719
High	8,445	8,445	4,310	4,310	6,844	8,385
Moderate	4,755	4,755	2,980	2,980	6,727	4,539
Low	2,122	2,487	950	2,561	-	-
Very Low	365	-	2,418	806	5,072	-
Total	17,232	17,232	16,106	16,106	18,643	18,643

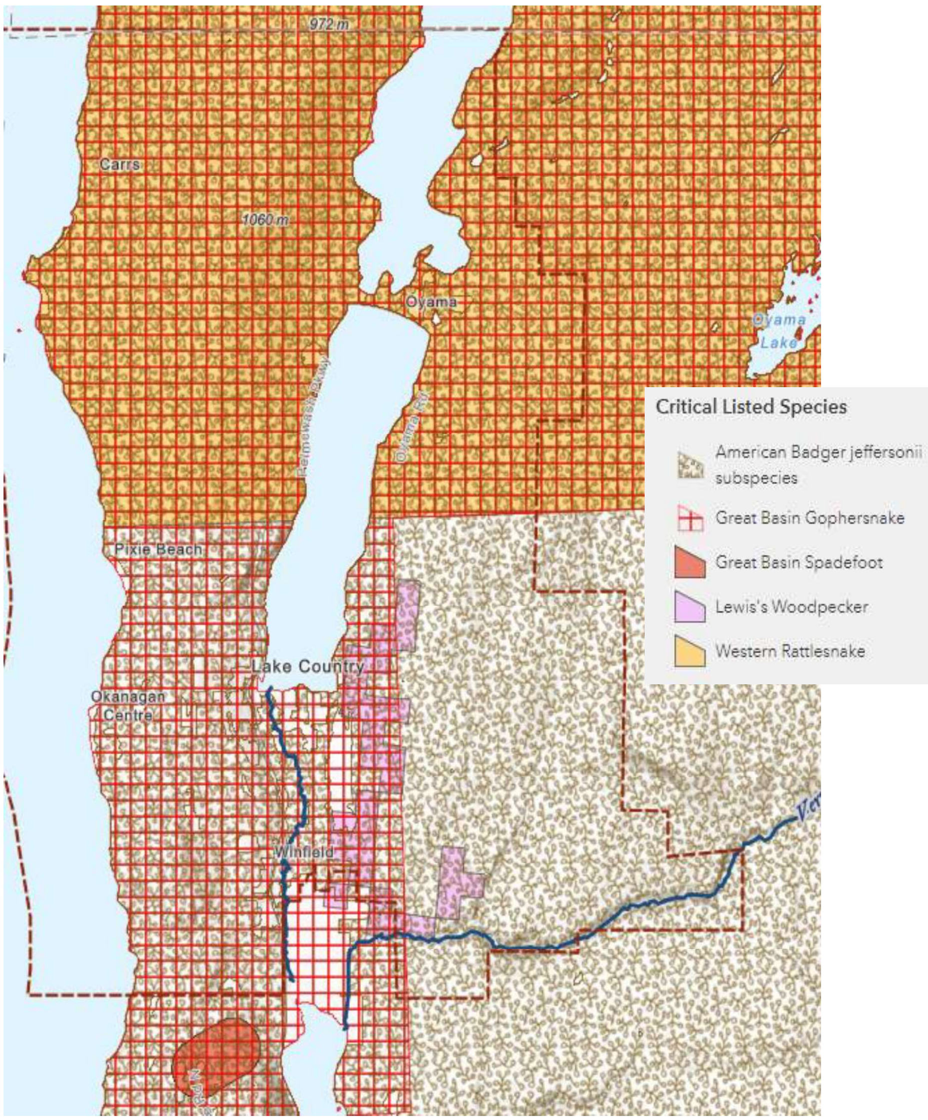
Figure 2.11: Recorded Fish Observations (Streams)



2.6.4. Wildlife

Only four critical-listed species have been identified within the District Boundaries – the American Badger, Great Basin Gopher Snake, Lewis's Woodpecker, and Western Rattlesnake. A small area just south of the District boundary, between Okanagan and Ellison lakes, has been identified as having the Great Basin Spadefoot. The general distribution of these species is shown in Figure 2.12.

Figure 2.12: Critical Listed Species



2.6.5. Riparian Areas

The District OCP includes mapping of riparian areas, which has been included in the ISMP interactive map system. Some of the mapped riparian areas are self-evident – the foreshore of each lake and the zone along each named stream. Many of the mapped areas, however, are intended to flag potential riparian areas for further assessment when adjacent development is proposed. The current mapping does not differentiate between what is and is not an actual riparian zone – this will require further work outside the scope of the ISMP.

2.7. Water Quality

2.7.1. General

Runoff from developed areas (residential, commercial, industrial, roads, etc.) typically becomes contaminated with a variety of pollutants, which are then carried to receiving waters. These include a variety of physical, chemical, and biological items that accumulate such as:

- debris (garbage, landscaping materials)
- suspended sediments (sands, gravels, and dust)
- nutrients (nitrogen and phosphorous)
- trace metals (copper, nickel, and zinc)
- organics / bacteria (animal waste)
- hydrocarbons (oil and grease)

These are called "non-point source" pollutants because their origin is often quite diffuse in the environment and thus their control can be challenging.

Stormwater quality is an important issue because much of the surface runoff is discharged directly to natural lakes and streams within the District. The District has four water intakes for potable (drinking) water use, one each on:

- Kalamalka Lake
- Okanagan Lake
- Oyama Creek
- Upper Vernon Creek

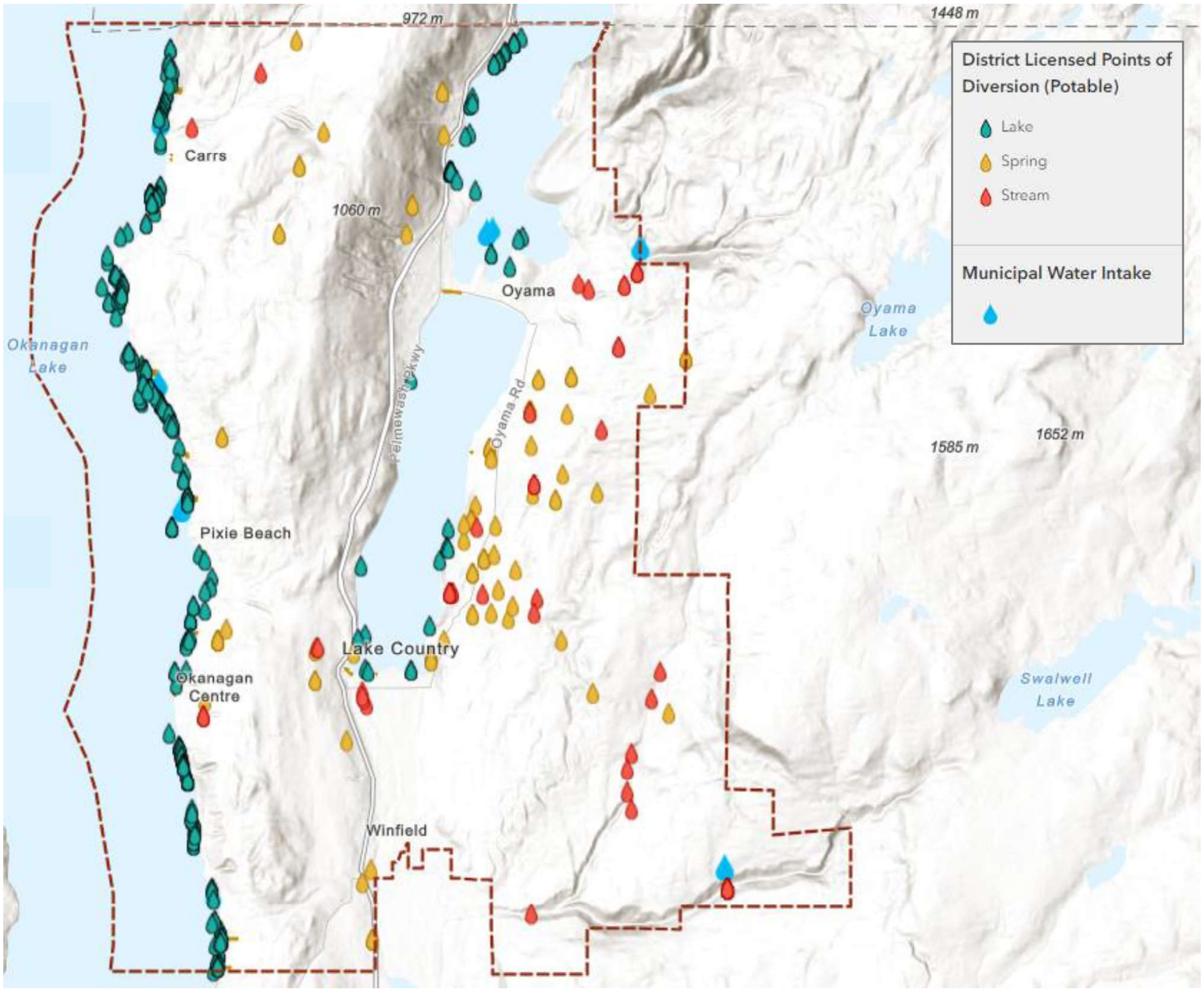
The Kalamalka Lake and Okanagan Lake intakes are protected by a designated intake protection zone as shown in Figure 2.13. There are also approximately 298 private, licensed points of diversion on the lakes, streams, and springs within the District. These are summarized in Table 2.5 and are also shown in Figure 2.13.

The lakes attract many users during the warmer months, so water quality along beaches and the shoreline in general is an important public health issue. Protection of fish and fish habitat is also a high priority for federal and provincial authorities – both in stream and along the lake shore.

Table 2.5: Active Licensed Points of Diversion (Potable Use)

Source	Number of PODs
Kalamalka Lake	23
Okanagan Lake	178
Vernon Creek (Upper)	2
Vernon Creek (Middle)	4
Wood Lake	12
Other Streams	26
Springs	53
Total	**298**

Figure 2.13: Municipal and Private Water Intakes



2.7.2. Erosion Hazard DPA

The OCP identifies areas within the District which are susceptible to erosion – especially with the natural landscape is disturbed. These areas form the Erosion Hazard Development Permit Area (Erosion Hazard DPA). Its purpose is to control development within the subject areas to ensure continued slope stability and to prevent erosion and subsequent downstream sediment deposition – especially into streams and lakes. These areas are shown in Figure 2.14 and in Water Quality map of the online ISMP Dashboard.

Figure 2.14: OCP Erosion Hazard Development Permit Areas

2.7.3. Studies / Sampling

In 2009, the District commissioned two studies (Larratt, 2010) to better understand the water quality at its lake intakes. These were comprehensive studies which characterized natural and anthropogenic-induced hazards to drinking water quality. Existing research was augmented by field studies of water currents near the intake and lab studies on the fall rates of particulate contaminants. The research was used to define the intake protection zones (IPZs) now in place. It is important to note that most of Kalamalka Lake and Okanagan Lake are situated outside of the District boundary, and therefore the District has limited control over what enters them. However, the lake intakes can be significantly influenced by conditions immediately adjacent to the intakes – something that is within the District's power to manage. The IPZs therefore identify the area around each intake at highest risk of contamination impacting water quality.

The District is also currently participating in a joint study of Kalamalka Lake limnology with the Regional District of North Okanagan. This study was initiated in 2000, and consists of annual sampling, trend analysis, and reporting with respect to physical, chemical, metallic, and biological constituents.

Kalamalka Lake

The Kalamalka Lake study found that:

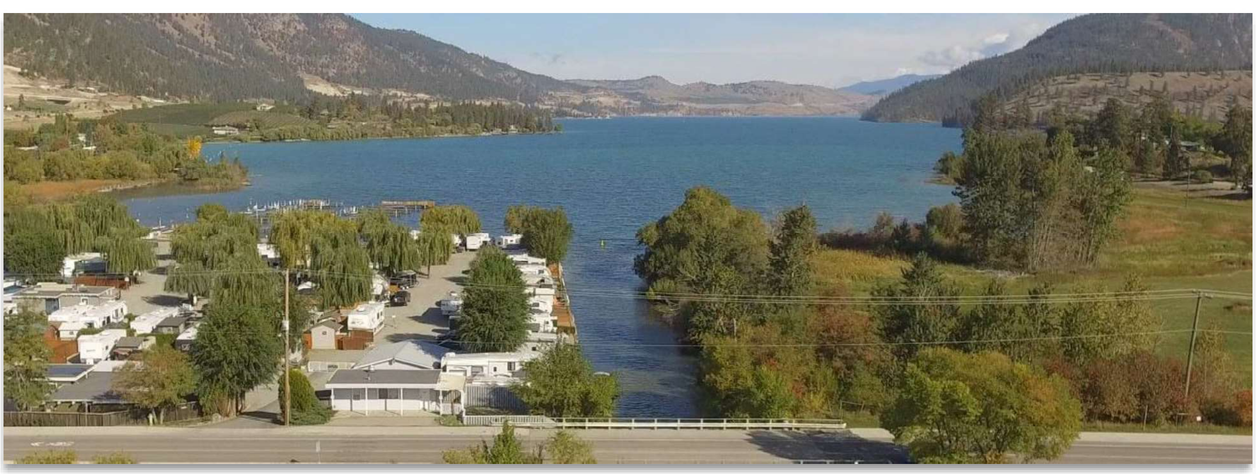
- The single greatest impact on water quality in Kalamalka Lake is the size of the freshet, affecting nitrogen-N, phosphorus-P, pH, calcium, sulphate, and organic/inorganic particulate inputs.
- Seiches - wind-driven tipping of a lake's water layers during the summer - increase the vulnerability of the intake to contaminants introduced to the surface water layer by storm water outfalls.
- Both sodium and chloride – the most stable and reliable indicator ion/anion respectively - have shown a slow, steady increase since 1976, indicating increased watershed disturbance, particularly municipal wastewater and storm water run-off.
- A high E. coli count in the intake water noted during an August 2006 storm may be the result of storm water entering the southern end of Kalamalka Lake.

The study recommends that stormwater outfalls not be allowed within the intake protection zone, and that treatment – or at least infiltration to ground or natural grassed buffers – be implemented for outfalls to the lake in general.

An in-house bacterial analysis was completed on two samples taken at Pioneer Beach and Beasley Beach respectively in 2014. The analysis concluded that most of both E-coli and non E-coli contamination came from Canada Goose droppings, which is not related to stormwater outfalls.

Current sampling and testing (with respect to constituents associated with stormwater) are conducted at the Kalamalka Lake intake as follows:

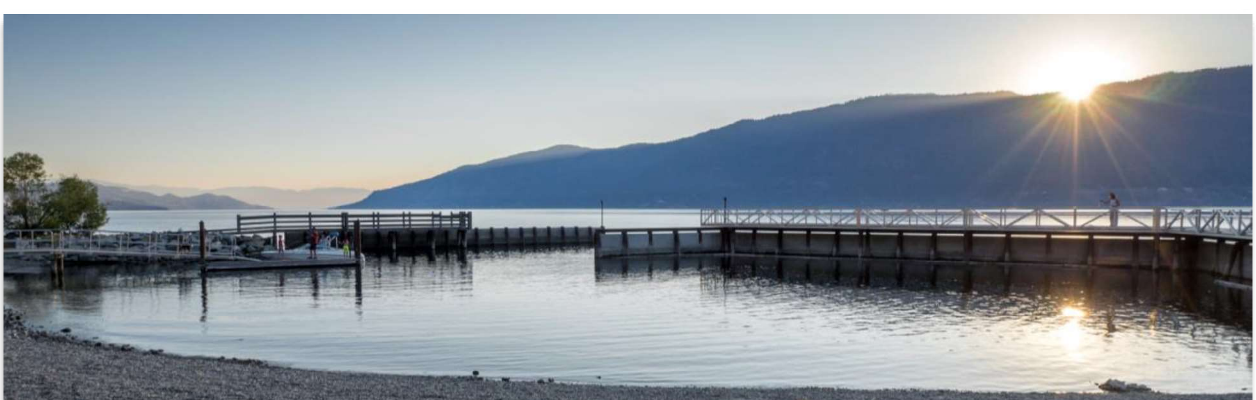
- bacteriological, total dissolved solids, turbidity – weekly
- total suspended solids, total organic carbon – monthly



Okanagan Lake

The Okanagan Lake study found that:

- Seiches - wind-driven tipping of a lake's water layers during the summer - increase the vulnerability of the intake to contaminants introduced to the surface water layer by storm water outfalls.
- Turbidity is generally low in the area and depth of DLC's primary intake. Over the years and season of operation, average annual turbidity has ranged from 0.3 to 0.65 NTU – indicating very low overall turbidity. (The BC Drinking Water Quality Guidelines recommend a background raw water upper limit of 50 NTU, with a change from the background level of no more than 10% or 5 NTU, whichever is less). The dates when turbidity exceeded 1.0 NTU are very rare and isolated, usually only one or two dates per year, and typically associated with seiches.
- Open water samples from Okanagan Lake rarely carry bacteria. Most bacteria in Okanagan Lake occur in the surface sediments or are carried in by recent inflows (streams and storm outfalls) to the lake.
- The stretch of Okanagan Lake near the DLC intake experiences fast-moving water currents parallel to shore. Horizontal water currents are strongest in the top 5 meters of Okanagan Lake, and during a storm, they can reach speeds of up to 9.5 cm/s (342 m/hr).
- The Lakestone stormwater outfall poses a threat to water quality at the intake:
- During summer, the storm water plume will behave like a creek inflow plume. If the particulate load is heavy during the "first flush" of materials off the streets into the storm water, then the inflow may form a density plume that travels along the lake bottom like a dirty cloud. After the initial flush, the storm water plume should be trapped by the thermocline and remain in the surface water. It will travel parallel to the shore dropping large particulates quickly while finer particulates will travel further.
- During the non-stratified winter period, the storm water can form a pool in front of the outfall and travel as a packet of water, diluting as it travels. The depth that the pool can form at will be deeper in the fall/winter than in the summer and is the most immediate potential source of contaminants to the 33 m deep DLC intake after November.
- Because of the above processes, it is unwise to count on stormwater dilution within the available volume in the region of the intake when water-borne contaminants are considered.



- Distributed runoff from the land that is not collected into a storm water outfall can affect this intake because the length of the DLC intake pipe from the shoreline is only 60 m. Shoreline properties have the highest potential to impact the lake. Surface flow from these properties is the most serious, followed by subsurface drainage which is slower and offers some in situ treatment. One of the recommendations is to extend the intake pipe further into the lake.

Specific recommendations of the study pertinent to stormwater management are as follows:

- Ideally no storm water outfalls should discharge within the intake protection zone or within two hour's transport during maximum current velocity, whichever is greater.
- Preferably, direct outfalls should be replaced with alternatives such as soak-away zones, retention for irrigation, etc.
- Landowners in the area should be encouraged to limit impervious surfaces and incorporate "rain gardens".

Current sampling and testing (with respect to constituents associated with stormwater) are conducted at the Okanagan Lake intake as follows:

- bacteriological, total dissolved solids, turbidity – weekly
- total suspended solids, total organic carbon – monthly

2.7.4. Stormwater Treatment

It is much simpler and more cost effective to capture and treat stormwater before it enters the receiving waters than to extract pollutants after they become part of the ambient condition. Currently, the District requires new developments to "provide water quality treatment for flows up to 50% of the 2-year event." The rationale for this is that most debris and sediments are flushed into the system during the initial part of the storm – the "first flush" principle. However, the District is in the process of updating Schedule M of the Subdivision Development and Servicing (SDDS) bylaw with more clearly-defined requirements. The update shifts treatment sizing from a flow rate to a volume-based approach, which better reflects current practice in BC. In addition, it not only specifies clear targets for allowable turbidity and total suspended solids (TSS) removal, but it also specifies targets for hydrocarbon (oils, greases) control.

Regardless of the stormwater treatment facility installed, all have the potential for collected sediments to be re-suspended during a rainfall event and discharged into the storm sewer system. This can be minimized through routine servicing by a vacuum truck to remove and dispose of the collected materials.

2.8. Operations and Maintenance

The District currently spends approximately $100,000 annually on inspections and maintenance of its stormwater management systems. The work includes:

- hydro-vacuuming each catch basin (≈1250),
- visually inspecting each manhole (≈570),
- visually inspecting each drywell - hydro-vacuuming them when "over 50% full" (inspect ≈420, maintain ≈40),
- hydro-vacuuming each CDS (≈3)

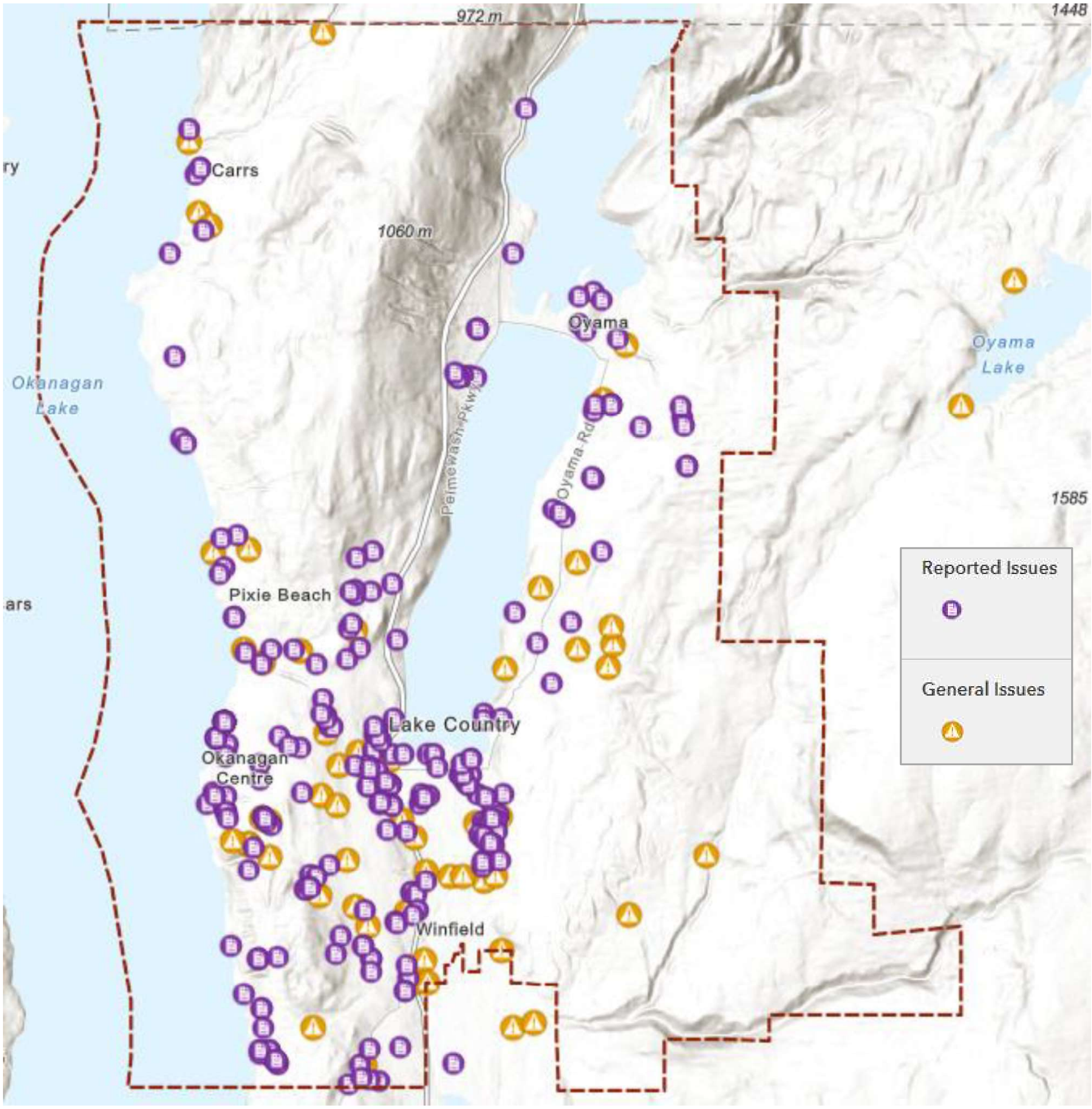
- hydro-vacuuming each oil-water separator unit (≈4),
- visually inspecting each detention storage tank/facility (≈10), and
- cleaning culverts as reported or noted by District Staff (varies).

Given that most of the District roads have rural cross sections, it is not surprising that approximately half of the annual O&M budget is allocated to culvert cleaning. Approximately 40% of the budget goes to cleaning catch basins, leaving only 10% for the remaining tasks. Interestingly, there are approximately only 690 culverts within the District, so it appears that maintaining a culvert takes significantly more effort than maintaining catch basins or drywells. Note that the above information provided by the District does not include repairs or replacement of damaged infrastructure.

In addition to the regularly scheduled inspections and maintenance, the District fields many calls from the public during each year. These reported drainage issues are documented and investigated when they are received. For the purposes of this ISMP, a copy of these issues was obtained to better understand the types of issues reported, where they occurred, and how many might be associated with greater than average rainfall events. The reported issues are from March 2018 to June 2022. They are mapped as "Reported Issues" in Figure 2.15 – more details are available on the interactive Operations/Maintenance map.

The reported issues range from requests to clean-out sediment-filled catch basins to flooding or erosion. When multiple reports were received on the same or on consecutive dates, the Okanagan Centre climate station data was checked to determine the amount of rainfall that occurred on or just before the subject date(s). Twenty-two rainfall events were flagged in association with some of the reported drainage issues. In 2011, District Staff identified drainage concerns to, and conducted a field visit with, Urban Systems in preparation to develop a Master Drainage Plan. The comments from this work are also provided on the interactive Operations/Maintenance map as "General Issues".

Figure 2.15: Documented Stormwater Management Issues



3. ANALYSES

3.1. Hydraulic Performance Criteria

The criteria presented in this section were used to assess stormwater asset capacities and are based on whether the asset is designed to function as part of the minor or part of the major system. The minor system is intended to manage runoff from frequent rainfall events and is often considered a "convenience" system. The major system is intended to safely convey runoff from less frequent, more extreme rainfall events – usually when the minor system's capacity is exceeded or when inlets to the minor system are blocked by debris.

The design storm return periods assigned to each of these two systems reflect the District's risk tolerance. The SDDS bylaw specifies that minor and major drainage systems be designed using return periods of 10 and 100 years respectively. Special cases - culverts and bridges on primary streams – are designed use flows with a 200 year return period. These return periods were used for analysis for this ISMP, and reflect the following risks for the District:

- a 10% probability that the minor system's capacity will be exceeded in any given year, and
- a 1% probability that the major system's capacity will be exceeded in any given year, and
- a 0.5% probability that the stream's culvert or bridge capacity will be exceeded in any given year.

Analysis scenarios and results are presented in Section 5 – Risk Assessment.

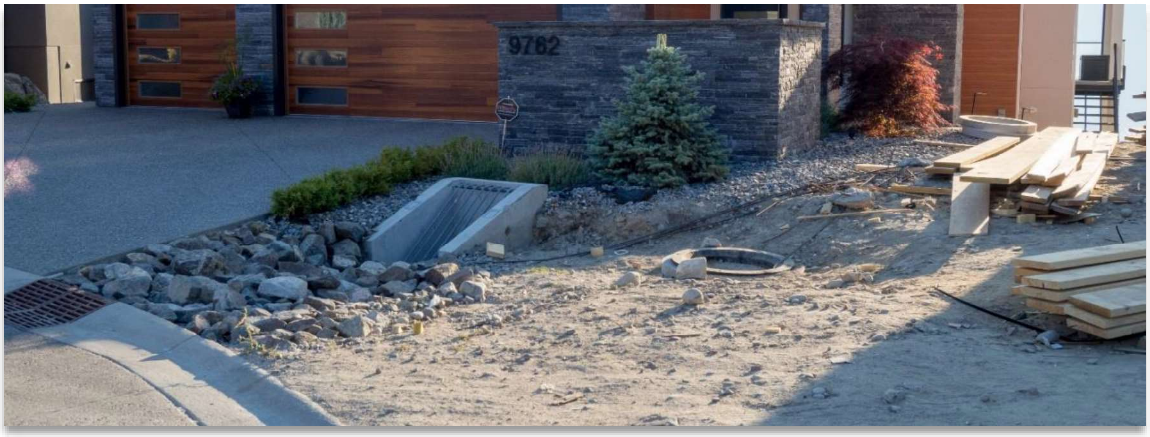


Table 3.1: Asset Performance Criteria

Asset Type	Design Return Period (years)	Criteria
Ditch	100	freeboard ≥ 0.3 m
Culvert	100	water depth ≤ top-of- inlet
Culvert/Bridge on a stream	200	freeboard ≥ 0.6 m
Gravity Main - Solid	10 or 100[5]	must be free-flowing (no surcharge at upstream end)
Gravity Main - Perforated	10	no discharge to surface at either end
Manhole	10 or 100	no surcharge
Drywell	10	freeboard ≥ 0.5 m
Catch Basin – at sump	10 or 100	ponding depth ≤ 150 mm
Catch Basin Lead (lateral)	10 or 100	must be free-flowing (no surcharge at upstream end)
Detention Storage	10 or 100[6]	no discharge to surface or overflow system

3.2. Pre-Development Runoff

To manage the hydrologic impacts of development (increased impervious area and piped drainage systems which result in increased runoff volume and peak flows), the District requires that runoff leaving the development site be attenuated to the site's pre-development peak runoff rate for the corresponding design return period (minor/major events). Within this context, "pre-development" refers to conditions without any anthropogenic changes to the landscape – that is, the land in its natural state prior to roads, logging, agriculture, or development of any kind. Ideally runoff volume would also be controlled to pre-development levels, but in practice this is difficult to achieve on hillsides where steeper slopes limit opportunities for surface infiltration / evaporation facilities.

Historically, pre-development flows were calculated using simplistic design tools such as the Rational Method. These are not appropriate for this task since they are inherently conservative, generating flow rates that ensure adequately-sized infrastructure, but which exceed peak flows that would naturally occur in the field for the same rainfall event. Such approaches can result in over-estimated pre-development flows from a given development site, resulting in post-development flow rates which may exceed downstream infrastructure or natural channel capacities. The District has experienced this, with excessive "pre-development" flows from new development washing out roads.

5 Piped major drainage is discouraged because once the capacity is exceeded, the probability of damage to infrastructure and downstream properties becomes significant. Open channel / surface flow routes are much preferred. However, piped major drainage can be implemented where no other feasible option exists.

6 Detention storage may, at times, be required to attenuate post-development 100-year runoff to an approved offsite discharge rate.

Within the study area, most undisturbed surficial soils have the capacity to infiltrate and hold most if not all the rainfall from more frequent (minor system) rainfall events. This is due to porous conditions caused by organic materials and live vegetation. The only undisturbed areas likely to generate surface runoff during a rainfall event are those comprised of sparsely-vegetated, highly impervious soils or exposed bedrock. Except during events with high, sustained rainfall intensities, runoff from undisturbed catchments within the study area is essentially zero. Managing all development runoff onsite to ensure zero offsite discharge is typically not a feasible option. So, the question regarding what a safe discharge rate would be must be addressed. In practice, much depends on what the receiving water is and how runoff from a development can be conveyed to it. Although each development site is unique, most reflect the following typical scenarios for both receiving water and offsite conveyance to it.

Receiving Water:

1. A lake. Within the study area, this includes Ellison, Wood, Kalamalka, and Okanagan lakes. In this case, no flow control is really required provided that the runoff is adequately treated and safely conveyed to the lake. Provincial approval of a new lake outfall would, however, be required.
2. A natural stream. Within the study area, this includes Middle Vernon Creek, Winfield Creek, Anderson Brook, Hayton Creek, Ribbleworth Creek, Oyama Creek, and Upper Vernon Creek. Although streams can function as a receiving water, they are sensitive to flow frequency and magnitude. Each has a threshold which, if exceeded, triggers bed and/or bank erosion, not to mention flood risk. None of the streams within the District are reliably instrumented to collect flow data, but a URR for each permanent stream can be calculated using active channel geometry and contributing catchment area. The assumption is that the active channel, which conveys frequent flows, is stable. The calculated URR would then govern the allowable discharge rate from the proposed development to the stream. As with discharges directly to a lake, provincial approval of a new stream outfall would be required.
3. Ground (infiltration). If an adequate receiving water is not sufficiently close to the development, it might be feasible to infiltrate the runoff. Section 2.3 of this report provides a general indication of where this might be feasible, but each site would require adequate hydro-geotechnical investigation to confirm as per Schedule M of the Subdivision Development and Servicing bylaw. If infiltration is deemed feasible by a qualified professional, then a well-designed system using design values from the hydro-geotechnical study would be required and need to be approved by the District Engineer. In this case, flow control would be dictated by the infiltration system design. This approach assumes that all infiltration works will be located on-site. It also assumes that a safe downstream route for emergency overflows exists or can be constructed.

Conveyance From the Development to the Receiving Water:

1. Existing trunk storm sewer in good condition. In this conveyance scenario, the residual capacity of the trunk would have to be calculated, and the URR would be the residual capacity divided by the contributing, projected long-term development area. The PCSWMM model developed for this ISMP could be used to estimate the residual trunk capacity. Note that if the existing trunk discharges to a stream instead of to a lake, the stream's URR must also be considered – the lessor of the two URRs (trunk or stream) would govern.
2. New trunk storm sewer. If a new trunk drainage system is required, then it should be sized to accommodate runoff from all existing and potential development that may connect to it. If the trunk is to discharge to a stream, then its capacity should be based on the stream's URR and the total

developable area draining to the trunk. If the trunk is to discharge to a lake, then flow control is not required unless it is more economical to incorporate some flow control to reduce trunk size and corresponding costs. In this case, a URR based on the design trunk capacity and the total developable area draining contributing to it should be calculated and applied to all developments with potential to connect.

3. Surface channel (ditch, swale, or natural channel). A controlled discharge to any of these conveyance options is required to prevent erosion and sediment transport. In this scenario, a detailed geotechnical investigation would be required to identify flow rate and duration thresholds that ensure channel and slope stability under both minor and major runoff conditions. A URR would be calculated using the recommended flow rate threshold and the total projected contributing development area.

Table 3.2 summarizes the recommended controlled discharge criteria for the combinations of receiving water and offsite conveyance system.

Table 3.2: Controlled Discharge Guidance

Receiving Water	Offsite Conveyance System	Controlled Discharge Criteria
Lake	Existing Trunk Sewer	URR based on residual trunk capacity
	Proposed Trunk Sewer	URR based on proposed trunk capacity
	Surface Channel	URR based on stable channel capacity
Stream	Existing Trunk Sewer	Lesser of the URRs based on residual trunk capacity and stable stream channel capacity
	Proposed Trunk Sewer	Lesser of the URRs based on proposed trunk capacity and stable stream channel capacity
	Surface Channel	Lesser of the URRs based on stable stream channel and surface channel capacities
Ground (Infiltration)	None – it is assumed that all infiltration systems will be located on-site	Infiltration rates and volumes recommended by a qualified professional

Where a URR is recommended, the allowable offsite discharge rate for a development is calculated as follows.

Equation 2: $Q = A \times URR$

Where: Q = the allowable discharge rate [Lps]
A = drainage area [ha]
URR = governing Unit Runoff Rate [Lps/ha]

4. PRIMARY DRAINAGE CATCHMENTS

4.1. General

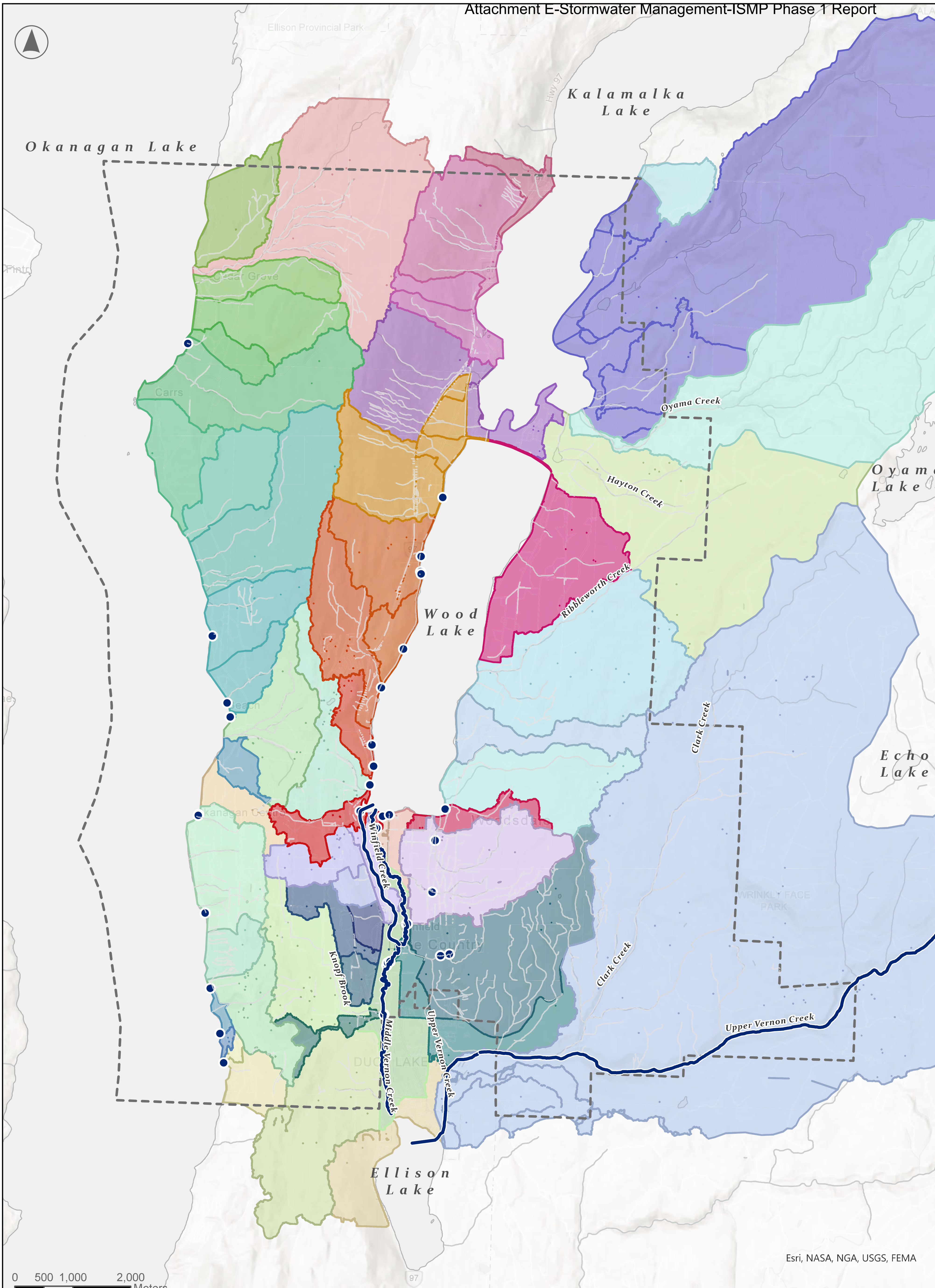
Table 4.1 summarizes the areas draining directly to each of the receiving waters for catchments which are within, or which at least pass through, the District as shown in Figure 4.1. Note that this excludes the catchments which drain to the upper lakes (Oyama and Swalwell).

Each receiving water, however, receives surface runoff from several primary catchments. The location of each primary outfall to one of the receiving waters, also shown in Figure 4.1, dictates how each corresponding drainage catchment is defined. Each primary catchment is comprised of many sub-catchments which are tributary to the main drainage course that discharges to the identified outfall. However, several of the primary catchments have been arbitrarily defined to include many small sub-catchments that each drain directly to a receiving water. This was done to facilitate discussion of and reference to general locations within the study area.

In addition to the three primary streams listed in Table 4.1, six named streams and hundreds of unnamed streams / gullies also discharge into these receiving waters. The named streams include:

- Anderson Brook
- Clark Creek
- Harvey Brook
- Hayton Creek
- Knopf Brook
- Ribbleworth Creek
- Oyama Creek

Upper Vernon Creek, Middle Vernon Creek, Winfield Creek, Hayton Creek, Clark Creek, and Knopf Brook are perennial streams – they have flow year-round. Anderson Brook, Harvey Brook, and Ribbleworth Creek are intermittent streams – they can dry-up during the late summer. The remaining primary catchments are named according to the receiving water that they discharge to or distinguishing feature that they contain (like a road). The primary drainage catchments are listed in Table 4.2, along with several key attributes. These attributes are weighted averages of the values assigned to each sub-catchment within the primary catchment. These sub-catchments are extensively characterized for modeling purposes, considering the impacts of soils, topography, and land cover on how rainfall is transformed into surface runoff. These details are presented in a technical memorandum and are available for viewing via the Interactive Maps.



Legend

- Outfalls
- Receiving Streams

Catchment - Primary

Anderson Brook, BWL Rd E, BWL Rd W, Camp Rd, Ellison Lake, Finch Road, Granite Rd, Harvey Brook, Hayton Creek, Knopf Brook, Middle Vernon Creek, OCRD East, OCRD West, OK Centre N, OK Centre S, Oceola Rd, Oyama Creek, Oyama Rd, RDNO 01, Ribbleworth Creek, Trewhitt Rd W, Upper Vernon Creek, WC-01, WC-02, Winfield Creek, Woodsdale

Kal Lake: Kal Lake 01, Kal Lake 02, Kal Lake 03, Kal Lake 04, Kal Lake 05, Kal Lake 06, Kal Lake 07, Kal Lake 08, Kal Lake 09, Kal Lake 10

MVC: MVC-01, MVC-02, MVC-03, MVC-04, MVC-05, MVC-06

Wood Lake: Wood Lake 01, Wood Lake 02, Wood Lake 03, Wood Lake 04, Wood Lake 05, Wood Lake 06, Wood Lake 07, Wood Lake 08, Wood Lake 09, Wood Lake 10, Wood Lake 11

OK Lake: OK Lake 01, OK Lake 02, OK Lake 03, OK Lake 04, OK Lake 05, OK Lake 06, OK Lake 07, OK Lake 08, OK Lake 09, OK Lake 10, OK Lake 11, OK Lake 12, OK Lake 13

Other

LAKE COUNTRY

Life. The Okanagan Way.

Master Drainage Plan

Receiving Waters and Primary Catchments

Figure 4.1

Table 4.1: Catchment Areas by Receiving Water

Receiving Water	Catchment Area (ha)		
	Within the District	Upstream of the District	Total
Upper Vernon Creek	1,982	3,631	5,613
Ellison Lake	0	189	189
Middle Vernon Creek	1,410	529	1,939
Winfield Creek	195	0	195
Wood Lake	3,162	79	3,241
Kalamalka Lake	1,809	4,799	6,608
Okanagan Lake	3,497	257	3,754
Total	**12,055**	**9,484**	**21,539**

Table 4.2: Primary Drainage Catchments – Weighted Key Parameters (Existing Conditions)

Primary Catchment	Area (ha)	Percent Impervious (%)	Directly Connected Impervious (%)	Pervious Depression Storage (mm)	Saturated Infiltration Rate (mm/hr)	Drainage Density (km/sq.km)
Anderson Brook	765.1	14.2	20.1	7.0	28.6	4.1
BWL Rd E	32.1	35.7	45.3	4.0	20.7	11.4
BWL Rd W	10.6	43.8	46.6	3.8	30.3	24.1
Camp Rd	78.2	37.8	35.0	5.5	75.7	7.7
Ellison Lake	188.9	26.0	49.4	3.7	55.8	10.8
Finch Road	86.9	29.2	21.4	7.9	83.2	8.2
Granite Rd	10.6	71.3	48.1	5.2	93.2	36.6
Harvey Brook	474.7	25.0	30.5	6.4	60.6	6.9
Hayton Creek	1104.3	13.0	22.4	7.5	29.7	2.9
Kal Lake 01	67.5	13.7	20.0	8.0	6.8	4.9
Kal Lake 02	2108.2	5.8	20.0	8.0	6.6	0.8
Kal Lake 03	366.5	12.3	20.0	8.0	19.7	5.7
Kal Lake 04	61.3	37.4	49.2	5.0	8.7	9.6
Kal Lake 05	23.4	31.9	43.3	5.0	67.9	9.7
Kal Lake 06	317.2	20.3	20.9	7.1	28.0	2.7
Kal Lake 07	88.3	27.9	25.4	6.8	23.3	5.3
Kal Lake 08	64.3	17.5	20.6	7.6	27.2	4.6
Kal Lake 09	319.2	21.3	21.0	7.1	64.0	2.4
Kal Lake 10	67.2	35.2	20.0	7.8	31.3	4.9

Primary Catchment	Area (ha)	Percent Impervious (%)	Directly Connected Impervious (%)	Pervious Depression Storage (mm)	Saturated Infiltration Rate (mm/hr)	Drainage Density (km/sq.km)
Knopf Brook	259.5	32.0	35.6	5.8	26.7	6.6
Middle Vernon Creek	225.7	35.3	41.8	4.4	62.7	11.5
MVC-01	39.7	38.9	30.1	6.5	38.6	10.8
MVC-02	195.4	26.8	32.6	4.7	93.4	10.0
MVC-03	587.5	12.4	23.0	5.2	56.8	5.2
MVC-04	40.3	32.1	45.9	3.9	0.8	3.4
MVC-05	79.4	28.3	40.6	4.9	21.2	6.8
MVC-06	36.9	23.3	45.3	4.9	0.8	5.0
Oceola Rd	202.2	32.9	39.4	5.0	33.5	11.8
OCRD East	255.6	29.8	30.9	6.4	28.9	6.6
OCRD West	163.5	41.5	26.7	6.9	53.7	11.2
OK Centre N	232.7	41.2	34.1	5.5	52.5	5.3
OK Centre S	78.9	43.6	34.8	5.3	46.6	3.3
OK Lake 01	191.6	25.7	20.8	7.9	42.8	4.1
OK Lake 02	130.0	23.2	23.1	6.7	53.5	2.2
OK Lake 03	208.4	31.3	23.4	7.4	41.2	2.9
OK Lake 04	67.9	36.5	25.8	7.4	28.4	0.6
OK Lake 05	368.9	27.4	25.1	7.4	25.2	3.6
OK Lake 06	163.8	40.6	32.1	6.3	12.6	3.2
OK Lake 07	185.6	35.0	25.9	7.1	19.9	5.0
OK Lake 08	419.0	21.8	22.3	7.3	29.1	4.3
OK Lake 09	183.4	25.6	31.3	6.9	23.2	3.9
OK Lake 10	95.2	32.5	40.2	5.9	26.4	5.5
OK Lake 11	49.3	34.0	36.8	5.5	39.9	2.8
OK Lake 12	11.9	47.9	21.5	5.0	74.1	7.4
OK Lake 13	7.6	58.2	44.8	5.5	69.4	27.1
Oyama Creek	1925.2	6.1	20.0	8.0	18.0	0.6
Oyama Rd	317.2	19.0	20.0	6.6	49.2	6.8
RDNO 01	95.3	7.6	20.0	8.0	5.0	6.9
Ribbleworth Creek	658.6	18.1	24.0	6.9	38.1	6.1
Trewhitt Rd W	171.0	22.0	24.0	6.2	46.4	5.6
Upper Vernon Creek	5612.5	10.6	20.1	7.7	31.9	3.3
WC-01	38.1	27.6	37.4	5.5	13.3	5.4
WC-02	101.8	35.0	43.5	4.4	59.7	8.8
Winfield Creek	55.1	26.9	40.4	5.4	44.9	18.4
Wood Lake 01	386.9	24.0	35.6	5.1	49.5	4.8

Primary Catchment	Area (ha)	Percent Impervious (%)	Directly Connected Impervious (%)	Pervious Depression Storage (mm)	Saturated Infiltration Rate (mm/hr)	Drainage Density (km/sq.km)
Wood Lake 02	51.5	29.6	20.9	5.6	54.7	5.8
Wood Lake 03	7.1	49.9	42.5	4.2	6.6	22.8
Wood Lake 04	3.2	40.2	46.2	3.8	38.2	14.0
Wood Lake 05	81.7	39.3	44.1	4.3	43.0	12.1
Wood Lake 06	66.4	26.8	34.6	5.7	38.4	15.6
Wood Lake 07	236.0	25.6	26.3	6.8	34.6	10.3
Wood Lake 08	76.3	14.0	20.1	8.0	32.3	7.0
Wood Lake 09	207.8	11.4	20.0	7.6	20.1	4.2
Wood Lake 10	250.5	13.3	21.1	7.7	26.1	7.6
Wood Lake 11	89.3	25.3	39.7	5.1	102.6	15.4
Woodsdale	392.6	19.4	29.3	5.0	45.3	6.2
Total / Weighted Average	**21,538.6**	**16.6**	**24.0**	**7.1**	**32.2**	**4.2**

The attributes listed in Table 4.2 are defined as follows:

- Area – surface area of the catchment's projection onto the horizontal plane.
- Percent Impervious – the percent of the catchment's surface which is covered by a hard surface (concrete, asphalt, surface bedrock, compacted soils, buildings, etc.). Greater amounts of impervious area within a catchment usually results in greater runoff generated from a given storm.
- Percent Directly Connected Impervious – the percent of the total impervious area which is directly connected to a drainage system that discharges to the catchment's outlet. Catchments with high amounts of directly connected impervious area convey runoff more quickly than catchments in which runoff generated on impervious areas flows onto pervious areas such as landscaping. This tends to cause peakier runoff hydrographs.
- Pervious Depression Storage – the amount of storage (expressed as depth over the entire catchment area) which must be filled before surface runoff can occur during a rainfall event. This impacts the volume of runoff generated.
- Saturated Infiltration Rate – the infiltration rate when surficial soils are thoroughly wetted. It is the minimum infiltration rate expected, and surface runoff from pervious areas is generated only when the rainfall intensity exceeds this infiltration rate.
- Drainage Density – the length of surface flow paths within a catchment divided by the catchment area. Catchments with greater drainage densities tend to generate "peakier" runoff hydrographs from a given storm.

In Phase 2 of the ISMP, additional information about each of the primary catchments will be provided. This information will establish more detailed context to understand specific stormwater management opportunities and constraints within them. It will also include proposed works to address priority issues.

5. RISK ASSESSMENT

5.1. General

This section summarizes a screening-level risk assessment that was conducted to identify surface drainage routes most at risk from pluvial (rainfall) events. The risk assessment was qualitative only, despite use of numerical scores for activation likelihoods and consequence severities. It was sufficient, however, to identify priority areas that require further investigation, assessment, and potentially capital project development.

As described in Section 2.5, storm runoff within the District is managed using dual drainage systems (minor and major infrastructure). By default, runoff that cannot be conveyed by the minor system, or where a minor system does not exist, is diverted to surface flow paths. Some surface flow paths are designed (roads, swales) while others are natural (gullies, ravines). In many situations, these major flow paths are not recognized as such and flow through them often causes damage to property and/or infrastructure.

The goal of this assessment was to assign a risk rating to each surface flow path. Since risk is a function of likelihood and consequence severity, the general methodology was follows:

- assess the likelihood that a storm event would activate a flow path (runoff enters the flow path), and
- assess the consequences severity of that activation.

The resulting risk scores described in Section 5.4xx will be used in Phase 2 to prioritize more detailed analyses of the systems and to inform a prioritized infrastructure upgrade/improvement process. More details about the risk assessment are provided in a technical memo in Appendix G.

5.2. Methodology

The flow paths and depressions were modeled using PCSWMM. The model also included existing drainage infrastructure (culverts, storm sewers, manholes, drywells, catch basins, detention tanks, and lift stations). Several scenarios – combinations of design storm and land use - were developed to stress the system. The scenarios included the following combinations:

1. Existing land use with a 1:10 year (minor) current climate design storm
2. Existing land use with a 1:100 year (major) current climate design storm
3. Future land use with a 1:10 year (minor) future (2040-2070) climate design storm
4. Future land use with a 1:100 year (major) future (2040-2070) climate design storm

5.2.1. Activation Likelihood

Each of the four scenarios presented above reflect combinations of climate and land use, both of which have an impact on runoff generation. Flow paths activated under the combination of existing land use and existing climate, but not under the other scenarios represents the highest likelihood of occurrence. If it takes runoff from the combination of future land use AND climate to generate enough runoff to activate a flow path, then the corresponding likelihood of activation is the lowest. The likelihood conditions and scores are summarized in Table 5.1.

Table 5.1: Activation Likelihoods

Likelihood Score	Conditions Scenario (under which flow path is first activated)
3	Flow path active for 1:10-year current climate
2	Flow path active for 1:10-year Year 2040-2070 climate OR Flow path active for 1:100-year current climate
1	Flow path active for 1:100-year Year 2040-2070 climate

The analyses were completed using model results based on existing infrastructure. (In Phase 2, when proposed infrastructure upgrades have been identified and conceptually defined, the risk assessment will be re-run to help validate the recommendations.)

To differentiate between flow paths that conveyed the minimum amount of flow (0.001 m^3/s for at least 30 minutes) and flow paths conveying significantly greater amounts, the likelihood of activation scores for flow paths conveying less than 0.01 m^3/s were reduced by 1 point, to a minimum adjusted score of 1. For example, if a flow path was active during the "10-year storm; current climate" scenario, it received an initial score of 3, but if its peak flow was less than 0.01 m^3/s, the likelihood score was reduced to 2.

5.2.2. Consequence Severity

The consequence severity of activation was based on what infrastructure / assets are located along the active flow path and the various types of consequences that might occur as a result. Consequence severities were assessed based on current zoning, as per Table 5.2:

Table 5.2: Consequence Severity of Activation

Consequence Severity Score	Classification
5	Only triggered with score modifier (multiple risk conditions exist)
4	Buildings in the following actual use[7] are within the flood buffer zone: • Commercial • Industrial and Utility • Non-residential Strata • Multi-family zoning Or critical infrastructure that is within flood buffer zone
3	• Single family buildings that are within flood buffer zone (includes acreage/farms/vineyards) • Flooding on mobile home strata parcel (These parcels typically don't have individual building footprints delineated but spacing between buildings is typically tight, so any flow through it could cause damage)
2	The following actual uses[1] that are within the flood buffer zone: • Private property (but not in proximity to building) • Civic parks and open spaces (including future "Parkland – Conservation")
1	Flow path stays within public road corridors

The consequences score was further modified by considering the priority layer of any impacted road corridors. For example, flow that impacts buildings or critical infrastructure, and additionally impacts a major road, was considered to have a higher consequence then flow which only impacts buildings, or only impacts roads. Additionally, flow across major roads was considered to be a higher consequence then flow across minor roads, which had the lowest base consequence score. The consequence score was increased by 2 for Priority 1 roads, and increased by 1 for Priority 2 roads, up to a maximum score of 5.

5.2.3. Risk Score

The risk score is the product of the Likelihood and Consequence scores, as illustrated in Table 5.3. A risk score of 15 represents the highest risk and a score of 1 the least risk. Note that a score of 3 or 5 represents a "special case" since it is either a high consequence with low likelihood, or high likelihood with a low consequence condition. Flow paths with a risk score of 3 (consequence is 1) or 5 require additional assessment with respect to prioritization.

Table 5.3: Risk Scores

Likelihood \ Consequence of Activation	1	2	3	4	5
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

[7] GIS attribute "actual_u_1"

5.3. Assessed Risks

The assessed risks are displayed as coloured flow paths in Figure 5.1. (Detailed mapping is provided in the Dashboard). A few high-level observations of the mapping include:

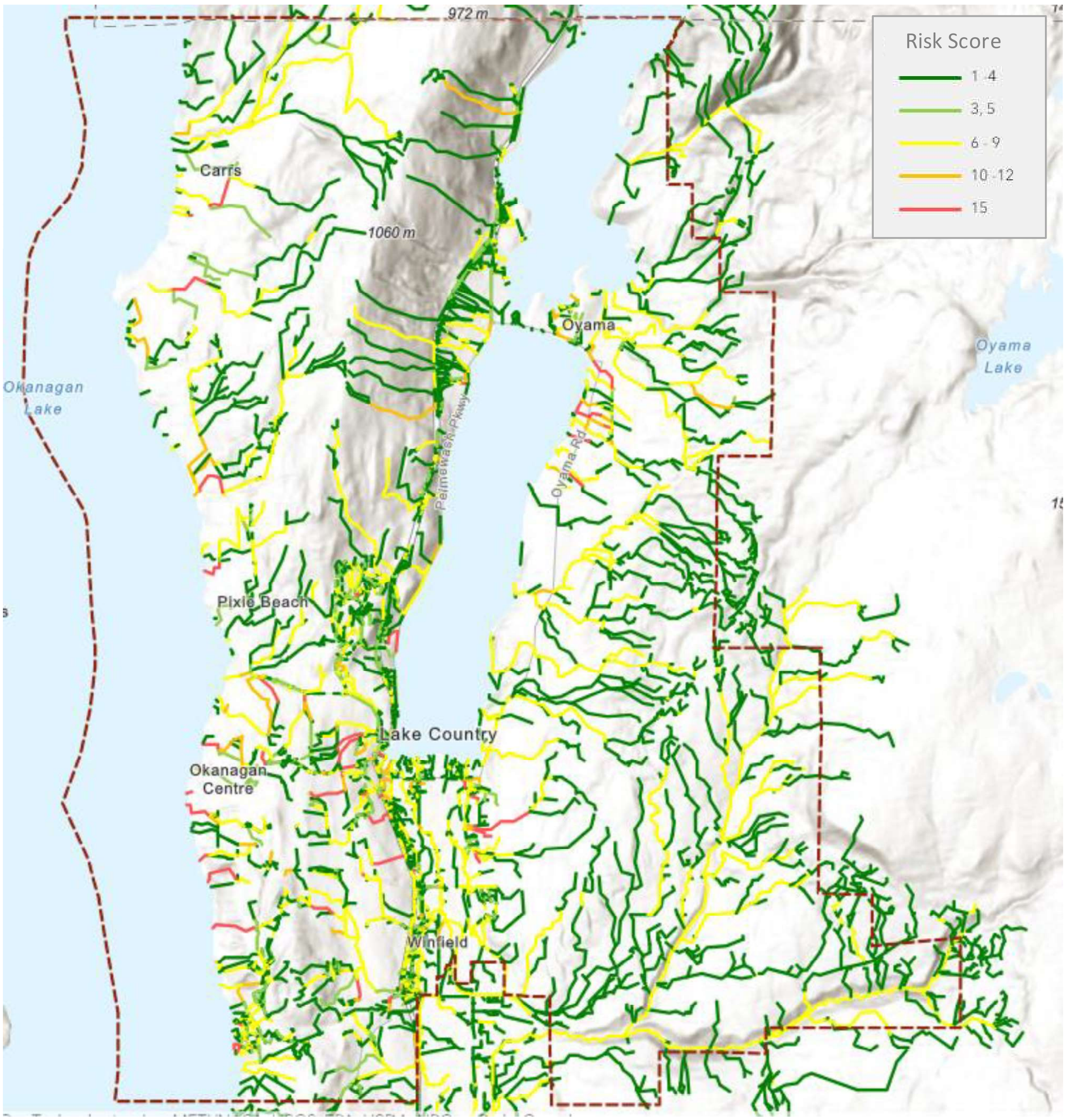
- High risk flow paths (red) are consistently seen where flow is not given a defined path (according to the District's GIS data and LiDAR)
- Woodsdale, Lakestone, and Cadence at the Lakes developments appear to have significant flow approaching the neighborhood minor systems from the undeveloped upstream hillsides. It appears that runoff is prone to flowing between homes in these areas due to insufficient capture and shallow surface flow routes.
- Further confirmation is recommended, whether onsite assessment or discussion with District staff that have observed large storm events in the area.

Table 5.4 summarizes the length of flow paths according to their risk scores. The "red" flow paths represent those most at risk from stormwater runoff. Further assessment and analysis in Phase 2 will determine the cause of the risks and recommend works to reduce them.

Table 5.4: Risk Score Summary

Risk Score	Length (km)
Low (1,2) – Dark Green	415
Special Case (3, 5) – Light Green	351
Moderate (6, 8, 9) – Yellow	64
Moderate-High (10, 12) - Orange	25
High (9) – Red	18
Total	873

Figure 5.1: Risk Assessment (Existing System)



6. PHASE 2 SCOPE (NEXT STEPS)

Section 1.4 introduces four phases of this ISMP - Phases 1 and 2 comprise the planning portion of the project while Phases 3 and 4 require implementation and management actions. The Risk Assessment presented in Section 5 of the current Phase 1 report identifies surface flow paths which, if activated during a rainfall event, represent a risk to the District. Each of these were assessed a risk rating ranging from 1 to 15xx. Flow paths assessed a risk rating of xx and higher are considered "issues" that should be addressed. Those with a risk rating lower than xx are worth knowing about but are considered relatively benign and do not warrant specific effort to address them. The primary objective for Phase 2, therefore, is to develop recommended works to address each of the identified issues. In general, the Phase 2 scope (the "next steps" of the ISMP) consists of the following:

1. Confirm Stormwater Management Strategies. Prior to conducting the bulk of the Phase 2 work, a list of stormwater management strategies should be developed to form the basis for developing capital works and other solutions to address the identified issues. It should include both green and grey infrastructure to convey, control, and treat storm runoff.
2. Confirm Options Selection Criteria. Where multiple options have been identified to address an issue, it will be necessary to select the preferred one. This should be done using a criteria-based approach, which could include effectiveness, resiliency, ease-of-construction, maintenance effort, capital and life-cycle costs, and potentially other considerations. Weightings could also be incorporated to reflect District priorities.
3. Issue Characterization. The Risk Assessment does not identify the cause of an issue, only that there is one and what level of risk it represents to the District. Each issue should be assessed to determine its cause (lack of infrastructure, undersized infrastructure, inadequate maintenance, etc.). The computer model should be used to quantify design flows where applicable.
4. Options Development. Once an issue is understood, options to address would be developed. Most issues are unlikely to warrant multiple options, but where more than one solution appears feasible, they should be identified and considered.
5. Detailed Analysis and Assessment. Where warranted, computer analysis should be conducted to assess the effectiveness of proposed solutions, and in the case of proposed new or upgraded infrastructure, modeling should be used to determine adequate sizing. Since issues within a drainage catchment can be impacted by each other, these relationships should be identified and addressed wholistically.
6. Cost Estimates. To facilitate preferred option selection when multiple options are identified, comparative capital and life-cycle costs should be estimated. These Class D costs should be based on a set of unit costs for standard items, and estimated quantities based on each option's concept.

7. Project Development. Where multiple solution options are identified for an issue, each should be reviewed and considered with the District. This should include an assessment using the weighted selection criteria and corresponding cost estimates. The preferred options would then be organized into distinct projects – either as capital works or operations & maintenance.

   All recommended projects should include the following information:

   - A unique project ID,
   - Existing and mitigated risk levels
   - Implementation priority,
   - A description of the issue(s), including whether the project is recommended to address existing deficiencies, support development, and/or adapt to climate change,
   - A summary of recommended works, cross-referenced to a map showing the same,
   - List of approvals/consultation required from other stakeholders,
   - An implementation trigger and strategy,
   - Existing and future design flows and/or volumes if applicable, and
   - Estimated capital and/or life-cycle costs.

8. Reporting. The ISMP Phase 2 report should include the following Sections:

   - Introduction
   - Stormwater Management Strategies
   - Options Selection Criteria
   - Issues, Options, and Recommended Solutions
   - Projects Summaries
   - General Recommendations
   - References
   - Appendices

   Summary figures and tables should be included, but detailed maps with appended information would be added to the ISMP Dashboard (online interactive maps). The General Recommendations section should address District-wide issues that include, but may not be limited to existing deficiencies mitigation, development servicing, cost recovery, progress tracking, ISMP additions and updates, policy and criteria, stakeholder relationships, future studies, data and information, education and outreach, and operations & maintenance.

A detailed scope of work, including schedule, milestones, and budget should be developed collaboratively with the District to reflect available funds and priorities.

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APPENDICES – TECHNICAL MEMORANDUMS

Appendix A – Data Gap Assessment

MEMORANDUM

URBAN SYSTEMS

DATE	July 27, 2023	FROM	Glen Zachary
TO	File	FILE	1577.0124.01
CC		SUBJECT	**ISMP Data Gap Assessment**

1.0 INTRODUCTION

The District of Lake Country (DLC) and Urban Systems Ltd. (USL) have been working to collect a variety of data over the past years, to summarize all existing stormwater infrastructure in GIS for DLC. This data was now further refined by USL to create a new drainage model of the entire district for the Integrated Rainwater Management Plan. This memorandum documents the sources and quality of the key data used for the ISMP – primarily the drainage infrastructure GIS data.

For modeling purposes, GIS data must include spatial information, such as the location of manholes, stormwater inlets, pipes, channels, and other relevant elements. These features are represented as points, lines, and polygons in GIS. Attribute data for each element is also necessary. This includes information such as conduit cross-section, dimensions, materials, slope, condition, invert elevations, and other hydraulic parameters. To be useful for generating the required hydrologic and hydraulic model, the data must be:

- complete,
- accurate, and
- reflect correct topology.

"Complete" means that all infrastructure in the field is recorded in the GIS – including required attributes. "Accurate" means that the recorded values are correct – including spatial location. "Correct topology" means that infrastructure elements reflect field conditions. For example, pipes that are connected in the field must be represented in the GIS as lines with ends that are snapped to each other at the same location. Ideally, "upstream" and "downstream" ends would also be identified.

This data review is based on the data provided to, or downloaded by, USL as of October 4th, 2022. It is meant as a summary of outstanding tasks before preliminary modeling results are generated in late October.

2.0 KEY DATA SOURCES:

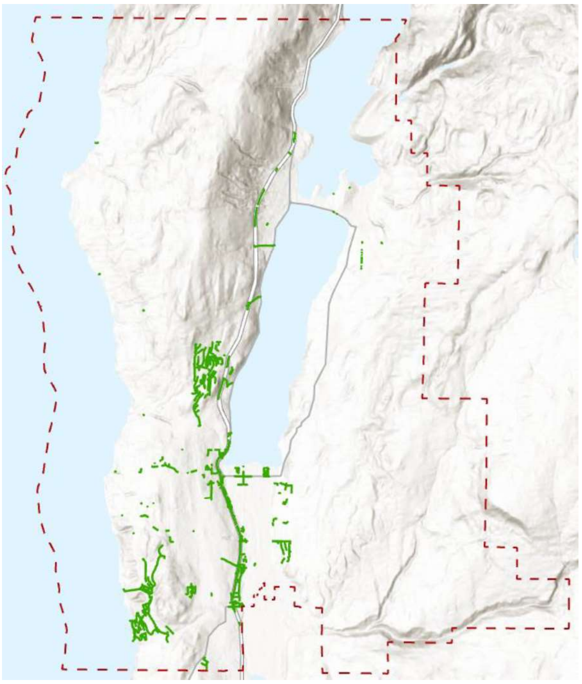
- LiDAR – 2018, resolution = 20cm cell size
- DLC Drainage GIS Data – Inventory is updated periodically as developments and works are completed. These updates were included when feasible.
- Select as-builts – Project scope does not allow a thorough review of as-builts, but they will be reviewed in Phase 2 as necessary.
- Local knowledge – Present and previous operators, as well as USL's experience from previous DLC projects were used to inform problem areas and typical drainage patterns.

3.0 DATA QUALITY ASSESSMENT (DRAINAGE INFRASTRUCTURE)

The following data sets were assessed for completeness, accuracy, and topological correctness. Each are discussed below with respect to key attributes.

3.1 STORM MAINS

There are a total of 1,147 pipe segments in the District GIS. As shown in the following table, the biggest data gap is elevation values at the upstream and downstream inverts. These values are used to determine pipe slope, which has a significant impact on available pipe capacity.



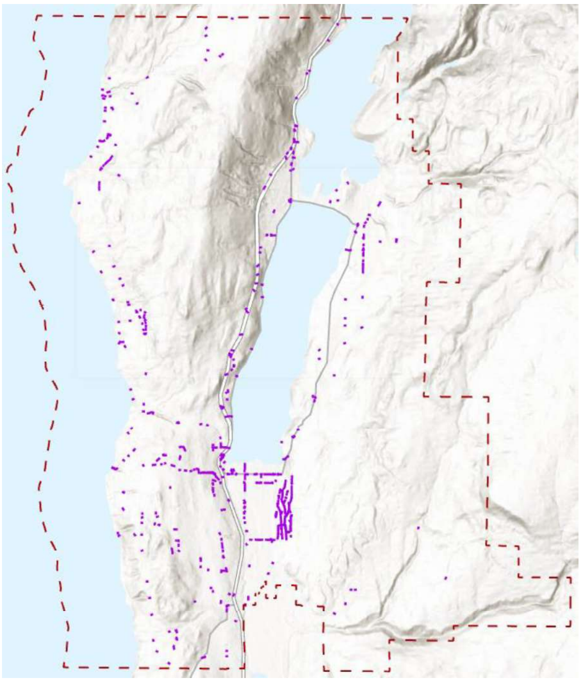
Attribute	% Complete
Diameter	83.7
U/S Invert	0.0
D/S Invert	0.0
Slope	4.8
Length [1]	100.0
Material	82.9
Topologically Connected [2]	92.5

[1] length is based on GIS element length, not on as-built length.

[2] Assumed connected if distance to nearest line is zero.

3.2 CULVERTS

There are a total of 689 culverts in the District GIS. This includes 273 cross-road, 413 driveway, and 3 "utility" culverts. As shown in the following table, the dataset is missing a significant number of diameters and offers no elevation data. While length is provided, note that the GIS lines are "representational" only – that is, they represent the existence of a culvert, but do not accurately reflect field length or even field location. Lines were often drawn at other than low points on a road and/or did not always extend fully across a road.

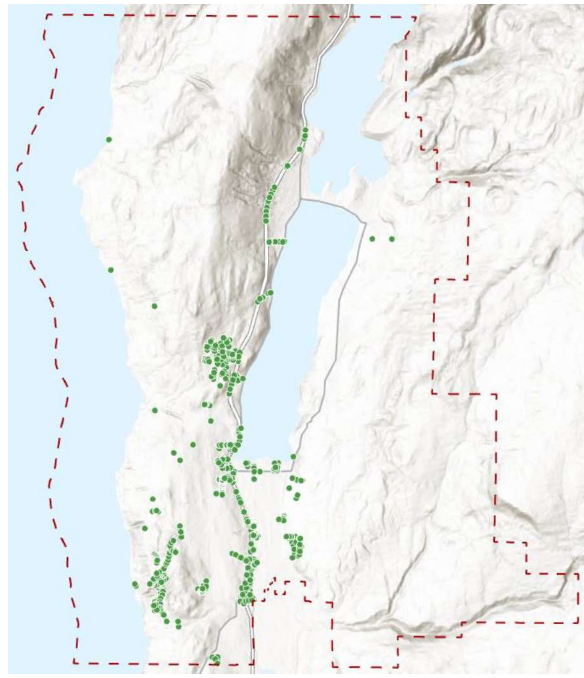


Attribute	% Complete
Diameter	34.3
U/S Invert	0.0
D/S Invert	0.0
Slope	0.0
Length (GIS, not field)	100.0
Material	97.7

3.3 MANHOLES

The District GIS contains 566 manholes. Other than spatial location, this data set offers little else. It is assumed that all manholes are standard 1050 mm diameter concrete manholes with iron lids. The following table summarizes the completeness of key attributes.

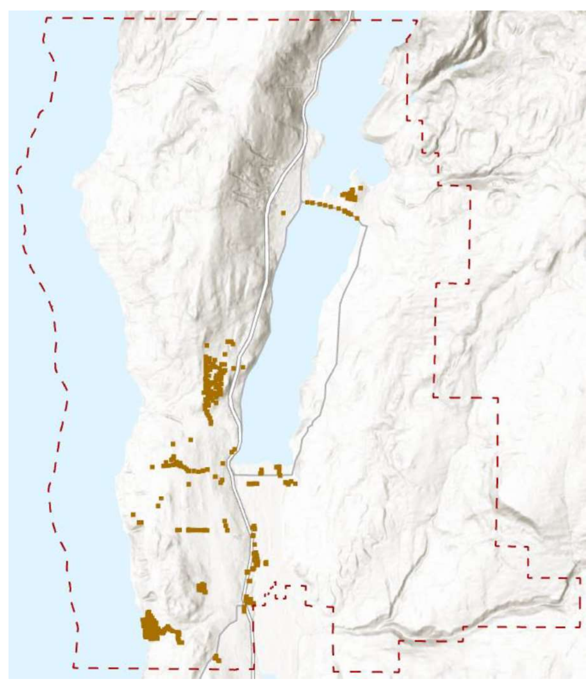
Attribute	% Complete
Invert (Sump) Elevation	8.7
Lid Elevation	0.0
MH Diameter	0.0
Material	0.2



3.4 DRYWELLS

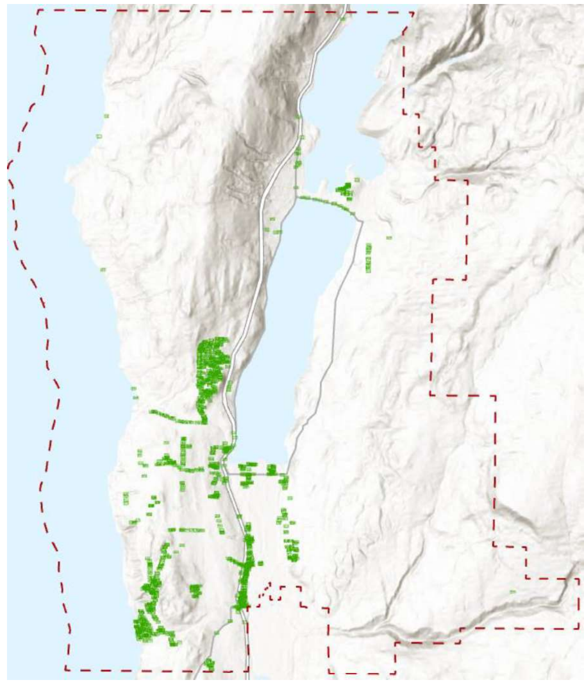
The District GIS contains 420 drywells. Many of these function as manholes – connecting two or more storm sewer reaches. However, some are also stand-alone, with either a connecting catch basin, or a grated lid. The following table summarizes the completeness of key attributes.

Attribute	% Complete
Depth	0.2
Invert (Sump) Elevation	0.0
Lid Elevation	0.0
Diameter	0.0



3.5 CATCH BASINS

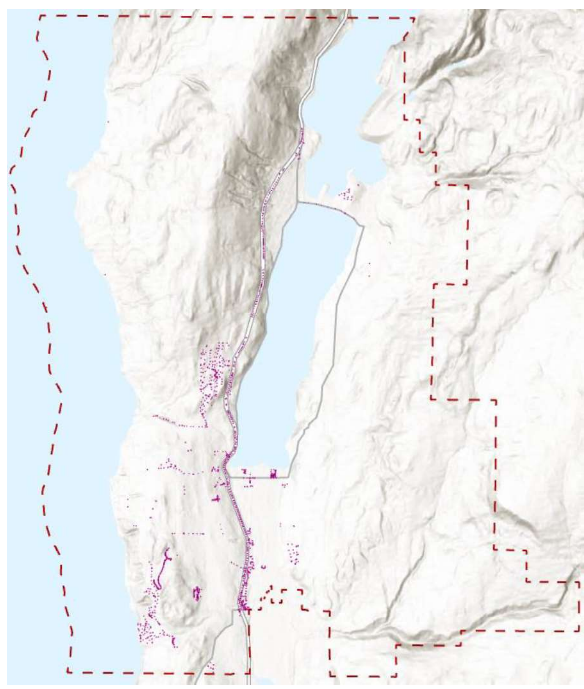
A total of 1,246 catch basins have been recorded. Other than their spatial location and general type (top inlet, side inlet, double inlet) little attribute data is available. The following table summarizes the completeness of key attributes.



Attribute	% Complete
CB Type	100.0
Top-of-Grate Elevation	0.0
Sump Elevation	2.2

3.6 DRAINAGE LEADS

With a total count of 1,720, there are significantly more drainage leads than catch basins. This is partially because the data set includes 67 roof drains, 250 service laterals, and 24 unidentified leads. However, there are still more "catch basin" leads than recorded catch basins, so the topology may have some issues. The following table summarizes the completeness of key attributes.



Attribute	% Complete
Type	98.6
Diameter	70.0
U/S Invert	0.0
D/S Invert	0.0
Length (GIS, not field)	100.0
Slope	0.5
Material	69.3

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4.0 ASSUMPTIONS AND METHODS

Given the large number of missing attributes – especially pipe and manhole invert elevations - it was necessary to fill the gaps with assumed values. (Without these values, it was impossible to develop the PCSWMM model.) This section summarizes the assumptions and methods used to "fill the gaps". While assumed attribute values increase the uncertainty corresponding to modeled scenario results, the analyses still provide insights into potential risks within the drainage systems. Assumed values were flagged as such in the GIS, and are as follows:

- Rim elevations of manholes, drywells, and catch basins were approximated from the LiDAR-based surface.
- Pipe and culvert inverts were estimated using:
    - Culverts or pipe daylights: invert estimated based on the lowest grade within 5 m laterally from the end of the pipe (to account for observed misalignment between ditches visible in LiDAR and location of the culvert or pipe on GIS).
    - Pipe inverts: prefer interpolation between known inverts; if no inverts are available, follow the ground (LiDAR) surface from the downstream end. If this results in a negative slope, assume a minimum slope of 0.1%.
- Manhole depth (bottom invert) values were determined based on lowest connecting pipe invert.
- Pipe and culvert diameters were assumed from nearby pipe/culvert infrastructure and/or ditch sizes. If the infrastructure proves to be at high risk of failure, field verification will likely be conducted in Phase 2.
- Culverts missing on major surface drainage routes that cross public roads were assumed to exist. These locations were identified during preliminary dual drainage modeling (unusual model surface ponding results). Additionally, locations/lengths of culverts in the original GIS layer which were obviously inaccurate when compared to the LiDAR surface were "corrected" using the LiDAR-based surface.
- Assets obviously missing from the GIS, or which were included on incorrect GIS layers, were added / corrected. For example, catch basins were missing at the end of some "leads", and the terms "culverts/mains/leads" were often used interchangeably. These edits should, however, be field verified.
- Drywells were assumed to have a grated cover if:
    - the nearest catch basin is over 25m away,
    - there are other manholes/drywells closer to the same catch basin, and/or
    - a Google Earth check clearly shows that this is the case.
- The GIS does not currently include an "outfalls" layer. (PCSWMM models outfalls differently than other end-of-conduit elements.) Therefore, the downstream end of the last storm sewer of each drainage system was manually flagged as an outfall. Boundary conditions (freefall, water level) were assumed based on LiDAR and design flood levels (see technical memo on Water Levels).
- Drainage ditch cross sections were approximated from the LiDAR surface where feasible. Where insufficient resolution was available, the following standard cross sections were assumed:
    - For minor ditches, a 5 m top width and 0.5 m deep triangular section.

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- For major ditches, a trapezoidal cross-section with side slopes of 5:1, depth of 0.5 m, and a bottom width based on averaging 0.25 m flow depth in the 100 year storm (to provide flexibility for the model to vary HGL throughout the storm)

5.0 CLOSING

This technical memorandum was prepared for documentation and information purposes only. It was prepared and reviewed by the following Urban Systems staff.

Glen Zachary, P.Eng.
Senior Water Resources Engineer

Taylor Swailes, P.Eng.
Water Resources Engineer (Reviewer)

/MvH

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Appendix B – Hydrogeological Report (Waterline)

HYDROGEOLOGICAL ASSESSMENT FOR THE DISTRICT OF LAKE COUNTRY INTEGRATED STORMWATER MANAGEMENT PLAN

Submitted To:

LAKE COUNTRY

Life. The Okanagan Way.

District of Lake Country
10150 Bottom Wood Lake Road
Lake Country, BC
V4V 2M1

Submitted By:

Waterline

Waterline Resources Inc.
Nanaimo, British Columbia
December 20, 2022
3536-22-001

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1.0 INTRODUCTION

The District of Lake Country is located between the cities of Vernon to the north and Kelowna, British Columbia to the south (Figure 1). The district encompasses several municipalities including Carr's Landing, Okanagan Center, Oyama and Winfield. The Council of the District of Lake Country (the Client) is developing an Integrated Stormwater Management Plan (ISMP) to support sustainable development that considers and mitigates impacts to the receiving environment from ongoing and potentially increasing stormwater runoff.

To assist the Client with managing stormwater and designing appropriate stormwater infrastructure, Urban Systems Ltd. (USL) is creating a digital drainage model using the Personal Computer Stormwater Management Model (PCSWMM) software program. An assessment of the watershed characteristics, current land use, geological conditions, and groundwater conditions for the District of Lake Country (the Study Area), defining the framework for the hydrogeological conceptual model, is required for calibrating PCSWMM, and assessing suitable areas for subsurface stormwater infiltration.

2.0 OBJECTIVES AND SCOPE OF WORK

On behalf of the Client, USL retained Waterline Resources Inc. (Waterline) to review the relevant hydrogeological data for the Study Area to calibrate the PCSWMM drainage model. To determine these parameters and develop a conceptual understanding of the subsurface stormwater infiltration potential across the Study Area, Waterline's scope of work included the following tasks:

- **Task 1 –** Reviewing and compiling public and site-specific data regarding land use, watersheds and topography, surficial materials (distribution, thickness, and hydraulic conductivity), and groundwater conditions.
- **Task 2 –** Describing the methodology used for the assessment of subsurface stormwater infiltration potential; and
- **Task 3** - Generating relevant data maps for the Study Area to assess the subsurface stormwater infiltration potential. These map layers will be delivered to USL in electronic formats to be utilized in PCSWMM.

3.0 METHODOLOGY

3.1 Desktop Review

To assess hydrogeological conditions across the Study Area, publicly available data was reviewed using Waterline's proprietary Environmental Web Services (EWS) geodatabase system. Data inputs for the Study Area were also obtained from the Client's Open Data Catalogue. This data was reviewed in addition to other technical reports provided by the Client. A list of the public and Client specific data sets used in this assessment is provided in Table 1.

Table 1: List of Data Sources used for the Hydrogeological Assessment

Relevant Data Layers	Reference
Public Data	
Watershed Data	BC FLNRORD, 2021
Aquifer Mapping and Water Wells	ENV,2022
Surficial Material Mapping	ENV, 2013 & ENV, 1986
Quaternary Stratigraphy and Geomorphology of the Central Okanagan Valley. British Columbia	Thomson, 2010
Late Glacial History and Surficial Deposits of the Okanagan Valley, British Columbia	Government of BC, 1962
Lake Country Open Data Catalogue	
Topography – 50 cm Lidar Data	Provided to Waterline by USL
Land Use Data	
Cadastral Data – Land Parcel Data	
Reports Prepared for the District of Lake Country	
Drainage Study, Tyndall Road – Okanagan Centre Hydrogeological Investigation	Terratech Western Profile Consultants Ltd. (Terratech), 1994
2001 Oyama Road & Williams Hill Master Drainage Plan and Geotechnical Investigation	Urban Systems Ltd. (USL), 2001
Lake Country Specific Data Sets	
District of Lake Country SWM Issues	Provided to Waterline by USL

3.2 Hydraulic Conductivity Testing and Analysis

Sieve testing results reviewed from consultant reports (USL, 2001) were used to determine a field saturated hydraulic conductivity (K_{fs}) for the surficial material collected from a discrete depth interval and location. The K_{fs} was calculated using the Hazen equation (Bear, 1972) which uses the grain size for the 90% passing or 10% retained (D_{10}). The Hazen method is best suited for fine to coarse sands and therefore is most reliable if the sampled grain size ranges between 0.1 mm and 3.0 mm. If there is greater than 10% of the sample that is outside of this range, the K_{fs} estimate using this method becomes more unreliable.

Where applicable, the K_{fs} value from the sieve analysis for the different surficial material was compared with a literature value. As the literature values are typically provided as a saturated hydraulic conductivity (K_{sat}), they were converted to K_{fs} by halving the value (ASTM, 2016). K_{fs} is typically lower than K_{sat} due to the entrapment of air between the pore spaces during the soil saturation process. This entrapped air slows down water movement, which is faster in a fully saturated media. K_{fs} values are presented in this report as they are needed input parameters for the PCSWMM calibration.

4.0 PHYSICAL FRAMEWORK

In accordance with the Ministry of Environment (ENV) best practices (ENV, 2014), stormwater infiltration is constrained by the following key parameters:

- **Land Use and Land Cover Type -** The infiltration capacity of surficial sediments can be impacted by current and future land use practices. Stormwater can infiltrate directly into the subsurface where surficial sediments are directly exposed at the surface with lesser infiltration capacity in vegetated areas. Engineered impermeable surfaces (roads, roofs, paved parking lots, etc.,) provide no infiltration potential and increase runoff.

- **Watershed and Topography Characteristics -** Sloped terrain with high infiltration potential at the surface tend to absorb less water than flatter terrain with similar land cover. Land slope can be categorized into three representative gradients for analysis of the stormwater infiltration potential (Aspect Consulting, 2017):
    - Low gradient less than 8%;
    - Moderate gradient between 8 to 20%; and
    - High gradient greater than 20%.

- **Surficial Geology Characteristics –** Surficial sediments with a high hydraulic conductivity will allow for higher rates of stormwater infiltration whereas low hydraulic conductivity surficial sediments and competent bedrock will promote surface water runoff. Identifying highly permeable sediments for implementation of infiltrative features (e.g., dry wells, bioswales, rain gardens, etc.) is a necessary component to stormwater management planning.

- **Groundwater Conditions -** Dependent on the surficial sediment distribution, a minimum unsaturated zone thickness is required for safe infiltration of stormwater to protect against groundwater contamination. Areas near surface water features are prone to having high groundwater tables and are not suitable for stormwater infiltration. Based on a modification of the best practices listed by ENV (2014), three unsaturated zone thickness are considered for the determination of the stormwater infiltration potential:
    - Less than 1.0 m;
    - Between 1.0 to 3.0 m; and
    - Greater than 3.0 m.

The following subsections outline the physical framework parameters and the technical evaluation of the data used to assess the hydrogeological conditions.

4.1 Land Use and Land Cover Type

The Study Area has a variety of land use designations (Figure 1), with both developed and undeveloped lands. The land use designations, corresponding land use area, and percentage of the overall Study Area, are summarized below in Table 2. It should be noted that in the eastern and southern portions of the Study Area, there are areas with no land use designations, which are outside the district's zoning.

Table 2: Breakdown of Land Use Designations and Associated Area

Land Use Designation	Area (km^2)	Percentage of Study Area
Agricultural	44.55	26%
Parkland	7.68	4%
Residential*	42.63	25%
Urban Residential	8.14	5%
Industrial	2.37	1%
Institutional	0.84	<1%
Commercial**	0.94	<1%
Water (Lakes)	23.12	13%
Roads/Paved Surfaces	6.21	4%
No Land Use Defined	36.1	21%
Total	***172.54***	***100%***

Notes: * Indicates all residential types (rural and high density) were combined; ** indicates all commercial types (tourist, mixed, highway and service) were combined

In addition to obvious impermeable roads and paved surfaces, it is assumed that all other land use designations have some percentage of impermeable surfaces such as building roofs, which are expected to increase runoff to the stormwater collection systems. Urban residential, industrial, and commercial areas are expected to have the highest percentage of impermeable surfaces, while agricultural and parkland areas are expected to be mostly vegetated with the least amount of impermeable surface.

4.2 Watershed and Topography Characteristics

The Study Area is 172.54 km^2 and encompasses eight watersheds, including Anderson Brook, Winfield Creek, Vernon Creek, Horse Creek, Clark Creek, Ribbleworth Creek, Hayton Creek and Oyama Creek (Figure 2). The watersheds have varying catchment sizes, draining areas of higher topography, discharging into Okanagan, Kalamalka, Wood and/or Ellison lakes. The topography is undulating, with the elevation ranging from 400 metres above sea level (masl) near the lake shores to greater than to 1450 masl along the western facing slopes in the eastern part of the Study Area. The land slope across the Study Area varies from less than 1% (0.5 degrees) to approximately 110% (48 degrees).

4.3 Surficial Geology

A surficial geological map of the Study Area is included as Figure 3. The delineation of dominant surficial sediments and bedrock outcrops were based on a combination of:

- Remote sensing interpretation from LiDAR data provided to Waterline by USL,
- Observed lithologies from driller's logs for registered groundwater wells compiled in the provincial database (GWELLS; ENV, 2022),
- Observed grain size data summarized from a technical report (Terratech, 1994; Table A1 of Appendix A), and
- Regional mapping completed by the BC Ministry of Environment (ENV,1986 & ENV, 2013).

To further understand the thicknesses of the mapped surficial material across the Study Area, descriptions of quaternary stratigraphy and geomorphology in the central Okanagan valley were referenced from published papers (Government of BC, 1962 and Thomson, 2010). A summary of the surficial material, thickness, and depositional environments is included in Table 3.

Table 3: Description of the Surficial and Bedrock Geology for the Study Area

Depositional Environment	Description
Organic	Small (<0.1 km^2), isolated pockets of Holocene peatlands occurring in depressional areas where underlying material is fine to medium textured. Most of the Organic deposits occur on the alluvial/glaciolacustrine plain connecting Kalamalka and Wood Lakes.
Bedrock Outcrop	Bedrock at ground surface, typically complexed with thin till veneers and thin in situ weathered bedrock above about 450 masl. Rock types include volcanic rocks (basalt), metamorphic rocks (orthogneiss) and intrusive rocks (granodiorite)
Lacustrine-Glaciolacustrine	Spatially varied thickness (veneer [<100 cm] or blanket [>100 cm]) overlying primarily till and bedrock. Typically, fine to medium textured (silt clay loam to silt loam), imperfectly to moderately well drained. Occurs at elevations below about 500 masl along margins of Wood Lake, Kalamalka Lake, and Ellison Lake, including on the saddle between Wood Lake and Okanagan Lake. Occurs beneath alluvial veneers on fluvial plains connecting Kalamalka Lake with Wood Lake, and Wood Lake with Ellison Lake.
Till (Morainal)	Spatially varied thickness (thin veneer [<50 cm], veneer, or blanket) overlying bedrock, often competent with very thin in-situ (<20 cm) physically weathered bedrock at crests of major ridgelines. Typically, medium to moderately coarse (gravelly silt loam to gravelly sandy loam), moderately well to well-drained. Occurs as thin sequences draped over bedrock at elevations above about 550 masl, with a thickness generally declining with increasing elevation. Additionally, a local terminal moraine (complexed with ice-contact glaciofluvial meltwater deposits) occurs on the southeast portion of Kalamalka Lake, downslope of the Cougar Canyon Ecological Reserve and Kalamalka Lake Park at an elevation between 400 and 500 masl.
Colluvial	Spatially varied thickness (thin veneer, veneer, or blanket) overlying till, glaciolacustrine, ice-contact glaciofluvial and/or bedrock. Typically, medium to coarse (silt loam to loamy gravelly sand), well to rapidly drained. Associated with short, steep slopes including relic, dormant, and active landslip, landslide, and erosional features.
Eolian	Spatially varied thickness (veneer or blanket) overlying till, glaciolacustrine, ice-contact glaciofluvial and/or bedrock. Typically, coarse textured (loamy sand to fine sand), well to rapidly drained. Occurs primarily on the southeast quadrant of the Study Area draped over moderately sloping till deposits and bedrock with northwest and west aspects.
Alluvial	Spatially varied thickness (veneer or blanket) overlying primarily glaciolacustrine and, to a lesser extent, till. Typically, medium to coarse textured (loam to loamy gravelly sand), imperfectly to well drained. Found on gently sloping plains around Wood Lake and along incised creek channels.
Glaciofluvial	Spatially varied thickness (veneer or blanket) overlying primarily till and, to a lesser extent, glaciolacustrine and bedrock. Typically, coarse textured (loamy gravelly sand to gravelly sand), well to rapidly drained, associated with the primary incised creek valleys/channels and in transitionary areas between the glaciolacustrine deposits on the lower valley/ toe slopes and the till deposits at higher elevations. Glaciofluvial deposits occur at elevations up to about 1,000 masl, with the majority occurring as relic outwash terraces between about 500 and 650 masl associated with the retreat of the Okanagan Glacier.

4.4 Hydraulic Conductivities and Infiltration Capacity for Surficial Materials

Based on the geological and soil descriptions for surficial material across the Study Area, a maximum and minimum K_{fs} value was assigned to each depositional environment from the literature values listed in the Stormwater Source Control Design Guidelines for the Greater Vancouver Sewerage and Drainage District (GVSDD) Stormwater Source Control Design Guidelines (2012) and from the sieve analysis (USL, 2001) within the Study Area; summarized in Table B1 of Appendix B.

Using the assigned K_{fs} values for each depositional environment and the approximate thickness of the material, a low to high surficial material infiltration capacity was subsequently assigned by Waterline; listed in Table 4 and displayed on Figure 4.

Table 4: Surficial Materials Infiltration Capacity Designation

Depositional Environment	K_{fs} from Testing (m/s)	Assigned K_{fs} from Literature Values (m/s)		Surficial Material Infiltration Capacity	
		Maximum	Minimum		
Organic	-	n/a	n/a	*Low*	
Bedrock Outcrop	-				
Lacustrine-Glaciolacustrine (veneer or blanket)	-	9.4×10^{-7}	2.1×10^{-7}	*Low*	
Till (veneer or blanket)	-	8.5×10^{-6}	9.4×10^{-7}	*Low*	*Moderate*
Colluvial (veneer or blanket)	-				
Eolian (veneer or blanket)	2.5×10^{-4}	2.9×10^{-5}	8.5×10^{-6}	*Moderate*	*High*
Alluvial (veneer or blanket)	-	2.9×10^{-5}	1.8×10^{-6}	*Moderate*	*High*
Glaciofluvial (veneer or blanket)	-	2.9×10^{-5}	3.6×10^{-6}	*Moderate*	*High*

Notes: K_{fs} means field saturated hydraulic conductivity; m/s means metres per second; n/a means not assigned

Generally, granular sediments composed of predominantly sand/gravel, and some silts are highly transmissive and provide high infiltration capacity. These zones within the Study Area were assigned a high surficial material infiltration capacity. Conversely, cohesive sediments with some silt but that are predominantly clay or have competent bedrock sub-cropping near surface tend to be less transmissive and can limit infiltration. These areas were assigned a low surficial material infiltration capacity. Competent bedrock outcrops, organic matter and impermeable surfaces were also assigned a low surficial material infiltration capacity. A moderate surficial material infiltration capacity was assigned where both cohesive sediments and granular sediments were mapped within the same surficial geological unit.

Furthermore, if the surficial material was deposited as a thin veneer (<1.0 m in thickness), the infiltration capacity was reduced in comparison to if the surficial material was a blanket (>1.0 m in thickness). If the surficial material was already assigned a low infiltration capacity, the thickness did not impact the rating as is the case for lacustrine-glaciolacustrine material.

4.5 Hydraulic Conductivity Safety Factor

Waterline recognizes that there is some uncertainty associated with the assignment of K_{fs} values for the different surficial materials. As these hydraulic conductivity values are being used for assessment of surficial material infiltration potential and are being utilized in the PCSWMM modelling, a safety factor should be applied to the range of values provided. A risk matrix was developed to assess each component that contributed to the K_{fs} values, summarised in Table 5.

Table 5: Safety Factor Assessment for the Field Saturated Hydraulic Conductivity

Input Parameters	Assigned Weight (w)	Factor Value (v)	Product (p)
			P = w x v
Assessment methods (site specific testing)	0.50	2	1
Soil texture	0.25	2	0.5
Soil variability	0.25	2	0.5
Safety Factor			**2**

Based on limited field testing, and the use of regional scale mapping of surficial material without ground truthing, a safety factor of two should be applied to all K_{fs} values for feasibility analysis. Additional safety factor from the PCSWMM model should be stated by USL.

4.6 Groundwater Conditions

4.6.1 Mapped Aquifers

Within the Study Area there are several unconsolidated sand and gravel aquifers (both confined and unconfined; Figure 5) mapped above bedrock. The mapped aquifer boundaries are based on the depositional environment, in combination with lithology descriptions from registered groundwater well data (ENV, 2022); aquifer characteristics are summarized in Table 6.

Table 6: Description of the Unconsolidated Aquifers within the Study Area

Aquifer Name	Ellison Lake to Wood Lake (Aquifer #344)	Oyama (Aquifer #345)	Oyama Creek (Aquifer #1238)	Wood Lake to south end of Kalamalka Lake (Aquifer #1239)
Material Type	Sand and Gravel			
Aquifer Type	Confined - Glacial		Unconfined - Alluvial fan	
Size (km^2)	8.7	6.2	0.5	1.9
Number of Groundwater Wells with reported water levels	24	52	2	7
Recharge	From Elliston Lake and Vernon Creek.	From infiltration and connection with Wood Lake.	From runoff, infiltration, and connection to surface water.	From runoff, infiltration, connection to surface water.
Comment	Confining material has been mapped as lacustrine deposits.	Confining material has been mapped as lacustrine deposits.	Composed mostly coarse-grained material. Hydraulic connection with creek.	Composed mostly coarse-grained material but thin layers of fine-grained material exist.

Notable conclusions from this information for the discussion of stormwater infiltration potential include:

- There are 85 groundwater wells with reported water level data associated with the unconsolidated aquifers (Figure 5). A list of the groundwater wells reviewed as part of this assessment are presented in Table C1 of Appendix C.
- Underlying the Study Area are four mapped unconsolidated aquifers, of which two aquifers are unconfined (Aquifer 1238 and Aquifer 1239; Table 5) and two aquifers are confined (Aquifer 344 and 345; Table 5).
- As the confined aquifers (Aquifer 344 and Aquifer 345; Table 5) are disconnected from ground surface by a lower permeable unit, predominantly composed of lacustrine-glaciolacustrine material, the groundwater table in these aquifers is not directly connected with ground surface. As such there is no unsaturated zone for subsurface stormwater infiltration. It is well documented that Aquifer 344 and Aquifer 345 have flowing artesian conditions and as such the aquifers' piezometric surfaces are at higher elevations than the ground level.
- The two unconfined aquifer make up an area of 2.4 km^2, which is equivalent to 1.4 % of the overall Study Area. These areas have the best potential for subsurface infiltration if the unsaturated zone thickness allows for proper treatment of infiltrated stormwater (ENV, 2014).
- Using groundwater level data from the nine wells associated with Aquifer 1238 and Aquifer 1239 (Table C1) and the lake shore elevation of Kalamalka and Wood Lake as an assumed zero datum for the groundwater depth, maps of the depth to groundwater or the unsaturated zone thickness were created (Figure 5).
  - Aquifer 1238 has an unsaturated zone that is less than 1 m near Kalamalka Lake, extending part way up the apron of the alluvial fan; the unsaturated zone thickness increases with topographic elevation. It is assumed that the thickness of the unsaturated zone is greater 3 m near the apex of the fan (mouth of the source valley).
  - For Aquifer 1239, there is a narrow strip along Wood and Kalamalka Lakes where the unsaturated zone thickness is less than 1 m, transitioning abruptly to greater than 3 m. This is because Aquifer 1239, consisting of alluvial fan material, was deposited over a short distance below an area of steep topography.

4.6.2 Areas Outside of the Mapped Aquifers

For areas outside of the mapped unconfined Aquifers 1238 and 1239, the surficial material drainage designation (rapid to poorly draining) from the Agriculture Canada, National Soil Pedon Database (2021) was referenced to help assess groundwater conditions (Figure 5). Where permeable sand and gravel sediments have accumulated (glaciofluvial and alluvial blankets; see Figure 3), these areas have the potential for storing and transmitting groundwater and could act as suitable locations for subsurface stormwater infiltration. The depth to groundwater, and thus the unsaturated zone thickness, in these locations will vary, controlled by surface topography and connection to surface water. One area that has rapid draining surficial material, suggesting there is a thick unsaturated zone, is the Vernon Creek alluvial fan (Figure 3).

4.6.3 Spring Data for the Study Area

The Client has mapped the location of springs within Study Area. These locations are in addition or synonymous with licensed spring locations registered in the provincial database (ENV, 2022; Figure 5). The springs are the result of topography intersecting the shallow groundwater table in the unconsolidated sediments above bedrock, generally near surface water features such as creeks. Waterline does not expect that the springs originate from the fractured bedrock aquifers (Aquifer 471, 1021 and 1022; ENV, 2022; Figure 5), as the mean depth to groundwater in these aquifers is 12 metres below ground level. This is based on a review of 66 registered water well records with groundwater level data (Table C2; Appendix C).

Given that the locations of the springs are mapped near surface water features and in areas of steep topography where surficial sediments are thin, these areas should be avoided for any future subsurface infiltration.

5.0 SUBSURFACE STORMWATER INFILTRATION POTENTIAL

Determining the subsurface stormwater infiltration potential across the Study Area was a two-step process. First, the surficial material infiltration capacity and the unsaturated zone thickness were assessed to rank areas of low, medium, and high infiltration potential (decision matrix included as Table 7). Where there are mapped impermeable surfaces, the stormwater infiltration potential was considered low.

Table 7: Subsurface Stormwater Infiltration Potential Decision Matrix – Step 1

		Surficial Material Infiltration Capacity [a]		
		Low	**Moderate**	**High**
Unsaturated Zone Thickness	**<1 m**	Low	Low	Low
	1 to 3 m	Low	Low	Moderate
	>3 m	Low	Moderate	High

Notes: [a] In addition to the surficial material infiltration capacity, impermeable surfaces (i.e., paved surfaces and buildings) are considered to have low infiltration capacity

As a final step in assessing the subsurface stormwater infiltration potential, the land slope percentage was considered with the stormwater infiltration potential from step 1. The decision matrix for step 2 is included in Table 8.

Table 8: Subsurface Stormwater Infiltration Potential Decision Matrix – Step 2

		Step 1 – Stormwater Infiltration Potential Results [a]		
		Low	Moderate	High
Topography (% Slope)	<8	Low	Moderate	High
	8 to 20	Low	Moderate	Moderate
	>20	Low	Low	Moderate

Notes: [a] The Step 1 – Stormwater Infiltration Potential Results of low to high are evaluated based on surficial material infiltration capacity and the estimated unsaturated zone thickness.

The results of the two-step process for assessing the subsurface stormwater infiltration potential across for the Study Area, indicate:

- Although there are many areas where the surficial material infiltration capacity has a high or moderate rating (Figure 4), the thin unsaturated zone and or steep topography have reduced the subsurface stormwater infiltration potential rating, most noticeable at higher elevations within the Study Area (Figure 6).
- A moderate subsurface stormwater infiltration potential rating was assigned for Aquifer 1239 due to the steep topography in the area (8-20%; Figure 2).
- There is high confidence that Aquifer 1238 has a high stormwater infiltration potential slightly upgradient of Kalamalka Lake (Figure 6).
- Determination of the unsaturated zone thickness for the areas of Anderson Brook, the west facing slopes of Okanagan Center, the Vernon Creek alluvial fan and the area downslope of the Cougar Canyon Ecological Reserve and Kalamalka Lake Park is required to confirm the high stormwater infiltration potential assigned for these areas (Figure 6).

6.0 DATA GAPS AND STUDY LIMITATIONS

The enclosed study provides general surficial material descriptions and boundaries. Based on Waterline's work, the Study Area appears to have an abundance of surficial material with moderate to high infiltrative capacity. However, data is lacking to assess the water table depth or unsaturated zone thickness. Therefore, there is some uncertainty with the stormwater infiltration potential assigned to some of the "high" rated areas near Anderson Brook, the west facing slopes of Okanagan Center, the Vernon Creek alluvial fan and the area downslope of the Cougar Canyon Ecological Reserve.

In addition, there was limited testing results available from the consultant reports to further assess/confirm the K_{fs} vales for the surficial materials across the Study Area. Only two sieve analyses were performed on soil samples collected near Oyama Road. As such, the assigned K_{fs} ranges should be considered as estimates only and are not suitable for making final development planning, design, or construction decisions.

7.0 CONCLUSION AND RECOMMENDATIONS

In conclusion, although there appears to be an abundance of surficial material with moderate to high infiltrative capacity in the Study Area, there were limited areas where a high subsurface stormwater infiltration potential could be assigned with confidence. This is exacerbated by the fact that there are only two mapped unconfined aquifers, both with small footprints, having useful groundwater level data to properly assess the unsaturated zone thickness. Where permeable sand and gravel sediments (glaciofluvial and alluvial blankets) have accumulated outside of these aquifer boundaries, data is lacking to properly assess the thickness of the unsaturated zone, reducing the confidence in the subsurface stormwater infiltration potential for these areas.

To provide more confidence in assessing the unsaturated zone thickness and subsequently the subsurface stormwater infiltration potential, installation and instrumentation of groundwater monitoring wells is recommended. Monitoring well locations should be chosen where subsurface stormwater infiltration features (e.g., dry wells, bioswales, rain gardens, etc.) are being proposed by USL. Installation of the monitoring wells will also have the added benefit of:

1. Further delineating of surficial materials (their extent and thickness). As per the best practices for protection of groundwater from underground stormwater infiltration (ENV, 2014), further investigation of the soil characteristics is required to determine the minimum unsaturated zone thickness for proper treatment of infiltrated stormwater; and
2. Further assessing the surficial material K_{fs} through field testing.

If the Client has percolation test results from septic field designs submitted as part of development permit approval (private data), this information could also be integrated into the PCSWMM model for future detailed analysis of field saturated hydraulic conductivity.

8.0 CERTIFICATION

This document was prepared under the direction of a professional geoscientist registered in the Province of British Columbia.

Waterline Resources Inc. trusts that the information provided in this document is sufficient for your requirements. Should you have any questions or concerns, please do not hesitate to contact the undersigned.

Respectfully submitted,

Waterline Resources Inc.
EGBC Permit No. 1000669

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Simon Wing, P. Geo. (BC)
Intermediate Hydrogeologist

Reviewed By

Jan Michaelian, P.Geo. (BC)
Principal Hydrogeologist

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10.0 LIMITATIONS AND USE

The information presented in this document was compiled exclusively for Urban Systems Ltd. and the District of Lake Country (the Client) by Waterline Resources Inc. (Waterline). This work was completed in accordance with the scope of work for this project that was agreed between Waterline and the Client. Waterline exercised reasonable skill, care, and diligence to assess the information acquired during the preparation of this document but makes no guarantees or warranties as to the accuracy or completeness of this information. The information contained in this document is based upon, and limited by, the circumstances and conditions acknowledged herein, and upon information available at the time of the preparation of this document. Any information provided by others is believed to be accurate but cannot be guaranteed. No other warranty, expressed or implied, is made as to the professional services provided to the Client.

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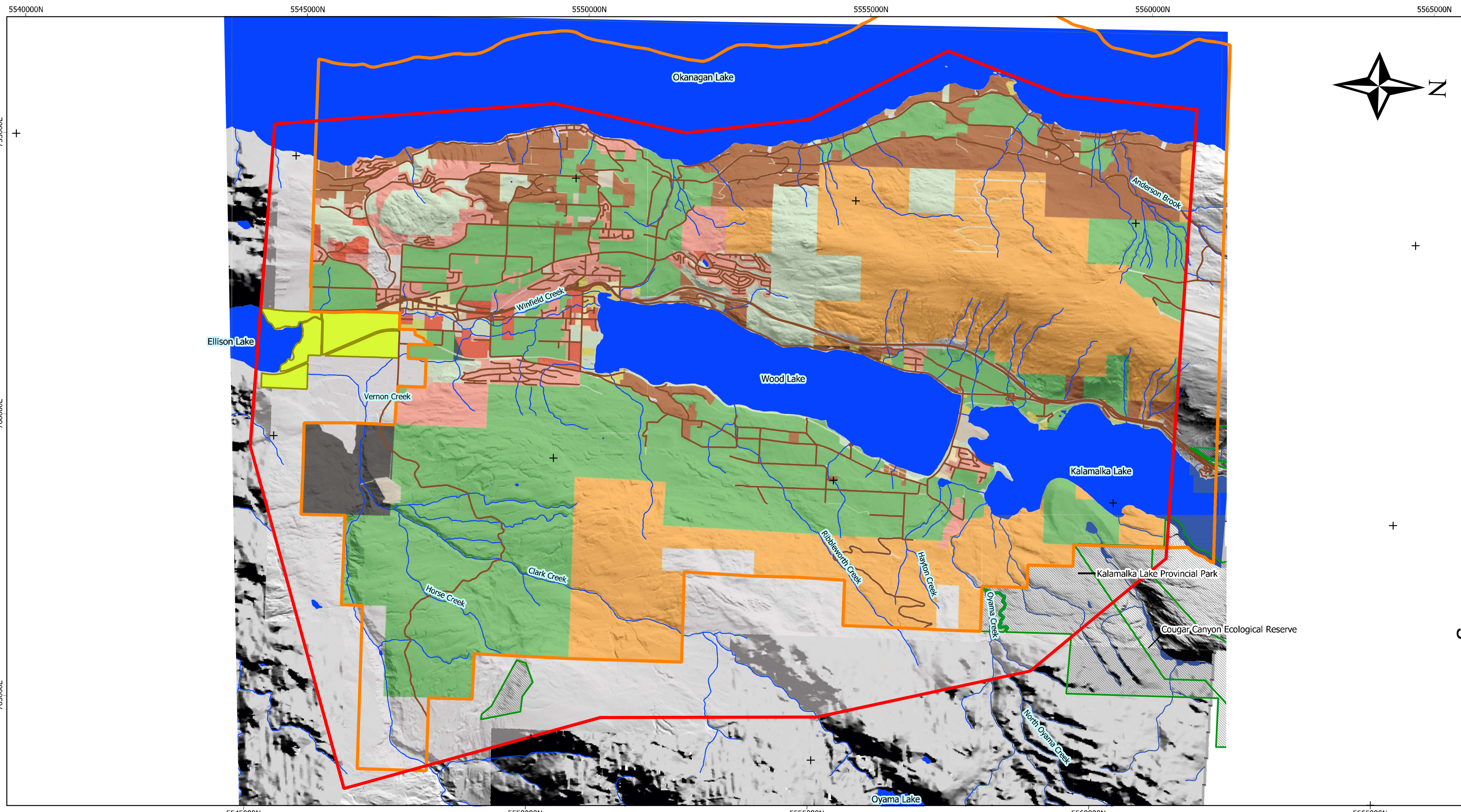
FIGURES



Study Area
District of Lake Country Municipal Boundary
Protected Areas
District of Lake Country Streets
Indigenous Reserve Lands
Lakes
Streams

District of Lake Country Land Use
- No Land Use Defined
- Agricultural
- Parkland
- Rural Residential
- Tourist Commercial
- High Density Residential
- Mixed Use Commercial
- Urban Residential
- Industrial
- Institutional
- Highway Commercial
- Rural
- Service Commercial

0 1 2 3 4 5 km

1:65,000

Coordinate System: NAD83 / UTM Zone 11

References:

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PROJECT
District of Lake Country
Integrated Stormwater Management Plan

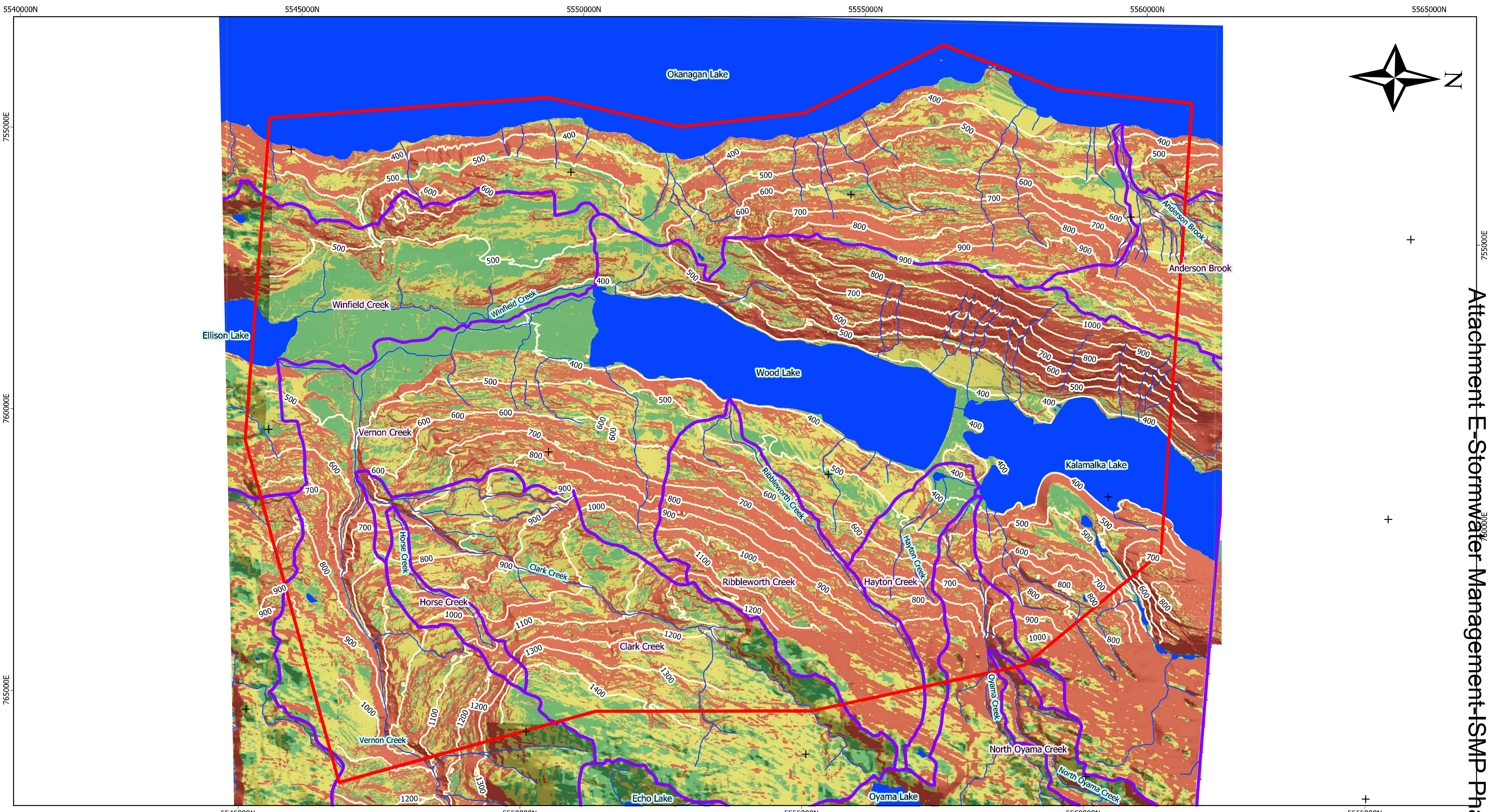
TITLE
Site Location Map and Land Use

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3536-22-001
Compiled By: cmiddleton
Date Issued: 2022-Sep-23
Date Revised: –

FIGURE 1

G:\Projects\Projects_2022\3536-22-001 USL - Kelowna Lake Country MDP\Surficial Materials Mapping.qgz



Study Area
Watersheds
Lakes
Streams

Slope Gradient (%)
<= 8
8 - 20
> 20

Ellison Lake — Lakes and Streams Labels
Coldstream Creek — Watersheds Labels

0 1 2 3 4 5 km

1:65,000

Coordinate System: NAD83 / UTM Zone 11

References:

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PROJECT

District of Lake Country
Integrated Stormwater Management Plan

TITLE

Topography and Watershed Map

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3536-22-001
Compiled By: cmiddleton
Date Issued: 2022-Sep-23
Date Revised: -

FIGURE 2

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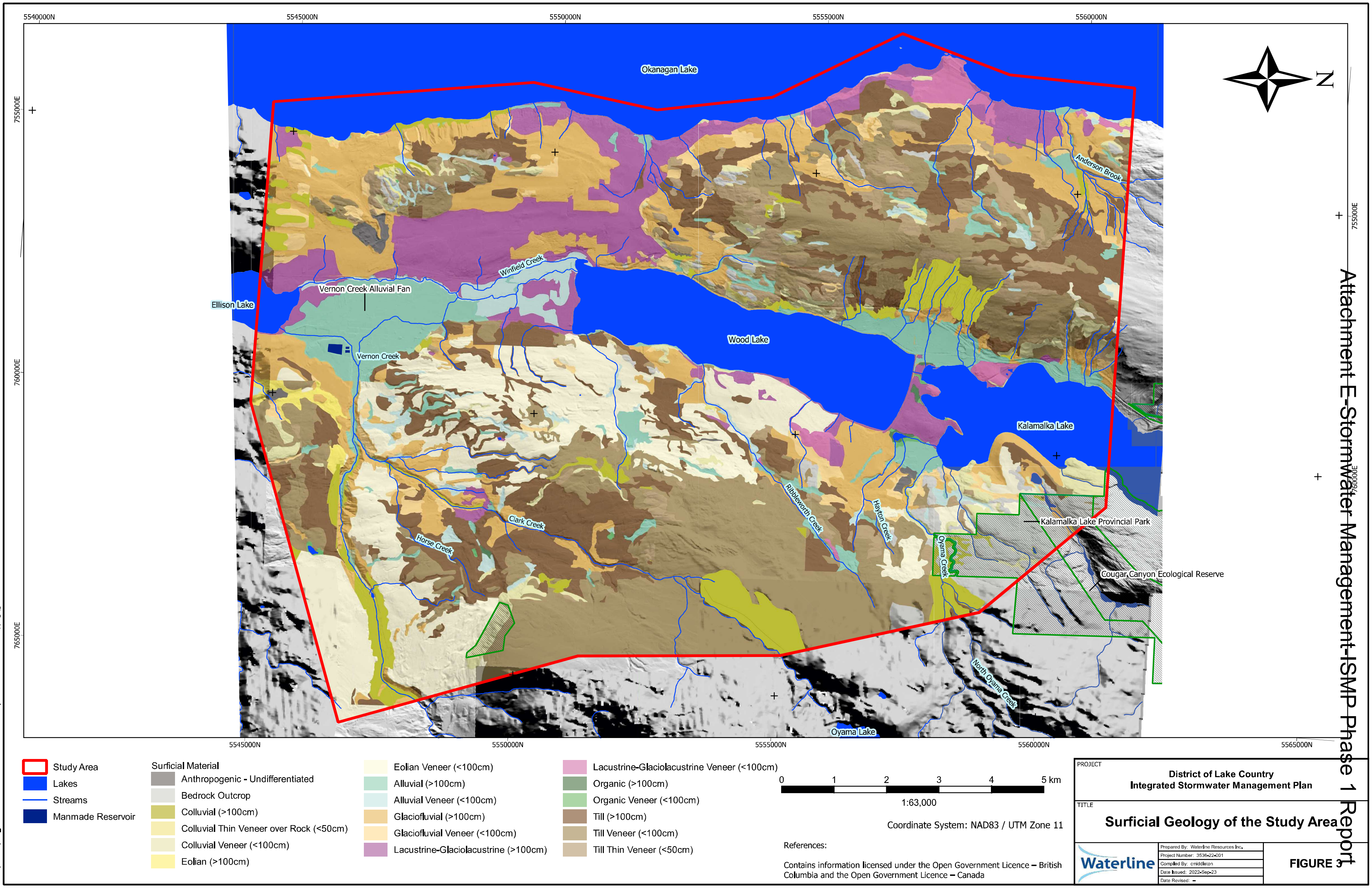
5540000N
5545000N
5550000N
5555000N
5560000N
5565000N
755000E
760000E
765000E
N
Okanagan Lake
Anderson Brook
Winfield Creek
Vernon Creek Alluvial Fan
Ellison Lake
Wood Lake
Vernon Creek
Kalamalka Lake
Ribbleworth Creek
Hayton Creek
Oyama Creek
Clark Creek
Horse Creek
Kalamalka Lake Provincial Park
Cougar Canyon Ecological Reserve
North Oyama Creek
Oyama Lake
Study Area
Lakes
Streams
Manmade Reservoir
Surficial Material
Anthropogenic - Undifferentiated
Bedrock Outcrop
Colluvial (>100cm)
Colluvial Thin Veneer over Rock (<50cm)
Colluvial Veneer (<100cm)
Eolian (>100cm)
Eolian Veneer (<100cm)
Alluvial (>100cm)
Alluvial Veneer (<100cm)
Glaciofluvial (>100cm)
Glaciofluvial Veneer (<100cm)
Lacustrine-Glaciolacustrine (>100cm)
Lacustrine-Glaciolacustrine Veneer (<100cm)
Organic (>100cm)
Organic Veneer (<100cm)
Till (>100cm)
Till Veneer (<100cm)
Till Thin Veneer (<50cm)
0 1 2 3 4 5 km
1:63,000
Coordinate System: NAD83 / UTM Zone 11
References:
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PROJECT
District of Lake Country
Integrated Stormwater Management Plan
TITLE
Surficial Geology of the Study Area
Waterline
Prepared By: Waterline Resources Inc.
Project Number: 3536-22-001
Compiled By: cmiddleton
Date Issued: 2022-Sep-23
Date Revised: –
FIGURE 3
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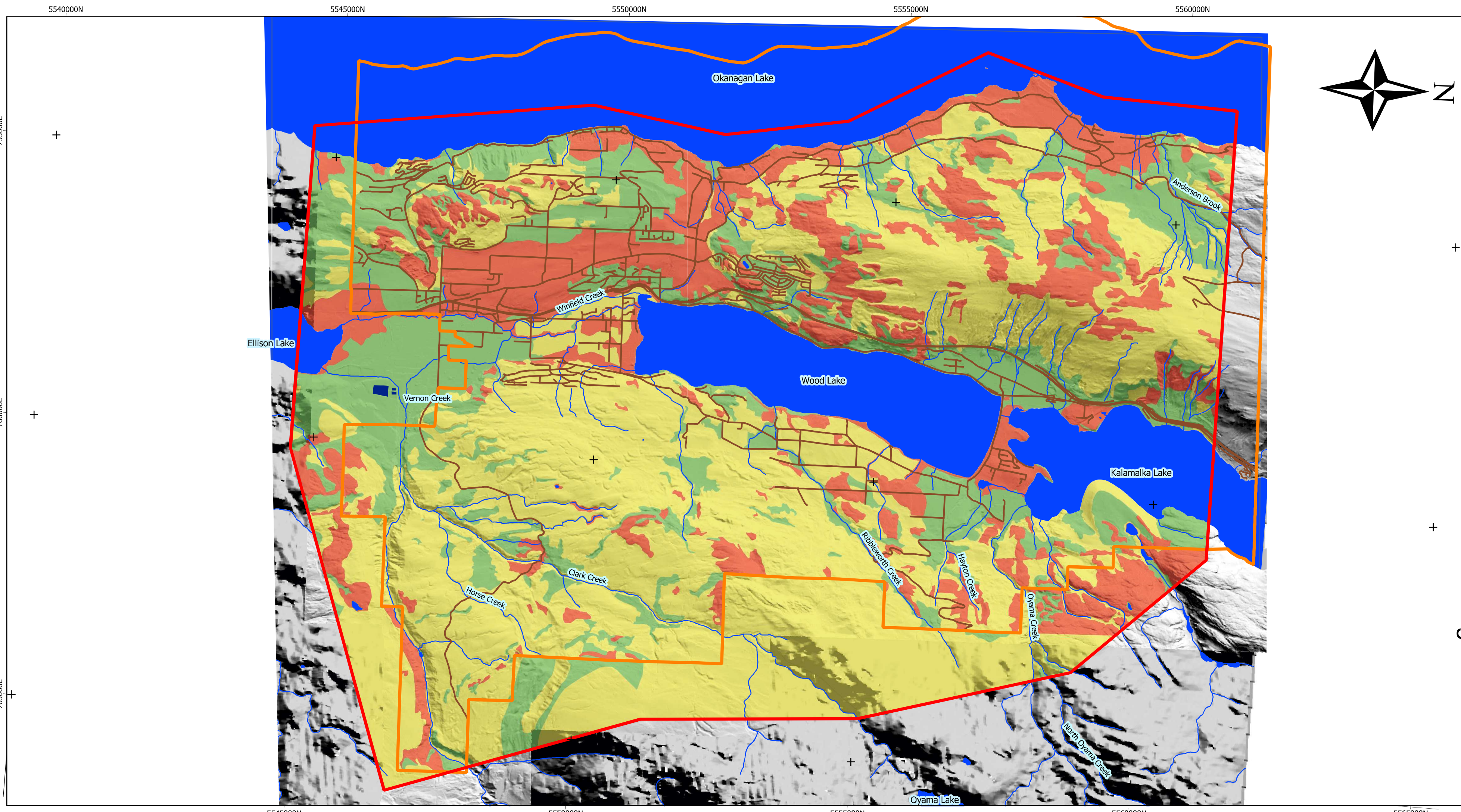

Study Area
District of Lake Country Municipal Boundary
District of Lake Country Streets
Lakes
Manmade Reservoir
Streams

Surficial Material Infiltration Capacity
High
Moderate
Low

0 1 2 3 4 5 km

1:65,000

Coordinate System: NAD83 / UTM Zone 11

References:

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PROJECT
District of Lake Country
Integrated Stormwater Management Plan

TITLE
Surficial Materials Infiltration Capacity

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3536-22-001
Compiled By: cmiddleton
Date Issued: 2022-Sep-23
Date Revised: –

FIGURE 4

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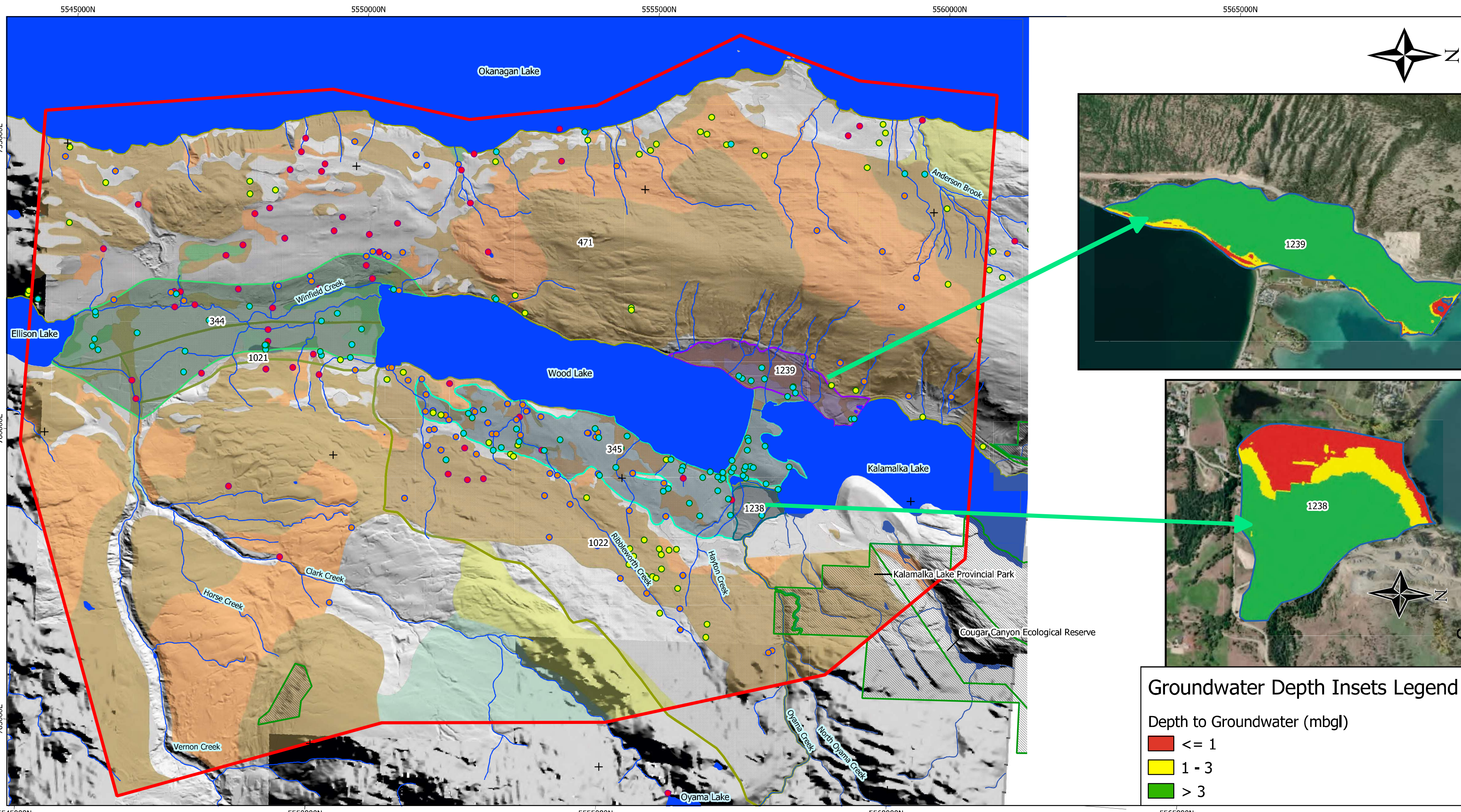

Main Map Legend

- Study Area
- Protected Areas
- Licensed Springs
- Client Identified Spring Locations
- Groundwater Wells (Unconsolidated)
- Groundwater Wells (Bedrock)
- Lakes
- Streams

Aquifers
- 344 - Confined
- 345 - Confined
- 1238 - Unconfined
- 1239 - Unconfined
- Bedrock Aquifer

Soil Drainage (Inferred Water Table Depth)
- Rapid (None Observed)
- Well (None Observed)
- Moderately Well (>75cm)
- Imperfect (<75cm)
- Poor (<50cm)
- Very Poor (<20cm)
- No Data

0 1 2 3 4 5 km

1:63,000

Coordinate System: NAD83 / UTM Zone 11

References:

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PROJECT

District of Lake Country
Integrated Stormwater Management Plan

TITLE

Aquifers and Inferred Water Table Depth

Waterline

Prepared By: Waterline Resources Inc.
Project Number: 3536-22-001
Compiled By: cmiddleton
Date Issued: 2022-Dec-15
Date Revised: -

FIGURE 5

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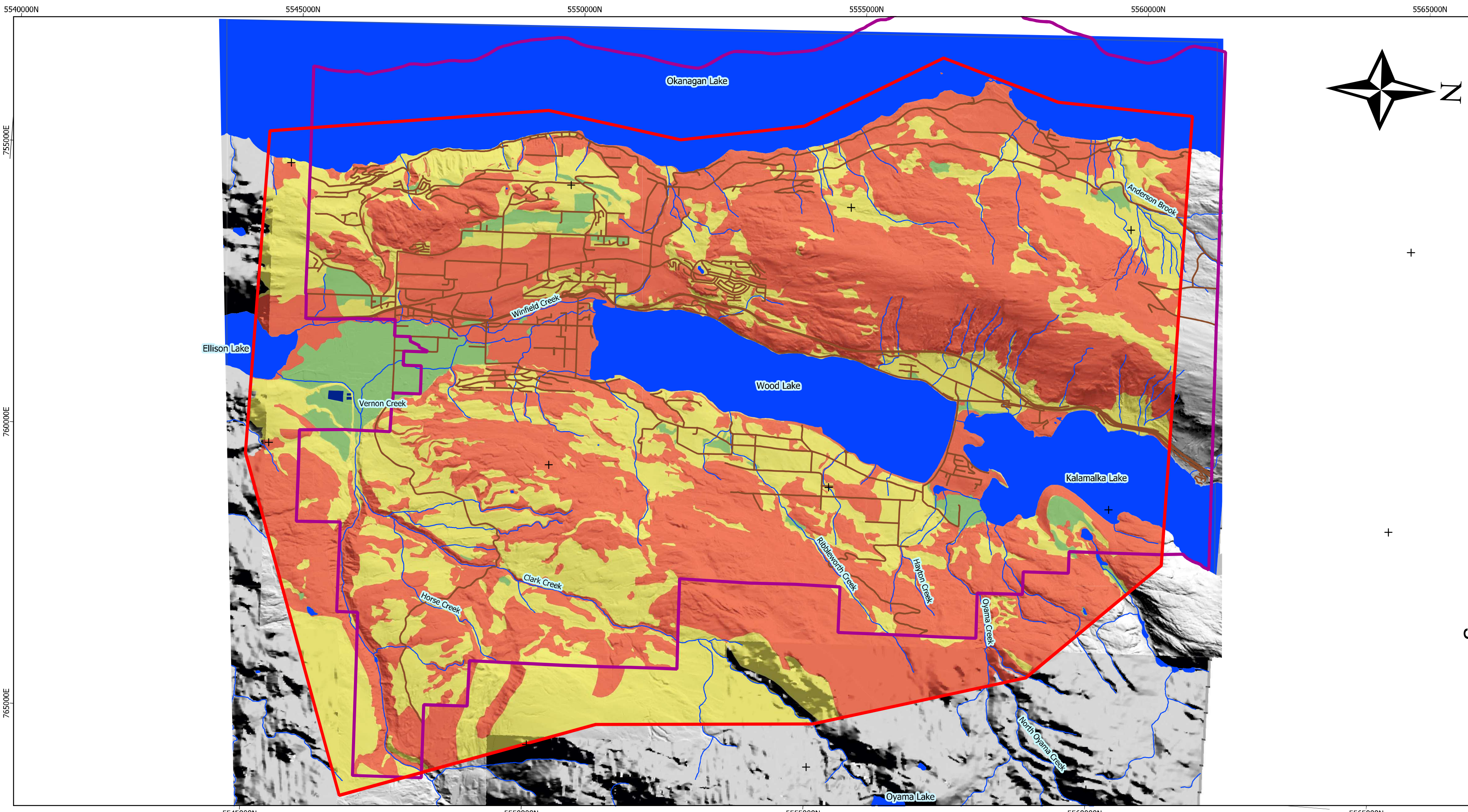

Study Area
District of Lake Country Municipal Boundary
District of Lake Country Streets
Lakes
Manmade Reservoir
Streams

Infiltration Potential
High
Moderate
Low

0 1 2 3 4 5 km
1:65,000
Coordinate System: NAD83 / UTM Zone 11

References:

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PROJECT
District of Lake Country
Integrated Stormwater Management Plan

TITLE
Subsurface Stormwater Infiltration Potential Map

Waterline

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Project Number: 3536-22-001
Compiled By: cmiddleton
Date Issued: 2022-Sep-23
Date Revised: -

FIGURE 6

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Appendix A

Summary of Grain Size Data from Consultant Report

Table A1: Estimated Grain Size Distribution from Terratech (1994)

Parent Material	Soil Test Number*	Total Depth (mbgl)	Grain Size Distribution			Comments
			Gravel (%)**	Sand (%)	Fines (%)	
Fluvial	3	0.30	20	65	5	Soil Tests are reported from Table 2 in the report (Terratech, 1994). Sample locations are unknown, collected from test holes, pits, trenches, etc. The grain size distribution is from field estimates.
	4	2.13	25	70	5	
	7	3.05	40	50	10	
	10	2.13	50	40	10	
	11	0.61	60	35	5	
	20	1.52	30	60	10	
	21	1.22	10	80	10	
	27	1.52	30	70	0	
	30	0.91	30	60	10	
	31	0.61	45	50	5	
	35	0.91	50	40	10	
	36	4.57	50	35	15	
	38	1.83	35	50	15	
	46	1.83	30	60	10	
	48	2.44	40	50	10	
	49	0.91	10	85	5	
	50	1.52	25	60	15	
	52	0.76	10	85	5	
	73	0.46	45	40	15	
	74	0.61	50	40	10	
	78	0.61	0	90	10	
	Average Values	***1.45***	***34.5***	***56.5***	***9.0***	
Glaciofluvial	1	0.91	20.0	50.0	30.0	
	6	0.15	10.0	70.0	20.0	
	8	2.13	30.0	40.0	30.0	
	14	0.30	30.0	50.0	20.0	
	18	1.52	30.0	50.0	20.0	
	19	0.91	10.0	60.0	30.0	
	24	0.61	20.0	60.0	20.0	
	25	0.61	10.0	75.0	15.0	
	43	3.05	30.0	40.0	30.0	
	51	0.91	25.0	55.0	20.0	
	54	0.46	0.0	70.0	30.0	
	69	0.46	20.0	50.0	30.0	
	75	0.61	30.0	35.0	30.0	
	79	0.61	10.0	70.0	20.0	
	80	0.61	0.0	90.0	10.0	
	Average Values	***0.92***	***18.3***	***57.7***	***24.0***	
Till (Morainal)	2	0.61	15.0	45.0	40.0	
	9	1.83	30.0	40.0	30.0	
	13	0.61	15.0	20.0	60.0	
	16	0.46	10.0	50.0	40.0	
	22	0.91	30.0	40.0	30.0	
	Average Values	***0.88***	***20.0***	***40.0***	***40.0***	
Glaciolacustrine	5	0.30	0.0	10.0	90.0	
	29	0.91	0.0	20.0	80.0	
	32	1.22	0.0	10.0	90.0	
	37	0.46	0.0	20.0	80.0	
	41	1.52	0.0	30.0	70.0	
	42	1.52	0.0	20.0	80.0	
	44	1.52	0.0	10.0	90.0	
	55	1.22	0.0	30.0	70.0	
	56	6.10	0.0	20.0	80.0	
	57	3.05	0.0	20.0	80.0	
	58	1.83	0.0	20.0	80.0	
	59	1.07	0.0	10.0	90.0	
	60	4.57	0.0	10.0	90.0	
	61	2.44	0.0	50.0	50.0	
	62	1.83	0.0	20.0	80.0	
	63	1.52	0.0	40.0	60.0	
	64	3.05	0.0	55.0	45.0	
	67	0.46	0.0	60.0	40.0	
	70	0.46	0.0	10.0	90.0	
	Average Values	***1.85***	***0.0***	***24.5***	***75.5***	

Notes:

- * indicates only soil test locations with conclusive and complete data sets are reported (60 of 80 tests)
- ** indicates the percentage of Gravel also includes clast size > 7.62 cm
- mbgl means metre below ground level

Appendix B

Summary of Sieve Data from Consultant Report

Table B1: Soil Description and Calculated Hydraulic Conductivity Values for Oyama Road (USL, 2001)

Borehole Number	Coordinates (UTM Zone 11)		Borehole Total Depth (mbgl)	Parent Material	D10 (mm)	Kfs (m/s)*	Geomean Kfs (m/s)	Ksat (m/s)	IRsat (mm/hr)
	Easting	Northing							
AH-2	328979	5547144	3.0	Sand and Gravel	0.210	4.4E-04	2.5E-04	5.0E-04	1814
AH-6	329173	5547722	3.0		0.120	1.4E-04			

Notes:

- Kfs is the field saturated hydraulic conductivity, Ksat is the saturated hydraulic conductivity, IRsat is the saturated infiltration rate
- * Kfs was calculated using the Hazen equation (Bear, 1972)
- 0.5 Ksat = Kfs (https://www2.gov.bc.ca/assets/gov/environment/waste-management/sewage/spmv3-24september2014.pdf)
- m/s means metres per second
- mbgl means metre below ground level
- mm/hr means millimeter per hour

Appendix C

Groundwater Level Data from Registered Wells

Table C1: Groundwater Levels for Mapped Unconsolidated Aquifers Within the Study Area (ENV, 2022)

Well Tag Number (WTN)	Coordinates (UTM Zone 11)		Aquifer ID	Reported Static Groundwater Level (mbgl)
	Easting	Northing		
84356	5546856	328269	344	10.00
70292	5546164	328721	344	16.00
22221	5546661	328760	344	4.00
105424	5542983	328333	344	63.00
82308	5547409	327584	344	0.00
103566	5546688	328535	344	1.50
82381	5543785	329009	344	52.00
105489	5542210	328559	344	52.00
82307	5544223	328116	344	14.00
83017	5545186	328551	344	6.00
92017	5542268	328026	344	30.00
97273	5542248	328441	344	44.00
105400	5546142	328657	344	13.00
102084	5542262	327970	344	34.00
82920	5546438	327998	344	19.00
20803	5544922	327875	344	73.00
37052	5545201	328622	344	36.00
84270	5546164	328129	344	3.50
32438	5543810	328651	344	40.00
23632	5541273	327748	344	13.00
82306	5543659	327662	344	22.00
83230	5545213	328543	344	8.00
23636	5545192	328544	344	2.00
81678	5542310	328625	344	27.00
8596	5553761	331485	1238	13.41
70268	5553529	331320	1238	3.35
82863	5554206	329433	1239	25.91
62257	5554303	329262	1239	28.96
55871	5553808	329129	1239	17.99
62264	5555355	329820	1239	11.59
50599	5553425	329123	1239	8.54
62168	5553364	329079	1239	3.66
18802	5553762	328937	1239	14.02
18891	5556228	325588	N/A	3.96
20709	5550708	324866	N/A	9.15
18893	5556574	325596	N/A	8.23
105019	5553231	325076	N/A	3.05
57814	5549152	327730	N/A	3.05
52736	5549180	325208	N/A	8.54
57817	5549176	327755	N/A	3.05
20065	5548313	330526	N/A	3.66
23705	5553054	330868	345a	1.52
26044	5552871	330732	345a	0.91
1394	5550007	330364	345a	0.61
8517	5553484	330839	345a	1.22
62171	5553518	330149	345a	1.22
8496	5551438	330116	345a	8.23
2807	5548956	329659	345a	2.74
27240	5554043	331035	345a	1.52
28632	5553817	330289	345a	0.61
62169	5553577	329162	345a	1.22
62262	5555308	329824	345a	2.13
27070	5554234	330647	345a	0.91
8376	5553237	330735	345a	1.83
20064	5549571	330212	345a	3.05
3002	5550949	330142	345a	10.67
18575	5549267	330313	345a	1.83
8372	5551336	330325	345a	2.74
8370	5551244	330656	345a	3.35
2620	5549528	329995	345a	3.05
8713	5553089	330745	345a	3.35
20066	5552061	331068	345a	6.10
8405	5553219	331481	345a	3.96
18244	5554342	329371	345a	3.05
20063	5550280	330180	345a	2.44
8729	5550962	330794	345a	1.52
2806	5548698	329725	345a	1.83
2143	5549126	330361	345a	0.61
17137	5553511	330359	345a	4.88
26043	5553247	330539	345a	0.91
18573	5548615	330069	345a	0.30
82363	5553530	330197	345a	2.44
26040	5553833	330940	345a	0.91
1945	5553274	330667	345a	4.27
114	5552193	330519	345b	8.84
8362	5553087	330846	345b	6.71
8623	5552149	331022	345b	20.73
8374	5553183	331202	345b	14.02
56995	5553439	330799	345b	18.29
97387	5553002	331060	345b	32.01
8703	5553565	330639	345b	25.00
62258	5554297	329274	345b	25.91
8608	5552741	330831	345b	35.98
14220	5552398	330646	345b	12.80
34818	5553460	330694	345b	11.28
17356	5548764	329800	345b	10.98
18142	5553614	330659	345b	19.21
8655	5553001	330821	345b	10.98
28166	5553480	330644	345b	17.68
8533	5550885	329986	345b	40.55
50788	5552378	330709	345b	28.96
8575	5552512	331273	345b	17.68
14028	5552691	331493	345b	45.73

Notes:

- mbgl means metre below ground level
- N/A indicates the well is not associated with a mapped aquifer

Table C2: Groundwater Levels for Mapped Bedrock Aquifers Within the Study Area (ENV, 2022)

Well Tag Number (WTN)	Coordinates (UTM Zone 11)		Aquifer ID	Reported Static Groundwater Level (mbgl)
	Easting	Northing		
62127	5550760	325008	471	20.43
33491	5544930	325934	471	2.44
62113	5542441	325741	471	7.62
58715	5541822	325129	471	29.57
37961	5549506	327689	471	51.83
62131	5551510	327900	471	5.49
38856	5555384	329329	471	1.52
84354	5557578	330297	471	6.71
22692	5557514	328466	471	4.57
82940	5557912	327379	471	33.54
52698	5549167	325379	471	3.05
69160	5551942	325077	471	111.28
62827	5555895	324886	471	6.10
62155	5552702	324865	471	16.16
62149	5552897	324612	471	7.93
68487	5551841	325187	471	15.85
62816	5553808	325272	471	3.05
34985	5555580	325483	471	5.49
41802	5541815	326430	471	36.59
82548	5549674	327992	471	37.50
62132	5551512	327941	471	7.62
62046	5541098	327661	471	8.54
62043	5541113	327603	471	4.27
79981	5551647	325251	471	137.20
97788	5558397	326560	471	7.32
82543	5553152	325087	471	7.32
62153	5552816	324905	471	18.29
62119	5544928	325717	471	21.34
82304	5553657	325189	471	18.29
22178	5555786	325057	471	9.15
37419	5555854	324736	471	6.10
38854	5545370	325869	471	42.68
103613	5557752	326929	471	26.52
62259	5554964	329241	471	9.15
76774	5557510	327885	471	30.49
105024	5556958	326191	471	7.32
82685	5556975	327497	471	73.17
21941	5556538	329789	471	10.98
62156	5557688	327251	471	15.55
62140	5546490	328799	1021	0.61
109732	5548090	329713	1022	79.27
91642	5551551	332191	1022	57.32
40471	5547575	329015	1022	6.71
83111	5552308	332746	1022	17.38
62813	5551999	333173	1022	12.20
62260	5552816	333364	1022	51.22
91645	5551485	332060	1022	10.67
62144	5552030	332410	1022	7.62
82475	5552795	333589	1022	20.12
62141	5549425	330428	1022	16.77
48911	5552114	330524	1022	42.68
82651	5552027	332163	1022	10.06
84347	5552289	332069	1022	37.20
52993	5552160	332085	1022	16.16
82477	5551876	332541	1022	5.49
53013	5551732	331909	1022	8.54
18864	5549551	330273	1022	1.83
107562	5548227	329751	1022	91.46
53007	5551992	332064	1022	10.37
69185	5547295	329138	1022	1.83
62142	5550739	331179	1022	5.79
62143	5551756	332531	1022	3.05
82286	5551938	332568	1022	6.40
57311	5549475	330466	1022	4.27
91612	5551471	332332	1022	23.17
26248	5549052	330229	1022	1.83

Notes:
- mbgl means metre below ground level

Appendix C – Draft Stormwater Management Design Guidelines

Stormwater Management Design Guidelines

Final Draft for Approval
2023-07-05

Contents

1. Introduction

These guidelines are intended to provide additional information and guidance with respect to designing stormwater management facilities as specified in Schedule M of the District Subdivision and Development Servicing (SDDS) bylaw. It is not intended to supersede Schedule M, and contains information based on best practices that are emerging with gained experience. These guidelines also contain design values based on currently available data which, from time-to-time require updating as new data are generated.

1.1. Overview

The objectives and design of stormwater management infrastructure has evolved significantly over the last couple decades. The key change is an emerging consensus that rainwater and snowmelt are resources to be valued rather than nuisances to be minimized or disposed of. This consensus comes with greater awareness of the negative consequences of disrupting natural hydrologic processes through urban and suburban development. In the past, the design of stormwater management infrastructure solely focused on protection of human life and property. Emerging best design practice encompasses these objectives plus broadens the focus to include the protection, enhancement, maintenance, and support of:

- Aquatic and terrestrial habitat,
- Surface water supply and groundwater resources,
- Recreational opportunities; and
- Community aesthetics and urban life.

Emerging stormwater management practice is increasingly shifting from simply attempting to mitigate the effects of stormwater runoff to avoiding the negative effects in the first place. This means designs should attempt to mimic or recreate the natural, pre-development balance or mix of interception, evapotranspiration, infiltration, and runoff on individual development sites and in neighbourhoods. Such an approach requires careful attention to conditions at each site, including climate, soils, topography, vegetation, and downstream watercourse conditions. Under natural conditions, land surfaces are generally covered with numerous small depressions, vegetation (grass; shrubs and trees), and soils of varying degrees of permeability - little or no runoff occurs at all for low intensity and/or low volume rain events. Designs that apply best practices which replicate these conditions are best able to mimic pre-development hydrology.

1.2. Stormwater Management Goals

The following three goals define the District of Lake Country's objectives for stormwater management. These form the framework within which any stormwater management plans and designs submitted as part of the development approval process will be assessed.

Goal #1 – Preserve and improve the environment and natural resources for present and future generations by:

- Minimizing the potential stormwater impacts of Development, such as increased or decreased stream flows, changes in groundwater regime, alteration of fish and wildlife habitat, increased pollution, and increased erosion and sediment transport.

- Where feasible, maintaining the shape and composition (geomorphology) of the natural stream channels or ravine geometry, natural biological indicator conditions, and the flow conditions (hydro-geometric regime).
- Employing stream protection measures to prevent adverse hydrological and water quality impacts for all recognized watercourses within the District.
- Infiltrating rainwater where feasible to maintain and enhance the hydrological regime.
- Promoting sound development that respects the natural environment.
- Where feasible and where opportunities allow, restoring currently enclosed to open channels.

Goal #2 – Reduce the risk of health hazards, loss of life, and property damage by:

- Providing both minor and major drainage protection for life, livelihood, and property.
- Controlling the incidence of nuisance or damage related to surface ponding and flooding to within an acceptable frequency.
- Building infrastructure that will respond to climate change through adaptation.
- Protecting municipal infrastructure.

Goal #3 – Conserve social and financial resources by:

- Treating stormwater as a resource rather than a waste product, ensuring that stormwater facilities are functional and aesthetically pleasing, and integrating multi-use objectives where possible.
- Providing a system of infrastructure and services that enhances general public convenience and safety, enhances aesthetics, and allows Development to proceed according to the community plan.
- Sustaining future Development, supporting orderly and managed Development of resources and integration of land uses within the District.
- Using best available technologies and management practices where feasible.
- Encouraging economic design of drainage systems. In other words, new drainage systems, as well as upgrades to existing systems, should be designed and built to ensure longevity and resilience to climate change and other impacts. This will minimize future operation and maintenance costs and extend the lifespan of the infrastructure so that the future tax burden on District residents is minimized.
- Providing consistency and a basis of fairness for balanced and planned Development within the community.

1.3. Terminology

The SDDS Bylaw uses the term development or subdivision to refer to the changes being proposed for a land parcel or group of land parcels. In these guidelines, the term “development” is used generically for the term “development or subdivision”.

2. Design Considerations

2.1. General

- The Owner's Engineer must design the stormwater management system so that all downstream drainage facilities are capable of handling the projected post development flows to a suitable discharge point as approved by the District Engineer.
- The design drainage catchment area should include the entire area tributary to the stormwater management system, including all catchments upslope of the Development.
- Where appropriate, design should consider and reflect applicable Master Stormwater, Drainage, and/or Integrated Stormwater/Rainwater Management Plans as directed by the District Engineer.
- As much as feasible, maintain natural features such as riparian corridors, streams, ponds, wetlands, surface depressions, soils and vegetation that are integral to the hydrologic cycle.
- As much as is feasible, capture rainfall on-site and infiltrate, evaporate, transpire, and/or reuse it. Implement Low Impact Development (LID) / Green Infrastructure standards and source controls (rain gardens, absorbent landscaping, infiltration facilities, dry wells, infiltration trenches, swales, porous pavements, rainwater reuse, etc.).
- The Owner's Engineer is encouraged to look for ways to reduce the amount of Effective Impervious Area within the development to reduce the amount of runoff generated and directed to the stormwater infrastructure. This includes reducing the amount of impervious area as well as the portion of it which is directly connected to the collection system.
- Detain runoff and release it at rates that approximate natural watershed conditions. Implement stormwater management facilities that retain or detain runoff using engineered or natural methods to control discharge rates. Divert excess flows only to an acceptable discharge point, such as a lake, major stream, ditch, or trunk main with adequate hydraulic capacity and which is approved by the District Engineer.
- For new Development and redevelopment areas that do not drain to a stream or river system, but which discharge directly to a large water body such as a lake, detention may not be required. In this case, collected runoff should be treated using approved methods and to an approved standard.

2.2. Risk Management for Major Systems

The Minor System is intended as a convenience system to safely convey surface runoff not managed on-site to a designated receiving water or system. It is designed to provide this function for runoff generated by relatively frequent rainfall events as defined in Schedule M. The Major System is intended to safely convey runoff when the Minor System's capacity is exceeded or the Minor System fails.

While design storms based on a specified return period and pattern are used to size Major System components, it is important to understand that even the Major System can fail. This might be due to runoff from rainfall events with greater rainfall (volume and/or intensities) than those used to design the Major System, or because of other hazards which might occur (inlet to a piped system clogging, for example). The Major System design storms provide a level of risk management and define an upper limit for design purposes. However, the design should consider what happens should the Major System fail. This requires a risk-management approach to the design.

The level of risk is a function of likelihood that a defined hazard might occur and the severity of the consequences should that hazard occur. It is usually expressed as Equation 1:

Equation 1: Risk = Likelihood x Severity

To reduce risk associated with a particular hazard, The Owner's Engineer can:

a) reduce the likelihood of the hazard occurring (by design modifications for example),
b) reduce the severity of the consequences should the hazard occur (by choosing a different location or implementing other design modifications for example), or
c) by reducing both the likelihood and severity.

The Owner's Engineer should therefore consider the following when designing a Major System and implement appropriate design measures to ensure acceptable risk:

- What hazards might the Major System be subject to?
- What are the potential consequences should one or more of these hazards occur?
- How severe might these consequences be?
- How likely is each hazard to occur? (Note that not all hazards are directly related to the design storm return period.)
- Where the risk associated with a hazard is considered medium to high, what additional design measures could reasonably be implemented to reduce this risk?

3. Environmental Considerations

3.1. Riparian Areas

An environmental review pursuant to applicable provincial and federal legislation is required where the top-of-bank of an existing watercourse, as defined in the BC Water Sustainability Act, is located within 30m of the proposed development. This review is to be conducted by a Qualified Professional, who will recommend the minimum Streamside Protection and Enhancement Area (SPEA). The minimum stream protection setback (SPEA) from the top-of-bank is 15.0 m. It is the Owner's responsibility to engage a Qualified Professional to conduct this review.

3.2. Approvals

Designs for stormwater related works in or near a "stream", as defined in the BC Water Sustainability Act, are required by law to follow protocols for submitting notices to and/or obtaining approvals by applicable provincial and federal authorities. Submitting these notices and/or obtaining these approvals is the responsibility of the Owner.

4. Stormwater Management Plan

4.1. General

Schedule M of the SDDS Bylaw requires that a Stormwater Management Plan (SMP) be prepared as part of the engineering application process in relation to development. The SMP should describe in detail how the proposed development will impact the existing drainage systems and how the proposed major and minor drainage infrastructure will meet the District's drainage policies and goals, master planning, and design criteria.

The SMP should be provided for all developments that alter the existing drainage characteristics, and where appropriate, can be developed in two stages at the expense of the Owner. The first stage (Preliminary SMP) should document existing hydrologic and drainage characteristics and present the proposed stormwater management strategy for the entire development (all phases). The second stage (Detailed SMP) should consist of detailed analysis and design of the proposed stormwater management facilities for each development phase as they are submitted for approvals.

The SMP should be developed or overseen by a Professional Engineer who is registered in the Province of British Columbia and who is experienced in hydrologic and hydraulic analysis. The SMP should be conservative in calculation, coupled with sound engineering judgment.

The economic aspects of the design should not be overlooked. Low maintenance and operational simplicity are preferred. Criteria and proposed solutions should be reviewed with and approved by the District Engineer. It is the Owner’s Engineer's responsibility to confirm the extent of the drainage catchments and the required level of SMP detail, so a discussion with the District Engineer prior to commencing design work is highly recommended.

4.2. Upstream Runoff

As part of the SMP, the Owner’s Engineer should provide the rationale for accommodating runoff from all drainage catchments tributary to the Development or Subdivision. This should include assumptions regarding upstream flow attenuation and accommodations for routing flows through the Development site utilizing natural or constructed surface corridors.

4.3. Preliminary SMP

The Preliminary Stormwater Management Plan should include, at a minimum, the following:

- Existing contours at 1.0 m elevation intervals for sloped areas, and 0.5 m elevation intervals for relatively flat areas.
- All drainage catchment boundaries tributary to the proposed development site, with existing and potential land uses indicated.
- Existing and proposed major flow paths.
- Existing watercourses, including environmental classifications and/ or fish presence information, if available.
- Location and description of proposed discharge / connection location(s) to downstream receiving waters and/or existing drainage systems respectively.

- Reference to the applicable Master Drainage Plan, Watershed Plan, or Integrated Stormwater Management Plan (the "Master Plan") if existing, including details indicating how the proposed site relates to the Master Plan and its recommendations.
- Where appropriate, an evaluation regarding the potential to use infiltration to ground for runoff management.
- Conceptual layout of proposed stormwater management systems, including locations of detention, infiltration, and quality treatment facilities.
- Preliminary sizing of key detention facilities to ensure that there is sufficient space for each facility.
- Proposed control features to meet water quantity and quality targets specified in SDDS Bylaw Schedule M.
- Capacity assessment of downstream works, or reference to the applicable Master Plan demonstrating adequate capacity.
- Pre-development and preliminary post-development flows and volumes both entering and leaving the development.

The Preliminary SMP should be submitted to the District Engineer for review and should be comprised of a written design brief and corresponding drawings, tables, and figures as per the information listed above .

4.4. Detailed SMP

In addition to the requirements listed for the Preliminary SMP, the Detailed SMP should include, at a minimum, the following:

- Proposed contours at 0.5 m elevation intervals.
- Detailed drainage catchment boundaries which reflect proposed conditions, clearly labeled with ID and catchment area, and cross-referenced to model and/or design tables.
- Major flow paths to a municipal drain or natural watercourse without impacting private property.
- Locations, elevations, sizes, design flows, and capacities of all existing and proposed conveyance works. In the case of an existing downstream system that will function as the "receiving water" for the development, the Owner's Engineer should confirm with the District Engineer the extents of said system to be included.
- Locations, elevations, sizes, design flows (in and out), and capacities of all existing and proposed runoff control and quality treatment works.
- Capacity assessment of receiving downstream works, or reference to the applicable Master Plan demonstrating adequate capacity. The District will provide the required stormwater area plans upon request.
- Minor and Major hydraulic grade line elevations on profiles for all proposed works.
- Proposed service connection locations and their associated minimum building elevations (MBE).

- All calculations and/or modelling results pertinent to the design of the drainage systems.
- Select Detailed SMP requirements for a development within rural or agricultural areas may be simplified or waived at the discretion of the District Engineer.

The Detailed SMP should be submitted for review, and should be comprised of a written report and corresponding drawings, tables, figures, calculations, and modeling results as per the information listed above.

5. Hydrogeological Investigation

5.1. General

When the Owner is required to commission a study by a Qualified Professional to determine the viability of ground disposal for storm water, it can be conducted in two phases:

- A preliminary, desktop study to determine if a detailed study is warranted, and if so,
- A detailed, field-based study which includes test pits, boreholes, and other field-based investigations.

The purpose of the hydrogeological investigation is to understand the site-specific soil and groundwater conditions for the design of green infrastructure, infiltration systems, and underground facilities such as basements and/or underground parking facilities. This type of study is particularly important for hillside development, and when required, is used to determine the following:

- The presence of and depth to groundwater.
- The presence of and depth to impermeable materials such as bedrock, dense clay, or other types of soils that can impede infiltration and limit soil water-storage capacity.
- Infiltration rates and soil permeability.
- Slope stability and corresponding risks.
- Groundwater mounding potential and corresponding risks.
- Groundwater surface break-out potential.
- Potential for damage or inconvenience to nearby property and structures.
- Local groundwater use (domestic and municipal water wells, aquifers that are utilised by the wells, etc.).

Sufficient site-specific investigations should be conducted at the locations of proposed works that rely on infiltration (drywells, perforated storm sewers, roof leader rock pits, infiltration basins, etc.). In cases where the water table is high and/or there is a possibility that development will interfere with the groundwater flow regime, additional information including groundwater flow directions and velocities, aquifer locations and hydraulic properties should also be determined.

Should the hydro-geologist determine that a shallow groundwater recharge system for the subject site is feasible; the report should also include the following information where applicable:

- Recommendations for recharge methods suitable for the proposed development, including but not limited to saturated infiltration rates and volumetric limitations.
- Effect of sediment loads on infiltration structures and the consequences of "blinding off" the water-soil interface.
- Impact on groundwater quality.
- Review of potential cumulative impacts of nearby developments as well as the impact resulting from irrigation components and inflow.
- Potential impacts on downstream development and infrastructure.

5.2. Infiltration Rate

Infiltration is a measure of the downward movement of water from the ground surface through the soil. The infiltration rate can vary, depending on the amount of water already in the soil. Unsaturated soils have a higher infiltration rate, and is an important parameter for hydrologic modeling. It is typically noted as the Maximum Infiltration Rate. Saturated soils have the lowest infiltration rate, and is typically noted as the Minimum or Saturated Infiltration Rate. Both of these values should be determined as part of the hydrogeological study.

Infiltration testing in the subsurface soils should be conducted for optimal design of infiltration systems. This testing should be conducted at the anticipated depth of the bottom of the infiltration system and in the lowest permeability strata located within 1.5 to 2.5 m of the bottom of the structure.

5.3. Domestic Wells and Streams

Depending on the size of the development and the potential impacts on groundwater conditions and steam flow, and at the discretion of the District Engineer, the yield and water quality of domestic wells near the development should be determined prior to commencing construction. If there are claims that the yield and/or water quality of an individual well has deteriorated as a result of the development, the wells can be re-tested to verify such claims.

Similarly, if down-gradient streams and/or wetlands are located near the development, the baseflow and/or water levels in these water bodies should be measured at the discretion of the District Engineer prior to construction, during construction, and after the development is completed.

The study should also assess potential water quality impacts to these water sources should infiltration systems be proposed to control and/or dispose of stormwater runoff.

5.4. Irrigation Impacts

Introduction of irrigated landscapes can introduce additional water to the underlying soils. The potential for this, and the overall impacts on the issues listed in Section 5.1, should be assessed in the hydrogeological study.

6. Runoff Analysis

6.1. Pre-Development Runoff

In general, and for the purposes of SDDS Bylaw Schedule M, “pre-development” refers to natural land cover prior to any disturbances or alterations by humans – including roads, clearings, agriculture, and buildings. In most cases, the Owner’s Engineer is expected to apply the Unit Runoff Rates for pre-development conditions as specified in Schedule M and presented in Section 6.2 of these guidelines.

With the approval of the District Engineer, the Owner may use the Hydrograph Method (computer modeling) to determine pre-development values. It is critical that the results are field-proofed to ensure that modeled flows correspond to field evidence for similarly-sized rainfall events. Such evidence could include:

- observations by local, long-term residents and Public Works staff,
- characteristics of surface flow routes (ditches, swales, natural channels), and
- flow measurements (where available).

It is useful to look for evidence of frequent surface flows, estimate surface flow route capacities, and compare these to the modeled results. It is also useful to assess if the modeled flows could realistically be conveyed by existing flow routes and confirm if such events have been observed over a reasonable time period (the longer the better).

Pre-development runoff should be determined using historical rainfall data. For return-period events, this would be IDF values combined with the design hyetographs as presented in Sections 6.3.2 and 6.4.3 of these guidelines respectively. Model calibration / validation should be completed as presented in Section 6.4.4.

6.2. Pre-Development URRs

The pre-development flow for a Development site shall be calculated using the Equation 2:

Equation 2: $$Q_T = A \times URR_T$$

Where: Q_T = pre-development runoff rate for a specified return period “T” [m^3/s]

A = drainage area [ha]

URR_T = Unit Runoff Rate for the return period “T” [Lps/ha]

URR determination is, in part, a function of catchment characteristics, receiving water type, and conveyance system type between the development site and the receiving water. For the purposes of these guidelines, the need for and criteria to develop a URR is based on the receiving water type and conveyance system. Although each development site is unique, most reflect the following typical scenarios for both receiving water and offsite conveyance to it.

Receiving Water:

1. A lake. Within the District, this includes Ellison, Wood, Kalamalka, and Okanagan lakes. In this case, no flow control is really required provided that the runoff is adequately treated and safely conveyed to the lake. Provincial approval of a new lake outfall would, however, be required.

2. A natural stream. Within the District, this includes Middle Vernon Creek, Winfield Creek, Anderson Brook, Hayton Creek, Ribbleworth Creek, Oyama Creek, and Upper Vernon Creek. Although streams can function as a receiving water, they are sensitive to flow frequency and magnitude. Each has a threshold which, if exceeded, triggers bed and/or bank erosion, not to mention flood risk. None of the streams within the District are reliably instrumented to collect flow data, but a URR for each permanent stream can be calculated using active channel geometry and contributing catchment area. The assumption is that the active channel, which conveys frequent flows, is stable. The calculated URR would then govern the allowable discharge rate from the proposed development to the stream. As with discharges directly to a lake, provincial approval of a new stream outfall would be required.
3. Ground (infiltration). If an adequate receiving water is not sufficiently close to the development, it might be feasible to infiltrate the runoff. Section 5 of these guidelines outlines what is required to determine where this might be feasible. If infiltration is deemed feasible by a qualified professional, then a well-designed system using design values from the hydro-geotechnical study would be required and need to be approved by the District Engineer. In this case, flow control would be dictated by the infiltration system design. This approach assumes that all infiltration works will be located on-site. It also assumes that a safe downstream route for emergency overflows exists or can be constructed.

Conveyance From the Development to the Receiving Water:

1. Existing trunk storm sewer in good condition. In this conveyance scenario, the residual capacity of the trunk would have to be calculated, and the URR would be the residual capacity divided by the contributing, projected long-term development area. Note that if the existing trunk discharges to a stream instead of to a lake, the stream's URR must also be considered – the lessor of the two URRs (trunk or stream) would govern.
2. New trunk storm sewer. If a new trunk drainage system is required, then it should be sized to accommodate runoff from all existing and potential development that may connect to it. If the trunk is to discharge to a stream, then its capacity should be based on the stream's URR and the total developable area draining to the trunk. If the trunk is to discharge to a lake, then flow control is not required unless it is more economical to incorporate some flow control to reduce trunk size and corresponding costs. In this case, a URR based on the design trunk capacity and the total developable area draining contributing to it should be calculated and applied to all developments with potential to connect.
3. Surface channel (ditch, swale, or natural channel). A controlled discharge to any of these conveyance options is required to prevent erosion and sediment transport. In this scenario, a detailed geotechnical investigation would be required to identify flow rate and duration thresholds that ensure channel and slope stability under both minor and major runoff conditions. A URR would be calculated using the recommended flow rate threshold and the total projected contributing development area.

Table 1 summarizes the recommended controlled discharge criteria for the combinations of receiving water and offsite conveyance system.

Table 1: Controlled Discharge Guidance

Receiving Water	Offsite Conveyance System	Controlled Discharge Criteria
Lake	Existing Trunk Sewer	URR based on residual trunk capacity
	Proposed Trunk Sewer	URR based on proposed trunk capacity
	Surface Channel	URR based on stable channel capacity
Stream	Existing Trunk Sewer	Lesser of the URRs based on residual trunk capacity and stable stream channel capacity
	Proposed Trunk Sewer	Lesser of the URRs based on proposed trunk capacity and stable stream channel capacity
	Surface Channel	Lesser of the URRs based on stable stream channel and surface channel capacities
Ground (Infiltration)	None – it is assumed that all infiltration systems will be located on-site	Infiltration rates and volumes recommended by a qualified professional

IDF Data

6.2.1. General

Rainfall intensities should be calculated using Equation 3. This equation is a modification of the two-parameter equation traditionally used by Environment and Climate Change Canada to fit curves to the values generated by frequency analysis. The three-parameter fitting equation tends to fit the frequency analysis results better than the traditional two-parameter equation.

Equation 3: $$I = A\,(T+t_0)^B$$

Where: I = rainfall rate in mm/hour
T = storm duration in hours
A, B, and t_0 = values as specified in Tables 2a or 3a

6.2.2. Historical Conditions

The values provided in Table 2a are based on historical precipitation records from the Kelowna A climate station (ECCC ID 1123970). This station's records span from 1969 to 2004 inclusive (34 years with sufficient useable data). The Gumbel distribution was used for the frequency analysis – the fitted curve equation values were obtained from the IDF_CC Tool (version 6.0).

Table 2a: IDF Equation Values Based on Historical Data

Variable	Return Period – T (years)					
	2	5	10	25	50	100
A	9.4	13.5	16.2	19.6	22.2	24.7
B	-0.716	-0.771	-0.794	-0.816	-0.829	-0.839
t_0	0.029	0.046	0.053	0.060	0.064	0.067

For convenience, Tables 2b and 2c summarize the rainfall intensity and total event precipitation respectively for key combinations of storm duration and return period.

Table 2b: Rainfall Intensities (mm/hr) Based on Historical Data

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	45.0	65.3	78.8	95.6	108.6	121.1
10 min	30.2	44.5	54.0	65.8	74.9	83.6
15 min	23.4	34.5	41.8	51.0	58.0	64.8
30 min	14.8	21.5	25.9	31.5	35.7	39.8
1 h	9.2	13.0	15.5	18.7	21.1	23.4
2 h	5.7	7.8	9.2	10.9	12.2	13.4
6 h	2.6	3.4	3.9	4.5	5.0	5.4
12 h	1.6	2.0	2.2	2.6	2.8	3.1
24 h	1.0	1.2	1.3	1.5	1.6	1.7

Table 2c: Total Event Precipitation (mm) Based on Historical Data

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	3.7	5.4	6.6	8.0	9.1	10.1
10 min	5.0	7.3	8.7	10.6	12.0	13.3
15 min	6.0	8.9	10.9	13.3	15.2	17.0
30 min	7.4	11.1	13.5	16.5	18.8	21.1
1 h	9.0	12.7	15.2	18.3	20.6	22.9
2 h	11.3	15.3	18.0	21.3	23.8	26.2
6 h	15.6	19.9	22.7	26.3	28.9	31.6
12 h	19.4	24.1	27.4	31.3	34.2	37.2
24 h	23.0	28.1	31.4	35.8	38.9	42.0

6.2.3. Future Conditions

The District accepts that climate patterns are changing, and that its residents may be impacted by runoff from more extreme storms, stream and lake flooding, extreme temperature fluctuations, high winds, and wildfires. As per SDDS Bylaw Schedule M, the District requires that the Owner's Engineer consider impacts of climate change when implementing a design - particularly in components where critical and long-term design decisions are being made, or in areas where the consequences of failure are high. The values provided in Table 3a were obtained using the IDF_CC Tool (version 6.0) for the Kelowna A climate station, and reflect the following:

- Future period from 2030 to 2100
- Pacific Climate Impacts Consortium (PCIC) bias-corrected ensemble of down-scaled CMIP6 GCMs based on SSP5.85
- GEV frequency distribution

Table 3a: IDF Equation Values for Future Climate Conditions

Variable	Return Period – T (years)					
	2	5	10	25	50	100
A	9.9	14.0	17.6	23.4	30.0	38.7
B	-0.686	-0.728	-0.765	-0.819	-0.875	-0.933
t_0	0.015	0.027	0.040	0.062	0.087	0.116

For convenience, Tables 3b and 3c summarize the rainfall intensity and total event precipitation respectively for key combinations of storm duration and return period.

Table 3b: Rainfall Intensities (mm/hr) for Future Climate Conditions

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	48.6	69.7	87.3	113.6	141.2	174.3
10 min	31.9	46.3	58.8	78.3	99.6	125.8
15 min	24.6	35.6	45.4	60.7	77.7	98.9
30 min	15.6	22.3	28.2	37.5	47.8	60.8
1 h	9.8	13.7	17.1	22.3	27.9	34.9
2 h	6.1	8.4	10.2	12.9	15.8	19.2
6 h	2.9	3.8	4.4	5.3	6.2	7.1
12 h	1.8	2.3	2.6	3.0	3.4	3.8
24 h	1.1	1.4	1.5	1.7	1.9	2.0

Table 3c: Total Event Precipitation (mm) for Future Climate Conditions

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	4.1	5.8	7.3	9.5	11.8	14.5
10 min	5.3	7.7	9.8	13.1	16.6	21.0
15 min	6.2	8.9	11.3	15.2	19.4	24.7
30 min	7.8	11.2	14.1	18.8	23.9	30.4
1 h	9.8	13.7	17.1	22.3	27.9	34.9
2 h	12.2	16.7	20.4	25.9	31.5	38.5
6 h	17.3	22.7	26.7	32.1	37.1	42.9
12 h	21.6	27.5	31.5	36.5	40.7	45.3
24 h	26.8	33.2	37.1	41.5	44.5	47.7

6.3. Hydrograph Method

6.3.1. Software

Software for the Hydrograph Method should be selected to suit the complexity of the watershed and the hydrologic processes that need to be considered (e.g., detention, groundwater recharge and infiltration, evapotranspiration, continuous simulation, etc.) It should have the ability to simulate both minor and major systems and their interrelation, and the ability to simulate submerged outfall and/or surcharged storm sewer conditions. The software should be able to report volumes, hydraulic grade lines, peak flow rates, velocities, runoff coefficients, infiltrated volumes, and other values pertinent to design and hydrologic analysis. These results should be available in both tabular and graphical formats, including time series such as hyetographs, hydrographs, and water levels for example. The most widely used software packages are those based on US Environmental Protection Agency's SWMM software, however other software may be used subject to approval by the District Engineer.

Note that the Soils Conservation Service (SCS) curve number (CN) method should not be used even though the software might offer it as an option.

6.3.2. Modeling Parameters

Drainage catchments for post-development conditions should be defined at a resolution that reflects the area which drains to each existing or proposed catch basin or system/culvert inlet. Catchment parameter values should reflect grading, ground cover, catchment geometry, hard (impervious) surfaces, and connectivity to the storm sewer system under both existing and proposed conditions. Infiltration parameter values should reflect soil type, soil depth, and typical antecedent moisture condition (AMC).

The model should include, at a minimum, two scenarios:

- Existing conditions to "proof" the model's hydrology (runoff from a known rainfall event which generally reflects observed field conditions) as per Section 6.4.4 of these guidelines, and
- Proposed conditions demonstrating that the proposed works have sufficient capacity and will perform as designed.

The model should include all existing and proposed system components with corresponding elevations, dimensions, and applicable rating curves. Hydraulic parameter values should reflect those specified in applicable sections of Schedule M.

All modeling parameter values and assumptions should be presented and referenced in a Design Report, reflect accepted values for the subject conditions, and should be approved by the District Engineer

6.3.3. Design Hyetographs

Stormwater management system component sizing is sensitive to the combination of a rainstorm's volume and peak intensity – essentially its hyetograph. Conveyance component capacity tends to be more sensitive to intensity while storage component capacity tends to be more sensitive to rainfall volume. To ensure that each proposed component is adequately sized to meet the District's design objectives, four design storms are defined for use with computer-based models. Each storm has a duration of 24 hours and is defined by a unique combination of return period and hyetograph time interval. Each design storm is to be developed using the Future Conditions IDF values as per Section 6.3.3.

Table M-4 in SDDS Bylaw Schedule M specifies inlet times for different return periods and land uses. Based on this, Table 4 summarizes the differentiating characteristics of each storm. The peak intensity should occur at 16 hours (2/3 of the storm duration) for all four storms.

Table 4: Design Storm Characteristics

Storm ID	Return Period T (years)	Hyetograph Time Interval (min)
1	10	15
2	10	10
3	100	10
4	100	5

All four storms are to be created using the Chicago Method for the following reasons:

- the hyetograph values can be calculated using the variables provided in Tables 2a and 3a (historical and future climate);
- the peak intensity equals the IDF intensity for the corresponding time interval (duration) and return period;
- the storm volume equals the IDF volume for the corresponding storm duration and return period;
- extreme rainfall in the Okanagan is historically generated by convective storms, which generally reflect the shape of a Chicago Storm;
- as the climate continues to change, more extreme convective storms are anticipated, which are likely to reflect a Chicago Storm-shaped hyetograph even more than they have historically.

The specified design storms are suitable for most design purposes. However, simulation of large watersheds or complex drainage systems may require extended duration storms or continuous rainfall data. It is incumbent on the Owner's Engineer to obtain the appropriate rainfall data for this type of analysis.

6.3.4. Model Calibration / Validation

Prior to using a computer model for design purposes, it should be tuned to reflect existing conditions (conditions prior to site construction, not necessarily pre-development conditions). Since the availability of site-recorded rainfall and runoff for true calibration is unlikely, the model should be tuned and validated using historical rainstorms and corresponding anecdotal runoff information. Rainfall event data can be obtained from Environment and Climate Change Canada as sub-hourly rainfall values or generated from historical weather radar records.[1] Anecdotal runoff information can be obtained from local residents, District Staff, and observation of culverts, ditches, and natural drainage routes.

6.3.5. Continuous Simulation

Continuous simulation is the preferred modeling method for systems which rely heavily on long-term storage and/or green infrastructure that uses infiltration and/or evaporation. Hourly rainfall and temperature data are required, and can be obtained from the District Engineer for this purpose. Specific objectives for continuous simulation should be confirmed with the District Engineer prior to completing the analyses.

6.3.6. Presenting Modeling Results

To document the design rational used to develop the hydrologic model and to standardize the presentation of model results, a Design Report should be prepared. It should include an appropriate section which presents the following information as used in the model(s):

- Type and version of modeling software.
- Summarized parameter values, including justification or references. Ideally, referenced values will be submitted in appendices to the Design Brief.
- Simulation assumptions (where the software offers options).
- Design hyetographs (graphs) with annotated peak and total depth.
- Volumetric runoff coefficient (runoff volume divided by rainfall volume) and unit peak flow (peak flow divided by area) summarized for each catchment.
- A summary of peak flows for each conveyance component.
- Inflow and outflow hydrographs for all:
    - storage facilities
    - control structures and bypasses/overflows
    - significant green infrastructure, including infiltration basins
    - lift stations
    - outfalls (outflow only).
- Discussion of any system reaches which show surcharge, including a plot of the subject reach with the modeled hydraulic grade line (HGL).

[1] Historical Climate Data - Climate - Environment and Climate Change Canada (weather.gc.ca)

- A plan showing sub-catchment areas, watershed boundary (including upstream catchments), and proposed stormwater management infrastructure. Note – model element IDs should match labels used in design drawings.
- Stage-area and storage-discharge curves for all storage / infiltration / green infrastructure components.
- Pump curves for proposed lift stations.

7. Site Design

7.1. Site and Lot Grading

The site and lot grading plan should, at a minimum, addressed the following:

a) Pre- and post-development contours.

b) Identification of cut and fill areas. Design recommendations from a geotechnical Engineer should be provided pertaining to areas of greater than 1 m of fill.

c) Building envelopes within the proposed lots. Ensure that areas around buildings are graded away from foundations.

d) Grade elevations at property corners and any other changes in grade.

e) A typical grading detail identifying general conditions and any special conditions for construction.

f) Minimum and maximum main floor elevations for buildings.

g) Directional arrows showing proposed drainage flow routes on each lot to an approved municipal drainage system or roadway. Cumulative drainage of two or more properties should be avoided, and where necessary, the Owner's Engineer should provide the rationale for this condition as well as propose a means of directing the flows to prevent impact on adjacent lots. This condition may require installation of special Works and Services by the Applicant and encumbrances registered on the lands.

h) Ensure that individual parcels do not direct surface, roof leader, or foundation drain discharge into any natural water course, park, or green belt area(s) - sheet flow should be used.

i) Ensure that driveway runoff does not enter any building on the parcel.

j) Show the location of and document any Low Impact Development and/or source control solutions proposed.

k) Existing drainage patterns adjacent to the site.

l) Legend identifying all notations.

m) Lot numbering as per the final registered plan.

The final grading plan submitted to provide guidance for the Development of buildings on the lots may omit pre-development contours and cut/fill notations.

To ensure flooding is avoided, carports or garages attached to residential buildings should not be constructed with their floor level below the curb or crown of pavement of the adjacent street, unless:

- the drainage of the driveway serving the carport or garage is connected by gravity to a District storm sewer meeting the connection criteria, or
- is above the 100-year flood line, or
- the runoff water from the driveway may flow past the carport/garage without accumulating and entering. All other relevant criteria of this Bylaw must also be met.

7.2. Geotechnical Considerations

Geotechnical investigations by a Qualified Professional to address issues related to the design of all stormwater detention facilities should be completed as part of the planning and design studies. Such investigations are a prerequisite to the final design of such facilities.

8. Erosion Control

8.1. Sediment and Erosion Control

Given that disturbed soils are highly vulnerable to erosion and subsequent sediment transport during rainfall events, sediment and erosion control (SEC) measures as specified in SDDS Bylaw Schedule N should be implemented to protect stormwater management facilities and receiving waters. This applies, but is not limited to, areas that are cleared and grubbed, slope cuts, fills, and stockpiled materials such as sand, gravel, native soils, and topsoil.

Appendix D – Lake and Stream Levels

URBAN SYSTEMS

Technical Memorandum

DATE: January 12, 2023
TO: Matthew Salmon, P.Eng., District of Lake Country
FROM: Glen Zachary, P.Eng.
FILE: 1577.0124.01
SUBJECT: District of Lake Country ISMP: Study Area Water Surface Elevations

1.0 INTRODUCTION

The purpose of this technical memorandum (tech memo) is to establish boundary conditions at drainage system outfalls to lakes and streams within the District of Lake Country Integrated Stormwater Management Plan (ISMP) study area. These boundary conditions are necessary for hydraulic modeling and reflect water surface elevations (WSEs) under specified conditions (modeling scenarios). The values presented in this tech memo are to be used to inform the PCSWMM models prepared for the ISMP and reflect the most current understanding of both recorded and projected future conditions.

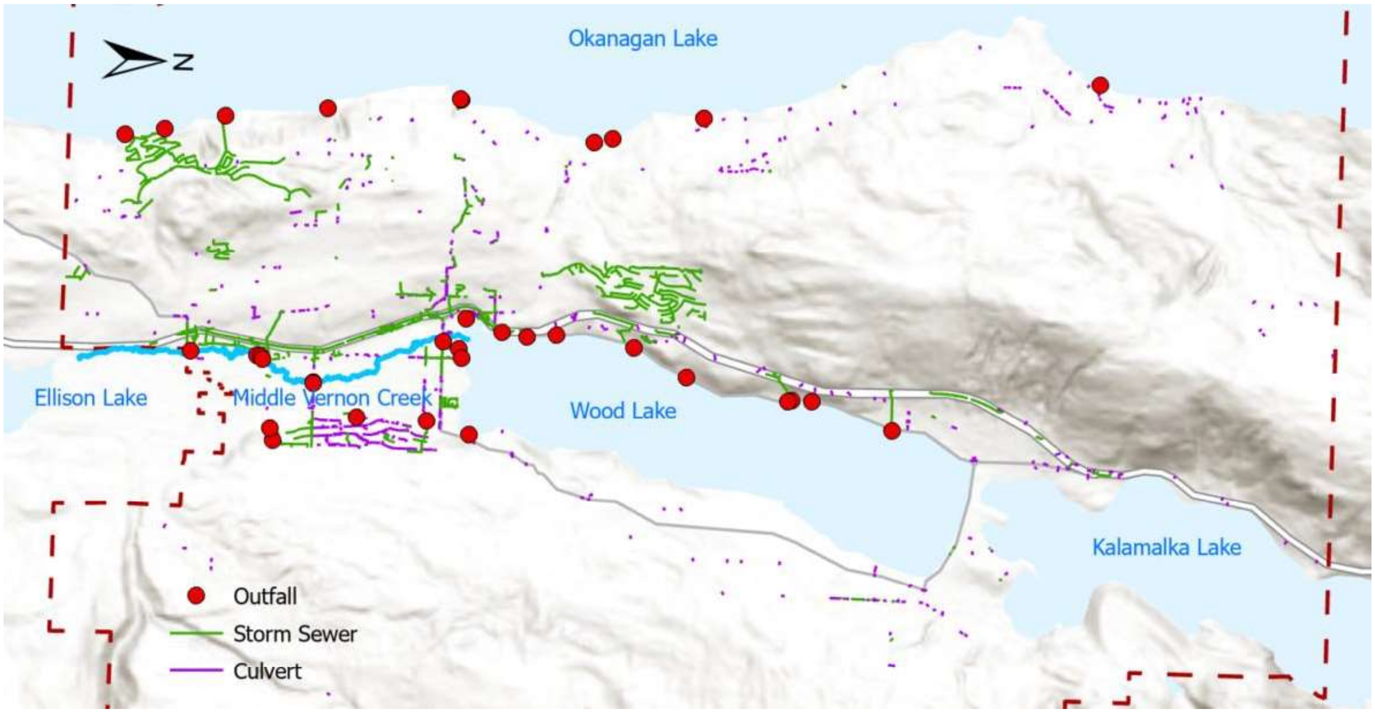
2.0 STUDY AREA WATERS

Figure 1 shows the primary waters to which the District of Lake Country (the District) drainage systems outfall. These include:

- Okanagan Lake
- Ellison Lake
- Wood Lake
- Kalamalka Lake
- Middle Vernon Creek

The figure also shows the location of systems outfalls located on each of these waters. Note that culverts and storm sewer systems may outfall to natural ravines or ditches which ultimately flow to one of these waters. However, since the hydraulic performance of these systems is not impacted by the water levels in the ultimate receiving waters, their outfalls are not shown.

Figure 1: Receiving Waters and Existing Outfalls



3.0 DATA SOURCES

Water levels are recorded at six Water Survey of Canada (WSC) stations as shown in Figure 2. Information about each station is summarized in Table 1. Data from these stations formed the basis for WSEs developed by Northwest Hydraulic Consultants (NHC) in a 2020 study[1] for the Okanagan Basin Water Board (OBWB). Values from this study are recommended for use in the ISMP and are discussed in more detail in Section 4.

Note that:

1. Geodetic elevations are calculated using correction factors. These factors differ, depending on the datum selected. NHC used the Canadian Geodetic Vertical Datum 2013 for its study.
2. The NHC study concluded that Wood Lake and Kalamalka Lake function hydraulically as a single water body. Therefore, the estimated design WSEs are the same for these two lakes. This is an oversimplification which ignores that the two lakes are connected by a channel which is subject to sedimentation, debris blockage, and (at some point) limiting hydraulic capacity. However, for the purposes of the ISMP, we have this maintained the assumption that the two lakes function as one with respect to water levels.
3. A review of the data indicates that same-day water levels on Okanagan Lake measured at the Kelowna and Penticton stations do differ from each other. The same is true for the Wood / Kalamalka Lakes gauges. The

[1] Northwest Hydraulic Consultants Ltd. (NHC), Okanagan Mainstem Floodplain Mapping Project, prepared for the Okanagan Basin Water Board, 2020-03-31.

NHC study assumes that the recommended flood WSEs for these lakes apply to all locations on the lakes. While this is a simplification, we have maintained this assumption for the purposes of the ISMP.

Table 1: WSC Hydrometric Stations

ID	Name	Status	From	To	Years
08NM050	Okanagan River at Penticton	Active	1921	2022	101
08NM066	Wood Lake at inlet to Oyama Canal	Discontinued	1928	1973	29
08NM067	Ellison Lake near Winfield	Discontinued	1968	1980	13
08NM071	Okanagan Lake at Penticton	Discontinued	1920	1974	55
08NM083	Okanagan Lake at Kelowna	Active	1943	2022	80
08NM143	Kalamalka Lake at Vernon Pumphouse	Active	1967	2022	56

Figure 2: WSC Hydrometric Stations

4.0 WATER SURFACE ELEVATIONS

4.1 DISCUSSION

Given that historical and projected WSEs correspond to only a few locations within the study area, and correspond to mainstem lakes only, it was necessary to estimate values at each of the outfall locations along Middle Vernon Creek. These were obtained from HEC-RAS modeling conducted for the Middle Vernon Creek Flood Risk Assessment project[2].

WSEs for the lakes were taken from the NHC study. Values were recommended for four periods – the tables are in Appendix A:

- Table 3-16 for historical period (1950 – 2019) – current regulation scheme
- Table 3-17 for the present period (2006-2035) – current regulation scheme

2 Urban Systems, Middle Vernon Creek Flood Risk Assessment Study, 2022.

- Table 3-19 for the mid-century period (2041-2070) – modified regulation scheme
- Table 3-21 for the end-of-century period (2071-2100) – modified regulation scheme

The "regulation scheme" refers to the complex system of regulating lake levels throughout the year to prevent flooding while also ensuring adequate water levels for shore spawning, recreation, and general lake health. The "current" scheme refers to how the lake levels are currently managed, while the "modified" scheme refers to a recommended scheme to account for increased inflows in the future due to climate change.

As indicated previously, the lake levels in these tables are based on the Canadian Geodetic Vertical Datum 2013. The conversion factors for the WSC hydrometric station data, however, were originally provided using the Geodetic Survey of Canada datum. For stations that provide conversion factors using both datums, the CGVD2013 levels can be significantly higher than those using the GSC datum – between 0.21 to 0.28 m for the stations listed in Table 1. Therefore, be aware of these differences when comparing water levels from the NHC tables to the WSC values and when applying them to the LiDAR-based DEM.

Table 2 summarizes values from both WSC and the NHC study. Two quantiles were selected for comparison purposes from the NHC study – the 2-year and 200-year return periods. Frequency analyses were not completed on the WSC data, but the recorded low, average, and high values are shown.

Table 2: Water Surface Elevations Summary for Select Conditions

Scenario	08NM067	08NM066	08NM143	08NM083
	Ellison Lake	**Wood Lake**	**Kalamalka**	**Okanagan**
WSC - GSCD				
High	427.040	392.463	392.444	343.245
Average	425.563	391.494	391.083	341.853
Low	424.739	391.186	386.210	341.193
WSC – CGVD 2013				
High	427.318	392.741	392.722	343.453
Average	425.841	391.772	391.361	342.061
Low	425.017	391.464	386.488	341.401
NHC 2-year				
(1950-2019) current regulation	425.830	391.970	391.970	342.670
(2006-2035) current regulation	426.030	391.970	391.970	342.690
(2041-2070) modified regulation	426.250	391.970	391.970	342.530
(2070-2100) modified regulation	426.600	391.970	391.970	342.600
NHC 200-year				
(1950-2019) current regulation	426.610	392.320	392.320	343.040
(2006-2035) current regulation	426.840	392.610	392.610	343.370
(2041-2070) modified regulation	427.280	392.840	392.840	343.480
(2070-2100) modified regulation	427.400	393.480	393.480	344.370

Note: *The values shown in red were approximated using the differences between the CGVD 2013 and GSCD values from the Kalamalka and Okanagan Lake stations. The GSCD* *values have been grayed-out since they are for information only and are not to be used for the ISMP.*

In general:

- The NHC 2-year levels are higher than the CGVD 2013 average values even though a return period of 2.33 years is considered approximately equal to the average.
- The NHC 200-year levels do not typically exceed the CGVD 2013 high values until mid to late century.

This is better illustrated in Figures 3 to 6, which plot the Average and High values from WSC and the 2-year and 200-year values from the NHC study for each of the four stations. The horizontal dashed lines facilitate comparison to the WSC CGVD 2013 values. The WSC GSCD levels are also shown for a visual comparison to the WSC CGVD 2013 levels.

Figure 3: Water Surface Elevations Comparison – Ellison Lake

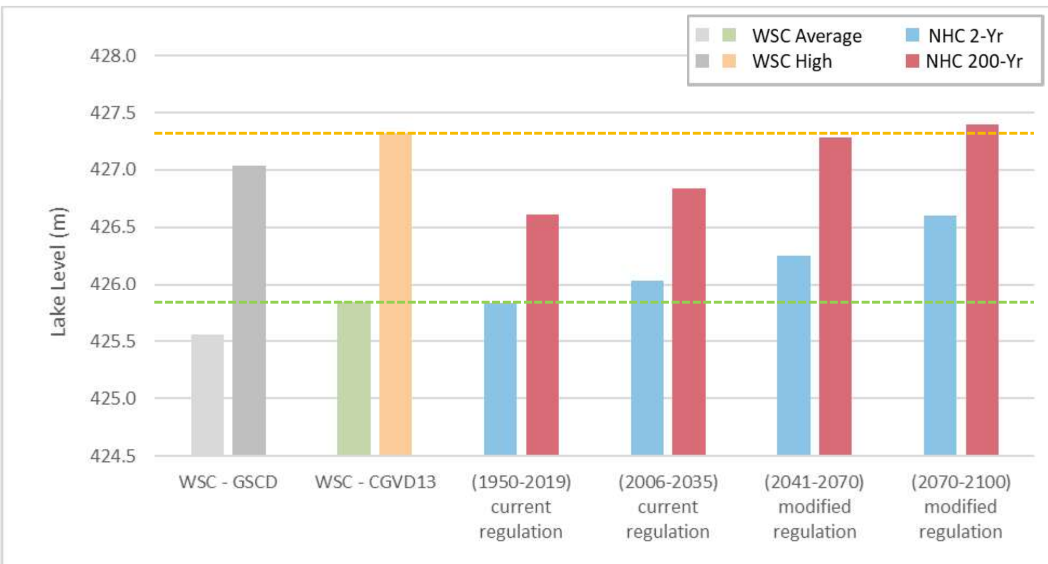


Figure 4: Water Surface Elevations Comparison – Wood Lake

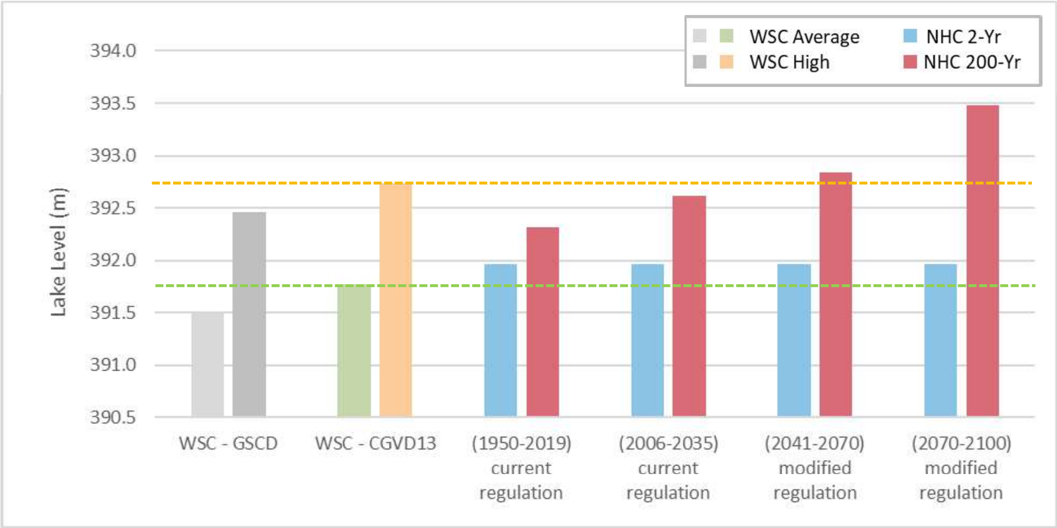


Figure 5: Water Surface Elevations Comparison – Kalamalka Lake

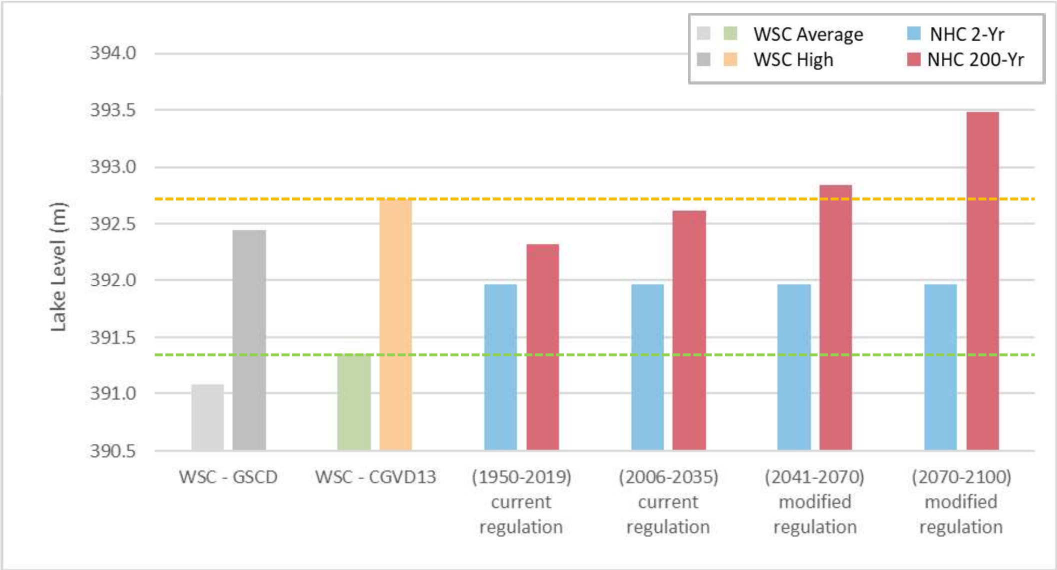


Figure 6: Water Surface Elevations Comparison – Okanagan Lake at Kelowna

4.2 RECOMMENDATIONS

Given that for some of the hydrometric stations, the NHC 2-year levels for the historical and present periods are significantly higher than the WSC CGVD 2013 average levels:

- the WSC average levels should be used for existing conditions modeling with scenarios based on average lake levels.

For modeling scenarios reflecting lake quantile flood levels (200-year for example):

- the NHC levels for Existing, Mid-Century, and End-of-Century conditions should be used.

Since the NHC report considers Wood Lake and Kalamalka Lake to function as a single water body, and since the WSC average level for Wood Lake is higher than that of Kalamalka Lake:

- the Wood Lake WSC average level should be used for both lakes during existing average conditions modeling scenarios.

The recommended levels are therefore summarized in Table 3.

Table 3: Recommended Lake Water Surface Elevations for Modeling

Scenario	CGVD 2013 Elevation (m)		
	Ellison Lake	Wood / Kalamalka Lakes	Okanagan Lake
Average Lake Levels			
Existing Conditions	425.841	391.772	342.061
Mid-Century (2041-2070)	426.250	391.970	342.530
End-of-Century (2070-2100)	426.600	391.970	342.600
100-Year Lake Levels			
Existing Conditions	426.770	392.520	343.110
Mid-Century (2041-2070)	427.220	392.770	343.360
End-of-Century (2070-2100)	427.300	393.340	344.190
200-Year Lake Levels			
Existing Conditions	426.840	392.610	343.370
Mid-Century (2041-2070)	427.280	392.840	343.480
End-of-Century (2070-2100)	427.400	393.480	344.370

APPENDIX A – WATER SURFACE ELEVATION TABLES FROM THE NHC STUDY

Table 3-16 Instantaneous peak lake levels for the Historical period (1950 - 2019) using the standard regulation scenario.

ARI (years)	Instantaneous Peak Lake Levels (m)					
	Ellison[1]	Kalamalka/Wood[2]	Okanagan[3]	Skaha[4]	Vaseux[5]	Osoyoos[6]
2	425.83	391.97	342.67	N/A	328.33	N/A
5	426.05	391.97	342.73	N/A	328.35	N/A
10	426.12	391.98	342.77	N/A	328.42	N/A
20	426.20	391.99	342.82	N/A	328.51	N/A
50	426.32	392.12	342.90	N/A	328.59	N/A
100	426.50	392.21	342.95	N/A	328.65	N/A
200	426.61	392.32	343.04	N/A	328.70	N/A
300	426.68	392.37	343.08	N/A	328.74	N/A
400	426.69	392.41	343.13	N/A	328.77	N/A
500	426.70	392.42	343.18	N/A	328.79	N/A

1. 0.015 m offset applied; used same offset as Kalamalka as no data available for Ellison Lake.
2. 0.015 m offset applied.
3. 0.012 m offset applied.
4. 0.001 m offset applied.
5. 0.01 m offset applied.
6. 0.008 m offset applied; data includes backwater from Similkameen.

Table 3-17 Instantaneous peak lake levels for the Present period (2006 - 2035) using the standard regulation scenario.

ARI (years)	Instantaneous Peak Lake Levels (m)[1]					
	Ellison	Kalamalka/Wood	Okanagan	Skaha	Vaseux	Osoyoos
2	426.03	391.97	342.69	N/A	N/A	N/A
5	426.18	391.98	342.74	N/A	N/A	N/A
10	426.29	392.03	342.81	N/A	N/A	N/A
20	426.51	392.16	342.89	N/A	N/A	N/A
50	426.69	392.35	343.03	N/A	N/A	N/A
100	426.77	392.52	343.11	N/A	N/A	N/A
200	426.84	392.61	343.37	N/A	N/A	N/A
300	426.86	392.66	343.41	N/A	N/A	N/A
400	426.95	392.77	343.45	N/A	N/A	N/A
500	426.95	392.77	343.45	N/A	N/A	N/A

1. Same offsets applied as in Table 3-16.

5.0 CLOSING

We trust that the assumptions and information provided in this technical memo align with the District's understanding of the issues and objectives for the ISMP. Please contact the undersigned if you have any questions, comments, or would like to discuss this topic further.

Sincerely,
URBAN SYSTEMS LTD.

PROFESSIONAL
PROVINCE OF
A. G. ZACHARY
BRITISH COLUMBIA
ENGINEER

2023-01-12

Glen Zachary, P.Eng.
Senior Water Resources Engineer

PERMIT TO PRACTICE
URBAN SYSTEMS LTD.
Signature
Date 2023-01-17
PERMIT NUMBER: 1000527
Engineers and Geoscientists BC (EGBC)

2023-01-17

Marliese von Huene, P.Eng.
Water Resources Engineer (Reviewer)

/agz

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Table 3-19 Instantaneous peak lake levels for the Mid-Century period (2041 - 2070) for the modified regulation scenario.

ARI (years)	Instantaneous Peak Lake Levels (m)[1]					
	Ellison	Kalamalka/Wood	Okanagan	Skaha	Vaseux	Osoyoos
2	426.25	391.97	342.53	N/A	N/A	N/A
5	426.67	391.97	342.71	N/A	N/A	N/A
10	426.84	392.13	342.75	N/A	N/A	N/A
20	426.98	392.30	342.89	N/A	N/A	N/A
50	427.12	392.56	343.10	N/A	N/A	N/A
100	427.22	392.77	343.36	N/A	N/A	N/A
200	427.28	392.84	343.48	N/A	N/A	N/A
300	427.31	392.95	343.55	N/A	N/A	N/A
400	427.32	392.98	343.64	N/A	N/A	N/A
500	427.33	392.99	343.84	N/A	N/A	N/A

1. Same offsets applied as in Table 3-16.

Table 3-21 Instantaneous peak lake levels for the End of Century period (2071 - 2100) for the modified regulation scenario.

ARI (years)	Instantaneous Peak Lake Levels (m)[1,2]					
	Ellison	Kalamalka/Wood	Okanagan	Skaha	Vaseux	Osoyoos
2	426.60	391.97	342.60	N/A	N/A	N/A
5	426.86	392.11	343.04	N/A	N/A	N/A
10	427.02	392.42	343.47	N/A	N/A	N/A
20	427.13	392.75	343.65	N/A	N/A	N/A
50	427.22	393.13	343.98	N/A	N/A	N/A
100	427.30	393.34	344.19	N/A	N/A	N/A
200	427.40	393.48	344.37	N/A	N/A	N/A
300	427.47	393.56	344.51	N/A	N/A	N/A
400	427.48	393.66	344.56	N/A	N/A	N/A
500	427.48	393.87	344.56	N/A	N/A	N/A

1. Same offsets applied as in Table 3-16.

Appendix E – Design Storms

Technical Memorandum

DATE: July 6, 2023
TO: File
FROM: Glen Zachary, P.Eng.
FILE: 1577.0124.01
SUBJECT: District of Lake Country ISMP: Historical and Design Storms

1.0 INTRODUCTION

The purpose of this technical memorandum (tech memo) is to present and document the storms used for the District of Lake Country (the District) Integrated Stormwater Management Plan (ISMP). Some of these storms are historical and were used to calibrate / validate the PCSWMM model. Other storms are synthetic – based on rainfall statistics and appropriate storm patterns – used to stress and/or size the modeled stormwater management infrastructure.

In general, the historical storms were derived from rainfall radar images recorded at the Environment and Climate Change Canada (ECCC) Silver Star station. These images show the rainfall intensities every 10 minutes, and PCSWMM has the functionality to extract rainfall intensity time series for specified locations from these images and generate corresponding hyetographs.

The synthetic, or "design" storms are generated by applying a total rainfall depth obtained from Intensity-Duration-Frequency (IDF) curves for a specific storm duration and return period to an industry standard storm pattern appropriate to the study area. This is explained in more detail in the following sections.

2.0 HISTORICAL STORMS

The storms presented in this section were selected because of the damage done to infrastructure and property by runoff generated during each of them. The anecdotal information regarding each event (discussions with District Staff, photographs, videos, and post-event site inspections) provides a means to estimate flow rates and volumes that can be used to calibrate the PCSWMM model.

Daily / hourly rainfall values from the following climate stations were also reviewed to provide further validation of each event's total rainfall.

Table 2.1: Relevant ECCC Climate Stations

ID	Name	Interval	Elev (m)
1123939	Kelowna	Hourly	433.1
1123996	Kelowna UBCO	Hourly	456.0
1125700	Okanagan Centre	Daily	370.0

2.1 2019-09-11

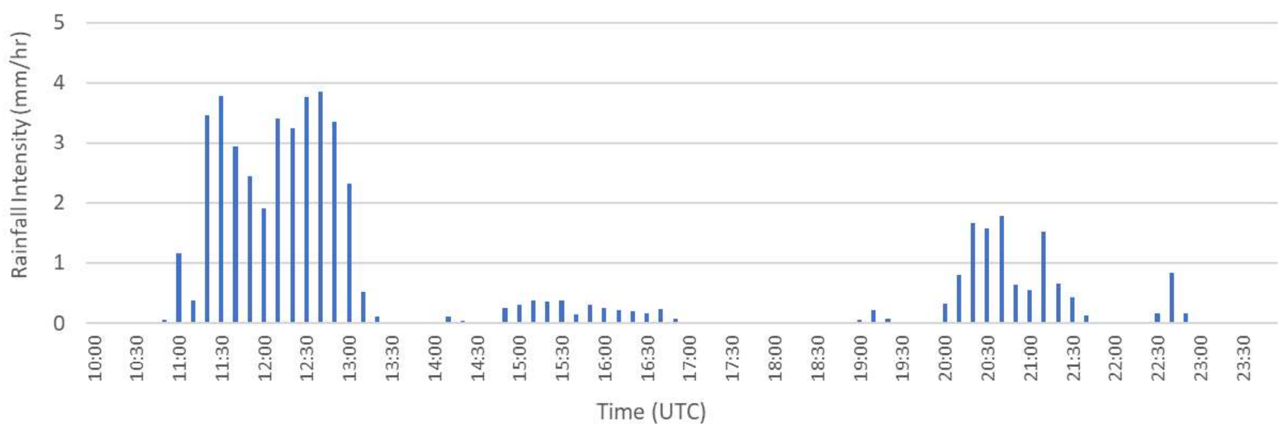
During this event, part of Okanagan Centre Road West (OCRW) north of the Lakestone development was washed-out when runoff overwhelmed the ditch along the east side of the road. The daily rainfall recorded at the three reference climate stations was:

- Okanagan Centre – n/a
- Kelowna – 0.6 mm
- Kelowna UBCO – n/a

Despite these low or unrecorded values, emails and photo metadata show that the washout did occur on this date. Appendix A includes radar images from the Silver Star Mountain station for September 11. They show a very small storm that passed over the study area, which likely missed the climate stations but impacted the study area significantly. Regardless, the stations do agree that prior to September 11, rain occurred every day during the four days preceding the event, dropping approximately 11 mm of rain during that time. This means that the soils surrounding the infiltration systems on OCRW were likely saturated, reducing available capacity for the event storm.

The September 11, 2019, hyetograph was developed from Silver Star radar station images. The more intense part of the storm lasted approximately 2 hours and deposited approximately 9 mm of rain. In terms of total rainfall, the storm's return period was approximately 2 years. In terms of rainfall intensity (10 minute), however, the return period was significantly less than 2 years. Note that the radar image resolution is quite low, so the above estimates reflect significant uncertainty. Also, while some of the image pixels where yellow (intensity ranges from 18 to 24 mm/hr), they may or may not have passed over the subject site). The developed hyetograph is shown in Figure 2.1.

Figure 2.1: 2019-09-11 Hyetograph



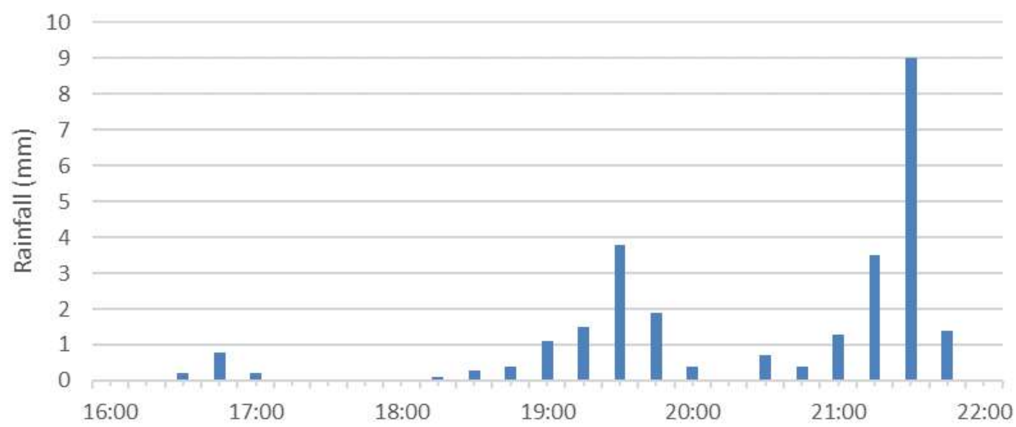
2.2 2020-05-12

During this event, part of Okanagan Centre Road West (OCRW) north of the Lakestone development was washed-out again when runoff overwhelmed the ditch along the east side of the road. The daily rainfall recorded at the three reference climate stations was:

- Okanagan Centre – 27 mm
- Kelowna – 11.3 mm
- Kelowna UBCO – n/a

Unfortunately, the Silver Star radar station was not functioning during this event. Therefore, a hyetograph for modeling purposes was generated using the total precipitation recorded at the OK Centre station, and the hourly data recorded at the Kelowna station (for the pattern). Based on the Kelowna data, the rainfall event lasted for approximately 6 hours. Given the difference in total rainfall for the event recorded at the Kelowna and Okanagan Centre stations, the hourly values were scaled-up by a factor of 2.39 (27.0/11.3). The 15-minute rainfall values for the hyetograph were manually estimated, but still maintain the integrity of the 1-hour rainfall values. Based on the storm duration and total rainfall, this storm had a return period of approximately 25 years. The developed hyetograph is shown in Figure 2.2.

Figure 2.2: 2020-05-12 Hyetograph



2.3 2022-01-12

Despite occurring in January, the recorded precipitation fell as rain because the temperature was above 0.0 deg C. As shown below, the recorded rainfall was significant, but not extremely high.

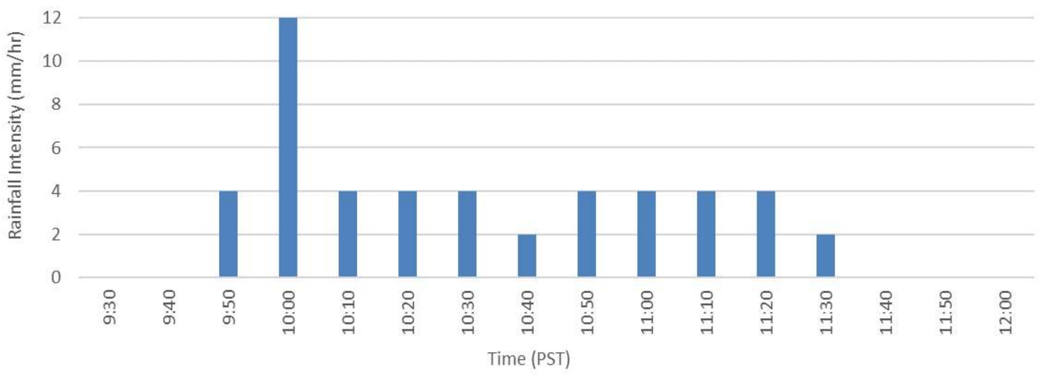
- Okanagan Centre – 12.0 mm
- Kelowna – 7.6 mm
- Kelowna UBCO – 6.6 mm

The event however, triggered several service calls. This could have been due to at least two confounding factors:

- Melting snow – the Okanagan Centre station shows that accumulated snow was on the ground during the event, and
- Frozen ground – the Okanagan Centre station shows that two weeks prior to the event, average daily temperatures were below -10 deg C, sometimes reaching -20 deg C. Although temperatures warmed during the week prior to the event, they were still below 0 deg C.

The hyetograph for the most intense 2 hour portion of the storm is shown in Figure 2.3. This was extracted from the Silver Star Radar data and carries significant uncertainty due to the coarseness of the imaging technology.

Figure 2.3: 2022-01-12 Hyetograph



3.0 DESIGN STORMS

As indicated in the introduction, design storms are generated using a total rainfall depth distributed over the storm duration using a temporal pattern appropriate for the study area. This section presents the method and parameters to be used when calculating rainfall intensities for different combinations of storm duration and return period for both historical (current) and future climate conditions. It also presents the design storm patterns considered appropriate for the study area. All of this information is reflected in the District Stormwater Management Design Guidelines that are to be used in conjunction with Schedule M of the Subdivision Development and Servicing bylaw.

3.1 IDF VALUES

3.1.1 General

Rainfall intensities are typically calculated using Equation 1. This equation is a modification of the two-parameter equation traditionally used by Environment and Climate Change Canada to fit curves to the values generated by frequency analysis. The three-parameter fitting equation tends to fit the frequency analysis results better than the traditional two-parameter equation.

Equation 1: $I = A\,(T+t_0)^B$

Where: I = rainfall rate in mm/hour
T = storm duration in hours
A, B, and t0 = values as specified in Tables 3.1a and 3.2a

3.1.2 Historical Conditions

The values provided in Table 3.1a are based on historical precipitation records from the Kelowna A climate station (ECCC ID 1123970). This station's records span from 1969 to 2004 inclusive (34 years with sufficient useable data). The Gumbel distribution was used for the frequency analysis – the fitted curve equation values were obtained from the IDF_CC Tool (version 6.0). These IDF values should be used to model existing conditions to identify current system deficiencies.

Table 3.1a: IDF Equation Values Based on Historical Data

Variable	Return Period – T (years)					
	2	5	10	25	50	100
A	9.4	13.5	16.2	19.6	22.2	24.7
B	-0.716	-0.771	-0.794	-0.816	-0.829	-0.839
t_0	0.029	0.046	0.053	0.060	0.064	0.067

For convenience, Tables 3.1b and 3.1c summarize the rainfall intensity and total event precipitation respectively for key combinations of storm duration and return period.

Table 3.1b: Rainfall Intensities (mm/hr) Based on Historical Data

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	45.0	65.3	78.8	95.6	108.6	121.1
10 min	30.2	44.5	54.0	65.8	74.9	83.6
15 min	23.4	34.5	41.8	51.0	58.0	64.8
30 min	14.8	21.5	25.9	31.5	35.7	39.8
1 h	9.2	13.0	15.5	18.7	21.1	23.4
2 h	5.7	7.8	9.2	10.9	12.2	13.4
6 h	2.6	3.4	3.9	4.5	5.0	5.4
12 h	1.6	2.0	2.2	2.6	2.8	3.1
24 h	1.0	1.2	1.3	1.5	1.6	1.7

Table 3.1c: Total Event Precipitation (mm) Based on Historical Data

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	3.7	5.4	6.6	8.0	9.1	10.1
10 min	5.0	7.3	8.7	10.6	12.0	13.3
15 min	6.0	8.9	10.9	13.3	15.2	17.0
30 min	7.4	11.1	13.5	16.5	18.8	21.1
1 h	9.0	12.7	15.2	18.3	20.6	22.9
2 h	11.3	15.3	18.0	21.3	23.8	26.2
6 h	15.6	19.9	22.7	26.3	28.9	31.6
12 h	19.4	24.1	27.4	31.3	34.2	37.2
24 h	23.0	28.1	31.4	35.8	38.9	42.0

3.1.3 Future Conditions

The District accepts that climate patterns are changing, and that its residents may be impacted by runoff from more extreme storms, stream and lake flooding, extreme temperature fluctuations, high winds, and wildfires. As per SDDS Bylaw Schedule M, the District requires that the Owner's Engineer consider impacts of climate change when implementing a design - particularly in components where critical and long-term design decisions are being made, or in areas where the consequences of failure are high. The values provided in Table 3.2a were obtained using the IDF_CC Tool (version 6.0) for the Kelowna A climate station, and reflect the following:

- Future period from 2030 to 2100
- Pacific Climate Impacts Consortium (PCIC) bias-corrected ensemble of down-scaled CMIP6 GCMs based on SSP5.85
- GEV frequency distribution

Table 3.2a: IDF Equation Values for Future Climate Conditions

Variable	Return Period – T (years)					
	2	5	10	25	50	100
A	9.9	14.0	17.6	23.4	30.0	38.7
B	-0.686	-0.728	-0.765	-0.819	-0.875	-0.933
t_0	0.015	0.027	0.040	0.062	0.087	0.116

For convenience, Tables 3.2b and 3.2c summarize the rainfall intensity and total event precipitation respectively for key combinations of storm duration and return period as calculated using the values in Table 3.2a.

Table 3.2b: Rainfall Intensities (mm/hr) for Future Climate Conditions

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	48.6	69.7	87.3	113.6	141.2	174.3
10 min	31.9	46.3	58.8	78.3	99.6	125.8
15 min	24.6	35.6	45.4	60.7	77.7	98.9
30 min	15.6	22.3	28.2	37.5	47.8	60.8
1 h	9.8	13.7	17.1	22.3	27.9	34.9
2 h	6.1	8.4	10.2	12.9	15.8	19.2
6 h	2.9	3.8	4.4	5.3	6.2	7.1
12 h	1.8	2.3	2.6	3.0	3.4	3.8
24 h	1.1	1.4	1.5	1.7	1.9	2.0

Table 3.2c: Total Event Precipitation (mm) for Future Climate Conditions

Event Duration	Return Period – T (years)					
	2	5	10	25	50	100
5 min	4.1	5.8	7.3	9.5	11.8	14.5
10 min	5.3	7.7	9.8	13.1	16.6	21.0
15 min	6.2	8.9	11.3	15.2	19.4	24.7
30 min	7.8	11.2	14.1	18.8	23.9	30.4
1 h	9.8	13.7	17.1	22.3	27.9	34.9
2 h	12.2	16.7	20.4	25.9	31.5	38.5
6 h	17.3	22.7	26.7	32.1	37.1	42.9
12 h	21.6	27.5	31.5	36.5	40.7	45.3
24 h	26.8	33.2	37.1	41.5	44.5	47.7

Table 3.2d illustrates the projected changes to rainfall intensities in the future. Note that the greatest changes are projected to occur for shorter duration storms with higher return periods.

Table 3.2d: Differences Between Future and Historical Intensities

T (years)	2	5	10	25	50	100
5 min	8%	7%	11%	19%	30%	44%
10 min	6%	4%	9%	19%	33%	50%
15 min	5%	3%	9%	19%	34%	53%
30 min	5%	4%	9%	19%	34%	53%
1 h	6%	5%	10%	19%	32%	49%
2 h	8%	8%	11%	19%	29%	43%
6 h	11%	12%	15%	19%	24%	31%
12 h	14%	16%	17%	18%	20%	24%
24 h	16%	19%	19%	18%	17%	16%

The CSA Group published guidelines for interpretation and use of IDF curves, including a method to adjust values for projected climate change (CSA, 2019). It is a simplified method based on the Clausius-Claperyron (CC) method which considers atmospheric moisture-carrying capacity as a function of temperature. Essentially, as the atmospheric temperature rises, it can carry more moisture, inferring greater rainfall when it occurs. Equation 2 is recommended by CSA as a means of estimating the change to rainfall intensities in the future.

Equation 2: $R_p = R_c \times (CC_{adj})^{\triangle T}$

Where: R_p = projected rainfall intensity (mm/hour)
R_c = current or historical rainfall intensity (mm/hour)
$\triangle T$ = projected change in temperature, or $T_{projected}$ - $T_{current}$ (°C)
CC_{adj} = adjustment factor calculated as 1+CF, where CF (change factor) is location dependent

The projected changes to average annual temperature for the District were obtained from Climatedata.ca[1], and are summarized in Table 3.3. The $CC_{adj}^{\triangle T}$ values corresponding to the indicated change in average temperature are also shown in Table 3.3 and were obtained from The Pacific Climate Impacts Consortium (PCIC) Design Value Explorer using Kelowna as the closest available location to the District of Lake Country.

Table 3.3: Clausius-Clapeyron Precipitation Adjustment Factors

Period	$T_{average}$ (°C)	$\triangle T$	$CC_{adj}^{\triangle T}$
Current	7.2		
2021-2050	9.3	2.1	1.212
2051-2080	10.9	3.7	1.404
2081-2100	12.5	5.3	1.626

The CC method shows that rainfall intensities are expected to increase by approximately 21% by mid-century and by 63% by the end of the century. Note that this method does not differentiate between durations and frequencies – the projected increase is applied uniformly to intensities corresponding to all combinations of duration and frequency. This approach does confirm, however, that the larger changes projected by the IDF_CC Tool for shorter duration and less frequent events may be reasonable. For the purposes of the ISMP, we have chosen to use intensities calculated using Equation 1 with values from Table 3.2a

3.2 STORM PATTERNS

Stormwater management system component sizing is sensitive to the combination of a rainstorm's volume and peak intensity – essentially its hyetograph. Conveyance component capacity tends to be more sensitive to intensity while storage component capacity tends to be more sensitive to rainfall volume. To ensure that each proposed component is adequately sized to meet the District's design objectives, four design storms are defined for use with the PCSWMM model(s). Each storm has a duration of 24 hours and is defined by a unique combination of return period and hyetograph time interval. Shorter time intervals yield higher peak rainfall intensities, while longer time

[1] ClimateData.ca was created through a collaboration between the Pacific Climate Impacts Consortium (PCIC), Ouranos Inc., the Prairie Climate Centre (PCC), Environment and Climate Change Canada (ECCC) Centre de Recherche Informatique de Montréal (CRIM) and Habitat7.

intervals yield lower peak rainfall intensities. Each design storm is to be developed using the appropriate IDF values for the given scenarios.

Table M-4 in SDDS Bylaw Schedule M specifies inlet times for different return periods and land uses. Based on this, Table 3.4 summarizes the differentiating characteristics of each storm.

Table 3.4: Design Storm Characteristics

Storm ID	Return Period T (years)	Hyetograph Time Interval (min)	Land Use
1	10	15	SF Residential
2	10	10	MF Residential, Industrial, Commercial, Institutional
3	100	10	SF Residential
4	100	5	MF Residential, Industrial, Commercial, Institutional

All four storms are to be created using the **Chicago Method**, with the peak intensity occurring at **16 hours (2/3 of the storm duration)**. The Chicago Method was selected for the following reasons:

- the hyetograph values can be calculated using the variables provided in Tables 3.1a and 3.2a (historical and future climate),
- the peak intensity equals the IDF intensity for the duration corresponding hyetograph time interval,
- the total storm depth equals the IDF depth for the corresponding storm duration and return period,
- extreme rainfall in the Okanagan is historically generated by convective storms, which generally reflect the shape of a Chicago Storm, and
- as the climate continues to change, more extreme convective storms are anticipated, which are likely to reflect a Chicago Storm-shaped hyetograph even more than they have historically.

The specified design storms are suitable for most design purposes. However, simulation of large watersheds or complex drainage systems may require:

- delayed starting times for adjacent catchments to simulate a storm moving through the full study area,
- extended duration storms, or
- continuous rainfall data.

REFERENCES

CSA Group (CSA), CSA PLUS 4013:19 Technical guide: Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners, 2019.

Pacific Climate Impacts Consortium (PCIC), Design Value Explorer, https://pacificclimate.org/analysis-tools/design-value-explorer

Simonovic, S.P., A. Schardong, R. Srivastav, and D. Sandink (2015), IDF_CC Web-based Tool for Updating Intensity-Duration-Frequency Curves to Changing Climate – ver 6.0, Western University Facility for Intelligent Decision Support and Institute for Catastrophic Loss Reduction, open access https://www.idf-cc-uwo.ca.

Urban Systems Ltd., Lakestone Stormwater Management Comprehensive Review, prepared for the District of Lake Country, December 2021.

4.0 CLOSING

This technical memorandum was prepared to document data sources, assumptions, analyses, and methods used to develop the historical and design storms for the District's Integrated Stormwater Management Plan. It was prepared and reviewed by the following Urban Systems staff.

Sincerely,
URBAN SYSTEMS LTD.

Glen Zachary, P.Eng.
Senior Water Resources Engineer

Marliese von Huene, P.Eng.
Water Resources Engineer (Reviewer)

/agz

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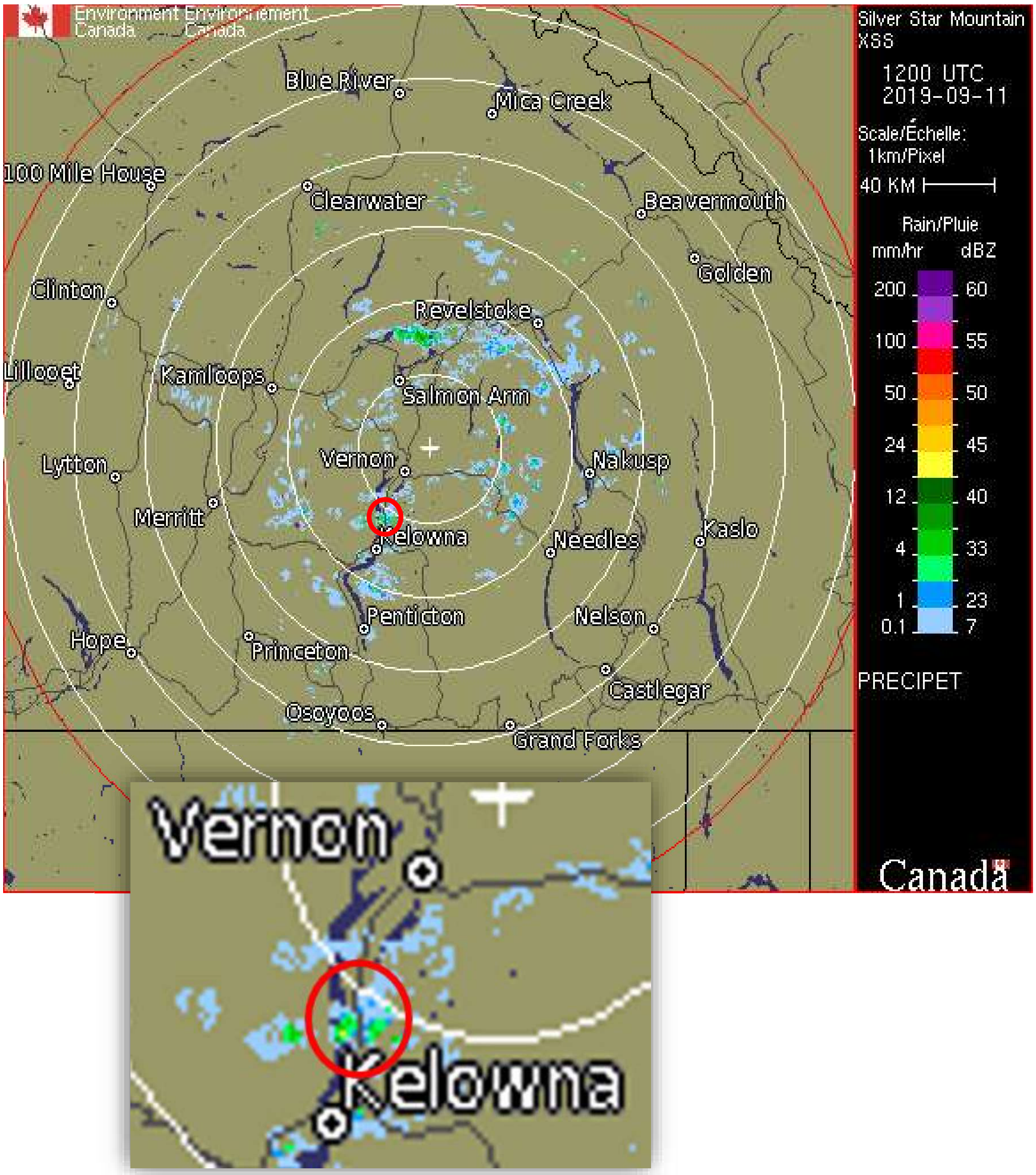
URBAN SYSTEMS MEMORANDUM

APPENDIX A – SILVER STAR MOUNTAIN RADAR IMAGES

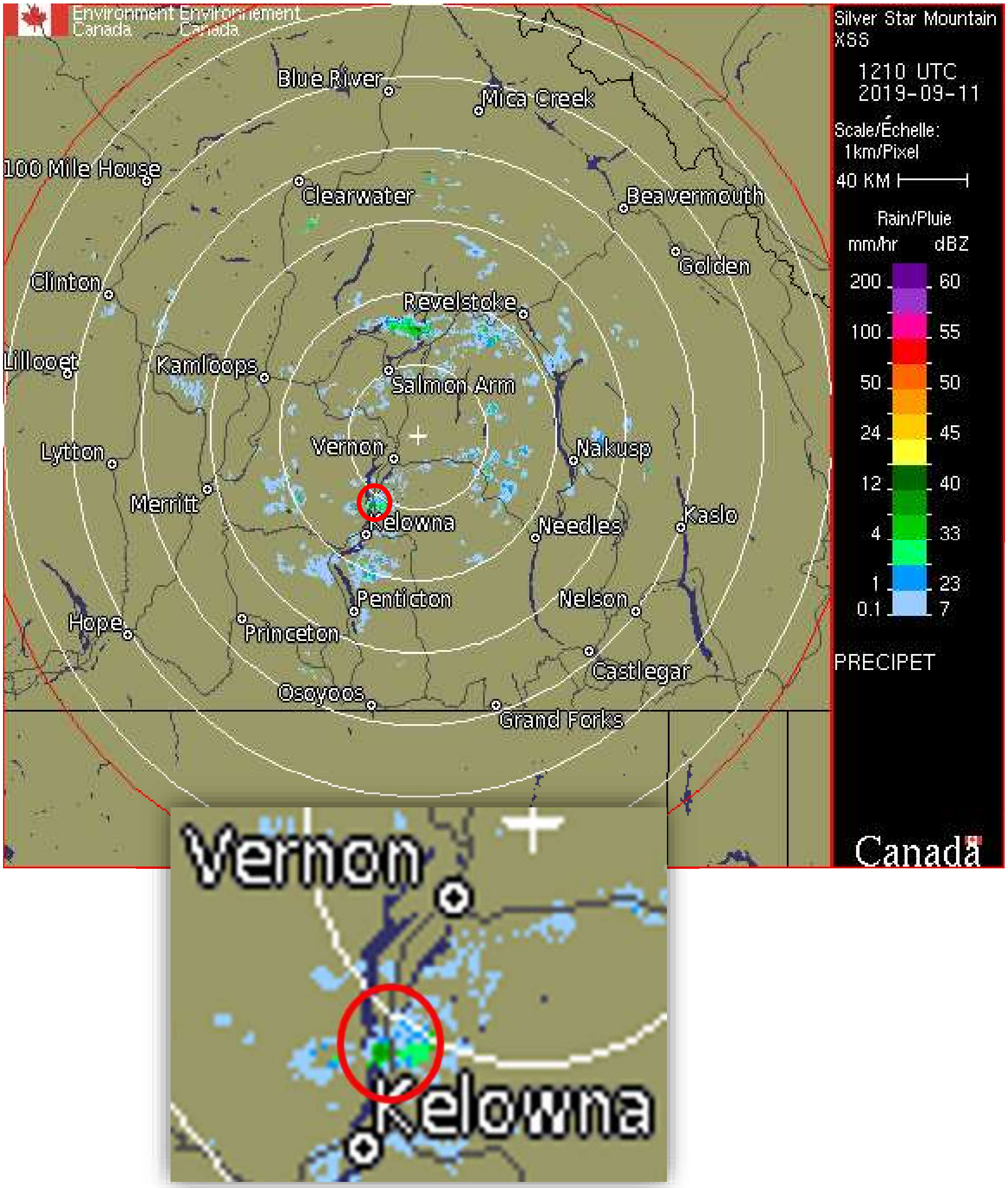
PRECIPET - Rain - 2019-09-11, 05:00 PDT, 7/13



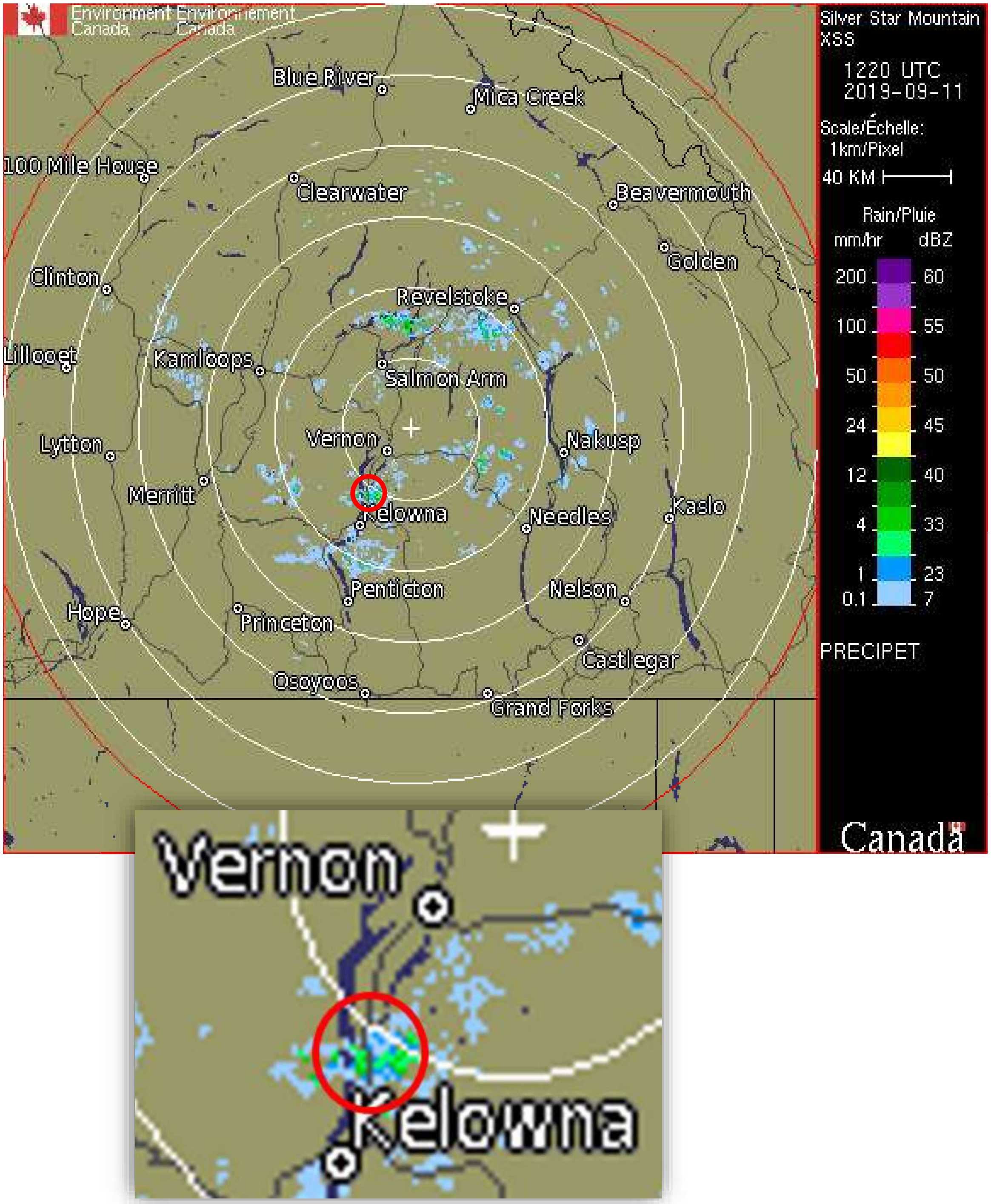
URBAN SYSTEMS MEMORANDUM

DATE: July 6, 2023 FILE: 1577.0124.01 PAGE: 13 of 20
SUBJECT: District of Lake Country ISMP: Historical and Design Storms

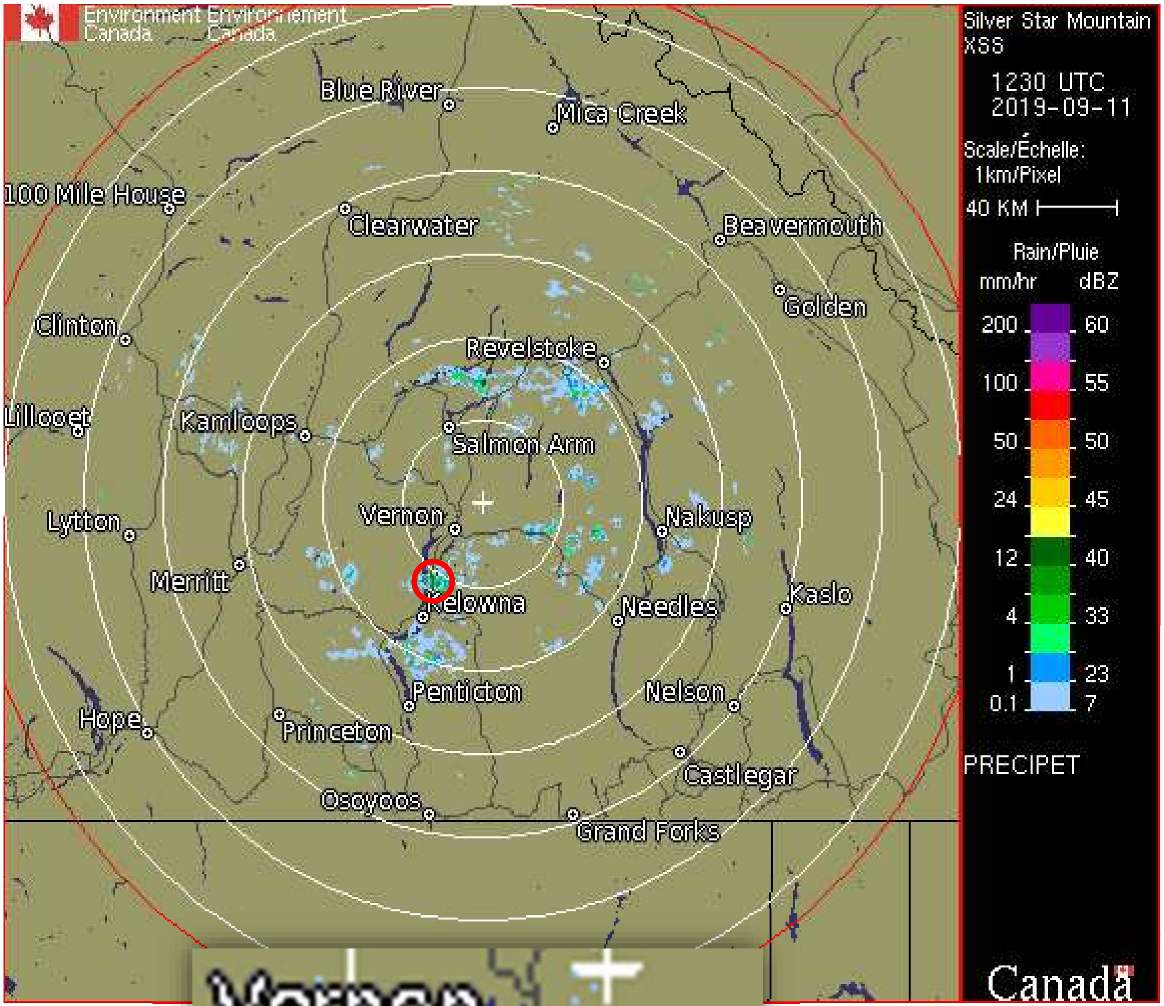
PRECIPET - Rain - 2019-09-11, 05:10 PDT, 8/13



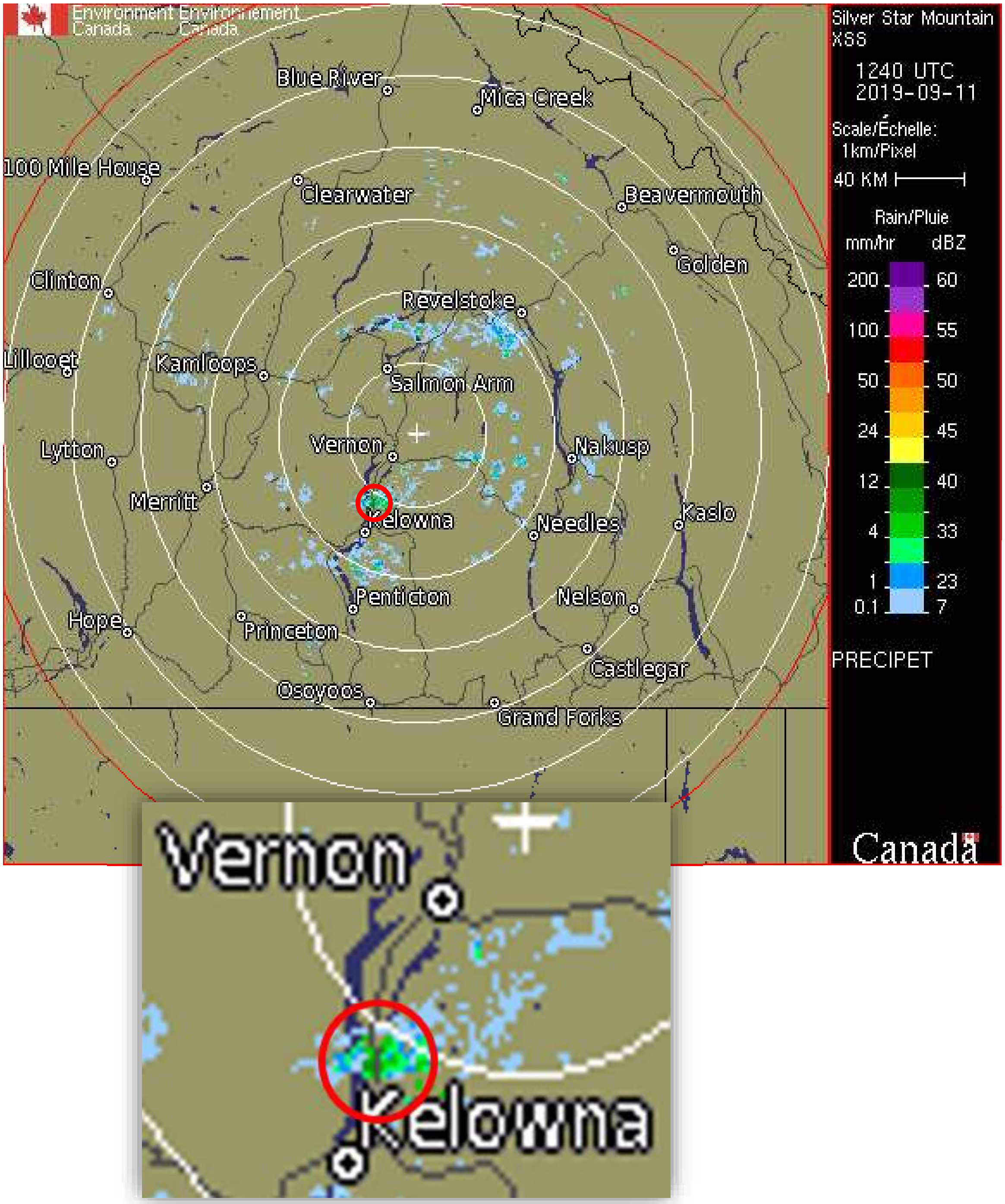
PRECIPET - Rain - 2019-09-11, 05:20 PDT, 9/13



PRECIPET - Rain - 2019-09-11, 05:30 PDT, 10/13



PRECIPET - Rain - 2019-09-11, 05:40 PDT, 11/13



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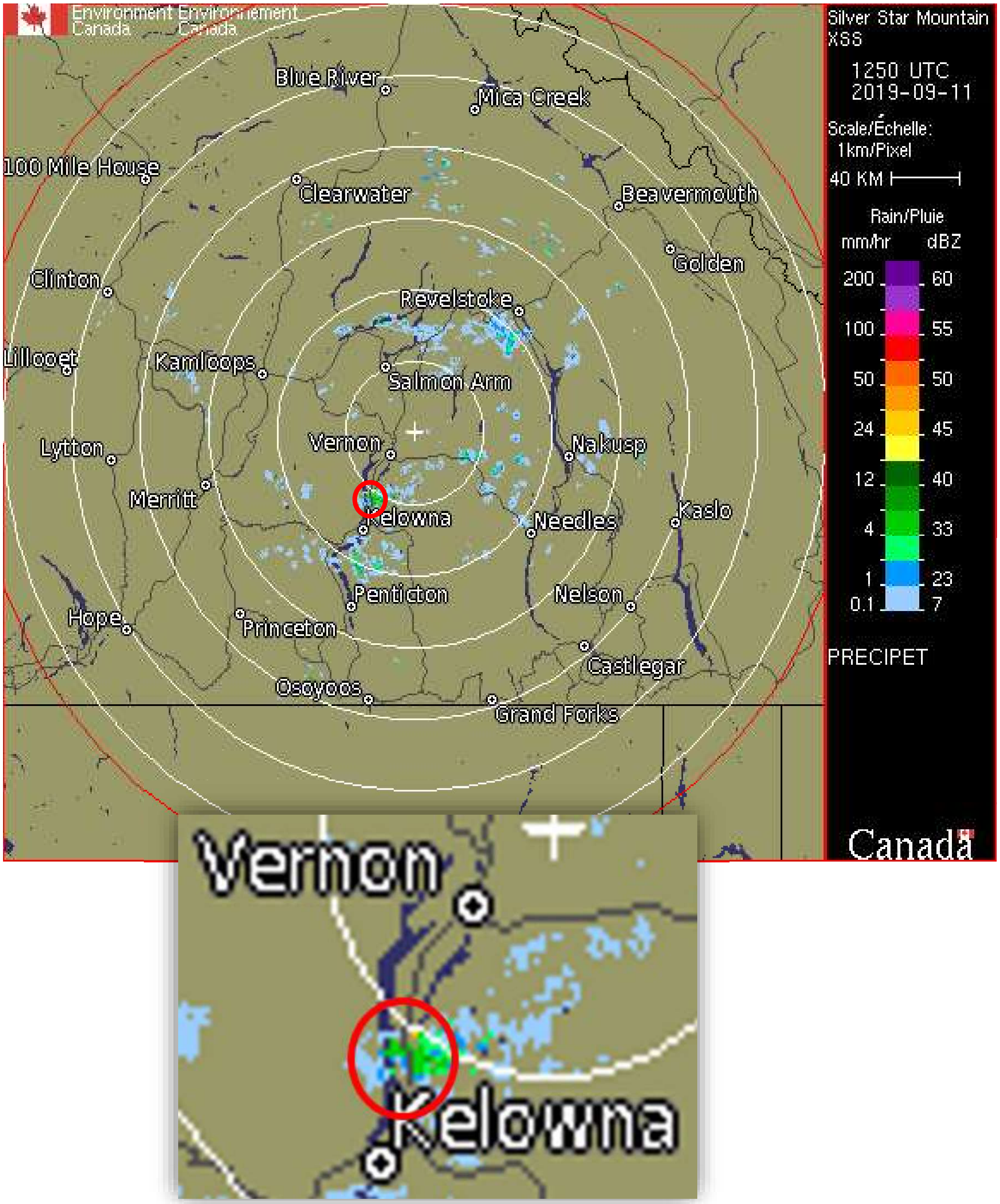

URBAN SYSTEMS Technical Memorandum

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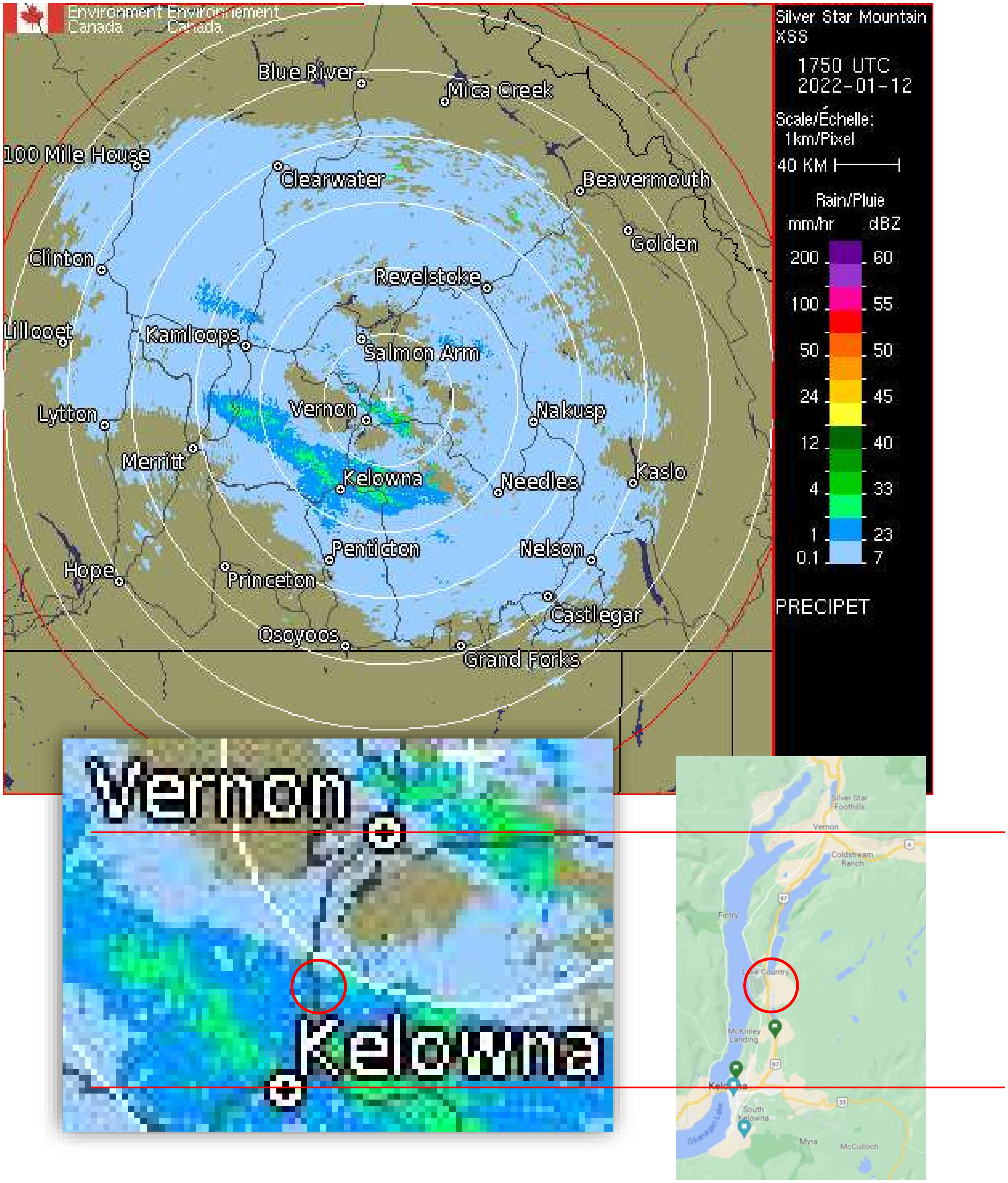

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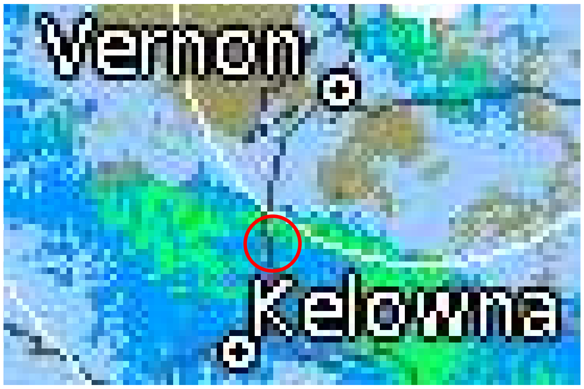

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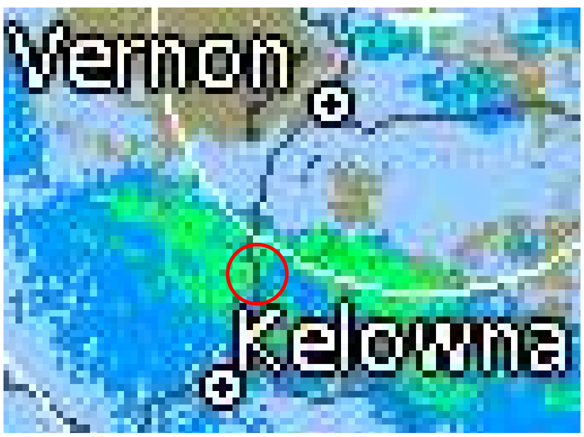

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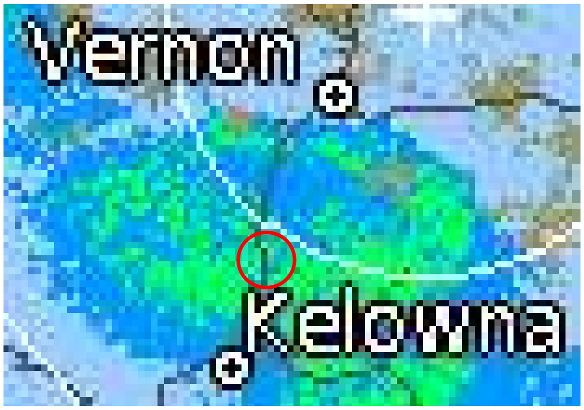

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Appendix F – Model Development

URBAN SYSTEMS

MEMORANDUM

DATE: December 5, 2023
TO: File
CC: Glen Zachary, MASc, P.Eng.
FROM: Taylor Swailes, P.Eng.
FILE: 1577.0124.01
SUBJECT: Model Building Assumptions

1.0 INTRODUCTION

This technical memo summarizes the details and assumptions used to build the PCSWMM model that underlies the risk assessment in Phase 1 of the Integrated Stormwater Management Plan (ISMP).

2.0 MODEL DEVELOPMENT

2.1 WHY DUAL DRAINAGE: RATIONALE AND METHODOLOGY

1D dual drainage models significantly advance the benefits drawn from stormwater simulations. Whereas conventional 1D stormwater models only model pipes, and therefore do not account for how runoff behaves on the surface, in a 1D dual drainage model, storages and flow paths are allowed to spill and cascade into one another: this approach more closely mimics actual drainage patterns.

The District's 1D dual drainage model better represents the interactions between the major and minor system which yields significant advantages over traditional models, namely:

- Historic pipe-only models struggled to represent both interception capacity and pipe capacity and how these two factors relate in the pipes and on the surface, unlike dual drainage models.
- In a dual drainage model - all flows and volumes in the system are tracked through the entire study area, and water is not lost when the minor system floods to the surface. This allows for accurate simulation of diverging major and minor flow paths.
- Dual drainage models provide high accuracy along every flow path, making it easier to pinpoint areas of risk to private property and the public.
- Future scenarios, idea-testing, added assets, and land developments can be added to the dual drainage model with greater accuracy which translates to better-defined capital projects and better trouble shooting. Municipalities with 1D dual drainage models are known to check ponding levels adjacent to existing properties, boundary conditions of concern (for example lake or creek levels), and any cumulative downstream impacts from proposed developments during design and approvals.

To date, through the District of Lake Country (the District) ISMP, the biggest advantage of these models has been easier communication with Public Works staff and the engineering team, facilitated by the interactive dashboard which can display model results and risk scores alongside other GIS layers such as infrastructure and planning and hydrogeology information. This helps present a more complete picture of how the system functions.

The model build process, including assumptions for the District of Lake Country, are outlined in the sections below.

2.2 MODEL ASSUMPTIONS

This section describes the assumptions that are used to develop the District's PCSWMM model, and how different parts of the dual drainage system are represented in the model.

There are three core parts to building the 1D-1D (1D Minor System, 1D Major System) dual drainage model:

1. Building the major system (overland) network
2. Building the minor system (underground) network
3. Connecting the major and minor systems.

Note on terminology:

Categorizing drainage infrastructure by the major or minor system is used because it guides how infrastructure performance is evaluated in the model, and is designed (i.e., is the asset type expected to convey the 10-year storm or 100-year storm).

The terms major system and minor system are used in different ways by different authors. Typically, the minor system is meant to refer to the system that drains the minor storm event (i.e. the 10 year storm) and the major system refers to the system that provides emergency conveyance when the minor system capacity is exceed, typically in the case of a major event (i.e. 100 year storm). In areas with fully urbanized curb-and-gutter drainage, this means that the underground system (pipes, manholes, and catchbasins) makes up the minor system, while the overland (surface of the road, stream channels) makes up the major system.

However, in mixed drainage areas (e.g. roadside ditch and culvert), like Lake Country, this distinction gets blurred: since the minor storm drains through the roadside ditches, the ditches can be referred to as part of the minor system. On the other hand, during a major storm event, excess runoff still travels through the same ditches (unlike in curb-and-gutter systems, where the pipe is full and major event runoff gets directed down the road, a completely different flow path).

Therefore, for simplicity and consistency, this report and model adopts the position that the major system simply means "overland system" and the minor system simply means "underground infrastructure". More specifically, all pipes and culverts are part of the minor system, even if they are conveying a large amount of flow (e.g. where a creek is piped underground), and all ditches are part of the major system, even if they also convey runoff from the minor design storm. This varies from some existing uses of the terms, but is an intentional decision to move towards a realistic and impact-based design criteria (e.g. towards designing infrastructure based on metrics such as "no overland ponding in the 10 year storm and no flooding causing risk to public safety or private property damage in the 100 year storm").

2.2.1 Building the Major System Network

2.2.1.1 LiDAR

The major system is delineated primarily using ArcHydro, a plugin for Arc GIS Pro, which can determine flow direction, accumulation, ponding, and catchments based on the LiDAR surface. This requires a high-resolution LiDAR surface to have the best possible chance of catching small flow paths or obstructions, such as curbs.

LiDAR was provided as part of the District's GIS, in 20 cm, 50 cm, and 1 m rasters, and compared to LiDAR BC. It was then processed and where needed, catchment features were added to improve accuracy or capture surface features that did not translate from LiDAR (for example, some areas around Middle Vernon Creek where the trees obscured the stream channel). Note that smaller or roadside ditches were not burned into the LiDAR, as most of these were either already captured in the LiDAR surface or were too small to contain any significant amount of flow without spilling, therefore having a negligible impact on model accuracy during design storm events. Similarly, no curb lines were burned into the LiDAR. Although there are some roads in the district with a curb, most roads either did not have a curb, had a curb but it was already captured on LiDAR, or had a curb that was poorly defined or frequently interrupted by driveways or other breaks. As with the roadside ditches, this assumption means the model may not capture the exact path of flow at a very small scale, but should have a negligible impact when considering general catchment areas and higher flows which occur during design storm events.

2.2.1.2 ArcHydro Delineation

Arc Hydro was then used to find all depressions in the LiDAR surface, which are local low areas where flow must pond up to the area's spill elevation before being able to continue further downstream (note that this is purely based on topography, not actual flow volumes during any particular storm event). These depressions were screened to remove spurious small depressions that were the result of noise in the LiDAR surface, or had a negligible catchment area or volume (e.g. potholes).

Next, the spill point of each depression was identified, as well as the corresponding downstream flow paths. These flow paths were allowed to follow the LiDAR surface, and were not constrained to particular channels or to the road right-of-way. This assumption means that the model correctly accounts for locations where flow spills out of the road right-of-way (ROW) and through private property. Note that there is a chance that the LiDAR surface misses a curb due to resolution; to address this, the flow paths were reviewed manually and spot checked throughout the catchment against aerial photos and Google Streetview. Overall, it appeared that flow paths were correctly following the road in most cases. The only cases where this was not the case was when the road had a small (several centimetres high) or poorly defined (breaks, poor condition, or driveway entrances) curb; during small storm events flow would be expected to follow this curb, but in large storm events it would likely be overtopped quickly, so the LiDAR-based delineation is appropriate.

2.2.1.3 Incorporating catchbasins, Silt Traps, and Other Connections

The next step is to incorporate any place in the storm drainage system where flow can transition back and forth between the major and minor systems. There are multiple different types of storm infrastructure in this category, such as:

- Catch-basins
- Silt traps
- Grated top manholes
- Headwalls
- Culvert ends

There are two different ways that these types of infrastructure can function in the model, which for the purpose of this model will be called *inlets* and *daylights:*

Inlets are places where the flow transition between the major and minor system is limited in rate by a grate, orifice, or some other physical constraint.

Daylights are places where flow transitions between the major and minor system freely, only limited by the hydraulics of the pipe and channel.

Overall, capturing inlets and daylights in the model plays a key role in accuracy and understanding major and minor system performance.

By their nature, many of these inlets and daylights are in locations that have already been identified as depressions in the ArcHydro delineation and are given a depth-capture curve. Because the District does not have empirical capture curves for their catchbasins, curves from the City of Calgary are used since the dimension and configuration of catchbasins in both Calgary and the District are similar.

For any that are not in depressions, this means that they are in a *flow-by* condition (e.g. a catch-basin on a continuous grade, that captures part of the flow as it goes by, as opposed to a catchbasin in a local low point, which captures everything and is only limited by the head pressure of ponded water on top of it). The catchments or flow paths that are intercepted by each flow-by was determined, and these catchments were split out of the catchments previously delineated to depressions using ArcHydro. Finally, and the depressions, flow-by's, and spill paths were connected together and formed into a single dendritic network.

2.2.1.4 Importing the Major System to PCSWMM

The major system flow network was then imported into PCSWMM to form the major system model. PCSWMM *storage* nodes were used to represent all of the depressions, with functional stage-area-volume curves calculated to match each individual depression's total volume and surface area at its spill depth. *Storage* nodes were also used to represent any of the flow-by's, but with an arbitrary small surface area; this is primarily for model stability and smoothing compared to using *junctions*. This has minimal impact on accuracy because the average storage is small, and the release rate is not constrained.

Next, PCSWMM *conduits* were used to represent all of the flow-paths from depression spill points and flow-by's. Wherever two flow paths met, *junctions* were used to join them together. As the flow paths in the District were primarily spilling off of the road, over the curb (as opposed to along the road gutter), a typical 5m wide by 0.5 m deep triangular transect was used for the conduits, representing typical flow through grass ditches or low points in fields. Larger flowpaths were modelled using trapezoidal cross sections, with 5:1 side slopes, and the bottom width sized to keep the flow depth at 0.5 m to prevent the model from erroneously assuming large pressure buildups in the open system. Calculation of individual transects for each flow path conduit based on the LiDAR surface was attempted but the LiDAR was found to have too many areas of noise or artifacts (e.g. from tree and building removal, crops, or very flat terrain), so the resulting transects were unreliable, and a global simplifying assumption was considered to be more appropriate. Finally, a series of cleaning steps were performed, including checking for any spurious negative slopes resulting from errors in the LiDAR surface, and combining very small conduits for model stability.

Figure 1 below is an example of the Major System in PCSWMM. Note, depressions show the maximum extent of ponding at their spill elevation, not the ponding during a specific design storm event. Each depression is represented by the “storage” node at its spill point. Subcatchments are delineated to each depression, or each inlet which is not in a depression. Inlets and depressions are connected by conduits representing flow paths between them.

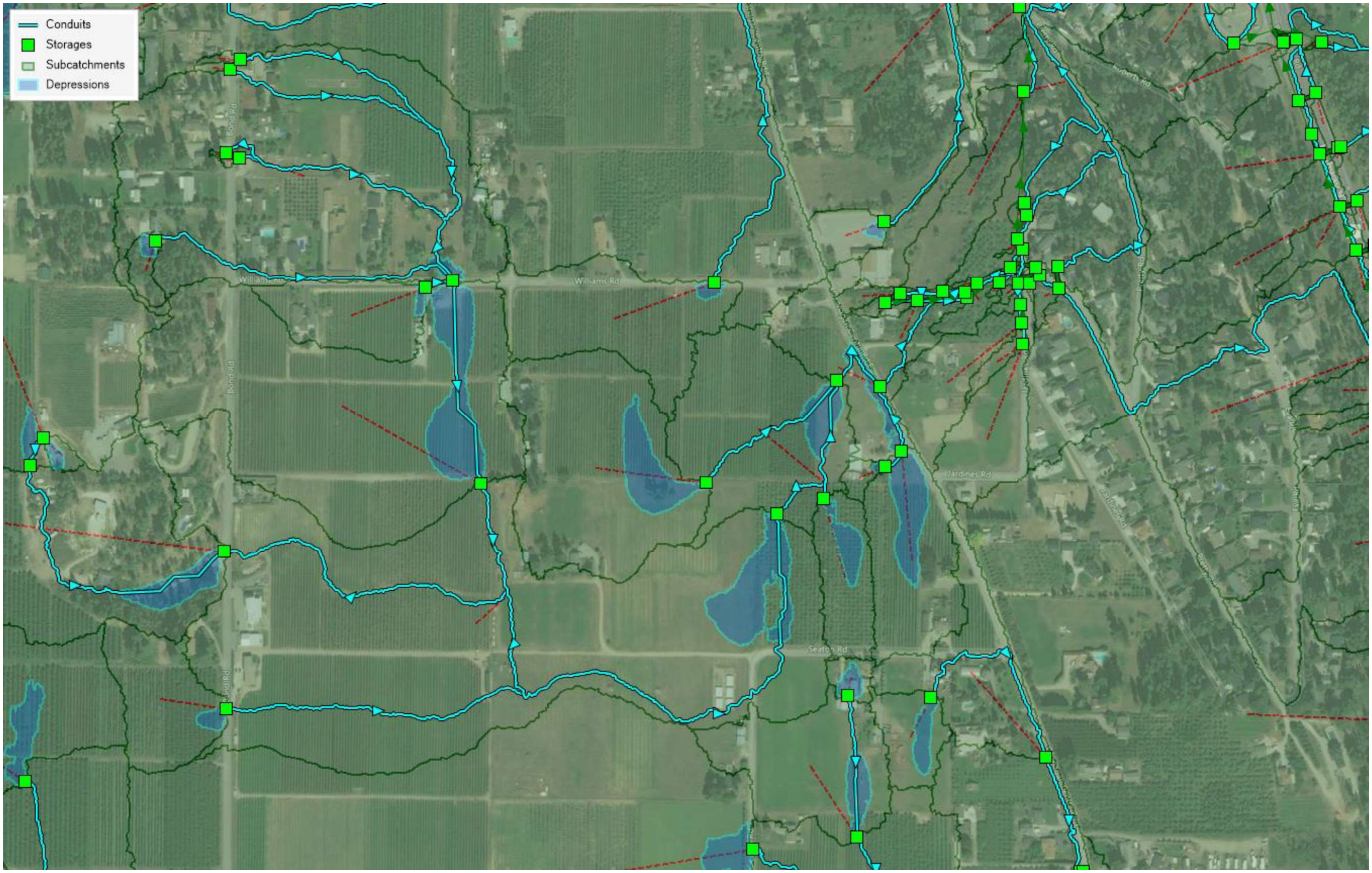

Figure 1: Example of the Major System in PCSWMM.

2.2.2 Building the Minor System Network

2.2.2.1 Data Cleaning

The minor system network was reviewed, and data gaps were cleaned, based on global assumptions. Due to the large size of the study area, checking individual infrastructure through field visits or survey was beyond the scope of the initial model build and risk assessment; in the future Phase II, select locations that are deemed to be high risk or otherwise important will be checked manually.

During the data cleaning process, select infrastructure was also removed to simplify the model while retaining the most important characteristics. For example, there were some communities where individual driveway culverts were identified on GIS. However, not all such culverts were identified, and many of them were incorrectly located when compared to the LiDAR and Aerial imagery. Additionally, even where driveway culverts were documented, there is no way to know whether homeowners are maintaining them properly (a review of Google Street View and several site visits suggested that a large portion of these culverts are grown over or simply filled in by residents who do not understand their purpose). In the majority of cases, removing these from the model resulted in flows spilling over the same driveways and collecting in the same locations downstream; therefore, this simplification means the model may be inaccurate at a high level of detail (individual lots), but still correctly accounts for flow and volume at larger scales.

Cleaned elements are noted with attributes in the model; it is not practical to list every element or cleaning process here, but examples of infrastructure that was examined, and general assumptions made during cleaning are provided below:

- Catchbasins
  - All existing catchbasins were imported; removed ones that were tagged “proposed”.
  - Manually added CB’s along the highway, as these are MOTI and did not appear in the District’s GIS
- Drywells
  - Drywells were not consistently identified in the GIS layers, and had to be inferred based on proximity to catchbasins, then further manually checked based on aerial imagery and connection to the main (if connected to a main near others with CBs, it was also assumed to not have grated inlet and not included on this layer).
  - The drywells layer itself does not contain a tag for whether it has a grated top or not.
  - Drywells were also inferred from the CB layer, because many CB’s had text “comment” notes identifying whether they were associated with a drywell; it was not made clear in these notes whether this meant the CB itself had an open bottom or whether there was an adjacent drywell structure nearby. Some of both were found. It is strongly recommended to avoid the use “comment” attributes on GIS layers, as the way different pieces of infrastructure were marked in this field was very inconsistent.

- Storm Mains
  - Missing inverts inferred from adjacent inverts or the ground surface.
  - Dead ends checked for whether there were grates or outfalls that weren't provided on other GIS layers.
  - Removed mains that were tagged "proposed".
  - Other cleaning had to do with elements in the storm mains layer that were believed to be culverts; see below.
- CB leads/Storm Laterals
  - Imported CB leads into the model as storm mains if they were culverts (based on corrugated metal material and location) or if they were the only drainage conveyance (e.g. from CB's with daylights into the nearest slope).
  - Removed laterals that were tagged "proposed".
- Manholes
  - Rims checked or inferred against LiDAR.
  - Inverts set to match the lowest connecting pipe, or an average depth for Manholes in the area if the connected pipes were missing inverts.
  - Removed manholes that were not connected to a storm main, lateral, or in proximity to a CB, unless it appeared to be a drywell based on location (e.g. in a ponded area).
- Headwalls and outlets
  - Elevations checked against LiDAR, and locations tied to the nearest identified overland flow path.
- Connections, Fittings, and Caps
  - Checked for whether they should actually be considered as a manhole.
- Culverts
  - This was the most challenging infrastructure type in terms of cleaning, because there were culverts identified on different layers (e.g. some of them also appeared on the storm mains or storm laterals layers). Where two culverts overlapped exactly, they were assumed to be duplicates and removed. However, some locations had two culverts which were drawn in slightly different locations (sometimes on two different layers), and it wasn't clear whether this represented a twin culvert, whether one was a replacement for the other in time, or whether this was a duplicated piece of infrastructure. If it wasn't clear that one was redundant, both culverts were kept in the model.
  - Driveway culverts were removed, as per the example above. This was primarily done by filtering out any culverts/mains/storm laterals less than 450 mm in diameter, except for culverts on significant flowpaths.
  - Culverts were also snapped to the nearest ditch or low point based on the LiDAR surface.

- Storage tanks (holding structures)
    - Checked for existing vs proposed tags.

2.2.2.2 Import to PCSWMM

The minor system was then imported to PCSWMM. PCSWMM's *junctions* were used for manholes and other minor system structures, while *conduits* were used for the pipes. Entry and exit loss coefficients of 0.5 and 0.2 were assigned on all pipes to be conservative when accounting for the mixture of physical conditions expected from a system which was built up over time (e.g. retrofit or repaired pipes, or overbuild manholes, which are typically not benched or aligned as well as prefabricated manholes and connections in new construction). Roughness coefficients were assigned based on the pipe material. Manhole rims were adjusted to match the LiDAR layer, as these typically were not complete in the GIS. Some short conduits were combined for model stability if they had the same size and slope (this is typically due to alignment constraints or overbuild manholes for private sites, leading to two manholes very close together). Where conduits had very different slopes, such as the flat ends at outfalls, the original geometry was maintained for accuracy. Overall, these adjustments have negligible impacts on model results yet greatly improve the stability of the model, allowing for faster runtimes and easier model adjustments, which in turn allows multiple scenarios to be developed quickly and effectively.

2.2.3 Combining the Major and Minor System

2.2.3.1 Connectivity

The final step in creating the dual drainage model is to tie the major and minor system together using inlets and daylights. This process is described below for both features:

- Where there was an **inlet** (e.g., catchbasins and grated top manholes), PCSWMM's *outlet* links were used to connect the *storage* node representing the surface above the inlet to the *junction* representing the nearest manhole. These *outlet* links were then assigned stage-capture curves based on whether they were in a ponding condition (e.g., a catchbasin in a depression) or in a flow-by condition. Both ponding and flow-by curves were based on City of Calgary K3 type catchbasins, because they have similar dimensions and configurations to the District's catchbasin, and have empirical capture curves which are not available from DLC. The *outlet* curves are configured to allow flow in both directions, so that flow can come back up out of catchbasins if a system is heavily surcharged, as it would in reality.
- In PCSWMM, **daylights** (e.g., pipe outfalls and culvert inlets or outlets) do not need an additional model element; the *conduit* representing the minor system pipe is simply joined directly to the *storage* node or *junction* representing the end of the major system flow path, where the daylight is located. PCSWMM then calculates flow transitioning between the major and minor systems dynamically based on the hydraulic grade line (HGL) in both systems, and inlet and outlet losses.

2.2.3.2 Subcatchment Parameters

The final step is to assign subcatchment parameters and the rest of the global parameters.

- The subcatchment imperviousness was area-weighted based on the land cover map, generated using aerial imagery (2020) and LiDAR (2018).
- Slope was calculated based on the LiDAR surface, with a 10 m smoothing radius applied to reduce the impact of noise in the LiDAR.
- Manning's *n* values and depression storage were chosen based on standard values from the SWMM manual.
- Green-Ampt infiltration parameters were area-weighted for each catchment based on the infiltration potential map created by Waterline Resources.

Figure 2 shows an example of the major and minor system tied together in PCSWMM. Pipes and manholes are represented with PCSWMM conduits and junctions. Outlets are used to represent catchbasin capture, separated into flow-by and ponded inlets based on whether they are in a depression.

Figure 2: Example of Major and Minor System Tied Together in PCSWMM.

2.2.4 Assumptions and Limitations

2.2.4.1 GIS Accuracy

The primary limitation of any large GIS-based model, whether it is dual drainage or pipe-only, 1D or 2D, is the accuracy of the GIS data. Due to the overall size of the study area, it is not possible to individually review every component in the model against design drawings, as-builts, and field information.

There were a series of checks conducted to review the GIS as much as practicable. These include the data filling assumptions described above, as well as spot checks using Google Streetview. A number of pattern-based checks were conducted, such as reviewing the density of catchbasins and manholes, to attempt to spot any areas which may have missing data. Additionally, conductivity checks were conducted to ensure that all the minor system components had downstream drainage paths and to spot any likely locations of culverts or other infrastructure not captured in GIS.

Despite these checks, it is possible that there are elements of the drainage system which are still missing from the model, simply because they were not captured in any of the GIS layers. This is especially likely for portions of the drainage system which are on private property, or rely on private infrastructure, which the District may not be aware of or may not keep in their GIS because it is not their responsibility to maintain. It is not possible to determine how the inclusion of private infrastructure would change modelling results due to the variety of infrastructure which could be in place and unknowns around its maintenance status. Therefore, it is recommended that instead of attempting to incorporate all private infrastructure into the District's GIS system, model accuracy should be addressed by comparing the model to known problem areas, and checking/adjusting the model against observations after large events in the future, so that the model gets better over time without the impracticable upfront cost of surveying all private infrastructure.

2.2.4.2 Level of Detail

Another fundamental limitation of the model is the resolution of data used for the major system delineation. This process was based on 0.5 m LiDAR which was reviewed and found to be very good quality. Flow lines from ArcHydro were spot checked as well as discussed with District staff and appear to be very accurate overall. In places with well-defined curb and gutter, the LiDAR appeared to catch them correctly, based on review of Streetview, Aerial, and ArcHydro Data, even with the 0.5 m spacing, because the road crown and sidewalk or boulevard cross-slope was still captured.

However, there are unavoidable uncertainties with delineation based on LiDAR. There is always noise (random small errors) in the LiDAR surface, which can cause the flowpath delineated with ArcHydro to appear to meander more than it does in real life, at a small scale (several metres). It is also possible that there are very small elements redirecting flow that did not get captured because of the LiDAR resolution, e.g., a small curb to deflect water that is less than 0.5 m wide, and not supported by the boulevard grading. Additionally, at an individual property level, homeowners often use small elements such as landscape bricks or drainage pipe to redirect flows, which is not possible to capture in LiDAR.

These uncertainties do not typically impact model results as they only redirect flow a short distance, i.e., it is unlikely that these kinds of elements redirect flow completely to a different street or catchment, so the location of the flowpath may be shifted by a few metres but the amount and timing of flow will be generally unaffected. This may, however, result in a building being flagged as “at risk” from overland spill contacting them, when in reality there is a safe swale, curb, pipe, or landscaping element directing flow around the building. Therefore, it is important to confirm these kinds of risk areas identified by the model with site visits and/or anecdotal observation to confirm they are a real risk, and the best way of mitigating them. These site visits, for select high risk areas, are planned as part of Phase II.

2.2.5 Discussion and Future Use of the Model

The fundamental limitations in LiDAR and GIS accuracy discussed above means that the model accuracy declines when zooming in to a very specific area (e.g. flow within an individual yard). However, the overall flow paths, directions, and magnitudes, especially for larger flow paths or for flow accumulated over more than several lots, are considered reliable and match observed data well. For example, small-scale redirection of flow, such as a homeowner placing a small curb or landscape feature, is likely to redirect flow only a short distance, and not significantly change the overall catchment area or flow accumulation downstream. Therefore, when designing the downstream trunk, the correct amount of flow is accounted for whether the landscape feature is modelled or not.

This means that the model is suitable for assessing pipe capacities, as well as overland flow rates, locations, and associated risks. However, lot-level details such as risk areas that are identified based on locations where flow paths contact buildings, should be confirmed in the field or with local knowledge prior to designing solutions because it is possible that small scale infrastructure, such as homeowner landscaping, has been used to redirect flow slightly. For example, if the District wishes to establish easements on private property to cover overland flow paths, the exact location of the flow path should be confirmed in the field through survey (or a high-resolution drone-flown LiDAR) because small details could mean the flow path is shifted several metres from where the model shows it (but the model is suitable to provide the general location and magnitude of the flow path to show specific spots where this increased level of study may be warranted).

In general, it is not cost effective to create lot-level accuracy across a study area of this size. Doing so would require much higher resolution (cm) LiDAR, which has a large cost due to the increased flight time. Additionally, at this level of detail, there can be rapid changes which mean the model would still require field verification (e.g., an individual homeowner is free to change their landscaping at will, with few constraints). Therefore, we recommend it is better to compare the model to observations and improve it over time, as this already provides much greater resolution than was previously known about the system.

Overall, we have worked with the District to identify known problem areas and to seek feedback on whether the model results generally reflect the behaviour of the system as staff understand it from field visits and service calls. This confirmation by staff, in combination with the calibration results, means that the model is appropriate to use for estimating risk areas across the District, as well as designing priority project upgrades, as long as the assumptions above are considered during design.

Additionally, the model is made to be adaptable and extensible by using standard components within SWMM, and modelling individual pieces of physical infrastructure (as opposed to modelling large abstract catchments and flow curves, that are hard to modify later without re-examining the model building assumptions). This means that if a localized area is found in the model that doesn't match the District's experience or site-specific information, it can be corrected within the model to make the specific site results more accurate. Generally, these localized improvements to the model are unlikely to impact the overall conclusions (main flow paths, risk areas, and pipe sizes outside of the immediate study area) that have been based on it, because the total cumulative flow is still accounted for. If there is a change as a result of more accurate details in a local area of the model, the holistic nature of the model allows the impact of that change on the rest of the system to be evaluated for decision making, in a way that is not possible with typical modelling approaches.

Because of this, it is recommended that the model be considered an ongoing tool, that can be adjusted and refined to become more accurate over time with continued use and additional field information. There are several ways the model can be used:

- When responding to service calls or known problem areas, the model can be checked to identify whether the problem was predicted. This can be used to refine the model further. If the problem was predicted, the model can show whether it is due to surface flow, surcharge in the pipes, lack of interception capacity, or another issue, to quickly focus on the root cause of the problem.
- The model can also be used to review development applications, because it provides a holistic estimate of the flows and remaining capacities in each pipe, as well as any surface flows through or near the target site, that must be accommodated in a post-development scenario.
- Any future projects or changes due to development can be directly added to the model based on the physical layout of the proposed infrastructure, with *storages* and *outlets* used to represent any proposed storage or ponding, *subcatchments* divided or altered to represent change in land cover, and *conduits* and *junctions* used to represent any new manholes or storm mains. This will allow the impact of the proposed change to be analyzed on the entire storm system, including the downstream major and minor systems all the way to the ultimate outfall, without requiring individual projects to remodel a large offsite system.

3.0 CLOSURE

This memorandum summarizes the process and assumptions made to build the District-wide dual-drainage model in PCSWMM. This model provides the District with a significantly improved understanding of the drainage system and risk areas, which are incorporated into the ISMP Dashboard. There are some limitations, discussed herein, which will be partially addressed with site visits and site-specific model upgrades as part of the future Phase II. The other limitations can be addressed over time based on comparing specific aspects of the model with the District's experiences. This model is intended to be on ongoing tool that the District can utilize for infrastructure upgrades, development reviews, and responding to service calls.

Sincerely,

URBAN SYSTEMS LTD.

Taylor Swailes, P.Eng.
Hydrologic Engineer

Glen Zachary, P.Eng.
Senior Water Resources Engineer (Reviewer)

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Appendix G – Risk Assessment

TECHNICAL MEMORANDUM

URBAN SYSTEMS

DATE	November 29, 2023	FROM	Taylor Swailes
TO	File	FILE	1577.0124.01

SUBJECT ISMP Risk Assessment

1.0 BACKGROUND

This memo outlines the methodology and results on how risk was identified for the District of Lake Country's major drainage system. For the context of this project, the major system is defined as overland flow paths and corresponding surface depressions. Some overland flow paths are designed (road, swale), others are natural (gulley, ravine), and others are unintended. Overland flow paths take over when the minor (piped) system has failed, or when no minor system is available. The goal is to assign a risk score to each overland flow path as an indicator of overall stormwater system function. The minor system is not specifically given scores in the mapping presented here, though the overland flow scores do assume that the existing minor system is functioning. Where overland flow is seen coinciding with piped infrastructure, the model is indicating that the piped infrastructure does not have enough capacity and that overland flow is likely to occur. Therefore, overland flow risk scores are a useful indicator of overall stormwater system function and can help narrow the focus for future capital project identification.

The methodology (**Section 2.0**) is broken down into two parts: an assessment of the likelihood of flow path activation, and an assessment of the consequence of flow path activation. The resulting risk scores described in **Section 3.0**, will be used to inform a prioritized capital works plan for stormwater management infrastructure. Higher likelihood and consequence of activation scores are associated with higher risk.

Parts of the District's infrastructure systems are strategically designed as overland flow routes. The occurrence of overland flow is not necessarily a failure in and of itself. Different instances of overland flow can result in different liabilities to the District, based, for example, on whether the flow is within a private or public corridor. One instance is where flow escapes from a public corridor and enters private property, which may create a liability for the District. Another is where flow remains within a public corridor. This too may cause some liability but is more important from a public safety perspective than a property damage perspective. These different scenarios may impact the final decision on which high risk flow paths are addressed as future capital projects. Note that this risk assessment is a qualitative tool to establish a risk ranking for further analysis and assessment. It does not represent legal advice - the District should seek legal counsel for any liability concerns related to stormwater management.

Our approach was to apply risk scores to flows associated with both public and private corridors; to be discussed in more detail with the District in future detailed risk assessments completed on a "primary catchment" basis.

2.0 METHODOLOGY

Model Setup

Using the LiDAR data provided by the District, two datasets were created: depression storage areas (depressions in the LiDAR surface with contributing areas greater than $100m^2$ that would hold a volume of water greater than $5m^3$), and overland flow paths (a linear network that shows the path water would take should it travel over the ground surface). Flow paths are initiated at the spill point of each depression storage area, and from each catch basin in the piped system. To remove insignificant potential flow paths as defined by LiDAR, flow paths were required to have flows greater than 0.001 m^3/s for durations above 30 minutes in the model to be included in the risk assessment.

The flow paths and depressions were modeled using PCSWMM. The model also included existing drainage infrastructure (culverts, storm sewers, manholes, drywells, catch basins, detention tanks, and lift stations). Several scenarios – combinations of design storm and land use - were developed to stress the system. The scenarios included the following combinations:

1. Existing land use with a 1:10 year (minor) current climate design storm
2. Existing land use with a 1:100 year (major) current climate design storm
3. Future land use with a 1:10 year (minor) future (2040-2070) climate design storm
4. Future land use with a 1:100 year (major) future (2040-2070) climate design storm

The following section describes how flow paths were ranked according to likelihood and consequence of activation to reach a risk score.

Likelihood of Activation

For this analysis, we have considered the return period of a storm as a proxy for overland flow path likelihood of activation. The return period of a storm, for example 1:10 years, is more appropriately stated as “a rainfall event with a 10% chance of occurrence in any given year”. Similarly, a 1:100 year storm is “a rainfall event with a 1% chance of occurrence in any given year”. These chances of occurrence are used in computing relative risk. Therefore, we have assessed which flow paths are activated under different return periods to assign a likelihood score. Note, these modeled scenarios do not include the impact of groundwater springs since no spring flow rate information is available.

Using the results of the dual drainage PCSWMM model, we analyzed all flow paths in public corridors that were activated during each scenario. In some cases, flow paths were activated (flooding through catch basin or spillover of depression storage area) and the flow path remained active all the way to a receiving water (lake or watercourse). In other cases, the activated flow path was re-captured by storm infrastructure (minor system) or a surface depression with remaining capacity and was terminated at that location.

The Likelihood of Activation score for each flow path, based on return period, is shown in **Table 1**. All scenarios are run under existing infrastructure conditions, but future models include climate change and expected OCP land use changes.

Table 1: Likelihood of Activation

Likelihood of Activation	Classification
3	Flow path active for 1:10-year current climate
2	Flow path active for 1:10-year Year 2040-2070 climate OR Flow path active for 1:100-year current climate
1	Flow path active for 1:100-year Year 2040-2070 climate

Modified Likelihood Score

The likelihood of an overland flow path causing damage increases in tandem with an increase in flow rate. After reviewing the model results, we realized that greater differentiation was needed between flow paths that conveyed the minimum amount of flow (0.001 m^3/s for at least 30 minutes) and flow paths conveying significantly greater amounts. Risk scores were modified to reduce the likelihood of activation scores for flow paths conveying less than 0.01 m^3/s, as outlined in **Table 2**. For example, if a flow path was active during the 1:10-year current climate and condition event it received a base score of 3. However, if its peak flow was less than 0.01 m^3/s, it was reduced to a score of 2.

Table 2: Modified Likelihood Score

Score Modifier	Classification
Decrease score by 1	If flows less than 0.01 m^3/s for a duration of at least one minute

Consequence of Activation

The consequence of activation is based on the overland flow path route, and the various types of consequences that might occur as a result. Consequence of activation was assessed based on current zoning, road priorities, buildings, and critical infrastructure, as per **Table 3**. To determine which flow paths are considered to be too close to buildings or critical infrastructure, an offset of 2 m on either side of the flow path was used; this is what is referred to as the "flood buffer zone" in the table below.

Table 3: Consequence of Activation

Consequence of Activation	Classification
5	Only triggered with score modifier (multiple risk conditions exist)
4	Buildings with the following actual use[1] that are within the flood buffer zone: • Commercial • Industrial and Utility • Non-residential Strata • Multi-family zoning Or critical infrastructure that is within flood buffer zone
3	• Single family buildings that are within flood buffer zone (includes acreage/farms/vineyards) • Flooding on mobile home strata parcel (These parcels typically don't have individual building footprints delineated but spacing between buildings is typically tight, so any flow through it could cause damage)
2	The following actual uses[1] that are within the flood buffer zone: • Private property (but not in proximity to building) • Civic parks and open spaces (including future "Parkland – Conservation")
1	Flow path stays within public road corridors

Modified Consequence Score

The consequences score was further modified by considering the priority layer of any impacted road corridors. For example, flow that impacts buildings or critical infrastructure, and additionally impacts a major road, was considered to have a higher consequence then flow which only impacts buildings, or only impacts roads. Additionally, flow across major roads was considered to be a higher consequence then flow across minor roads, which had the lowest base consequence score. For this ranking, the District's snow plough priority layer was used, rather than the road classification, as this layer has been made by the district considering real-world impact factors such as whether a road accesses a school, whether it has a steep slope, and whether it's the only access to a group of properties.

Score Modifier	Classification
Increase by 2	• Flow on a priority 1 road
Increase by 1	• Flow on a priority 2 road

[1] GIS attribute "actual_u_1"

Risk Score

All flow paths were assigned an overall risk score. The risk score combines the likelihood of asset activation and the consequence of activation into a single 1 to 15 rating. A risk score of 15 represents the highest risk and a score of 1 the least risk. **Table 4** correlates the consequence and the likelihood of activation to the risk score. Note that a score of 3 or 5 represents a "special case" since it is either a high consequence with low likelihood, or high likelihood with a low consequence. Flow paths with a risk score of 3 (consequence is 1) or 5 require additional assessment with respect to prioritization.

Table 4: Risk Score

Likelihood \ Consequence of Activation	1	2	3	4	5
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

3.0 EXISTING SYSTEM FLOW PATH RISK SCORES

The methodology described in Section 2.0 was applied to the overland flow paths using spatial analysis tools in ArcGIS Pro. Figure 1 shows the results of the risk assessment across the study area.

A few high-level observations of the mapping include:

- High risk flow paths (red) are consistently seen where flow is not given a defined path (according to the District's GIS data and LiDAR)
- Woodsdale, Lakestone, and Cadence at the Lakes developments appear to have significant flow approaching the neighborhood minor systems from the undeveloped upstream hillsides. It appears that runoff is prone to flowing between homes in these areas due to insufficient capture and shallow surface flow routes.
- Further confirmation is recommended, whether onsite assessment or discussion with District staff that have observed large storm events in the area.

Table 5 summarizes the risk scores within the study area. Flow path risk scores are summarized by length (kilometers) and count. The term "count" refers to each individual flow path segment, not a single flow path from origin to destination. Flow paths are segmented at each intersection with another flow path or a roadway.

Table 5: Risk Score Summary

Risk Score	Length (km)	Count
Low (1,2,3)[2] – Dark Green	415	2542
Special Case (3, 5)[3] – Light Green	351	2318
Moderate (6, 8, 9) – Yellow	64	346
Moderate-High (10, 12) - Orange	25	124
High (15) – Red	18	50
Total	**873**	**5380**

4.0 FUTURE RISK ASSESSMENT CONSIDERATIONS

In future risk assessments for more specific locations in the District, there may be additional scenarios that should be considered beyond the criteria listed here. Some of these scenarios have been listed for consideration:

Once primary catchments have been prioritized for additional study:

- Zoning should be examined in more detail by the District, to ensure scores are not being over- or under-valued based on the “actual_u_1” attribute that was used for this study.
- Zoning of “Civic-Recr” land should be examined in more detail, and possibly modified for consequence of activation for school or hospital land uses.

This current risk assessment will be used to prioritize primary catchments for further detailed analysis that will inform recommendations for capital works as part of the Integrated Stormwater Management Plan (ISMP). Given that the District’s GIS has some gaps with respect to existing infrastructure, and that zoning / future land use data are generalized and carry uncertainty, the risk assessment results should be carefully reviewed by District Staff. This is especially true for areas where concerns already exist.

[2] A risk score of 3 is considered “Low” risk when the Likelihood score = 1 and the Consequence of Activation = 3.

[3] A risk score of 3 is considered a “Special Case” risk when the Likelihood score = 3 and the Consequence of Activation = 1.

5.0 CLOSING

We trust that this risk assessment will be useful to better understanding drainage risks to the District and look forward to reviewing it with you and your team at the upcoming workshop.

Note that Figure 1 is also available on the ISMP Dashboard, which you have access to, under the "Risk Assessment" tab. This will allow you and your staff to review the results in more detail. Clicking on any of the flow path segments will open a pop-up window that shows the corresponding likelihood, consequence, and risk scores.

Sincerely,

URBAN SYSTEMS LTD.

TSwailes

Taylor Swailes, P.Eng.
Hydrologic Engineer

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Appendix H – ISMP Dashboard (Web-based Maps)

Technical Memorandum

DATE: July 6, 2023
TO: File
FROM: Glen Zachary, P.Eng.
FILE: 1577.0124.01
SUBJECT: District of Lake Country ISMP: Dashboard Interactive Maps

1.0 OVERVIEW

Given the large amount of information generated to inform the District's Integrated Stormwater Management Plan (ISMP), an ArcGIS "dashboard" was developed to manage and present it digitally and interactively. A dashboard is a web-based tool provided by ESRI, a leading geographic information system (GIS) software company. It allows users to create interactive and dynamic maps to visualize and analyze spatial data collaboratively in a centralized manner. Dashboards are customizable and can include maps, charts, graphs, tables, and other tools to present and understand geographic-based information.

The ISMP Dashboard is comprised of eleven maps. Each map reflects a theme and includes one or more layers that can be displayed or hidden according to the user's requirements and preferences. Some maps include tables and/or charts that summarize select information about the data presented. Some of the data layers may be displayed on more than one map to help provide context to better understand the primary data presented.

Sources for the data presented in the ISMP Dashboard are referenced in the ISMP Phase 1 report.

2.0 DASHBOARD MAPS

Each of the eleven maps in the ISMP Dashboard are described in this section. This includes a list of the layers, their significance, and descriptions of the corresponding attributes.

OVERVIEW

This map shows the ISMP study area in terms of jurisdiction, key stakeholders, and previous work done in relation to stormwater and flood management. Available data layers are summarized in the following table.

Data Layer	Description
Administrative Boundaries	Shows the boundaries of the local governments adjacent to the District of Lake Country
Regional Districts	Same as the Administrative Boundaries, but outlined only because of each polygon's size
MoTI Roads	Shows the key roads through the District which are owned and maintained by the Ministry of Transportation and Infrastructure

Data Layer	Description
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.
Previous Studies	Shows the extents of previous studies which provide context for the ISMP. Clicking on a study polygon opens an attribute window showing the study's name, author, and publication year.

CATCHMENTS

This map shows the primary drainage catchments which outlet to one of the key receiving waters. While most of the primary catchments are defined by topography and outlet location, those bordering a lake typically include several smaller sub-catchments which outlet individually to the lake. This artificial amalgamation of smaller, independent sub-catchments was done to limit the number of total catchments for discussion and refence purposes. Available data layers are summarized in the following table.

Data Layer	Description
Administrative Boundaries	Shows the boundaries of the local governments adjacent to the District of Lake Country
District Boundary	Emphasized polygon showing the extents of the District
Receiving Waters - Streams	The lakes which receive surface runoff are clearly shown in the background map – this layer shows the two key streams which also function as receiving waters – Middle Vernon Creek and Winfield Creek
Outlets - Primary Catchments	The dots show the location where runoff from each primary catchment is discharged, or *assumed* to be discharged, to a receiving water. Primary catchments which border a lake may have several unique outlet locations as evidenced by the Surface Flow Paths. However, for discussion and reference purposes, each Primary Catchment is assumed to have only one outlet.
Surface Flow Paths	Flow paths based on Digital Elevation Model generated from LiDAR. Shows where surface runoff would flow if culverts and drainage infrastructure were not functioning.
Primary Catchments	Areas that flow to, or are assumed to flow to, the Outlets on the receiving waters. Clicking on a polygon in this layer opens a window which displays select attributes. These are as follows: • Catchment name • Area (hectares) • Weighted average Percent Impervious - total impervious surface divided by catchment area (%) • Weighted average Directly Connected Impervious - percent of total impervious area which drains directly to the conveyance system (%)

Data Layer	Description
	• Weighted average Minimum Infiltration Rate – saturated infiltration rate of surficial soils (mm/hr) • Drainage Density – total length of mapped surface flow paths within each catchment divided by the catchment's area (km/sq.km) – higher values infer a faster runoff response and "peakier" runoff hydrograph
Vegetation Cover	Indication of the type of vegetation that is currently found in the study area.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

DRAINAGE INFRASTRUCTURE

This map shows the existing, inventoried drainage infrastructure, which includes culverts, storm sewers, manholes, drywells, catch basins, detention facilities, etc. It also includes MoTI culvert locations along Highway 97. Two summary widgets and two plot widgets provide insights regarding the District infrastructure displayed within the active map extents. These are as follows:

- Counts of each type of non-linear (point) infrastructure
- Counts of culverts and summary length of the other types of linear (piped) infrastructure
- Plot showing percent of the gravity mains comprised of indicated materials
- Plot showing length of gravity mains by pipe diameter

More information about the sources and quality of the infrastructure data is provided in a separate technical memo – Appendix xx in the Phase 1 ISMP report. The layers are summarized in the following table.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
Drainage Infrastructure (Linear) - Existing	Existing conduits (pipes and culverts). Click on an element to open an attribute window, which includes (where available) asset ID, diameter, material, type, etc.
Drainage Infrastructure (Point) - Existing	Existing point elements such as manholes, drywells, CB inlets, etc. Click on an element to open an attribute window to show asset ID, type, install date, status, etc.
MoTI Culverts	The MoTI data is downloaded as a point layer, even though the points represent linear culvert locations. Click on a point to open an attribute window, which shows culvert diameter, material, type, location within the road, etc.
Municipal Water Intakes	Shows the location of the District's water intakes – provided for context regarding how close intakes may be to storm system outfalls.

Data Layer	Description
Municipal Water Intake Protection Zones	Shows the areas where extra care is required to protect water quality near select water intakes.
Surface Flow Paths	Flow paths based on a Digital Elevation Model generated from LiDAR. Shows where surface runoff would flow if culverts and drainage infrastructure were not functioning.
Land Ownership	Shows the type of land ownership (private, municipal, etc.) – provided for context when considering system extension or upgrades. Click on a polygon to open an attribute window.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

HYDRO-GEOLOGY

The layers in this map were generated by Waterline Resources Inc. (Waterline) as part of the hydrogeological assessment it completed for the ISMP. This information was used to inform drainage catchment characterization (infiltration capacity, natural imperviousness, groundwater conditions, etc.). It also provides context for stormwater management planning, identifying areas where infiltration systems might be feasible to use. The following table summarizes the map layers.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
Soil Drainage	Shows the BC classification for soil drainage (rapid, well, moderately well, etc.). These classifications consider only soil characteristics and contribute only in part to a location's infiltration capacity. Clicking on a polygon opens an attribute window displaying all of the classifications assessed by the BC Geology and Soils Survey.
Surficial Geology	Shows the dominant surficial soil material (alluvial, bedrock, colluvial, etc.). Clicking on a polygon opens an attribute window displaying all of the classifications assessed by the BC Geology and Soils Survey.
Groundwater Wells	Shows the location of registered groundwater wells. No attribute data are available.
Licensed Springs	Shows groundwater springs on which one or more licenses have been granted by the BC Water Rights branch. Clicking on a point opens an attribute window.
Infiltration Potential	Shows the potential (high, moderate, low) for using infiltration systems to manage collect stormwater runoff. This considers soil drainage characteristics, depth to impermeable layers, and groundwater conditions.

Data Layer	Description
Unconsolidated Aquifers	Shows the four aquifers within the Vernon Creek valley. Provincially assigned attributes are available in a pop-up window.
Surficial Material Infiltration Capacity	Similar to Soil Drainage, but with more resolution since the polygons are correlated to the Surficial Geology layer.
Primary Catchments	Provided to better understand hydrogeological characteristics within specific primary catchments. Limited attributes available by clicking on a polygon.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

LAND USE

This map is configured to show existing land use as well as potential future changes to it. Existing land use is symbolized using a muted colour palette – future land use changes use a more intense version of the same colour palette. Two charts show the percentage of each OCP designation (equivalent for existing land use) within the map extents. The following table summarizes the map layers.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
OCP Equivalent - Existing	Existing land use is typically expressed through zoning, but to enable comparison between existing and future land uses, an equivalent OCP designation was assigned to each existing land use zone. An attribute window opens when a polygon is clicked on and includes existing zoning.
OCP Designation - Future	Shows the parcels where the OCP designation (future land use) differs from the OCP equivalent designation (existing land use). Parcel attributes are also available by clicking on a polygon.
OCP Growth Areas	Obtained from the District's OCP, it shows the locations where future growth is anticipated.
Areas of Interest	Shows areas highlighted during a conversation with Planning Staff – available attributes include conversation notes and anticipated time frame for development.
Future Roads	Shows the location of planned new and extended roads. This can impact local runoff generation. Road class implies potential road width.
Agricultural Land Reserve	In general, development of ALR parcels is not anticipated. They are, however, mapped to provide additional context.
Land Ownership	Shows the type of land ownership (private, municipal, etc.) – provided for. Click on a polygon to open an attribute window.

Data Layer	Description
Hillside Development Permit Area	From the District OCP, this layer infers steeper slopes, which requires a development permit for any type of development. Provided for context.
Primary Catchments	Provided to better understand existing and future hydrology within specific primary catchments. Limited attributes available by clicking on a polygon.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

WATER QUALITY

This map shows the location of both municipal and private / commercial water intakes and licensed "points of diversion". It also includes the location of drainage outfalls to the receiving water, providing context with respect to potential conflicts between potentially polluting stormwater and potable water intakes. The following table summarizes the map layers.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
Municipal Water Intakes	Shows where the District owns and operates intakes that supply water to its distribution system. Limited attributes (name, elevation, etc.) are available by clicking on a point.
Municipal Water Intake Protection Zones	Shows the geographical extents of zones established to protect water quality for specific water intakes.
Licensed Points of Diversion (Potable)	Obtained from the Provincial mapping service, these points show the approximate location of licensed points of diversion. They are symbolized to differentiate between lake, stream, and spring water sources. Provincially defined attributes are available by clicking on a desired point.
Public Beaches	Shows official public beaches, which can be impacted by poor water quality. Limited attributes are available by clicking on a desired polygon.
Erosion Hazard DPA	These OCP-defined development permit areas indicate where soil could be eroded and transported to the receiving waters. This layer provides context when considering development applications.
Outfalls	Shows the location of natural or storm system outfalls to the receiving waters. Provided for context when considering potential water quality impacts to existing water intakes and beaches.
Environmental Monitoring	Shows the locations where some form of environmental testing or monitoring has been conducted. Limited information is provided by clicking on a desired point.

Data Layer	Description
Primary Catchments	Provided to better understand how runoff from a specific primary catchment might impact receiving water quality. Limited attributes available by clicking on a polygon.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

ENVIRONMENTAL

This map presents information about environmental resources that have the potential to be impacted by stormwater management systems and associated runoff. Focus is on aquatic resources, but terrestrial resources are also included for context. The following table summarizes the map layers.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
FIM Aquatic Habitat Index (Current)	Shows the Foreshore Inventory and Mapping Aquatic Habitat Index on the lakes that is currently assessed. It is presented as five classifications ranging from "Very High" (high value) to "Very Low" (very low value) Provincial standard attributes are available by clicking on a desired line segment.
FIM Aquatic Habitat Index (Potential)	Shows the Foreshore Inventory and Mapping Aquatic Habitat Index on the lakes that potentially could be assessed. Provincial standard attributes are available by clicking on a desired line segment.
Fish Observations	Shows the location where fish were observed in streams. Limited attributes (species, stream, and observation date) are available by clicking on a selected point.
Riparian Areas	From the District OCP – 30 m buffer on each side of a stream or gulley that MAY have riparian potential.
Foreshore Vegetation	Shows documented locations of vegetation within the foreshore area of Okanagan Lake. Categorized by vegetation type.
Receiving Waters – Streams	Shows the key streams which function as receiving waters for primary catchment outfalls.
BEC Zones	Shows the Biogeoclimatic Ecosystem Classification zones – a generalized characterization of zones based primarily on vegetation species, temperature, and precipitation. Attributes are available by clicking on a selected polygon.
BCS Conservation Ranking	From the District OCP – shows areas ranked by conservation value (Very High, High, Moderate, and Low).
Critical Listed Species	From the District OCP – shows the range of animal species that are on either the BC Red or Blue lists of species at risk.

Data Layer	Description
Main Wildlife Corridor	From the District OCP – shows a single, north-south route that is used by wildlife to move through the District.
Natural Environment DPA	From the District OCP – shows the areas which contain sensitive environmental features that should be protected.
Environmental Monitoring	Shows the locations where some form of environmental testing or monitoring has been conducted. Limited information is provided by clicking on a desired point.
Primary Catchments	Provided to better understand how runoff from a specific primary catchment might impact environmentally sensitive species or features. Limited attributes available by clicking on a polygon.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

RISK ASSESSMENT

This map provides the results from the ISMP Phase 1 risk assessment. The primary layer is the Flow Path Risk Assessment, which colour-codes the natural flow paths according to assessed risk:

- 15 = High Risk
- 10 to 12 = Moderately High Risk
- 6 to 9 = Moderate Risk
- 3 or 5 = Special Case (high likelihood with low consequence, or high consequence with low likelihood)
- 1, 2, or 4 = Low Risk

Additional details about the Risk Assessment are available in the Risk Assessment technical memo (ISMP Phase 1 report Appendix G). The following table summarizes the map layers.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
Flow Path Risk Assessment	As described in this sub-section's writeup
Drainage Infrastructure (Linear) - Existing	Same data as in the Drainage Infrastructure map – for context only
Drainage Infrastructure (Point) - Existing	Same data as in the Drainage Infrastructure map – for context only
MoTI Culverts	Same data as in the Drainage Infrastructure map – for context only
Building Footprints	Obtained from the District – used as part of the risk assessment criteria – mapped for context
Hillside Development Permit Area	From the District OCP – provided as context since consequences can be more severe on steeper slopes

Data Layer	Description
Primary Catchments	Provided to better understand surface flow risks in a specific primary catchment. Limited attributes available by clicking on a polygon.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

OPERATIONS/MAINTENANCE

This map is currently focused on two data layers – both of which provide insights into the location and type of drainage-related issues that have been noted by Staff or reported by residents. The following table summarizes these and additional map layers.

Data Layer	Description
District Boundary	Emphasized polygon showing the extents of the District
Reported Issues	Shows the approximate location of issues reported by residents. The information was originally provided in an Excel spreadsheet and the locations were matched to recorded addresses. All information provided in the spreadsheet are provided as attributes by clicking on a selected point.
General Issues	Shows the approximate location of issues identified to Urban Systems in 2011. Attributes include an issue name and general description.
Surface Flow Paths	Flow paths based on a Digital Elevation Model generated from LiDAR. Shows where surface runoff would flow if culverts and drainage infrastructure were not functioning. Provided for context.
Cadastral	Parcel polygons. Attributes such as zoning, OCP designation, parcel size, BCAA Actual Use, etc. can be viewed by clicking on a parcel polygon.

CAPITAL PROJECTS

This map will be completed as part of the ISMP Phase 2 work. It will show proposed capital projects and provide links to detailed project descriptions, priorities, capital cost estimates, and other pertinent information.

MVC FLOOD HAZARD

This map was provided for convenience only. The mapping is from the 2023 Middle Vernon Creek Flood Hazard Risk Assessment completed for the District by Urban Systems. The flood extents were developed for the 200-year event under a Mid-Century (2041-2070) climate scenario.

3.0 ACCESS

The dashboard was built on ESRI's cloud-based ArcGIS Online environment. Currently, the data resides on Urban System's internal ArcGIS Enterprise server, but the plan is to migrate everything to the District's system at some point during Phase 2 of the ISMP.

Access to the dashboard is currently limited to select users and is protected by password. Ultimately, however, the District intends to make the dashboard available to the public, but with limited access to some of the data layers and/or data attributes. These details will also be refined during Phase 2 of the ISMP.

4.0 UPDATES

The ISMP is intended to be a "living" document – a tool that is often used by Staff during development application reviews and approvals, capital works planning, and operations & maintenance activities. Some of the data layers will be "static" – snapshots in time reflecting existing conditions and assumptions. These layers have the potential, however, to be manually updated to reflect new information, completed capital works, revised assumptions, etc. In these cases, the original layer will be time stamped and archived and the updated layer will be active in the dashboard. The archived layers may or may not be available in the dashboard, depending on the District's needs and objectives.

Other data layers – especially those providing background or context, will be linked to the District's GIS layers. In this case, these "dynamic" dashboard layers will reflect any changes to the District's GIS layers, providing the most current information available.

The following table lists the current dashboard layers and indicates if they are to be static or dynamic. Currently, all the layers are considered static, but once the dashboard has been migrated to the District's system, the dynamic layers will be linked and become active.

Data Layer	Static	Dynamic	Comments
Administrative Boundaries		✓	
Agricultural Land Reserve		✓	
Areas of Interest	✓		Reflects one-time discussion
BCS Conservation Ranking		✓	
BEC Zones		✓	
Building Footprints		✓	

Data Layer	Static	Dynamic	Comments
Cadastral		✓	
Capital Projects	✓		Use attributes to track implementation progress
Critical Listed Species		✓	
District Boundary		✓	
Drainage Infrastructure (Linear) - Existing	✓	✓	Currently static, but could be dynamic
Drainage Infrastructure (Point) - Existing	✓	✓	Currently static, but could be dynamic
Environmental Monitoring		✓	
Erosion Hazard DPA		✓	
FIM Aquatic Habitat Index (Current)		✓	
FIM Aquatic Habitat Index (Potential)		✓	
Fish Observations		✓	
Flow Path Risk Assessment	✓		Update periodically to reflect improvements
Foreshore Vegetation		✓	
Future Roads		✓	
General Issues		✓	
Groundwater Wells		✓	
Hillside Development Permit Area		✓	
Infiltration Potential	✓		Update manually to reflect site-specific studies
Land Ownership		✓	
Licensed Points of Diversion (Potable)		✓	
Licensed Springs		✓	
Main Wildlife Corridor		✓	
MoTI Culverts	✓		Must be downloaded from MoTI manually
MoTI Roads		✓	
Municipal Water Intake Protection Zones		✓	
Municipal Water Intakes		✓	
Natural Environment DPA		✓	
OCP Designation - Future		✓	
OCP Equivalent - Existing	✓		Requires interpretation of zoning
OCP Growth Areas		✓	
Outfalls	✓	✓	Currently static, but could be dynamic
Outlets - Primary Catchments	✓		Dependent on Primary Catchments layer
Previous Studies	✓	✓	Currently static, but could be dynamic
Primary Catchments	✓		
Public Beaches		✓	
Receiving Waters - Streams	✓		
Regional Districts		✓	
Reported Issues		✓	
Riparian Areas		✓	
Soil Drainage	✓		
Surface Flow Paths	✓		
Surficial Geology	✓		
Surficial Material Infiltration Capacity	✓		
Unconsolidated Aquifers	✓		
Vegetation Cover		✓	

5.0 CLOSING

This technical memorandum was prepared for documentation and information purposes only. It was prepared and reviewed by the following Urban Systems staff.

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