City of Merritt

Integrated Stormwater Master Plan

REPORT

Associated Engineering

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Associated Engineering
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March 5, 2014
File: 20122231.00.E.03.02

Shawn Boven, AScT
Public Works Manager
City of Merritt
PO Box 189, 2185 Voght Street
Merritt, BC V1K 1B8

Re: CITY OF MERRITT INTEGRATED STORMWATER MASTER PLAN

Dear Mr. Boven:

On behalf of Associated Engineering (BC) Ltd., Summit Environmental Consultants Inc. and GeoAdvice Engineering Ltd., I am pleased to present the final report of the Integrated Stormwater Master Plan for the City of Merritt.

We would like to acknowledge the City of Merritt's operations and engineering staff for their assistance and input into the development of this project. We also acknowledge the friendly residents in Merritt who engaged our project team and discussed their local drainage issues and historical perspective.

You will find enclosed two copies of the final report, along with a digital copy of the InfoSWMM models and background information.

Finally, we would like thank you for the opportunity to work with the City on this important project. We are certain that questions will arise in the future about details in the plan. We will be pleased to offer any assistance and clarifications where necessary.

Yours truly,

Rod MacLean, P. Eng.
Project Manager

RM/rl

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1 General

1.1 INTRODUCTION

Associated Engineering was retained by the City of Merritt to complete an Integrated Stormwater Master Plan (ISMP). The objective of an ISMP is to monitor, develop strategies and conceive plans to manage stormwater consistent with the planning objectives of the City of Merritt, while adhering to the ISMP Terms of Reference Template prepared by the Ministry of Environment.

Summit Environmental Consultants Inc. (Summit), developed the environmental components of the ISMP. Summit completed aquatic, terrestrial, groundwater, and hydro-geological assessments, gaining information pertaining to fish and wildlife values, examine soil conditions, and identify general areas that may allow for small, medium, and large scale infiltration practices within the study area. Field information was collected to assess the quality and quantity of fish and wildlife habitat present, provide information on potentially sensitive habitat areas, and assess erosion or sedimentation concerns within the watershed.

GeoAdvice Ltd. of Langley, BC, produced a model of the current stormwater layout using InfoSWMM, incorporating the information researched by Summit Environmental and ground reconnaissance work completed by Associated Engineering. Once calibrated, a future scenario was modeled based on future development plans obtained by the City and included in the City's latest Official Community Plan. Results from the model process were used to determine where capital upgrades may be required to meet capacity needs into the future.

The ISMP will seek to improve the overall watershed system by preserving aquatic and riparian habitats, protecting the aquifer that lies beneath the town site, and improving the quality of the stormwater being released into the Coldwater and Nicola River. The ISMP process examines the area as a whole and recommends best management practices and capital works to mitigate risks involved with managing stormwater discharges, while allowing for development to occur.

This report is intended to provide key direction, strategies and specific actions. Prioritization of recommendations and measures will be included along with estimated cost of implementation of the proposed recommendations.

1.2 BACKGROUND/PROJECT OVERVIEW

Over the last century, the City of Merritt has grown from a ranching/farming community to an urban centre, complete with industry development in forestry, coal mining, and transportation services. The community has grown to a population of 7,100 residents in approximately 2,800 residences (2011 census).

Population growth and new development in Merritt has resulted in significant changes to stormwater runoff. The City of Merritt and the BC Ministry of Environment have committed to implementing an ISMP with the purpose of identifying all stormwater related issues (man-made and naturally occurring) in a manner that preserves the physical and biological values of existing watercourses and addresses a range of capital and planning needs of the community.

The City has a long history of river flooding and ice-jams that have impacted both how the stormwater system was designed and how it is operated. In this plan, the City has defined goals and objectives to guide the ISMP process. The goals and objectives relate to the management of the natural resources within the watershed area, including aquatic and terrestrial resources, flood and erosion control, and surface and groundwater resources.

The project team met with City staff to evaluate operations, problem areas, land planning and policy considerations.

1.3 PROJECT PARTICIPANTS

The consultant team is comprised of personnel from Associated Engineering, Summit, and GeoAdvice. Key team members are:

Associated Engineering (BC) Ltd.
Rod MacLean – Project Manager
Michael Owen – Lead Technical Engineer
Drew Lejbak – Review

Summit Environmental Consultants Inc.
Dan Austin - GIS
Sandra Meidinger – Riparian Areas and Environmental Values
Christopher Holmes - Hydrogeology
Joe Alcock – Hazard Risk Assessment
Trina Koch – River Water Quality

GeoAdvice Engineering Ltd.
Julien Bell, P. Eng. – Stormwater Model Project Coordinator
Werner de Schaetzen, Ph.D. P. Eng. – Senior Review

City of Merritt
Shawn Boven – Public Utility Manager
Shahrzard Honarmand - Technologist
Jordan Goerlitz - Technologist
Operations Staff

1.4 GOALS AND OBJECTIVES

This ISMP report is intended to provide key direction, strategies and specific actions. Prioritization of recommendations and measures will be included along with estimated cost of implementation of the proposed recommendations. The objective of an ISMP is to monitor, develop strategies and conceive plans to manage stormwater consistent with the planning objectives of the City of Merritt; while adhering to the ISMP Terms of Reference Template prepared by the Ministry of Environment (See **Figure 1-1**). The seven steps to developing an ISMP are as follows:

1. Secure Political Interest and Support
2. Watershed Problems and Opportunities
3. Develop Objectives and Alternate Scenarios
4. Collect Meaningful Data and Refine Scenarios
5. Evaluate Alternatives and Develop Component Plans
6. Develop an Implementation Program
7. Refine through Adaptive Management

This report supports this general structure. We note that the ISMP is an active plan and reporting process. By providing more regular and focused measurements of water quality, water temperature and stormwater flows entering the watershed, downstream and with its boundaries, the City will better understand the impacts of implementing its ISMP. The capital works planning component can then be adjusted as required to meet the ever changing development needs in the community.

Being the City of Merritt's first ISMP, developing an understanding of the systems needed to be integrated with capital planning. For this first analysis, a focus was maintained on the following details.

- Maintain performance capacity and condition of both the overland and sub-surface storm sewer system.
- Limit pipe surcharging to prevent local road flooding.
- Provide adequate servicing to new development and reduce or minimize downstream impacts.
- Ensure that new developments don't negatively impact the current system.
- Protect integrity of the City's drinking water aquifer, creeks, and watercourses.
- Where possible, control and/or store stormwater being released into the watercourses and mitigate contaminants in the stormwater by taking appropriate measure to store and clean this prior to discharge.
- Control sediment loading and erosion potential.
- Slow flows on route to decrease carrying capacity and slow flows prior to release to provide adequate time for settlement to occur.
- Minimize detrimental impacts on aquatic life and wildlife habitats.
- Protect and enhance habitats whenever possible.

Figure 1-1. ISMP Overview
Excerpts from MOE (2002) – Guidelines from Stormwater Planning

Fundamental Question:
How can the ecological values of stream corridors and receiving waters be protected and/or enhanced and drainage related problems prevented, while at the same time facilitating land development and/or redevelopment?

Objectives
- Drainage Objectives: Alleviate existing and/or potential drainage, erosion and flooding concerns.
- Stream Protection Objectives: Protect and/or restore stream health including riparian and aquatic habitat.
- Water Quality Objectives: Remediate existing and/or potential water quality problems.

Elements
1. What do we have? (Understanding watershed issues)
2. What do we want? (setting achievable performance targets)
3. How do we get there? (Developing an ISMP implementation program)

Layers
1. Goals (First Layer) – Identify the stormwater-related objectives for a watershed (e.g. protection of aquatic resources, protection of life and property, protection of water quality). These objectives define what the ISMP is striving to achieve.
2. Strategies (Second Layer) – Develop strategies to achieve the watershed objectives. This includes setting performance targets to guide selection of site design solutions.
3. Projects (Third Layer) – Implement appropriate site design solutions (e.g. source controls) for achieving performance targets that suit local objectives and conditions.
4. Monitoring/Measurement

7 Steps to developing an ISMP
1. Secure Political Interest and Support
2. Frame the watershed problems and opportunities
3. Develop Objectives and Alternate Scenarios
4. Collect Meaningful Data and Refine Scenarios
5. Evaluate Alternatives and Develop Component Plans
6. Develop and Implementation Program
7. Refine through Adaptive Management

Table 9-3 Synopsis of the Seven-Step Process for ISMP Development and Implementation

Step	Scope	Outcome	Deliverable
1	Secure Political Interest and Support	❑ Define a guiding philosophy ❑ Formulate supporting policies ❑ Establish design criteria to achieve policies	❑ Document 1 - Policy and Design Criteria Manual
2	Frame the Watershed Problems and Opportunities (Apply the Knowledge-Based Approach) ❑ Land Use Working Session ❑ Drainage Working Session ❑ Ecology Working Session ❑ Interdisciplinary Roundtable Session	❑ Identify resources to be protected ❑ Establish an order of priority for plan development at the sub-watershed scale	❑ Document 2 – Understanding the Watershed • Watershed Base Map • Watershed Issues Summary • Sensitive Ecosystem Inventory • Land Use Map • Drainage System Inventory • Soils and Groundwater Map
3	Develop Objectives and Alternative Scenarios ❑ Flood Management Scenario Modeling ❑ Source Control Scenario Modeling	❑ Identify inadequate drainage facilities ❑ Establish a customized performance target for each sub-watershed	❑ Document 3 – Results of Flood Management Scenario Modeling ❑ Document 4 – Results of Source Control Scenario Modeling
4	Collect Meaningful Data and Refine Scenarios ❑ Concurrent Rainfall and Streamflow Data ❑ Data on Soils and Groundwater ❑ Water Quality Data ❑ Data on Fish and Their Habitats	❑ Identify gaps ❑ Supplement existing programs	❑ Document 5 – Data Collection Framework
5	Evaluate Alternatives and Develop Component Plans	❑ Make decisions	❑ Document 6 – Flood Risk Mitigation Plan ❑ Document 7 – Habitat Enhancement Plan ❑ Document 8 – Land Development Action Plan
6	Develop an Implementation Program	❑ Consolidate supporting documents ❑ Develop financial plan ❑ Create a recommended bylaw approach	❑ Document 9 - Implementation Report
7	Refine Through Adaptive Management	❑ Establish rules of adaptive management ❑ Implement comprehensive monitoring program	❑ Document 10 - Performance Evaluation Plan

1.5 WORK PLAN

The work plan was divided into four work phases and their relevant sub-tasks:

PHASE 1 - DATA COLLECTION AND REVIEW

1. Project Management/Meetings
2. Project Initiation Meeting
3. Collect and Review Background Information
4. Aquatic/Terrestrial Review
5. Desktop Hydrogeological Assessment
6. Natural Hazard Review
7. Water Quality Review

PHASE 2 - MODELING EXISTING CONDITIONS

1. Build Trunk Storm Utility Model
2. Model Calibration and Validation

PHASE 3 - ASSESS OPTIONS/PRELIMINARY REPORT

1. System Analysis
2. Long Range Capital Improvements
3. Stormwater Management Plan Recommendations

PHASE 4 - STORMWATER MANAGEMENT PLAN

1. Preliminary Report
2. Round Table Discussion
3. Final Report

The resulting technical memoranda are found annexed to this final report and are defined as follows:
A - Hydrogeological Assessment
B - Natural Hazard Review
C - Aquatic and Terrestrial Species and Habitat Review
D - Water Quality Review
E - Model Construction and Calibration Assumptions
F - Model Results
G - Future Model Results
H - Long Term Capital Improvements

2 Summary of Observations

The following sections summarize detailed findings found in the technical memoranda annexed to this report. Each report was independently produced and separate observations were made by each project team member. Below are key observations which form the basis of our analysis.

2.1 FIELD RECONNAISSANCE

Associated Engineering undertook a reconnaissance of the study area to collect field data in October, November, and December 2012. We examined conditions and collected pipe system information, outfall information, as well as other pertinent information such as typical city layout with respect to stormwater flows, slopes, and visible flow routes. Site photos were taken and are provided in a digital photograph inventory included in the project CD-ROM attached to this report.

2.2 EXISTING STORMWATER SYSTEM AND STANDARDS

The existing City of Merritt stormwater system are a blend of storm sewers, manholes, road ditches, drainage ditches, culverts, outfalls, catch-basins, storm leads and curb/gutter systems. The stormwater systems in the older parts of town are designed to route through the shortest path to either the Nicola or Coldwater Rivers. Where outfalls are not available, the City relies on a system of shallow and deep dry wells. These structures are excavated to a coarse gravel layer which allows drainage into the groundwater system.

The newer stormwater systems, particularly in the newer developments and commercial areas appear to be designed to more recent stormwater standards. There are several design reports in the City of Merritt files referencing stringent stormwater design standards. These standards include routing stormwater underground for the 1 in 10-year event, and surface routing considerations for the 1 in 100-year storm. Stormwater ponds are now part of the City standard to reduce runoff rates to pre-development levels.

2.3 DATA COLLECTION

We gathered Geographical Information System (GIS) data for hydraulic structures from the information the City of Merritt provided, in the form of CAD files, GIS shape files, as well as incorporating field collected information. For missing information, the data gaps were filled through field investigation reconnaissance.

2.4 HYDROGEOLOGY

An extensive desktop review of past reports, mapping and water quality results were used to address both hydrological and geophysical issues within and underneath the City of Merritt's boundaries. Detailed findings can be found in the technical memorandum in **Appendix A**. Key observations are noted below:

- The City of Merritt is underlain by the Merritt aquifer; an unconfined, unconsolidated sand and gravel surficial aquifer. The Merritt aquifer is a highly productive, but under high demand (mostly due to municipal and irrigation wells) is susceptible to contamination. The City's potable supply is from five groundwater wells: Voght Park #1, Voght Park #2, Fairley Park, Collettville, and Kengaard (See **Figure 2-1**).

- The aquifer is hydraulically connected to the Nicola and Coldwater Rivers and to the underlying confined aquifers below the City of Merritt. Any contamination could potentially occur in the surficial aquifer would likely have a direct, though delayed, effect on the water quality of the wells near the Nicola River, and eventually those in the Merritt confined aquifer.
- A groundwater protection zone (**Figure 2-1**) has been outlined within the City Boundaries.
- The dry wells, noted earlier, appear to be a significant contributor to groundwater levels in several areas of the City. Those located within the boundary of the Merritt aquifer pose a potential hazard to the water supply. Acute effects from a hydrocarbon spill draining through one of these wells would be immediate, having a pronounced impact on the groundwater quality. Other potentially chronic effects results from the build-up of fertilizers, pesticides, road film, and salt directly from the surface into the groundwater supply, affecting quality.

2.5 NATURAL HAZARDS

A site reconnaissance and detailed desktop review was performed as part of the natural hazards review to assess potential slope stability, surface and river erosion, river flooding, ice-jam flooding and land subsidence conditions that exists affecting stormwater planning and management. More detail of the review can be found in **Appendix B**.

Landslides

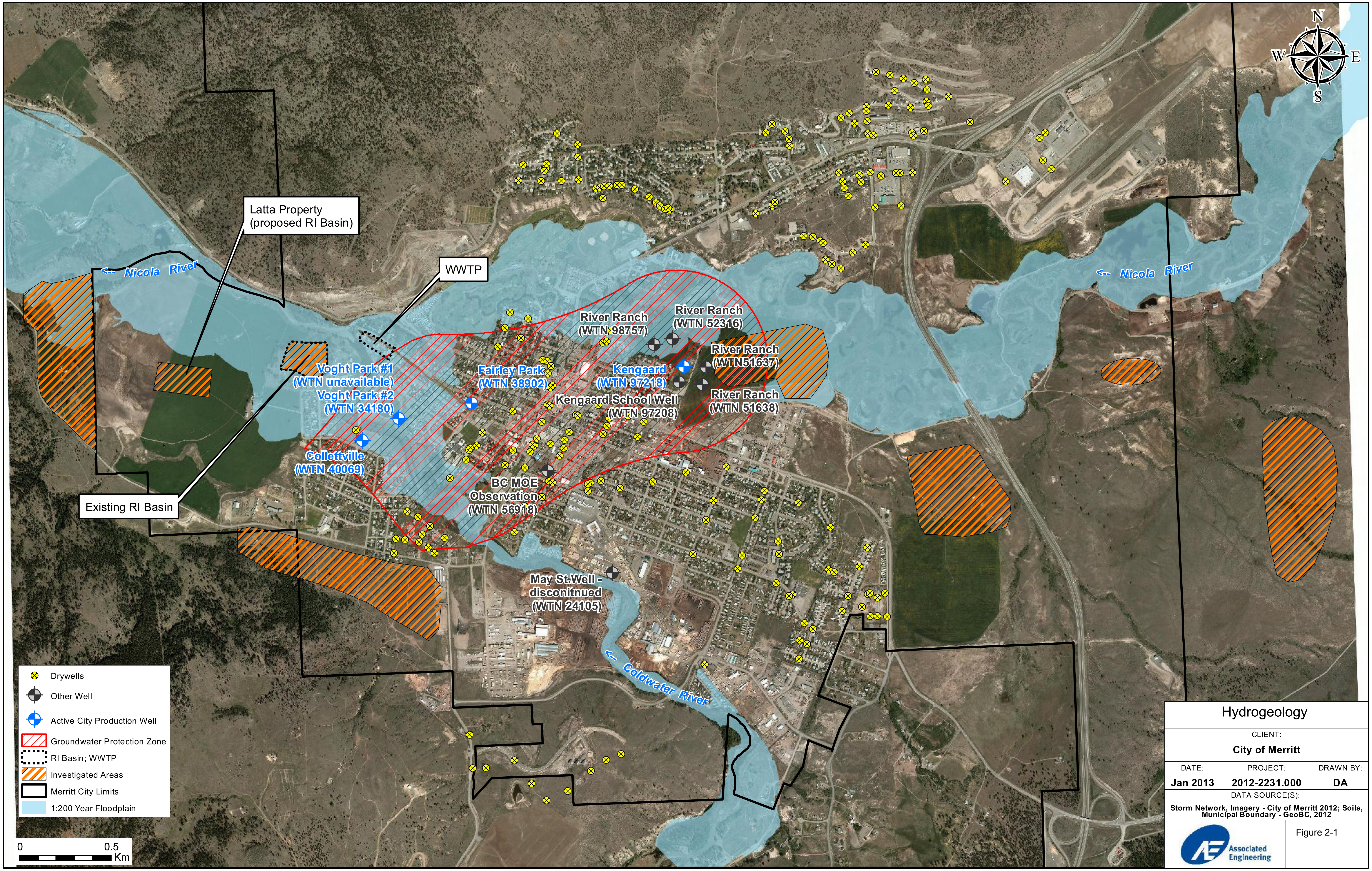
While the steep valley slopes above the City have the potential for debris slides and rock fall, no significant landslide events have been reported.

Excess Surface Water from Irrigation

Irrigated fields are located on the west and east sides of Merritt. Excess irrigation water can result in higher quantities of surface runoff and high groundwater conditions, leading to slope stability issues and increased runoff. Few hazards, however, were noted in our site inspections.

Slope Gullying

There are several instances of erosion, block falls, slumps, piping, and surface sheet erosion within the City's boundaries. Since land development, uncontrolled stormwater drainage from streets has caused further gullying and ravine formation at a number of locations along the north valley bottom. Motorcycle and ATV use along the steep slopes has caused rutting and compaction, which has resulted in water redirection and surface erosion. With this new gullying and erosion, the ravines may widen and erode head ward. Sediment could be deposited downstream and the local slopes may be destabilized.



N
W
E
S
Latta Property (proposed RI Basin)
WWTP
Nicola River
Nicola River
River Ranch (WTN 98757)
River Ranch (WTN 52316)
River Ranch (WTN51637)
Kengaard (WTN 97218)
Fairley Park (WTN 38902)
Voght Park #1 (WTN unavailable)
Voght Park #2 (WTN 34180)
Kengaard School Well (WTN 97208)
River Ranch (WTN 51638)
Collettville (WTN 40069)
BC MOE Observation (WTN 56918)
Existing RI Basin
May St Well - disconitnued (WTN 24105)
Coldwater River
Drywells
Other Well
Active City Production Well
Groundwater Protection Zone
RI Basin; WWTP
Investigated Areas
Merritt City Limits
1:200 Year Floodplain
0
0.5
Km
Hydrogeology
CLIENT:
City of Merritt
DATE:
Jan 2013
PROJECT:
2012-2231.000
DRAWN BY:
DA
DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012
Associated Engineering

Figure 2-1

Flooding

The Nicola River has a long history of major floods in the City: December 1980, November 1990, February 1999 (snow melt and ice jam), and June 2012. The 1 in 200-year floodplain mapping is integrated into the Flood Protection Measures Overall Map in the City of Merritt Official Community Plan (OCP). The vegetated riparian area and some areas of housing and roads are included in the 1 in 200-year flood limit.

The City has also constructed earthen dykes along some sections of the lower Coldstream River and along sections of the right and left banks of the Nicola River upstream of the confluence. Some sections of Nicola River bank were also armoured upstream of the confluence.

Ice Jams and Floods

Ice jams on the Nicola and Coldwater Rivers during ice freeze-up or breakup have caused some rapid floods, sediment transport and erosion, and damage from ice floes moving over the banks. Significant ice jam events occurred:

- On the Coldwater River in December 1979 and December 1980, which also caused minor overbank flooding in the City (Doyle 1983).
- On the Nicola River in January 1984 and 1991.

Previous Coal Mining and Subsidence

Between 1906 and the late 1950's, about 3-million tons of thermal grade coal was mined by underground methods immediately south of Merritt (Gilmar and Sharman 1981). Incidents including the collapse of previous tunnels and excavations have been reported. There are also suggestions that some coal is burning underground.

Wildfire Hazards

Fire is always a concern in the British Columbia Interior. Areas where wildfires have occurred in the recent past have reduced vegetative cover and, therefore, higher erosive potential. There are areas of steep forested and grassland slope areas in the southwest, south central and southeastern parts of the City. These are currently designated as development permit areas, based on predicted wildfire behaviour and potential from suggested underground smouldering coal seams.

2.6 ENVIRONMENTAL CONSIDERATIONS

The stormwater planning considerations outlined below reflect the known environmentally sensitive areas (ESA's) within the defined study area, best management practices and environmental regulations. Following a review of the previously completed reports and databases, the key observations for environmental planning are summarized in **Appendix C** as follows:

Terrestrial Habitats

There is limited wildlife habitat within the City Center. Currently, the ESA's in the OCP are limited to the riparian areas of streams and do not incorporate terrestrial species and ecosystems.

Riparian Health

The riparian health of the major creeks and tributaries should be assessed in the study area, namely at Godey, Spanish and Hamilton Creeks. Development within the city core has heavily encroached and impacted the riparian area of these water bodies. Riparian enhancement planning should be included as part of new development plans. These development plans should include a building setback suitable to the RAR, which in turn should enhance terrestrial habitat, improve water quality (temperature, sediment control) and provide a stormwater catchment for adjacent impervious surfaces.

Aquatic Habitat

Of particular concern to aquatic habitat are seasonal low flows, increasing water temperatures and degraded water quality from point and non-point sources. The Coldwater River, near the music festival grounds, experiences low flows and high temperatures during the warmer season, which can be detrimental to fish. Implementing riparian development setbacks and enhancement plans will likely help improve temperature conditions by creating shade values that will assist in temperature moderation.

Heritage Resources

The potential for encountering an archaeological site is high in the region. Developers should be required to complete an Archaeological Impact Assessment (AIA) and seek the advice of an archaeological professional in areas with high potential.

2.7 STORMWATER QUALITY ISSUES

A limited amount of information was available to address river source, outfalls and well water issues. Well locations and areas of data collection are addressed in detail in **Appendix D.**

Stormwater Quality Data

There is no water quality information available from the City's nine stormwater outfalls (three outfalls flow into the Coldwater River and six flow into the Nicola), or drywells.

River Water Quality Data

Data from testing on 17 surface-water locations (10 Nicola River and 7 Coldwater River), 10 groundwater sampling locations near the rapid infiltration basins were reviewed. Most sampling locations were concentrated at the west end of Merritt for the purpose of detecting contamination in surface and ground water caused by releases from the Waste Water Treatment Plant and rapid infiltration basins.

In addition, databases from EMS, WaterTrax, and the City's annual environmental reporting include 100 Nicola River sample events, 84 Coldwater River sampling events and 6,714 groundwater sampling events; 98% of which occurred at three groundwater drinking supply wells.

Surface Water

Exceedances of applicable water quality guidelines were tabulated and mapped. 12 surface water sites (4 Coldwater River and 8 Nicola River) exceeded the Approved Water Quality Guideline (MOE 2010) for phosphorous suggesting that conditions in both rivers occasionally become more eutrophic. Phosphorous guideline exceedances occurred during all seasons of the year. The highest Nicola River phosphorous concentration of 0.199 mg/L occurred at the City's environmental monitoring site upstream of the confluence with Coldwater River in 2008 and the highest Nicola River phosphorous concentration of 0.68 mg/L occurred at EMS Site 0600502 in 1988.

Groundwater Quality

Seven groundwater wells exceeded the total coliform drinking water guideline of 1 CFU or MPN/100 mL, including one of the City's drinking water wells (WTN 024517, Voght Park #2). Of these seven wells, the Voght Park #2 well also exceeded the same guideline for fecal coliforms. Sources of total and fecal coliform in groundwater can include agricultural runoff, effluent from septic systems or sewage discharges and infiltration of domestic or wild animal fecal matter (MOE 2007). Poor well maintenance and construction (particularly shallow dug wells) can also increase the risk of bacteria and other harmful organisms getting into a well water supply (MOE 2007).

Water Temperature

Approved water quality temperature guidelines (MOE 2010) of 15^{0}C for drinking water was exceeded in two wells downstream of the rapid infiltration basins (MWI deep and shallow), one well downstream of the Coldwater River confluence (MW2 Deep), one well on the north bank of the Coldwater River (E250651). Two surface water locations (Coldwater D/S outfall and E279796 located downstream of the Coldwater River confluence) exceeded the Approved Water Quality Guideline (MOE 2010) for the protection of aquatic life of 15^{0}C. Since 2007, MOE has reported that summer temperatures in the lower Coldwater River exceed lethal limits (24^{0}C) for salmon, trout and char and are well above optima for rearing juvenile fish.

Turbidity

Turbidity is caused by suspended matter, such as silt, clay, fine organic and inorganic matter, and sometimes by microorganisms (NSE 2009). High levels of turbidity increase the total available surface area of solids in suspension upon which bacteria can grow. Turbidity also interferes with the disinfection of drinking water and is aesthetically unpleasant.

Turbidity levels exceeded the water quality guideline for the protection of drinking water (change in background of 5 NTU) in six of the City's environmental monitoring wells (MWI Deep and MWI Shallow, MW2 Deep, MW3 Deep, MW4 Deep and MW4 Shallow) and exceeded the water quality guideline for the protection of aquatic life (change in background of 8 NTU) in three surface water sites (Nicola D/S 1 located 75 m downstream of the Coldwater confluence, and Nicola D/S 2 located 300 m downstream of the Coldwater River confluence, and Coldwater D/S Outfall located 20 m upstream of the Coldwater River confluence). The high turbidity readings in the deeper wells should be examined further, as this may be sign of some connectivity between surface and aquifer zones.

3 Stormwater Model

3.1 STORMWATER MODEL DEVELOPMENT

The stormwater modeling component is detailed in **Appendix E**. **Figure 3-1** presents the City of Merritt stormwater drainage system as modeled. The boundaries of the model consist of all areas serviced by the City's drainage infrastructure, i.e. all areas that are:

- Conveyed directly to the Nicola and Coldwater Rivers via traditional piped storm sewers and open ditches.
- Conveyed to one of four neighborhood detention ponds:
  - The Wal-Mart detention pond (southeast of Highway 5 and west of the Airport)
  - The Merritt Golf and Country Club detention pond (north of the Nicola River)
  - The Midday Road detention pond (natural low spot on Midday Road)
  - The River Ranch Road detention pond (south of Ranch River Road)
- Conveyed to the City's various rock pits and dry wells.

The scope of the model does not include:
- Un-serviced areas
- The Nicola River
- The Coldwater River

Design criteria and existing system model development are outlined in **Appendix E**. An extensive review and data gap analysis were conducted with City staff, and confirmed in the field. The result is a connected model throughout the City.

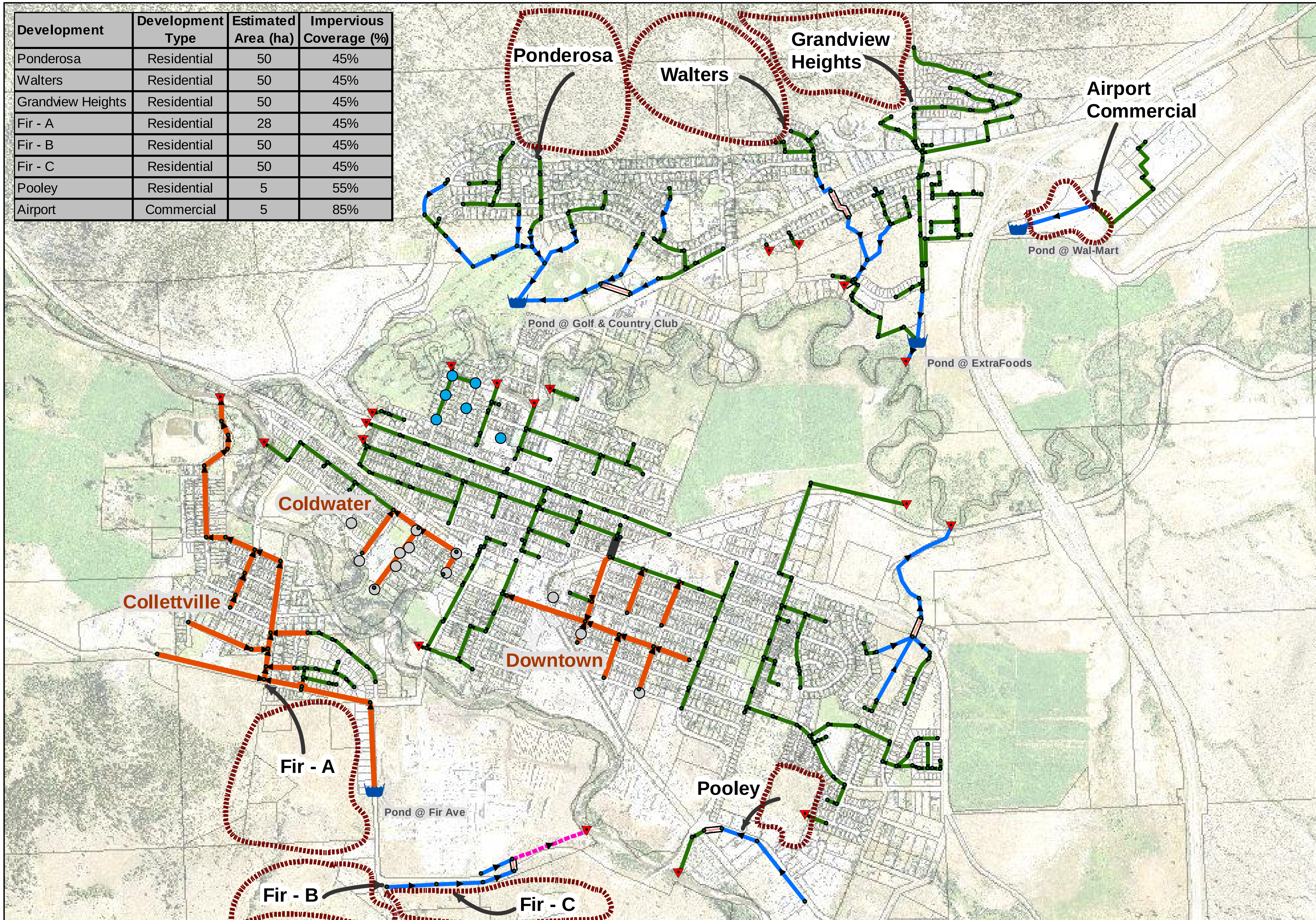
The model results help identify areas of concern, or where upgrades are likely required. The model was calibrated to operate according to current expectations and observations (see **Appendix F**). Scenarios were then developed to examine the system reaction to more intensive rainstorms and storm runoff routing. We note here that a key objective of the ISMP is to identify improvements to the existing stormwater system required to eliminate surface flooding (at dry wells) and pipe surcharging (within the piped system) under the 10-year storm event. The modeller has identified the following items that may need addressing later in the analysis.

Additional development areas, proposed new structures and modifications to the systems were then analyzed through a series of scenario runs, alternatives and storm flow routing solutions. This model analysis, which incorporates all the slope, soils, zoning, impervious zones, hydrology and hydraulics were incorporated into the InfoSWMM model. This model was reviewed and then supplied to the City.

3.1.1 Sewer Upgrades

Table 3-1 provides a summary of existing pipe upgrades required to meet the 10-year design storm, which is required under the current City of Merritt Subdivision Bylaw. **Figure 3-2** includes the location of

Development	Development Type	Estimated Area (ha)	Impervious Coverage (%)
Ponderosa	Residential	50	45%
Walters	Residential	50	45%
Grandview Heights	Residential	50	45%
Fir - A	Residential	28	45%
Fir - B	Residential	50	45%
Fir - C	Residential	50	45%
Pooley	Residential	5	55%
Airport	Commercial	5	85%



City of Merritt

Legend

- Outfall
- Detention Pond
- Culvert

Dry Well
- Existing
- Decommissoned

Stormmain
- Existing
- Proposed
- Decommissioned (flow diversion)

Ditch
- Existing
- Proposed

System Overview & Future Development

GeoAdvice Engineering Inc.

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

N S W E

0 0.5 1
Kilometers

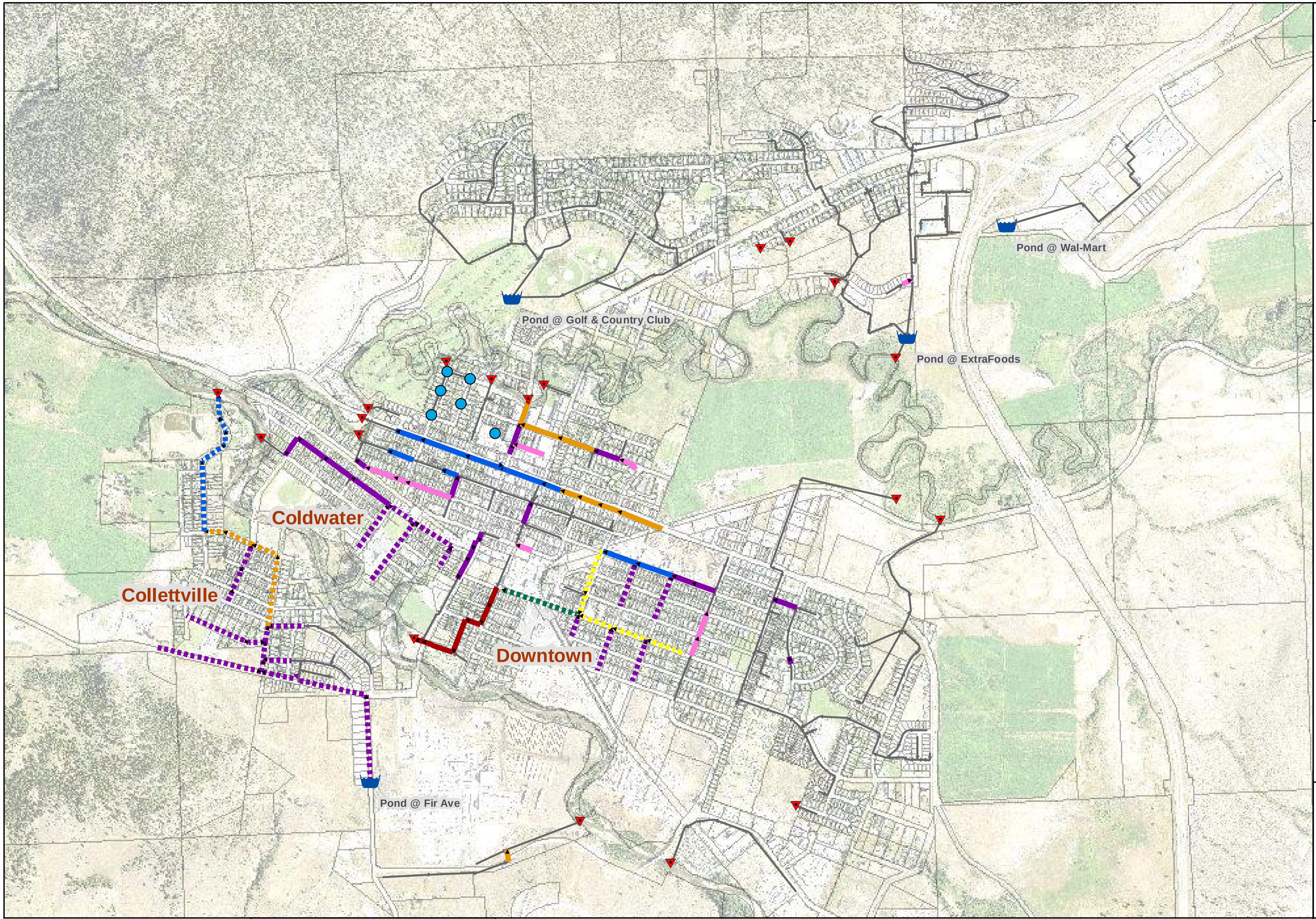
Project: City of Merritt ISMP
Model Development and System Analysis

Project ID: 2012-038-MER

Date: April 2013

Figure 3-1

City of Merritt



Legend

- Outfall
- Dry Well
- Detention Pond
- Existing System

Existing Pipe Upgrade Diameter (mm)

- 300
- 375
- 450
- 525
- 900

Proposed New Pipe Diameter (mm)

- 375
- 450
- 525
- 600
- 750

Proposed System Improvement

GeoAdvice Engineering Inc.

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.5 1
Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER | Date: April 2013

Figure 3-2

recommended upgrades and additions to the existing stormwater system required to meet the 10-year design requirement.

Table 3-1
Existing Pipe Upgrades

Upgrade Diameter (mm)	Length (m)	Percent of Total Length
300	930	3%
375	1,660	4%
450	980	3%
525	1,270	3%
750	20	<1%
900	570	2%
Total	5,430	15%

3.1.2 Dry Well Upgrades

The modeling of the future system identified dry wells at City Hall that are expected to experience surface flooding under the 10-year event.

Note that the hydrogeological investigations found that many of the dry wells pose the risk of directly impacting water quality within the City's potable water aquifer. The modeling results above indicate that to eliminate surface flooding, approximately 300 m^3 of additional storage capacity is required. If dry wells are not to be used, then other detention facilities, increased capacity of storm sewers or additional surface routing will be required in their place.

3.1.3 Improvement Impacts

This section compares the pre and post-improvement system performance. The model results are summarized in Table 3-2 and Table 3-3.

Table 3-2
Surcharged Pipes (10-Year Event)

Model Results	Pre-Improvement	Post-Improvement
Length of Surcharged Pipes (m) (d/D>=1)	6,299	0
% of Total Pipe Length	17%	0%

Table 3-3
Impacts of Improvements on System Flooding

Model Results	10-year (Pre/Post)*	100-year (Pre/Post)*
# of Junctions with Surface Flooding	9/0	26/9
Total Junction Flood Loss Volume (m^3)	995/0	5,147/293
# of Dry Wells Flooded	1/0	1/0
Total Dry Well Flood Loss Volume (m^3)	304/0	528/0

*Note: These values represent model results before implementing modifications (pre) and after upgrades are implemented (post).

The majority of system flooding is concentrated in the downtown area; as such, system upgrades are generally in the downtown area. To satisfy the 10-year design requirement for the future system:

- approximately 5.5 km of pipe upgrades (existing pipe that requires upsizing) and
- approximately 300 m^3 of additional storage are required.

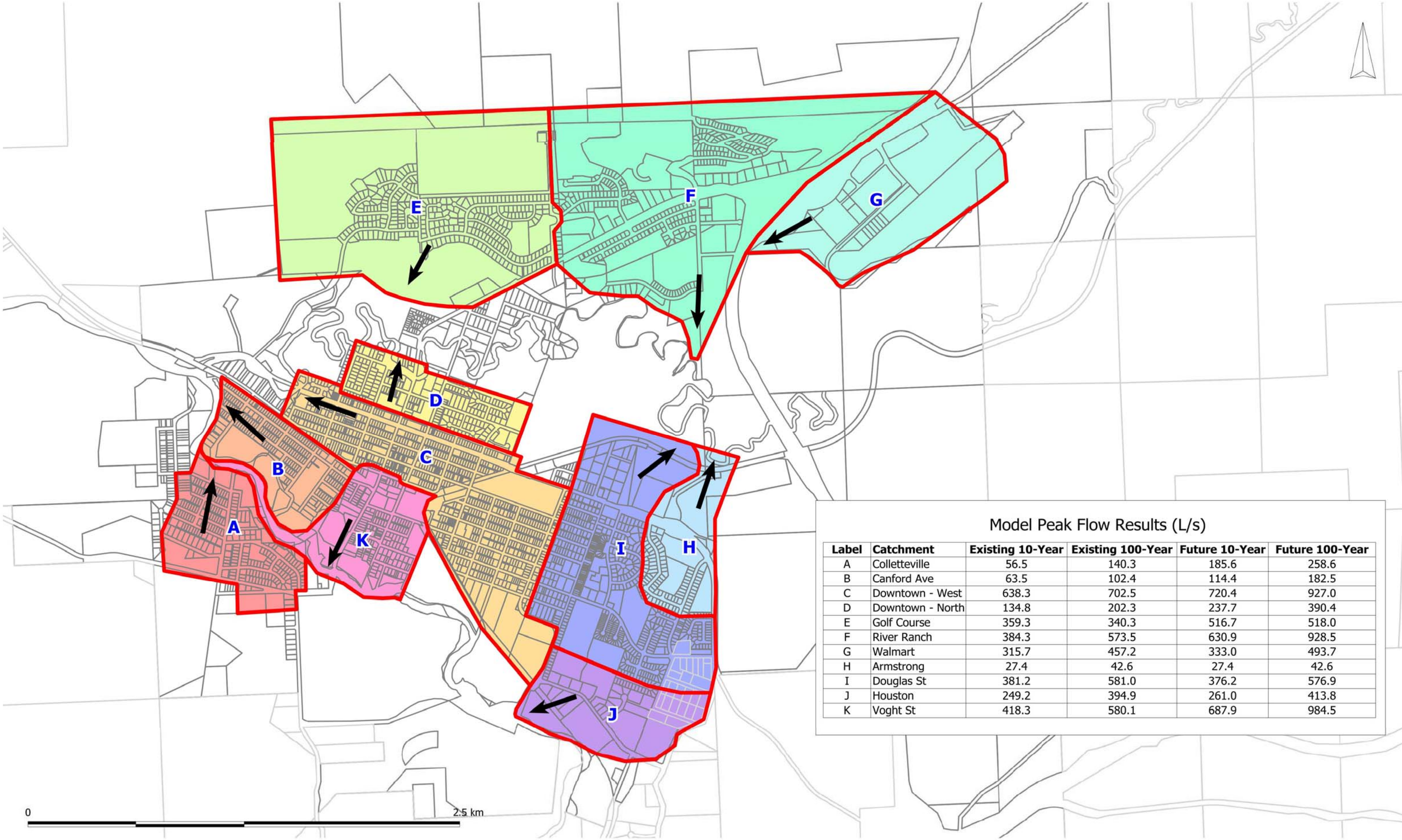
This is in addition to the proposed 6.4 km of localized stormwater system modifications (additional storm system installations).

The eight development areas outlined in **Figure 3-2** (taken from the current OCP), do not directly trigger improvements to the existing stormwater drainage system as there is sufficient downstream capacity in the existing system to convey the 10-year flows from these new development areas.

The ultimate storm flow routing is presented in **Figure 3-3**.

3.2 LONG RANGE CAPITAL IMPROVEMENTS

Based on the background data collected, discussions with maintenance personnel and the model results several long range capital improvements have been identified and are discussed in more detail in **Appendix G**, as well as in the implementation section of this report. A summary is shown in **Table 3-4**.



Model Peak Flow Results (L/s)

Label	Catchment	Existing 10-Year	Existing 100-Year	Future 10-Year	Future 100-Year
A	Colletteville	56.5	140.3	185.6	258.6
B	Canford Ave	63.5	102.4	114.4	182.5
C	Downtown - West	638.3	702.5	720.4	927.0
D	Downtown - North	134.8	202.3	237.7	390.4
E	Golf Course	359.3	340.3	516.7	518.0
F	River Ranch	384.3	573.5	630.9	928.5
G	Walmart	315.7	457.2	333.0	493.7
H	Armstrong	27.4	42.6	27.4	42.6
I	Douglas St	381.2	581.0	376.2	576.9
J	Houston	249.2	394.9	261.0	413.8
K	Voght St	418.3	580.1	687.9	984.5

No.	REVISION	DATE

(Name) (Date)
(Name) (Date)
(Name) (Date)

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Merritt

City of Merritt ISMP
Figure 3-3
10 and 100 Year Storm Routing

PROJECT No: 20122231
DATE: May 31 2013
SCALE: 1:20,000

Time: 10:54:38 AM I Date: 6/3/2013
Scale: 1:20,000
Map File: \\s-kel-fs-01\projects\20122231\00_SW_Plan\Engineering\01.00_Background_Data_Collection\GIS\map_merritt_jb_20121207.map

Table 3-4.
Issue Identification

Reason for Improvement / Cause	Improvement
Erosion of silt banks near the golf course	Extend outlet pipe to base, and/or riprap armour the outfall
Ponding next to Midday Valley Road	Complete phase 1 construction, and redirect the artesian well flow to the north east, towards the river.
Flooding in the Downtown East area	Install underground piping system to convey the flows to the west and then south to the Voght St park outlet
Collettville Improvements	Install piping along with curb, gutters and sidewalks.
Piping surcharged in Merritt Ave Network	Upsize pipe as per model recommendations. 1000 m
Piping surcharged in Nicola Ave Network	Upsize pipe as per model recommendations. 1200 m
Piping surcharged in Quilchena Ave Network	Upsize pipe as per model recommendations. 1100 m
Piping surcharged in Coldwater Ave Network	Upsize pipe as per model recommendations. 600 m
Piping surcharged in Voght/Garcia/Houston Network	Upsize pipe as per model recommendations. 1150 m
No quality control/sediment control on outlets	Install/establish stormwater management pond at Voght Street Park
No quality control/sediment control on outlets	Install/establish stormwater management pond at end of Douglas Rd in cutoff oxbow
Ponding on roads at various low points throughout the network	Investigate the cause, and install mitigation measures where appropriate, such as curb breaks, swales, CBs.
Drywells infiltrating into the drinking water aquifer	Remove drywells in the aquifer and add infiltration ponds where possible, including additional storm sewer network to protect the aquifer.

4 Recommended Tasks

The following section summarizes the recommendations from the various technical memoranda. An implementation plan, including budgetary requirements and timing, is discussed in more detail in **Section 6**.

4.1 PROTECT THE MERRITT DRINKING WATER AQUIFER

The surficial aquifer provides the majority (if not all) of the potable water for the City of Merritt. Pressure on this water source will increase as population increases, as well as possible increases in demands from agriculture. From a purely health perspective, aquifer protection measures should be a priority to the community and, therefore, impacts stormwater routing practices differently than in the past. We recommend the following practices:

- The City Development Bylaw should include the Groundwater Protection Zone (GPZ), defined earlier in **Figure 2-1**, to assure that all future development measures include protecting the City's potable water supply.
- Within the GPZ, enhanced Best Management Practices (BMP's) should be standard. These should include:
  - "Disposal-to-ground" ponds or basins.
  - Underground and above-ground storage tanks.
  - Industrial or commercial interests with a known liquid effluent component (fuels, heavy-oils, solvents, industrial chemicals, paints, dry-cleaner fluids, wood preservatives).
- Increased water quality testing and reporting at the City wells. Testing should be regular, and include hydrocarbons, herbicides, insecticides and fertilizers.
- Stormwater ponds or detention systems need to be installed at key outfall locations. These protect the rivers against toxic spills and mitigate flow peaks directly into the river systems.
- Downtown, implement residential and commercial stormwater capture concepts, such as "rain-barrel" programs or capture ditches to collect rooftop drainage. This would decrease some peaks from impervious surfaces from impacting the drainage system.

4.2 STORMWATER QUALITY MONITORING

Implement a regular water quality monitoring system to measure progress. The current information collected to date is spotty and project driven. The City would benefit by better understanding the influence that stormwater has on the Nicola River, Coldwater River and groundwater resources. Sample locations should include stormwater outfalls, major or key drywells, and river sites immediately upstream and downstream of the nine outfalls.

4.3 PROTECT PUBLIC SAFETY AND AVOID NATURAL HAZARDS

The City should continue to optimize its resources to protect the public and avoid costly natural hazards.

- All new stormwater structures should be constructed outside of the river's high water level (HWL). Where options are limited, add protective design features to improve safety.
- Assure that all stormwater infrastructure, especially in areas with silt and clay deposits, has erosion protection measures (surface armour, re-vegetation, slope grading, etc.).
- Avoid directing surface stormwater flow into local gullies unless in a pipe or flume, or unless designed to be fully armoured.

4.4 ENVIRONMENTAL CONSIDERATIONS

4.4.1 Terrestrial Habitats

The City should complete a sensitive ecosystem inventory (SEI) within its town boundary. Having SEI data will assist land-use planners and developers to identify critical habitat for species and ecosystems at risk. This will assure compliance with the Wildlife Act, and encourage better land-use decisions. Other recommendations include:

- Assure that development applications include specific vegetation surveys, particularly in areas with native vegetation; as well as weed control and prevention plan.
- Partner with stakeholders such as the Nicola Naturalist Society to expand the amphibian study area to include the floodplain areas of the Coldwater and Nicola River.

4.4.2 Riparian Areas

Assure that all stormwater upgrade locations (including ditching, pipe and manhole infrastructure, detention ponds, etc.) comply with the Provincial Riparian Areas Regulation and the City's OCP. **Table 4-1** includes recommendations for riparian setbacks on known surface water features within the study area. These setbacks should be included in the Development Bylaw.

Table 4-1
Recommended Riparian Setbacks for Environmental Protection

Water Feature	Width of Water Feature	Recommended Riparian Setback
Nicola River	> 10 m	30 m
Hamilton Creek	3 to 9 m	10 to 30 m*
Coldwater River	> 10 m	30 m
Spanish Creek	3 to 9 m	10 to 30 m*
Godey Creek	3 to 9 m	10 to 30 m*
Other tributaries and Drainage Ditches (connected to surface water)	< 3 m	10 m
Fish	2 x channel width	5 to 10 m*
Non-Fish	n/a	2 m*

**depends on the results of a riparian assessment based on the RAR Assessment Methods (2006).*

4.4.3 Aquatic Habitat

- Construct drainage structures that prevent direct discharge of stormwater and sediment directly into surface water, such as detention ponds, catch basins, and bio-swales.
- Identify barriers to fish passage in stream reaches (blocked culverts, debris, man-made features) and promote methods to remove these fish barriers.
- Include wildlife habitat features in new development areas that improve water quality and increase habitat. This may include incorporating features into detention pond designs, such as amphibian basking logs, rushes and emergent vegetation.
- Upgrade bylaws to note that all in-stream remediation work requires a Section 9 approval under the province's Water Act, as well as a project review by Fisheries and Oceans Canada (DFO).

4.5 INFORMATION AND DATA GAPS

The stormwater model was developed using the best available information, and with consideration of current industry standards. We believe the model developed here is a reasonable representation of the system performance. Where there was uncertainty in model parameters, conservative assumptions were made. Better information allows for more precision in the results from the model process.

We recommend the City examine obtaining more precise slope, soils and updated land use data, and update the data for more regular and detailed operation. Familiarity with the data and system operation will lead to obvious improvements in design and efficiency. We suggest the following to improve the model:

- Implement a stormwater flow monitoring program to better calibrate the system.
- Undertake an infrastructure survey program to fill existing stormwater infrastructure data gaps; particularly pipe invert elevations, diameters, detention pond geometry, and confirmation of catch basin, dry well and driveway culvert locations.
- Obtain a LiDAR survey of the City. A more detailed digital elevation model (DEM) of the City would allow for the development of a dual drainage model. The dual drainage model would help analyze overland flow, permitting an evaluation of the City's current level of service and risk under extreme precipitation events (e.g. 100-year design event).

5 Recommended Best Management Practices

There are several BMP's and stormwater management strategies that should be implemented within the City of Merritt boundaries and encompassing watersheds to effectively manage stormwater at the City, sub-watershed, and watershed levels. These following BMPs should be applied to both new development and re-development projects, and consider most general property zoning.

5.1 URBAN RESIDENTIAL LOTS

The following source control measures should be applied to urban (single family) residential lots at the time of re-development:

- Shrub planting
- Tree planting
- Growing medium depth
- Pervious pavement
- Minimum setbacks from EMS zones

Overall, each redeveloped lot should be required to meet performance targets for control of runoff volumes and peak flow rates. Ensure proposed developments (re-development and new) address stormwater retention on-site, using infiltration or re-use (i.e. rain barrels, recycling) techniques.

5.2 INDUSTRIAL, COMMERCIAL AND MULTIPLE RESIDENTIAL LOTS

The following source control measures should be applied to commercial, industrial, and multiple residential lots at the time of development or re-development:

- Shrub planting
- Tree planting
- Pervious pavement
- Green roof / detention roof or other detention/retention systems
- Enhanced growing medium depth
- Bioswale / infiltration trench
- Rain garden
- Minimum setbacks from EMS zones

5.3 LOCAL AND COLLECTOR ROAD RIGHTS-OF-WAY

Where feasible, source control measures should be applied to future local and collect road rights-of-way:

- Enhanced growing medium
- Tree planting
- Shrub planting

- Pervious parking lanes
- Infiltration / retention systems

5.4 ARTERIAL ROAD RIGHTS-OF-WAY

For future road improvement projects, the following practices should be incorporated into arterial road rights-of-way.

- Enhanced growing medium in medians
- Tree planting in medians and boulevards
- Enhanced growing medium in boulevards
- Shrub planting in medians and boulevards
- Infiltration / retention in boulevards.

5.5 STORMWATER MANAGEMENT PONDS

Stormwater management ponds are recommended to isolate all outfalls to the Nicola and Coldwater Rivers. These are required to better control runoff, minimize the risk of deleterious substances entering the river systems and provide relief to downstream stormwater infrastructure and watercourses.

As land availability is often the greatest hurdle in the development of these ponds, we recommend the City secure these sites as opportunity arises. We recommend that these facilities be placed outside of riparian areas, where possible.

5.6 RIPARIAN AREAS

We recommend maintaining and restoring riparian areas in the Nicola River and Coldwater River and along the remaining natural or quasi-natural watercourses. This could be achieved as part of the re-development planning process for larger developments, but may not be feasible with single residential lots undergoing redevelopment. This will likely be an opportunity driven process, linked to re-development proposals.

Riparian areas can be associated with community amenity features, such as greenways, and though Provincial Authorities (or DFO) usually prefer that access to the creek itself be prevented, multi-use paths and pedestrian bridges will encourage the public to use riparian zones as recreational areas. Other additions could include:

- Educational signage that informs users of the sensitive ecosystems within riparian zones and hopefully foster a sense of environmental stewardship.
- Encourage fencing to protect environmental sensitive areas and resources.
- Consider conservation covenant areas, parkland dedication, management agreements, and land trust areas in comprehensive planning approaches.

6 Implementation Plan

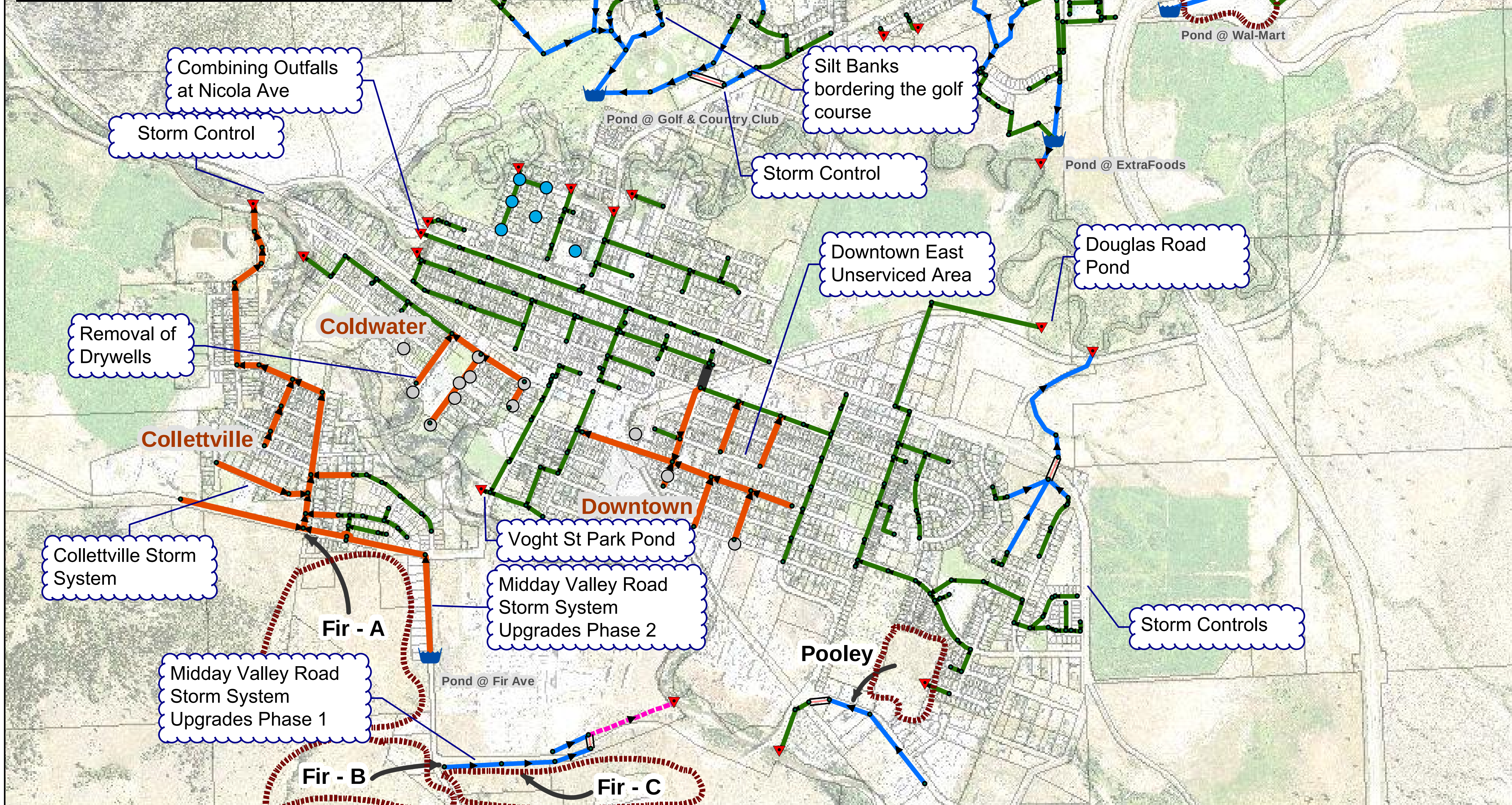
To implement the ISMP plan over the next 20 years, the City will require capital budget and manpower allocation. The tables at the end of this section summarize the recommended activities noted in this plan, from immediate implementation to long term expectations (See **Figure 6-1**). Each table includes elements of:

- Capital improvements
- Implementation of best management practices
- Implementing measurement systems for flow and water quality

The costs estimates for different projects are detailed further in **Appendix G**. These costs roughly represent the total cost of each upgrade or new addition to the system, and when the implementation should begin. Many of these projects will be phased over several years as budgets and funding permit. With this in mind, we have limited the number of new projects in the 10-20 year scenario. There are still BMP's, measurements and other initiatives identified that will still be required during this period.

Other BMP's should be implemented within the City Subdivision and Development Servicing Bylaw and paid for by developments as they come forward. Following the tables, we also introduce such issues as funding sources, possible enforcement strategies, suggested checklists and incentives, as well as suggested changes to the City of Merritt Bylaws and documents that are impacted by the recommendations of the ISMP.

Development	Development Type	Estimated Area (ha)	Impervious Coverage (%)
Ponderosa	Residential	50	45%
Walters	Residential	50	45%
Grandview Heights	Residential	50	45%
Fir - A	Residential	28	45%
Fir - B	Residential	50	45%
Fir - C	Residential	50	45%
Pooley	Residential	5	55%
Airport	Commercial	5	85%



City of Merritt

Legend

- Outfall
- Detention Pond
- Culvert

Dry Well

- Existing
- Decommissoned

Stormmain

- Existing
- Proposed
- Decommissioned (flow diversion)

Ditch

- Existing
- Proposed

System Overview & Future Development

GeoAdvice Engineering Inc.

N W E S

0 0.5 1
Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: April 2013

Figure 6-1

Table 6-1
IMMEDIATE MEASURES (0-2 YEAR PLAN) – RECOMMENDATIONS

No.	Recommendations	Objective	Cost
0 - 2 Year Capital Requirements			
1	Repair silt banks bordering the golf course.	Decrease immediate erosion issues	$200,000
2	Midday Road Storm System Upgrades (ditch and redirection east)	Midday Rd/Houston Rd	$50,000
Environmental Enhancements			
3	Water Quality Testing at Key Sites	Improve long-term measurement ($10k /y)	$20,000
Operational Measures			
4	OCP revisions	General	$40,000
5	Development and Servicing Bylaw revisions	General	$40,000
Budget Summary			
Total Costs per 2 year Period			$350,000
Average Annual Cost			$175,000 /yr.

Table 6-2
2-5 YEAR PLAN - RECOMMENDATIONS

No.	Recommendations	Objective	Cost
2-5 Year Capital Requirements			
1	Downtown-East un-serviced area 2,600m new sewer + 1,300m of sewer upsizing	Reduce Flooding	$1,530,000
2	Voght St Park – New storm pond	Reduce Risk of Spill, Eliminate dry wells	$180,000
3	Douglas Road – New storm pond	Reduce Risk of Spill, Eliminate dry wells	$60,000
4	Downtown East - Removal of drywells in aquifer sensitive areas (option - include in construction projects above).	Reduce risk on aquifer	$600,000
Environmental Enhancements			
5	Water Quality Testing at Key Sites	Provide measurement to assure objectives are met ($10k/yr).	$30,000
6	Implement Flow Monitoring Program	Assist with calibration of model in future	$10,000
7	Implement Sensitive Ecosystem Inventory (SEI), identifying critical habitat areas.	Simplify development process	$20,000
Operational Measures			
8	Implement Rain-Barrel Stormwater Capture Program in downtown and other “problem” areas only	Methods of reducing impact of stormwater runoff.	$10,000
Budget Summary			
Total Costs per 3 year Period			$2,440,000
Average Annual Cost			$815,000 / yr.

Table 6-3
5-10 YEAR PLAN - RECOMMENDATIONS

No.	Recommendations	Objective	Cost
5-10 Year Capital Requirements			
1	Collettville Storm System (~3200m of new storm main)	Improve neighborhood layout	$1,200,000
2	Midday Road Storm System Upgrades (storm main installation to north)	Service Properties	$400,000
3	Miscellaneous ditch/swale/piping installations	Reduce and control surface flows	$1,000,000
Environmental Enhancements			
4	Restrictive Covenant Fencing for Future Development	Protect riparian areas and corridors ($10k/yr)	$50,000
5	Remove Invasive and Nuisance Weed Species and Re-Vegetate Weed Control Areas	Reduce impacts to local river and riparian areas	$50,000 first yr. $20,000 per yr.
6	Require Development to complete an Archaeological Impact Assessment (AIA).	Reduce construction impacts, assure City makes developers aware of local FN issues	Developer Cost
Operational Measures			
7	Water Quality Testing at Key Sites	Provide measurement to assure objectives are met ($10k/yr)	$50,000
8	Update the Stormwater Master Plan	To update the project list, and confirm past objectives	$100,000
9	Obtain LiDAR survey of City for Stormwater Model	Assist developers to make informed decisions.	$25,000
Budget Summary			
Total Costs per 5 year Period			$2,900,000
Average Annual Cost			$580,000 /yr.

Table 6-4
LONG TERM (10-20 YEAR PLAN) RECOMMENDATIONS

No.	Recommendations	Objective	Cost
10-20 Year Capital Requirements			
1	Mainline Replacement (Carry-over)		
2	Several ditch/swale/piping installations	Control and route flows properly	$3,000,000
3	Combining outfalls at Nicola Ave and provide treatment for storm flow prior to release.	Reduce risk to aquifer	$120,000
Operations and Maintenance (Annual)			
4	Water Quality Testing at Key Sites	Provide measurement to assure objectives are met ($10k/y).	$50,000
5	Regular Maintenance of Culverts and Removal of Debris	Assure that storm routing is efficient	$10,000
6	Annual Maintenance and Upkeep of Setback Fencing	Maintain riparian boundaries.	$5,000
Management Activities (Annual)			
7	Implement other environmental provisions in the subdivision bylaw for development: • Site specific natural vegetation surveys, • Weed control regulation • Tree and shrub retention in new development • Tree topping and limbing in riparian areas. • Establish riparian setbacks. • Assess critical streams • Reduce barriers for fish passage • Incorporate wildlife features in riparian areas.	Add environmental controls to servicing bylaw	Developers
Budget Summary *Total Additional Costs per 10 year Period*			$3,300,000

6.1 FUNDING SOURCES

Funding to implement, operate, and maintain the stormwater best management practices developed in the Merritt ISMP will come from a variety of sources. These sources include:

- City of Merritt Capital Construction Program.
- Land owners and developers.
- Development driven upgrades applied to City directly by the developer or through Development Cost Charges (DCC).
- Federal Funding - The Federal Government provides funding for infrastructure and environmental projects, primarily through Infrastructure Canada and Environment Canada. While these sources are not widely utilized for storm drainage related projects, on rare occasions they may provide useful funds for specific projects and should be considered when advancing projects. These programs are:
  - Canada Building Fund
  - Green Infrastructure Fund
  - Eco-Action Community Funding Program
  - Green Municipal Fund
- Provincial Funding - the Infrastructure Planning Grant Program.

6.2 CHECKLISTS FOR DEVELOPMENT AND RE-DEVELOPMENT PROJECTS

A checklist should be developed for each development application to ensure that the recommended best management strategies developed in the ISMP are properly accounted for at every stage of the development process. Checklists can be incorporated into existing processes and will encourage proper implementation of the stormwater management recommendations.

6.3 INCENTIVES

Compliance with the recommendations of the City of Merritt ISMP may be more easily achieved if land owners and developers are offered incentives for implementing, operating, and monitoring stormwater best management strategies. Possible incentives include one-time rebates, stormwater utility fees or some form of publicity achievement recognition program for compliant businesses.

6.4 RECOMMENDED CHANGES TO CITY BYLAWS AND DOCUMENTS

The City of Merritt has bylaws in place to regulate and enforce practices within the municipal boundary. We identified three bylaws that will be impacted by the best management strategies recommended in the ISMP. We recommend that each bylaw be amended accordingly to promote the implementation of best management strategies. Changes are recommended to the following by-laws and documents:

- City of Merritt Zoning Bylaw
- City of Merritt Subdivision and Development Bylaw
- City of Merritt Supplementary Master Municipal Construction Document.

7 Conclusions and Recommendations

An Integrated Stormwater Master Plan has been developed for the City of Merritt. The results and discussions from this planning process are consistent with the Ministry of Environment (MOE 2002) guidelines. This report provides much of the technical basis for development of the long-term ISMP, and sets the stage for developing goals for City that can be incorporated into the Official Community Plan.

This report identifies the unique features within the City of Merritt catchment area, and identifies key issues to be mitigated to meet drainage, stream protection and water quality objectives. The plan identifies issues and improvements required to better manage stormwater runoff in a financially and environmentally sustainable manner.

1 Secure Political Interest and Support

Associated Engineering (BC) Ltd., with assistance from sub-consultants, Summit Environmental Consultants Inc. and Geo-Advice Ltd, were retained by the City of Merritt to work with Council, staff and stakeholders to complete this ISMP. This report is the first plan for the City and will, therefore, progress into the future. This report was presented to Council on March 5, 2014.

Recommendation: The City needs to formulate supporting policies as outlined in this report, including updates to development bylaws and aligning with the OCP.

2 Frame the Watershed Problems and Opportunities

The project team included a Drainage Engineer, Fisheries Biologist, Geomorphologist, Hydrogeologist, Habitat Ecologist, Water Quality Scientist and Wastewater Treatment Specialists. The team conducted individual studies in their areas of expertise. Two internal round-table discussions were held to identify areas of concern and gaps in information and mapping. The project team worked with City of Merritt staff, including the project lead, technologist, operations and maintenance personnel, to identify and address many of the stormwater issues in the Nicola Valley. Base maps were developed to identify all the issues.

Recommendation: Continue to promote research and coordinate more precise information collection.

3 Develop Objectives and Alternate Scenarios

A comprehensive stormwater model was developed using InfoSWMM. The model's boundary encompassed all areas serviced by the City's drainage infrastructure, and was used to identify areas of concern, or where upgrades would likely be required. Significant effort was made to confirm that the system modeled actually represented the city system. Once calibrated, alternatives and scenarios were developed to examine the system reaction to more intensive rainstorms and storm runoff routing.

Recommendation: The City's GIS and stormwater model components should be managed as a single entity. When future modeling is performed, the updated GIS data from the City can be easily adapted into the existing model.

4 Collect Meaningful Data and Refine Scenarios

Identifying meaningful data was a significant component of this work. Research was conducted on four relevant areas:

- *Hydrogeology:* The City is underlain by the Merritt Aquifer; an unconfined, unconsolidated sand and gravel surficial aquifer which is highly productive and under high demand. The aquifer appears to be hydraulically connected both to the Nicola and Coldwater Rivers. Any contamination that can potentially occur in the surficial aquifer will likely impact the drinking water supply of the City.
-
- *Natural Hazards:* A review discovered areas of slope instability, surface and river erosion, flooding, ice-jamming and land subsidence conditions that impact future stormwater planning. Areas were identified that will require future monitoring and risk mitigation.
-
- *Wildlife and Ecology:* Environmentally sensitive areas, relevant applicable environmental regulations and best management practices for mitigation were identified. There is limited wildlife habitat within the city center due to development. The Nicola and Coldwater Rivers riparian areas are heavily encroached within the City core. The impacts are significant as water temperature increases during seasonal low flows; impacting fish survival.
-
- *Stormwater Quality:* Historical measurements from twelve surface water sites (four Coldwater River and eight Nicola River) show exceedances for phosphorous, suggesting that conditions in both rivers occasionally become more eutrophic. This is limited detailed information available on long term water quality impacts. The research has found incidences where well water has exceeded the total coliform drinking water guidelines of 1 CFU; water temperatures have exceeded 15^{o}C; where summer temperatures in the lower Coldwater River exceed lethal limits (24^{o}C) for salmon, trout and char, or turbidity levels sometimes exceed drinking water quality guidelines in six of the City's environmental monitoring wells.

Recommendation: The City requires more testing and information to address the need for additional water quality information from the river source, drinking water wells, and its nine stormwater outfalls. The results of this monitoring system will assist in determining the success of long term strategies and objectives being met.

5 Evaluate Alternatives and Develop Component Plans

The modeling assisted in identifying improvements to the existing stormwater system required to eliminate surface flooding (at dry wells) and pipe surcharging (within the piped system) under the 10-year storm event. The majority of these improvements were concentrated in the downtown area, including approximately 5.5 km of storm sewer upgrades and the addition of 300 m^3 of storm water storage. Other works involve over 6.4 km of localized storm sewer modifications or additions outside the City centre.

The eight development areas identified do not directly trigger improvements to the existing stormwater drainage system as there is sufficient downstream capacity in the existing system to convey the 10-year flows from these new development areas.

Recommendation: The scope of this plan focused on City of Merritt stormwater requirements. River flooding of the Nicola is also a key issue in the City and should be incorporated in future modeling efforts.

6 Develop an Implementation Program

A long-range capital improvement plan (20 year) was developed to address capital, infrastructure and operational concerns. This plan was developed with the input from City planning and maintenance staff. Bylaws updates have been recommended. To implement the ISMP over the next 20 years, the City will require capital budget and manpower allocation for the following:

- Immediate Measures (0 to 2 years) $ 350,000
- 2-5 Year Plan $2,440,000
- 5-10 Year Plan $2,900,000
- Long Term (10-20 Years) $3,300,000

Recommendation: The City should develop a financial plan to implement the above projects.

7 Refine through Adaptive Management

The ISMP is an active plan and reporting process. By providing more regular and focused measurements of water quality, water temperature and stormwater flows entering watershed, downstream and with its boundaries, the City will better understand the impacts of implementing its Integrated Stormwater Master Plan. The capital works planning component can then be adjusted as required to meet the ever changing development needs in the community.

Recommendation: Report the results of water quality information and key objectives annually.

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REPORT

Certification Page

This report presents our findings regarding the City of Merritt Integrated Stormwater Master Plan.

Respectfully submitted,

Prepared by:

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Reviewed by:

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RM/rl

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

Appendix A - Hydrogeological Assessment

Report

Associated Engineering
GLOBAL PERSPECTIVE.
LOCAL FOCUS.

City of Merritt

Integrated Stormwater Management Plan
105 - Hydrogeology

February 2013

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1 Introduction

Summit Environmental Consultants Inc. undertook an overview hydrogeologic investigation of the Merritt Area for the Merritt Integrated Stormwater Management Plan (ISMP). The hydrogeology of the Merritt area is highly complex, with two major river systems influencing subsurface aquifers with marked surface water – groundwater interaction (Figure 1-1). The hydrogeologic conditions in the uppermost surficial deposits determine the feasibility of subsurface infiltration of stormwater drainage as a measure to achieve runoff reduction. Summit completed a literature review and desktop study of the available information to date for the study area. The results will allow for planning of future assessment phases of the suitability and effectiveness of infiltration-based stormwater management techniques, including best management practices for stormwater and low impact development.

We note that infiltration-to-ground is not the only approach for reducing runoff volumes, but is often relied upon if large-scale development has drastically reduced the natural vegetative cover and forest canopy and created a large concentration of impervious surfaces.

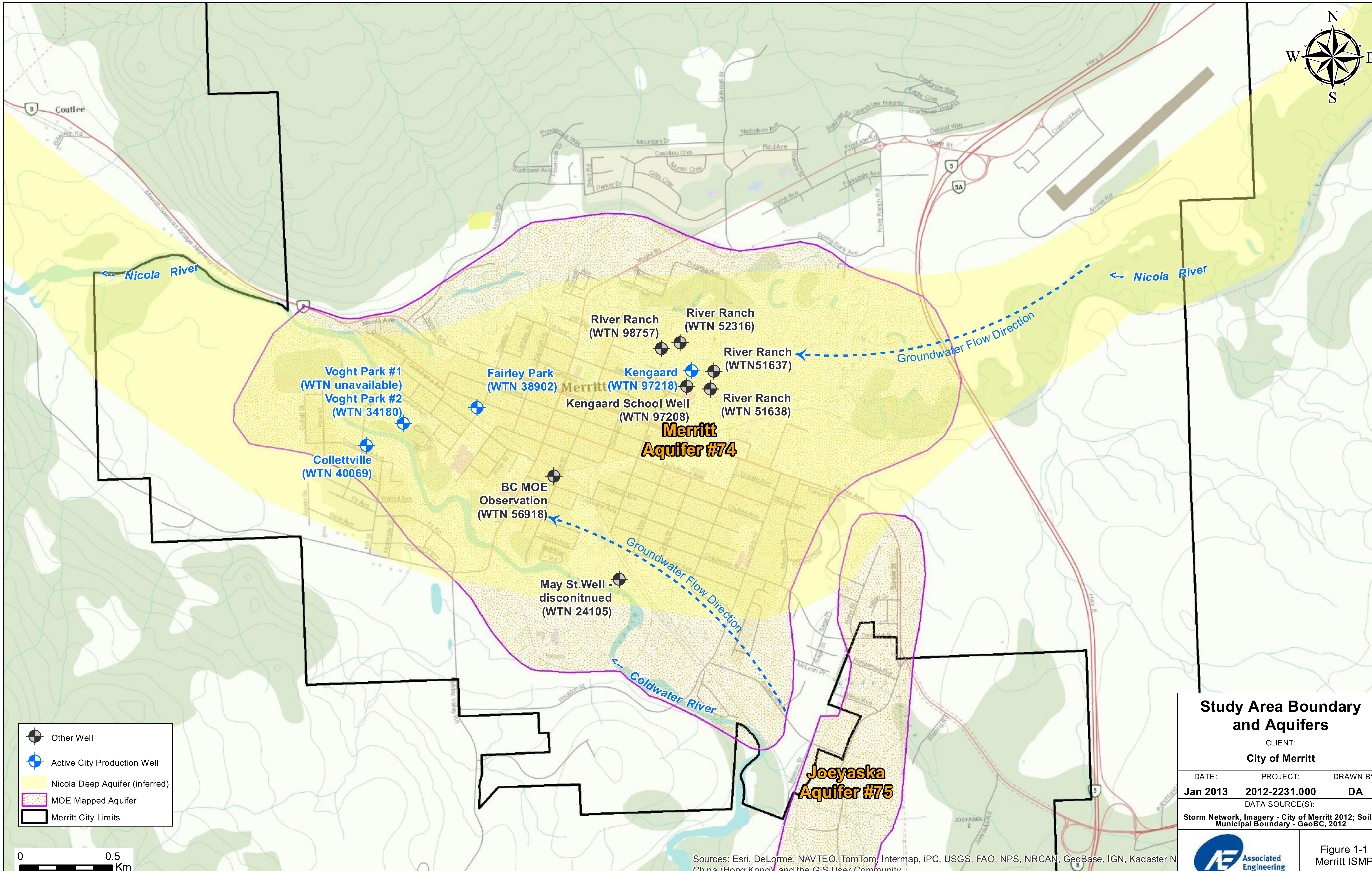


Figure 1-1
Merritt ISMP

2 Background Information

The background physical characteristics that relate to the hydrogeological conditions in the study area have been compiled from various sources, and are summarized below.

2.1 LOCATION

The City of Merritt ("the City") is located in the Nicola Valley of the south-central Interior of British Columbia. Located east of the confluence of the Nicola and Coldwater Rivers, the City is set along the Nicola Valley, a thin strip of flatland set between the coastal mountains and the BC interior high plateau.

The City of Merritt is composed of five distinct residential areas: Bench, Collettville, Central, Diamondvale and Lower Nicola. The Bench is a residential mountain bench, sited on the northwest side of the valley. Collettville, on the southwest edge of the community south of the Coldwater River, is the newest addition to Merritt, joining the municipality in 1995. Central is situated at the south of the city centre. Diamondvale is in the heart of the valley, and is the most populated. Lower Nicola is about ten kilometres outside of the City of Merritt, but most residents are serviced by and work in the City.

2.2 CLIMATE

Climate normal data (calculated for date from 1971-2000) is available for Merritt STP (Climate ID: 1125079), located at an elevation of 609m, at 50°06'51.004" N and 120°48'03.005" W. Average annual precipitation and temperature are 322.2 mm and 7.4°C respectively, with most of the precipitation in the form of rain. The wettest months are in the winter (December and January), though not insignificant rain can be present in June, and the driest month is April. The coldest months are December (-3.9C) and January (-4.5C), and the hottest month is July (18.4C).

Table 2-1
Climate Normals for Merritt STP (STM 1125079), 1971-2000

Merritt STP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain (mm)	14	10.8	11.3	13.4	26.5	34.1	25.8	22.1	23.3	21.7	21.7	14.3	238.9
Snow (mm)	23.2	12.8	5.3	1.2	0.3	0	0	0	0.4	1.8	13	25.3	83.3
Precipitation (mm)	37.2	23.6	16.6	14.5	26.8	34.1	25.8	22.1	23.6	23.5	34.6	39.6	322.2
Average Temperature (mm)	-4.5	-0.9	3.7	7.8	12	15.4	18.4	18.1	13.6	7.6	0.9	-3.9	7.4

Source: Environment Canada, 2012a.

The Nicola Watershed is one of the drier watersheds in the province, and the Merritt area in particular is considered as having a semi-arid climate. The Coastal Mountain Range acts as a natural barrier for precipitation coming in from the west, and the Nicola Valley is located in its rain shadow.

2.3 Bedrock Geology

Two bedrock expressions are mapped underlying the Merritt area. Toward the east, the Merritt Basin is part of the Princeton Group sedimentary rocks. These tertiary period rocks are of Eocene age (between 56.5 and 35.4 million years old), and are described as sandstone, conglomerate, argillite and coal. The formation includes “Coldwater beds” and Allenby Formation of the Princeton Group. Toward the west, the Western Volcanic Facies are part of the Nicola Group volcanic rocks. These Mesozoic era rocks are of the Upper Triassic period (between 235 and 208 million years old), and consist of mafic to felsic pyroclastic rocks and flows; argillite, sandstone and local carbonate rocks (BCMOE 2012).

Depth to bedrock below the middle of the Merritt Aquifer is highly variable, with reports of unconsolidated sediments extending to a depth of 172m (WTN 97208- Kengaard School Well) in one well, and bedrock encountered at a depth of 165m in another (WTN 97218 – Kengard Production Well) on the same property (BCMOE 2012).

2.4 Surficial Geology

The following is a reference from the 1970 letter to the City of Merritt from Ed Livingston, commonly referenced for the chronology of sediment deposition in the Merritt area.

> *"At the time of melting of the last glaciers in the Merritt area the Nicola Valley was dammed, probably by ice both east and northwest of Merritt, forming a lake at least 250 feet deep at Merritt. Dirty meltwater from the Coldwater Valley brought sand, silt and clay into this lake. These sediments were deposited on the lake bottom as the prominently banded clays (lake beds) seen in road and river cuts in the Merritt area. As the dams forming the lake were destroyed the lake level decreased and it finally disappeared in the Merritt area. Once the lake had gone the Coldwater River which was probably choked with gravel above the former lake level, cut into the soft lake beds to a level perhaps as much as 100 feet below its present level. As the size of the river decreased due to depletion of ice in the mountains to the southwest the river channel became filled with clean gravel forming the gravel fan on which most of the town is built."*

Surficial materials which underlie the Merritt area are the result of this glacial, glaciofluvial, glaciolacustrine, and recent fluvial deposition. Geologic interpretation of the strata is made possible from observation of exposures along the valley margins and by interpretation of available well logs completed within the valley.

The City of Merritt is directly underlain by shallow sand and gravel strata associated with post-glaciofluvial and fluvial deposition. This surficial layer is approximately 5 to 15 metres thick, and spans the area between the two rivers, from their confluence in the west to the Coquihalla Highway in the east. The City of Merritt and Collettville wells are completed in the same deposit, but in a deeper gravel filled "trough". This trough, located at the western end of town is very narrow, extends in an east-west orientation, and down to a depth of 50 metres or more. BC MOE Observation Well No. 296 is completed in this surficial aquifer, but did not encounter this trough of coarse grained sediments.

Several irrigation wells on the River Ranch property have intersected saturated sandy gravel layers up to several metres thick below the glaciolacustrine silts to a depth of about 100 metres. These deeper gravels are interpreted to originate from glaciofluvial deposition that occurred prior to the ice damming of the valley. The total thickness of these deposits is largely unknown, but the borehole for the recently installed Kengaard well encountered bedrock at a depth of 165 metres below grade. The position of these sediments suggests the potential existence of a paleo-channel which follows the present course of the Nicola River, and may extend as far east as Nicola Lake (KALA 2004).

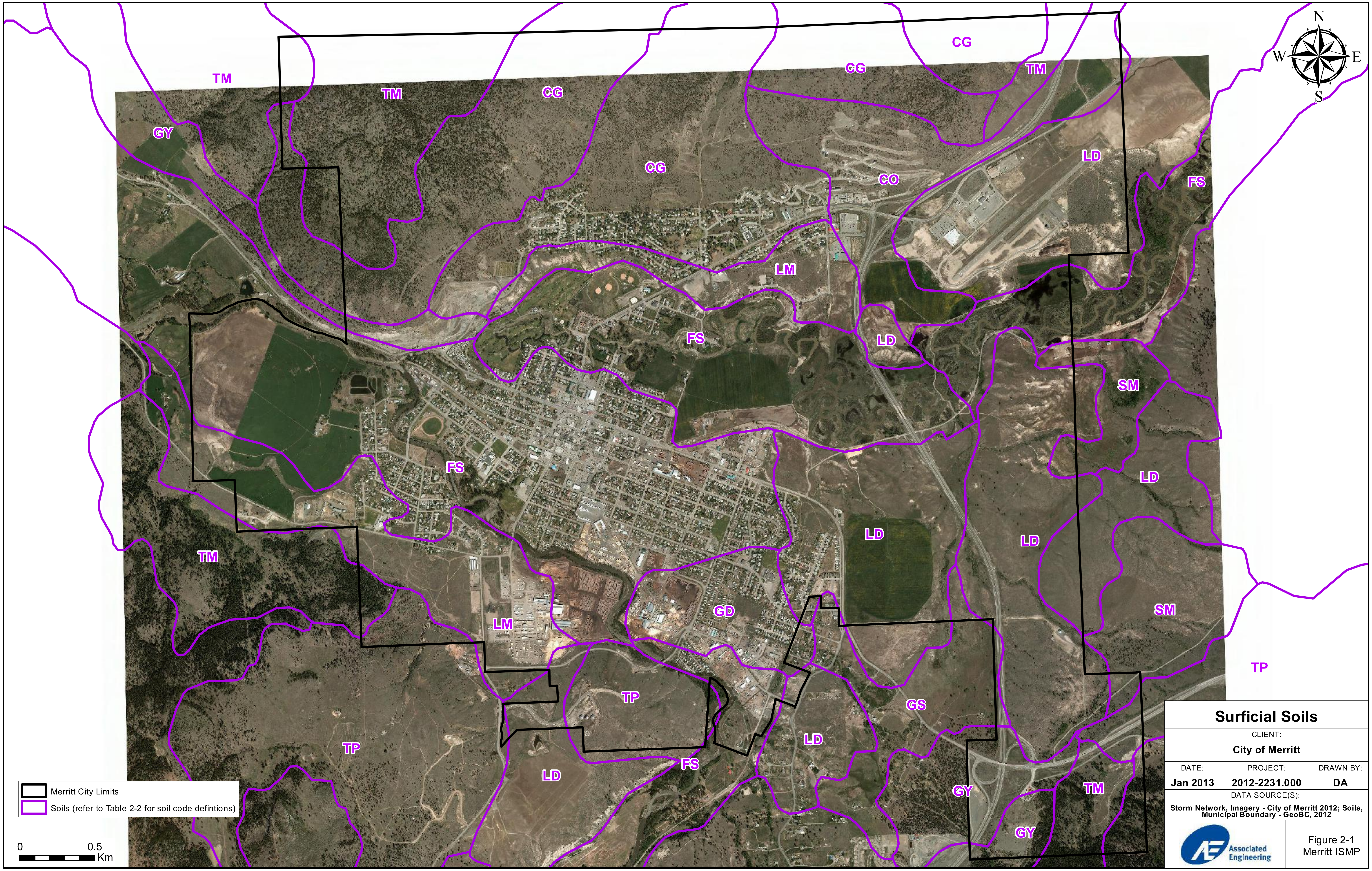
Summit reviewed the surficial geology maps for the Merritt area, and generated a base-map that identified areas of similar surficial geology. The polygons created were based upon the soil maps from Soils of the Ashcroft Area[1], as they provided finer resolution of surficial sediment/soil type than the surficial geology maps available for the same area. From the surficial soil maps and the descriptions of the materials present at surface, Summit created a surficial sediment catalogue that outlined the soil units, classified them according to soil parent material and soil texture classification, and grouped them together according to similar lithologic properties. We assigned each material type a range of hydraulic conductivities based upon literature values gleaned from several sources[2]. This provided a book value based first order approximation of the hydraulic properties for the surficial materials for use in the hydraulic modelling portion of the program.

The surficial sediment catalogue including estimated ranges of infiltration rates is listed in Table 2-1, and the surficial soils map that accompanies the catalogue is presented in Figure 2-1. SWMM5 is a commonly used stormwater management model developed by the USEPA, used to simulate runoff quality and quantity from urban areas. Green Ampt is the method of filtration estimation that accounts for soil suction head, water content and hydraulic conductivity used in the computer model. The remaining K_{sat} values literature-sourced ranges for common material types.

[1] Soils of the Ashcroft Area, Map Merritt 92I/SE, Soil Survey Report No. 26, Drafting Section, Resource Analysis Branch, Ministry of Environment, 1972-76
[2] Soils of the Ashcroft Area, Map Merritt 92I/SE, Soil Survey Report No. 26, Drafting Section, Resource Analysis Branch, Ministry of Environment, 1972-76
[2] Green Ampt (by email, 2012), Rawls et al. (1983) and Freeze and Cherry (1979).

Table 2-2
Surficial Sediment Catalogue

Symbol	Name	Soil_parent_material	Drainage	Grouping	Soil_Texture_Classification	SWMM5 (mm/hr)	Green Ampt (mm/hr)	Ksat_Value_low (mm/hr)	Ksat_Value_high (mm/hr)
CG	Cavanaugh	Gravelly, coarse textured colluvial and colluvial fan deposits, moderately to exceedingly stony.	well	1	Gravel			3.60E+03	3.60E+06
CO	Commonage	Coarse textured colluvial fan deposits; moderately to very stony.	well	1	Gravel			3.60E+03	3.60E+06
TM	Timber	Medium and moderately fine textured morainal deposits; slightly to moderately stony.	well	2	Clayey silt gravel sand		2.18E+01	3.60E-06	3.60E+00
TP	Trapp Lake	Medium and moderately fine textured morainal deposits; slightly to moderately stony.	well	2	Clayey silt gravel sand		2.18E+01	3.60E-06	3.60E+00
GD	Godey	Gravelly, coarse textured fluvioglacial deposits with thin, loamy or sandy eolian cappings, slightly to very stony.	rapid	3	Sandy gravel		2.36E+02	3.60E+00	3.60E+04
GS	Glimpse	Coarse and moderately coarse textured textured fluvioglacial deposits; moderately to very stony.	rapid-well	3	Sandy gravel		2.36E+02	3.60E+00	3.60E+04
GY	Glossey	Gravelly, coarse textured fluvioglacial deposits with gravelly, loamy cappings; moderately to very stony.	rapid-well	3	Sandy gravel		2.36E+02	3.60E+00	3.60E+04
SM	Shumway	Moderately coarse and medium textured fluvial and fluvioglacial fan deposits; stone-free or slightly stony.	well	4	Sand	1.20E+02		1.80E+01	3.60E+04
LM	Lundbom	Moderately fine textured lacustrine deposits; stone-free.	well	5	Silty Clay Loam	1.52E+00			
LD	Lac du Bois	Medium and moderately fine textured lacustrine deposits; stone-free.	well	5	Silty Clay Loam	1.52E+00			
FS	Frances	Moderately coarse and medium textured fluvial deposits; stone-free.	imperfect	6	Sandy Loam	1.09E+01			



Surficial Soils

CLIENT:
City of Merritt

DATE:	PROJECT:	DRAWN BY:
Jan 2013	2012-2231.000	DA

DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012

Associated Engineering

Figure 2-1
Merritt ISMP

3 Hydrogeology

The Merritt Aquifer is an unconfined aquifer underlying the City of Merritt, and is largely bounded by the Coldwater River to the south and the Nicola River to the north. Previous studies (BCG 2011, EBA 2002, KALA 2004) indicate that the Merritt Aquifer is an unconfined aquifer over much of its areal extent.

The British Columbia Ministry of Environment (BCMOE) Aquifer Classification system categorizes the Merritt Aquifer (Aquifer #74) as a type IA aquifer, identifying it as one of the most highly developed and vulnerable aquifers in the province. The Merritt Aquifer, though highly productive[3], is under high demand (with both City supply and irrigation use) and is highly vulnerable to contamination (largely unconfined). The BCMOE has given the aquifer a ranking value of 16 via their Aquifer Classification System[4], and less than 4% of the currently mapped aquifers in the province have a rating above 14. This surficial sand and gravel aquifer is approximately 6.5 km^2 in size, and is recharged through a combination of precipitation and baseflow recharge from the Coldwater and Nicola Rivers; this high degree of surface water – groundwater interaction may be contributing to seasonal depletion of the nearby rivers from pumping of the City wells [5](WMC 2008).

The City currently satisfies all potable water quantity requirements via groundwater extraction from the Merritt Aquifer. Four of the five supply wells are completed in the surficial unconfined sediments of the Merritt Aquifer, and one additional well is completed in a lower confined aquifer (the Kengard well).

In addition, within the study area the Joeyaska Aquifer (Aquifer #75) extends south from the downtown core of the City, toward Spanish Creek. The Joeyaska Aquifer is classified as a IIC confined sand and gravel aquifer, moderately productive, under moderate demand and is considered at low risk for contamination. The BCMOE has given the aquifer a ranking value of 8. The aquifer is approximately 1.4 km^2 in size and extends from the Merritt-Princeton Highway 97C at Nicola Avenue in the north to Spanish Creek south of Coldwater Rd. in the south. The Joeyaska Aquifer is not considered a development target for the City of Merritt, however it's interconnection with the surficial Merritt Aquifer and deeper aquifer system identified beneath the City is poorly understood.

Based upon production well logs, the thickness of the Merritt Aquifer ranges from 5 to 50 metres, however, about 80 percent of the aquifer is interpreted to be less than 10m thick. The area that is less than 10m thick occurs mostly on the floodplain between the Coldwater and Nicola Rivers. Drill logs from the BCMOE Water Resources Atlas also suggest the presence of a deeper "trough" within the aquifer that could extend down to a depth of almost 50m. The trough is interpreted to extend from the old May Street production well

[3] the total combined capacity of the City's water production wells based upon the 2011 Annual Report is 371 L/s (5900 USgpm) (WW, 2012)
[4] Kreye, R., Ronneseth, K. , and Wei, M. An Aquifer Classification System for Groundwater Management In British Columbia, BCMOE, Water Management Division, Hydrology Branch.
[5] Of noted exception is the Nicola River, when being recharged by the surficial aquifer (a gaining reach). The Coldwater River is seen to be a continually losing reach at Merritt.

(east) to Collettville (west). The deepest part of the trough is interpreted to be about 0.5km wide, and extend from the Fairley Park well (north) to Collettville (south). The trough appears to run sub-parallel to the current course of the Coldwater River, suggesting that it may be an in-filled paleo-river channel.

Four of the five city production wells access this deep trough for the City water supply, (Collettville, Voght Park #1, Voght Park #2 and Fairley Park). An average estimate of 100 litres per second of groundwater was extracted from five City of Merritt production wells in 2006 (projected to be 120 L/s by 2010), although the maximum peak rate is on the order of 225 litres per second (BCG 2011). This set included the May Street well, which was taken out of service in 2007. The groundwater that is accessed by the four remaining wells is pumped from the trough in the unconfined surficial aquifer

The fifth city production well (the Kengard well) is completed in a lower, regional confined aquifer (unmapped) that is inferred to follow the Nicola River Valley. This regional basal aquifer is projected to extend beyond the Merritt Basin, and may extend as far east at Nicola Lake. It is completed in an area adjacent to the River Ranch irrigation wells, and at a depth of 139m, encountered several confining layers and water bearing zones during drilling (BCG 2011)

The composition of the aquifer is typically a mixture of sand and gravel with a variable silt fraction to a depth of 10m. In the area of the trough at a depth below 10m, the aquifer is composed of coarse gravel with distinct layers of silty sand and gravel. Hydraulic testing of the City production wells suggests the following hydraulic parameters apply:

1. **transmissivity (T) ranges from $1x10^{-2}$ to $8x10^{-2}$ m^2/s**, and
2. **hydraulic conductivity (K) ranges from $1x10^{-4}$ to $2x10^{-3}$ m/s** (EBA, 2002).

The range in transmissivity is consistent with literature transmissivity values for clean sands and gravels (Freeze and Cherry, 1979), and is consistent with the transmissivity observed at Observation Well No. 296 during pumping (1.65 $x10^{-2}$ m^2/s, BCMOE, 1988). Similar transmissivity and hydraulic conductivity values are estimated for the underlying deep aquifer at the River Ranch wells (T = $3x10^{-2}$ m^2/s, KALA, 2004) and at the Kengard well (T = $2x10^{-2}$-$1x10^{-1}$ m^2/s, K = $4x10^{-4}$-$2x10^{-3}$ m/s, BCG 2011). The range in hydraulic conductivity is also consistent with the RI basin hydrogeologic investigation hydraulic conductivity value ($1.8x10^{-3}$ m/s, AGRA 1999).

The regional groundwater gradient is toward the west, with a magnitude of 0.005 m/m (EBA 2002), based upon topography. Groundwater flow directions from the Coldwater River were measured to be toward the north-northwest, with a groundwater gradient of 0.007 m/m for the stretch between the May Street and Voght Park wells (BCMOE 2009) (Figure 1-1).

The coarse composition of the Merritt Aquifer suggests the aquifer is unconfined, recharged by precipitation and river loss. This is supported by the observed response of the May Street production well in response to pumping. Pump test data from the Collettville and Voght Park wells, however, suggest the deep sand and gravel trough (Figure 1-1) may respond as a leaky-confined aquifer. The Coldwater River may act as a recharge source for the trough, but the rate of leakage from the river may not be adequate to stabilize the long-term drawdown within the wells. Additional recharge must also come from an additional source, and groundwater flow from upgradient portions of the aquifer likely provides the additional water required to stabilize long-term production well drawdown (EBA 2002).

Static water levels measured in the aquifer ranged from 1.9 to 4.3m below ground surface for many of the wells near the City centre (Figure 1-1). It was suggested that the shallowest static water levels occur at the Fairley Park well, located mid-way between the Coldwater and Nicola Rivers. If this is indeed the case, then precipitation and/or recharge from the City stormwater drainage network (the dry wells) is mounding up the groundwater table at this location, and are likely significant sources of recharge to the aquifer.

The aquifer is underlain by glacial till in areas, and by soft lacustrine fine sand, silt and clay deposits formed by the deposition of fine grained sediments into a prehistoric glacial lake covering Merritt. The River Ranch wells located northeast of the City core are completed into confined water bearing sand and gravel sediments (flowing artesian aquifers) below this upper confining layer deposit (BCMOE 1998).

4 Hydrology

Hydrology, and surface water – groundwater interaction is a large component to the hydraulics of the Merritt area. Two large rivers border the City of Merritt: the Nicola River toward the north and the Coldwater River toward the south. The City of Merritt downtown core lies at the confluence of these two rivers, and spreads out toward the east (Figure 1-1).

Flows within the Coldwater and Nicola Rivers have been monitored since the 1900's. Average low annual flow in the Coldwater River is about $1m^3/s$ for the period of record, with a historical low of 0.1 m^3/s reported. The Nicola River typically experiences average low annual flows of $5m^3/s$, with a historical low of about $1m^3/s$ reported (KALA 2004).

Historical discharge hydrographs of both rivers are presented in Figures 4-1 to 4-3. The Coldwater River at Merritt (STN# 08LG010) is an active hydrometric station located on the Coldwater River near Collettville (1913-2010 data presented). The Nicola River at Outlet of Nicola Lake (STN# 08LG065) is located at the head of the Nicola Valley downstream of the Nicola Dam, and is highly regulated. The hydrometric station Nicola River near Merritt (STN# 08LG007) is no longer being actively monitored (1911-2007 data presented). It was located downstream of the City of Merritt near Lower Nicola, after the confluence of the two rivers.

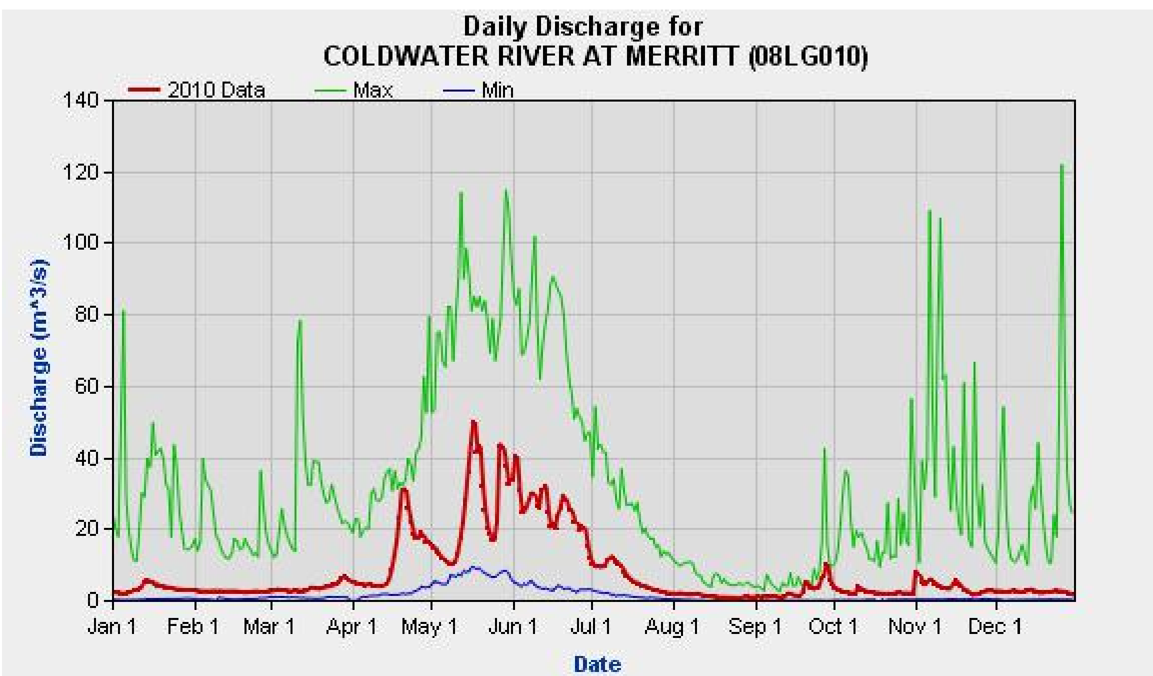


Figure 4-1
Hydrograph for the Coldwater Rivers Upstream of Confluence

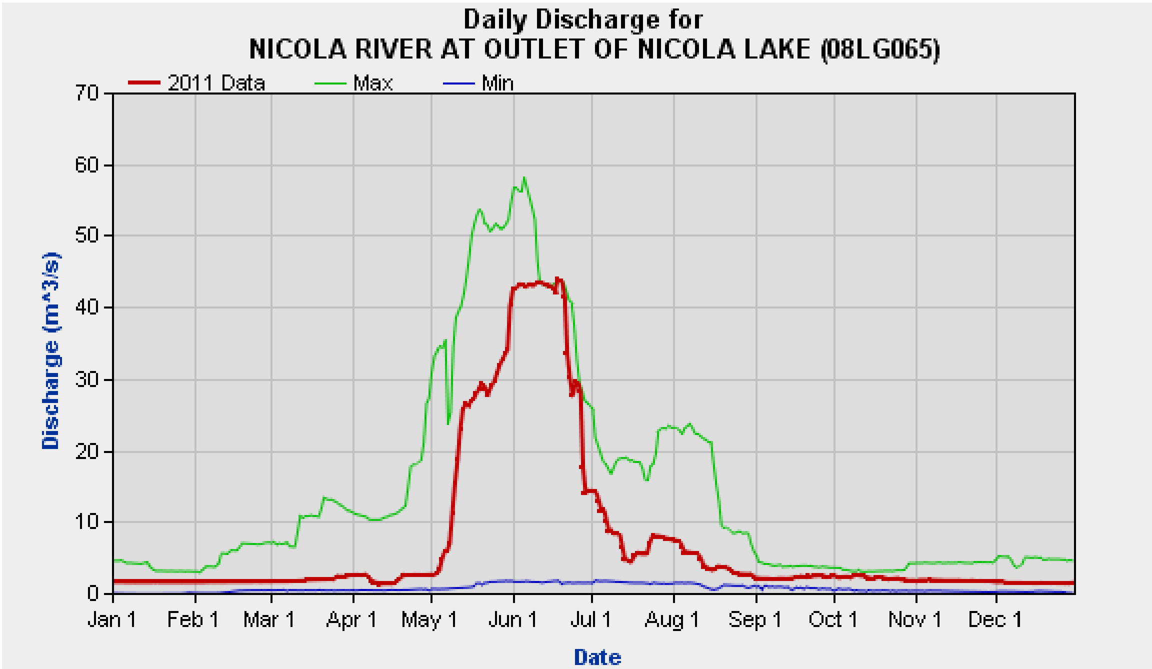


Figure 4-2
Hydrograph of the Nicola River Upstream of the Confluence

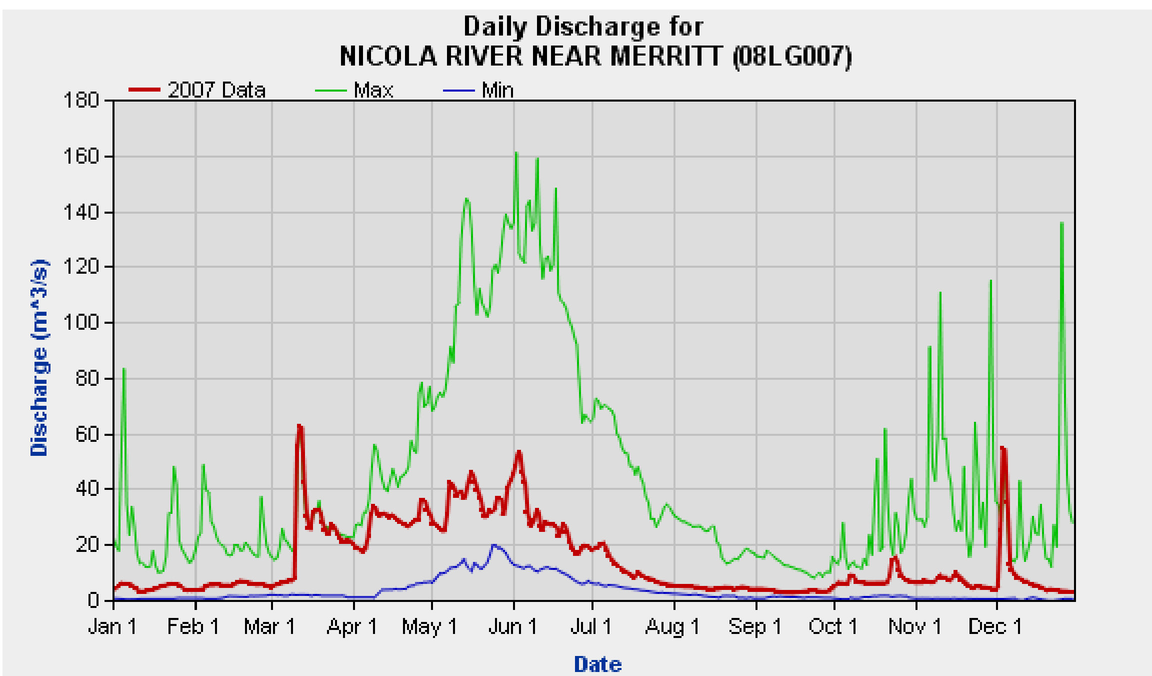


Figure 4-3
Hydrograph for the Nicola River Downstream of Confluence

Source: Environment Canada, 2012b.
Note: most recent data (year) available with historical statistics shown for all hydrographs.

The surficial Merritt Aquifer is replenished by two major sources of recharge:

1. **Precipitation**
2. **Surface water losses from both the bordering Nicola and Coldwater Rivers.**

In general, a stream can be a gaining stream, a losing stream or a disconnected stream. A gaining stream occurs when the groundwater level in the aquifer surrounding the stream is higher than the stream level. Consequently, the stream is gaining since groundwater is flowing into the stream. A losing stream occurs where the groundwater level is lower than the stream level. As a result, the stream loses water to recharge the groundwater system. In some cases the groundwater level can become disconnected to the stream. In the case where the stream is disconnected from the groundwater system, the rate of loss from the stream is limited by the conductance of the stream bed and the aquifer below (WMC 2008).

Groundwater present in the surficial aquifer is in balance with the surface water in the Coldwater and Nicola Rivers; however the relationship of the surface water-groundwater interaction is different for each river. During periods of flood (e.g.: the annual freshet), the Nicola River provides water to the surficial aquifer (a losing stream), providing a short but intense period of groundwater recharge. The remainder of the year, the Nicola is either in balance with the surficial aquifer, or receives recharge from the surficial aquifer (a gaining stream) during low-flow periods.

The Coldwater River does not have this same hydraulic connection. The Coldwater River is hydraulically disconnected from the water table in the adjacent surficial aquifer throughout the year. Surface water from the Coldwater River continually recharges the surficial aquifer (a constantly losing stream), whether the stream is in high or low-flow periods. Further, the leakage rate from the Coldwater River is controlled by the unsaturated vadose zone beneath the river, and leaks at a fairly steady rate, regardless of the water table in the adjacent surficial aquifer. As such, pumping the wells poses a low risk of causing surface water depletion in the Coldwater River (BCG 2011).

This difference helps to explain differences in water chemistry. An analysis of the water chemistry in both rivers and the City production wells indicate that the majority of the recharge to the trough portion of the aquifer comes from the Nicola River. (BCG 2011)

This difference also helps to explain previous pumping test data. Historical pumping tests for wells completed within the trough (Voght Park and Collettville) suggested that drawdown interference occurs between the Colletteville and Voght Park wells, even though they are on opposite sides of the Coldwater River. The data suggests that that the finer sediments directly above the trough act to partially confine the trough portion of the aquifer and somewhat isolate it from the surficial sediments and the hydraulic connection to the Coldwater River (KALA 2004). As the Coldwater River is now taken to be hydraulically disconnected from the surficial aquifer, the observed interferences become more plausible.

Trend analysis data from the BC MOE monitoring well No. 296 (located at the intersection of Garcia St. and Coldwater Ave.) suggest that aquifer levels are sensitive to recharge from precipitation and seasonal flooding of the Nicola and Coldwater Rivers. Further, the lowest groundwater levels in monitoring well No. 296 were observed to correlate with elevated pumping rates recorded for the City production wells. This indicates that the transmissivity is high in the surficial aquifer, and that the capture zone for the aggregate City production wells extends at least as far as Observation Well No. 296 (approximately 1km away, Figure 1-1).

From the 2009 study conducted on reaches of the Coldwater River, the BCMOE predicted the majority of water input to the surficial aquifer came from river losses. The following table summarizes the post-development groundwater budget constructed during the study (BCMOE 2009):

Table 4-1
Post-Development (present day) Groundwater Budget

Inflow (recharge) + Storage Contribution		**Outflow (discharge)**	
Precipitation & irrigation return flow	140,000 m^3/yr	Flow out of aquifer	3,000,000 m^3/yr
Net water removed from storage	100,000 m^3/yr	Pumping	3,150,000 m^3/yr
Flow from adjacent silt formation	5,000 m^3/yr		
Upward flow from deep aquifer system	40,000 m^3/yr		
Alluvial sediments along Coldwater R.	980,000 m^3/yr		
Alluvial sediments along Nicola R.	160,000 m^3/yr		
Net River losses (leakage)	4,725,000 m^3/yr		
Total	6,150,000 m^3/yr	Total	6,150,000 m^3/yr

From Review of Ground Water/Surface Water Interactions within the City of Merritt, June 2009

5 Water Quality

Water quality will be described in greater detail in Technical Memorandum 107 – Water Quality Review.

Water chemistry has been extensively monitored in several reports (EBA 2002, BCG 2011, BCMOE 2009) to aid in determining the genesis of groundwater sources, help further our understanding of the interconnected aquifers beneath the City, and the role that surface water-groundwater interactions with both the Nicola and Coldwater Rivers play in the water balance at Merritt.

Analysis of water from the surficial aquifer along the Coldwater River showed that the groundwater transitions from calcium-sodium-bicarbonate to calcium-bicarbonate type as the groundwater flows in a westerly direction toward the existing production wells. Similarly, water chemistry from production wells drilled in the Coldwater River Valley, further south of the City was also of calcium-sodium-bicarbonate type.

Parallel analysis from the surficial aquifer along the Nicola River showed that the groundwater transitions from calcium-bicarbonate-chloride to calcium bicarbonate type as the groundwater flows in a westerly direction towards the existing production wells.

Analysis of the water chemistry from the production wells themselves, display a calcium-bicarbonate type with an increasing chloride signature. As the chloride is seen present in the Nicola River system at Merritt, and not the Coldwater River, the recharge to the trough appears to originate predominately from the Nicola River (BCG 2011). We refer to the 2006 Surface Water – Groundwater Assessment (BGC 2006) for the Piper Diagrams, and further detail.

Further study of the water chemistry from the production wells also indicates that the waters received at the production wells (Voght Park wells and Collettville well) contained no coliforms over an extensive sampling history. In contrast, the Nicola and Coldwater Rivers have averaged fecal coliform counts of between 8-58 and 7-32 MPN/100mL, respectively for the period 2007-2011 (G3 2012); and total coliform counts much higher. For many years, the City relied on the aquifer to effectively filter the water recharging from the rivers, and provided no treatment or chlorination to their raw water supply.

Water treatment in Merritt currently consists of injecting a 12% sodium hypochlorite solution into the distribution system near each wellhead. The addition of chlorine in this manner provides some level of disinfection and maintains chlorine residual in the lines to prevent the regrowth of bacteria, but does not meet the criteria of primary disinfection with contact time (CT) system-wide (WW 2012).

6 Implications for Stormwater Drainage

The City of Merritt is built atop its drinking water aquifer. Historically, the city centre being located proximal to the potable water supply was convenient, cost effective and provided the citizenry with an abundance of water for their needs.

However, the City has grown substantially over the years, and the demands on the aging municipal infrastructure continue. The supply wells themselves were installed between 1966 (Fairley Park) and 1978 (Collettville), meaning that the steel and appurtenances, though in good shape are on the order of 34-46 years old[6] (WW 2012).

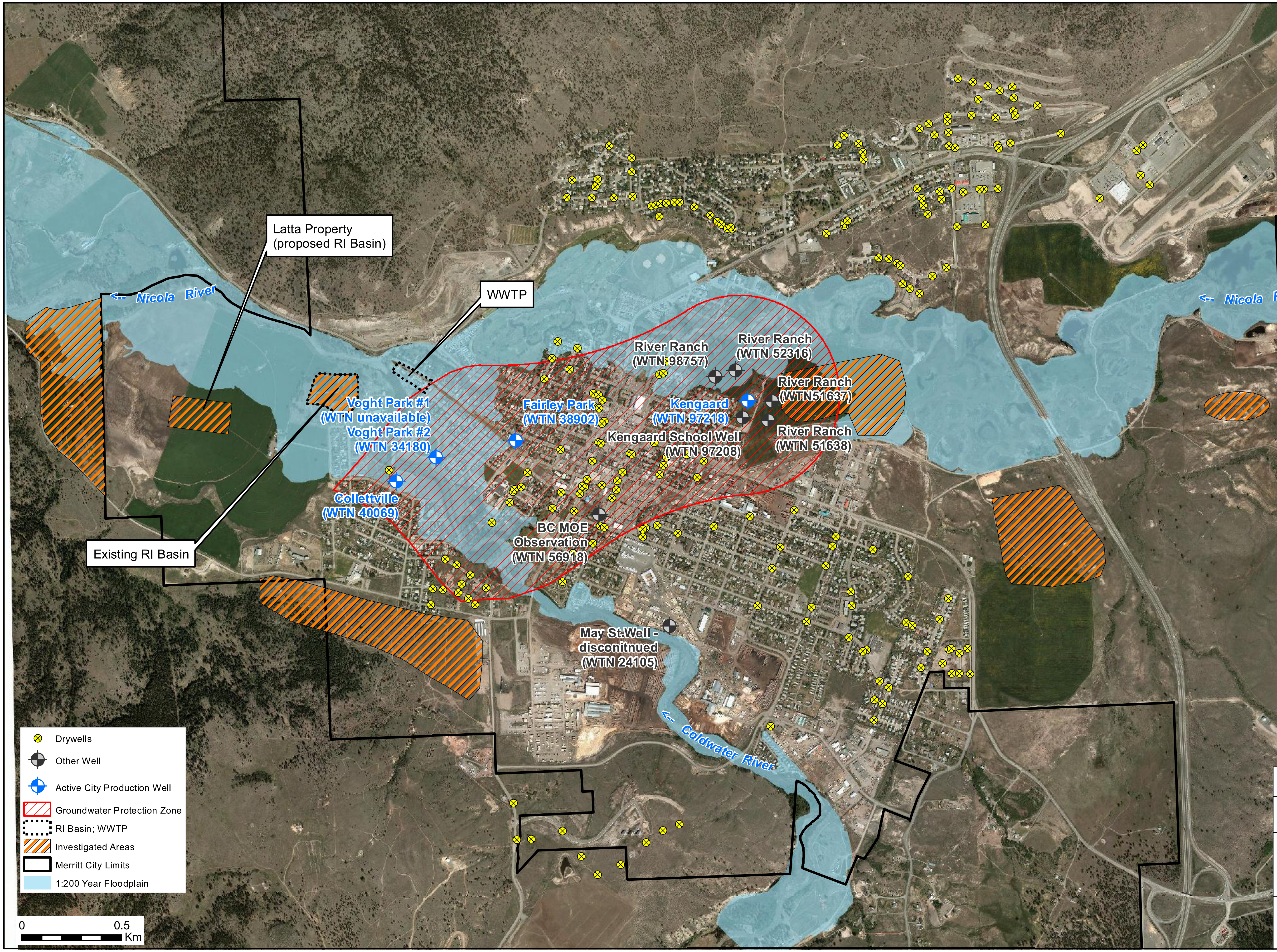
The City of Merritt has a comprehensive network of dry wells, as part of the stormwater sewerage system. These dry wells act as “sumps” allowing for water collected at surface storm drains and gutters to discharge to a sunken gravel filled chamber, and infiltrate directly to ground. These dry wells work very well in arid areas, under more flashy flow conditions, where grade is difficult to establish, and where underlying surficial materials are granular in nature. Figure 6-1 – Investigated Areas shows the locations of the dry wells spatially across the City.

These dry wells contribute directly to the surface aquifer beneath the City, and act as the shortest route for surface-to-ground dispersal. Were the surficial unconfined aquifer not relied upon so heavily for the production of potable water, this practice would be highly recommended, as these wells allow for distributed influx-to-ground underneath what would otherwise be an impervious surface, or channelled to a sewerage network that would remove the water from site.

However, as it currently stands, the dry wells pose a threat to the potable groundwater supply, as the network overall acts as potential non-point source for contamination (chronic effect) from the build-up of substances washed from the surface into the storm drains (e.g.: road film with minor hydrocarbons, salt, fertilizers) . Further, should a spill of leak occur at surface, and fluids report to the dry wells, the impact would be felt as a point-source of contamination with a significantly shortened travel time to the City’s supply wells (acute effect). As four of the supply wells have overlapping capture zones, the effect would be exacerbated, as several of the production wells could be impacted by the same event.

The ability to dispose of water quickly, in one centralized location has also been addressed. There have been several studies investigating the availability of dispersal to ground options for sewerage effluent in the area surrounding the City (AGRA 1999, and Stantec 1999). As the hydraulic properties are identical for dispersal to ground options for stormwater, we have reviewed these studies, and eliminated areas considered unsuitable or unavailable for ground dispersal options. Over eight locations were investigated, and those within our study area are illustrated on Figure 6-1.

[6] A notable exception is the Kengard deep well, installed as the City’s fifth well in 2007, to replace the aging May Street well.



Investigated Areas

CLIENT:

City of Merritt

DATE:	PROJECT:	DRAWN BY:
Jan 2013	2012-2231.000	DA

DATA SOURCE(S):

Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012

Associated Engineering

Figure 6-1
Merritt ISMP

Of the eight locations presented, seven were deemed unsuitable for reasons such as subsurface lithology (fine sediments underlying the surficial sands and gravels would not allow for an acceptable percolation rate, causing breakout at surface), proximity to existing infrastructure, location with respect to the flood plain or the groundwater protection zone, insufficient thickness of surficial coarse sediments and proximity to riparian areas or waterways.

The one location investigated that did prove suitable for an RIB, was adjacent to the existing City RIB, toward the west of Collettville, on the west side of the Coldwater River. Their new preferred location and described layout is above the 1:200 year flood plain of both rivers (the current RIB is not), the underlying soils are suitable for ground disposal (granular, and with a favourable apparent depth to fining sediments), and there is sufficient travel time in the subsurface prior to discharge to the Nicola River (downstream of the confluence).

While this location would also prove suitable for disposal to ground of stormwater, two main constraints present themselves:

1. Due to slightly elevated location on the far end of town, stormwater would have to be pumped to the RIB; and
2. Due to competing land use, the most favourable area for RIB development should be earmarked for the more difficult to dispose of liquid (in this case the effluent from the WWTP).

Should expansion of the WWTP and land disposal areas be abandoned, this Site (the Latta property, formerly the Collett Ranch) may provide a viable option for stormwater management. Further, should the WWTP be upgraded, and the existing RIB become obsolete for septic use, it could be retrofitted for use as a stormwater RIB; though pumping of stormwater would still be required.

7 Conclusions

The City of Merritt is underlain by the Merritt Aquifer; an unconfined, unconsolidated sand and gravel surficial aquifer (Aquifer #74). The Merritt Aquifer is classified as an IA aquifer; highly productive, but under high demand (mostly due to municipal and irrigation wells) and is highly susceptible to contamination.

The City of Merritt has five groundwater wells, four of which are completed within the Merritt Aquifer (Voght Park #1, Voght Park #2, Fairley Park and Collettville). Water from the May Street well is no longer used to supply potable water to the City. The fifth active well, known as the Kengard Well (PW2007-1) was completed in the deeper regional aquifer in an area known to have a confining layer (proximal to the River Ranch Wells). Subsequent pumping tests of this deep production well showed that the water table in the surficial aquifer was affected by pumping of the deep aquifer, and that deep and surficial aquifers are hydraulically connected.

The surficial aquifer is hydraulically connected both to the Nicola and Coldwater Rivers, and to the underlying confined aquifers below the City of Merritt. However, wells completed in the deepened trough in the surficial aquifer, toward the west of the City core, exhibit semi-confined or “leaky confined” aquifer hydraulic characteristics that have been presented by others. As such, transitioning the City’s domestic water supply into the deeper aquifer will only provide a lengthened travel pathway from the surficial aquifer to the tap. Any contamination that does occur in the surficial aquifer will likely have a direct, though delayed effect on the water quality of the wells completed in the trough, and eventually those completed in the lower confined aquifer.

A groundwater protection zone has been outlined in the aquifer protection plan (EBA 2002), and an additional critical protection zone has been recommended for the Kengard well (BCG 2011). These two zones are based upon initial capture zone analysis for the production wells that service the City, and provide a conservative area of groundwater influence. Should a reduction in the area protected be desired, the groundwater protection zones could be refined further by subsequent pumping tests coupled with numerical modelling.

The City currently employs the use of dry wells to drain stormwater mains in several flat areas of the city, where the maintaining of grade in a traditional storm sewerage system would prove difficult. In a typical arid climate area, these dry wells would be an excellent way to distribute stormwater spatially, and allow for distributed release to the surficial sediments below ground. However, as the Merritt Aquifer has a shallow groundwater table, is an unconfined aquifer, and is relied upon heavily to provide the water for the citizenry, these dry wells pose a potential hazard to the water supply. Acute effects from a hydrocarbon spill draining through one of these wells would be immediate, having a pronounced impact on the groundwater quality. Chronic effects of the build-up of fertilizers, pesticides, road film and salt reporting to the dry wells also have some impact on the groundwater quality, but are significantly diluted.

The area to the west of the existing RIB (the adjacent Latta property, Stantec 1999) has already been identified as having favourable properties for RIB development. However, as there would be competing land use for this area with sewage disposal, this area should be earmarked for the more difficult material to dispose of (in this case, the effluent from the sewage treatment plant). Should this area not be required for sewage disposal, this area could be considered for stormwater disposal, or the current RIB could be retrofitted and used in its place.

8 Recommendations

Protection of the Merritt Aquifer should be of paramount concern to the citizens of Merritt. As the surficial aquifer continues to provide the majority of the potable water for the community at Merritt, the City's dependence on the potability of the water contained within the aquifer has never been higher. Demand for this potable water source is expected to increase due to an increasing population base projected for the City of Merritt, and an increase in the demand from agricultural water users in the upstream reaches of both Coldwater and Nicola Rivers due to climate change. Aquifer protection measures should be prioritized higher than stormwater mitigation, in the interest of human health.

The previously identified Groundwater Protection Zones should be included in the OCP, to limit the amount of risk allowed near the producing wells. These zones should be based upon a refinement of the capture zone analysis (perhaps refined by numerical modelling) for each of the wells, and vectors such as enhanced disposal-to-ground ponds or basins, underground and above ground storage tanks, and industry or commercial interests with a known liquid effluent component (fuels, heavy-oils, solvents, industrial chemicals, paints, dry-cleaner fluids, wood preservatives) should be minimized from within the excluded areas, or significant impact assessment should be required prior to development.

Monitoring the existing disposal-to-ground infrastructure should be expanded, by means of monitoring wells in close proximity to several of the dry wells. These monitoring wells would be installed to test the groundwater within the influence of the dry well, and be screened across the dry season water table to allow for year round sampling. Alternatively, the use of suction lysimeter to collect pore waters from the shallow vadose zone could also be used.

Additional water quality testing should be implemented at the five production wells (Voght Park #1, Voght Park #2, Collettville, Fairley Park and Kengard Well). An enhanced analyte list should be collected annually for the production wells, and include analysis for the vectors listed in recommendation 2:

- Hydrocarbons: Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH), Polycyclic Aromatic Hydrocarbons (PAH), and Volatile Hydrocarbons (including Benzene, Toluene, Ethylbenzene and Xylene [BTEX])
- Glycols
- Perchloroethylene (PERC)
- Fertilizers
- Herbicides and insecticides
- Phenols including pentachlorophenol (wood preservatives)
- Polycyclic aromatic hydrocarbons
- Dissolved Metals
- Chloride
- Nitrates
- Phosphates

Enhanced dispersal-to-ground and RIB's should be sought in areas outside of the groundwater protection zone. Inside the zone, lined storage basins could be used to provide capacity for stormwater storage, in areas not suitable for dispersal-to-ground. In areas of thick successions of high clay content materials at surface, basins could be excavated into the native fine-grained sediments directly. Alternatively, imported clay or geomembrane liners could be used to artificially provide storage. These basins would provide the storm capacity required, and be either pumped-out or left to evaporate over time. Alternatively, habitat for waterfowl and other animals could be enhanced by employing "wetland-type" management practices.

As many of the residential homes in the Merritt area are single family residences, the implementation of a "rain-barrel" program could assist in keeping stormwater out of the collection main, and distribute the dispersal of stormwater water over a much larger area and time. Individual homeowners would acquire a rain-barrel, and use it to collect rooftop drainage, intercepting the drainage from the downspouts, prior to the drain tile for the home. The water could then be stored, and used for irrigation purposes in drier times. With an individual rain barrel having a capacity of up to 170L (45 USgal), and the number of dwellings and households in the Merritt area totalling 2,820 (OCP, 2011), the amount of water retained in this way could be on the order of 479,400 L (126,900 USgal).

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A Well Logs

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 24105 Owner: CITY OF MERRITT Address: MAY STREET Area: WELL LOCATION: KAMLOOPS (KDYD) Land District District Lot: Plan: 717 Lot: 2 Township: Section: Range: Indian Reserve: Meridian: Block: 54 Quarter: Island: BCGS Number (NAD 27): 092I017111 Well: 2 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Unknown Constru Diameter: 16.0 inches Casing drive shoe: Well Depth: 100 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: N File Info Flag: N Sieve Info Flag: N Screen Info Flag: N Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1970-10-22 00:00:00.0 Driller: A. C. Drillers Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 400 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: N Artesian Flow: Artesian Pressure (ft): Static Level: 10 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: E250651 Water Chemistry Info Flag: Y Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: N Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 34180 Owner: TOWN OF MERRITT Address: 1500 CANFORD AVENUE Area: MERRITT WELL LOCATION: KAMLOOPS (KDYD) Land District District Lot: Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092I016222 Well: 5 Class of Well: Water supply Subclass of Well: Domestic Orientation of Well: Status of Well: New Well Use: Water Supply System Observation Well Number: Observation Well Status: Construction Method: Unknown Constru Diameter: 16 inches Casing drive shoe: Well Depth: 114 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: N File Info Flag: N Sieve Info Flag: N Screen Info Flag: N Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1976-01-01 00:00:00.0 Driller: A. C. Drillers Well Identification Plate Number: 12728 Plate Attached By: PUMP INSTALLER Where Plate Attached: UNKNOWN PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 1960 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: N Artesian Flow: Artesian Pressure (ft): Static Level: 12 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: E250649 Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: N Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
WELL PUMP INSTALLATION REPORT AVAILABLE.

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 38902

Owner: CITY OF MERRITT

Address: QUILCHENA AVE

Area: MERRITT

WELL LOCATION:
KAMLOOPS (KDYD) Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092I017111 Well: 1

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well:
Status of Well: New
Well Use: Water Supply System
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 12 inches
Casing drive shoe:
Well Depth: 98 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: Y
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1978-01-01 00:00:00.0

Driller: Rural Well Drillers
Well Identification Plate Number: 12730
Plate Attached By: PUMP INSTALLER
Where Plate Attached: UNKNOWN

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: Y
Artesian Flow:
Artesian Pressure (ft):
Static Level: 7 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID: E250650
Water Chemistry Info Flag: Y
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	null	null	null

GENERAL REMARKS:
PUMPHOUSE

LITHOLOGY INFORMATION:

From	0 to	.5 Ft.	topsoil
From	.5 to	6 Ft.	brown clay

From	6	to	10	Ft.	loose medium gravel
From	10	to	16	Ft.	brown silt
From	16	to	66	Ft.	loose clean fine to medium gravel
From	66	to	83	Ft.	medium sandy gravel
From	83	to	97	Ft.	grey silt
From	97	to	98	Ft.	sandy gravel

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 40069 Owner: COLDWATER IMPROVEMEN Address: Area: WELL LOCATION: KAMLOOPS (KDYD) Land District District Lot: 173 Plan: 14807 Lot: 1 Township: 91 Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092I016222 Well: 1 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 10.0 inches Casing drive shoe: Well Depth: 161 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Y Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1978-07-08 00:00:00.0 Driller: A. C. Drillers Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 421 (Driller's Estimate) U.S. Gallons per Minute Development Method: Pump Test Info Flag: Y Artesian Flow: Artesian Pressure (ft): Static Level: 13 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 51637 Owner: RIVER RANCH Address: Area: MERRITT WELL LOCATION: KAMLOOPS (KDYD) Land District District Lot: 121 Plan: 30934 Lot: A Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092I017112 Well: 3 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Irrigation Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 225 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1983-01-01 00:00:00.0 Driller: Sage Hills Well Drilling Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 51638 Owner: RIVER RANCH Address: Area: MERRITT WELL LOCATION: KAMLOOPS (KDYD) Land District District Lot: 121 Plan: 30934 Lot: A Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092I017112 Well: 4 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 305 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1983-01-01 00:00:00.0 Driller: Sage Hills Well Drilling Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 250 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 6 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

- Return to Main
- Return to Search Options
- Return to Search Criteria

Information Disclaimer
The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 52316 Owner: RIVER RANCH Address: Area: MERRITT WELL LOCATION: KAMLOOPS (KDYD) Land District District Lot: 121 Plan: 30934 Lot: A Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092I017113 Well: 1 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Unknown Constru Diameter: 9.0 inches Casing drive shoe: Well Depth: 303 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1983-06-17 00:00:00.0 Driller: McHarg Drilling Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 1000 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 56918

Owner: Ministry of Environment

Address: COLDWATER AVE.

Area: MERRITT

WELL LOCATION:
KAMLOOPS (KDYD) Land District
District Lot: Plan: 570 Lot: 3
Township: Section: Range:
Indian Reserve: Meridian: Block: 29
Quarter:
Island:
BCGS Number (NAD 27): 092I017111 Well: 11

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Observation Well
Observation Well Number: 296
Observation Well Status: Active
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 56 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: Y
Sieve Info Flag: Y
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1987-03-04 00:00:00.0

Driller: M. Schibli Drilling
Well Identification Plate Number: 21152
Plate Attached By: Kevin Bennett
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 78 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: Y
Artesian Flow:
Artesian Pressure (ft):
Static Level: 13 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID: E206918
Water Chemistry Info Flag: Y
Field Chemistry Info Flag:
Site Info (SEAM): Y

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	null	null	null

GENERAL REMARKS:
SEE NTS FILE 92I/2 #12.OBS.WELL #296.//

LITHOLOGY INFORMATION:

From	0 to	1 Ft.	topsoil
From	1 to	9 Ft.	sand and gravel with boulders
From	9 to	15 Ft.	gravel fine to medium
From	15 to	50 Ft.	sand and gravel
From	50 to	56 Ft.	very fine silty sand

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Construction Date: 2007-06-21 00:00:00.0

Well Tag Number: 97208

Owner: MERRITT KENGAARD SCHOOL

Address: 2485 MERRITT AVENUE

Area: MERRITT

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092I017113 Well:

Class of Well: Monitoring
Subclass of Well: Temporary
Orientation of Well: Vertical
Status of Well: New
Well Use:
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: Y
Well Depth: 565 feet
Elevation: feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: Y
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Driller: J. R. Drilling Central Ltd. Partnership
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 75 (Driller's Estimate) U.S. Gallons per Minute
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: Y
Material: Concrete grout
Method: Pumped
Depth (ft): 200 feet
Thickness (in): 2.5 inches
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
220	565	6	Steel	Y

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 20 Ft. Medium SAND GRAVEL brown coarse
From 20 to 40 Ft. Medium SAND GRAVEL brown coarse
From 40 to 43 Ft. Soft brown silt
From 43 to 60 Ft. Soft brown silty clay
From 60 to 80 Ft. Medium CLAY SILT brown
From 80 to 120 Ft. Soft MINOR SILT brown clay
From 120 to 175 Ft. Soft MINOR SILT brown clay
From 175 to 180 Ft. Medium GRAVEL COBBLES 20 U.S. Gallons per Minute grey
From 180 to 200 Ft. Hard GRAVEL COBBLES 75 U.S. Gallons per Minute
From 200 to 220 Ft. Medium grey gravel
From 220 to 235 Ft. Medium brown gravel
From 235 to 315 Ft. Medium grey clay
From 315 to 325 Ft. Medium FINE SAND grey silty sand
From 325 to 370 Ft. Medium brown gravel
From 370 to 380 Ft. Medium SILT & ROCK brown
From 380 to 465 Ft. Medium brown gravel

```
From   465 to   475 Ft.  Hard    COMPRESSED grey  gravel
From   475 to   565 Ft.  Medium     brown  gravel
From   565 to       Ft.   BOTTOMED OUT
```

- Return to Main
- Return to Search Options
- Return to Search Criteria

Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 97218

Owner: CITY OF MERRITT

Address: 2485 MERRITT

Area: MERRITT

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092I017113 Well:

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Water Supply System
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: Y Y
Well Depth: 457.7 feet
Elevation: feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 541 feet
Lithology Info Flag: Y
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: Y

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2007-10-26 00:00:00.0

Driller: J. R. Drilling Central Ltd. Partnership
Well Identification Plate Number: 29680
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: (Driller's Estimate)
Development Method: Air lifting
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: Y
Material: Bentonite clay and cement mixture
Method: Pumped
Depth (ft): 100 feet
Thickness (in): 2 inches
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
384.4	396.9		null
396.9	457.7		80

Casing from	to feet	Diameter	Material	Drive Shoe
0	300	20	Steel	Y
null	null	16	Steel	Y

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 4 Ft. Soft brown silty clay
From 4 to 28 Ft. Medium GRAVEL SAND TILL brown
From 28 to 39 Ft. Medium CLAY SILT grey
From 39 to 44 Ft. Medium GRAVEL SAND SILT POSSIBLY SOME WATER grey
From 44 to 182 Ft. Soft GREY BROWN vari-coloured silt
From 182 to 184 Ft. Soft GREY BROWN, TRACE GRAVEL vari-coloured silt
From 184 to 205 Ft. Soft GREY BROWN vari-coloured silt
From 205 to 225 Ft. Medium SILT SMALL GRAVEL SAND GREY BROWN vari-coloured
From 225 to 267 Ft. Medium COBBLES GRAVEL SAND SILT GREY BROWN WATER BEARING vari-coloured
From 267 to 271 Ft. Loose SILTY CLAY SOME GRAVEL SAND SILT grey

```
From   271 to   308 Ft.  Loose GRAVEL SAND SILT   WATER BEARING grey
From   308 to   322 Ft.  Medium TRACE GRAVEL SOME SAND MOSTLY SILT    grey
From   322 to   357 Ft.  Loose COBBLES GRAVEL SAND SILT   WATER BEARING grey
From   357 to   363 Ft.  Loose SOME GRAVEL MOSTLY SAND SOME SILT    grey
From   363 to   366 Ft.  Medium MOSTLY SILT SOME SAND GRAVEL    grey
From   366 to   367 Ft.  Loose GRAVEL SAND SILT    grey
From   367 to   441 Ft.  Loose COBBLES GRAVEL SAND SOME SILT   WATER BEARING FAIRLY CLEAN grey
From   446 to   462 Ft.  Loose SMALL COBBLES GRAVEL SAND SOME SILT    grey
From   472 to   541 Ft.  Loose SMALL COBBLES GRAVEL SAND SILT   WATER BEARING FAIRLY CLEAN grey
From   462 to   472 Ft.  Dense GRAVEL SAND SILT   VERY HARD DRILLING grey
From   541 to   545 Ft.  Dense TALC & BEDROCK    white
```

- Return to Main
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Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 98757

Owner: SIMON

Address: 2400 MCGORAN PLACE

Area: MERRITT

WELL LOCATION:
KAMLOOPS (KDYD) Land District
District Lot: 124 Plan: B873 Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092I017113 Well:

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Irrigation
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: Y Y
Well Depth: 360 feet
Elevation: feet (ASL)
Final Casing Stick Up: 18 inches
Well Cap Type: WELDED
Bedrock Depth: feet
Lithology Info Flag: Y
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: Y

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2008-11-02 00:00:00.0

Driller: J. R. Drilling Central Ltd. Partnership
Well Identification Plate Number: 24140
Plate Attached By: JERRY OPPER
Where Plate Attached: CASING

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 500 (Driller's Estimate) U.S. Gallons per Minute
Development Method: Air lifting
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 18 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: Y
Material: Bentonite clay
Method:
Depth (ft): 20 feet
Thickness (in):
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
143	146		null
146	151		20
151	161		60

Casing from	to feet	Diameter	Material	Drive Shoe
0	345	8	Steel	Y
0	20	10	Steel	Y

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 15 Ft. Loose SILT SAND WITH CLAY/SILT brown dry
From 15 to 37 Ft. Loose SAND WITH GRAVEL WET brown
From 37 to 50 Ft. DENSE/STIFF LIGHT GREY MOIST grey clay
From 50 to 57 Ft. Loose SAND WITH GRAVEL WET brown
From 57 to 105 Ft. DENSE/STIFF MOIST brown clay
From 105 to 150 Ft. DENSE/STIFF MOIST WITH TRACES OF ROCK brown clay
From 150 to 154 Ft. DENSE/STIFF MOIST WITH TRACES OF ROCK brown clay
From 154 to 185 Ft. DENSE/STIFF WET brown clay
From 185 to 210 Ft. DENSE/STIFF MOIST brown clay
From 210 to 228 Ft. Loose SAND WITH CLAY/SILT LIGHT GREY WET grey
From 228 to 238 Ft. Loose FINE MEDIUM SAND & SAND WITH GRAVEL HIGH PRODUCTION

```
From   238 to   257 Ft.  Dense CLAY   MOIST brown
From   257 to   270 Ft.  Loose SAND WITH GRAVEL   WET grey
From   270 to   305 Ft.  Dense CLAY & SAND WITH GRAVEL   WET brown
From   305 to   312 Ft.  Loose SAND WITH GRAVEL   HIGH PRODUCTION
From   312 to   340 Ft.  Loose MEDIUM COARSE SAND & SAND WITH GRAVEL   HIGH PRODUCTION grey
From   340 to   360 Ft.  Loose SAND WITH GRAVEL   HIGH PRODUCTION grey
```


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Appendix B - Natural Hazard Review

Technical Memorandum

City of Merritt

Integrated Stormwater Management Plan
Natural Hazards Review

February 2013

Table of Contents

TECHNICAL MEMORANDUM

1 Introduction

Associated Engineering (AE) is preparing an Integrated Stormwater Management Plan (ISMP) for the City of Merritt. This technical memo will review potential natural hazards within the City area which could affect stormwater infrastructure and stormwater conveyance and disposal. The City of Merritt boundaries and site locations are presented on Figure 1-1 at the beginning of the main report.

2 Goals

The goals of the natural hazards review is to assess the potential slope stability, surface and river erosion, river flooding, ice-jam flooding and land subsidence conditions that may affect stormwater planning and management, and to provide recommendations to reduce potential impacts from natural hazards

3 Office Review

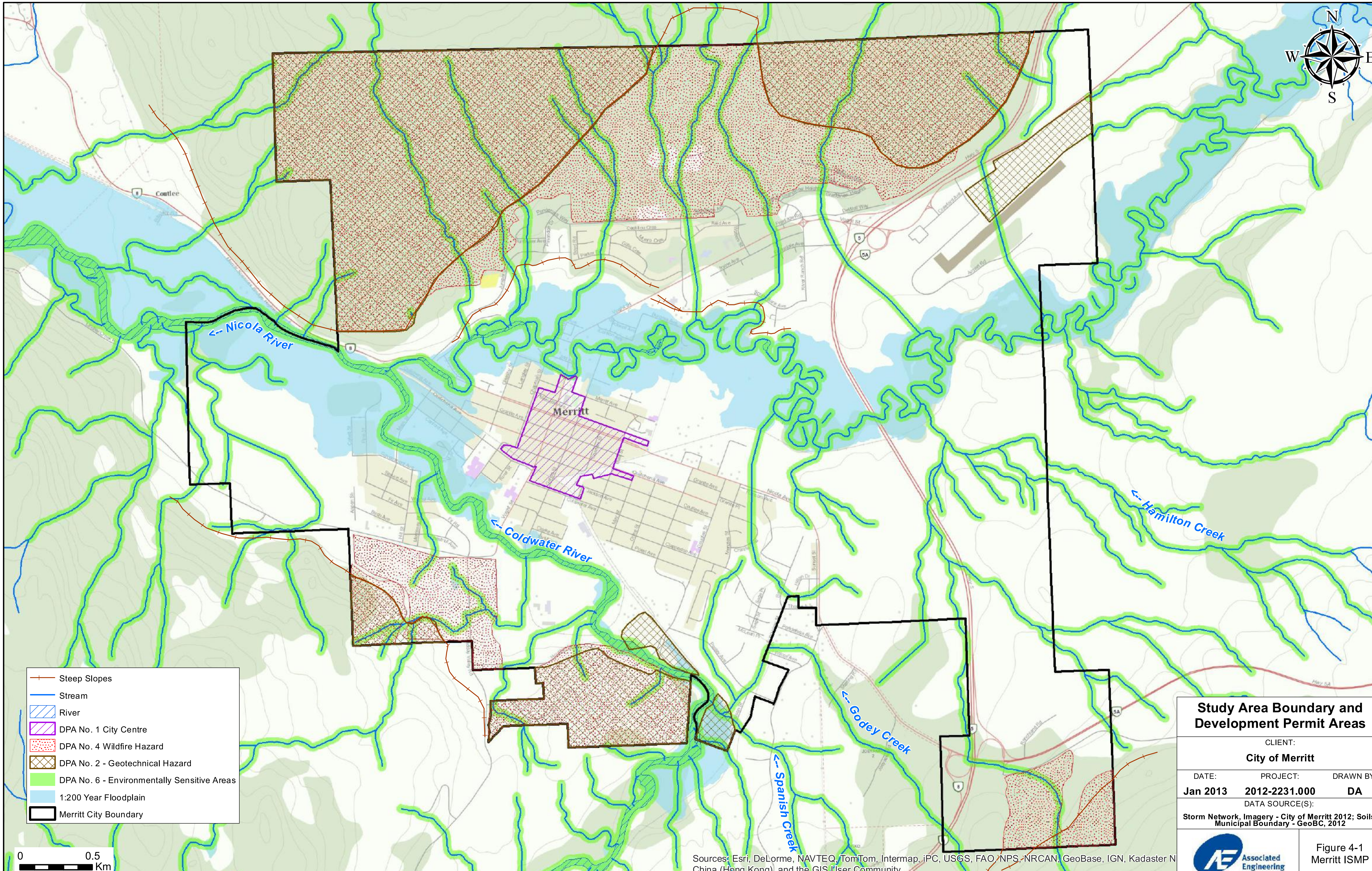
The natural hazards review is an office-based exercise and considers the surficial and bedrock geology, the hydrometric records for the Coldstream River and Nicola River, and a literature review of active and potential natural hazard processes, such as landslides, flooding, subsidence, erosion and wildfires. Photographs of slope and river conditions and erosion were acquired by AE during their preliminary site assessments and are referred to in this technical bulletin.

4 Official Community Plan Development Permit Areas

The City of Merritt Official Community Plan (OCP) includes a map of Development Permit Areas (DPAs) where the City discourages development, and where professional review and permitting would be required before residential, commercial or industrial development were allowed (Figure 4-1). The OCP indicates it is Council policy to:

"Prevent development within areas designated as hazardous slopes or unstable soils where hazards cannot be mitigated. These include areas adjacent to steep slopes with grades of 30% or greater, areas of soil subsidence, rock fall, land slip or erosion hazards which are known or suspected."

Steep slope areas are present in the north, southwest, south-central and southeast portions of the City area, and may represent hazards for rockfall, landslides or erosion which would require roads, buildings and infrastructure to have special design and construction for safe use. For the section of Merritt south of the major bend in the Coldwater River, the OCP describes how abandoned coal mines underline much of the area. There is a potential subsidence hazard (sink holes) due to underground tunnels to any planned surface development. The mine workings may also represent a source of methane and carbon monoxide gases.


Study Area Boundary and Development Permit Areas
CLIENT:
City of Merritt
DATE:
Jan 2013
PROJECT:
2012-2231.000
DRAWN BY:
DA
DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012
Associated Engineering
Figure 4-1
Merritt ISMP
Steep Slopes
Stream
River
DPA No. 1 City Centre
DPA No. 4 Wildfire Hazard
DPA No. 2 - Geotechnical Hazard
DPA No. 6 - Environmentally Sensitive Areas
1:200 Year Floodplain
Merritt City Boundary
<-- Nicola River
<-- Coldwater River
<-- Hamilton Creek
<-- Godey Creek
<-- Spanish Creek
Merritt
Coutlee
N
S
E
W
0
0.5
Km
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, China (Hong Kong), and the GIS User Community

5 Results

5.1 Physiography, Surficial and Bedrock Geology

The landforms in Merritt consist of the main gently-sloped Nicola River valley, adjoined by valley slopes and rolling uplands, leading up to steep bedrock hills with talus aprons (Photos 1, 2 and 3, in Appendix A).

The Merritt area has been glaciated multiple times (Fulton 1962; Fulton *et al.* 1992). The surficial deposit types and distribution are indicated on Figure 2-1 in the Groundwater Technical Bulletin. Glacial till and colluvial deposits are found on the surface of the uplands and valley slopes. The glacial till deposits are formed from eroded and abraded volcanic and sedimentary bedrock and in many locations were consolidated through deposition under the glacial ice. The colluvial deposits were formed through accumulation of rockfall and debris falls of till and other sediments.

Glacial lake sediments were deposited behind ice blockages in the valley bottom and are typically rhythmically-bedded sand, silt and clay layers. These deposits are present in the upper parts of the valley bottom and have been eroded away in places by later glacial meltwater streams and the modern rivers.

Modern alluvial deposits are found along the rivers and streams (Fulton 1962; Bobrowsky *et al.* 2002) (Photos 7 - 14). The Coldwater River has active bedload transport and frequent cobble and sand lateral bars while the smaller Nicola River has minor bedload transport and tortuous-shaped meanders in its floodplain and less sediment transport and erosion. Late glacial fan deposits are present at the surface at stream mouths along the edge of the valley floor.

The glacial sediments are underlain by various flat lying to steeply dipping sedimentary rock beds. Within the south central portion of the City (south of the Coldstream River), shallow underground coal mines were previously operated.

5.2 Natural Hazards

Several types of natural hazards are present within the City of Merritt area, related to the surficial deposits and current slope and hydrologic processes.

5.2.1 Landslides

The steep valley slopes above the City have the potential for debris slides and rock fall and therefore were included in development permit areas in the OCP. No landslide events have been reported and the available aerial photographs do not indicate landslide scars or unstable slopes. However, the steep lands included in the northwest and northeast parts of the City are steep and rockfall or landslides could potentially occur and roads and buildings would require geotechnical engineering.

5.2.2 Slope Gullying

The glacial lake deposits (Figure 2-1, Unit LD in the Hydrogeology Appendix) have a tendency to erode through gullying, block falls, slumps, piping and surface sheet erosion. These deposits tend to form steep, gullied slopes where eroded by the rivers and tributary streams and surface runoff (Photos 2, 3 and 4).

After deglaciation, the glacial lake deposits were eroded during incision by the Nicola River along the north boundary of its active meander belt. Steep slopes were left which were gullied and rilled over time by natural drainage. Since land development, uncontrolled stormwater drainage from streets has caused further gullying and ravine formation at a number of locations along the north valley bottom (Photo 10). As well, motorcycle and ATV use along the steep slopes has caused rutting and compaction which has resulted in water redirection and surface erosion. With this new gullying and erosion, the ravines may widen and erode headward, sediment will be deposited downstream and the local slopes may be destabilized.

5.2.3 Nicola and Coldwater River Floods and Ice-Jams

5.2.3.1 River Floods

The Nicola River flows through the north part of the City and is locally controlled by a dam at the outlet of Nicola Lake several kilometres northeast of Merritt. The larger Coldwater River flows northwards then northwest through the south part of the City, and joins the Nicola River near the western City boundary (Figure 4-1). The Nicola River then flows west toward the Thompson River at Spences Bridge. Within the City, several smaller creeks also join the two rivers.

The Nicola River has tortuous pattern meanders, with many abandoned oxbow lakes and a wide vegetated floodplain, indicating a very low gradient and a tendency to flood. The Coldwater River has a wider channel and larger discharge than the Nicola River, with longer wavelength meanders, larger lateral bars and with more evidence of meander erosion and progression downstream.

The 1 in 200 year floodplain mapping (Ministry of Environment 1988a, 1988b) was integrated into the Flood Protection Measures Overall Map in the City of Merritt Official Community Plan (OCP) (City of Merritt 2002) (Figure 4-1). The wide, gently sloped topography of the valley bottom results in a substantial area of potential flood inundation, up to 700 top 800 m wide at the 1 in 200 year flood elevation. The vegetated riparian area and some areas of housing and roads are included in the 1 in 200 year flood limit.

With climate change and continued land development in the watershed, it is expected that the 1 in 200 year flood elevation is now changed from 1988, and possibly higher than previously calculated.

Major river floods have previously occurred, such as in December 1980, November 1990, February 1999 (snow melt and ice jam) and June 2012 (rainfall after continued wet weather) (Doyle 1983; Doyle *et al.* 1993).

In 2011, the Ministry of Transportation and Infrastructure (BC MOTI) re-built the English Bridge north of Merritt, replacing it with a 22 m precast concrete girder bridge which was elevated to meet the 1 in 200 year flood level (BC MOTI 2010).

Dikes made of earth (sand and gravel) and concrete lock blocks are present along some sections of the lower Coldstream River on both banks above the junction with the Nicola River. In addition, some dikes are present along sections of the right and left banks of the Nicola River upstream of the confluence. Some sections of Nicola River bank were also armoured upstream of the confluence.

5.2.3.2 Ice Jams and Floods

Ice jams on the Nicola and Coldwater Rivers during ice freeze-up or breakup have caused some rapid floods, sediment transport and erosion, and damage from ice floes moving over the banks. These jams occurred when wet, warm weather followed periods of intense cold early in the winter (November/December) (Doyle 1983). Ice jams occurred on the Coldwater River in December 1979 and December 1980, which also caused minor overbank flooding in the City (Doyle 1983).

A large ice jam occurred in January 1984 on the Nicola River and its tributaries when cold weather conditions were followed by several days of heavy rain and warm temperatures. Ice jams formed and failed, with high discharges occurring in conjunction with ice-jam failure. Bank erosion, bed scour and deposition and channel relocation occurred along several kilometers of river channel as a result of these ice jams and associated water surges (Doyle et al. 1993).

Significant spring flooding also occurred in 1991 due to ice jams (Beltaos et al. 1996).

5.2.4 River Bank Erosion

Several sections of river bank along the Coldstream River, where it adjoins glaciolacustrine sediment, are subject to erosion and near vertical river banks have been formed (Photos 10, 13). In some cases, these are in the vicinity of new residential areas.

5.2.5 Previous Coal Mining and Subsidence

Between 1906 and the late 1950s, about 3 million tons of thermal grade coal was mined by underground methods immediately south of Merritt (Gilmar and Sharman 1981). Incidents including the collapse of previous tunnels and excavations have been reported. There are also suggestions that some coal is burning underground, which keeps certain areas at surface snow-free in winter. It is understood that no comprehensive program of mine remediation has taken place, and so further collapse of tunnels and subsidence could occur.

5.2.6 Wildfire Hazards

Steep forested and grassland slope areas in the southwest, south central and southeastern parts of the City have been designated as a development permit areas, based on predicted wildfire behaviour. The area of former coal mine workings is also included in this Wildfire Hazard area, due to the proximity to forested slopes and grasslands, and the potential from underground smouldering coal seams.

5.2.7 Excess Surface Water from Irrigation

Irrigated fields are located on the west and east sides of Merritt. There are reported concerns of excess irrigation water causing surface runoff, high soil moisture conditions and water table rise on private and public lands outside the irrigated areas. The irrigation problems are seasonal, during the periods when irrigation is active in spring through late summer. High soil moisture conditions and the associated possibility of reduced soil strength may lead to local slope instabilities.

6 Recommendations for Merritt Integrated Stormwater Management Plan

For the Merritt ISMP, the following recommendations are provided:

1) Surface and subsurface stormwater infrastructure should be restricted from the Schedule D Development Permit Areas (DPA), including DPA No. 2 Geotechnical Hazards; and DPA No. 6 Environmentally Sensitive Lands. This is due to possible infrastructure foundation problems, potential damage to surface structures from land subsidence or collapse, and possible slope destabilization (landslides) from underground disposal or leakage of water.

2) In DPA No. 4, Wildfire Hazards, it is possible that stormwater infrastructure at surface could be damaged from natural wildfires (e.g. the burning and collapse of structures with wood or metal). Above ground structures using these materials should be restricted from the area.

3) The glacial lake silt and clay deposits, where present at surface, are prone to perched water tables, surface sheet erosion, gullying and piping, and collapse of steep banks. All stormwater infrastructure must have suitable foundation drainage, especially in areas with silt and clay deposits. Erosion protection measures (surface armour, revegetation, grading of slopes to stable angles) must be used when dealing with fine-grained surficial deposits at infrastructure installation sites. The glacial lake deposits generally have low hydraulic conductivity and so will be unsuitable for disposal of stormwater by infiltration. Addition of uncontrolled stormwater to this type of deposit would tend to cause piping and gullying. Ditches and culvert outfalls installed across silt and clay deposits would require suitable armouring and sediment capture features (collection basins).

4) The Nicola and Coldwater Rivers have a history of large winter ice jams which have caused rapid, high elevation flooding and some channel erosion. The flooding is temporary (generally a few days) but the ice jams, the floating ice floes and water inundation can cause damage to surface structures. Flooding also occurs due to spring floods with little or no ice content.

   All stormwater structures and pipes should be located outside of the river channel and dike areas where most of the flooding, water erosion and ice damage are focussed. If stormwater pipes must pass below the rivers, special engineering assessment should be completed in advance, as these rivers have experienced up to several meters of lateral erosion and deep vertical erosion. Large (>2 m) boulders have been moved by ice and water force in the river, and so any design and armouring must accommodate these potential effects.

   The highest urban stormwater discharges occur in early winter and spring, when the local watercourses may not be able to accommodate further water discharge. Consideration should be given to creating surface water detention areas and dry wells for slow release of stored stormwater into the natural watercourses.

5) Significant erosion has resulted from the redirection of surface stormwater flow into local gullies formed in lacustrine silts and clays. In some cases these gullies have been transformed into deep (5 m) ravines with destabilized slopes with sediment deposition occurring at the ravine-base. To avoid this concern, surface stormwater should not be directed down natural gullies unless in a pipe or flume, or unless the gully bottom can be fully armoured with crushed rock, geotextile or other erosion control materials.

   Motorcycle paths also have the potential to redirect surface water flow and cause undesirable erosion conditions, which could affect stormwater infrastructure. Surface water management practices for active tracks should include the use of armoured swales where drainage tracks are crossed. Disused trails should be rehabilitated with armoured drainage swales, re-vegetation and access barriers to avoid further redirection of surface water.

   Irrigation of forage fields near and in the City has caused excess soil moisture conditions, increase in the water table elevation and some flooding in adjacent areas. As many fields have fine-grained surface soils, and excess irrigating runs off, the irrigation operators should be required to pay attention to irrigation rates and duration, in order to avoid flooding and/or excess soil moisture in the City area.

   Wet soil conditions caused by nearby irrigation may affect subsurface soil conditions and the installation and operation of stormwater infrastructure.

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Appendix A – Project Area Photographs

Photo 1: View from south side of Merritt over the gullied hill slopes and former mining area, over to the city residential areas along the Coldstream and Nicola Rivers.

Photo 2: Overview of natural gullied hill slopes above the west end of Merritt.

Photo 3: In photo centre, development permit area on steeper slopes above northeast part of Merritt. Hilltop has mainly bedrock and talus.

Photo 4: Road cut in horizontally layered lacustrine sediments, with initial rilling of cut and ditch.

Photo 5: Recent gully from uncontrolled stormwater drainage formed at base of natural old gully, northwest part of Merritt.

Photo 6: Detail of gully eroded into lacustrine sediment formed by uncontrolled stormwater drainage, northwest part of Merritt.

Photo 7: Coldstream River with riparian vegetation and gravel lateral bars.

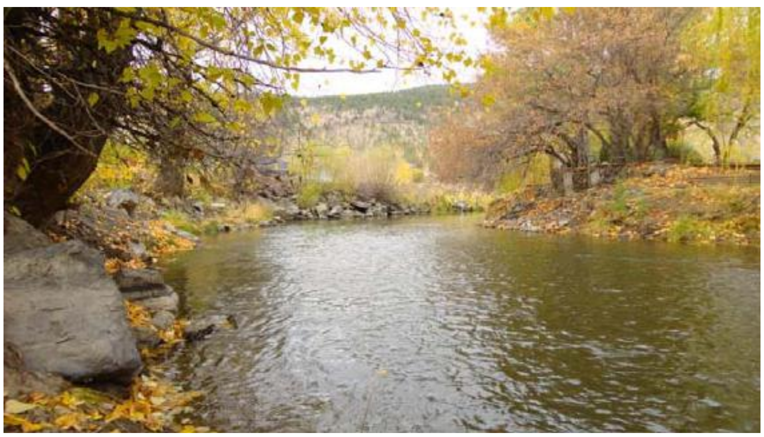


Photo 8: Coldwater River in west part of Merritt, showing bank armour and dikes.

Photo 9: Nicola River in northeast part of Merritt showing road crossing, riparian area and straight channel reach.

Photo 10:, Orthoimage showing details of a Nicola River meander bend with bank erosion (left) and rilling (right), with recent residential development above. Stormwater conveyance and disposal must be carefully managed in such situations.. Bing Map image.

Photo 11: Bing Map image of west side of Merritt with confluence of larger Coldstream River (bottom) and smaller Nicola River (top). The circular park area may be a former coal mining area and is used for floodwater detention.

Photo 12: Coldstream River with residential buildings near channel.

Photo 13: Coldstream River with steep banks in lacustrine sediment, near residential housing.

Photo 14: Coldstream River above Merritt with wider channel and gravel islands and bars.

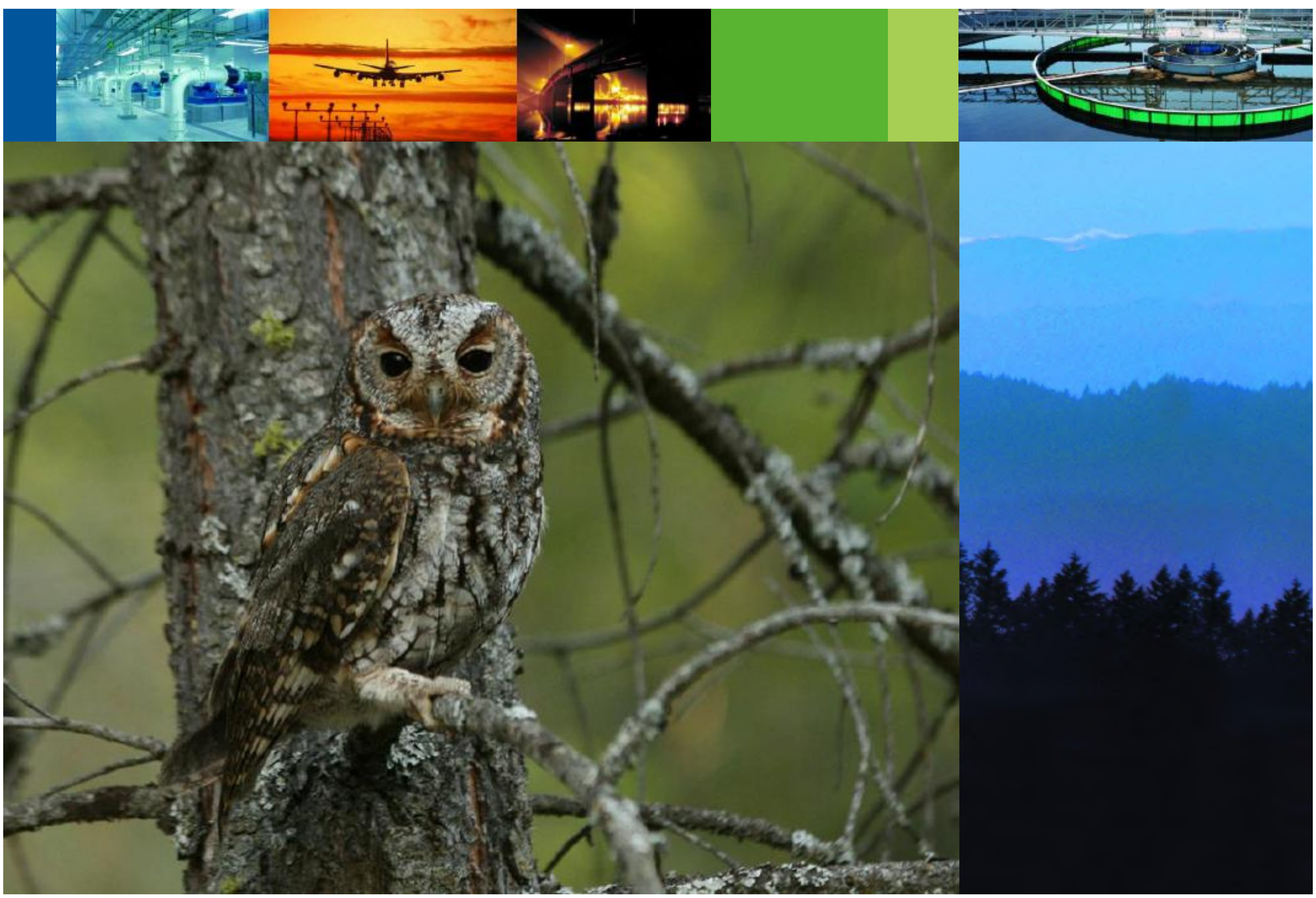
Appendix C - Aquatic and Terrestrial Species Habitat Review

Report

City of Merritt

Integrated Stormwater Management Plan
Aquatic and Terrestrial Task 104

February 2013



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1 Introduction

1.1 PROJECT BACKGROUND AND OBJECTIVE

The City of Merritt has commissioned Associated Engineering (BC) Ltd. to prepare an Integrated Stormwater Management Plan (ISMP) as per Section 3.2.3.4 of the Official Community Plan (OCP), which is to be used as a planning tool for future upgrades. In keeping with the City's OCP and commitment to environmental protection, a review of the terrestrial and aquatic habitat values within the City of Merritt municipal boundary (herein referred to as the 'study area') will assist planners and engineers with incorporating heritage values and environmentally sensitive areas into the ISMP, and identify areas where more information is required.

The objectives of this review are to develop strategies to avoid, minimize or mitigate potential impacts at the planning stage and to identify areas where more studies or information are required. Specific objectives are to

- Prepare a summary of the inventory of aquatic and terrestrial species and habitats, including any gaps in available information;
- Determine the extent and quality of environmentally sensitive areas;
- Identify potential environmental impacts of current and future development and stormwater management, and recommend measures to minimize negative impacts;
- Recommend measures to facilitate better watershed management and land use decisions to be considered within the ISMP. These recommendations will support the policy statement in Merritt's OCP to maintain geographical, environmental, and cultural values that contribute to the liveability of the Nicola Valley.

1.2 INFORMATION REVIEW

The following review is a result of compiling background information, such as biogeoclimatic zone maps, fisheries data, and results of a site-specific search of the B.C. Conservation Data Centre database and ecosystem maps. Any other reports completed within the study area, including those completed by Summit were also reviewed. Key data sources for this report include:

- Habitat wizard, Fisheries Information Summary System (FISS) and BC fisheries websites;
- Conservation Data Centre (CDC) Rare Element Occurrence Report and the CDC Tracking List for listed species of flora and fauna potentially occurring in the area;
- Environmental protection guidelines outlined in the Stormwater Planning: A Guidebook for British Columbia (MWLAP 2002);
- Existing information sources pertaining to the local environment (i.e., BC Conservation Data Centre
- Fisheries and Oceans Canada and BC Ministry of Environment, Canadian Wildlife Service/Environment Canada, Sensitive Habitat Inventory Mapping [SHIM]);

- Records of any local stewardship and natural history groups;
- Develop with Care (MFLNRO 2012), and Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia (MWLAP 2004).

2 Regulatory Context

The federal and provincial regulations outlined below are specific to the planning, designing and construction of stormwater and other City infrastructure. These regulations also provide justification in developing land-use policies for future development and conservation areas.

2.1 FEDERAL LEGISLATION

2.1.1 Migratory Birds Convention Act

The federal *Migratory Birds Convention Act* protects migratory birds and nests from indiscriminate harvesting and destruction (Government of Canada 1994). The Migratory Bird Regulations stipulate that “no person shall disturb, destroy or take a nest, egg, nest shelter, eider duck shelter or duck box of a migratory bird” (Section 6 [a]), and “no person shall deposit or permit to be deposited oil, oil wastes or any other substance harmful to migratory birds in any waters or any area frequented by migratory birds (Section 35 [1]) (Government of Canada 1994). Restrictions on disturbance have been put in place during the migratory bird season (March 15 to August 15; Canadian Wildlife Service 2008) as well as the breeding bird season (April 1 to July 31; MWLAP 2004b).

2.1.2 Species at Risk Act

The federal *Species at Risk Act* (SARA) provides legal protection to “at risk” wildlife and their habitats in Schedule 1. Habitats include “residences” and “critical habitat” for which the definitions are currently being drafted. At-risk wildlife and plants are listed in Schedule 1 of SARA (Government of Canada 2002). The purpose of SARA is to prevent Canadian indigenous species, subspecies and distinct populations from becoming extirpated or extinct, and to encourage the management of other species to prevent them from becoming at risk. This protection applies to all federal lands in Canada. If a species at risk is identified on private or provincial crown land, best management practices and good environmental stewardship are encouraged. In addition, anyone required to undertake an environmental assessment under an Act of Parliament must notify Environment Canada in writing of the project if it is likely to affect a listed wildlife species or its critical habitat (Section 79 (1)) of the *Species at Risk Ac*t.

2.1.3 Fisheries Act

The federal *Fisheries Act* is the main federal legislation affecting all fish, fish habitat and water quality. Subsection 36(3) prohibits the deposit of deleterious substances of waterways frequented by fish. The harmful alteration, disruption or destruction of fish habitat was prohibited under Section 35 (1); however, recent amendments (2012) to the *Fisheries Act*, Section 35 (1) now states “No person shall carry on any work, undertaking or activity that results in serious harm to fish that are part of a commercial, recreational or Aboriginal fishery, or to fish that support such a fishery.”

2.2 PROVINCIAL LEGISLATION

2.2.1 Water Act

The provincial *Water Act* ensures the quality of water, fish and wildlife habitat, and the rights of licensed water users (Government of British Columbia, 1996a). Under the Act, “habitat” includes the watercourse and the streamside (riparian) vegetation that provides nutrients and shade to the stream, whether they support fish or not. Any activities that result in changes occurring in or about a stream require notification or approval under Section 9 of the Act. This includes “modifications to the nature of the stream, including the land, vegetation, natural environment or flow of water within the stream,” and “any activity or construction within the stream channel that has or may have an impact on a stream.”

2.2.2 Riparian Areas Regulation

The Riparian Areas Regulation (RAR) is a provincial regulation that was enacted under the *Fish Protection Ac*t in 2006. The regulation states that any permanent structure within 30 m of a water body, which requires a development permit from a local government, is subject to the regulation. The City has adopted the principals of RAR under Section 6.6 of the OCP, as part of Development Permit No. 6 – Environmentally Sensitive Areas. Therefore, to obtain a development permit in mapped ESAs, a Qualified Environmental Professional (QEP) must assess the proposed development and prepare a report for submission on the RAR Notification Database.

2.2.3 Wildlife and Wildlife Amendment Acts

The *Wildlife Act* of British Columbia protects virtually all vertebrate animals from direct harm, except as allowed by regulation (e.g., hunting or trapping). The Minister may issue permits to authorize certain activities if they will not jeopardize the survival or recovery of that species. The Wildlife Act was amended to protect and recover certain species at risk identified by Cabinet, making it an offence to kill, harm, harass or capture an animal considered at risk. Cabinet also has the ability to define and protect the residence of a species at risk, and it is an offence to damage or destroy such residences. The *Wildlife Amendment Act* (WAA) provides for the protection and recovery of certain species at risk identified by Cabinet, making it an offence to kill, harm, harass or capture an animal considered at risk. WAA also provides that the government will not pay any compensation to a person who suffers any reduction in the value or use of land in which they have an ownership interest, or any other damages or losses due to their obligation to comply with WAA.

2.2.4 Heritage Conservation Act

The *Heritage Conservation Act* protects British Columbia's archaeological resources, which are considered the physical remains of past human activity predating 1846 on public and private land (Government of British Columbia, 1996). The *Act* stipulates that “archaeological sites may not be destroyed, excavated or altered" without a permit issued by the Minister or designate (Section 13[2]).

3 Environmental Overview

3.1 LAND USE AND TOPOGRAPHY

The City of Merritt has a population of over 7,000 people (Statistics Canada, 2006) with required amenities (i.e. schools, hospital, regional airport) to support a growing community. Residents of the city are employed largely in sales and service industries and trades. The community has a rich history of First Nations heritage, fur trading, coal mining and ranching. Popular recreational activities for the area include fishing, hiking, cross-country skiing, and snowmobiling. There are no designated provincial parks or federal parkland within the municipal boundary.

The City is situated to the east of the Coastal Mountains, at the confluence of the Coldwater and Nicola Rivers, part of the Thompson River watershed. The river floodplains provide rich soils for farming and consequently, significant portions of land dedicated to the agricultural land Commission (ALR). ALR lands are primarily located in River Ranch and Grasslands Area, and Collettville (City of Merritt 2011). Also, there are three historic ranches located north of Merritt (outside of the study area); Nicola, Douglas Lake, and Quilchena Ranch. Douglas Lake Ranch being named as one of Canada's oldest ranches (Tourism BC 2013). The surrounding natural grasslands along the valley bottom lends to diverse wildlife habitat and rare ecosystems.

Important to the land base is the nearby Lower Nicola Indian Band and additional 7 communities that form the Nicola Tribal Association: Coldwater Indian Band; Cook's Ferry Indian Band; Nicomen Indian Band; Nooaitch Indian Band; Shackan Indian Band; Siska Indian Band; and Upper Nicola Indian Band. These communities are downstream of the Nicola River and are directly influenced by changes in water quality and quantity.

See Appendix A for the City of Merritt Land Use Designation Map which identifies the location and area names referenced within this report.

3.2 TERRESTRIAL HABITATS

3.2.1 Vegetation and Ecosystems

The study area is primarily within the Bunchgrass Very Dry Hot (BGxw1) and the Ponderosa Pine Very Dry Hot (PPxh2) biogeoclimatic zones (MOE 2013)[1] with a few small areas in the Interior Douglas Fir Very Dry Hot (IDFxh2a). The grasslands tend to dominate the lower elevations (700 to 1000 m) of the Southern Interior valley bottoms with native vegetation generally consisting of bunchgrasses (i.e. junegrass, Sandberg's bluegrass, bluebunch wheatgrass, needle and thread

[1] The Biogeoclimatic Ecosystem Classification (BEC) system defines zones having characteristic vegetation with associated climate, soils and animals. In B.C., each forested zone occurs under a broadly similar macro-climate and is usually named by one or more of the dominant tree species which are capable of self-regeneration on most of the zone's habitats.

grass) and sagebrush (i.e. rabbit brush, big sage, pasture sage; MOF 1991). Indicative vegetative species of the high elevation ponderosa pine parkland are ponderosa pine (*Pinus ponderosa*), rough fescue (*Festuca scabrella*), slender hawksbeard (*Crepis atrabarba*), and timber milk vetch (*Astragulus miser*; MOF 1991.

In addition to the grasslands and ponderosa pine parkland features, the study area also supports a continuous riparian ecosystem along the Nicola and Coldwater Rivers and various tributaries throughout the study area. Dry vegetated gullies likely drain the upland areas during periods of high run-off; however, they are not expected to be connected to fish-bearing waters and tend to infiltrate the surface. Other features in the study area include extensively modified areas for agriculture and residential housing. Table 3-1 below summarizes the three native ecosystem types for the study area and the expected vegetation species.

Table 1 in Appendix B lists the rare ecosystems in B.C. and the potential location within the study area. There are 11 red-listed and 2 blue-listed communities that have potential to occur in the one of the following three ecosystems. Of particular importance in the study area are the sagebrush and wheatgrass communities that are dominated by development in the grassland areas.

Table 2 in Appendix B lists the rare plants with potential to occur in the study area. The blue-listed Porcupine sedge (*Carex hystericina*) was documented by the Conservation Data Center (CDC) as occurring 3 kilometers northwest of merit on Highway 8, in a ditch between the highway and railway (Appendix C).

Table 3-1
Three native ecosystems within the study area.

Ecosystem	**BEC**	**Expected vegetation species (MOF 1991)**
Riparian Forest (Floodplain)	BGxw1	trembling aspen, snowberry, (black cottonwood), Oregon grape, red-osier dogwood and several species of willow (*Salix* sp.), Nootka rose (*Rosa nootkana*)
Native grasslands	BGxw1	Open grasslands with grizzlybear prickly pear cactus, sagebrush, bluebunch wheat grass.
Parkland Forest (includes vegetated gullies)	PPxh1 (IDFxh2a)	Open ponderosa pine stand with some Douglas fir, yarrow, cinquefoil, arrow-leaved balsam root, Saskatoon, sagebrush and bluegrasses.

3.2.2 Wildlife Habitat Review

The study area provides valuable ecological and wildlife habitat because of the diversity of habitat along the landscape, including open forest, sagebrush, grassland and rocky outcrops. Wildlife such as deer, big horn sheep, raptors and snakes all have potential to occur in the study area. Disturbed agriculture land provide habitat for insects (e.g., grasshoppers) and some small mammals (e.g., mice and voles) that attract predators (e.g., snakes, raptors, coyotes and foxes). Rodent burrows provide cover for rare salamanders and snakes, like the western rattlesnake (red-listed and Threatened) and the gopher snake (blue-listed and Threatened).

The vegetated gullies in the highlands will provide corridors for movement up and down slopes and often provide cover, nesting and foraging habitat for passerine and upland game birds, ungulates, snakes and small mammals. Birds, particularly passerines, nest in these shrubs and rely on them for protective cover. Deer and bears also use these areas for cover and foraging.

Birds

The Nicola Naturalist Society is actively involved in winter bird counts contributing to a database maintained by the National Audubon Society (Nicola Naturalist Society 2013). The results of the 1995 to 2011 Christmas counts are provided online (Nicola Naturalist Society 2013a); the 2012 results are not currently available. In summary, 793 species have been observed over-wintering in the Merritt area. Of particular note, there were unusual sightings of the following species in November/December 2012 (Nicola Naturalist Society 2013b):

- Double-crested cormorant (Nicola Lake);
- Common grackle (north bench area Merritt);
- Anna's hummingbird (Merritt).

In grassland and grazed pasture land, potential populations of grassland bird species could include many sensitive species, including raptors (e.g., Swainson's hawk (red-listed [2]), Peregrine falcon (red-listed), Prairie falcon (red-listed), Great blue heron (blue-listed), Lewis's woodpecker (red-listed), short-eared owl (blue-listed[3], Special Concern), long-billed curlew (blue-listed and Special Concern), horned lark (blue-listed) and grasshopper sparrow (red-listed). Other common species would likely include meadow larks, magpies, and crows.

Riparian corridors, especially those associated with major rivers such as the Nicola and Coldwater River, are important refuge, foraging and nesting habitat for raptors and migratory birds. They also provide important migratory routes for seasonal and daily movements.

Amphibians and Reptiles

The Nicola Naturalist Society has also initiated (in 2011) an amphibian monitoring study within the Nicola region (80 by 90 km radius). Of the five sites located in the Merritt city limits, the only amphibian species observed was the tadpoles and egg masses of the Pacific chorus frog, within a

[2] Red-listed species are those indigenous species, subspecies or ecological communities that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed.

[3] Blue-listed species are those indigenous species, subspecies or ecological communities considered to be of Special Concern in British Columbia because of characteristics that make them particularly sensitive to human activities or natural events.

small pond on private property. Additionally four western garter snakes were observed near the City sewage ponds in 2011 (Sopuck pers. comm. 2013).

Although the Columbia spotted frog, Great basin spadefoot, long-toed salamander, and western toad have not been observed within the city limits by the Nicola Naturalist Society, they have documented occurrences within the Nicola region and there is likely suitable habitat features within the study area. Table 3-2 below summarizes the amphibians known to the Nicola region with the potential to occur within the study area and the preferred habitat features.

Table 3-2
Amphibians with potential to occur within the study area.

Common name	Scientific name	Status, observation and preferred habitat*
Columbia spotted frog	*Rana luteiventris*	**No status -** permanent lakes, ponds, slow-moving streams and marshes in a wide variety of wetlands, forest types, grassland, sage brush land and even alpine tundra between 950-2000 metres above sea level
Great basin spadefoot	*Spea intermontana*	**Blue; Threatened -** Breeds in shallow ponds; forages in semi-arid grasslands, shrub lands, and open woodlands
Long-toed salamander	*Ambystoma macrodactylum*	**No status –** prefer a variety of habitats ranging from wet rainforests and cold mountain meadows to dry sagebrush prairie.
Pacific chorus frog	*Pseudacris regilla*	**No status** - woodlands, meadows, pastures, and even urban areas, often quite far from the nearest body of water. Moving to shallow (ephemeral) wetlands during the breeding seasons where there is a lot of plant cover.
Western toad	*Anaxyrus boreas*	**Blue; Special Concern -** Nicola and Douglas Lakes Breed in shallow, littoral zones of lakes, temporary and permanent pools and wetlands, bogs and fens, and roadside ditches (i.e., toads may be found in all lacustrine and palustrine habitats); tadpoles associate with benthic habitats.

** observed within or near the Nicola region as reported in the Community- based Amphibian Monitoring Study (Biolinx 2011).

Wildlife Species at Risk

Rare wildlife found in the province are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and protected under the federal *Species at Risk Act*, and provincially under the *Wildlife Act*. There were no rare wildlife observations documented by the CDC (2013) in the study area; however, three rare wildlife species were identified outside of the study area (Table 3-2; locations shown in Figure 1 in Appendix C) and so it is expected that they may be observed or may find alternate suitable habitat within the City of Merritt at some time.

The study area also provides foraging and denning habitat for several federally-listed snakes, such as racers (*Coluber constrictor)*, rubber boas (*Charina bottae*), western rattlesnakes (*Crotalus oreganus*) and Great Basin gopher snakes (*Pituophis catenifer*). Table 3 in Appendix B lists the rare wildlife with potential to occur within the study area.

Table 3-3
Rare wildlife observations adjacent to the study area (CDC 2013)

Common name	Scientific name	Status, observation and preferred habitat
Great Blue Heron, Herodias Subspecies	*Ardea herodias herodias*	**Red listed; Special concern (SC) Occurrence ID #10091 -** Nest tree, Merritt; Nests in the upper part of the main tree canopy near foraging habitats.
Peregrine Falcon, Anatum Subspecies	*Falco peregrinus anatum*	**Blue listed; Occurrence ID # 7482 -** Nester Creek and Nicola Lake. Nests on cliffs or escarpments with dry steppes or grasslands nearby for hunting.
Sharp-tailed Grouse, Columbianus Subspecies	*Tympanuchus phasianellus columbianus*	**Blue listed; Occurrence ID # 3592 and 2591** - Merritt and Quilchena; Associated with native bunchgrass and shrub-steppe communities

3.3 AQUATIC HABITAT REVIEW

The study area is located at the confluence of the Nicola and Coldwater Rivers, which are part of the Thompson River watershed. In addition to these major river systems, there are a number of creeks and tributaries associated with the rivers that provide significant value to fish and fish habitat, many of which are located in the study area.

From Nicola Lake, the Nicola River flows southwest through the City of Merritt and then northwest for 60 kilometers to the Thompson River, at Spence's Bridge, B.C. The Coldwater River drains the Fraser River basin and is a major tributary of the Nicola River. It originates in the Cascade Mountains (Coquihalla Lakes) to the south and flows northwest along the western boundary of the study area and into the Nicola River. Both rivers are known to support many salmonids and other important fish species. Table 3-1 summarizes the fish species known to reside in the Nicola and Coldwater River, including coho salmon

(*Oncorhynchus kisutch)* which have been listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) since May 2002 (MOE 2013). The Coldwater River, near the Music Festival grounds and upstream of the study area, has been study by the Ministry of Forest Lands and Natural Resource Operations (formerly known as MOE). Results suggest low flows and increased temperatures cause concern for resident salmon and trout (MOE 2009).

Hamilton Creek, a tributary of the Nicola River within the study area, does not provide documented fish habitat. Hamilton Creek is a stream order 3 and is 12.8 km long. Major tributaries of the Coldwater River, within the study area include Spanish Creek (no data) and Godey Creek, known to support coho salmon.

There are other mapped tributaries or drainages in the study area for which we did not find baseline information. No lakes or wetland features are located within the study area.

Table 3-4
Fish species known to reside in the Nicola and Coldwater River

English name	Scientific name	Nicola	Coldwater
bridgelip sucker	*Catostomus columbi anus*	X	
bull trout	*Salvelinus confluentus*	X	X
burbot	*Lota lota*	X	
chinook salmon	*Oncorhynchus tshawytscha*	X	X
chiselmouth	*Acrocheilus alutaceus*	X	
coho salmon**	***Oncorhynchus kisutch***	**X**	**X**
Dolly varden	*Salvelinus malma*	X	X
kokanee	*Oncorhynchus nerka*	X	
lake trout	*Salvelinus namaycush*	X	
lake whitefish	*Coregonus clupeaformis*	X	
leopard dace	*Rhinichthys falcatus*	X	X
longnose dace	*Rhinichthys cataractae*	X	X
longnose sucker	*Catostomus catostomus*	X	
mountain whitefish	*Prosopium williamsoni*	X	X
northern pikeminnow	*Ptycholcheilus oregonensis*	X	
Pacific Lamprey	*Lampetra tridentata*	X	X
peamouth chub	*Mylocheilus caurinus*	X	
pink salmon	*Oncorhynucus gorbuscha*	X	
prickly sculpin	*Cottus asper*	X	
rainbow trout	*Oncorhynchus mykiss*	X	X
redside shiner	*Richardsonius balteatus*	X	X
river lamprey	*Lampetra ayresii*	X	
sculpin (general)	*Cottus spp.*	X	X
slimy sculpin	*Cottus cognatus*	X	
sockeye salmon	*Oncorhynchus nerka*	X	
steelhead	*Oncorhynchus mykiss*	X	X
sucker (general)	*Catostomus spp.*	X	X
western brook lamprey	*Lampetra richardsoni*	X	
white sucker	*Catostomus commersonii*	X	

****listed as endangered by COSEWIC.**

3.4 ARCHAEOLOGICAL, CULTURAL AND HERITAGE RESOURCES

Archaeological data for the Merritt area (including a 5 kilometer buffer) was requested from the Archaeology Branch of the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). A majority of the study area, particularly to the south of the Nicola River, has high archaeological potential and there are 25 known sites identified within the study area (see Figure 2 in Appendix C).

The Nicola valley is a major First Nations settlement area with eight communities within 20 kilometers. River valleys are generally known as culturally sensitive areas and migration routes. Given the history and the biophysical features of the study area, a search of the archaeological database suggests a high potential for archaeological resources to be present on the south side of the Nicola River, within the study area.

4 Stormwater Planning Considerations

The stormwater planning considerations outlined below reflect the known environmentally sensitive areas within the defined study area, best management practices and environmental regulations. Following a review of the previously completed reports and databases, the key environmental planning considerations are defined as:

- Terrestrial habitat (native and rare vegetation, ecological communities, weed management);
- Riparian areas;
- Aquatic habitat (rivers, creeks, and tributaries);
- Heritage Resources; and
- General best management practices.

Each planning consideration is discussed in detail below and further studies are recommended to gain information of the environmental values within the study area and to support policies for environmental protection as stated in the OCP. The following recommendations are largely based on environmental regulations in place, the Develop with Care Environmental Guidelines for Urban and Rural Development in B.C. (MFLNRO 2012), and the Stormwater Planning Guidebook (MWLAP 2002).

A summary of the known environmental and heritage areas are shown in Appendix C attached.

4.1 TERRESTRIAL HABITATS

With a majority of the study area being altered from its natural state for urban and rural development, there is limited wildlife habitat within the city center. There are, however; remaining native grasslands, riparian and forested areas surrounding the core development areas. Very little is known about the native vegetated areas remaining with the study area and in a growing community, urban sprawl has potential to impact these areas. Currently, the Environmentally Sensitive Areas (ESAs) in the OCP are limited to the riparian areas of streams and do not incorporate terrestrial species and ecosystems.

It is recommended that the City of Merritt complete a Sensitive Ecosystem Inventory (SEI) for the study area and outside areas of influence. Having SEI data will assist land-use planners to identify critical habitat for species and ecosystems at risk, and will encourage land-use decisions and management strategies that will protect these ecosystems ensuring new development will protect Species at Risk in the study area in compliance with the *Wildlife Act.*

Further planning recommendations to protect rare and native vegetation within the study area include:

- Require site specific vegetation surveys for development, especially in areas with native vegetation. Efforts to protect or re-locate rare vegetation should be included in the development plan;
- Implement weed control and prevention as part of new development plans;
- Encourage retention of trees and native vegetation, particularly shrub thickets, in

development areas;

- Follow Best Management Practices for Tree Topping and Limbing in Riparian Areas (MOE, no date) to create wildlife trees.
- Partner with the Nicola Naturalist Society to expand the amphibian study area to include the floodplain areas of the Coldwater and Nicola River. Incorporate the best management practices for Amphibians and Reptiles in Urban and Rural Environments in B.C. (MWLAP 2005; MFLNRO 2012) to preserve and enhance habitats in development plans.

4.2 RIPARIAN AREAS

All stormwater upgrade locations (including ditching, pipe and manhole infrastructure, detention ponds, etc.) should be assessed under and comply with the provincial Riparian Areas Regulation (RAR) and City of Merritt OCP (Section 6). Therefore, any development proposed within the 30 meter Riparian Assessment Area (RAA) of all surface water features that are connected by surface flow to fish bearing water within the study area, require and assessment and determination of a setback (termed as Streamside Protection and Enhancement Area or SPEA). The setbacks are calculated based on zones of sensitivity (litter fall and insect drop, large woody debris, and shade values). Table 4-1 recommends riparian setbacks for known surface water features within the study area.

Removal of riparian vegetation within the identified setback should be limited for the following reasons:

1. The banks of a watercourse are significantly cut, this indicates a highly active channel during seasonal flow. Removal of vegetation will contribute to decreased bank stability. Alternatively, allowing existing vegetation to grow will enhance channel stability and reduce the risk of channel erosion on the development;
2. As a fish-bearing stream, riparian vegetation provides significant value to habitat within the creek (i.e. shade, litterfall, and large woody debris recruitment);
3. Riparian vegetation helps to attenuate flooding waters and floodplain erosion, and
4. Local wildlife may use the riparian vegetation as important travel corridors. Protection of riparian vegetation will continue to provide a continuous corridor for wildlife and serve as a locally-important food source.

The riparian health of the major creeks and tributaries should be assessed in the study area, namely at Godey, Spanish and Hamilton Creeks. Development within the city core has heavily encroached and impacted the riparian area of these water bodies. Identifying key areas for riparian enhancement opportunities, ensuring new development includes a building setback suitable to the RAR and a suitable riparian enhancement plan will enhance terrestrial habitat, improve water quality (temperature, sediment control) and provide a storm water catchment for adjacent impervious surfaces.

Table 4-1
Recommended riparian setbacks for environmental protection.

Water feature	Width of Water Feature (projected)	Recommended Riparian Setback
Nicola River	Greater than 10 m	30
Hamilton Creek	3 to 9 m	10 to 30 m*
Coldwater River	Greater than 10 m	30
Spanish creek	3 to 9 m	10 to 30 m*
Godey creek	3 to 9 m	10 to 30 m*
Other tributaries and drainages	Less than 3 m	10 m
Ditches (connected to surface water)		
Fish	2 x channel width	5 to 10 m*
Non-Fish	n/a	2 m*

*depends on the results of a riparian assessment based on the RAR Assessment Methods (2006).

4.3 AQUATIC HABITAT

Of particular concern to aquatic habitat are seasonal low flows, increasing water temperatures and degraded water quality from point and non-point sources. It has been identified that the Coldwater River, near the Music Festival grounds, experiences low flows and high temperatures during the warmer season, which can be detrimental to fish. Implementing riparian development setbacks and enhancement plans will help improve temperature conditions by creating shade values that will assist in temperature moderation.

Receiving waters from stormwater infrastructure are also prone to erosion (i.e. cut banks, slope instability) due to fluctuating water flows outside of the natural flow regime. Critical stream reaches in the study area that receive current storm water include the length of the Coldwater River through the study area, the Nicola River particularly in the center of the City.

Recommendations for further assessment and to improve aquatic habitat within the study area:

- Assess critical streams reaches and identify areas for enhancement, preservation, and restoration. Recommendations in these stream reaches may include erosion and sediment control, riparian planting, instream habitat enhancement (i.e. large woody debris, riffles). There are significant cut-banks on the Nicola River that are adjacent to the community of North Nicola, which are of concern for fluctuating water levels, especially during high water flows;
- Use a bio-engineering approach for areas requiring stream bank restoration to maximize habitat characteristics for fish (dissuade rock retaining wall and gabion walls);
- Identify barriers to fish passage in stream reaches (blocked culverts, debris, man-made features) and prescribe a means to remove fish barriers;
- Prevent direct discharge of stormwater into surface water features by utilizing stormwater detention ponds, catch basins, and bioswales, where possible;
- Consider incorporate wildlife habitat features into potential detention pond design, such as amphibian basking logs, rushes and emergent vegetation to create bird habitat and improve water quality;
- Use effective planning and sediment and erosion control techniques to prevent sediment-laden water from entering natural aquatic habitats; and

Any instream remediation work will require a *Water Act* (Section 9) notification and a project review by DFO.

4.4 HERITAGE RESOURCES

If an archaeological site is encountered during development and the appropriate permits are not in place, proponents will be in contravention of the *Heritage Conservation Act* and face possible fines and likely experience development delays while the appropriate permits are obtained (Cooper pers comm. 2013). Developers should be required to complete an Archaeological Impact Assessment (AIA) in areas of known sites, and to seek the advice of an archaeological professional in areas with high potential.

Further detail on specific known archaeological sites and mapping layers is included in attached CD.

4.5 GENERAL BEST MANAGEMENT PRACTICES

The following best management practices can be incorporated into land-use policies and stormwater planning:

- Ensure proposed developments (re-development and new) address storm water retention on-site, using infiltration or re-use (i.e. rain barrels, recycling) techniques;
- Improvements to the city center can be implemented by incorporating green spaces and utilization of drought tolerant species. Additional vegetation will utilize some storm water run-off in an area that is primarily impermeable;
- Proposed storm-water detention ponds and any other storm water infrastructure should be placed outside of riparian areas;

- Avoid development and site disturbance in areas that have been identified as environmental or culturally sensitive by a qualified professional (i.e. riparian areas, listed ecological communities, archaeology sites) and encourage increasing densities within already developed areas, or cluster development in less sensitive areas;
- Encourage fencing to protect environmental sensitive areas and resources; and
- Consider conservation covenant areas, parkland dedication, management agreements, land trust areas in comprehensive planning approaches.

5 Summary

In summary, there are important environmentally and culturally sensitive areas within the City of Merritt despite the development of this area. By implementing the recommendations from Section 4 into the land-use policies, these areas may be protected from future infrastructure proposed within the study area. The recommendations for additional studies will also provide valuable tools to guide the City of Merritt with policy and bylaw development for the protection of the environment.

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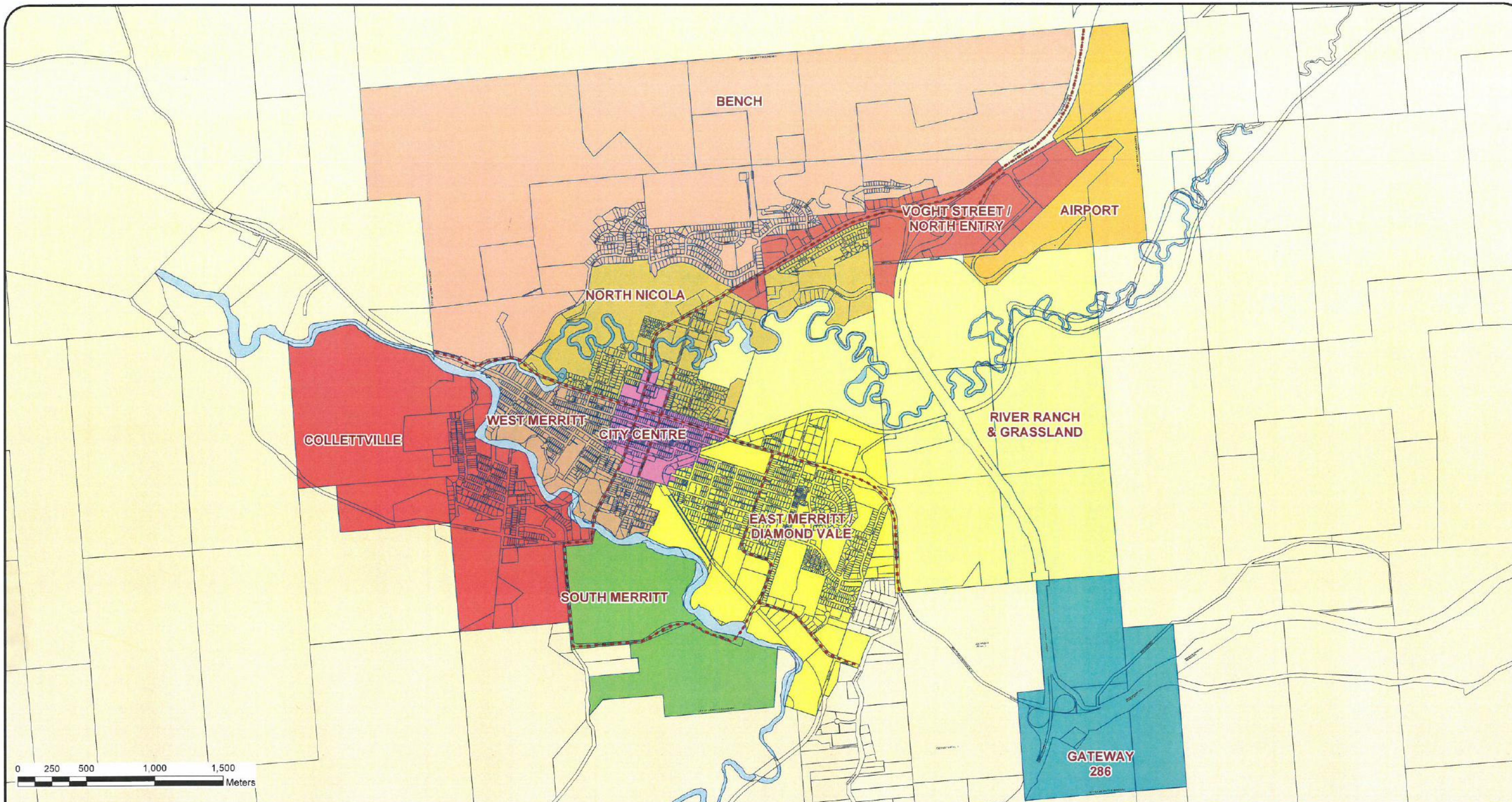
A Appendix A - City of Merritt Land Use Designation Map



City of Merritt

Official Community Plan

Flourishing Under The Sun

SECTOR MAP

Land Use Designation Map

Official Community Plan Bylaw No. 2116, 2011

B Appendix B - Species and Ecosystems At Risk

Table 1. Listed ecological communities with potential to occur within the study area.

English Name	Scientific Name	BC List	BEC	Potential Occurrence in Study Area
alkali saltgrass Herbaceous Vegetation	*Distichlis spicata var. stricta Herbaceous Vegetation*	Red	PPxh	Grasslands
big sagebrush / bluebunch wheatgrass	*Artemisia tridentata / Pseudoroegneria spicata*	Red	BGxw/PPxh	Grasslands
black cottonwood / common snowberry - roses	*Populus trichocarpa / Symphoricarpos albus - Rosa spp.*	Red	BG	Riparian Forest (floodplain)
black cottonwood - water birch	*Populus trichocarpa - Betula occidentalis*	Red	PPxh	Riparian Forest (floodplain)
bluebunch wheatgrass - junegrass	*Pseudoroegneria spicata - Koeleria macrantha*	Red	BG	Grasslands
Douglas-fir / common snowberry - saskatoon	*Pseudotsuga menziesii / Symphoricarpos albus - Amelanchier alnifolia*	Red	PPxh	Forest
giant wildrye Herbaceous Vegetation	*Leymus cinereus* Herbaceous Vegetation	Red	BG	Grassland
narrow-leaf willow Shrubland	*Salix exigua* Shrubland	Red	BG	Riparian Forest (floodplain)
ponderosa pine / bluebunch wheatgrass	*Pinus ponderosa / Pseudoroegneria spicata*	Blue	BG	Forest
ponderosa pine / bluebunch wheatgrass - rough fescue	*Pinus ponderosa / Pseudoroegneria spicata - Festuca campestris*	Blue	BGxw/PPxh	Forest
rough fescue - bluebunch wheatgrass	*Festuca campestris - Pseudoroegneria spicata*	Red	BGxw/PPxh	Grassland
trembling aspen / common snowberry / Kentucky bluegrass	*Populus tremuloides / Symphoricarpos albus / Poa pratensis*	Red	BG	Riparian Forest (floodplain)
water birch / roses	*Betula occidentalis / Rosa* spp.	Red	BGxw/PPxh	Riparian Forest (floodplain)

Table 2. Rare vegetation with potential to occur within the study area

English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
American chamaerhodos	*Chamaerhodos erecta* ssp. *nuttallii*		Blue	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
awned cyperus	*Cyperus squarrosus*		Blue	Agricultural;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
Colorado rush	*Juncus confusus*		Red	Grassland/Shrub Steppe;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
dwarf groundsmoke	*Gayophytum humile*		Blue	Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Geyer's onion	*Allium geyeri* var. *tenerum*		Blue	Estuary;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
giant helleborine	*Epipactis gigantea*	SC (May 1998)	Blue	Lakes;Wetland;Stream/River
grizzlybear prickly pear	*Opuntia* x *columbiana*		Blue	Rock/Sparsely Vegetated Rock
hairy water-clover	*Marsilea vestita*		Red	Lakes;Wetland
Hall's willowherb	*Epilobium halleanum*		Blue	Forest;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
low hawksbeard	*Crepis modocensis* ssp. *modocensis*		Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
many-headed sedge	*Carex sychnocephala*		Blue	Grassland/Shrub Steppe;Lakes;Wetland;Rock/Sparsely Vegetated Rock
mock-pennyroyal	*Hedeoma hispida*		Red	Agricultural;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
mutton grass	*Poa fendleriana* ssp. *fendleriana*		Red	Forest;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
northern linanthus	*Leptosiphon septentrionalis*		Blue	Forest;Grassland/Shrub Steppe;Wetland;Stream/River;Rock/Sparsely Vegetated Rock;Shrubland

English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
Okanogan fameflower	*Phemeranthus sediformis*	NAR (May 1990)	Yellow	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
Oregon checker-mallow	*Sidalcea oregana* var. *procera*		Red	Grassland/Shrub Steppe;Stream/River;Rock/Sparsely Vegetated Rock;Shrubland
ovalpurse	*Hornungia procumbens*		Blue	Alkali Pond/Salt flat;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock;Shrubland
peach-leaf willow	*Salix amygdaloides*		Red	Lakes;Wetland
porcupine sedge	*Carex hystericina*		Blue	Grassland/Shrub Steppe;Lakes;Wetland;Rock/Sparsely Vegetated Rock
porcupinegrass	*Hesperostipa spartea*		Red	Forest;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
poverty-weed	*Iva axillaris*		Red	Agricultural;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
prairie wedgegrass	*Sphenopholis obtusata*		Red	Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
rough dropseed	*Sporobolus compositus* var. *compositus*		Blue	Alkali Pond/Salt flat;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Sand/Dune;Shrubland
scarlet gaura	*Gaura coccinea*		Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
scarlet globe-mallow	*Sphaeralcea coccinea*		Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
sheathing pondweed	*Stuckenia vaginata*		Blue	Lakes;Stream/River
silvery orache	*Atriplex argentea* ssp. *argentea*		Red	Agricultural;Alkali Pond/Salt flat;Rock/Sparsely Vegetated Rock;Shrubland

English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
slender hawksbeard	*Crepis atribarba* ssp. *atribarba*		Red	Forest;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
slender mannagrass	*Glyceria pulchella*		Blue	Lakes;Wetland
stretching suncress	*Boechera sparsiflora*		Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
Suksdorf's lupine	*Lupinus bingenensis* var. *subsaccatus*		Red	Forest;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
tall beggarticks	*Bidens vulgata*		Red	Lakes;Wetland
thyme-leaved spurge	*Chamaesyce serpyllifolia* ssp. *serpyllifolia*		Blue	Grassland/Shrub Steppe;Lakes;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
toothcup meadow-foam	*Rotala ramosior*	E (May 2000)	Red	Lakes;Wetland
wedgescale orache	*Atriplex truncata*		Blue	Alkali Pond/Salt flat;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
western centaury	*Centaurium exaltatum*		Red	Alkali Pond/Salt flat;Lakes;Wetland;Rock/Sparsely Vegetated Rock
western low hawksbeard	*Crepis modocensis* ssp. *rostrata*		Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland

Table 3: Wildlife species at Risk with potential to occur within the study area.

English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
Birds				
American Avocet	*Recurvirostra americana*		Red	Alkali Pond/Salt flat;Estuary;Lakes;Wetland;Stream/River;Rock/Sparsely
Barn Swallow	*Hirundo rustica*	T (May 2011)	Blue	Agricultural;Estuary;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
Bobolink	*Dolichonyx oryzivorus*	T (Apr 2010)	Blue	Agricultural;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Brewer's Sparrow, *breweri* subspecies	*Spizella breweri breweri*		Red	Rock/Sparsely Vegetated Rock;Shrubland
Bull Trout	*Salvelinus confluentus*	SC (Nov	Blue	Lakes;Stream/River
Burrowing Owl	*Athene cunicularia*	E (Apr 2006)	Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
Canyon Wren	*Catherpes mexicanus*	NAR (May	Blue	Rock/Sparsely Vegetated Rock
Common Nighthawk	*Chordeiles minor*	T (Apr 2007)	Yellow	Agricultural;Forest;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock;Shrubland
Flammulated Owl	*Otus flammeolus*	SC (Apr	Blue	Forest;Rock/Sparsely Vegetated Rock
Great Blue Heron, *herodias* subspecies	*Ardea herodias herodias*		Blue	Agricultural;Estuary;Forest;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
Horned Lark, *merrilli* subspecies	*Eremophila alpestris merrilli*		Blue	Agricultural;Alkali Pond/Salt flat;Alpine/Tundra;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock

English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
Lark Sparrow	*Chondestes grammacus*		Red	Agricultural;Forest;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
Lewis's Woodpecker	*Melanerpes lewis*	T (Apr 2010)	Red	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Long-billed Curlew	*Numenius americanus*	SC (May 2011)	Blue	Estuary;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Peregrine Falcon, *anatum* subspecies	*Falco peregrinus anatum*	SC (Apr 2007); 1-T (May 2003)	Red	Estuary;Rock/Sparsely Vegetated Rock
Prairie Falcon	*Falco mexicanus*	NAR (May 1996)	Red	Agricultural;Alpine/Tundra;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
Rusty Blackbird	*Euphagus carolinus*	SC (Apr 2006)	Blue	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
Sage Thrasher	*Oreoscoptes montanus*	E (Nov 2010)	Red	Agricultural;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
Sharp-tailed Grouse, *columbianus* subspecies	*Tympanuchus phasianellus columbianus*		Blue	Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
Short-eared Owl	*Asio flammeus*	SC (Mar 2008)	Blue	Agricultural;Alpine/Tundra;Estuary;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Swainson's Hawk	*Buteo swainsoni*		Red	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Williamson's Sapsucker, *thyroideus* subspecies	*Sphyrapicus thyroideus thyroideus*	E (May 2005)	Red	Forest;Rock/Sparsely Vegetated Rock
Mammals				
American Badger	*Taxidea taxus*	E (Nov 2012)	Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock

English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
Bighorn Sheep	*Ovis canadensis*		Blue	Alpine/Tundra;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
Fringed Myotis	*Myotis thysanodes*	DD (May 2004)	Blue	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Subterranean;Urban
Great Basin Pocket Mouse	*Perognathus parvus*		Red	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock;Shrubland
Little Brown Myotis	*Myotis lucifugus*	E (Nov 2012)	Yellow	
Spotted Bat	*Euderma maculatum*	SC (May 2004)	Blue	Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland;Subterranean
Townsend's Big-eared Bat	*Corynorhinus townsendii*		Blue	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland;Subterranean
Western Screech-Owl, *macfarlanei* subspecies	*Megascops kennicottii macfarlanei*	T (May 2012); 1-E (Jan 2005)	Red	Agricultural;Forest;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
Western Small-footed Myotis	*Myotis ciliolabrum*		Blue	Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland;Subterranean
Amphibians and reptiles				
Columbia Spotted Frog	*Rana luteiventris*	NAR (May 2000)	Yellow	Lakes;Wetland;Stream/River
Gopher Snake	*Pituophis catenifer*		No Status	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
Great Basin Spadefoot	*Spea intermontana*	T (Apr 2007)	Blue	Forest;Wetland;Stream/River;Rock/Sparsely Vegetated Rock;Shrubland

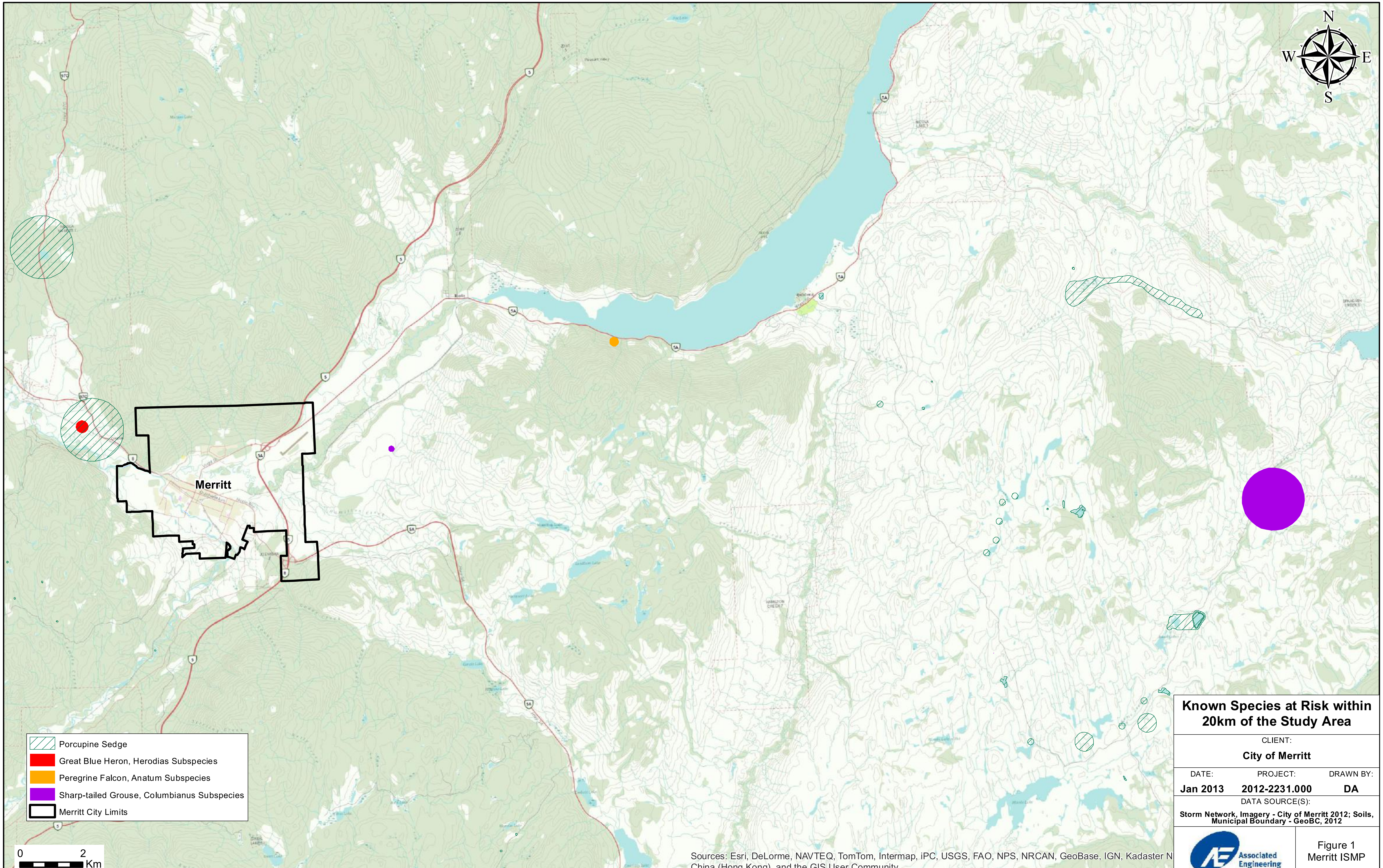
English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
Northern Rubber Boa	*Charina bottae*	SC (May 2003)	Yellow	Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland
North American Racer	*Coluber constrictor*	SC (Nov 2004)	Blue	Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Shrubland;Subterranean
Painted Turtle - Intermountain - Rocky Mountain Population	*Chrysemys picta pop. 2*	SC (Apr 2006)	Blue	Wetland;Stream/River
Western Rattlesnake	*Crotalus oreganus*	T (May 2004)	Blue	Grassland/Shrub Steppe;Wetland;Stream/River;Rock/Sparsely Vegetated Rock;Shrubland;Subterranean
Western Toad	*Anaxyrus boreas*	SC (Nov 2012)	Blue	Agricultural;Forest;Grassland/Shrub Steppe;Lakes;Wetland;Stream/River;Rock/Sparsely Vegetated Rock
Fish				
Chiselmouth	*Acrocheilus alutaceus*	NAR (May 2003)	Blue	Lakes;Stream/River
Mountain Sucker	*Catostomus platyrhynchus*	SC (Nov 2010)	Blue	Stream/River
White Sturgeon	*Acipenser transmontanus*	E (Nov 2003)	No Status	Estuary;Lakes;Ocean;Stream/River
White Sturgeon (Middle Fraser River population)	*Acipenser transmontanus* pop. 6	E (Nov 2003)	Red	Lakes;Stream/River
Invertebrate				
California Hairstreak	*Satyrium californica*		Blue	Forest;Rock/Sparsely Vegetated Rock;Shrubland
Common Sootywing	*Pholisora catullus*		Blue	Agricultural;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock
Hagen's Bluet	*Enallagma hageni*		Blue	Lakes

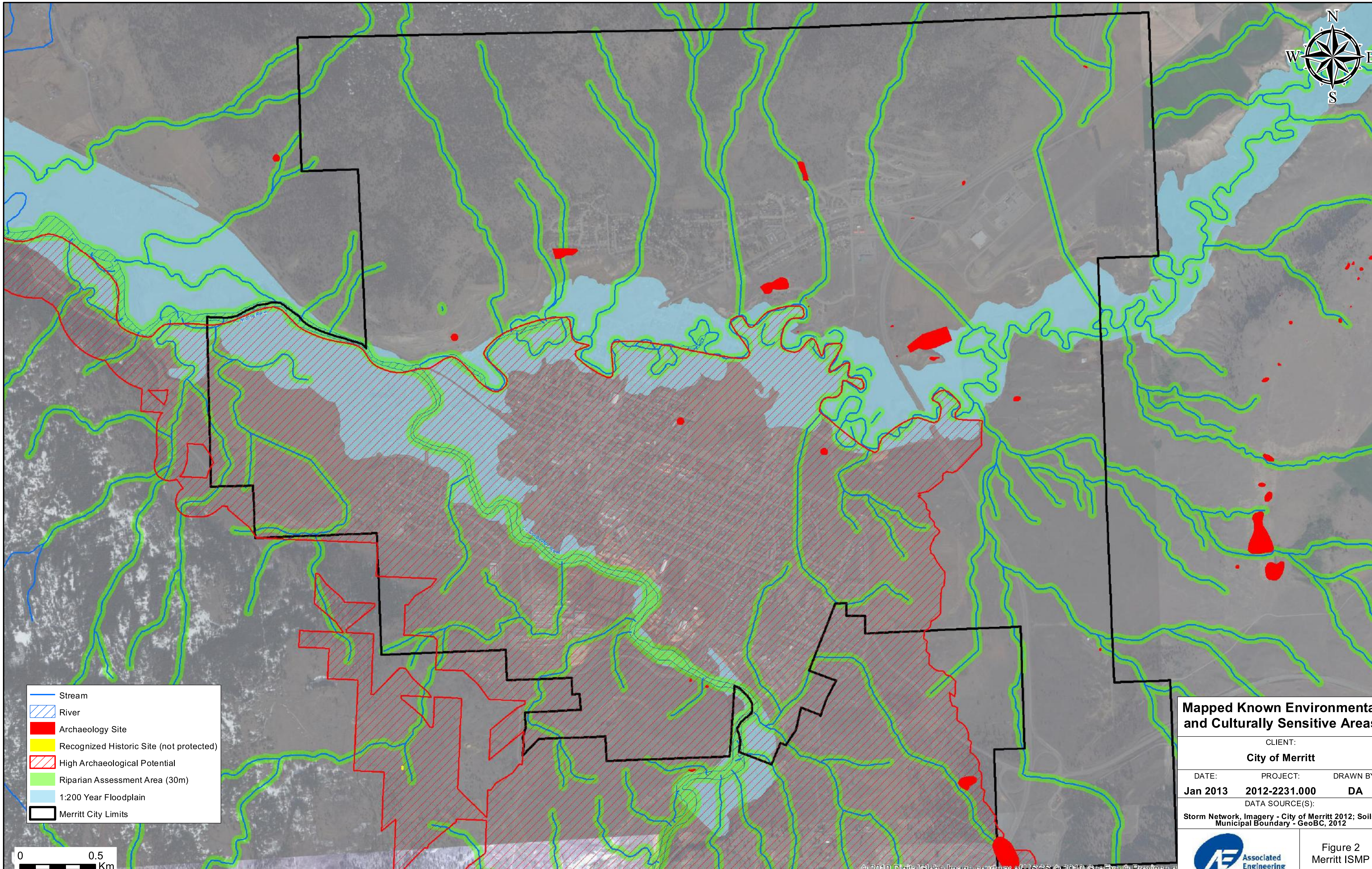
English Name	Scientific Name	COSEWIC/SARA	BC List	Habitat Type
Monarch	*Danaus plexippus*	SC (Apr 2010)	Blue	Agricultural;Forest;Grassland/Shrub Steppe;Wetland;Rock/Sparsely Vegetated Rock;Sand/Dune;Shrubland
Nevada Skipper	*Hesperia nevada*		Blue	Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
Olive Clubtail	*Stylurus olivaceus*	E (May 2011)	Red	Lakes;Stream/River
Silky Vallonia	*Vallonia cyclophorella*		Blue	Forest;Grassland/Shrub Steppe;Rock/Sparsely Vegetated Rock
Umbilicate Sprite	*Promenetus umbilicatellus*		Blue	Wetland;Stream/River

Bold + grey highlight = CDC mapped known locations within 20 km of city Center

grey higlight = observed near study area

C Appendix C - Mapped Known Environmentally and Culturally Significant Areas


N
E
S
W
Merritt
Porcupine Sedge
Great Blue Heron, Herodias Subspecies
Peregrine Falcon, Anatum Subspecies
Sharp-tailed Grouse, Columbianus Subspecies
Merritt City Limits
0 2 Km
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster N
China (Hong Kong), and the GIS User Community
Known Species at Risk within 20km of the Study Area
CLIENT:
City of Merritt
DATE:
Jan 2013
PROJECT:
2012-2231.000
DRAWN BY:
DA
DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012
Associated Engineering
Figure 1
Merritt ISMP



Mapped Known Environmental and Culturally Sensitive Areas

CLIENT:

City of Merritt

DATE:	PROJECT:	DRAWN BY:
Jan 2013	2012-2231.000	DA

DATA SOURCE(S):

Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012

Associated Engineering

Figure 2
Merritt ISMP

Appendix D - Water Quality Review

Technical Memorandum

City of Merritt

ISMP Technical Memo
Water Quality Review Task 107

February 2013

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1 Introduction

Summit was retained to conduct a review of existing water quality data to support a desktop investigation of the effects of stormwater discharge on receiving water bodies within the City of Merritt. This technical memorandum addresses Task 107: Water Quality Review outlined in the City of Merritt's Integrated Stormwater Plan RFP dated August 17th 2012.

1.1 OBJECTIVES

The objectives of Task 107 include performing a desktop investigation to assess the effects of Merritt's stormwater system on surrounding groundwater and surface water resources and provide recommendations on future stormwater monitoring.

1.2 STUDY AREA

The study area includes the City of Merritt (the City) stormwater service area within the city limits, which is surrounded by a sinuous branch of the Nicola River to the north and a meandering branch of the Coldwater River to the south (Figure 1-1). The Nicola River flows through the City in a southwest direction before it is joined by the Coldwater River, flowing in a northwest direction. The stormwater system includes a series of storm mains between about 75 and 900 mm in diameter that move stormwater collected from roadsides into a series of ditches, drywells, settling ponds and outfalls, some of which flow directly into the Nicola River or Coldwater River.

Surface water and groundwater resources are used differently within the study area. The Nicola River and the Coldwater River are not formally used as drinking water sources but provide important habitat for wildlife, invertebrates and many fish species, including Chinook salmon (*Oncorhynchus keta*), coho salmon (*Oncorhynchus kisutch*), steelhead salmon (*Oncorhynchus mykiss*) and pink Nicola River runs salmon (*Oncorhynchus gorbuscha*) (MOE 2012a). Groundwater, on the other hand, provides potable water to Merritt's citizens. The City currently operates five drinking water production wells, all of which are within the study area (Western Water 2012).

Land use surrounding each river within the study area is distinguished by a variety of OCP zones (City of Merritt 2011). At the western end of the study area land use surrounding the Nicola River is dominated by residential and commercial properties and some public utilities, including Merritt's Waste Water Treatment Plant (WWTP), whereas land use around the Coldwater River is dominated by parks, schools, churches and public utilities including wastewater rapid infiltration basins. This area also includes Collettville, a subdivision south of the Coldwater River. At the eastern end of the study area land use evolves into mostly agricultural development around the Nicola River and is predominantly heavy industry around the Coldwater River (City of Merritt 2011).

The WWTP is of significance to the review of water quality data because of the treatment plant's potential influence on surface and groundwater quality. It is located just east of Coldwater River near its confluence with the Nicola River (Figure 2-1). Effluent is treated by digestion and removal of biosolids then directed into one of three rapid infiltration basins in Collettville (Figure 2-1). From the rapid infiltration basins the effluent naturally percolates into the ground and enters the groundwater system (G3 Consulting Ltd. 2011). Due to the proximity of groundwater discharged to the Nicola River and the unconfined characteristic of the aquifer (see Task 105), there is a potential to compromise the water quality of the Nicola River (G3 Consulting Ltd. 2011). Additionally, the WWTP maintains an outfall 100 m upstream of the confluence of the Nicola and Coldwater Rivers which has not been used to discharge effluent since 1997 but if final effluent were required to be discharged under emergency circumstances, this would occur directly into the Coldwater River (G3 Consulting Ltd. 2011).

2 Methodology

Available water quality data were used to evaluate stormwater quality and its effect on receiving water bodies. Areas of focus included outfalls discharging directly into the Nicola or Coldwater Rivers, groundwater sampling locations within 50 m of the rivers or the rapid infiltration (RI) basins within the study area, surface water sampling locations within the study area and surface water sampling locations upstream and downstream of the study area. Water quality parameters commonly assessed in stormwater monitoring (Summit 2012) were prioritized in this assessment. These included total suspended solids (TSS), total coliforms, fecal coliforms, chloride, nitrate-N, total phosphorus, ortho-phosphorus and petroleum hydrocarbons (or oil and grease).

Water quality data from four existing (three Nicola River and one Coldwater River) and 13 discontinued (six Coldwater River and seven Nicola River) surface water quality monitoring sites were reviewed in conjunction with eight existing and two discontinued groundwater quality monitoring sites (Figure 2-1). Groundwater sampling sites were limited to those within about 50 m of the Nicola River, Coldwater River or rapid infiltration basins. Nine stormwater outfalls were identified as entering the Coldwater or Nicola Rivers. Three flow into Coldwater River and six flow into Nicola River. Water quality data from the outfalls were not available. Photographs of the outfalls are attached as Appendix A.

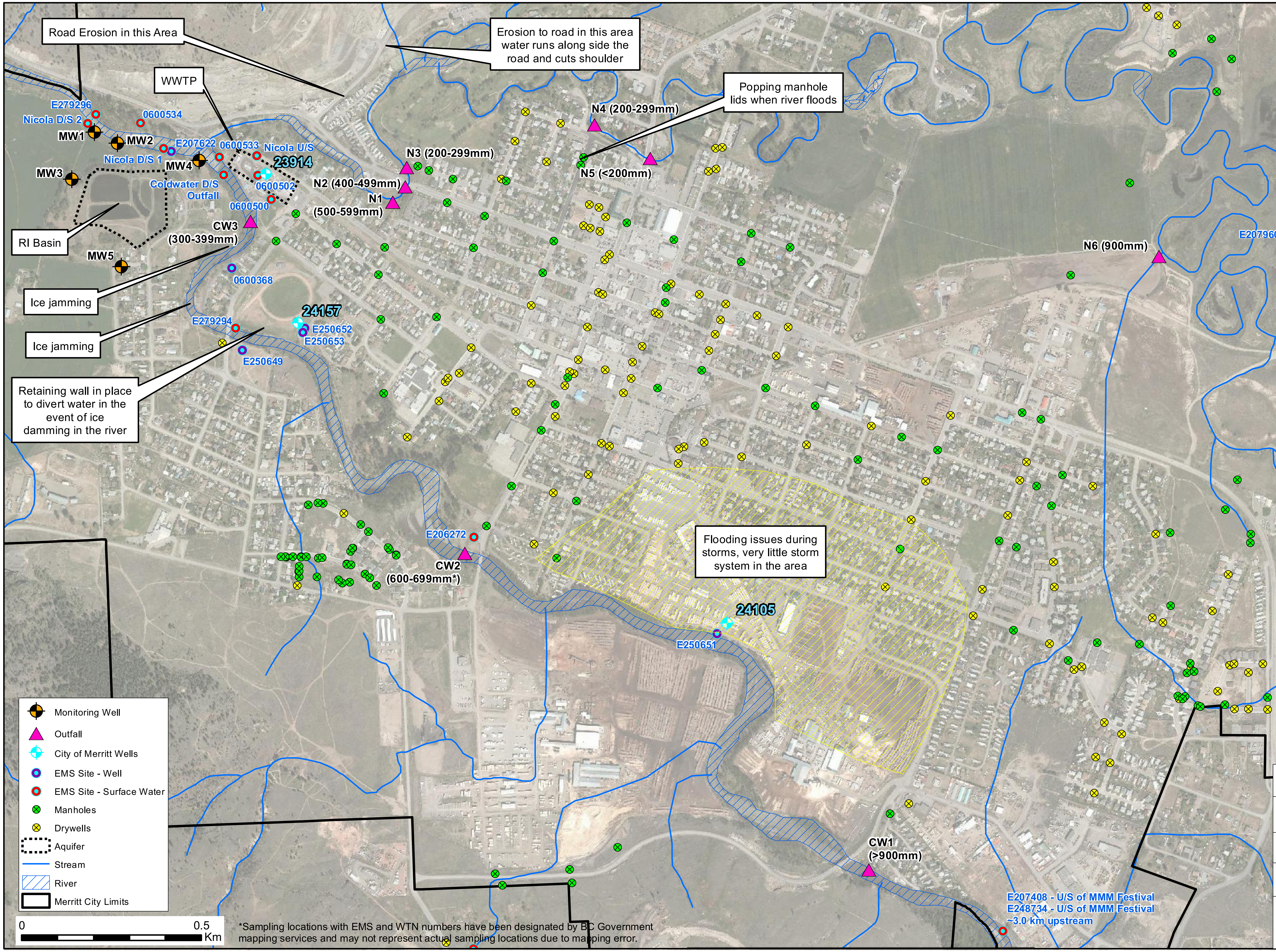
Existing monitoring sites included those being monitored annually by the City and three (of five) drinking water wells that provide chlorinated drinking water to residents of Merritt (Western Water2012). Water quality results from the environmental monitoring sites were extracted from the City's 2011 Environmental Monitoring Report (G3 Consulting Ltd. 2011) and include water quality results for four wells, three Nicola River locations and one Coldwater River location. Samples from the City's environmental monitoring locations, collected throughout the year, were analyzed for phosphates and nitrates, total and fecal coliforms, sulphate, pH, temp, DO, conductivity and turbidity (Appendix B). Water quality data for three of the City's five drinking water wells was obtained through the WaterTrax database (Watertrax 2012). WaterTrax parameters include total and fecal coliforms, *E.coli* and turbidity (Appendix F).

Discontinued monitoring sites were identified as BC Ministry of Environment (MOE) Electronic Monitoring System (EMS) locations using the Water Resource Atlas (MOE 2012a). EMS water quality data for these locations was retrieved from the provincial web-based EMS reporting database (MOE 2012c). EMS parameters included ammonia, chloride, total and fecal coliforms, nitrates, TDS, TSS, Specific conductance, temperature, turbidity and pH (Appendix C, D and E).

Since the City uses groundwater as a potable source and the Nicola and Coldwater Rivers provide important aquatic life habitat, surface water and groundwater quality data were compared to relevant guidelines. Surface water quality data were compared to Approved Water Quality Guidelines (MOE 2010) for to the protection of aquatic life and Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines. Bacteria parameters (*E.coli* and fecal coliforms and total coliforms) were compared to the Approved Water Quality Guidelines (MOE 2010) for the protection of livestock. Groundwater quality data was compared to Approved Water Quality Guidelines (MOE 2010) for drinking water.

Guideline exceedances in groundwater and surface water quality data were identified Historical reporting on groundwater and surface water interaction in the study area was also referenced. Since stormwater flow is highly affected by rain events, surface water quality data from EMS monitoring sites were compared to daily precipitation data collected at the Merritt STP Station between 1985 and 2012 (EC 2012).

Stormwater outfall and water quality sampling locations were mapped and Official Community Plan (OCP) zoning was considered in the assessment of water quality results (City of Merritt 2011). Information on site-specific stormwater issues, provided by the City, was also considered in the results assessment. Information gaps were identified and used to develop storm water monitoring recommendations.



Water Qualiy Assessment

CLIENT:
City of Merritt

DATE:	PROJECT:	DRAWN BY:
Jan 2013	2012-2231.000	DA

DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012

Associated Engineering

Figure 2-1:
Merritt ISMP

3 Results

3.1 STORMWATER OUTFALLS

Outfall Description

Outfalls that flow into surface water bodies have the potential to negatively affect surface water quality. Nine outfalls were identified as flowing immediately into or have overland flow that connects to Nicola River or Coldwater River. Three outfalls, identified as CW1, CW2 and CW3 release flows that may enter Coldwater River. Six outfalls, identified as N1, N2. N3, N4, N5 and N6 release flows that may enter the Nicola River. Samples collected at the outfalls were not taken and historical water quality results from the outfalls were not found.

The WWTP maintains an outfall 100 m upstream of the confluence of the Nicola and Coldwater Rivers for emergencies, although this has not been used to discharge effluent since 1997 (G3 Consulting Ltd. 2011).

Table 3-1 provides a description of the location and size of each stormwater outfall and the distance to the water body it flows into. Outfall locations are shown in Figure 2-1 and pictured in Appendix A.

Table 3-1
Outfall Location, Size and Distance to River

	Outfall	Location	Photo #	Size (mm)	*Distance to River (m)
1	CW1	On the north bank of the Coldwater River and west side of the Houston Bridge	1-3	900	3-5
2	CW2	On the north bank of the Coldwater River and west side of the Voght Street bridge	4-6	600-699	10-30
3	CW3	On the east bank of the Coldwater River at the northwest end of Stanford Ave	7-9	300-399	0-2
4	N1	On the southeast bank of the Nicola River at the northeast end of Spring Street.	10-12	500-599	0-2
5	N2	On the east bank of the Nicola River at the northeast end of Nicola Avenue	13-15	400-499	3-5
6	N3	On the east bank of the Nicola River at the north east end Fairway Place	16-18	200-299	3-5
7	N4	On the south bank of Nicola River at the north end of Chapman Street	19-21	200-299	3-5
8	N5	On the south bank of the Nicola River at the north end of Voght Street	22-24	<200	3-5
9	N6	On the south bank of the Nicola River	25-27	900	3-5

***During Low Water**

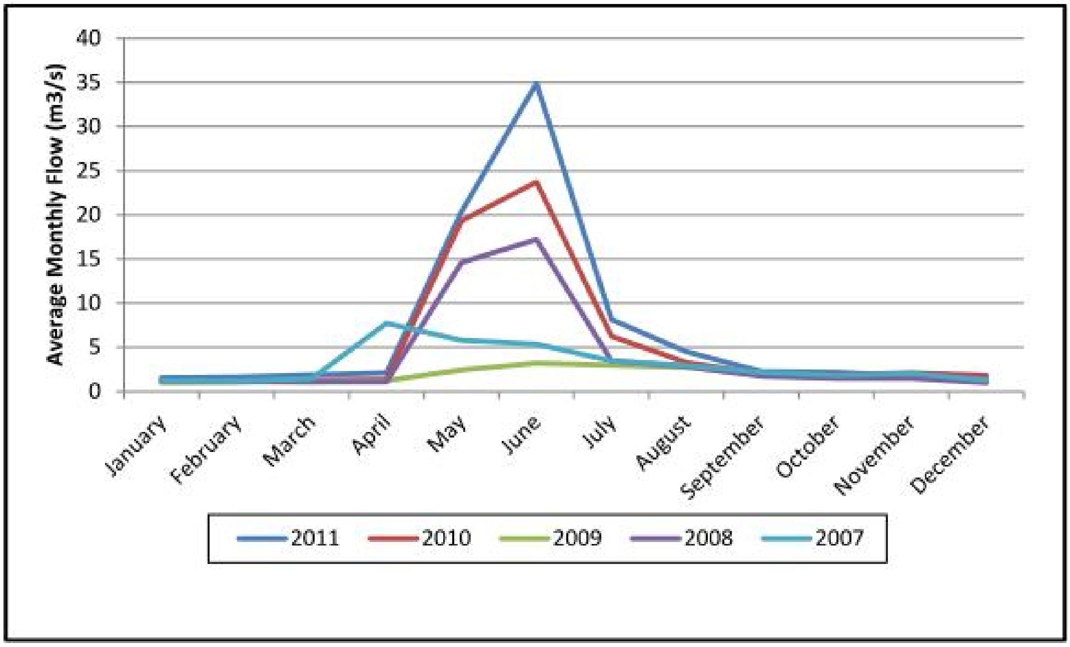


Figure 3-1
Nicola River Average Monthly Flow

3.2 NICOLA RIVER

The Nicola River watershed is approximately 7,227 km^2 and the river main stem is approximately 213 km long. The sinuous section flowing through the northern half of study area is approximately 2.5 km long and includes oxbows and backflow channels. Nicola River average flow by month ranges from a low of 0.2 m^3/s to a high of 35 m^3/s (Figure 3-1).

Preliminary average monthly flow data from Water of Survey of Canada Sites 08LG007 (Nicola River at Merritt) and 08LG065 (Outlet of Nicola Lake), shown above (G3 Consulting Ltd. 2011), indicates that spring freshet begins in mid-April, peaks around mid-June and has ended by about mid-August. The lowest flows occur in the winter months. Nicola River flows are controlled upstream of the study area by releases from the Nicola Lake Dam (Associated Engineering 2012). During most storm events, upstream flows are captured in Nicola Lake. However, water quality in the Nicola River has been reportedly impacted by the increases in storm drainage (Associated Engineering 2012).

Nicola River water quality data from three existing and seven discontinued water sampling locations collected on 100 separate sampling dates were reviewed. Existing locations (Nicola D/S 1, Nicola

D/S 2 and Nicola D/S Confluence) include those being monitored annually by the City. Discontinued locations include those documented in the EMS database and mapped on the Water Resources Atlas (MOE 2012b) and include the following locations identified with EMS numbers: 060053, 0600534, E206441, E206471, E207622, E279296, E207960. Table 3-2 describes each sample location, sampling duration, number of sampling events and water quality data source. Sampling locations are shown in Figure 2-1.

Tables of annual water quality data for Nicola D/S 1, Nicola D/S 2 and Nicola Upstream, extracted from the City's annual environmental monitoring report (G3 Consulting Ltd. 2011), are shown in Appendix B (Tables 4-14 to 4-16). EMS water quality results, including data from 90 separate Nicola River sampling events, are tabulated in Appendix C.

Table 3-2
Nicola River Water Quality Locations, Sampling Durations and Data Sources

#	Sampling Location / EMS Number	Location Description	Sampling Duration	# Sample Events	Data Source
1	Nicola D/S 1	75 m downstream of the Coldwater River confluence	2007-2011	5	City of Merritt Annual Environmental Report (G3 Consulting Ltd. 2011)
2	Nicola D/S 2	300 m downstream of the Coldwater River confluence (downstream of the rapid infiltration basins)	2007-2011	5	City of Merritt Annual Environmental Report (G3 Consulting Ltd. 2011)
3	Nicola U/S Confluence	Immediately upstream of the WWTP and the Coldwater River confluence	2007-2011	5	City of Merritt Annual Environmental Report (G3 Consulting Ltd. 2011)
4	0600533	Nicola River about 15 m upstream of the Coldwater River confluence	1985-1989	19	EMS Web Reporting (MOE 2012c)
5	0600534	Nicola River about 18 m downstream of the Coldwater River confluence	1985-1989	20	EMS Web Reporting (MOE 2012c)
6	E206441	Nicola River downstream of lagoons	1985-1986	9	EMS Web Reporting (MOE 2012c)
7	E206471	Nicola River at Lindley Creek Road.	1985-1989	17	EMS Web Reporting (MOE 2012c)
8	E207622	Nicola seepage	1988-1989	2	EMS Web Reporting (MOE 2012c)
9	E279296 (most downstream location)	Nicola River 350 m downstream of the Coldwater River confluence	2010	14	EMS Web Reporting (MOE 2012c)
10	E207960 (most upstream location)	Nicola Lake Beach	1985, 1989	4	EMS Web Reporting (MOE 2012c)
				Total=100	

Significant Findings

Significant findings were considered as those that exceeded water quality guidelines for the protection of aquatic life except for bacteriological parameters, which were compared to guidelines for the protection of livestock. Nicola River sampling location parameters with exceedances included fecal coliforms, total coliforms, total phosphorous, total suspended solids (TSS), temperature, turbidity and pH. Precipitation data were considered on each date where an exceedance occurred.

Total coliforms exceeded the Approved Water Quality Guidelines (MOE 2010) for the protection of livestock of 200 CFU/100 mL (or MPN) during 11 out of 85 of Nicola River EMS sampling events occurring between 1985 and 2010 (Appendix C). Total coliform counts were highest (9500 MPN/100 mL) at EMS site E206411 in 1985 (downstream of WWTP lagoons) and were high (1800, 920 and 920 MPN/100mL) on three occasions at EMS site 0600533 located about 15 m upstream of the Coldwater River confluence between 1985 and 1986. The highest total coliform counts at these locations coincided with heavy rainfall (13.5 mm) on September 9, 1985. Fecal coliforms exceeded the guideline downstream of at EMS site E206411 (downstream of WWTP lagoons) in 1985 (240 MPN/100mL). Total coliform exceedances occurred at all three of the City's Nicola River environmental monitoring locations. Mean annual total coliform concentrations at the Nicola U/S confluence sampling location has exceeded the total coliform guideline for the protection of livestock every year since monitoring began (2007-2011). Whereas mean annual total coliform concentrations at the Nicola D/S 2 location exceeded the guideline in 2009 and 2010 and at the Nicola D/S 1 location in 2010 only (Table 3-3).

Total phosphorous concentrations were compared to the CCME guideline for the protection of aquatic life in a river exhibiting meso-eutrophic conditions with phosphorous concentrations between 0.02 and 0.035 mg/L. Exceedances were noted during 16 of the 85 EMS sampling events and were highest (0.159 mg/L) in 1989 at EMS location E207622 and elevated at EMS site 0600533 during two sampling events in 1986 (0.101 mg/L and 0.128 mg/L; (Table 3-3). Total phosphorus was also analyzed in 2007 and 2008 from samples collected from the City's environmental monitoring locations. Two of these locations, Nicola D/S 2 and Nicola U/S Confluence exceeded the total phosphorus guideline on both years.

Total suspended solids (TSS) exceeded the CCME guideline for protection of aquatic life, defined as a change of 25 mg/L TSS from background (considered the lowest concentration in the dataset), during three sampling events in April and May of 2010 at EMS site E279296 (Table 3-3). This location is the furthest downstream Nicola River sampling location investigated during this assessment and is located about 350 m downstream of the Coldwater River confluence. The highest TSS concentration of 240 mg/L occurred there on April 21, 2010. TSS was not analyzed in the City's environmental monitoring sampling locations.

Temperature exceeded the CCME guideline for protection of aquatic life of 15º C at site E279296 on July 21, 2010 (15.9 º C).

Turbidity exceeded the CCME guideline for protection of aquatic life, defined as a change of 8 NTU from background (considered the lowest concentration in the dataset), during three sampling events in April and May of 2010 at EMS site E279296. Similar to TSS, the highest turbidity concentration of 130 NTU occurred at this site on April 21 2010. Mean annual turbidity concentrations exceeded this guideline at all of the City's Nicola River environmental monitoring locations on most years.

Parameter exceedances are shown in Table 3-3. Turbidity and TSS exceedance locations are mapped in Figure 3-3 and phosphorous, total coliforms, fecal coliforms and temperature exceedance locations are mapped in Figure 3-4.

Table 3-3. Nicola River Water Quality Parameter Exceedances

		Precip.:T	Coli:Fec	Coli:Tot	Phos.T	TSS	Temp	Turb.
	Units	mm	MPN	MPN	mg/L	mg/L	C^0	NTU
	[1]CCME				[2]0.02-0.035	[3]Δ 25	15	[3]Δ 8
	[1]BC Ambient		[4] 200	[4] 200				
EMS ID	START DATE							
600533	08/08/1985	0			**0.039**			
600533	05/09/1985	13.5		**920**				
600533	09/12/1985	0			**0.035**			
600533	07/01/1986	3			**0.044**			
600533	04/02/1986	1		**920**	**0.101**			
600533	10/03/1986	0			**0.128**			
600533	24/02/1988	0			**0.082**			
600533	08/09/1988	0			**0.041**			
600533	14/02/1989	0			**0.043**			
600534	08/08/1985	0		**350**				
600534	22/08/1985	0		**240**				
600534	05/09/1985	13.5		**1800**				
600534	04/02/1986	1		**240**				
600534	08/09/1988	0			**0.093**			
E206441	08/08/1985	0	**240**	**350**				
E206441	05/09/1985	13.5		**9500**				
E206441	05/11/1985	0		**350**				
E206441	04/02/1986	1			**0.037**			
E206471	04/02/1986	1		**240**	**0.039**			
E206471	10/03/1986	0		**350**	**0.068**			
E206471	08/09/1988	0			**0.095**			
E207622	14/02/1989	0			**0.159**			
E279296	21/04/2010	0				**240**		**130**
E279296	10/05/2010	0				**44**		**29**
E279296	19/05/2010	0				**150**		**57.6**
E279296	21/07/2010	0					**15.9**	
E279296	24/11/2010	1.5			**0.042**			
Nicola U/S Confluence	2007 Mean			**275**	**0.055**			**19.53**
Nicola U/S Confluence	2008 Mean			**259**	**0.199**			**27.61**
Nicola U/S Confluence	2009 Mean			**524**				
Nicola U/S Confluence	2010 Mean			**531**				**35.69**
Nicola U/S Confluence	2011 Mean			**210**				**30.4**
Nicola D/S 1	2010 Mean			**201**				**22.89**
Nicola D/S 1	2007 Mean							**39.22**
Nicola D/S 1	2009 Mean							**17.32**
Nicola D/S 1	2011 Mean							**12.5**
Nicola D/S 2	2009 Mean			**205**				
Nicola D/S 2	2010 Mean			**441**				**26.45**
Nicola D/S 2	2007 Mean				**0.036**			**44.28**
Nicola D/S 2	2008 Mean				**0.08**			
Nicola D/S 2	2011 Mean							**17.2**
E207960	27/08/1995	0			0.047			

[1] For the protection of drinking water

[2] meso-eutrophic conditions

[3] Δ X = Change from background by X units

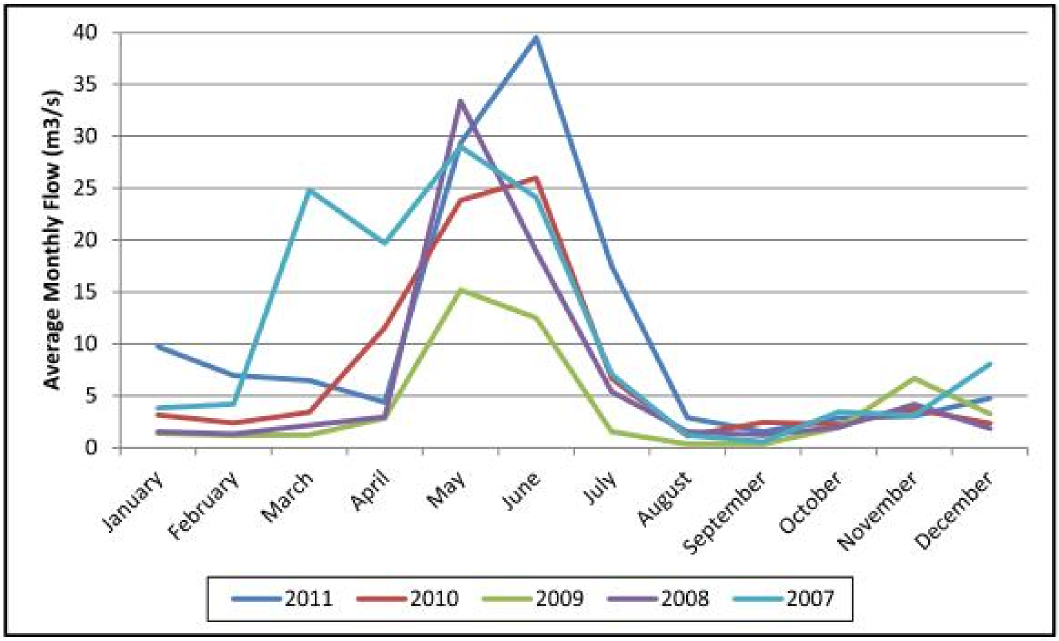


Figure 3-2
Coldwater River Average Monthly Flows

3.3 COLDWATER RIVER

The Coldwater River Watershed is about 914 km^2. It is a 91.7 km long meandering tributary of the Nicola River. About 3.5 km of the Coldwater flows in a northwest direction through the southern end of the study area. Coldwater River average monthly flow is shown in Figure 3-2.

Preliminary average monthly flow data from Water of Survey of Canada Sites 08LG010 (Coldwater River at Merritt), shown above (G3 Consulting Ltd. 2011), indicates that the beginning of freshet is somewhat variable but generally begins in mid-April, peaks around mid-May and has ended by about mid-August. The lowest flows occur in September, January and February and there is a slight increase in flow between October and December (Figure 3-2).

The naturalized (no withdrawals) mean annual flow (MAF) for the Coldwater River at Merritt has been calculated by MOE to be approximately 8.5 m^3/sec. Over several consecutive summers MOE Ecosystem staff have documented extended periods of low flow conditions, high stream temperatures and reductions in aquatic habitat in the lower Coldwater River. These low flow conditions are often well below recommended in-stream flow levels and are inadequate to maintain good aquatic habitat for salmon and trout (MOE 2009)

Coldwater River water quality data from samples collected on 84 separate sampling dates from one existing and six discontinued water sampling locations were reviewed (Table 3-4). The monitoring location, Coldwater D/S Outfall, is being monitored annually by the City (G3, 2011). Discontinued locations include those documented in the EMS database and mapped on the Water Resources Atlas (MOE 2012b) and include the following locations identified with EMS numbers: 600502, 600500, E206272, E207408, E248734 and E279294. Table 3-4 describes the sample location, sampling duration, number of sampling events and the data source. Sampling locations are mapped in Figure 2-1.

A table with the annual water quality results for the Coldwater D/S Outfall, extracted from the City's annual environmental monitoring report (G3 Consulting Ltd. 2011), is shown in Appendix B (Table 4-13). EMS water quality results for Coldwater River sampling locations are tabulated in Appendix D.

Table 3-4
Coldwater River Water Quality Locations, Sample Duration and Data Sources

#	Sampling Location / EMS Number	Location Description	Sampling Duration	Number of Sampling Events	Data Source
1	Coldwater D/S Outfall	Immediately downstream from the WWTP outfall and 20 m upstream of the Coldwater River confluence	2007-2011	5	City of Merritt Annual Environmental Report (G3 Consulting Ltd. 2011)
2	0600502	About 15 m downstream of the WWTP outfall	1986-1988	19	EMS Web Reporting (MOE 2012c)
3	0600500	Upstream of the WWTP	1985-1989	3	EMS Web Reporting (MOE 2012c)
4	E206272	Immediately downstream of Collette Bridge in Claybanks Park	1985-1989	1	EMS Web Reporting (MOE 2012c)
5	E207408	Upstream of the NMV Lumber Yard near the Houston St. Bridge	1988-2002	4	EMS Web Reporting (MOE 2012c)
6	E248734	Upstream of the Merritt Mountain Music Festival (most upstream location)	2002	2	EMS Web Reporting (MOE 2012c)
7	E279294	10 m upstream of the Collette Bridge beside Voght Park	2010-2011	50 Total=84	EMS Web Reporting (MOE 2012c)

Significant Findings

Significant findings were considered those that exceeded water quality guidelines for the protection of aquatic life except for bacteriological parameters which were compared to guidelines for the protection of livestock. Coldwater River sampling location parameters with exceedances included ammonia, fecal coliforms, total coliforms, total phosphorous, TSS, temperature, dissolved oxygen and turbidity. Precipitation data was considered on each date where an exceedance occurred (Table 3-5).

Total coliforms exceeded the Approved Water Quality Guidelines (MOE 2010) for the protection of livestock of 200 CFU/100 mL (or MPN/100 mL) during three out of 84 sampling events. Total coliform counts of 920 and 280 MPN/100 mL (EMS 600502) and 346 CFU/100 mL (Coldwater D/S outfall) occurred downstream of the WWTP outfall in October 1986, July 1986 and 2009. On September 8 1988 at EMS site 0600500, fecal coliforms exceeded the fecal coliform guideline of 200 CFU/100 mL with a count of 3500 CFU/100 mL, dissolved ammonia exceeded the CCME Guideline of 1.04 mg/L with a concentration of 3.09 mg/L and total phosphorous exceeded the guideline for mesotrophic conditions (0.01-0.02 mg/L) with a concentration of 0.68 mg/L (Table 3-5).

Total phosphorous exceeded the guideline at EMS site 0600500 (Upstream of the WWTP) in August 1985 and in March 1986, at EMS site E279294 (10 m upstream of Colette bridge) in May 2010, at EMS site E248734 (upstream of the Merritt Mountain Music Festival) in July 2002 and at the City's monitoring location, Coldwater D/S Outfall, in 2007 (Table 3-5).

TSS exceeded the CCME guideline for protection of aquatic life twice at EMS site 0600500 (Upstream of the WWTP) in August 1985 and September 1988 and once at EMS site E279294 in May 2010 (Table 3-5).

Similar to the Nicola River EMS Site E279296 (350 m downstream of the Coldwater River confluence), temperature exceeded the CCME guideline for protection of aquatic life of 15º C at the Coldwater D/S Outfall site in 2010 (15.9 º C). At the same location, turbidity exceeded the CCME guideline for protection of aquatic life, defined as a change of 8 NTU from background (considered the lowest concentration in the dataset), in 2007 and 2010 and dissolved oxygen was far below the CCME Guideline for aquatic life of 9.5 mg/L in 2008 (3.7 mg/L) (Table 3-5).

Precipitation measurements of 0 mm were recorded on all of the dates where exceedances occurred at EMS sample locations. Parameter exceedances are shown in Table 3-5. Turbidity and TSS exceedance locations are mapped in Figure 3-3 and phosphorous, total coliforms, fecal coliforms and temperature exceedance locations are mapped in Figure 3-4.

The "Coldwater River at Merritt" station also records surface water temperature. In 2009 MOE reported that daytime summer temperatures in the lower Coldwater River as high as 24 ºC are exceeding lethal limits for salmon, trout and char which are well above optima for rearing juvenile fish. Temperature data for the Coldwater River at Merritt from April 2007 to April 2008 exceeded 24 ºC in August 2007 (MOE 2009). In 1997, a report prepared by Streamline Research for the Fraser Action Plan documented a period of sixteen days where lower Coldwater River temperatures exceeded 25 ºC, which is considered lethal for salmon and trout (MOE 2009).

Table 3-5
Coldwater River Water Quality Data Guideline Exceedances

		Precip:T	Amonia: D	Coli:T	Coli:Fec	Coli:T	Phos:T	TSS	Temp	Oxy:D	Turb.
Units		mm	mg/L	CFU/100mL	CFU/100mL	MPN	mg/L	mg/L	C^0	mg/L	NTU
[1] CCME Guidelines			[2] 1.04				[4] 0.01-0.02	[5] Δ 25	15	9.5	[5] Δ 8
[1] BC Ambient Water Quality Criteria				[3] 200	[3] 200	[3] 200					
EMS ID	START DATE										
600500	10/03/1986	0					**0.049**	**40**			
600502	08/08/1985	0				**280**					
600502	10/03/1986	0				**920**	**0.074**	**34**			
600502	08/09/1988	0	**3.09**		**3510**		**0.68**				
E279294	19/05/2010	0					**0.021**	**140**			
E248734	21/07/2002	0					**0.027**				
Coldwater D/S Outfall	2009 Mean			**346**							
Coldwater D/S Outfall	2007 Mean						**0.025**				36.8
Coldwater D/S Outfall	2010 Mean								**15.9**		30.6
Coldwater D/S Outfall	2008 Mean									3.7	

T:Total, D:Dissolved

[1]For the protection of aquatic life unless otherwise stated

[2] Assuming average pH of 8 and temperature of 10^{0}C

[3] Guideline for the Protection of Livestock

[4] Mesotrophic Conditions

[5] Change from background X

3.4 GROUNDWATER

3.4.1 Aquifer Description

The City of Merritt draws drinking water from the aquifer below the City. It is an unconfined aquifer extending between the Coldwater and Nicola Rivers with a rank of 'IA' (heavily developed and highly vulnerable to contamination) as classified by the BC MOE Water Stewardship Division (MOE 2012a). Pumping of the City wells may be contributing to the depletion of the nearby rivers because of the high degree of surface water and groundwater interaction (WMC 2008). Furthermore, because the down gradient flow of groundwater from the WWTP is directed towards the Nicola River, there is no groundwater extraction for potable use between the rapid infiltration basins and the Nicola River (G3 Consulting Ltd. 2011). A detailed description of groundwater resources in the study area is given in the Task 105 Technical Memo.

3.4.2 Wells

Groundwater quality data from 6,714 samples collected between 1986 and 2012 at eight existing and two discontinued water sampling locations within about 50 m of the Nicola River, Coldwater River and rapid infiltration basins were reviewed. The majority (98%) of the samples were collected at the City's drinking water wells. Existing locations include four sets of shallow and deep piezometers that are part of the City's environmental monitoring program (MW1. MW2, MW3 and MW4) and four of the City's drinking water wells including Voght Park 1 (WTN 024157), Voght Park 2 (WTN 034180), City Works Yard (WTN 023914) and the Collettville well (EMS E250649). Voght Park 1 and Voght Park 2 wells provide about 2/3 of the City's annual drinking water (WESTERN WATER 2012). Discontinued locations include the City's May Street Well (EMS E250651 and WTN 024105) and the Copeland Well (EMS 0600368). Table 3-6 describes the sample location, sampling duration, number of sampling events and sample data source. Sampling locations are shown in Figure 2-1.

Well depths of all the wells identified above are relatively shallow. MW1, WM2, WM3 and WM4 shallow wells are about 4.5 m deep and deep wells are about 9.1 m deep. The May Street Well, Voght Park 1 and Voght Park 2 are between 30 and 34 m deep. The City Works Yard well is 12 m deep and the Collettville well is the deepest at 45 m. All the wells are completed in Merritt's unconfined aquifer which is known to be recharged by the Nicola River at the north end of the study area and loose water to the Coldwater River and Nicola River at the south end of the study area (MOE 2009).

Voght Park 1, Voght Park 2, the Collettville well and the Fairly Park well (not included in this water quality review) are screened in the lowermost sediments of the Merritt Aquifer, within a deepened sand and gravel filled trough (BCG 2011). The groundwater that reports to this location is primarily recharged from the Nicola River, as evidenced by water chemistry comparison (BCG 2011). Losses observed from the Coldwater River recharge the upper surficial sediments (<15m) of the Merritt

Aquifer, but are not seen to contribute significantly to recharging the water of the trough in areas proximal to the production wells (BCG 2011). Evidence suggests that the Merritt Aquifer is recharged by the Nicola River from the north and the Coldwater River from the south and discharges towards the west, near the confluence of the two rivers.

Tables of annual ground water quality data for MW1, MW2, MW3 and MW4 extracted from the City's annual environmental monitoring report (G3 Consulting Ltd. 2011), are shown in Appendix B (Tables 4-3 to 4-11). EMS water quality results are tabulated in Appendix E. Water quality data for the May Street Well, the City Works Yard well, Collettville well, Voght Park 1 (Voght Park Electric Pumphouse Tap) and Voght Park 2 (Voght Park VFD Pumphouse Tap) is attached as Appendix F (WaterTrax 2012).

Table 3-6. Groundwater Quality Locations, Well Depth, Sample Duration and Data Sources

#	Well Name	Well ID	Location Description	Well Depth m	Sampling Duration	# Sampling Events	Data Source
1	MW1 (Shallow/Deep)	No WTN: Piezometers	Northwest of the rapid infiltration basins (down-gradient of WWTP)	Shallow: 4.5 Deep: 9.1	2007-2011	5	City of Merritt Annual Environmental Report (G3 2011)
		EMS E206590	Merritt Well Number 1 (not known if deep or shallow)		1986, 1991	2	EMS Web Reporting (MOE 2012c)
2	MW2 (Shallow/Deep)	No WTN - Piezometers	North of the rapid infiltration basins (down-gradient of WWTP)	Shallow: 4.5 Deep: 9.1	2007-2011	5	City of Merritt Annual Environmental Report (G3 2011)
		EMS E206591	Merritt Well Number 2 (not known if deep or shallow)		1986, 1991	3	EMS Web Reporting (MOE 2012c)
3	MW3 (Shallow/Deep)	No WTN: Piezometers	Property line west of rapid infiltration basins (down-gradient of WWTP)	Shallow: 4.5 Deep: 9.1	2007-2011	5	City of Merritt Annual Environmental Report (G3 2011)
4	MW4 (Shallow/Deep)	No WTN: Piezometers	Background monitoring well northeast of rapid infiltration basins (up-gradient of WWTP)	Shallow: 4.5 Deep: 9.1	2007-2011	5	City of Merritt Annual Environmental Report (G3 2011)
		EMS E206592	Merritt Well Number 4 (not known if deep or shallow)		1986	2	EMS Web Reporting (MOE 2012c)
5	May Street Well	WTN 024105	May Street Well about 50 m from the north bank of the Coldwater River	30	2005-2007	67	WaterTrax Database (WaterTrax 2012)
		EMS E250651	City of Merritt May Street Well		2003-2004	6	EMS Web Reporting (MOE 2012c)
6	Voght Park 1	WTN 024157	Voght Park Well 1 Pumphouse about 20 m from the north bank of Coldwater River, Electric Pumphouse Tap	30	2005-2012	3341	WaterTrax Database (WaterTrax 2012)
		EMS E250652	City of Merritt Voght Park Well 1		2008-2009	4	EMS Web Reporting (MOE 2012c)
7	Voght Park 2	WTN 034180	Voght Park Well 2 Pumphouse about 20 m from the north bank of Coldwater River, VFD Pumphouse Tap	34	2005-2012	1486	WaterTrax Database (WaterTrax 2012)
		EMS E250653	City of Merritt Voght Park Well 2		2003-2009	14	EMS Web Reporting (MOE 2012c)
8	City Works Yard	WTN 023914	City Works Yard Pumphouse about 50 m from the north bank of Coldwater River	12	2005-2012	256	WaterTrax Database (WaterTrax 2012)
9	Copeland Well	EMS 0600368	Merritt Copeland Well (background)	unknown	1985	2	EMS Web Reporting (MOE 2012c)
10	Collettville Well	No WTN; Piezometer	Collettville Well Pumphouse Tap	45	2005-2012	1502	WaterTrax Database (WaterTrax 2012)
		EMS E250649	City of Merritt Collettville Well		2003-2009	14	EMS Web Reporting (MOE 2012c)
						Total=6,714	

Significant Findings

Significant findings were considered those that exceeded water quality guidelines for the protection of drinking water. Groundwater sampling location parameters with exceedances included nitrate + nitrite, fecal coliforms, total coliforms, temperature, pH and turbidity.

Nitrate + Nitrite exceeded the Approved Water Quality Guidelines (MOE 2010) for the protection of drinking water of 10 mg/L at MW2 in April of 1986. It is unknown whether the sample was collected from the shallow or deep piezometer.

Total coliforms and fecal coliforms exceeded the Approved Water Quality Guidelines (MOE 2010) for the protection of drinking water of 1 CFU/100 mL (or MPN) on more than 20 sampling events. Twenty three fecal coliform exceedances and 21 total coliform exceedances occurred in the City's environmental monitoring wells MW1, MW2, MW3 and MW4. Two total coliform exceedances occurred in April 2008 and June 2011 at the City's water supply well, Voght Park 1. The highest total coliform count of 93 MPN/100 mL occurred in 2009 at the MW3 Shallow piezometer. Total coliform counts between 23 and 29 were recorded at MW2 Shallow in 2010, MW2 Deep in 2007 and MW3 Shallow in 2007 and 2008. The highest fecal coliform count of 6 MPN/100 mL also occurred at the MW3 Shallow piezometer in 2009. Fecal coliform counts between 3 and 5 also occurred at MW2 Shallow in 2009 and 2010 and MW3 Shallow in 2007 and 2008.

Temperature exceeded the Approved Water Quality Guidelines (MOE 2010) for the protection of drinking water of 15º C at the May Street Well (EMS E250851) in September 2003 (16.5 ºC), MW2 Deep in 2011 (16.2 º C), MW3 Shallow (19.1 ºC) and MW3 Deep (17.1ºC).

Turbidity exceeded the Approved Water Quality Guidelines (MOE 2010) for the protection of drinking water, defined as a change of 5 NTU from background (considered the lowest concentration in the dataset), in 2008 and 2010 at MW1 Shallow, 2007 and 2008 at MW1 Deep, in 2007, 2008 and 2010 at MW2 Deep, in 2008 and 2010 at MW3 Deep and in 2007, 2008 and 2011 in MW4 Deep.

Groundwater quality parameter exceedances are shown in Table 3-7. Turbidity and TSS exceedance locations are mapped in Figure 3-3 and phosphorous, total coliforms, fecal coliforms and temperature exceedance locations are mapped in Figure 3-4.

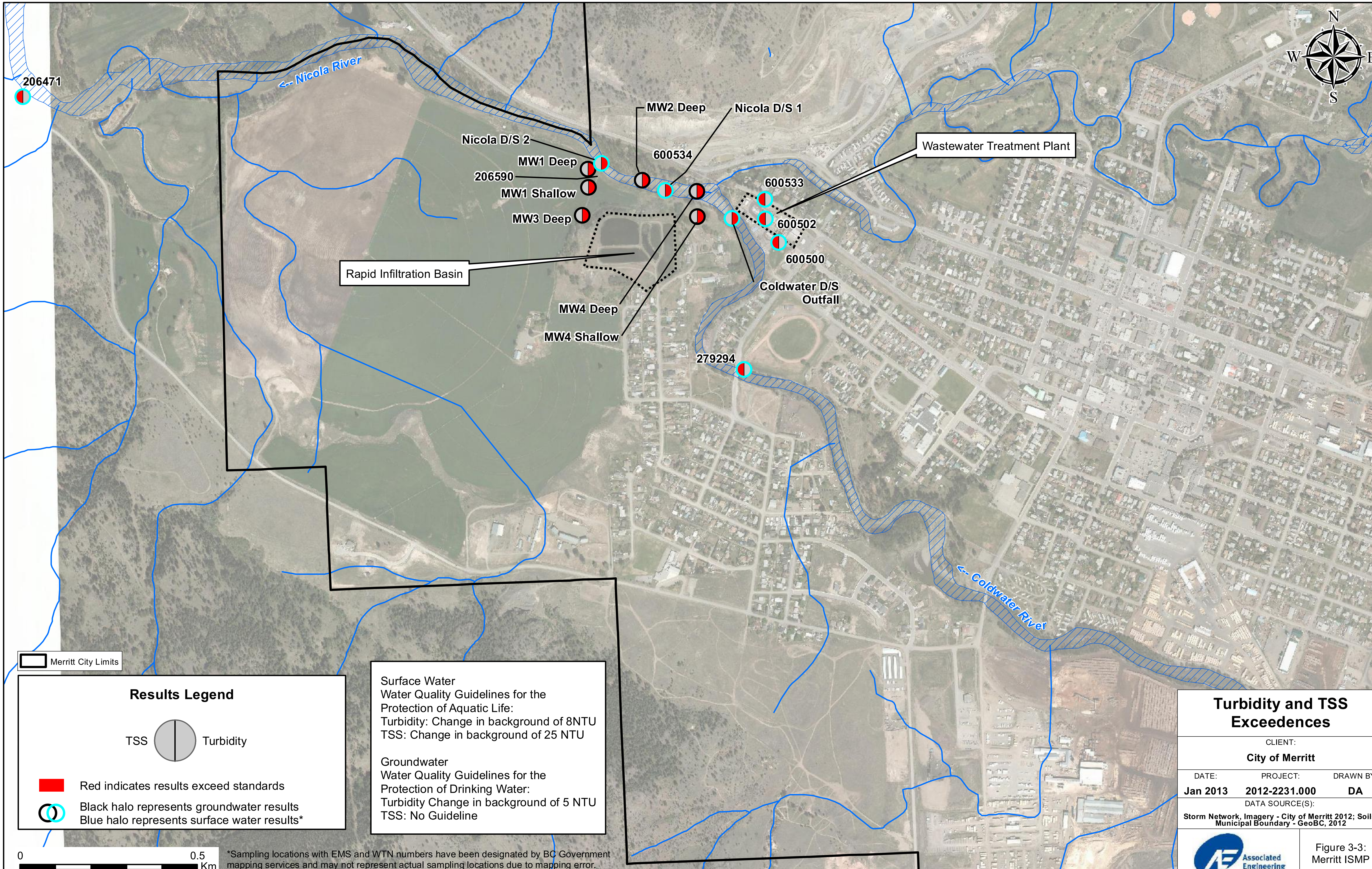
Table 3-7. Groundwater Exceedances

		Nitrate + Nitrite:D	pH	Temp	Coli:T	Coli:Fec	Turbidity
	Units	mg/L	pH units	Cº	MPN	MPN	NTU
[1]BC Ambient Water Quality Criteria		10	6.5-9	15	1	1	[2] Δ 5
LOCATION	START DATE						
EMS E206591	09/04/1986	**10.8**					
EMS E250651	25/09/2003			**16.5**			
EMS E250652	10/08/2009		**6.2**				
EMS E250649	10/08/2009		**6.3**				
EMS E250653	10/08/2009		**6.2**				
MW1 Shallow	2007 Mean				**2**	**2**	
MW1 Shallow	2008 Mean				**2**	**2**	
MW1 Shallow	2009 Mean				**2**	**2**	
MW1 Shallow	2008 Mean						**86.03**
MW1 Shallow	2010 Mean						**39.06**
MW1 Deep	2007 Mean				**2**	**2**	
MW1 Deep	2008 Mean				**4**	**2**	
MW1 Deep	2009 Mean				**2**	**2**	
MW1 Deep	2007 Mean						**239.04**
MW1 Deep	2008 Mean						**331.56**
MW2 Shallow	2007 Mean				**4**	**2**	
MW2 Shallow	2008 Mean				**4**	**2**	
MW2 Shallow	2009 Mean				**5**	**2**	
MW2 Shallow	2010 Mean				**23**	**4**	
MW2 Deep	2007 Mean				**29**	**5**	
MW2 Deep	2008 Mean				**2**	**2**	
MW2 Deep	2009 Mean				**2**	**2**	
MW2 Deep	2011 Mean			**16.2**			
MW2 Deep	2007 Mean						**330.47**
MW2 Deep	2008 Mean						**315.33**
MW2 Deep	2010 Mean						**215.73**
MW3 Shallow	2007 Mean				**25**	**5**	
MW3 Shallow	2008 Mean				**16**	**3**	
MW3 Shallow	2009 Mean				**93**	**6**	
MW3 Shallow	2008 Mean				**24**		
MW3 Shallow	2011 Mean			**19.1**			
MW3 Deep	2007 Mean				**2**	**2**	
MW3 Deep	2008 Mean				**3**	**2**	
MW3 Deep	2009 Mean				**2**	**2**	
MW3 Deep	2011 Mean			**17.1**			
MW3 Deep	2008 Mean						**29.51**
MW3 Deep	2010 Mean						**41.82**
MW4 Shallow	2007 Mean						**35.32**
MW4 Shallow	2008 Mean						**438.24**
MW4 Deep	2007 Mean						**435.22**
MW4 Deep	2008 Mean						**299.34**
MW4 Deep	2011 Mean						**151.3**
WTN 024157	04/22/2008				**1**		
WTN 024157	06/15/2011				**1**		

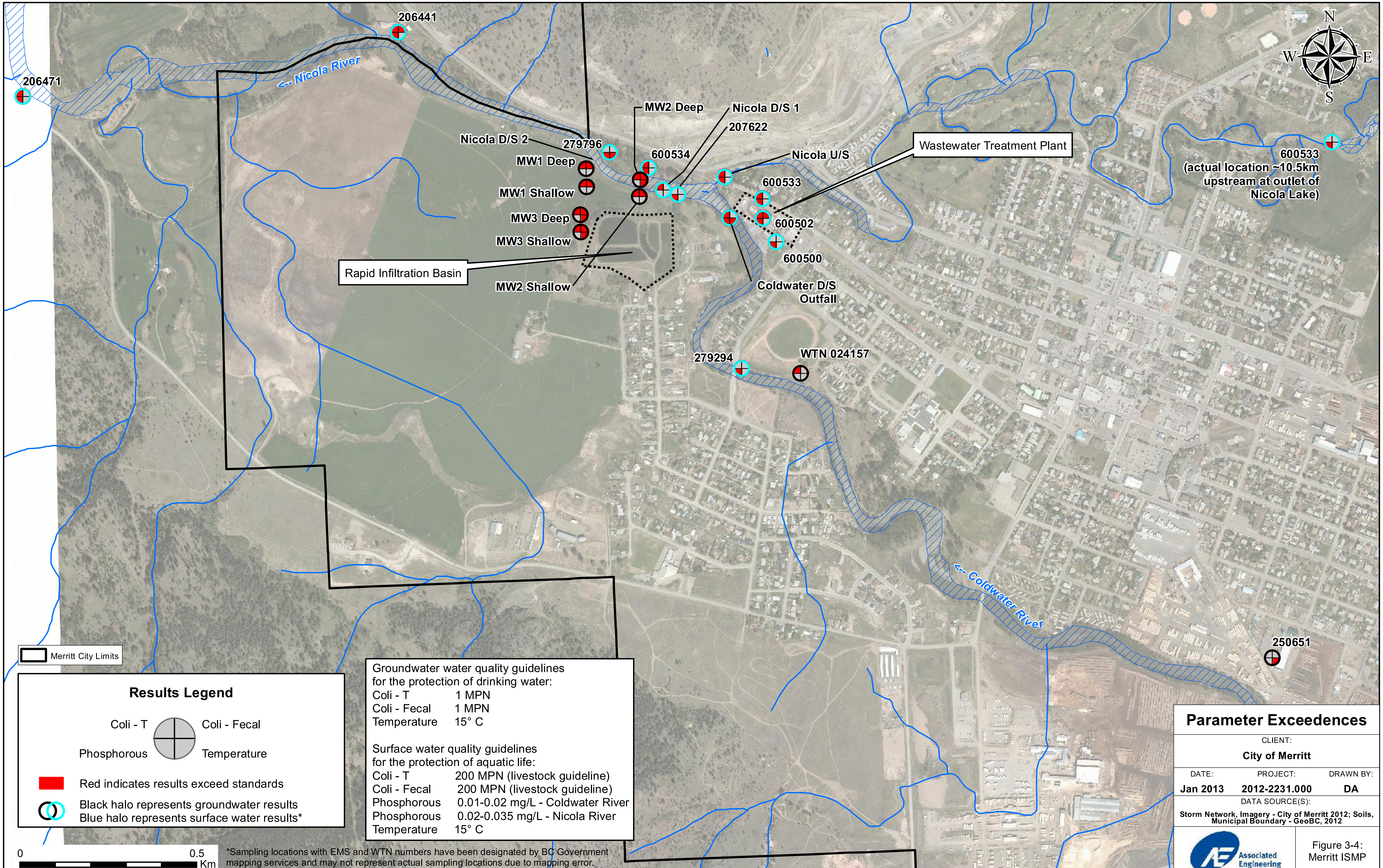
D:Dissolved, T:Total,

[1] For the protection of drinking water

[2] Δ 5 = Change from background by 5 NTU if background value is less than 5 NTU, OR 10% of background if background is greater than 5 NTU



206471
<-- Nicola River
MW2 Deep
Nicola D/S 1
Nicola D/S 2
600534
Wastewater Treatment Plant
MW1 Deep
206590
MW1 Shallow
600533
MW3 Deep
600502
600500
Rapid Infiltration Basin
Coldwater D/S Outfall
MW4 Deep
MW4 Shallow
279294
<-- Coldwater River
N
W
E
S
Merritt City Limits
Results Legend
TSS
Turbidity
Red indicates results exceed standards
Black halo represents groundwater results
Blue halo represents surface water results*
Surface Water
Water Quality Guidelines for the Protection of Aquatic Life:
Turbidity: Change in background of 8NTU
TSS: Change in background of 25 NTU
Groundwater
Water Quality Guidelines for the Protection of Drinking Water:
Turbidity Change in background of 5 NTU
TSS: No Guideline
0
0.5
Km
*Sampling locations with EMS and WTN numbers have been designated by BC Government mapping services and may not represent actual sampling locations due to mapping error.
Turbidity and TSS Exceedences
CLIENT:
City of Merritt
DATE:
Jan 2013
PROJECT:
2012-2231.000
DRAWN BY:
DA
DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012
Associated Engineering
Figure 3-3:
Merritt ISMP



206441
206471
<-- Nicola River
MW2 Deep
Nicola D/S 1
207622
Nicola D/S 2
279796
600534
MW1 Deep
MW1 Shallow
MW3 Deep
MW3 Shallow
Nicola U/S
Wastewater Treatment Plant
600533
600502
600500
600533
(actual location ~10.5km
upstream at outlet of
Nicola Lake)
Rapid Infiltration Basin
MW2 Shallow
Coldwater D/S
Outfall
279294
WTN 024157
<-- Coldwater River
250651
N
W
E
S
Merritt City Limits
Results Legend
Coli - T
Coli - Fecal
Phosphorous
Temperature
Red indicates results exceed standards
Black halo represents groundwater results
Blue halo represents surface water results*
Groundwater water quality guidelines
for the protection of drinking water:
Coli - T 1 MPN
Coli - Fecal 1 MPN
Temperature 15° C
Surface water quality guidelines
for the protection of aquatic life:
Coli - T 200 MPN (livestock guideline)
Coli - Fecal 200 MPN (livestock guideline)
Phosphorous 0.01-0.02 mg/L - Coldwater River
Phosphorous 0.02-0.035 mg/L - Nicola River
Temperature 15° C
0
0.5
Km
*Sampling locations with EMS and WTN numbers have been designated by BC Government
mapping services and may not represent actual sampling locations due to mapping error.
Parameter Exceedences
CLIENT:
City of Merritt
DATE:
Jan 2013
PROJECT:
2012-2231.000
DRAWN BY:
DA
DATA SOURCE(S):
Storm Network, Imagery - City of Merritt 2012; Soils, Municipal Boundary - GeoBC, 2012
Associated Engineering
Figure 3-4:
Merritt ISMP

4 Discussion and Conclusions

Nine stormwater outfalls and an extensive series of ditches and drywells were identified in Merritt's stormwater system. Three of the outfalls flow into the Coldwater River and six flow into then Nicola River. No water quality data were available for the stormwater outfalls or drywells.

Water quality results from 17 surface water locations (ten Nicola River and seven Coldwater River) and ten groundwater sampling locations within about 50 m of either river and the rapid infiltration basins were reviewed. Most surface and ground water quality sampling locations were concentrated around the western end of Merritt and have been historically sampled for the purpose of detecting contamination in surface and ground water caused by releases from the WWTP and rapid infiltration basins.

Water quality information was gleaned from the provincial EMS database (MOE 2012c), WaterTrax database (WaterTrax 2012) and the City's annual environmental reporting (G3 Consulting Ltd. 2011). Database information included 100 Nicola River samples events, 84 Coldwater River sampling events and 6,714 groundwater sampling events, 98% of which occurred at three groundwater drinking supply wells.

Exceedances of applicable water quality guidelines were tabulated and mapped. Significant surface water findings were considered those that exceeded water quality guidelines for the protection of aquatic life and those that exceeded water quality guidelines related to bacteriological parameters for the protection of livestock. Significant groundwater findings were considered those that exceeded water quality guidelines for the protection of drinking water. TSS and turbidity exceedances are mapped in Figure 3-3 and total and fecal coliforms, total phosphorous and temperature exceedances are mapped in Figure 3-4.

Sources of phosphorus contamination in surface water include agriculture, municipal sewage treatment plants, decaying plant material, runoff from urban areas and construction sites, stream bank erosion, and wildlife. Since phosphorus is generally the limiting nutrient for aquatic primary production, its input to fresh water systems can cause proliferations of algal growth. Inputs of phosphorus are the prime contributing factors to eutrophication in most fresh water systems (MOE 1998). Twelve surface water sites (four Coldwater River and eight Nicola River) exceeded the Approved Water Quality Guideline (MOE 2010) for phosphorous suggesting that conditions in both rivers occasionally become more eutrophic. Phosphorous guideline exceedances occurred during all seasons of the year. The highest Nicola River phosphorous concentration of 0.199 mg/L occurred at the City's environmental monitoring site upstream of the confluence with Coldwater River in 2008 and the highest Nicola River phosphorous concentration of 0.68 mg/L occurred at EMS site 0600502 in 1988.

Coliform bacteria are described and grouped, based on their common origin or characteristics, as either total or fecal coliform. The total group includes fecal coliform bacteria such as *Escherichia coli* (*E .coli*), as well as other types of coliform bacteria that are naturally found in the soil. Fecal Coliform bacteria exist in the intestines of warm blooded animals and humans, and are found in bodily waste, animal droppings, and naturally in soil (MOE 2007). Seven groundwater wells exceeded the total coliform drinking water guideline of 1 CFU or MPN/100 mL, including one of the City's drinking water wells (WTN 024517, Voght Park 2). Of these seven wells the Voght Park 2 well also exceeded the same guideline for fecal coliforms. Sources of total and fecal coliform in groundwater can include agricultural runoff, effluent from septic systems or sewage discharges and infiltration of domestic or wild animal fecal matter (MOE 2007). Poor well maintenance and construction (particularly shallow dug wells) can also increase the risk of bacteria and other harmful organisms getting into a well water supply (MOE 2007).

Temperature exceedances occur in surface water during warms temperatures and low flow conditions and may be occurring in the Merritt Aquifer because it is directly connected to Coldwater River (MOE 2009). Approved Water Quality Guideline (MOE 2010) temperature guideline of 15ºC for drinking water was exceeded in two wells downstream of the rapid infiltration basins (MWI deep and shallow), one well downstream of the Coldwater River confluence (MW2 Deep), one well on the north bank of the Coldwater River (E250651) Two surface water locations (Coldwater D/S outfall and E279796 located downstream of the Coldwater River confluence) exceeded the Approved Water Quality Guideline (MOE 2010) for the protection of aquatic life of 15ºC.. Temperature exceedances occurred during summer months or represented mean annual values. Since 2007 MOE has reported that summer temperatures in the lower Coldwater River exceed lethal limits (24 ºC) for salmon, trout and char and are well above optima for rearing juvenile fish (MOE 2007).

Turbidity is caused by suspended matter, such as silt, clay, fine organic and inorganic matter, and by microorganisms (NSE 2009). Turbidity may be present in surface water and may occur naturally in groundwater as a result of soluble minerals in the aquifer. It may also be caused by degraded water supply pipes, poor well construction and shock chlorination (NSE 2009). High levels of turbidity increase the total available surface area of solids in suspension upon which bacteria can grow. High turbidity reduces light penetration; therefore, it impairs photosynthesis of submerged vegetation and algae. In turn, the reduced plant growth may suppress fish productivity (MOE 1998). Turbidity also interferes with the disinfection of drinking water and is aesthetically unpleasant. Turbidity exceeded the water quality guideline for the protection of drinking water (change in background of 5 NTU) in six of the City's environmental monitoring wells (MWI Deep and MWI Shallow, MW2 Deep, MW3 Deep, MW4 Deep and MW4 Shallow) and exceeded the water quality guideline for the protection of aquatic life (change in background of 8 NTU) in three surface water sites (Nicola D/S 1 located 75 m downstream of the Coldwater confluence, and Nicola D/S 2 located 300 m downstream of the Coldwater River confluence, and Coldwater D/S Outfall located 20 m upstream of the Coldwater River confluence).

High concentrations of TSS increase turbidity, which restricts light penetration and hinders photosynthetic activity (MOE 1998). Suspended material can result in damage to fish gills and settling suspended solids can cause impairment to spawning habitat by smothering fish eggs (MOE 1998). Suspended solids can also interfere with water treatment processes (MOE 1998). TSS results were not available for the groundwater wells investigated in this report but were available for most of the surface water locations. Three Coldwater River locations (E279294 located on the Coldwater River 10 m upstream of the Collette bridge near Voght Park, E600502 located 15 m downstream of the WWTP outfall and E600500 located upstream of the WWTP) and two Nicola River locations (E600533 located about 15 m upstream of the

Coldwater River confluence and E206471 located on the Nicola River about 1.5 km downstream of the Coldwater River confluence at Lindley Creek Road).

5 Recommendations

To better understand the influence that stormwater has on the Nicola River, Coldwater River and groundwater resources within the study area, increased water sampling is required. Sample locations should include stormwater outfalls, drywells that drain the largest water mains, river sites immediately upstream and downstream of the nine outfalls and river sites (Nicola River and Coldwater River) immediately upstream of the study area and immediately downstream (Nicola River).

Samples from the above locations should be collected after the start of a significant rain event and preferably after a first flush event for at least one year. A first flush event is defined as a significant rain event occurring after two to three weeks of drought. A significant rain event in Merritt is considered about 5 mm of precipitation (EC 2012). Outfall flow rates and water sample temperature should also be measured in the field during these sampling events. Samples should be sent to the lab within 24 hours of collection. An optimal water quality analysis should include samples collected from various locations and analyzed for the parameters shown in Table 3-8.

Table 5-1
Suggested Sampling Parameters and Locations

Parameter	**Sample Locations**
General Chemistry	wells, rivers, outfalls, drywells
Dissolved Metals	wells, rivers, outfalls, drywells
Chloride	wells, rivers, outfalls, drywells
Nitrates	wells, rivers, outfalls, drywells
Phosphates	wells, rivers, outfalls, drywells
Fecal Coliforms and *E.coli*	wells, rivers, outfalls, drywells
Dissolved Oxygen	rivers
Hydrocarbons: Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH), Polycyclic Aromatic Hydrocarbons (PAH), and Volatile Hydrocarbons (including Benzene, Toluene, Ethylbenzene and Xylene [BTEX])	wells, outfalls, drywells
Glycols	wells, drywells, outfalls
Perchloroethylene (PERC)	wells, drywells, outfalls
Fertilizers	wells, drywells, outfalls
Pesticides	wells, drywells, outfalls
Wood Preservatives (pentachlorophenol)	wells, drywells, outfalls

In order to detect stormwater influence on drinking water quality, analysis of the parameters listed above should also be completed annually at each drinking water supply well.

The above list of parameters would results in an expensive water quality analysis but could indicate the presence of contaminants from surrounding land uses (i.e. wood preservatives from the mill and fertilizers from agricultural land). Depending on the priorities set by the City, a modified list of parameters could be justified.

Results of analyses from river locations upstream and downstream of outfalls would help to provide an understanding of how each outfall affects surface water quality. Results of analyses from Nicola River and Coldwater River locations upstream of the study area compared to a location on the Nicola River downstream of the study area would provide an overall indication of the effects of Merritt's stormwater runoff on surface water.

If results of stormwater sampling show that stormwater discharge is negatively affecting surface and/or groundwater water sources, residential and urban best management practices that reduce stormwater flow should be implemented.

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A Appendix A - Photographs

Photograph 1. Coldwater River Outfall 1 (CW 1)

Photograph 2. Coldwater River Outfall 1 (CW 1)

Photograph 3. Coldwater River Outfall 1 (CW 1)

Photograph 4. Coldwater River Outfall 2 (CW 2)

Photograph 5. Coldwater River Outfall 2 (CW 2)

Photograph 6. Coldwater River Outfall 2 (CW 2)

Photograph 7. Coldwater River Outfall 3 (CW 3)

Photograph 8. Coldwater River Outfall 3 (CW 3)

Photograph 9. Coldwater River Outfall 3 (CW 3)

Photograph 10. Nicola River Outfall 1 (N1)

Photograph 11. Nicola River Outfall 1 (N1)

Photograph 12. Nicola River Outfall 1 (N1)

Photograph 13. Nicola River Outfall 2 (N2)

Photograph 14. Nicola River Outfall 2 (N2)

Photograph 15. Nicola River Outfall 2 (N2)

Photograph 16. Nicola River Outfall 3 (N3)

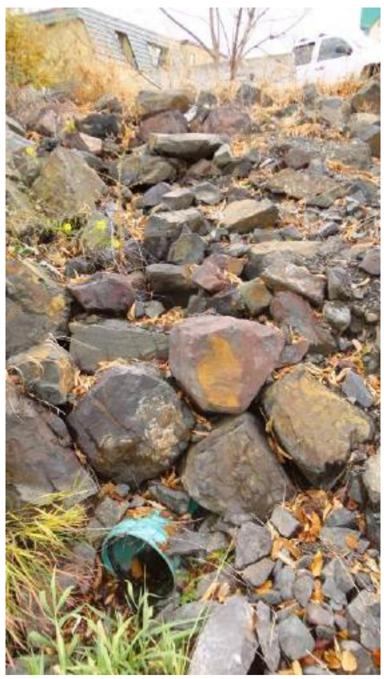
Photograph 17. Nicola River Outfall 3 (N3)

Photograph 18. Nicola River Outfall 3 (N3)

Photograph 19. Nicola River Outfall 4 (N4)

Photograph 20. Nicola River Outfall 4 (N4)

Photograph 21. Nicola River Outfall 4 (N4)



Photograph 22. Nicola River Outfall 5 (N5)

Photograph 23. Nicola River Outfall 5 (N5)

Photograph 24. Nicola River Outfall 5 (N5)

Photograph 25. Nicola River Outfall 1 (N6)

Photograph 26. Nicola River Outfall 6 (N6)

Photograph 27. Nicola River Outfall 6 (N6)

B Appendix B - City of Merritt WWTP Environmental Monitoring Progress Results

Table 4-3: Mean Monitoring Well 4 (Shallow) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	<0.010	0.0037 ± 0.0014	0.0031 ± 0.0020	0.0037 ± 0.0004	0.0037 ± 0.0008
TP (mg/L)	N/A	N/A	N/A	0.0352 ± 0.0309	0.0083 ± 0.0060
TN (mg/L)	0.45 ± 0.21	0.34 ± 0.35	0.139 ± 0.023	1.842 ± 1.211	0.245 ± 0.217
ON (mg/L)	0.20 ± 0.19	0.050 ± 0.009	0.085 ± 0.073	0.122 ± 0.134	0.073 ± 0.034
Total Ammonia (mg/L)	0.02 ± 0.01	0.010 ± 0.007	0.020 ± 0.001	0.016 ± 0.008	0.021 ± 0.002
Nitrate (mg/L)	0.23 ± 0.26	0.213 ± 0.217	0.0458 ± 0.0295	1.2680 ± 0.4498	0.1784 ± 0.2010
Nitrite (mg/L)	0.01 ± 0.00	0.002 ± 0.003	0.0010 ± 0.0000	0.195 ± 0.164	0.0014 ± 0.0005
Total Coliforms (MPN/100mL)	<1.4[2]	<2	<2	<2	<2
Fecal Coliforms (MPN/100mL)	<1.7[2]	<2	<2	<2	<2
Chloride (mg/L)	22.2 ± 8.4	18.2 ± 8.4	10.03 ± 3.43	22.98 ± 6.28	13.90 ± 3.91
Total Alkalinity (mg/L)	N/A	88.6 ± 30.9	65.0 ± 8.0	N/A	N/A
Sulphate (mg/L)	N/A	21.3 ± 17.2	8.7 ± 2.9	N/A	N/A
pH	4.09 ± 0.44[1]	7.28 ± 0.18	7.41 ± 0.33	7.17 ± 0.48	7.32 ± 0.24
Temperature (°C)	15.0 ± 2.5	8.8 ± 4.7	9.2 ± 5.8	9.8 ± 2.3	8.4 ± 5.5
DO (mg/L)	3.83 ± 0.24	6.2 ± 2.8	7.98 ± 2.59	6.02 ± 1.08	5.49 ± 2.81
Conductivity (mS/cm)	0.353 ± 0.066	0.292 ± 0.078	0.188 ± 0.048	0.297 ± 0.063	0.208 ± 0.065
Turbidity (NTU)	1.40 ± 0.86	4.10 ± 4.87	N/A	438.24 ± 811.06	35.32 ± 53.85

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-4: Mean Monitoring Well 4 (Deep) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0327 ± 0.0136	0.0378 ± 0.0166	0.0712 ± 0.0230	0.0988 ± 0.0308
TP (mg/L)	N/A	N/A	N/A	0.3790 ± 0.2007	0.6237 ± 0.3848
TN (mg/L)	0.59 ± 0.30	0.49 ± 0.27	0.369 ± 0.051	1.445 ± 0.249	0.363 ± 0.126
ON (mg/L)	0.25 ± 0.14	0.213 ± 0.138	0.102 ± 0.050	0.242 ± 0.277	0.161 ± 0.171
Total Ammonia (mg/L)	0.11 ± 0.04	0.128 ± 0.050	0.132 ± 0.086	0.016 ± 0.008	0.171 ± 0.098
Nitrate (mg/L)	0.21 ± 0.18	0.173 ± 0.170	0.2153 ± 0.2313	1.1538 ± 0.4169	0.0099 ± 0.0055
Nitrite (mg/L)	0.03 ± 0.04	0.001 ± 0.000	0.0045 ± 0.0033	0.102 ± 0.020	0.0022 ± 0.0021
Total Coliforms (MPN/100mL)	<2.1[2]	<3	<2	<3	<2
Fecal Coliforms (MPN/100mL)	<2.1[2]	<2	<2	<3	<2
Chloride (mg/L)	22.0 ± 2.9	17.7 ± 1.9	16.35 ± 0.90	19.85 ± 6.38	13.03 ± 3.30
Total Alkalinity (mg/L)	N/A	155.8 ± 14.2	159.5 ± 15.9	N/A	N/A
Sulphate (mg/L)	N/A	25.4 ± 3.2	21.1 ± 2.5	N/A	N/A
pH	4.05 ± 0.27[1]	7.78 ± 0.25	7.49 ± 0.29	7.30 ± 0.50	7.50 ± 0.19
Temperature (°C)	12.2 ± 0.9	8.4 ± 2.8	9.5 ± 3.9	9.8 ± 2.3	10.4 ± 2.8
DO (mg/L)	4.57 ± 1.75	5.5 ± 2.3	5.74 ± 1.50	5.16 ± 1.58	3.09 ± 1.41
Conductivity (mS/cm)	0.393 ± 0.004	0.373 ± 0.019	0.385 ± 0.054	0.266 ± 0.033	0.373 ± 0.043
Turbidity (NTU)	151.30 ± 196.15	94.87 ± 240.54	N/A	299.34 ± 333.16	435.22 ± 372.99

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-5: Mean Monitoring Well 5 (Shallow) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0104 ± 0.0008	0.0102 ± 0.0025	0.0081 ± 0.0038	0.0102 ± 0.0004
TP (mg/L)	N/A	N/A	N/A	0.2218 ± 0.1622	0.0554 ± 0.0120
TN (mg/L)	1.61 ± 1.27	1.68 ± 1.34	2.030 ± 1.125	0.164 ± 0.165	1.957 ± 1.282
ON (mg/L)	0.12 ± 0.01	0.051 ± 0.008	0.342 ± 0.288	0.178 ± 0.160	0.129 ± 0.059
Total Ammonia (mg/L)	0.05 ± 0.03	0.010 ± 0.007	0.024 ± 0.009	0.017 ± 0.008	0.020 ± 0.000
Nitrate (mg/L)	1.44 ± 1.24	1.511 ± 1.148	2.1932 ± 1.2455	0.0361 ± 0.0348	1.8300 ± 1.2429
Nitrite (mg/L)	0.01 ± 0.00	0.001 ± 0.000	0.0010 ± 0.0001	0.139 ± 0.136	0.0010 ± 0.0001
Total Coliforms (MPN/100mL)	<1.9[2]	<2	7	3	14
Fecal Coliforms (MPN/100mL)	<1.1[2]	<2	2	3	3
Chloride (mg/L)	26.0 ± 16.6	19.5 ± 8.6	25.63 ± 8.26	9.04 ± 3.60	22.40 ± 11.27
Total Alkalinity (mg/L)	N/A	76.9 ± 4.6	85.1 ± 3.7	N/A	N/A
Sulphate (mg/L)	N/A	17.1 ± 4.5	22.1 ± 5.6	N/A	N/A
pH	4.05 ± 0.21[1]	6.85 ± 0.18	7.25 ± 0.65	7.48 ± 0.18	7.12 ± 0.40
Temperature (°C)	13.2 ± 0.0	9.5 ± 1.5	10.2 ± 2.3	8.8 ± 6.1	9.6 ± 1.6
DO (mg/L)	5.90 ± 1.56	5.9 ± 1.3	5.44 ± 2.00	7.67 ± 2.57	4.55 ± 2.11
Conductivity (mS/cm)	0.264 ± 0.056	0.264 ± 0.051	0.331 ± 0.060	0.193 ± 0.057	0.266 ± 0.064
Turbidity (NTU)	56.98 ± 76.40	46.57 ± 34.60	N/A	43.88 ± 63.86	194.59 ± 342.56

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-6: Mean Monitoring Well 5 (Deep) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0040 ± 0.0010	0.0023 ± 0.0016	0.0031 ± 0.0009	0.0027 ± 0.0001
TP (mg/L)	N/A	N/A	N/A	0.1618 ± 0.1413	0.0565 ± 0.0274
TN (mg/L)	1.64 ± 0.88	2.31 ± 1.90	2.673 ± 1.368	0.529 ± 0.273	1.488 ± 0.614
ON (mg/L)	0.13 ± 0.04	0.070 ± 0.021	0.273 ± 0.201	0.086 ± 0.021	0.090 ± 0.047
Total Ammonia (mg/L)	0.04 ± 0.02	0.010 ± 0.007	0.021 ± 0.001	0.162 ± 0.105	0.020 ± 0.000
Nitrate (mg/L)	1.47 ± 0.84	1.961 ± 1.331	2.5045 ± 1.0307	0.0878 ± 0.1150	1.3990 ± 0.5880
Nitrite (mg/L)	<0.01	0.004 ± 0.007	0.0010 ± 0.0000	0.405 ± 0.352	0.0011 ± 0.0001
Total Coliforms (MPN/100mL)	<1.0[2]	<2	3	2	5
Fecal Coliforms (MPN/100mL)	<1.2[2]	<2	2	2	2
Chloride (mg/L)	24.5 ± 7.0	25.5 ± 13.4	31.60 ± 14.28	13.30 ± 1.13	20.83 ± 8.47
Total Alkalinity (mg/L)	N/A	73.5 ± 4.4	80.1 ± 3.0	N/A	N/A
Sulphate (mg/L)	N/A	18.0 ± 5.2	22.4 ± 7.6	N/A	N/A
pH	4.00 ± 0.20[1]	6.93 ± 0.12	7.35 ± 0.47	7.43 ± 0.15	7.19 ± 0.35
Temperature (°C)	11.2 ± 0.2	8.9 ± 1.9	10.5 ± 2.0	9.4 ± 3.9	10.5 ± 2.2
DO (mg/L)	5.07 ± 1.75	4.9 ± 1.1	4.70 ± 1.99	4.26 ± 1.75	3.95 ± 1.91
Conductivity (mS/cm)	0.286 ± 0.062	0.275 ± 0.044	0.320 ± 0.057	0.373 ± 0.018	0.262 ± 0.047
Turbidity (NTU)	39.75 ± 15.49	50.79 ± 31.40	N/A	433.20 ± 546.49	208.74 ± 372.51

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-7: Mean Monitoring Well 3 (Shallow) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	0.106 ± 0.038	0.1325 ± 0.0051	0.1197 ± 0.0327	0.1415 ± 0.0318	0.1266 ± 0.0308
TP (mg/L)	N/A	N/A	N/A	0.1680 ± 0.0394	0.1312 ± 0.0284
TN (mg/L)	4.15 ± 5.05	4.58 ± 2.24	7.965 ± 5.263	7.903 ± 4.943	3.516 ± 5.043
ON (mg/L)	0.28 ± 0.17	0.312 ± 0.022	0.596 ± 0.338	0.481 ± 0.073	0.357 ± 0.086
Total Ammonia (mg/L)	0.02 ± 0.01	0.014 ± 0.007	0.278 ± 0.232	0.957 ± 0.940	0.097 ± 0.105
Nitrate (mg/L)	3.79 ± 5.22	5.121 ± 3.398	6.1257 ± 5.0288	6.3298 ± 5.3283	3.0931 ± 5.0492
Nitrite (mg/L)	0.07 ± 0.04	0.048 ± 0.060	0.0242 ± 0.0252	1.438 ± 0.970	0.0070 ± 0.0120
Total Coliforms (MPN/100mL)	<3.2[2]	24	93	16	25
Fecal Coliforms (MPN/100mL)	<1.3[2]	<3	6	3	5
Chloride (mg/L)	77.2 ± 18.6	81.0 ± 8.9	78.73 ± 7.91	79.40 ± 7.03	78.90 ± 4.03
Total Alkalinity (mg/L)	N/A	104.2 ± 9.0	89.4 ± 7.9	N/A	N/A
Sulphate (mg/L)	N/A	44.5 ± 2.8	47.4 ± 2.4	N/A	N/A
pH	4.02 ± 0.29[1]	7.34 ± 0.91	6.76 ± 0.28	6.81 ± 0.27	6.97 ± 0.19
Temperature (°C)	19.1 ± 2.3	12.8 ± 6.1	11.2 ± 6.0	11.1 ± 5.2	11.4 ± 5.0
DO (mg/L)	2.26 ± 0.00	3.6 ± 1.1	3.67 ± 1.96	3.08 ± 0.99	1.64 ± 0.68
Conductivity (mS/cm)	0.497 ± 0.012	0.569 ± 0.053	0.600 ± 0.061	0.652 ± 0.072	0.603 ± 0.036
Turbidity (NTU)	2.90 ± 1.58	12.45 ± 18.88	N/A	13.04 ± 17.69	2.63 ± 3.36

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-8: Mean Monitoring Well 3 (Deep) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0028 ± 0.0013	0.0029 ± 0.0017	0.0029 ± 0.0017	0.0021 ± 0.0003
TP (mg/L)	N/A	N/A	N/A	0.0261 ± 0.0179	0.0065 ± 0.0021
TN (mg/L)	1.91 ± 0.58	1.99 ± 0.68	2.668 ± 1.002	2.207 ± 0.946	1.697 ± 0.312
ON (mg/L)	0.15 ± 0.01	0.071 ± 0.005	0.220 ± 0.184	0.079 ± 0.033	0.079 ± 0.035
Total Ammonia (mg/L)	0.07 ± 0.03	0.039 ± 0.008	0.051 ± 0.036	0.049 ± 0.021	0.028 ± 0.007
Nitrate (mg/L)	1.70 ± 0.56	1.786 ± 0.356	2.8392 ± 1.9074	1.7588 ± 0.8036	1.6033 ± 0.3156
Nitrite (mg/L)	0.01 ± 0.00	0.006 ± 0.008	0.0071 ± 0.0069	0.129 ± 0.054	0.0025 ± 0.0013
Total Coliforms (MPN/100mL)	<1.0[2]	<3	2	3	2
Fecal Coliforms (MPN/100mL)	<1.1[2]	<2	2	2	2
Chloride (mg/L)	45.1 ± 4.2	37.0 ± 6.9	38.53 ± 9.42	29.03 ± 3.43	25.07 ± 7.42
Total Alkalinity (mg/L)	N/A	164.0 ± 1.4	160.3 ± 9.4	N/A	N/A
Sulphate (mg/L)	N/A	35.5 ± 4.9	33.2 ± 5.6	N/A	N/A
pH	4.13 ± 0.14[1]	7.68 ± 0.11	7.35 ± 0.24	7.25 ± 0.45	7.42 ± 0.20
Temperature (°C)	17.1 ± 0.4	12.4 ± 3.4	10.9 ± 4.2	11.3 ± 3.6	11.5 ± 2.0
DO (mg/L)	3.75 ± 0.00	3.9 ± 1.0	4.60 ± 0.95	3.47 ± 1.40	2.13 ± 0.49
Conductivity (mS/cm)	0.533 ± 0.004	0.491 ± 0.036	0.509 ± 0.049	0.491 ± 0.071	0.472 ± 0.029
Turbidity (NTU)	4.10 ± 1.22	41.82 ± 60.83	N/A	29.51 ± 36.76	7.70 ± 5.52

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-9: Mean Monitoring Well 2 (Shallow) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	0.096 ± 0.064	0.1538 ± 0.0247	0.1350 ± 0.0087	0.1603 ± 0.0138	0.1567 ± 0.0176
TP (mg/L)	N/A	N/A	N/A	0.5677 ± 0.9045	0.1660 ± 0.0087
TN (mg/L)	2.00 ± 2.77	2.37 ± 1.29	6.588 ± 4.491	3.495 ± 2.731	3.543 ± 4.777
ON (mg/L)	0.26 ± 0.10	0.208 ± 0.042	0.430 ± 0.282	0.354 ± 0.154	0.217 ± 0.052
Total Ammonia (mg/L)	0.03 ± 0.01	0.090 ± 0.050	0.197 ± 0.162	0.166 ± 0.159	0.036 ± 0.010
Nitrate (mg/L)	1.73 ± 2.86	3.434 ± 2.642	4.6768 ± 3.3430	2.9145 ± 2.9454	3.2620 ± 4.7594
Nitrite (mg/L)	0.01 ± 0.00	0.004 ± 0.009	0.0074 ± 0.0081	0.520 ± 0.167	0.0075 ± 0.0113
Total Coliforms (MPN/100mL)	<1.4[2]	23	5	4	4
Fecal Coliforms (MPN/100mL)	<1.1[2]	4	2	2	2
Chloride (mg/L)	75.5 ± 12.8	80.0 ± 9.6	83.95 ± 10.54	80.25 ± 6.23	79.90 ± 5.48
Total Alkalinity (mg/L)	N/A	114.7 ± 11.3	105.8 ± 20.4	N/A	N/A
Sulphate (mg/L)	N/A	43.8 ± 4.1	47.9 ± 4.9	N/A	N/A
pH	4.06 ± 0.22[1]	6.93 ± 0.10	6.65 ± 0.22	6.62 ± 0.16	6.92 ± 0.18
Temperature (°C)	14.3 ± 0.4	12.5 ± 4.8	11.3 ± 4.2	11.4 ± 4.2	11.6 ± 3.3
DO (mg/L)	2.53 ± 0.00	2.9 ± 0.9	4.32 ± 1.87	3.32 ± 1.53	2.21 ± 0.81
Conductivity (mS/cm)	0.522 ± 0.017	0.579 ± 0.029	0.613 ± 0.052	0.661 ± 0.034	0.603 ± 0.027
Turbidity (NTU)	17.12 ± 18.22	7.96 ± 8.32	N/A	9.03 ± 20.85	5.09 ± 7.36

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-10: Mean Monitoring Well 2 (Deep) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0020 ± 0.0008	0.0013 ± 0.0005	0.0025 ± 0.0019	0.0014 ± 0.0004
TP (mg/L)	N/A	N/A	N/A	0.7462 ± 0.8867	0.5800 ± 0.6929
TN (mg/L)	3.30 ± 0.69	3.74 ± 2.07	5.398 ± 0.678	5.513 ± 1.248	6.053 ± 1.722
ON (mg/L)	0.62 ± 0.17	0.410 ± 0.137	0.435 ± 0.114	0.603 ± 0.585	0.793 ± 1.126
Total Ammonia (mg/L)	0.53 ± 0.10	1.101 ± 0.839	1.500 ± 0.221	2.180 ± 0.393	1.683 ± 1.367
Nitrate (mg/L)	2.14 ± 0.54	2.450 ± 0.953	3.4317 ± 0.8986	2.5500 ± 1.4090	3.3433 ± 1.6318
Nitrite (mg/L)	0.02 ± 0.02	0.022 ± 0.031	0.0573 ± 0.0495	2.783 ± 0.335	0.0484 ± 0.0316
Total Coliforms (MPN/100mL)	<1.4[2]	<2	2	2	29
Fecal Coliforms (MPN/100mL)	<1.4[2]	<2	2	2	5
Chloride (mg/L)	80.9 ± 3.6	76.8 ± 3.4	84.48 ± 6.32	79.70 ± 5.44	74.50 ± 5.22
Total Alkalinity (mg/L)	N/A	120.8 ± 1.3	119.8 ± 7.5	N/A	N/A
Sulphate (mg/L)	N/A	44.9 ± 3.2	46.4 ± 2.5	N/A	N/A
pH	4.07 ± 0.22[1]	7.02 ± 0.18	6.82 ± 0.16	6.70 ± 0.14	7.05 ± 0.23
Temperature (°C)	16.2 ± 1.4	12.6 ± 3.1	11.5 ± 3.6	11.0 ± 3.3	11.9 ± 1.9
DO (mg/L)	2.73 ± 0.00	4.5 ± 1.1	4.31 ± 1.47	2.76 ± 1.04	2.18 ± 0.53
Conductivity (mS/cm)	0.563 ± 0.011	0.571 ± 0.019	0.636 ± 0.033	0.650 ± 0.031	0.594 ± 0.017
Turbidity (NTU)	104.30 ± 104.23	215.73 ± 286.40	N/A	315.33 ± 537.82	330.47 ± 187.26

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-11: Mean Monitoring Well 1 (Shallow) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0035 ± 0.0005	0.0027 ± 0.0009	0.0025 ± 0.0011	0.0033 ± 0.0003
TP (mg/L)	N/A	N/A	N/A	0.0567 ± 0.0230	0.0137 ± 0.0038
TN (mg/L)	2.47± 1.29	4.03 ± 1.84	5.423 ± 3.204	2.980 ± 1.891	4.830 ± 2.616
ON (mg/L)	0.27 ± 0.12	0.183 ± 0.052	0.417 ± 0.405	0.287 ± 0.102	0.171 ± 0.066
Total Ammonia (mg/L)	0.37 ± 0.12	0.438 ± 0.097	0.372 ± 0.052	0.895 ± 0.750	0.402 ± 0.108
Nitrate (mg/L)	1.82 ± 1.32	3.154 ± 2.048	4.6208 ± 2.7137	2.2960 ± 1.6846	4.2367 ± 2.6801
Nitrite (mg/L)	<0.01	0.001 ± 0.001	0.0118 ± 0.0120	1.181 ± 0.817	0.0038 ± 0.0023
Total Coliforms (MPN/100mL)	<1.0[2]	<2	2	2	2
Fecal Coliforms (MPN/100mL)	<1.3[2]	<2	2	2	2
Chloride (mg/L)	75.7 ± 8.0	66.1 ± 17.1	76.70 ± 21.74	69.38 ± 16.13	68.23 ± 5.60
Total Alkalinity (mg/L)	N/A	111.6 ± 9.3	114.3 ± 15.1	N/A	N/A
Sulphate (mg/L)	N/A	42.1 ± 8.3	45.4 ± 6.2	N/A	N/A
pH	3.99 ± 0.16[1]	7.04 ± 0.21	6.76 ± 0.23	6.73 ± 0.18	6.92 ± 0.19
Temperature (°C)	13.3 ± 1.1	10.7 ± 2.6	10.7 ± 3.1	10.4 ± 2.9	11.3 ± 2.0
DO (mg/L)	2.97 ± 1.13	3.8 ± 0.9	3.83 ± 1.55	2.76 ± 1.50	1.89 ± 0.94
Conductivity (mS/cm)	0.511 ± 0.025	0.529 ± 0.068	0.609 ± 0.067	0.622 ± 0.046	0.568 ± 0.036
Turbidity (NTU)	17.30 ± 1.56	39.06 ± 17.23	N/A	86.03 ± 136.40	19.54 ± 16.37

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-12: Mean Monitoring Well 1 (Deep) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	< 0.010	0.0024 ± 0.0005	0.0020 ± 0.0007	0.0024 ± 0.0008	0.0025 ± 0.0001
TP (mg/L)	N/A	N/A	N/A	0.2660 ± 0.1868	0.2320 ± 0.0472
TN (mg/L)	2.66 ± 0.12	2.90 ± 0.51	3.183 ± 0.394	3.770 ± 1.311	4.727 ± 1.368
ON (mg/L)	0.41 ± 0.20	0.158 ± 0.086	0.063 ± 0.269	0.045 ± 0.091	0.047 ± 0.127
Total Ammonia (mg/L)	0.83 ± 0.17	1.158 ± 0.138	1.368 ± 0.094	1.393 ± 0.500	1.957 ± 0.180
Nitrate (mg/L)	1.41 ± 0.12	1.680 ± 0.436	1.9651 ± 0.5101	2.1673 ± 1.9155	2.7233 ± 1.2007
Nitrite (mg/L)	0.01 ± 0.00	0.012 ± 0.011	0.0338 ± 0.0371	1.438 ± 0.557	0.0212 ± 0.0298
Total Coliforms (MPN/100mL)	<3.3[2]	<2	2	4	2
Fecal Coliforms (MPN/100mL)	<2.1[2]	<2	2	2	2
Chloride (mg/L)	57.1 ± 2.0	47.6 ± 6.0	54.53 ± 3.40	51.68 ± 15.47	48.07 ± 14.17
Total Alkalinity (mg/L)	N/A	117.8 ± 8.0	124.8 ± 4.2	N/A	N/A
Sulphate (mg/L)	N/A	33.8 ± 3.6	36.2 ± 0.9	N/A	N/A
pH	4.10 ± 0.23[1]	7.20 ± 0.21	7.01 ± 0.22	6.74 ± 0.14	7.07 ± 0.20
Temperature (°C)	14.1 ± 1.3	11.0 ± 1.6	10.9 ± 3.0	10.4 ± 2.1	11.8 ± 1.9
DO (mg/L)	4.12 ± 1.53	3.8 ± 1.0	4.14 ± 1.14	3.10 ± 1.40	1.72 ± 0.90
Conductivity (mS/cm)	0.444 ± 0.004	0.443 ± 0.040	0.497 ± 0.020	0.485 ± 0.029	0.470 ± 0.043
Turbidity (NTU)	110.20 ± 35.07	113.25 ± 192.21	N/A	331.58 ± 284.37	239.04 ± 256.46

N/A: Not Available

[1] Suspected instrument error

[2]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See Table 2-1 for details.

Table 4-13: Mean Coldwater River Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	<0.0055	0.0019 ± 0.0015	0.0011 ± 0.0001	0.0061 ± 0.0096	0.0014 ± 0.0005
TP (mg/L)	N/A	N/A	N/A	0.0205 ± 0.0275	0.0247 ± 0.0316
TN (mg/L)	0.13 ± 0.00	0.117 ± 0.082	0.104 ± 0.029	0.190 ± 0.130	0.142 ± 0.016
ON (mg/L)	0.09 ± 0.03	0.093 ± 0.071	0.124 ± 0.110	0.134 ± 0.088	0.087 ± 0.035
Total Ammonia (mg/L)	0.02 ± 0.02	0.007 ± 0.003	0.020 ± 0.000	0.029 ± 0.029	0.024 ± 0.008
Nitrate (mg/L)	0.01 ± 0.00	0.022 ± 0.015	0.0084 ± 0.0068	0.0235 ± 0.0216	0.0191 ± 0.0244
Nitrite (mg/L)	0.01 ± 0.01	0.001 ± 0.000	0.0010 ± 0.0000	0.163 ± 0.110	0.0010 ± 0.0000
Total Coliforms (MPN/100mL)	177[1]	153	346	74	83
Fecal Coliforms (MPN/100mL)	7[1]	7	32	31	11
Chloride (mg/L)	7.50 ± 4.10	7.64 ± 5.09	8.29 ± 3.96	9.34 ± 5.37	8.51 ± 4.65
Total Alkalinity (mg/L)	N/A	N/A	N/A	N/A	N/A
Sulphate (mg/L)	N/A	7.04 ± 0.00	N/A	N/A	N/A
pH	8.10	8.18 ± 0.00	8.09 ± 0.25	7.09 ± 0.45	8.00 ± 0.22
Temperature (°C)	14.0 ± 2.2	15.9 ± 9.8	10.4 ± 10.0	14.0 ± 4.1	9.3 ± 7.8
DO (mg/L)	9.97 ± 1.46	11.60 ± 0.00	11.28 ± 2.83	3.70 ± 0.95	10.76 ± 2.36
Conductivity (mS/cm)	0.125 ± 0.109	0.489 ± 0.421	0.157 ± 0.055	0.745 ± 0.127	0.141 ± 0.055
Turbidity (NTU)	9.83	30.59 ± 40.75	10.43	6.04 ± 2.52	36.81 ± 92.71

N/A: Not Available

[1]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See report section 3.3.2 for details.

Table 4-14: Mean Nicola River (Upstream Confluence) Parameters

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	0.0119 ± 0.0027	0.0244 ± 0.0050	0.0113 ± 0.0096	0.0735 ± 0.1277	0.0214 ± 0.0201
TP (mg/L)	N/A	N/A	N/A	0.1994 ± 0.2048	0.0553 ± 0.0316
TN (mg/L)	0.56 ± 0.08	0.616 ± 0.127	0.588 ± 0.116	0.793 ± 0.188	0.588 ± 0.317
ON (mg/L)	0.23 ± 0.31	0.502 ± 0.039	0.467 ± 0.139	1.118 ± 1.149	0.374 ± 0.054
Total Ammonia (mg/L)	0.03 ± 0.02	0.019 ± 0.006	0.038 ± 0.032	0.256 ± 0.444	0.031 ± 0.019
Nitrate (mg/L)	0.04 ± 0.05	0.125 ± 0.101	0.1291 ± 0.1377	0.2783 ± 0.2081	0.1895 ± 0.2902
Nitrite (mg/L)	0.01 ± 0.01	0.001 ± 0.000	0.0017 ± 0.0010	1.374 ± 1.587	0.0019 ± 0.0016
Total Coliforms (MPN/100mL)	210[1]	531	524	259	275
Fecal Coliforms (MPN/100mL)	42[1]	28	8	58	13
Chloride (mg/L)	3.65 ± 2.60	5.75 ± 1.17	5.86 ± 0.84	7.96 ± 3.80	6.07 ± 1.45
Total Alkalinity (mg/L)	N/A	N/A	N/A	N/A	N/A
Sulphate (mg/L)	N/A	14.60 ± 0.00	N/A	N/A	N/A
pH	9.07	8.34 ± 0.30	8.08 ± 0.65	7.74 ± 0.34	8.15 ± 0.47
Temperature (°C)	12.5 ± 4.2	14.4 ± 9.2	11.6 ± 9.7	8.6 ± 7.2	9.5 ± 8.2
DO (mg/L)	9.93 ± 0.60	11.55 ± 2.33	11.98 ± 1.44	11.46 ± 1.37	10.91 ± 1.73
Conductivity (mS/cm)	0.249 ± 0.057	0.233 ± 0.028	0.259 ± 0.023	0.277 ± 0.031	0.264 ± 0.036
Turbidity (NTU)	30.40	35.69 ± 50.78	7.08	27.61 ± 47.31	19.53 ± 24.78

N/A: Not Available

[1]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See report section 3.3.2 for details.

Table 4-15: Mean Nicola River Downstream #1 Parameters

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	0.0102 ± 0.002	0.0089 ± 0.0054	0.0046 ± 0.0028	0.0162 ± 0.0211	0.0042 ± 0.0035
TP (mg/L)	N/A	N/A	N/A	0.0343 ± 0.0303	0.0237 ± 0.0144
TN (mg/L)	0.26 ± 0.19	0.330 ± 0.110	0.285 ± 0.077	0.483 ± 0.353	0.266 ± 0.090
ON (mg/L)	0.26 ± 0.25	0.227 ± 0.088	0.194 ± 0.121	0.276 ± 0.123	0.155 ± 0.070
Total Ammonia (mg/L)	0.02 ± 0.02	0.012 ± 0.006	0.024 ± 0.003	0.051 ± 0.071	0.024 ± 0.007
Nitrate (mg/L)	0.03 ± 0.03	0.125 ± 0.112	0.1028 ± 0.1017	0.1550 ± 0.1936	0.0686 ± 0.0936
Nitrite (mg/L)	0.01 ± 0.01	0.001 ± 0.000	0.0010 ± 0.0000	0.328 ± 0.182	0.0012 ± 0.0002
Total Coliforms (MPN/100mL)	101[1]	201	148	117	94
Fecal Coliforms (MPN/100mL)	28[1]	13	10	40	7
Chloride (mg/L)	4.36 ± 3.23	9.78 ± 6.55	8.81 ± 3.32	9.21 ± 6.05	7.52 ± 3.48
Total Alkalinity (mg/L)	N/A	N/A	N/A	N/A	N/A
Sulphate (mg/L)	N/A	11.60 ± 0.00	N/A	N/A	N/A
pH	8.90	7.55 ± 0.59	7.78 ± 0.39	7.67 ± 0.31	7.93 ± 0.23
Temperature (°C)	13.7 ± 1.6	11.0 ± 9.8	10.2 ± 9.0	7.8 ± 6.0	8.1 ± 6.7
DO (mg/L)	10.05	12.75 ± 1.20	11.60 ± 1.61	11.64 ± 1.36	11.15 ± 1.75
Conductivity (mS/cm)	0.160 ± 0.154	0.490 ± 0.387	0.184 ± 0.067	0.203 ± 0.077	0.178 ± 0.064
Turbidity (NTU)	12.50	22.89 ± 30.58	17.32	5.96 ± 2.95	39.22 ± 99.62

N/A: Not Available

[1]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See report section 3.3.2 for details.

Table 4-16: Mean Nicola River Downstream #2 (Downstream RI Basins) Parameters (2007-2011)

Parameter	2011	2010	2009	2008	2007
BOD_5 (mg/L)	N/A	N/A	N/A	N/A	N/A
TSS (mg/L)	N/A	N/A	N/A	N/A	N/A
Ortho P (mg/L)	0.0092 ± 0.0012	0.0123 ± 0.0088	0.0055 ± 0.0054	0.0343 ± 0.0535	0.0060 ± 0.0062
TP (mg/L)	N/A	N/A	N/A	0.0802 ± 0.0897	0.0361 ± 0.0279
TN (mg/L)	0.26 ± 0.14	0.366 ± 0.126	0.313 ± 0.162	0.677 ± 0.583	0.343 ± 0.155
ON (mg/L)	0.21 ± 0.16	0.258 ± 0.060	0.219 ± 0.105	0.439 ± 0.322	0.237 ± 0.134
Total Ammonia (mg/L)	0.03 ± 0.03	0.013 ± 0.005	0.021 ± 0.002	0.108 ± 0.172	0.022 ± 0.004
Nitrate (mg/L)	0.03 ± 0.03	0.087 ± 0.076	0.0968 ± 0.1414	0.1293 ± 0.1116	0.0723 ± 0.1097
Nitrite (mg/L)	0.01 ± 0.01	0.001 ± 0.000	0.0010 ± 0.0000	0.547 ± 0.492	0.0011 ± 0.0002
Total Coliforms (MPN/100mL)	144[1]	441	205	98	135
Fecal Coliforms (MPN/100mL)	41[1]	22	7	30	11
Chloride (mg/L)	4.88 ± 3.95	6.43 ± 3.38	6.86 ± 2.79	7.90 ± 4.07	6.59 ± 2.97
Total Alkalinity (mg/L)	N/A	N/A	N/A	N/A	N/A
Sulphate (mg/L)	N/A	12.70 ± 0.00	N/A	N/A	N/A
pH	8.55	8.07 ± 0.07	7.75 ± 0.36	7.61 ± 0.24	7.86 ± 0.27
Temperature (°C)	13.5 ± 1.1	11.0 ± 9.5	10.3 ± 9.7	8.4 ± 6.3	8.2 ± 7.0
DO (mg/L)	10.48 ± 1.02	11.77 ± 2.20	11.60 ± 1.91	11.68 ± 1.41	11.29 ± 1.87
Conductivity (mS/cm)	0.160 ± 0.142	0.400 ± 0.330	0.188 ± 0.071	0.203 ± 0.049	0.181 ± 0.056
Turbidity (NTU)	17.20	26.45 ± 34.08	10.28	9.04 ± 7.34	44.28 ± 99.38

N/A: Not Available

[1]Fecal coliforms were measured in CFU/100mL and in MPN/100mL. See report section 3.3.2 for details.

C Appendix C - Nicola River EMS Data (CD Format)

D Appendix D - Coldwater River EMS Data (CD Format)

E Appendix E - Groundwater EMS Data (CD Format)

F Appendix F - WaterTrax Data (CD Format)

Appendix E - Model Construction and Calibration Assumptions - GeoAdvice

City of Merritt ISMP – Model Development and System Analysis

TECHNICAL MEMORANDUM

Task No. 201/202

Final

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1. INTRODUCTION

The City of Merritt retained Associated Engineering (AE) and GeoAdvice Engineering Inc. (GA) to complete the City of Merritt Integrated Stormwater Management Plan (ISMP). The primary objective of this study is to develop a long-term plan that meets the requirements of the Ministry of Environment for ISMP. One of the main objectives of this ISMP is to build an "all-pipes" model of the City's stormwater system using InfoSWMM (Innovyze Inc. software). The model will be used to:

- Evaluate the stormwater system
- Evaluate the capacity and performance of the rock pits

2. SCOPE OF WORK

The scope of this memorandum covers the following items:

- Development of the existing drainage model
- Model validation and sensitivity analysis
- Analysis of the existing drainage system

3. SYSTEM OVERVIEW

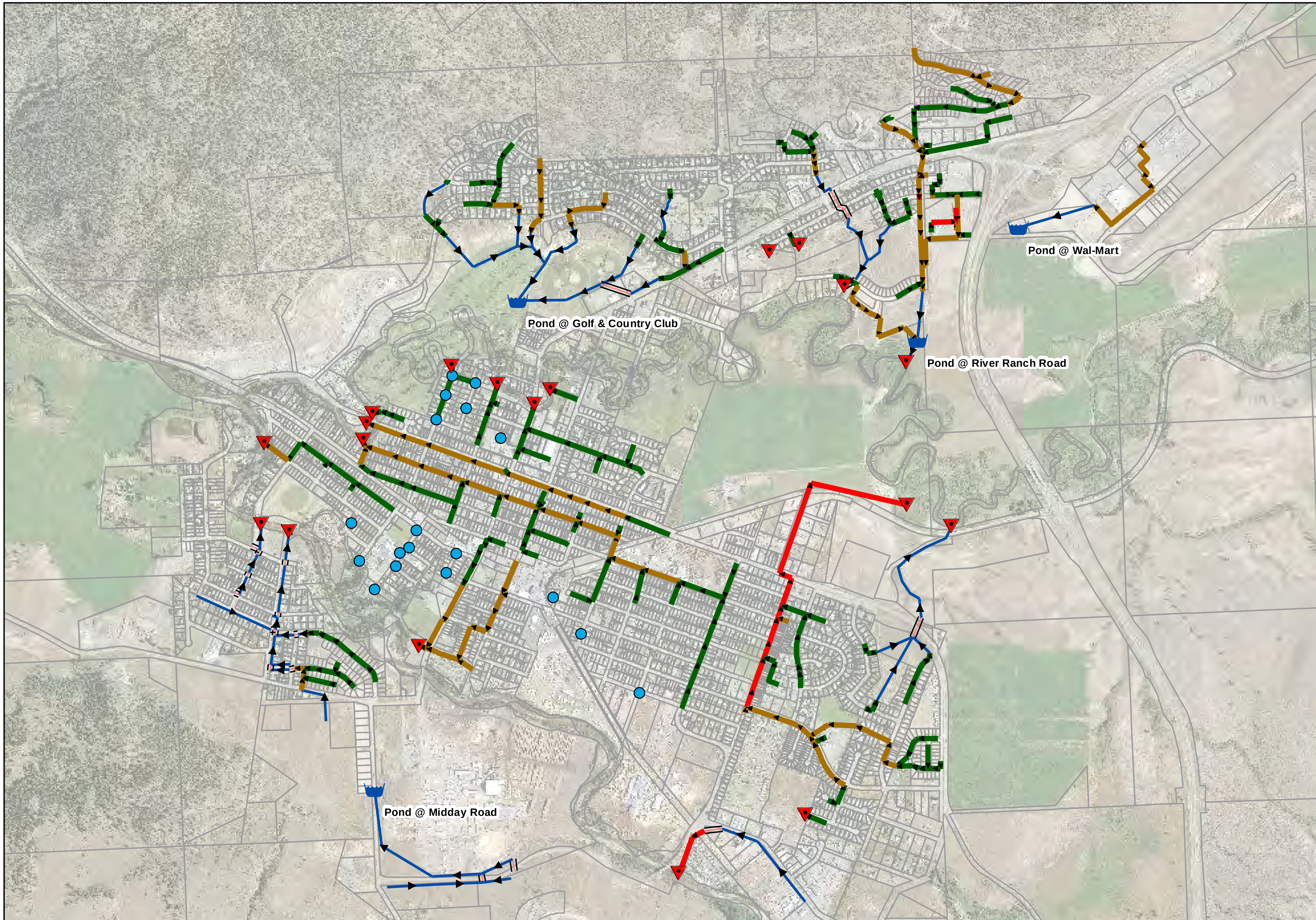
Figure 3.1 presents the City of Merritt drainage system. The boundaries of the model consist of all areas serviced by the City's drainage infrastructure, i.e. all areas that are:

- Conveyed to the Nicola and Coldwater Rivers via traditional storm sewers and open ditches
- Conveyed to one of four neighborhood detention ponds:
    - The Wal-Mart detention pond (South East of Hwy 5 and West of the Airport)
    - The Merritt Golf and Country club detention pond (North of the Nicola River)
    - The Midday Road detention pond (on Midday Road)
    - The River Ranch Road detention pond (South of Ranch River Road)
- Conveyed to the City's various rock pits and dry wells

The scope of the model does not include:

- Unserviced areas
- The Nicola River
- The Coldwater River

City of Merritt



Legend

- Outfall
- Dry Well
- Detention Pond
- Culvert
- Ditch

Conduit Diameter (mm)

- < 375
- 375 - 600
- > 600

Engineering base plan provided by Summit Environmental Consultants Inc.

System Overview

GeoAdvice Engineering Inc.

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

N E S W

0 0.5 1
Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 3.1

4. PHYSICAL MODEL DEVELOPMENT

4.1 COLLECT AND REVIEW BACKGROUND DATA

Information on the City's stormwater system is documented in the *City of Merritt ISMP – Model Development and Data Review Report*, dated January 15th, 2013. The report can be found in **Appendix A**.

4.2 HYDRAULIC MODEL DEVELOPMENT

The drainage system analysis was completed using the InfoSWMM (Innovyze) modeling software. A further description of the InfoSWMM modeling software can be found in **Appendix B**. The model's network topology (i.e. the nodes and pipes) was primarily built using the City's infrastructure database as provided by AE. Physical attributes were extracted from the infrastructure database where possible. However, as highlighted in the *Data Review Report*, there were a number of connectivity issues and data gaps in the GIS data. To increase the accuracy of the model, AE completed a field review to aid in populating the missing infrastructure data. Further, the results of an interview with City Staff were also used to populate a number of data gaps. A summary of the modeling assumptions and data can be found in **Appendix C**.

For the purpose of this study, the entrance and exit losses of the stormmains were assumed negligible. Culvert entrance and exit losses were also assumed negligible.

The stormmain and ditch properties were assigned as described in **Section 2.1** of the *Data Review Report.*

4.3 HYDROLOGIC MODEL DEVELOPMENT

4.3.1 SUBCATCHMENT GEOMETRY

The subcatchments (area, slope, and width) were delineated using the following data sets:

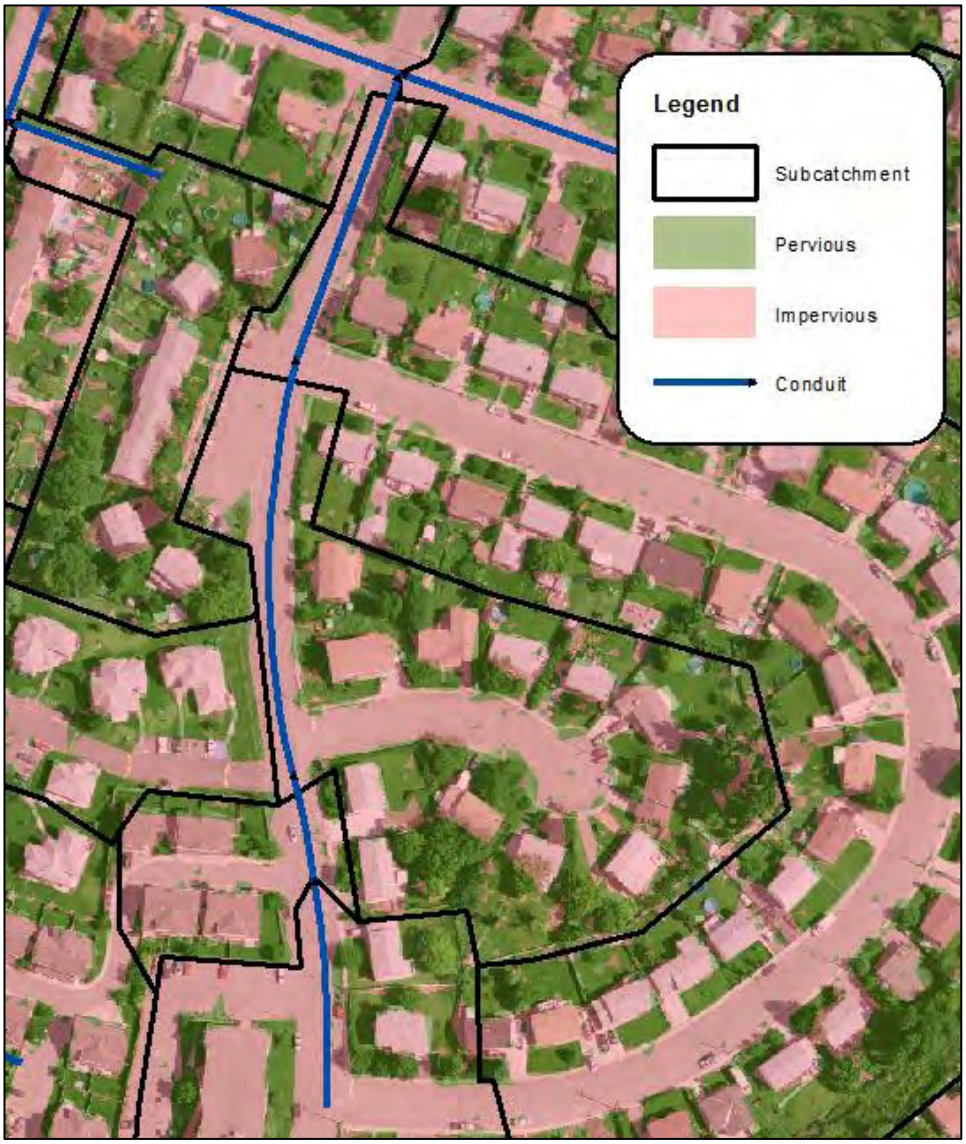
- Topographic data (contour data/LIDAR)
- Property boundaries
- Orthophotos
- Infrastructure information (storm services, catch basins, drainage ditches, etc.)

Further, while developing the subcatchment geometry it was assumed that along the roadway there was either a roadside ditch/swale or curb acting as a localized drainage barrier. **Appendix C** provides further details on the subcatchment geometry parameters.

4.3.2 IMPERVIOUS COVERAGE

Available orthophotos were used to estimate the existing impervious coverage. **Figure 4.1** below provides a sample of how the orthophotos were used to classify the existing impervious coverage. The existing impervious coverage was then used to estimate the imperviousness of each subcatchment.

Figure 4.1: Impervious Coverage



Further, to account for older established residential areas, it was generally assumed that:

- Impervious roof areas are disconnected from sewers; and
- The majority of residential areas do not have curb and gutter along the roadways.

As such:

- Residential subcatchments with an impervious coverage <=60%, assumed that on-lot impervious areas (roof, driveway, patio, etc.; but, excludes roadways) are disconnected (would first drain to the pervious areas).
  - On-lot residential impervious areas was assumed to account for 80% of the total catchment impervious area.
- All remaining subcatchments with impervious coverage >60%, and all roadways, commercial and industrial catchments, assumed impervious areas are directly connected (drain directly to the catchment outlet).

The above assumptions were derived during the calibration process by adjusting the impervious coverage ratio at which residential catchments were assumed to be directly connected/disconnected until the model results aligned with the observed anecdotal data.

4.3.3 HYDROLOGIC PARAMETERS

When estimating runoff there are a number of key hydrologic parameters that influences both the total runoff volume and peak runoff flow rates. These key parameters include:

<u>Catchment's Depression depth/storage</u>
The volume that must be filled prior to the occurrence of runoff. It represents the loss or "initial abstraction" caused by such phenomena as surface ponding, surface wetting and interception. For example, increasing the depression storage effectively increases the total volume of water that is lost on the catchment before runoff can occur; thus, reducing the total runoff volume.

<u>Catchment's Roughness (Manning's 'n' value)</u>
The overland flow Manning's n roughness. By increasing the catchment roughness, the speed at which runoff flows off the catchment is reduced; thus, decreasing the peak runoff rate.

<u>Catchment's Infiltration Properties (Saturation hydraulic conductivity)</u>
The rate at which water infiltrates into the soil; applicable only to the pervious portion of the subcatchment. Increasing the soil infiltration rate effectively increases the rate at which ponded water on the catchment surface (water in the storage loss) in infiltrated into the soil, effectively increasing the total volume of water that is lost on the catchment; thus, reducing the total runoff volume.

Table 4.1 and **Table 4.2** summarize the calibrated hydrologic parameters. The subcatchment infiltration parameters were assigned based on the largest soil coverage (see **Figure 4.2**).

Table 4.1: Hydrologic Calibrated Parameters

Parameter	Pervious	Impervious
Depression depth/storage (mm)	5.0	1.5
Manning's 'n' value	0.25	0.02

Table 4.2: Soil Infiltration Calibrated Parameters

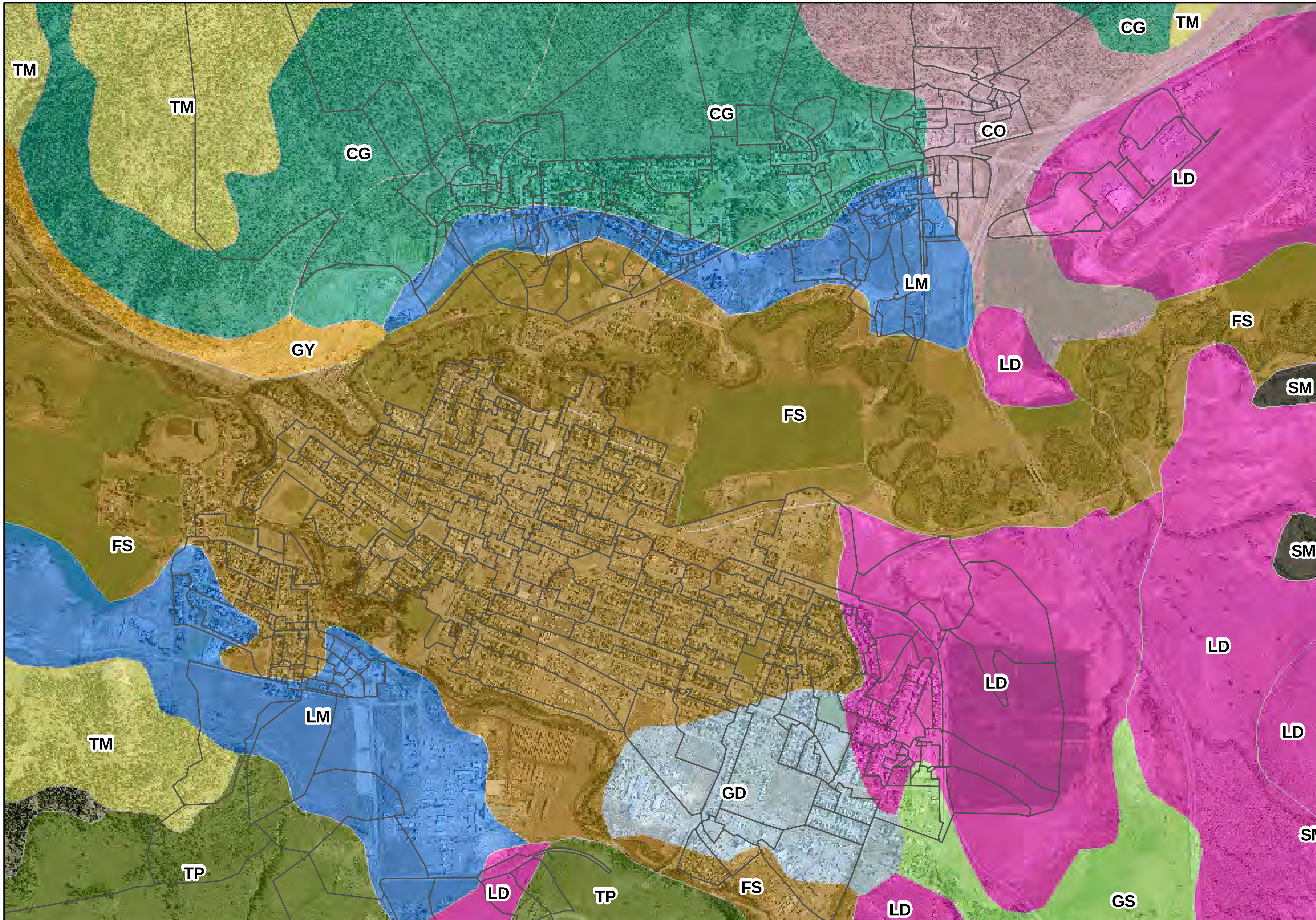
Soil ID	Soil Description	Classification	Saturation Hydraulic Conductivity (mm/hr)	Suction (mm)	Initial Deficit
CG	Cavanaugh	Sand	2.18E+01	49.5	0.404
CO	Commonage	Sand	2.18E+01	49.5	0.404
FS	Frances	Sandy Loam	2.00E+00	110.1	0.358
GD	Godey	Sand	2.36E+02	49.5	0.404
GS	Glimpse	Sand	2.36E+02	49.5	0.404
GY	Glossey	Sand	2.36E+02	49.5	0.404
LD	Lac du Bois	Silty Clay Loam	2.18E+01	273	0.263
LM	Lundbom	Silty Clay Loam	2.18E+01	273	0.263
SM	Shumway	Sand	2.18E+01	49.5	0.404
TM	Timber	Sand	2.18E+01	49.5	0.404
TP	Trapp Lake	Sand	2.18E+01	49.5	0.404

4.1 Rainfall Data

Table 4.3 below presents the design events used to assess the drainage system.

Table 4.3: Design Storms

Storm Duration	1:2-year Total Depth (mm)	1:10-year Total Depth (mm)	1:100-year Total Depth (mm)	Design Storm Shape
1-hr	7.9	14.0	21.5	1-Hour AES – BC Interior
2-hr	10.2	17.2	26.0	2-Hour AES – BC Interior
6-hr	15.0	23.4	34.6	6 Hour AES – BC Interior
12-hr	19.2	28.8	41.4	12 Hour – SCS Type 1A
24-hr	24.5	36.0	50.4	24 Hour – SCS Type 1A



City of Merritt

Legend

Subcatchment

Soil Type

- CG - Cavanaugh
- CO - Commonage
- FS - Frances
- GD - Godey
- GS - Glimpse
- GY - Glossey
- LD - Lac du Bois
- LM - Lundbom
- SM - Shumway
- TM - Timber
- TP - Trapp Lake

Engineering base plan provided by Summit Environmental Consultants Inc.

Soil Coverage

GeoAdvice Engineering Inc.

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N E S W

0 0.5 1

Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure 4.2

5. MODEL CALIBRATION

5.1 Review Model Results Against Observed Performance

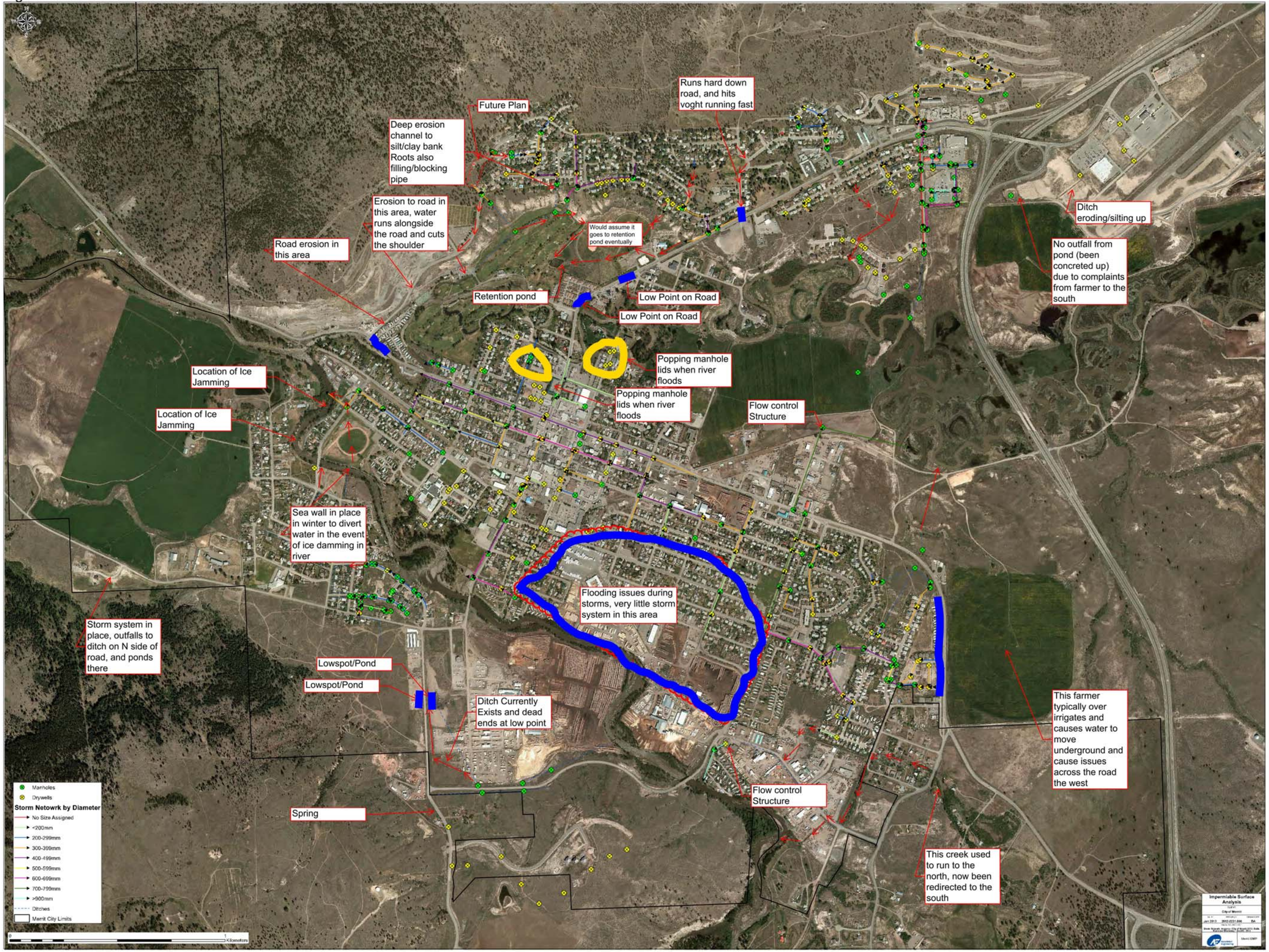
Model results were compared against anecdotal information collected via interviews with City Operations staff. The City does not maintain detailed records of all service call locations listing the magnitude and cause of the flooding issues. However, City staff was able to identify a number of “problem areas” (e.g. main downtown Merritt – north of Coldwater River) that experience chronic flooding. City staff also identified a number of “historic” flood events. **Figures 5.1** below summarizes the identified flood areas.

Figure 5.2 presents the model predicted flooding areas under the design 2-year and 10-year storm events. The model predicted flooding at manholes located in the area north of Merritt Ave and south of Nicola River. The model also predicted a more severe flooding in this area during high river levels, which is in line with the “historic” flood events identified by City staff. Further, under the 10-year storm event, the model predicted multiple flooding locations close to the downtown area; an area identified by City staff as being prone to flooding.

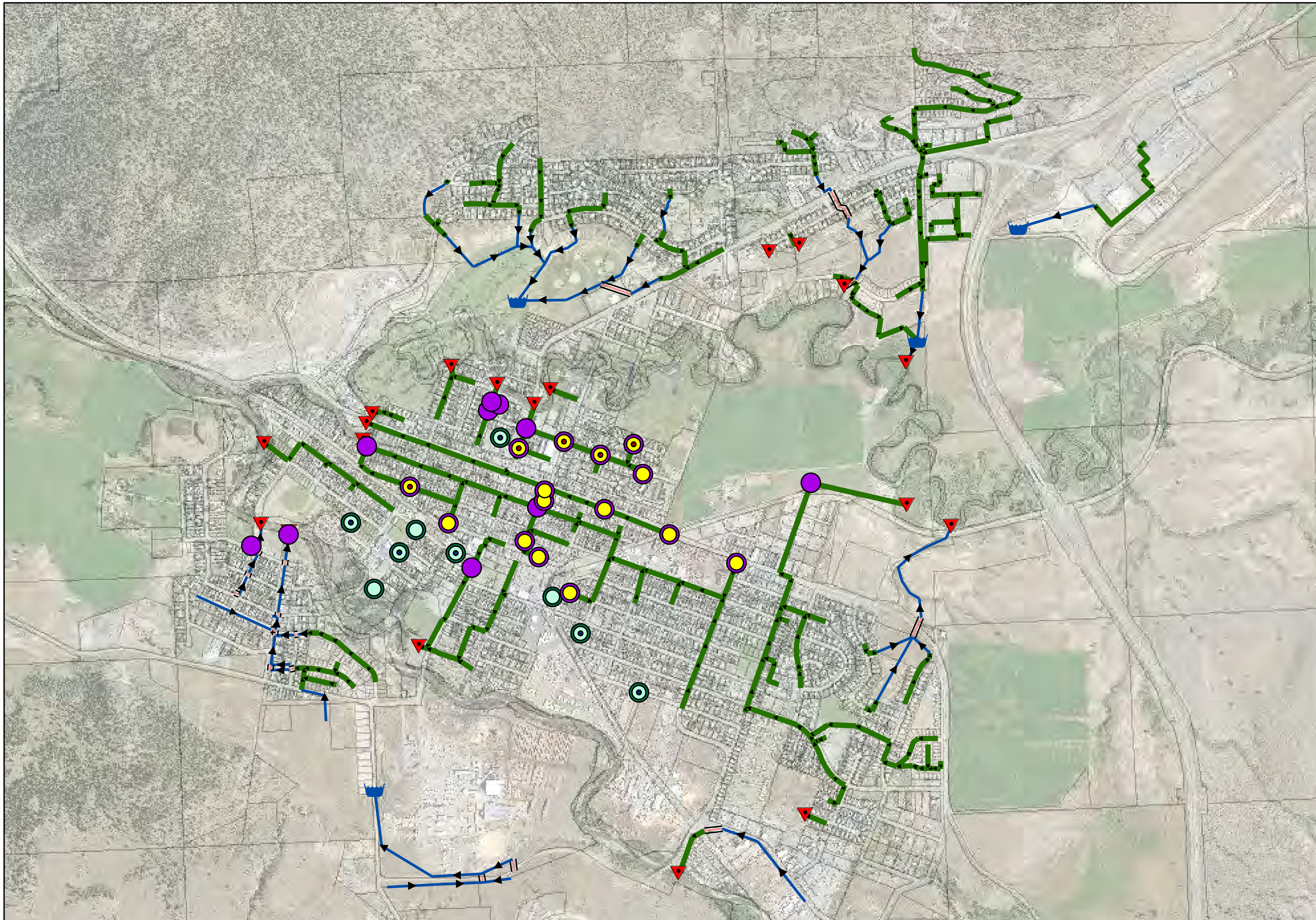
The model results appear to over-predict flooding at dry wells, south west of downtown, relative to the City staff observations. However, as there are no specific design standards or performance records for these dry wells, it is difficult to ascertain the cause of this discrepancy.

In summary, the model results appear to be generally consistent with observed historic system performance with model discrepancies tending to be conservative, i.e. the model over predicting flows.

Figure 5.1: Identified Flood Areas



City of Merritt



Legend

- Outfall
- Detention Pond
- Culvert
- Ditch
- Stormmain

Manhole (Floodloss)

- 2 Yr Flooding
- 10 Yr Flooding
- 10 Yr Flooding 20 Yr River Level

Dry Well (Floodloss)

- 2 Yr Flooding
- 10 Yr Flooding
- 10 Yr Flooding 20 Yr River Level

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System - Predicted Flooding

GeoAdvice Engineering Inc.

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0 0.5 1
Kilometers

Project: City of Merritt ISMP
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure 5.2

5.2 Flow Validation

Following the model calibration, the model was simulated using the full suite of design events. The objective was to compare the system performance against typical design standards and Regional flow rates.

Table 5.1 and **Table 5.2** summarize the model results for the 2-year, 10-year, 100-year design events.

Table 5.1: Discharge Peak Flow Matrix to Nicola and Coldwater Rivers

	Peak Flow (L/s/ha)*		
Duration\Return Period	**2 yr**	**10 yr**	**100 yr**
1hr	0.85	2.89	5.42
2hr	1.25	3.31	5.59
6hr	1.55	2.93	4.52
12hr	3.77	5.51	7.74
24hr	3.19	4.64	6.40

*Flow averaged over subcatchments contributing to Nicola and Coldwater Rivers only. Outer subscatchments were also excluded.

Table 5.2: Runoff Coefficent Matrix

	Runoff Coefficient (/)*		
Duration\Return Period	**2 yr**	**10 yr**	**100 yr**
1hr	0.059	0.077	0.085
2hr	0.068	0.081	0.087
6hr	0.078	0.086	0.090
12hr	0.260	0.267	0.304
24hr	0.255	0.261	0.282

*Flow averaged over subcatchments contributing to Nicola and Coldwater Rivers only. Outer subscatchments were also excluded.

Based on the above model results, the predicted unit area flow rates and runoff coefficients are in line with typical rates seen in other BC interior municipalities. The model predicted large losses through ground infiltration, particularly acute in undeveloped areas, relative to the small total rain depth. These combined conditions resulted in the low unit area rates observed.

Table 5.3 to **Table 5.7** summarize the overall storm system performance.

Table 5.3: Number of Junctions Flooded Matrix

	# of Junctions with Surface Flooding		
Duration\Return Period	**2 yr**	**10 yr**	**100 yr**
1hr	0	3	14
2hr	0	5	16
6hr	0	4	11
12hr	5	15	31
24hr	4	8	25

Table 5.4: Number of Dry Wells Flooded Matrix

	# of Dry Wells with Surface Flooding		
Duration\Return Period	**2 yr**	**10 yr**	**100 yr**
1hr	0	1	3
2hr	0	3	5
6hr	2	4	6
12hr	6	9	13
24hr	6	7	13

Table 5.5: Length of Surcharged Pipes Matrix

	Length of Surcharged Pipes (m) (d/D >1)*	% of Total Pipe Length**
Duration\Return Period	10-year Storm Event	
1hr	1,406	4%
2hr	1,603	5%
6hr	1,406	4%
12hr	6,299	19%
24hr	5,535	17%

*The d/D (maximum flow depth/pipe diameter) ratio is used to indicate if the pipe is surcharging (d/D>1)
**Total pipe length is approximately 33 km

The total floodloss volume is a measure of the total runoff volume that can not enter into the drainage system due to insufficient downstream pipe capacity or insuficient storage capacity. This “lost volume” is expected to induce localized water ponding and/or overland flow, and be used as a measure of the location and severity of flooding.

Table 5.6: Total Junction Floodloss Volume Matrix

	Total Floodloss Volume (m^3)		
Duration\Return Period	**2 yr**	**10 yr**	**100 yr**
1 hr	0	20	322
2hr	0	55	542
6hr	0	60	454
12hr	146	891	3,795
24hr	72	411	2,069

Table 5.7: Total Dry Well Floodloss Volume Matrix

	Total Floodloss Volume (m^3)		
Duration\Return Period	**2 yr**	**10 yr**	**100 yr**
1 hr	0	13	113
2hr	0	54	174
6hr	23	140	350
12hr	672	1,396	3,218
24hr	852	1,570	3,299

5.2.1 Dry Well Performance

It is our understanding that the City's dry wells (DW) were typically built without any specified standard drawing. As such, dry well geometry and properties were assumed based on the results of the interview with City staff: "*Typical procedure in the past was to dig to gravel layer, drop in DW structure, backfill with gravel, typically 10 feet deep to get to gravel layer*". **Table 5.8** summarizes the assumed dry well geometries and infiltration parameters.

Table 5.8: Dry Well Modeled Parameters

Parameter	Value
Volume (m^3)	20
Depth (m)	3
Infiltration Model	Green Ampt
Capillary Suction (mm)	49.5
Hydraulic Conductivity (mm/hr)	235.6
Initial Moisture Deficit (dimensionless)	0.404

5.2.2 Detention Pond Performance

The City has no known detention pond performance issues. It is our understanding that the City's detention ponds were generally designed to detain the 100-year event. Due to missing detention pond geometry information, the detention pond geometry and the overall volume were modified to fully capture the predicted 100-year 24-hour runoff volume as part of the model calibration process. **Table 5.9** summarizes the assumed detention pond geometries.

Table 5.9: Detention Pond Modeled Parameters

Pond	Depth (m)	Estimated Volume (m^3)	Soil*
Wal-Mart Detention	2	6,000	CO
Golf & Country Club Detention	2	1,000	FS
Midday Road Detention	2	600	LM
River Ranch Road Detention	2	1,000	FS

*See **Table 4.2** for soil infiltration parameters

5.3 Sensitivity Analysis

To further enhance our understanding of the system, a sensitivity analysis was completed to test the model sensitivity to changes in various hydrologic parameters. **Table 5.10** lists the various scenarios that were reviewed.

Table 5.10: Hydrologic Parameters Modifications

Parameter Review	Modification
Modifying Impervious Coverage	+/-5%
Modifying Depression Storage	+/-1mm, +/-3mm
Modifying Catchment Width	+/-50%, +100%
Modifying Catchment Slope	+/-25%, +/-50%
Modifying Catchment Roughness	+/-50%, +100%
Modifying Soil Infiltration	$10^{+/-1}$
Modifying Nicola and Coldwater River Levels	20 year, 200 year

5.3.1 Sensitivity Analysis results

Modifying Impervious Coverage

The results of the sensitivity analysis indicate that the overall system performance is relatively non-sensitive to changes in impervious coverage, with +/- 5% change in total impervious area resulting in marginal changes in the total length of surcharged pipes (10-year event) and locations of surface flooding (100-year event).

Given that impervious coverage was estimated using orthophotos, and that the system performance is only marginally impacted by changes in total impervious coverage, there is a high-level of confidence in the impervious coverage assumed in the model.

Modifying Depression Storage

The results of the sensitivity analysis indicate that the overall system performance is relatively non-sensitive to increase in the catchment depression storage. However, a decrease in depression storage results in an increase in the total length of surcharged pipes (10-year event) and locations of surface flooding (100-year event).

Modifying Catchment Width

The results of the sensitivity analysis indicate that the overall system performance is relatively non-sensitive to decreases in the catchment width. However, increases in catchment width can result in increases in the total length of surcharged pipes (10-year event) and locations of surface flooding (100 year event).

Modifying Catchment Slope

The results of the sensitivity analysis indicate that the overall system performance is relatively non-sensitive to decreases in the catchment slope. However, increases in catchment slope result in increases in the total length of surcharged pipes (10-year event) and locations of surface flooding (100 year event).

Modifying Catchment Roughness

The results of the sensitivity analysis indicate that the overall system performance is relatively non-sensitive to increases in the catchment roughness. However, decreases in catchment roughness result in increases in the total length of surcharged pipes (10-year event) and locations of surface flooding (100-year event).

Modifying Soil Infiltration

The results of the sensitivity analysis indicate that the overall system performance is relatively non-sensitive to changes in soil infiltration parameters, with +/- 1 order of magnitude change in soil infiltration resulting in marginal change in the total length of surcharged pipe (10-year event) and locations of surface flooding (100-year event).

Modifying Nicola and Coldwater River Levels

The base model assumes free outfalls at the system discharges to the Nicola and Coldwater Rivers. When the river outlets are modified to represent the 20-year flood level, the model results show increases in system flooding in the areas North of Merritt Avenue South of the Nicola River. These new flooding areas correlate well with the observed system performance as provided by City staff and summarized in **Figure 5.1**.

This is an indication that the observed flooding areas North of Merritt Avenue South of the Nicola River are not a function of undersized drainage capacity but a function of high river levels. Thus, modification to the River outfall would be required to address these localized flood issues. Further, the limited increase in flooding due to the increased river levels indicates that much to the systems performance is not impacted by the normal fluctuations of Nicola and Coldwater Rivers levels.

6. EXISTING SYSTEM PERFORMANCE REVIEW

6.1 Evaluation Criteria

The evaluation criteria used to assess the City of Merritt drainage system are summarized below:

Pipe system:

1. 10-year – maintain system HGL within the pipe
2. 100-year – provide a safe overland flow path for the 100-year flow

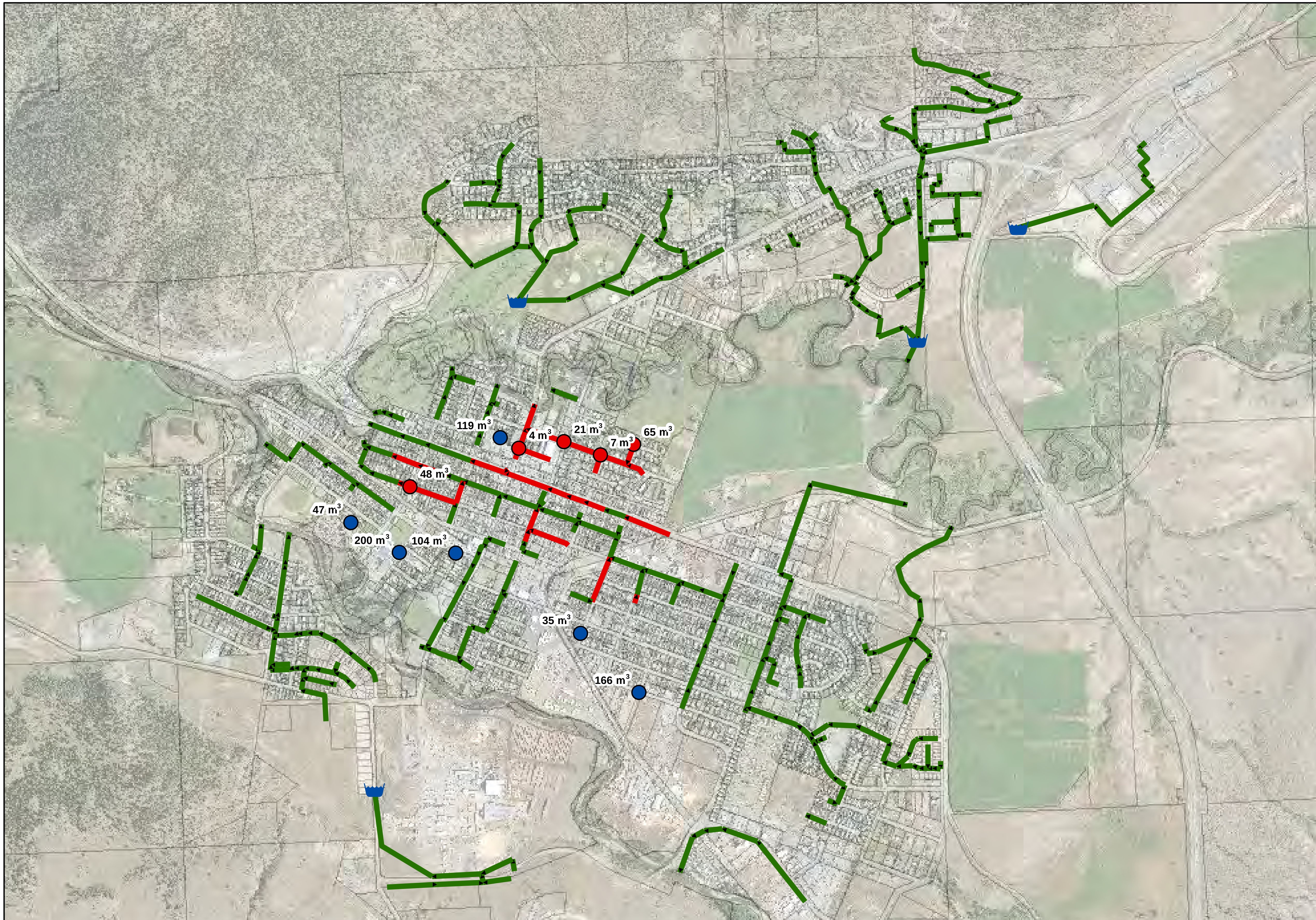
Dry well:

3. 10-year – sufficient storage to manage the 10-year flow

6.2 System Performance Review

The existing model was assessed under the 2-year, 10-year, and 100-year events using the existing land use. **Figure 6.1**, **Figures 6.2a**, **b**, and **Figures 6.3a**, **b** summarize the model results. Please refer to **Section 5.2** for tabular summary of results.

Appendix D provides a detailed accounting of the identified 10-year system deficiencies. Further, **Appendix D** provides the locations and volumes of the modeled 100-year flood losses.



City of Merritt

Legend

Detention Pond

Manhole (Floodloss)

2 Yr Flooding

Dry Well (Floodloss)

2 Yr Flooding

System Performance (d/D)

<1

>=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (2-Year Event)

GeoAdvice Engineering Inc.

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N W E S

0 0.5 1

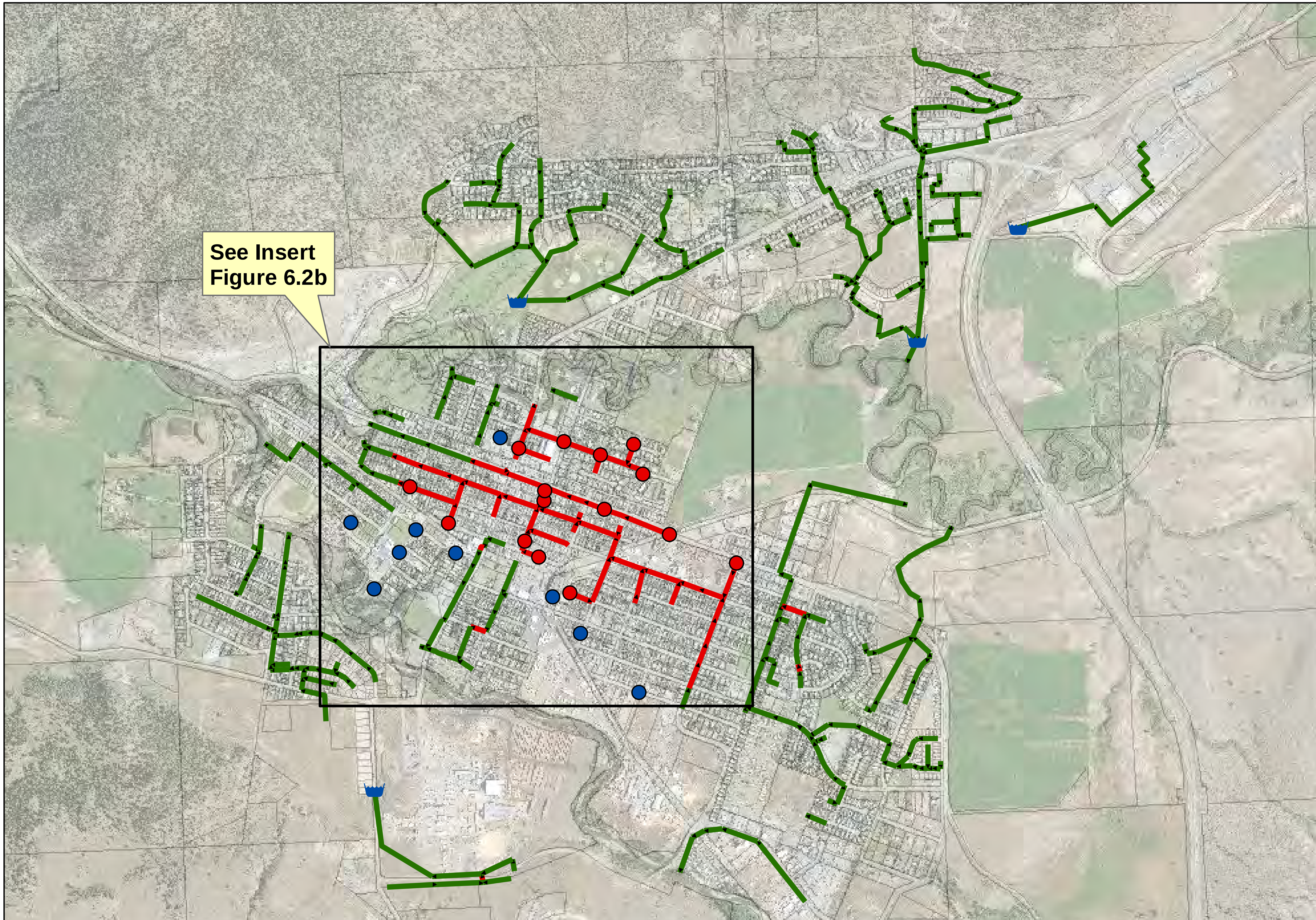
Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 6.1



City of Merritt

Legend

Detention Pond

Manhole (Floodloss)

10 Yr Flooding

Dry Well (Floodloss)

10 Yr Flooding

System Performance (d/D)

<1

>=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (10-Year Event)

GeoAdvice Engineering Inc.

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N W E S

0 0.5 1

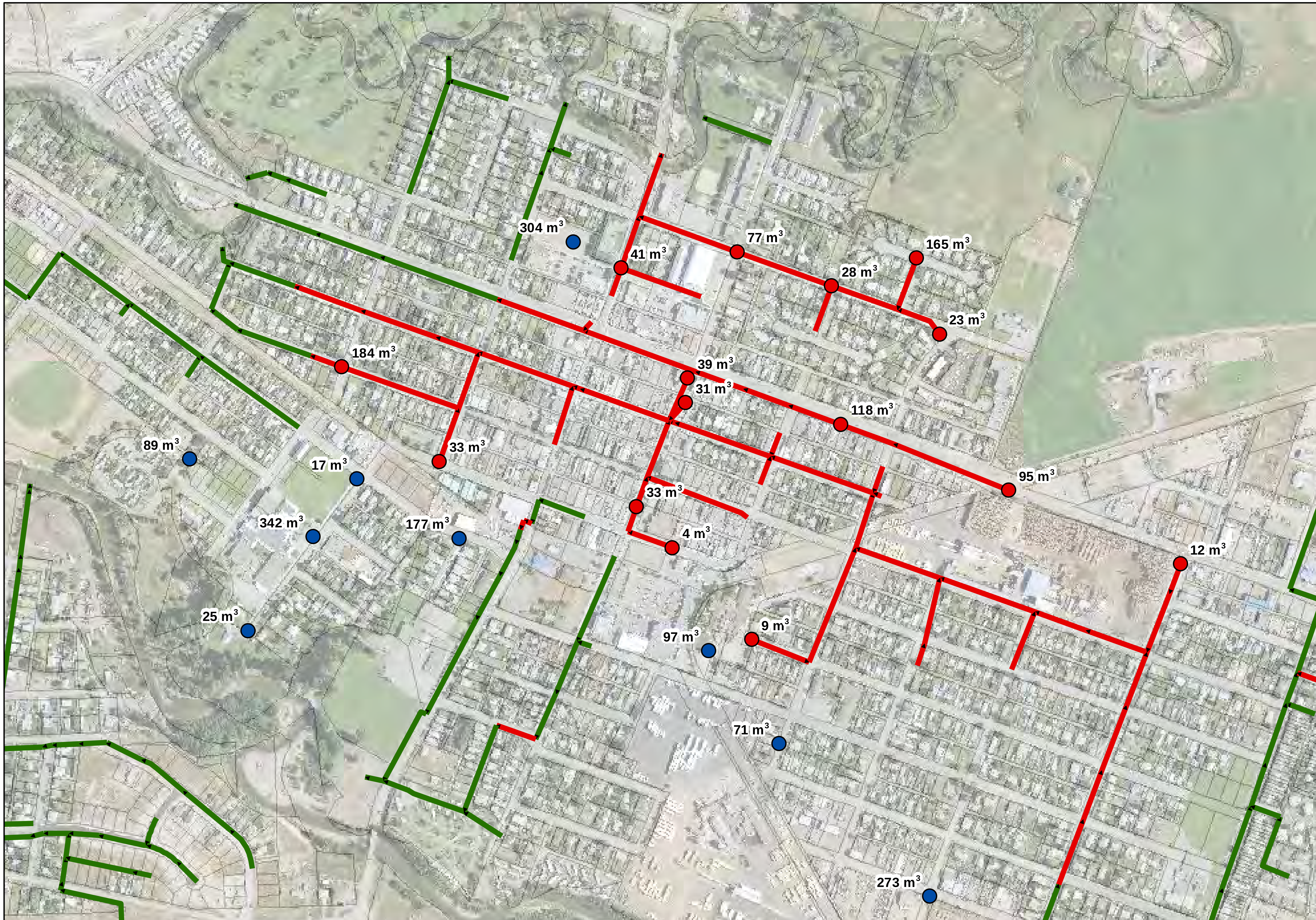
Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure 6.2a



City of Merritt

Legend

Detention Pond

Manhole (Floodloss)

10 Yr Flooding

Dry Well (Floodloss)

10 Yr Flooding

System Performance (d/D)

<1

>=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (10-Year Event)

GeoAdvice Engineering Inc.

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0 0.1 0.2
Kilometers

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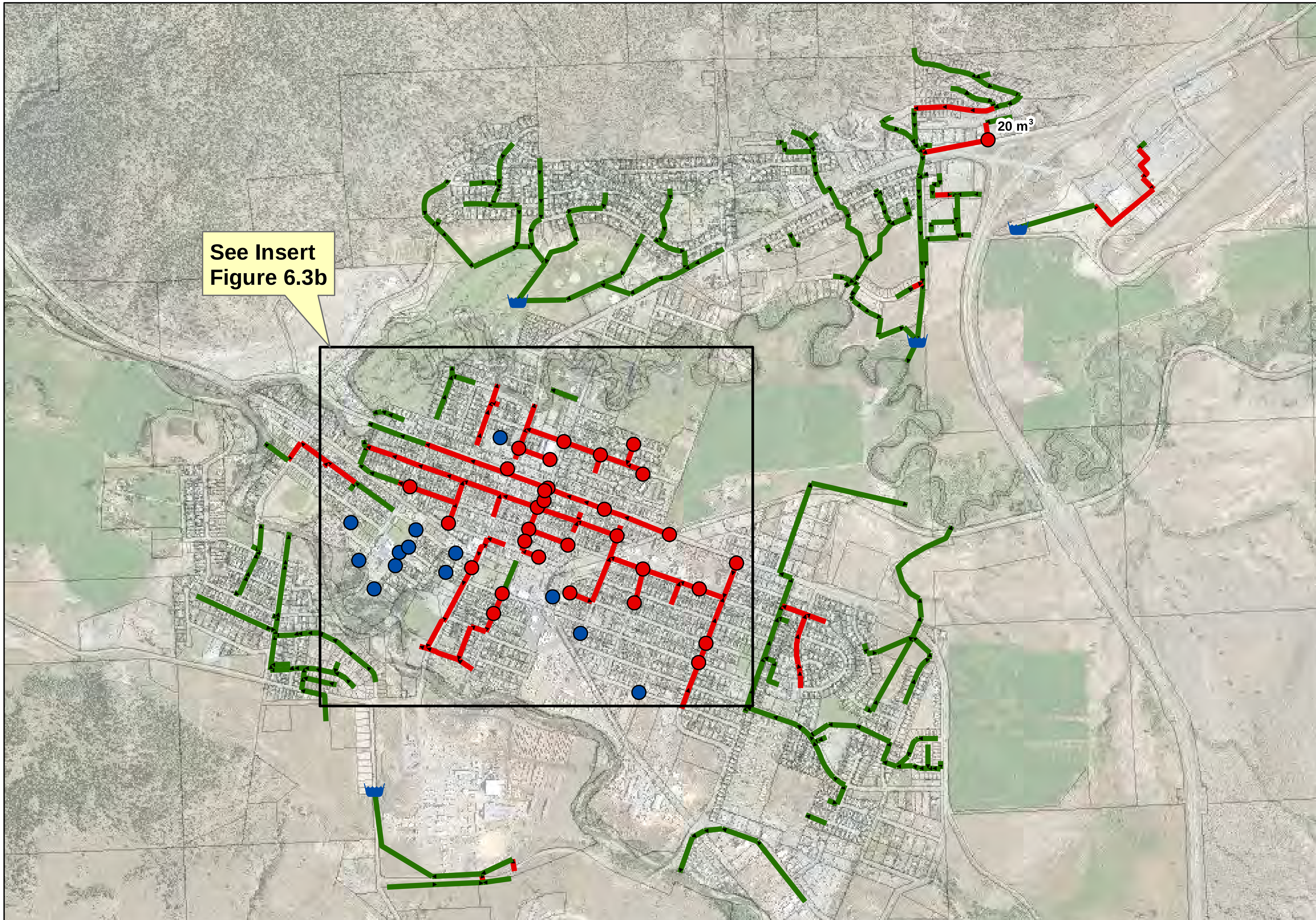
Date: May 2013

Figure 6.2b



City of Merritt

Legend

- Detention Pond

Manhole (Floodloss)

- 100 Yr Flooding

Dry Well (Floodloss)

- 100 Yr Flooding

System Performance (d/D)

- <1
- >=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (100-Year Event)

GeoAdvice Engineering Inc.

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N S W E

0 0.5 1

Kilometers

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Model Development and System Analysis

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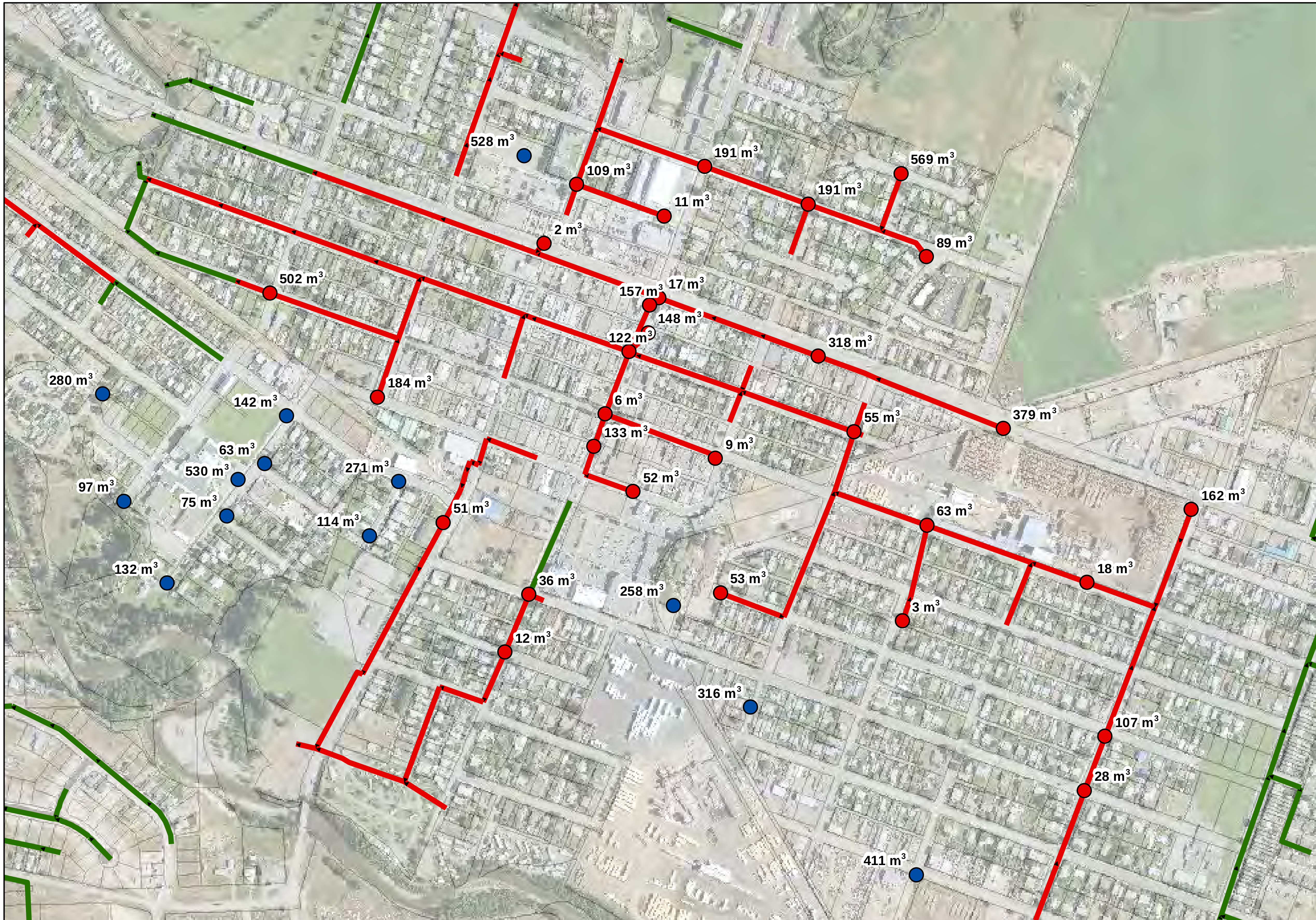
Date: May 2013

Figure 6.3a

City of Merritt



Legend

Detention Pond

Manhole (Floodloss)

100 Yr Flooding

Dry Well (Floodloss)

100 Yr Flooding

System Performance (d/D)

<1

>=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (100-Year Event)

GeoAdvice Engineering Inc.

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N W E S

0 0.1 0.2

Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 6.3b

7. RECOMMENDATIONS

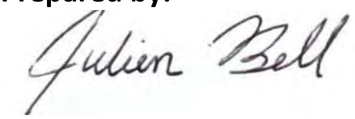
Based on available information, and with consideration of current industry standards, the model is a reasonable representation of the system performance. Where there was uncertainty in model parameters, conservative model assumptions were made. These conservative assumptions generally lead to higher peak flows and total runoff volumes. Should the City of Merritt wish greater certainty in the modeling results, the following data acquisition programs could be undertaken to enhance the model's accuracy and/or capabilities.

1. **Undertake flow monitoring program**: to allow for a more refined model calibration and validation process.
2. **Undertake an infrastructure survey program**: to fill existing infrastructure data gaps such as missing pipe invert and diameter data, detention pond geometry, and confirmation of catch basin, dry well, and driveway culvert locations.
3. **LiDAR survey of the City**: A more detailed Digital Elevation Model (DEM) of the City would allow for the development of a dual drainage model. The dual drainage model would allow for the modeling and quantification of overland flows permitting the City to evaluate the City's current level of services and surface flooding risks under more extreme precipitation events (e.g. 100-year design event).

TECHNICAL MEMORANDUM SUBMISSION

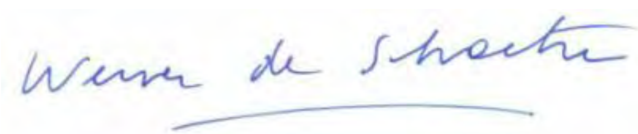
Should the City of Merritt have any questions please do not hesitate in contacting the undersigned.

Prepared by:



Julien Bell, P.Eng.
Project Manager

Reviewed and Approved by:



Werner de Schaetzen, Ph.D., P.Eng.
Technical Director/QA/QC
President & CEO

APPENDIX A DATA REVIEW REPORT

GeoAdvice Engineering Inc.
UNIT 204, 2502 ST. JOHNS STREET
PORT MOODY, BC V3H 2B4
CANADA

January 15th, 2013

MR. ROD MACLEAN, P.ENG. – ASSOCIATED ENGINEERING.
SUITE 610 - 1632 DICKSON AVE.
KELOWNA, BC V1Y 7T2
CANADA

Attention: Mr. Rod MacLean

Re: City of Merritt Integrated Stormwater Management Plan –Model Development and Data Review Report.

Dear Rod:

This letter report is intended to provide an overview summary of the stormwater modeling development and calibration assumptions that will be used to build the City of Merritt stormwater drainage model. Also included in this report is a summary data gap review of the stormwater drainage infrastructure data, with respect to our stormwater drainage modeling needs.

1 DATA REVIEW

1.1 DATA SUMMARY

GeoAdvice has been provided with the following information:

- Site visit photos, and summary field map
- Parcel shapefile
- Orthophotos
- Elevation contours shapefile
- Impervious coverage shapefile
- Surficial soils coverage shapefile
- Flood plain map, with 20 year and 200 year elevations (PDF)
- Storm utility map (PDF)
- Storm utility shapefiles
    - Stormmains
    - Manholes
    - Catchbasins
    - Dry wells
    - Catchbasin leads
    - Ditches

  - o Culverts

1.2 DATA GAP REVIEW

. The following data was reviewed and found to be complete and comprehensive:

- Parcel shapefile
- Orthophotos
- Elevation contours shapefile
- Impervious coverage shapefile
- Surficial soils coverage shapefile
- Flood plain map, with 20 year and 200 year elevations (PDF)

1.2.1 STORM UTILITY REVIEW

The hydraulic model will be built using the following shapefiles:

- Stormmains
- Manholes
- Dry wells
- Ditches
- Culverts

The following provides a summary of the available hydraulic information contained in each of the shapefiles:

<u>Stormmains</u>

The following tables summarize the GIS information provided.

Table 1-1: Stormmains GIS Summary (Slope)

Slope Available?	Number of Stormmains	Length of Stormmains (m)	% of Length	Number of Stormmains to Model*
True	257	17,232.0	76.3%	215
False	80	6,908.9	23.7%	77
Total	**337**	**24,140.9**	**100.0%**	**292**

*The shapefile contains a number of small short stormmain sections that are connected together without an accompanying structure. To limit the number of model elements these short sections, that had matching pipe size and slope, were combined together.

Table 1-2: Stormmain GIS Summary (Diameter)

Diameter (mm)	Number of Stormmains	Length of Stormmains (m)	% of Length	Number of Stormmains to Model
0*	19	314.1	5.6%	2
<=200	30	2,502.0	8.9%	29
>=250	230	16,220.5	68.2%	203
>=600	58	5,104.3	17.2%	58
Total	**337**	**24,140.9**	**100.0%**	**292**

*17 of the 19 elements were mislabelled CB leads, which will be excluded from the model.

Manholes

The following tables summarize the GIS information provided.

Table 1-3: Manhole GIS Summary (Rim Elevation)

Rim Elevation Available?	Number of Manholes	Number of Manholes to Model
True	6	6
False	305	214
Total	**311**	**220**

Table 1-4: Manhole GIS Summary (Invert Elevation)

Invert Elevation (Measured Down) Available?	Number of Manholes	Number of Manholes to Model
True	36	36
False	275	184
Total	**311**	**220**

Table 1-5: Manhole GIS Summary (Diameter)

Diameter (mm)	Number of Manholes	Number of Manholes to Model*
<=250	11	1
600	3	0
900	10	10
1500	1	1
Blank	286	208
Total	**311**	**220**

*The manhole shapefile contains several elements that are disconnected from the stormmain system. Many of these elements appears to be errors resulting from the CAD to GIS conversion, these elements were excluded from the model.

Dry Wells

The following tables summarize the GIS information provided.

Table 1-6: Dry Well GIS Summary (Diameter)

Diameter (mm)	Number of Dry Wells	Number of Dry Wells to Model
900	7	7
Blank	199	169
Total	**206**	**176***

*146 to be modeled as standard manholes, and 30 to be modeled as dry wells

Table 1-7: Dry Well GIS Summary (Rim Elevation)

Rim Elevation Available?	Number of Dry Wells	Number of Dry Wells to Model
True	5	5
False	201	171
Total	**206**	**176***

*146 to be modeled as standard manholes, and 30 to be modeled as dry wells

Table 1-8: Dry Well GIS Summary (Invert Elevation)

Invert Elevation (Measured Down) Available?	Number of Dry Wells	Number of Dry Wells to Model
True	21	21
False	185	155
Total	**206**	**176***

*146 to be modeled as standard manholes, and 30 to be modeled as dry wells

Ditches

The following tables summarize the GIS information provided.

Table 1-9: Ditch GIS Summary (Slope)

Slope Available?	Number of Ditches	Length of Ditches (m)	% of Length	Number of Ditches to Model*
True	6	1,478.2	17.6%	5
False	28	4,242.8	82.4%	28
Total	**34**	**5,721.0**	**100.0%**	**33**

*One ditch section excluded from the model

Culverts

The following tables summarize the GIS information provided.

Table 1-10: Culvert GIS Summary (Diameter)

Diameter (mm)	Number of Culverts	Length of Culverts (m)	% of Length	Number of Culverts to Model
0	1	76.5	5.9%	1
300	1	76.2	5.9%	1
450	13	424.2	76.5%	13
900	2	128.2	11.8%	1
Total	**17**	**705.1**	**100.0%**	**16**

*One culvert excluded from the model

Based on a review of the GIS, there are a significant number of data gaps that will need to be resolved in order to construct the stormwater drainage model. The following sections discuss the methods and assumptions that will be used to resolve these identified data gaps.

1.3 Required Data

The following information is still outstanding, and is required before we can finalize the City's ISMP stormwater modeling.

- Detention structure design drawings

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2 HYDRAULIC MODEL DEVELOPMENT

2.1 STORMMAIN NETWORK CONNECTIVITY

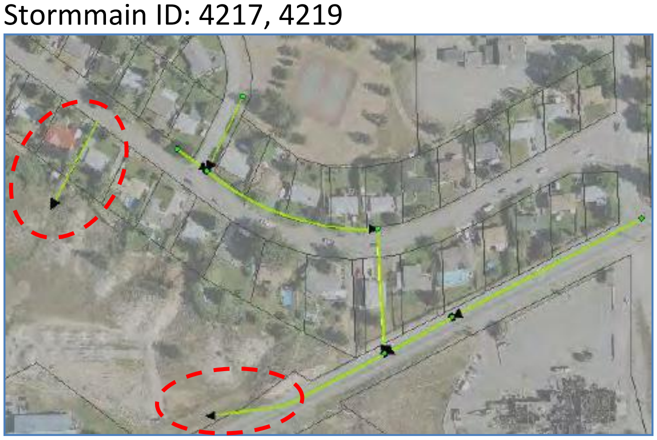
The hydraulic model will be constructed using the GIS data provided. In order to complete the network connectivity, drainage ditches will be added to the model. Ditch alignments will be estimated based:

- Site visit, and photos
- Contour elevations
- Orthophotos

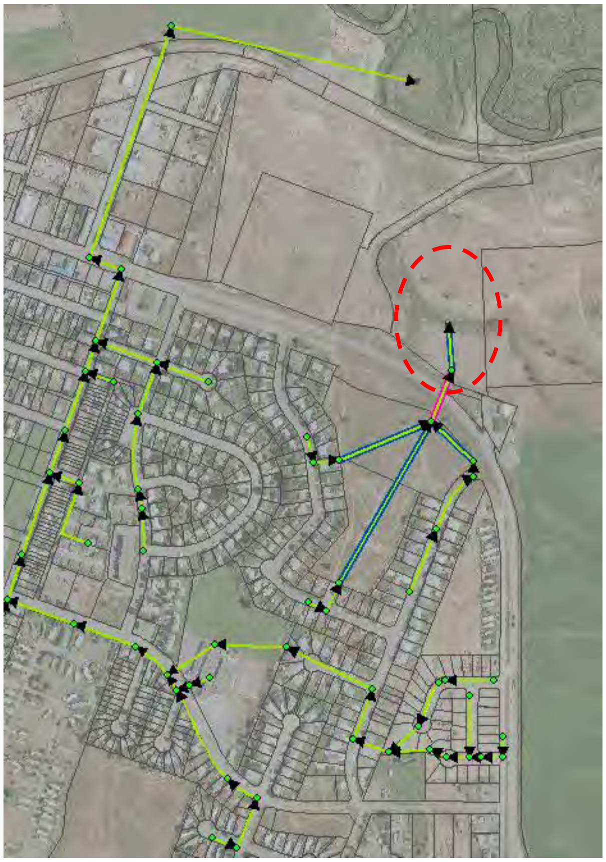
The table below lists the assumptions made in order to complete the model network connectivity.

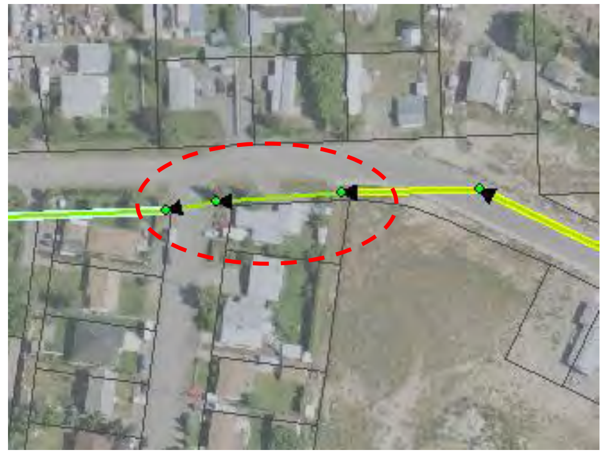
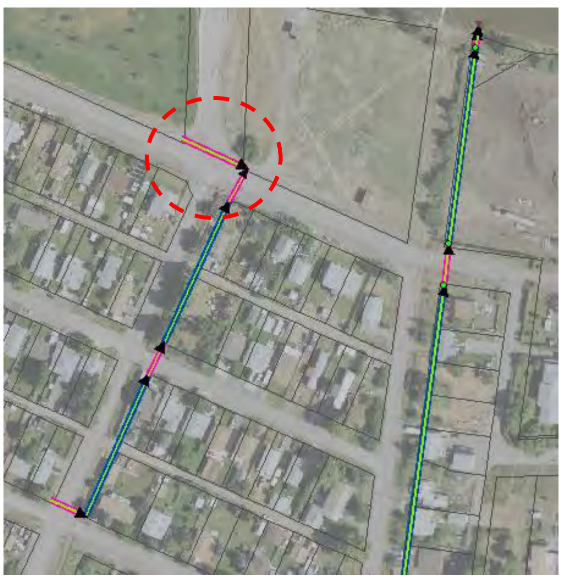
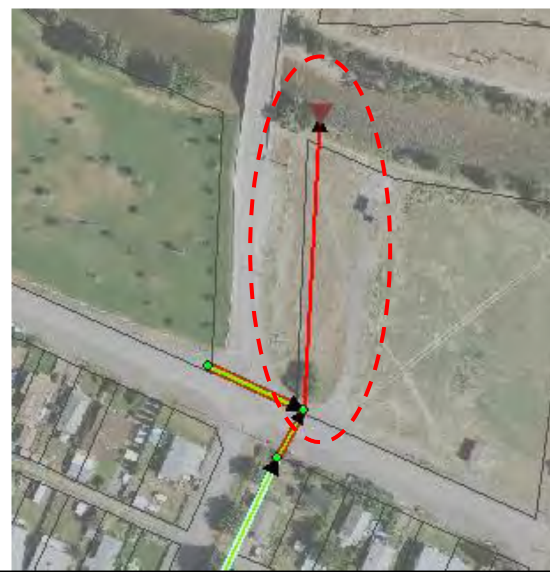
Table 2-1: Network Connectivity Assumptions

Issue #	Description	Assumption
1.	**Missing downstream system**: Reference Culvert ID: 35782 	Add downstream ditch system to connect system to the Nicola River. Based on contour and orthophotos. 
2.	**Missing downstream system:** Reference Stormmain ID: 4122, 4124 	No apparent downstream system. Assume flow infiltrates into the ground. Add model outfalls. 

Issue #	Description	Assumption
3.	**Missing downstream system:** Reference Stormmain ID: 4193 	Add ditch to join downstream system to the south. Based on site photos. 
4.	**Missing downstream system:** Reference Stormmain ID: 4217, 4219 	No apparent downstream system. Assume flow infiltrates into the ground. Add model outfalls 

Issue #	Description	Assumption
5.	**Missing downstream system:** Reference Stormmain ID: 36288 	Add ditch to join system to the south. Based on orthophotos and site photos. 
6.	**Missing downstream system:** Reference Stormmain ID: 4188 	No apparent downstream system. Assume flow infiltrates into the ground. Add model outfall. 

Issue #	Description	Assumption
7.	**Missing downstream system:** Reference Ditch ID: 35794 	Add downstream ditch system to connect system to the Coldwater River. Based on contour and orthophotos. 

Issue #	Description	Assumption
8.	**Missing downstream connection:** Reference Stormmain ID: 36339 	Add ditch and culvert. Based on site photos. 
9.	**Missing downstream connection:** Reference Culvert ID: 36219 	Add downstream ditch system to connect system to the Coldwater River. Based on site photos. 

Issue #	Description	Assumption
10.	**Missing downstream connection**: Reference Ditch ID: 34218. Reference Culvert ID: 36224 	To exclude circled ditch and culvert from the model. Based on site photos.

The table below summarizes the total projected number of modeled conduits (stormmains, culverts, ditches), junctions, outfalls and dry wells. In order to ensure proper network connectivity, several "model" junctions and "model" conduits will need to be added.

Table 2-2: InfoSWMM Model Elements

Element	Model	GIS Elements
Conduit*	358	388*
Junction	359	311
Outfall	22	N/A
Dry Well	30	206

*Includes stormmains, culverts and ditches

2.1.1 RIM ELEVATION

Missing rim elevations will be estimated using available contour elevations.

2.1.2 INVERT ELEVATION

Missing pipe inverts will be estimated using the following stepwise process (assumption level):

- Level 1. Estimated using the measured depth (where available)
- Level 2. Extrapolated using identified pipe slopes,
- Level 3. Interpolated between known upstream and downstream elements
- Level 4. Assuming minimum of pipe cover of 1.0 m

Figure 2-1, **Table 2-3** and **Table 2-4** provide a summary of the degree of "interpolation" used to populate the system inverts.

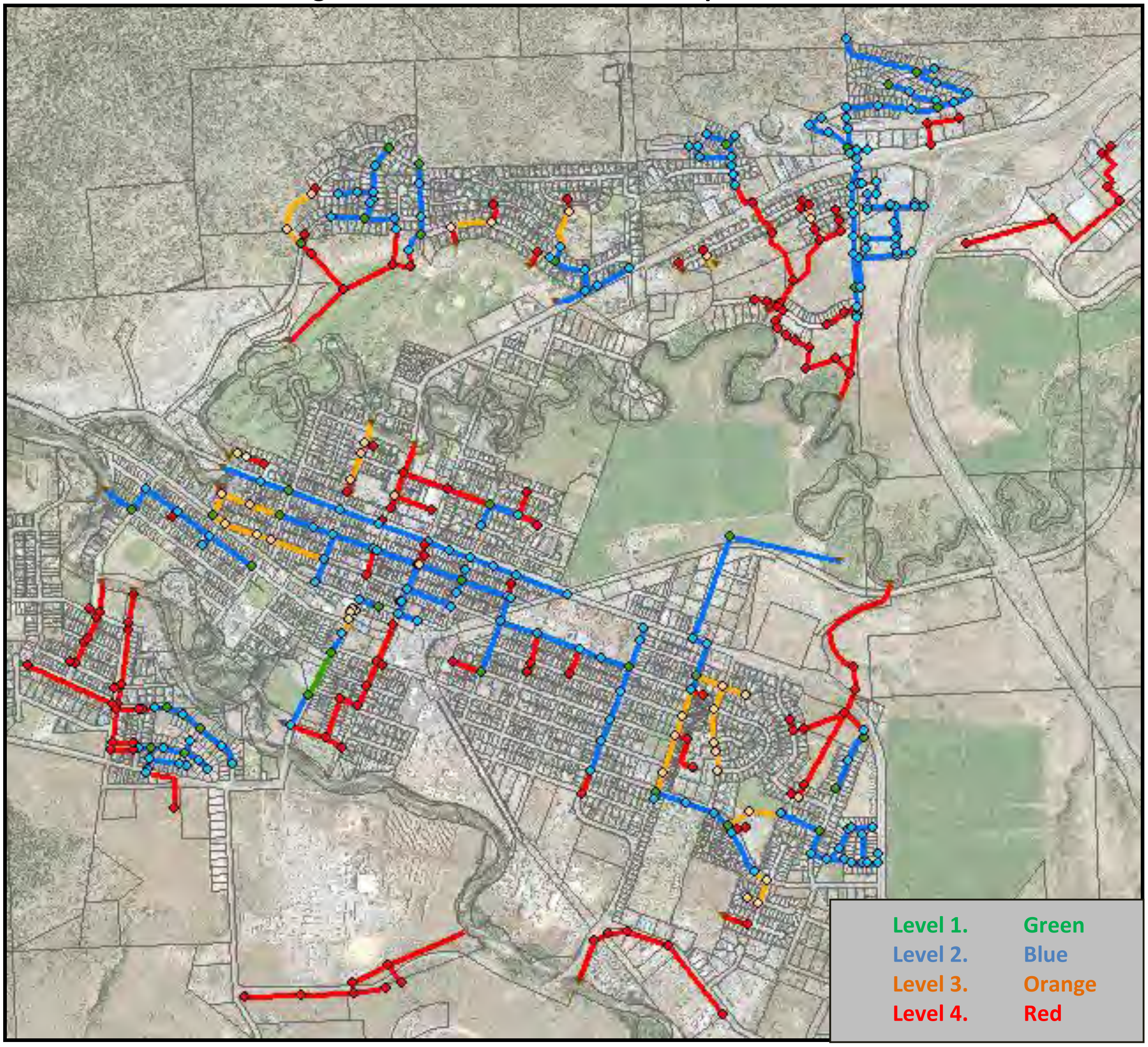
Table 2-3: Conduit Invert Assumption Summary

Pipe Invert	Assumption Level				Total
	1	2	3	4	
Upstream Invert	36	162	38	122	358
Downstream invert	50	160	45	103	358

Table 2-4: Manhole Invert Assumption Summary

Manhole Invert	Assumption Level				Total
	1	2	3	4	
Number of Manholes	36	161	38	124	359

Figure 2-1: Invert Elevation Assumption Levels



Once all pipe inverts have been estimated, the pipe profiles will be reviewed and profile discontinuities will be adjusted to maintain positive drainage to the outfalls.

2.1.3 SYSTEM ROUGHNESSES

The following Manning's n coefficient will be used:

- Stormmains = 0.013
- Culverts = 0.024
- Ditches = 0.050

2.1.4 GEOMETRY

The following element geometries will be used:

- Stormmains
    - Use diameter listed in the GIS
    - If diameter is missing use upstream diameter
- Culverts
    - Use diameter listed in the GIS
    - If diameter is missing assume 600 mm diameter
- Ditches
    - Use trapezoidal section with:
        - 1 m bottom width,
        - 2 m top width, and
        - 0.5m depth

2.1.5 OUTLET BOUNDARY CONDITIONS

The Nicola of Coldstream Rivers will not be included in the model. The system capacity will be evaluated assuming free outflow at the outlets. Further, modeling will include sensitivity analysis to review the impacts of the 20-year freshet level on system performance.

Several systems appear to be discharging to open fields with no clear downstream drainage to the Nicola or Coldstream Rivers. These systems will be modeled with a free outflow.

2.1.6 EXISTING DRY WELLS

The geometry and design capacity of existing dry wells/ infiltration structures are unknown. The following assumptions will be made:

- Infiltration capacity to be estimated using surficial soils information (see Section 2)
- Structure has storage capacity of 10 m^3
- Volume to be reviewed as part of the model validation

The "Dry Wells Drawing" shapefile provided shows dry wells located at unexpected locations (along stormmains). **Figure 2-2** illustrates the elements we propose to model as dry wells, a total of 30 dry wells. We propose modeling all other structures as conventional manholes.

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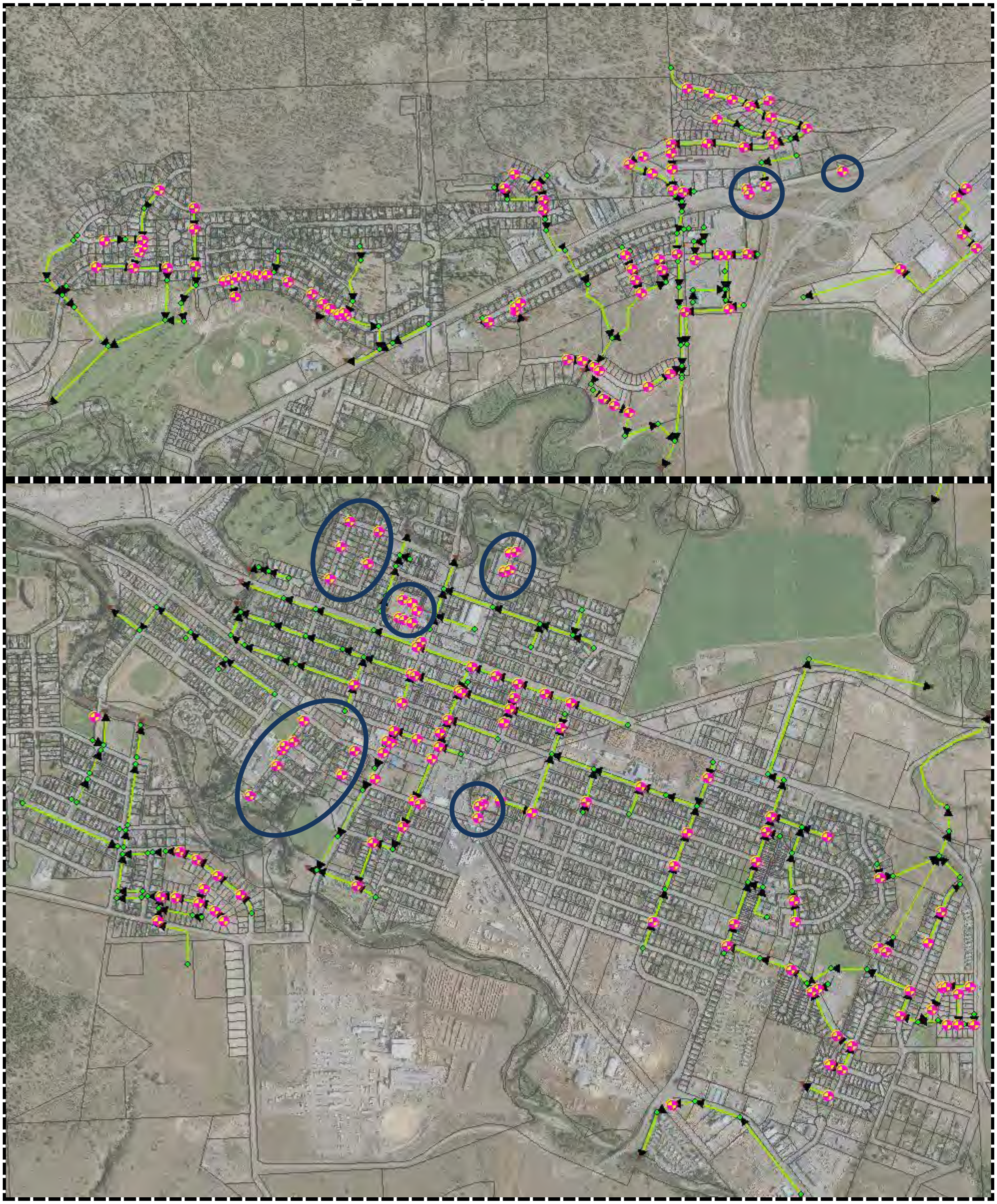
Figure 2-2: Dry Wells to Model



2.1.7 EXISTING DETENTION PONDS

The geometry and outlet control of existing detention ponds are unknown. The detention pond design drawings are required in order to model the detention ponds.

3 HYDROLOGIC MODEL DEVELOPMENT

3.1 CATCHMENT GEOMETRY

3.1.1 CATCHMENT DELINEATION

Stormwater drainage catchments will be manually delineated using:

- LiDAR
- Orthophoto
- Existing drainage infrastructure

When delineating the drainage catchments we will assume that roadways have either a roadside ditch/swale or curb acting as a localized drainage barrier.

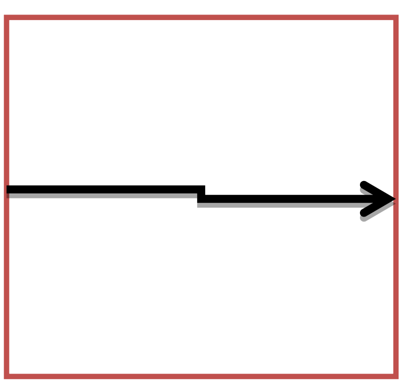
3.1.2 CATCHMENT WIDTH

Catchment width will be estimated based on catchment area using the relationship below:

$$W = \frac{A}{L};\ L = 1.75 * \sqrt{A}$$

Rationale: That a combination of catchment shape and local flow barriers increase the overland flow length

$L = \sqrt{A}$



$L = 1.75 * \sqrt{A}$

3.1.3 CATCHMENT SLOPE

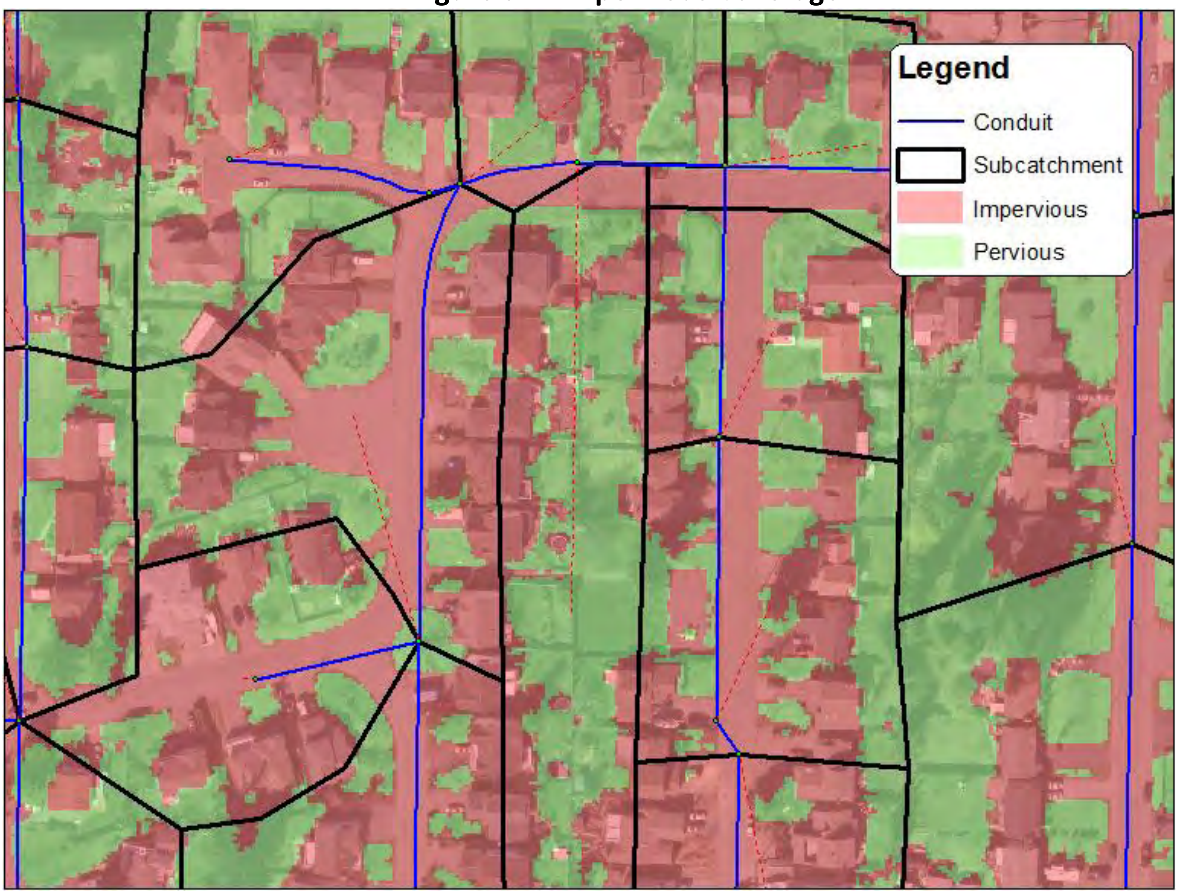
Catchment slope will be estimated using the local topography using the following equation (please see rational for catchment width):

$$Slope_{catchment} = \frac{Slope_{Topography}}{2}$$

3.2 CATCHMENT IMPERVIOUS

Impervious coverage will be estimated using impervious coverage provided. Each catchment's impervious coverage will be individually calculated. See figure below for example.

Figure 3-1: Impervious Coverage



3.3 SOIL INFILTRATION

The model will use the Green Ampt method to calculate soil infiltration. Green Ampt parameters will be estimated based on the surficial soils as follows:

Table 3-1: Surficial Soil Types

Symbol	Name	Soil Parent Material	Drainage	Soil Texture Classification	Model Hydraulic Connectivity (mm/hr)	Hydraulic Connectivity low (mm/hr)	Hydraulic Connectivity High (mm/hr)
CG	Cavanaugh	Gravelly, coarse textured colluvial and colluvial fan deposits, moderately to exceedingly stony.	well	Gravel	2.18E+01	3.60E+03	3.60E+06
CO	Commonage	Coarse textured colluvial fan deposits; moderately to very stony.	well	Gravel	2.18E+01	3.60E+03	3.60E+06
TM	Timber	Medium and moderately fine textured morainal deposits; slightly to moderately stony.	well	Clayey silt gravel sand	2.18E+01	3.60E-06	3.60E+00
TP	Trapp Lake	Medium and moderately fine textured morainal deposits; slightly to moderately stony.	well	Clayey silt gravel sand	2.18E+01	3.60E-06	3.60E+00
GD	Godey	Gravelly, coarse textured fluvioglacial deposits with thin, loamy or sandy eolian cappings, slightly to very stony.	rapid	Sandy gravel	2.36E+02	3.60E+00	3.60E+04
GS	Glimpse	Coarse and moderately coarse textured textured fluvioglacial deposits; moderately to very stony.	rapid-well	Sandy gravel	2.36E+02	3.60E+00	3.60E+04
GY	Glossey	Gravelly, coarse textured fluvioglacial deposits with gravelly, loamy cappings; moderately to very stony.	rapid-well	Sandy gravel	2.36E+02	3.60E+00	3.60E+04
SM	Shumway	Moderately coarse and medium textured fluvial and fluvioglacial fan deposits; stone-free or slightly stony.	well	Sand	2.18E+01	1.80E+01	3.60E+04
LM	Lundbom	Moderately fine textured lacustrine deposits; stone-free.	well	Silty Clay Loam	2.18E+01		
LD	Lac du Bois	Medium and moderately fine textured lacustrine deposits; stone-free.	well	Silty Clay Loam	2.18E+01		
FS	Frances	Moderately coarse and medium textured fluvial deposits; stone-free.	imperfect	Sandy Loam	2.0E+00		

3.4 REMAINING HYDROLOGICAL PARAMETERS

All remaining hydrological parameters will be globally applied as follows:

Table 3-2: Hydrological Parameters

Parameter	Units	Value	
		Pervious	Impervious
Manning's n	()	0.25	0.020
Depression Storage	mm	1.5	5

These values will be reviewed and adjusted as part of the model validation.

4 RAINFALL DATA

4.1 DESIGN EVENTS

Design rainfall depths will be estimated using the Environment Canada IDF curve for the City of Merritt.

The drainage system will be evaluated under the following design events:

- 2 year
- 10 year
- 100 year

5 MODEL VALIDATION

The model will be validated by simulating the 2 year and 10 year design events and comparing the modeled performance against the performance information provided by City Staff. See questionnaire.

6 EVALUATION CRITERIA – AE TO DEFINE

The system capacity will be evaluated using the following criteria:

Pipe system:

- 10 year – maintain system HGL within the pipe
- 100 year – provide a safe overland flow path for the 100 year flow

Dry wells:

- 10 year – sufficient storage to manage the 10 year flows

We request that AE please review and validate are proposed modeling assumption.

We trust that the above meets your requirements. Should you have any questions please do not hesitate in contacting the undersigned.

Thanks you for your continued support.

Regards.

Julien Bell

Julien Bell, P.Eng.
Water Resource Engineer

APPENDIX B INFOSWMM SOFTWARE OVERVIEW

The following is a brief overview of the InfoSWMM modeling software. Much, of the information below was collected from Innovyze InfoSWMM website. http://www.innovyze.com/products/infoswmm/ and the EPA SWMM website http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/.

InfoSWMM is a fully-dynamic sanitary, combined sewer, and stormwater management modeling software that can analyze sanitary, combined sewer, and stormwater systems using the industry standard EPA SWMM engine. InfoSWMM offers a direct link to GIS operating as a module within the ArcGIS program.

InfoSWMM can be used to model the entire land phase of the hydrologic cycle as applied to urban stormwater performing either single event or long-term (continuous) rainfall-runoff simulations accounting for:

- time-varying rainfall
- evaporation of standing surface water
- snow accumulation and melting
- rainfall interception from depression storage
- infiltration of rainfall into unsaturated soil layers
- percolation of infiltrated water into groundwater layers
- interflow between groundwater and the drainage system
- nonlinear reservoir routing of overland flow
- runoff reduction via Low Impact Development (LID) controls

Spatial variability in all of these processes are achieved by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed:

- between sub-areas,
- between subcatchments, or
- between entry points of a drainage system.

InfoSWMM can also predict runoff quality including buildup and washoff of pollutants from primarily urban watersheds.

InfoSWMM program routes flows through the drainage network using a 1-D hydraulic model that supports:

- a wide variety of standard closed and open conduit shapes as well as natural channels
- special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- either kinematic wave or full dynamic wave flow routing methods
- various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels

Further detail on the key hydraulic and hydrologic parameters and the general assumptions and capabilities of the InfoSWMM model, please refer to the InfoSWMM and EPA SWMM websites.

APPENDIX C MODELING ASSUMPTIONS AND DATA

Table C.1 summarizes the model inventory of the existing system.

Table C.1: Stormwater System Model Inventory

Component	Total
Number of Conduits:	375 (34 km)
Number of Pumps:	0
Number of Orifices:	0
Number of Weirs:	0
Number of Network Nodes:	410
Number of Junctions:	369
Number of Dividers:	0
Number of Outfalls:	20
Number of Storage Features:	21
Number of Subcatchment:	357 (2,053 ha)

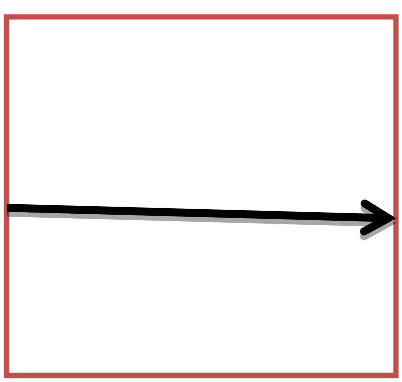
Subcatchment Width and Slope

The subcatchment width is estimated based on the catchment area using the relationship below:

$$W = \frac{A}{L} \qquad ; \qquad L = 1.75 * \sqrt{A}$$

Rationale: That both catchment shape and local flow barriers increase the overland flow length.

$L = \sqrt{A}$



$L = 1.75 * \sqrt{A}$

The drainage catchment was divided into 18 zones and outer subcatchments (see **Figure C.1**); based on general catchment configuration and site topography. The subcatchments within the same zone were assigned the same slope.

Catchment slope was estimated using the local topography using the following equation (Refer to rational for catchment width):

$$Slope_{catchment} = \frac{Slope_{Topography}}{1.5}$$

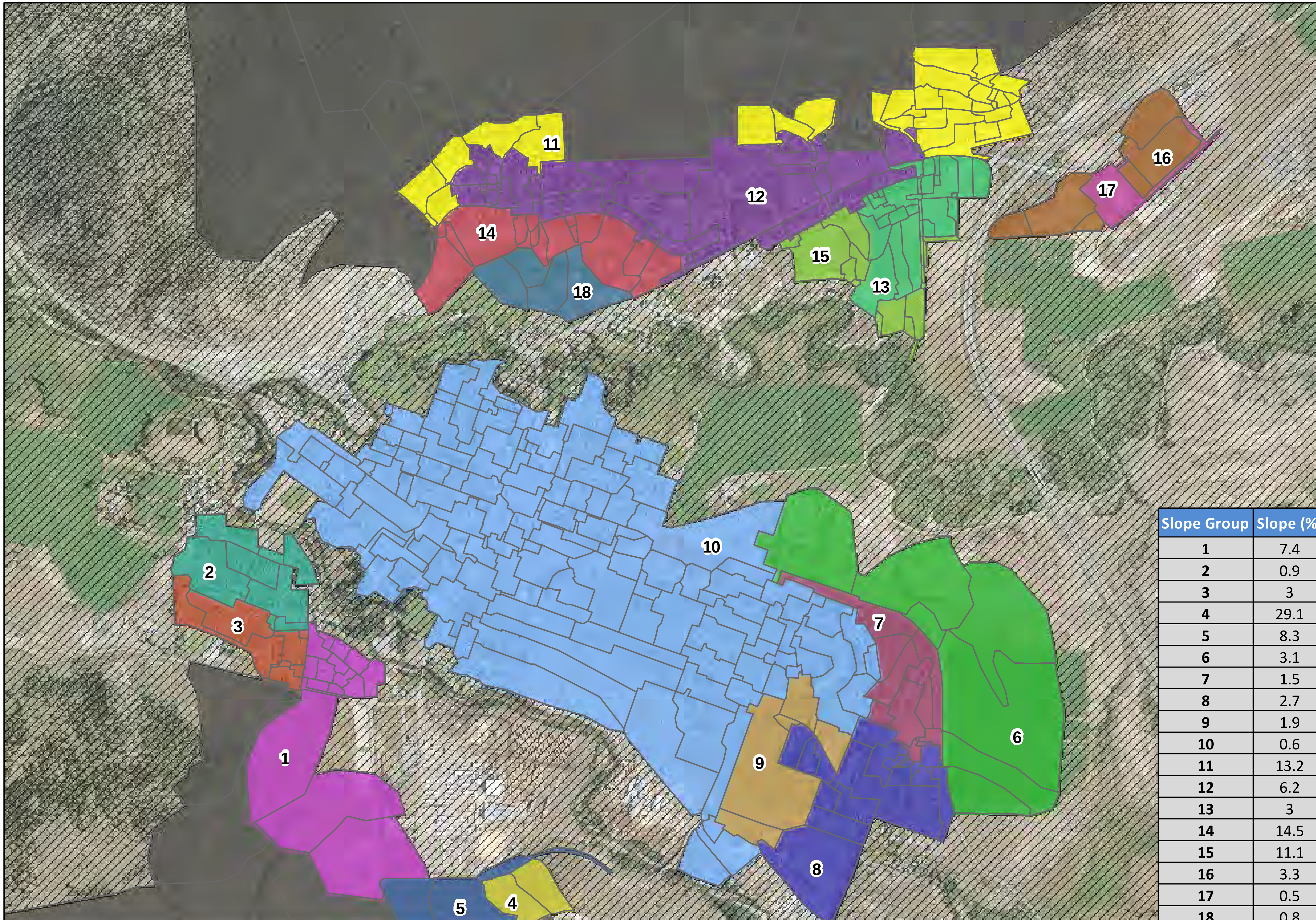
Outer subcatchment widths and slopes were calculated independently based on site topography.

Table C.2: Subcatchment Slope

Slope Group	Slope (%)
1	7.4
2	0.9
3	3.0
4	29.1
5	8.3
6	3.1
7	1.5
8	2.7
9	1.9
10	0.6
11	13.2
12	6.2
13	3.0
14	14.5
15	11.1
16	3.3
17	0.5
18	0.8
Outer*	N/A

*Slopes of outer subcatchments were calculated independently on a catchment by catchment basis.

City of Merritt



Slope Group	Slope (%)
1	7.4
2	0.9
3	3
4	29.1
5	8.3
6	3.1
7	1.5
8	2.7
9	1.9
10	0.6
11	13.2
12	6.2
13	3
14	14.5
15	11.1
16	3.3
17	0.5
18	0.8

Legend

Subcatchment

Slope Group

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18

Outer Subcatchments

Not Modeled

Engineering base plan provided by Summit Environmental Consultants Inc.

Slope Groups

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N S W E

0 0.5 1

Kilometers

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Date: May 2013

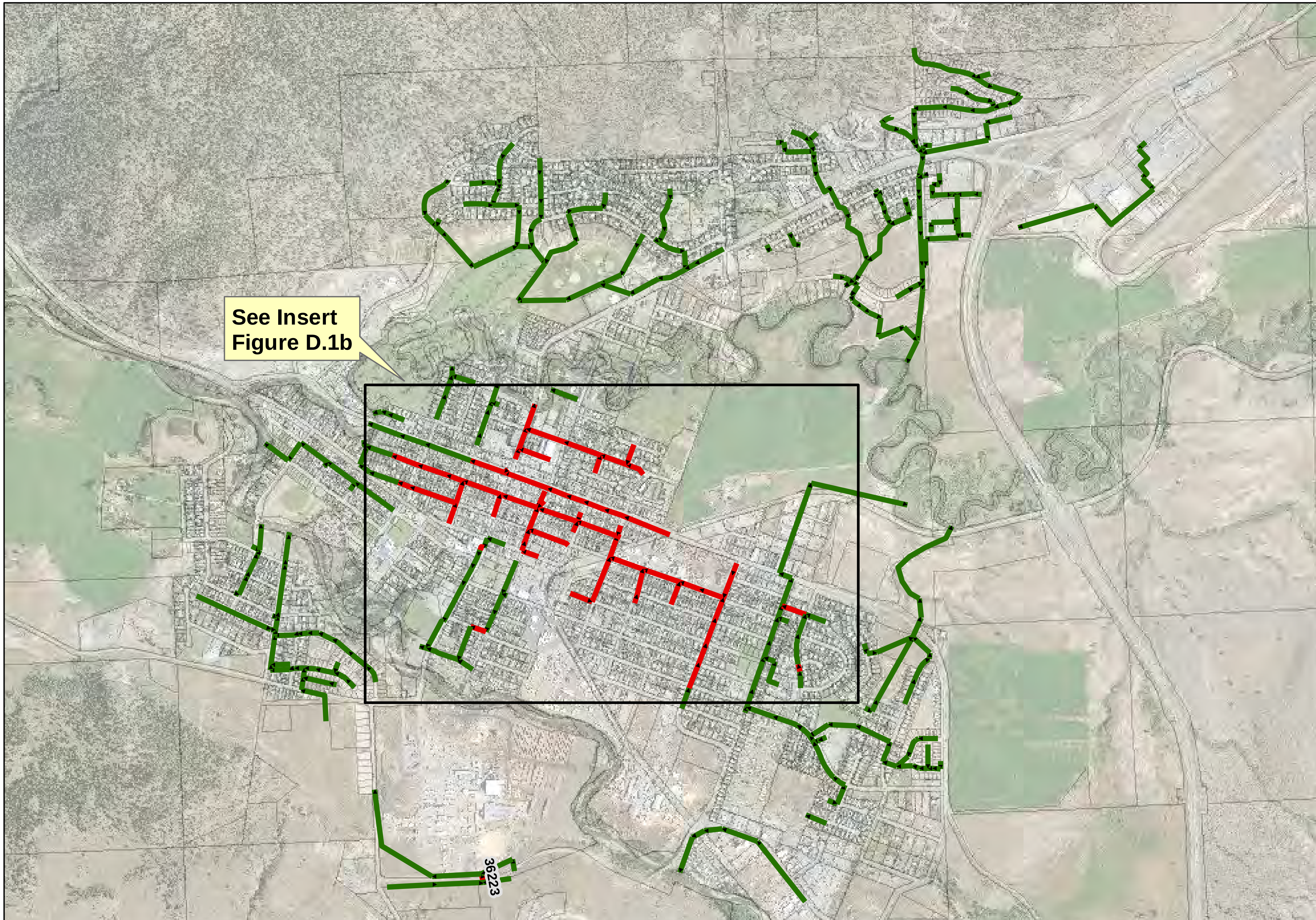
Figure C.1

APPENDIX D EXISTING SYSTEM DEFICIENCIES

Table D.1: Surcharged Pipes (10-year Event)

Conduit ID	Length (m)	Diameter (mm)	Pipe Type
4303	204	300	Stormmain
36280	204	250	Stormmain
4340	202	300	Stormmain
4456	197	400	Stormmain
4300	179	450	Stormmain
4454	179	300	Stormmain
4452_1	171	200	Stormmain
4453	167	600	Stormmain
4341	165	450	Stormmain
4358	165	600	Stormmain
4452	165	200	Stormmain
4380	154	600	Stormmain
4357	151	400	Stormmain
4285	147	450	Stormmain
4451	139	200	Stormmain
4442	131	525	Stormmain
36276	116	450	Stormmain
4267	115	200	Stormmain
36268	114	200	Stormmain
36271	113	200	Stormmain
36395	112	300	Stormmain
4342	110	200	Stormmain
4321	107	300	Stormmain
36257	107	300	Stormmain
4464_1	104	200	Stormmain
4343	103	300	Stormmain
36394	101	300	Stormmain
36275	101	300	Stormmain
4373	100	300	Stormmain
4409	97	300	Stormmain
4464	96	200	Stormmain
4284	95	450	Stormmain
36269	94	300	Stormmain
4396	93	300	Stormmain

Conduit ID	Length (m)	Diameter (mm)	Pipe Type
4299	92	400	Stormmain
4281	92	400	Stormmain
4269	90	200	Stormmain
4314	89	300	Stormmain
36267	87	200	Stormmain
4301	84	400	Stormmain
4268	83	200	Stormmain
4276	79	200	Stormmain
4296	78	400	Stormmain
36398	76	300	Stormmain
4390	74	250	Stormmain
4356	74	500	Stormmain
36410	69	600	Stormmain
4428	54	150	Stormmain
4261	52	300	Stormmain
4395_1	52	300	Stormmain
36331	49	200	Stormmain
4350	48	200	Stormmain
36330	46	300	Stormmain
4395	43	300	Stormmain
4291	42	200	Stormmain
36399	40	300	Stormmain
36272	38	200	Stormmain
36263	33	300	Stormmain
36337	20	200	Stormmain
4399	16	300	Stormmain
36332	14	450	Stormmain
4398	13	300	Stormmain
4411	13	600	Stormmain
4363	11	600	Stormmain
4385	11	300	Stormmain
36223	38	450	Culvert



City of Merritt

Legend

System Performance (d/D)

- <1
- >=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (10-Year Event)

Surcharged Pipes

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0 0.5 1
Kilometers

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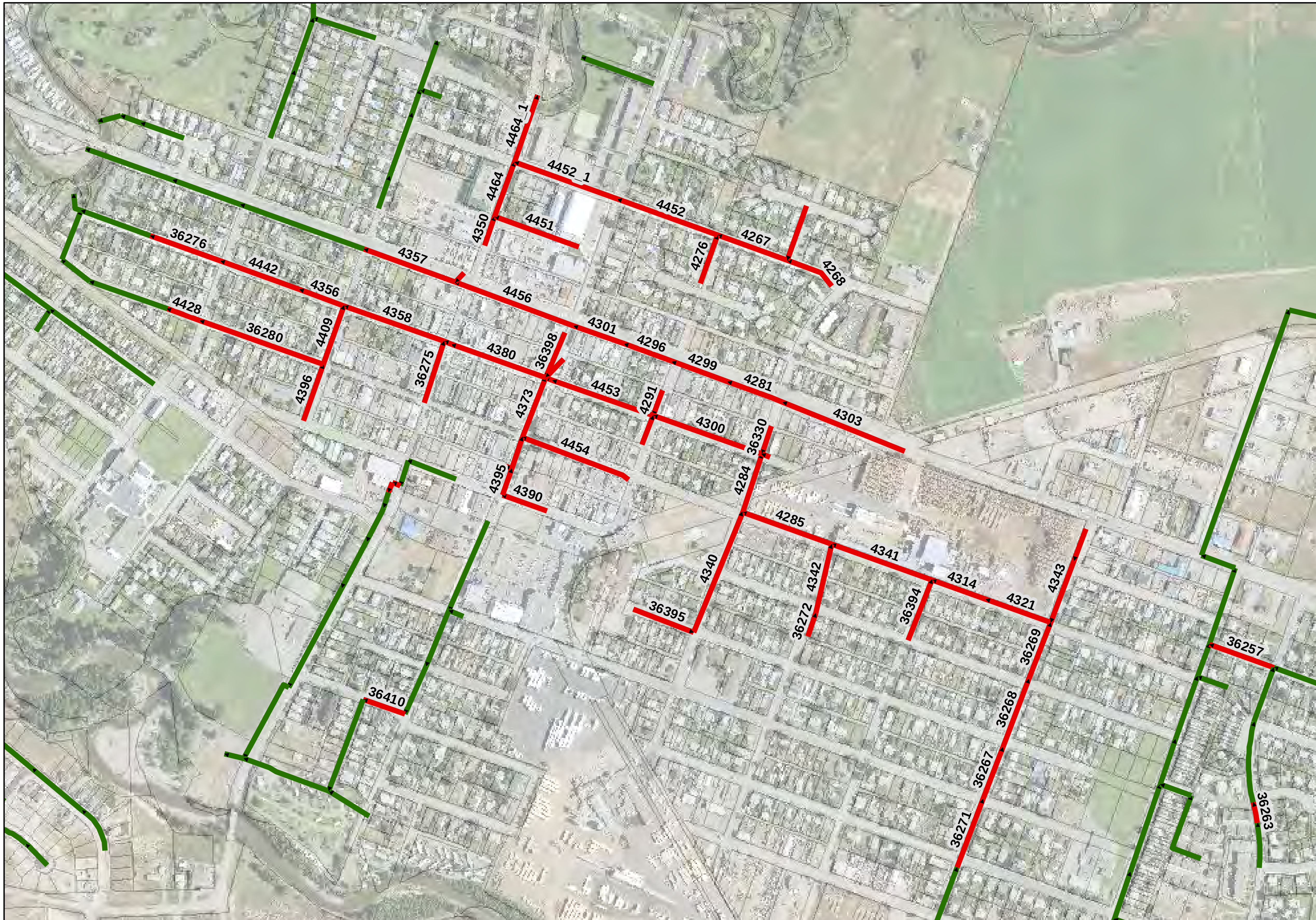
Figure D.1a



City of Merritt

Legend

System Performance (d/D)

- <1
- >=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (10-Year Event)

Surcharged Pipes

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N S W E

0 0.15 0.3

Kilometers

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Date: May 2013

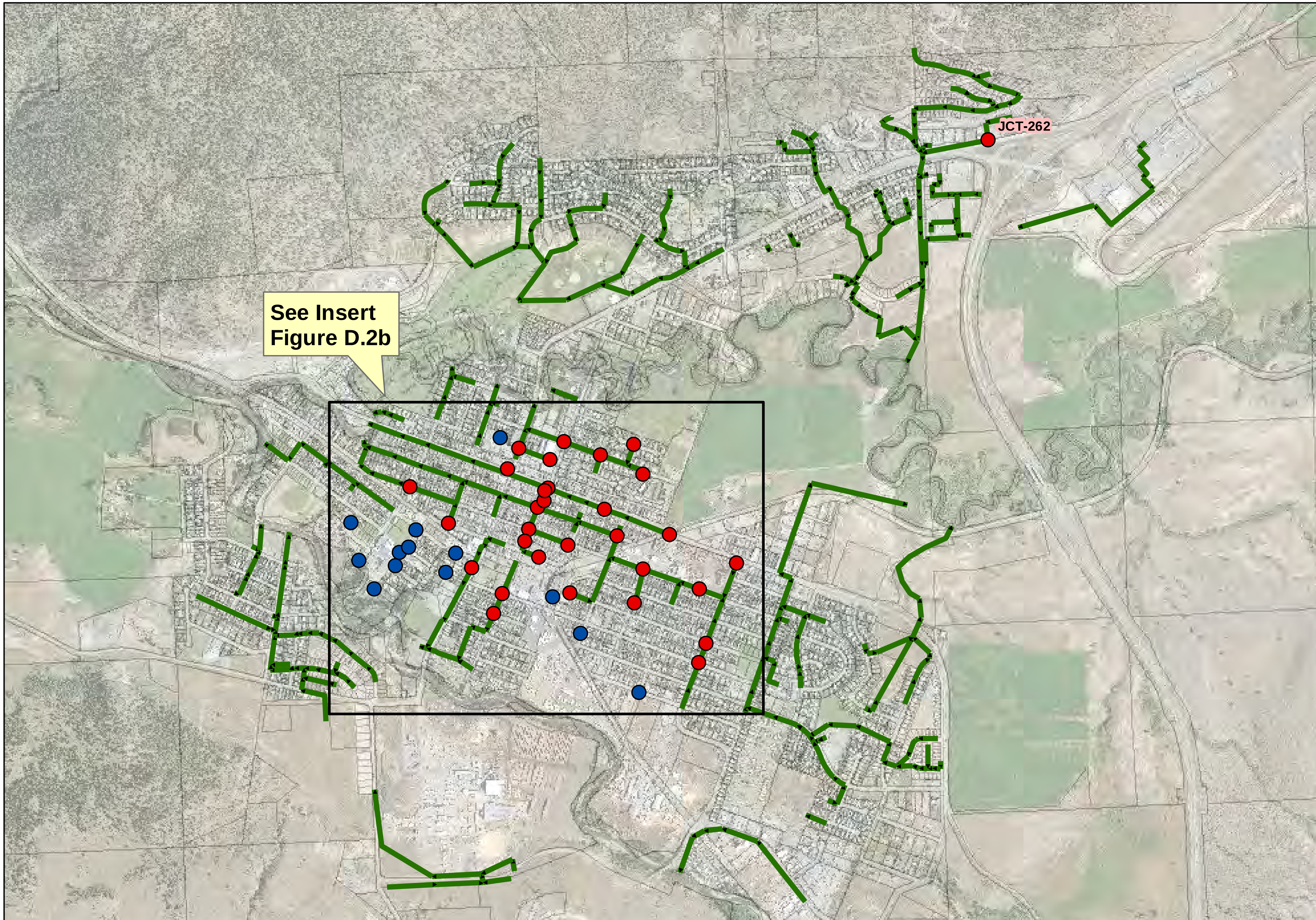
Figure D.1b

Table D.2: Junction Floodloss Volume (100-year Event)

Junction ID	Floodloss Volume (m^3)
JCT-124	569
JCT-100	502
JCT-110	379
4912	318
4908	191
JCT-120	191
JCT-98	184
JCT-82	162
36397	157
36396	148
JCT-84	133
5019	122
4992	109
4974	107
JCT-122	89
4919	63
4925	55
JCT-226	53
5040	52
5072	51
JCT-230	36
4971	28
JCT-262	20
4963	18
4906	17
JCT-232	12
4903	11
4942	9
5031	6
JCT-88	3
4998	2

Table D.3: Dry Well Floodloss Volume (100-year Event)

Dry Well ID	Floodloss Volume (m^3)
STU-12	530
STU-06	528
STU-17	411
STU-18	316
STU-07	280
STU-16	271
STU-19	258
STU-14	142
STU-09	132
STU-15	114
STU-08	97
STU-11	75
STU-13	63



City of Merritt

Legend

- Conduit
- Flooding Junction
- Flooding Dry Well

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (100-Year Event)

Flooding Junctions & Dry Wells

GeoAdvice Engineering Inc.

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N S W E

0 0.5 1

Kilometers

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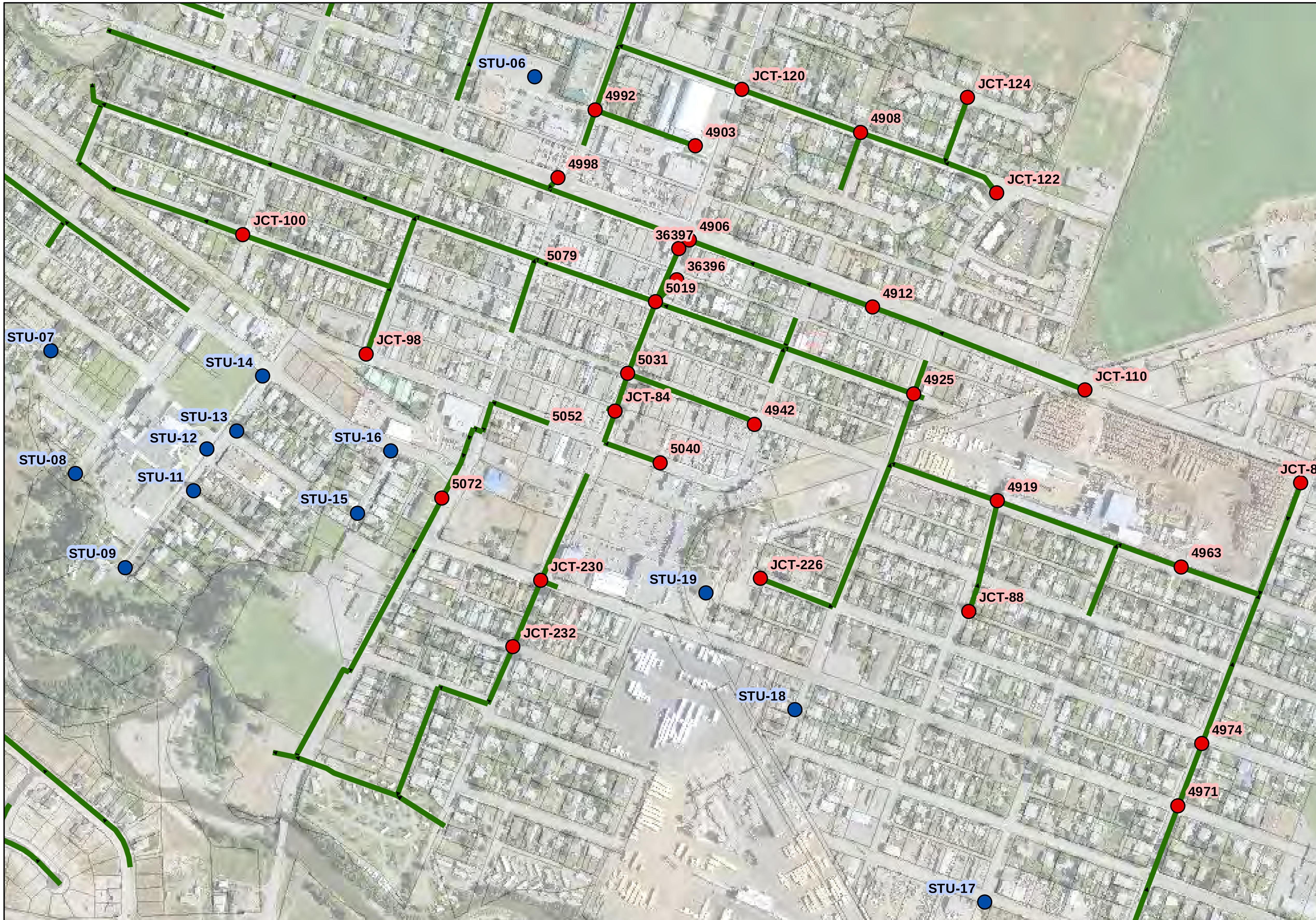
Date: May 2013

Figure D.2a

City of Merritt



Legend

- Conduit
- Flooding Junction
- Flooding Dry Well

Engineering base plan provided by Summit Environmental Consultants Inc.

Existing System Performance (100-Year Event)

Flooding Junctions & Dry Wells

GeoAdvice Engineering Inc.

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N W E S

0 0.15 0.3

Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure D.2b

Appendix F - Model Results - GeoAdvice

City of Merritt ISMP – Future System Performance Review

TECHNICAL MEMORANDUM #2

Task No. 301

Final

Prepared for:
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Port Moody, BC V3H 2B4

First Issue Date: **May 7th, 2013**

Contact: Mr. Julien Bell, P.Eng.
Re: Project 2012-038-MER

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Statement of Qualifications and Limitations

This document represents GeoAdvice Engineering Inc. best professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinary exercised by member of the engineering profession currently practicing under similar conditions. No warranty, express or implied is made.

Table of Contents

1. INTRODUCTION

The City of Merritt retained Associated Engineering (AE) and GeoAdvice Engineering Inc. (GeoAdvice) to complete the City of Merritt Integrated Stormwater Management Plan (ISMP). The primary objective of this study is to develop a long-term plan that meets the requirements of the Ministry of Environment for ISMP.

To meet the objective of this study, GeoAdvice developed an "all-pipes" model of the City's stormwater system using InfoSWMM (Innovyze Inc. software), the details of which are documented in the Technical Memorandum *"Merritt ISMP – Model Development and System Analysis"*, Task No. 201/202.

This phase of the study is to evaluate the impacts of proposed development sites and localized stormwater system modifications will have on the existing drainage infrastructure.

2. SCOPE OF WORK

The scope of this memorandum covers the following items:

- Summarize the proposed development sites and localized stormwater system modifications;
- Analyze the existing system performance under the proposed future conditions;
- Size the proposed localized stormwater system modifications; and
- Identify the system improvements required to convey the 10-year future condition flows.

3. FUTURE SYSTEM OVERVIEW

3.1 FUTURE LANDUSE CHANGE

In 2010, the City of Merritt developed their Official Community Plan (OCP) setting out the City's long-term (20-year) growth plan. The OCP identifies a number of "Development Areas" for both residential and ICI developments; however, the OCP does not quantify the anticipated growth for each of these "Development Areas". In consultation with the City, AE identified the potential form and location of these future developments that will be used to assess future conditions. A total of eight "Development Areas" impacting the City's existing drainage system were identified.

Table 3-1 provides a summary of the eight development areas. The development areas are further summarized in **Figure 3-1**. Impervious coverage was estimated using existing typical residential and commercial coverage.

Table 3-1: Developments Areas

Development	Development Type	Subcatchment Model ID	Estimated Area (ha)	Impervious Coverage (%)
Ponderosa	Residential	FUT-SUB-DEV-1	50	45%
Walters	Residential	FUT-SUB-DEV-2	50	45%
Grandview Heights	Residential	FUT-SUB-DEV-3	50	45%
Midday - A	Residential	FUT-SUB-DEV-4	28	45%
Midday - B	Residential	FUT-SUB-DEV-5	50	45%
Midday - C	Residential	FUT-SUB-DEV-6	50	45%
Pooley	Residential	FUT-SUB-DEV-7	5	55%*
Airport	Commercial	FUT-SUB-DEV-8	5	85%

*Typical residential impervious coverage for south east Merritt

3.2 PROPOSED LOCALIZED STORMWATER SYSTEM MODIFICATION

As part of the first phase of the ISMP, the City had identified a number of areas with known drainage issues and/or areas the City wishes to implement a formalized pipe stormwater drainage system. Further, the "*105 - Hydrogeology*" report identified the south west portion of Downtown Merritt (Coldwater) that currently uses dry wells to manage the stormwater runoff are within the City's drinking water aquifer. In consultation with the City, AE has recommended that these dry wells within the aquifer boundary be decommissioned and a formalized pipe stormwater drainage system be installed.

New stormwater infrastructure was reviewed for the following three areas; Coldwater, Collettville, and Downtown. The layouts of the new systems were provided by AE, and were sized to convey the 10-year design storm, with a minimum pipe diameter of 375 mm. A pipe diversion, located east of the rail right-of-way, was also proposed as part of the stormwater system modification in the Downtown area. The diversion redirects flow, along Quilchena Avenue, southwest to Garcia Street.

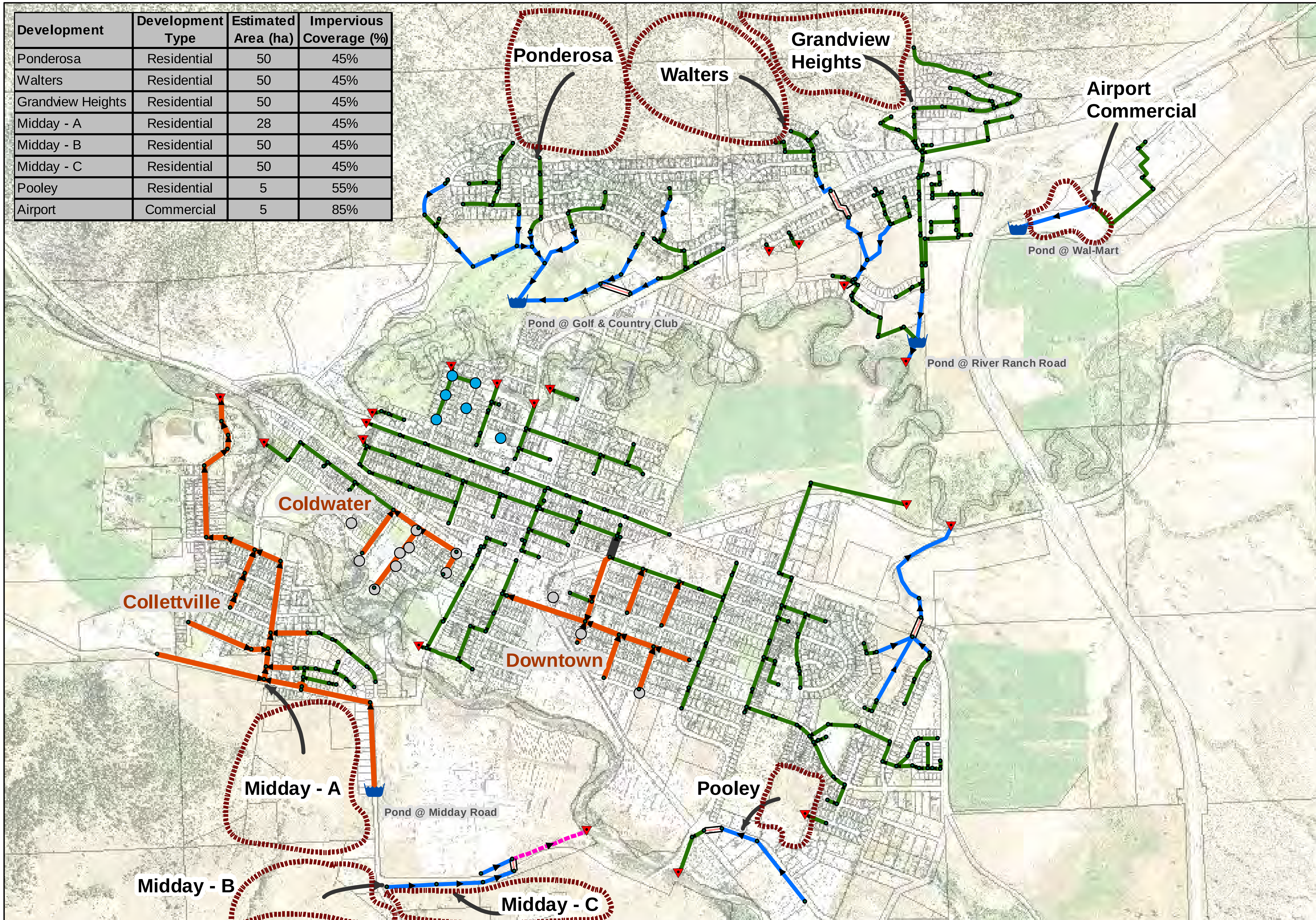
Table 3-2 summarizes the sizing of the new pipe stormwater system and **Figure 3-1** highlights the location of the proposed stormwater system modifications. The proposed pipe sizes are also summarized in **Figure 5-1**.

Table 3-2: New Stormwater System

Location	Diameter (mm)	Length (m)
Downtown	375	880
	600	770
	750	350
	Subtotal	**1,990**
Collettville	375	2,260
	450	550
	525	620
	Subtotal	**3,430**
Coldwater	375	970
	Subtotal	**970**
Total		**6,390**

City of Merritt

Development	Development Type	Estimated Area (ha)	Impervious Coverage (%)
Ponderosa	Residential	50	45%
Walters	Residential	50	45%
Grandview Heights	Residential	50	45%
Midday - A	Residential	28	45%
Midday - B	Residential	50	45%
Midday - C	Residential	50	45%
Pooley	Residential	5	55%
Airport	Commercial	5	85%



Legend

- Outfall
- Detention Pond
- Culvert

Dry Well
- Existing
- Decommissoned

Stormmain
- Existing
- Proposed
- Decommissioned (flow diversion)

Ditch
- Existing
- Proposed

Engineering base plan provided by Summit Environmental Consultants Inc.

System Overview & Future Development

GeoAdvice Engineering Inc.

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N W E S

0 0.5 1
Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure 3-1

4. FUTURE SYSTEM PERFORMANCE REVIEW – 20 YEAR GROWTH SCENARIO

4.1 EVALUATION CRITERIA

The evaluation criteria used to assess the future City of Merritt drainage system are summarized below:

Pipe system:

1. 10-year – maintain system HGL within the pipe
2. 100-year – provide a safe overland flow path for the 100-year flow

Dry well:

3. 10-year – sufficient storage to manage the 10-year flow

4.2 FUTURE SYSTEM MODELING

To assess the future system performance, the existing InfoSWMM model was modified to reflect the landuse changes specified in **Section 3**. The future system model modifications included:

- Modifying the existing catchment boundaries and impervious coverage as summarized in **Table 3-1** and shown in **Figure 3-1**.
- Removing existing drywells and modifying the local drainage system as summarized **Section 3.2** and shown in **Figure 3-1**.

All other infrastructure data, model parameters, and modeling assumptions remained unchanged.

Further details on the existing model development and the InfoSWMM modeling software are summarized in GeoAdvice Technical Memorandum *"Merritt ISMP – Model Development and System Analysis"*, Task No. 201/202.

4.3 FUTURE SYSTEM PERFORMANCE

The performance of the proposed future system, new developments and localized stormwater system modifications, were assessed under the 10-year and 100-year design events. **Table 4-1** and **Table 4-2** summarize the critical system performance results.

Table 4-1: System Flooding

Model Results	10-year System Performance (E/F)*	100-year System Performance (E/F)*
# of Junctions with Surface Flooding	15/9	31/26
Total Junction Floodloss Volume (m^3)	891/995	3,795/5,147
# of Dry Wells Flooded**	9/1	13/1
Total Dry Well Floodloss Volume (m^3)	1,396/304	3,218/528

*(E/F) = (Existing Landuse & System/Future Landuse & System)

**Nine (9) dry wells in the Collettville area and three (3) dry wells in the Downtown area were removed from the future system due to the implementation of pipe stormwater drainage system

In the future system there is an increase in total system flows due to an increase in the total impervious are coverage; leading to an overall increase in system flood volume and length of surcharged pipes. However, the proposed pipe diversion in the Downtown area that redirects flow, along Quilchena Avenue, southwest to Garcia Street does help to reduce the total number of junctions that are expected to experience surface flooding.

Table 4-2: Surcharged Pipes

	Length of Surcharged Pipes (m) (d/D >1)*	% of Total Pipe Length**
Duration\Return Period	**10-year Storm Event (E/F)*** **	
12-hour	6,299/6,350	19%/17%

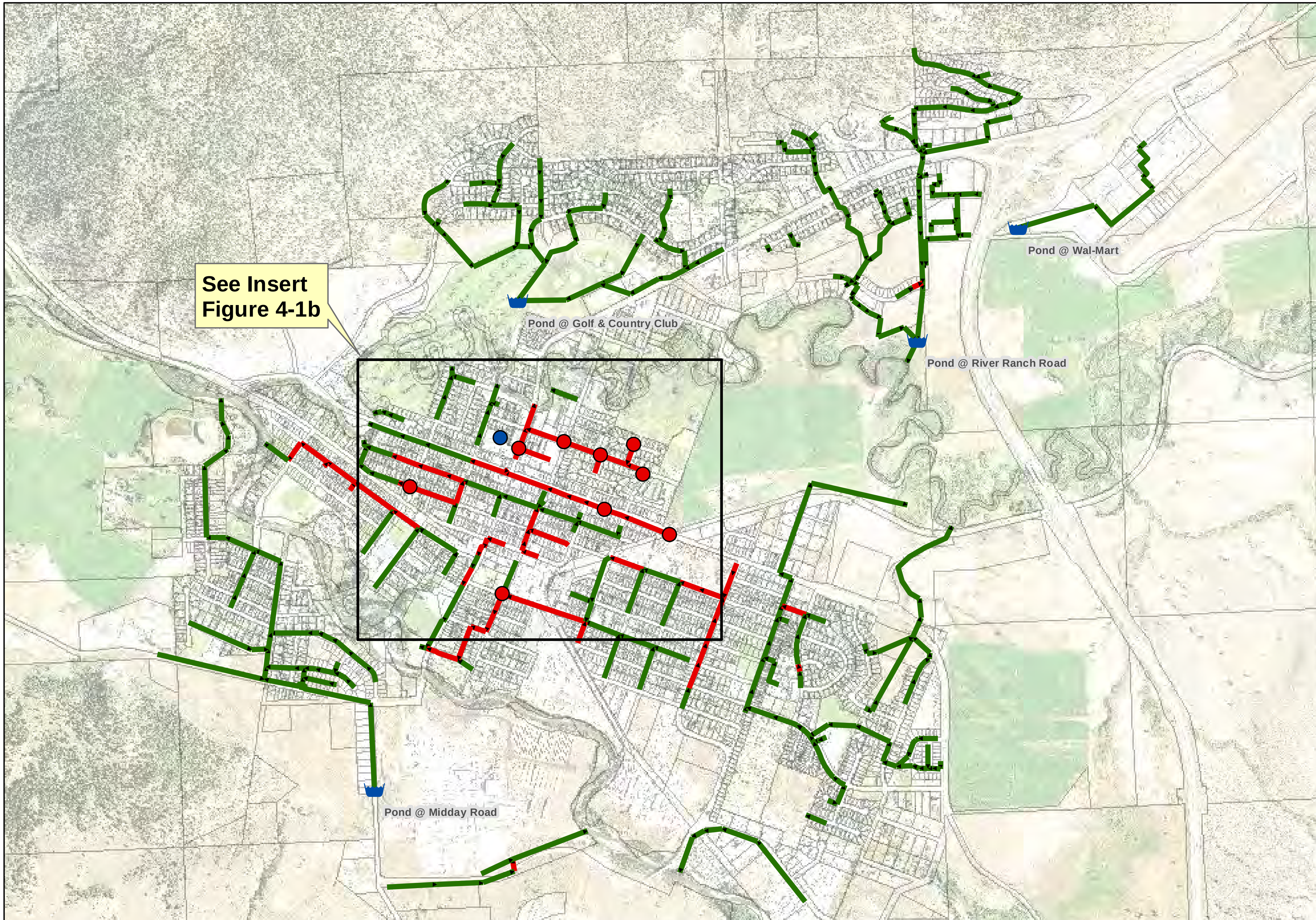
*The d/D (maximum flow depth/pipe diameter) ratio is used to indicate if the pipe is surcharging (d/D>1).

**Total pipe length is approximately 37 km

***(E/F) = (Existing Landuse & System/Future Landuse & System)

The total length of surcharged pipes increased under the future conditions (from 6,299 m to 6,350 m). However, due to the significant addition of new stormmains, the length of surcharged pipes as a percentage of the total pipe length decreased (from 19% to 17%).

Figure 4-1a, Figure 4-1b, **Figure 4-2a**, and **Figure 4-2b**, summarize and locate the system deficiencies. **Appendix A** provides a detailed accounting of the identified 10-year system deficiencies, and the locations and volumes of the modeled 100-year floodlosses.



City of Merritt

Legend

Detention Pond

Manhole (Floodloss)

10 Yr Flooding

Dry Well (Floodloss)

10 Yr Flooding

System Performance (d/D)

<1

>=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (10-Year Event)

GeoAdvice Engineering Inc.

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N E S W

0 0.5 1

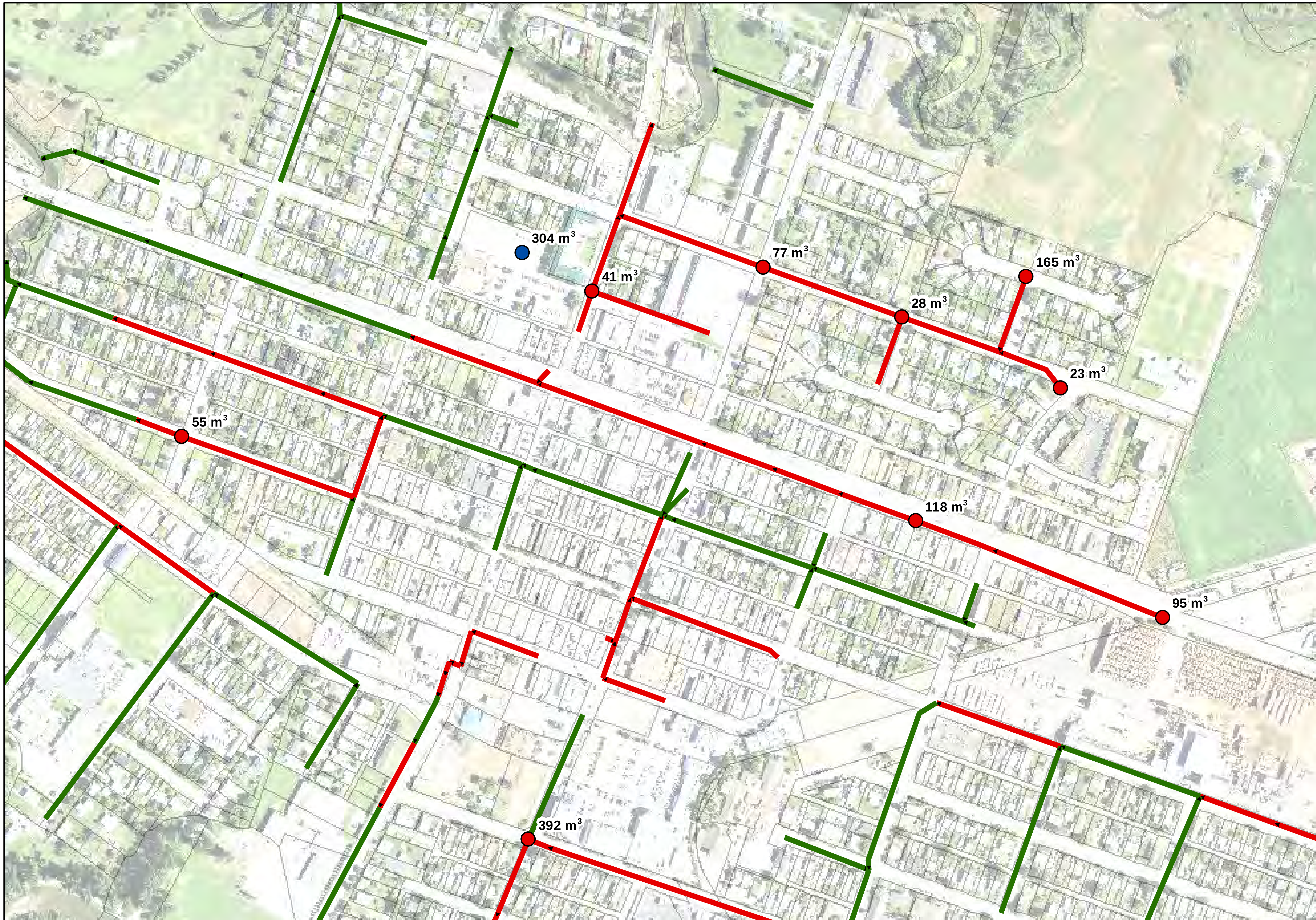
Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure 4-1a



City of Merritt

Legend

Manhole (Floodloss)

10 Yr Flooding

Dry Well (Floodloss)

10 Yr Flooding

System Performance (d/D)

<1

>=1

Assumes no river flooding on river outfalls.

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (10-Year Event)

GeoAdvice Engineering Inc.

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0 0.1 0.2
Kilometers

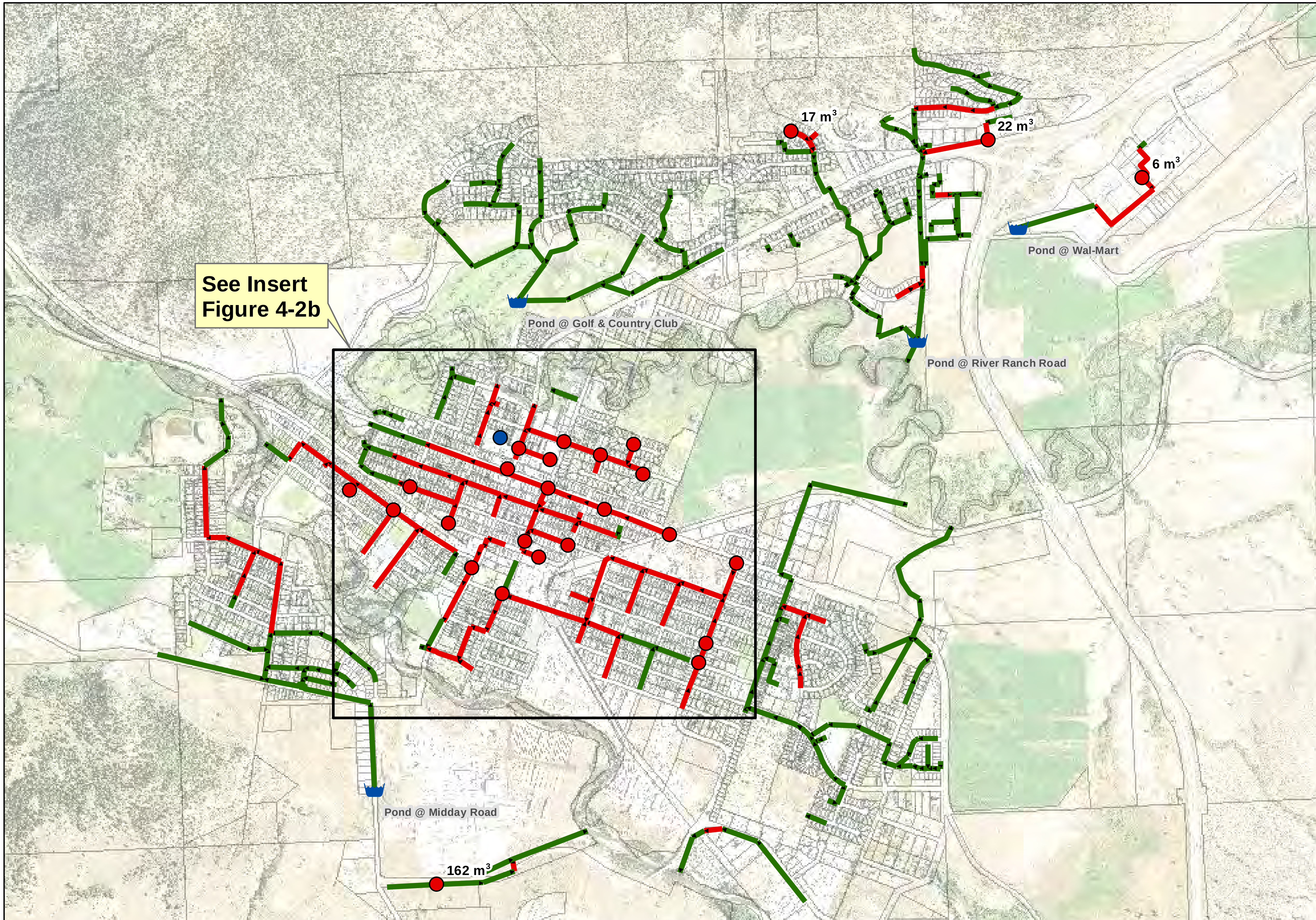
Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 4-1b

City of Merritt



Legend

Detention Pond

Manhole (Floodloss)

100 Yr Flooding

Dry Well (Floodloss)

100 Yr Flooding

System Performance (d/D)

<1

>=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (100-Year Event)

GeoAdvice Engineering Inc.

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N S E W

0 0.5 1

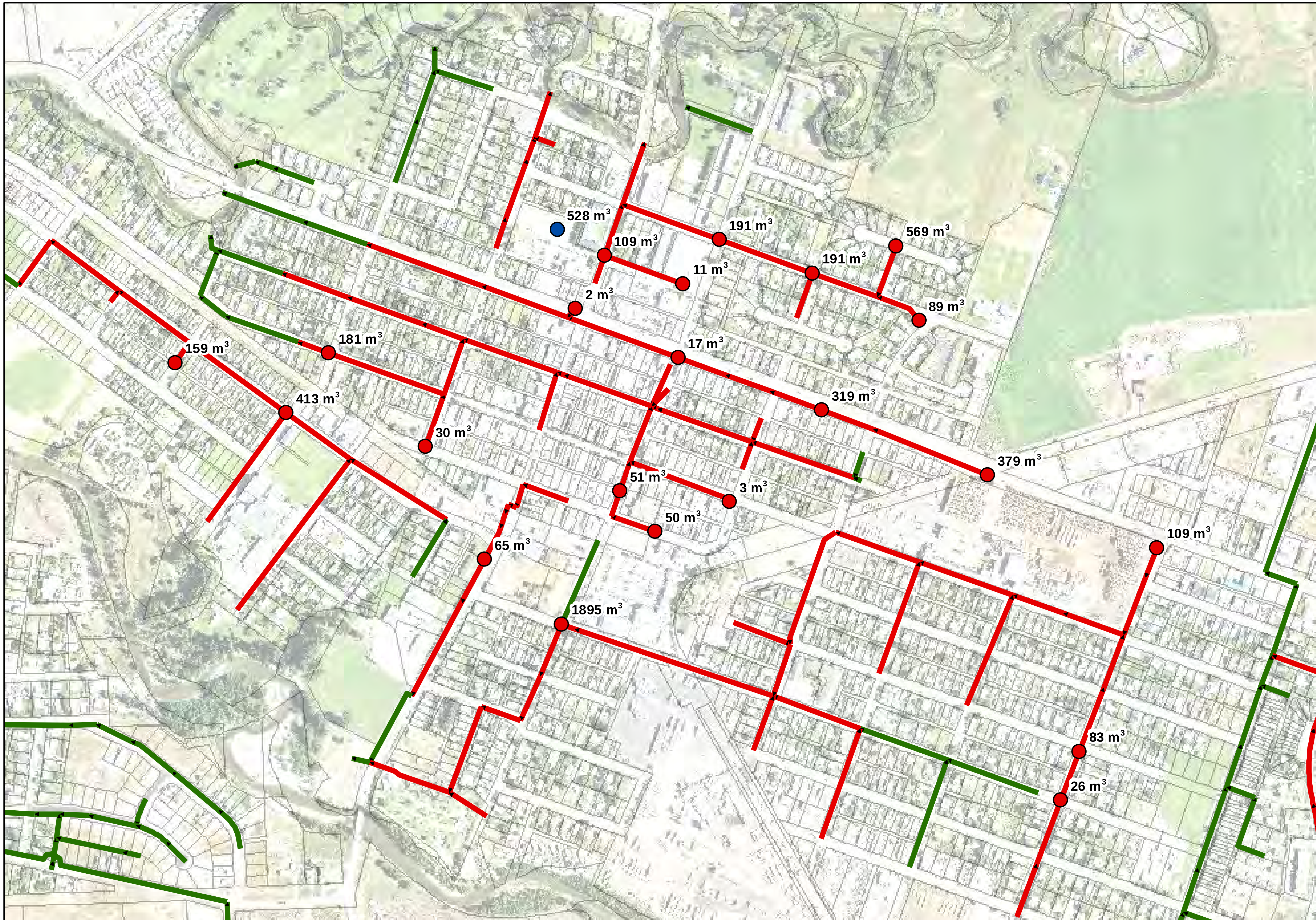
Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 4-2a



City of Merritt

Legend

Manhole (Floodloss)

- 100 Yr Flooding

Dry Well (Floodloss)

- 100 Yr Flooding

System Performance (d/D)

- <1
- >=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (100-Year Event)

GeoAdvice Engineering Inc.

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N E S W

0 0.2 0.4

Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 4-2b

5. PROPOSED SYSTEM IMPROVEMENT

One of the objectives of the ISMP is to identify improvements to the existing stormwater system required to eliminate surface flooding (at dry wells) and pipe surcharging (within the piped system) under the 10-year storm event.

5.1 Storm Sewer Upgrades

Table 5-1 provides a summary of existing pipe upgrades required to meet the 10-year design requirement. **Figure 5-1** highlights the location of improvements to the existing stormwater system required to meet the 10-year design requirement.

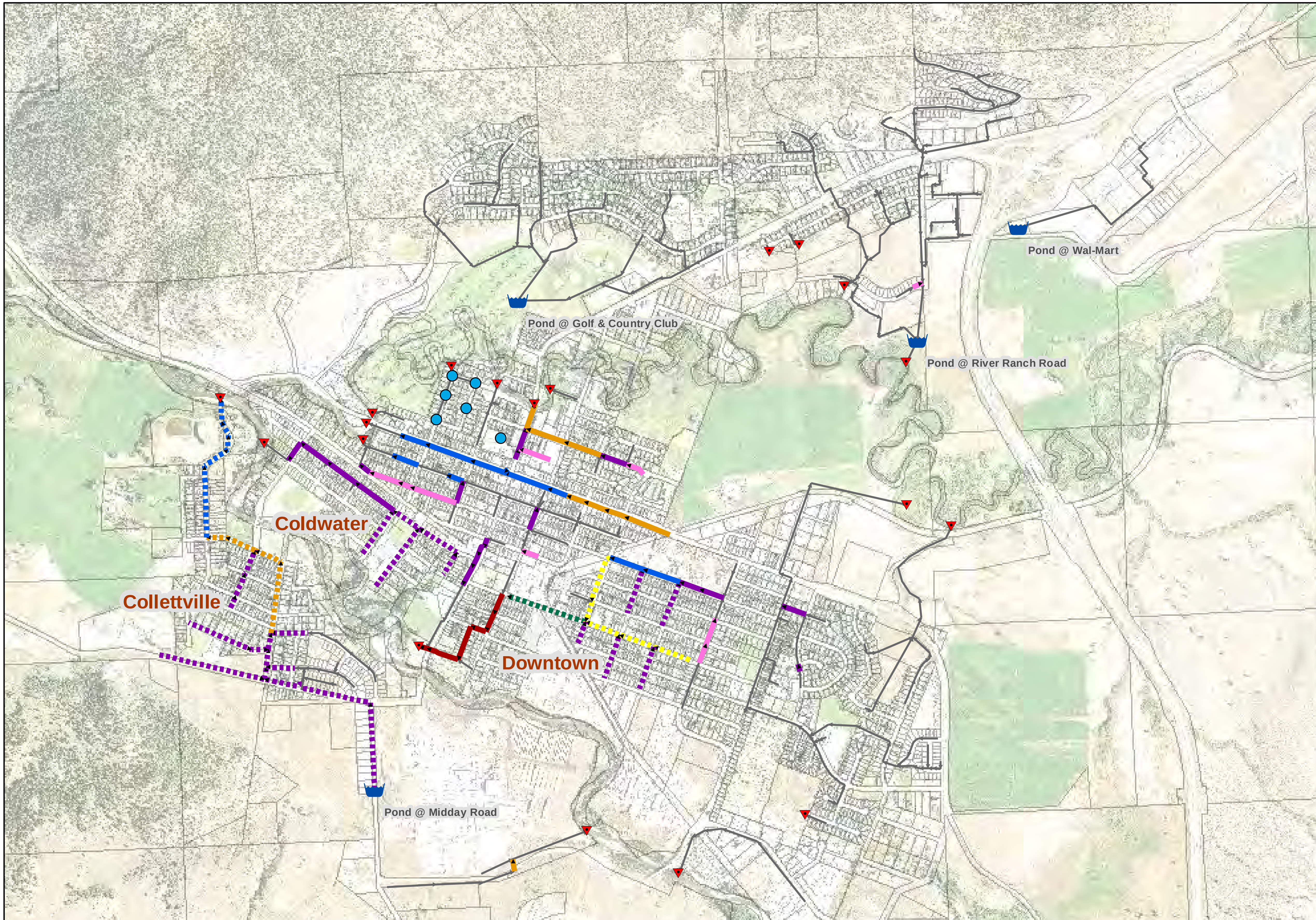
Table 5-1: Existing Pipe Upgrades

Upgrade Diameter (mm)	Length (m)	% of Total Length
300	930	3%
375	1,660	4%
450	980	3%
525	1,270	3%
750	20	<1%
900	570	2%
Total	**5,430**	**15%**

5.2 Dry Well Upgrades

The future system analysis identified dry wells at City Hall are expected to experience surface flooding under the 10-year event (see **Figure 4-1b**). To eliminate surface flooding, approximately 300 m^3 of additional storage capacity is required.

City of Merritt



Legend

- Outfall
- Dry Well
- Detention Pond
- Existing System

Existing Pipe Upgrade Diameter (mm)

- 300
- 375
- 450
- 525
- 900

Proposed New Pipe Diameter (mm)

- 375
- 450
- 525
- 600
- 750

Engineering base plan provided by Summit Environmental Consultants Inc.

Proposed System Improvement

GeoAdvice Engineering Inc.

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N W E S

0 0.5 1

Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure 5-1

5.3 IMPROVEMENT IMPACTS

This section compares the pre- and post-improvement system performance, the model results are summarized in **Table 5-2** and **Table 5-3**.

Table 5-2: Surcharged Pipes (10-year Event)

Model Results	Pre-Improvement	Post-Improvement
Length of Surcharged Pipes (m) (d/D>=1)	6,299	0
% of Total Pipe Length (m)	17%	0%

Table 5-3: System Flooding

Model Results	10-year (Pre/Post)*	100-year (Pre/Post)*
# of Junctions with Surface Flooding	9/0	26/9
Total Junction Floodloss Volume (m^3)	995/0	5,147/293
# of Dry Wells Flooded	1/0	1/0
Total Dry Well Floodloss Volume (m^3)	304/0	528/0

*(Pre/Post) = (Pre-Improvement/Post-Improvement)

6. PROJECT CLOSING

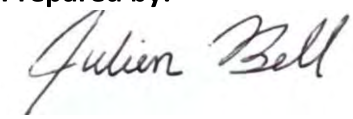
The majority of system flooding is concentrated in the Downtown area; as such, system upgrades are generally in the Downtown area. To satisfy the 10-year design requirement for the future system, approximately 5.5 km of pipe upgrades and approximately 300 m^3 of additional storage are required. This is in addition to the proposed 6.4 km of localized stormwater system modifications.

The eight (8) development areas do not directly trigger improvements to the existing stormwater drainage system as there is sufficient downstream capacity in the existing system to convey the 10-year flows from these new development areas.

TECHNICAL MEMORANDUM SUBMISSION

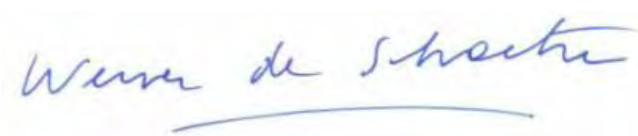
Should the City of Merritt have any questions please do not hesitate in contacting the undersigned.

Prepared by:



Julien Bell, P.Eng.
Project Manager

Reviewed and Approved by:



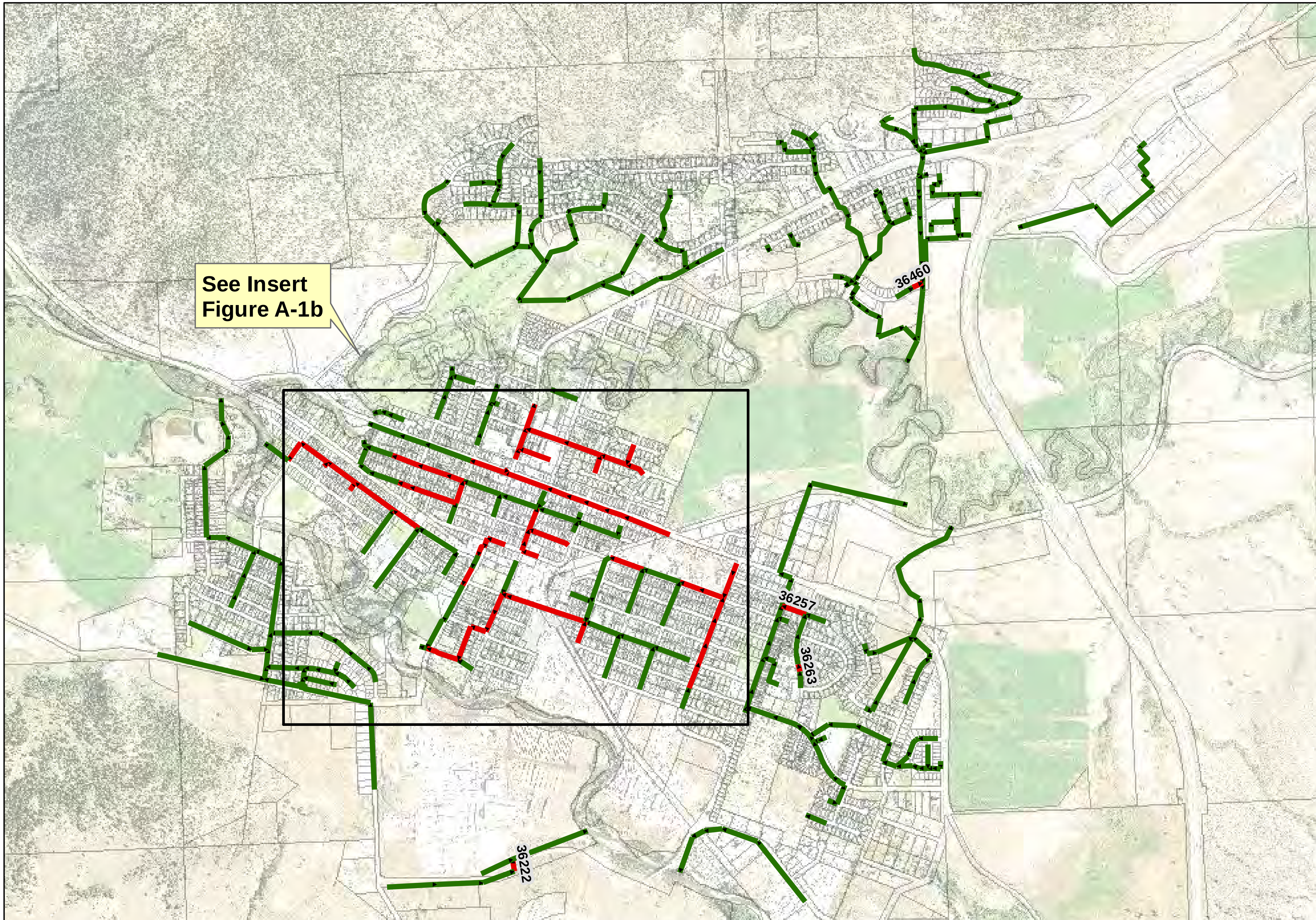
Werner de Schaetzen, Ph.D., P.Eng.
Technical Director/QA/QC
President & CEO

APPENDIX A FUTURE SYSTEM DEFICIENCIES

Table A-1: Surcharged Pipes (10-year Event)

Conduit ID	Length (m)	Diameter (mm)	Pipe Type
CDT-95	348	375	Stormmain
4303	204	300	Stormmain
36280	204	250	Stormmain
36279	200	250	Stormmain
4456	197	400	Stormmain
4454	179	300	Stormmain
4452_1	171	200	Stormmain
4452	165	200	Stormmain
36411	152	600	Stormmain
4357	151	400	Stormmain
4285	147	450	Stormmain
36278	145	250	Stormmain
36274	141	600	Stormmain
36283	141	300	Stormmain
4451	139	200	Stormmain
CDT-75	131	375	Stormmain
4442	131	525	Stormmain
36276	116	450	Stormmain
4267	115	200	Stormmain
36268	114	200	Stormmain
36271	113	200	Stormmain
4321	107	300	Stormmain
36257	107	300	Stormmain
4464_1	104	200	Stormmain
4343	103	300	Stormmain
4373	100	300	Stormmain
4409	97	300	Stormmain
CDT-97	96	375	Stormmain
4464	96	200	Stormmain
36269	94	300	Stormmain
36408	93	600	Stormmain
36281	93	300	Stormmain
4299	92	400	Stormmain
4281	92	400	Stormmain

Conduit ID	Length (m)	Diameter (mm)	Pipe Type
4269	90	200	Stormmain
4314	89	300	Stormmain
36267	87	200	Stormmain
4301	84	400	Stormmain
4268	83	200	Stormmain
4450	82	300	Stormmain
36409	81	600	Stormmain
4404	80	200	Stormmain
4276	79	200	Stormmain
4296	78	400	Stormmain
4390	74	250	Stormmain
4356	74	500	Stormmain
36410	69	600	Stormmain
4428	54	150	Stormmain
4261	52	300	Stormmain
4395_1	52	300	Stormmain
4350	48	200	Stormmain
36460	46	250	Stormmain
4395	43	300	Stormmain
4397	41	300	Stormmain
36277	40	250	Stormmain
36263	33	300	Stormmain
4402	25	300	Stormmain
36284	25	250	Stormmain
36412	24	600	Stormmain
36337	20	200	Stormmain
4399	16	300	Stormmain
4398	13	300	Stormmain
4385	11	300	Stormmain
36222	76	300	Culvert



City of Merritt

Legend

System Performance (d/D)

- <1
- >=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (10-Year Event)

Surcharged Pipes

GeoAdvice Engineering Inc.

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N W E S

0 0.5 1

Kilometers

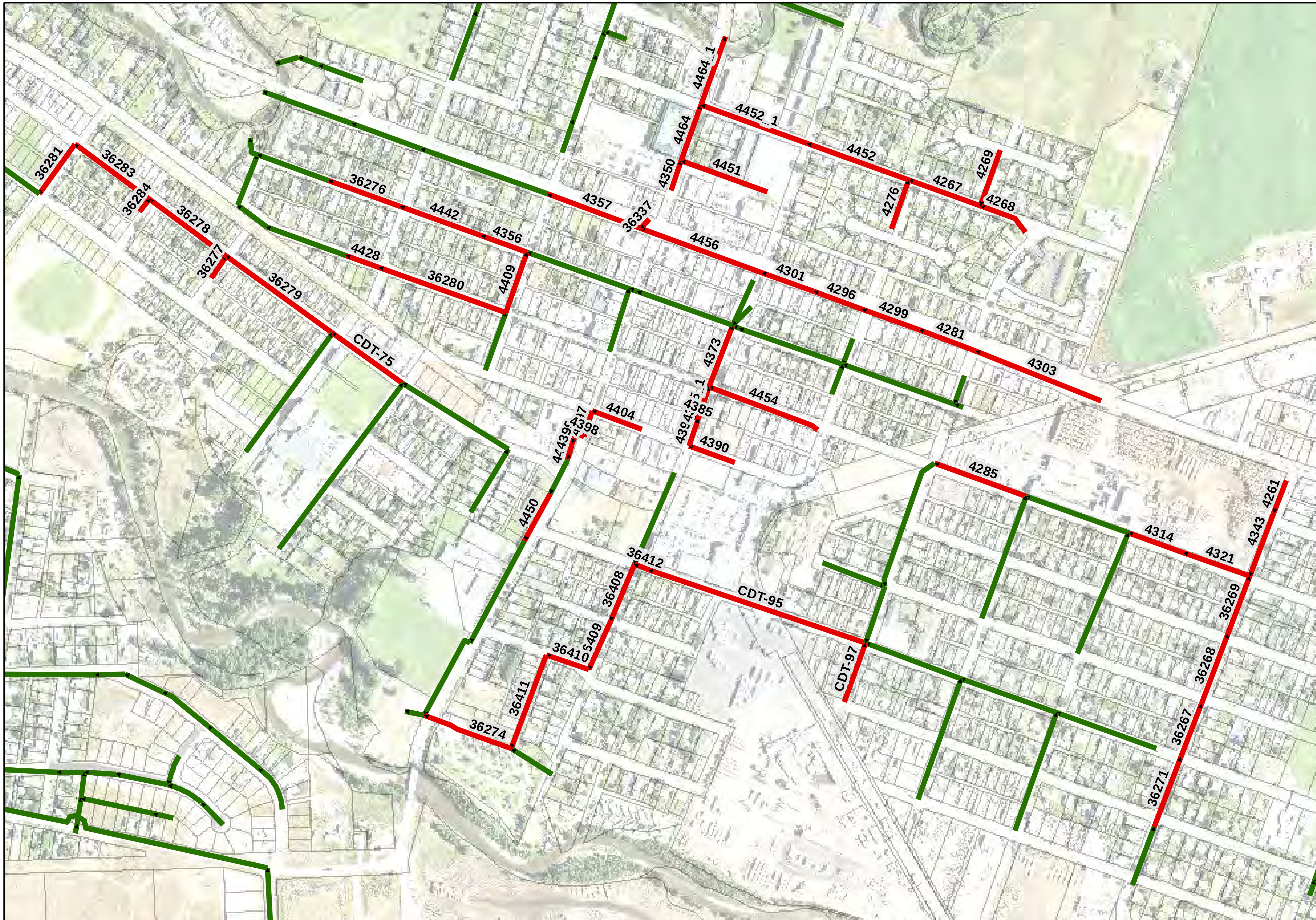
Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure A-1a

City of Merritt



Legend

System Performance (d/D)

- <1
- >=1

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (10-Year Event)

Surcharged Pipes

GeoAdvice Engineering Inc.

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N S W E

0 0.15 0.3

Kilometers

Project: **City of Merritt ISMP**
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

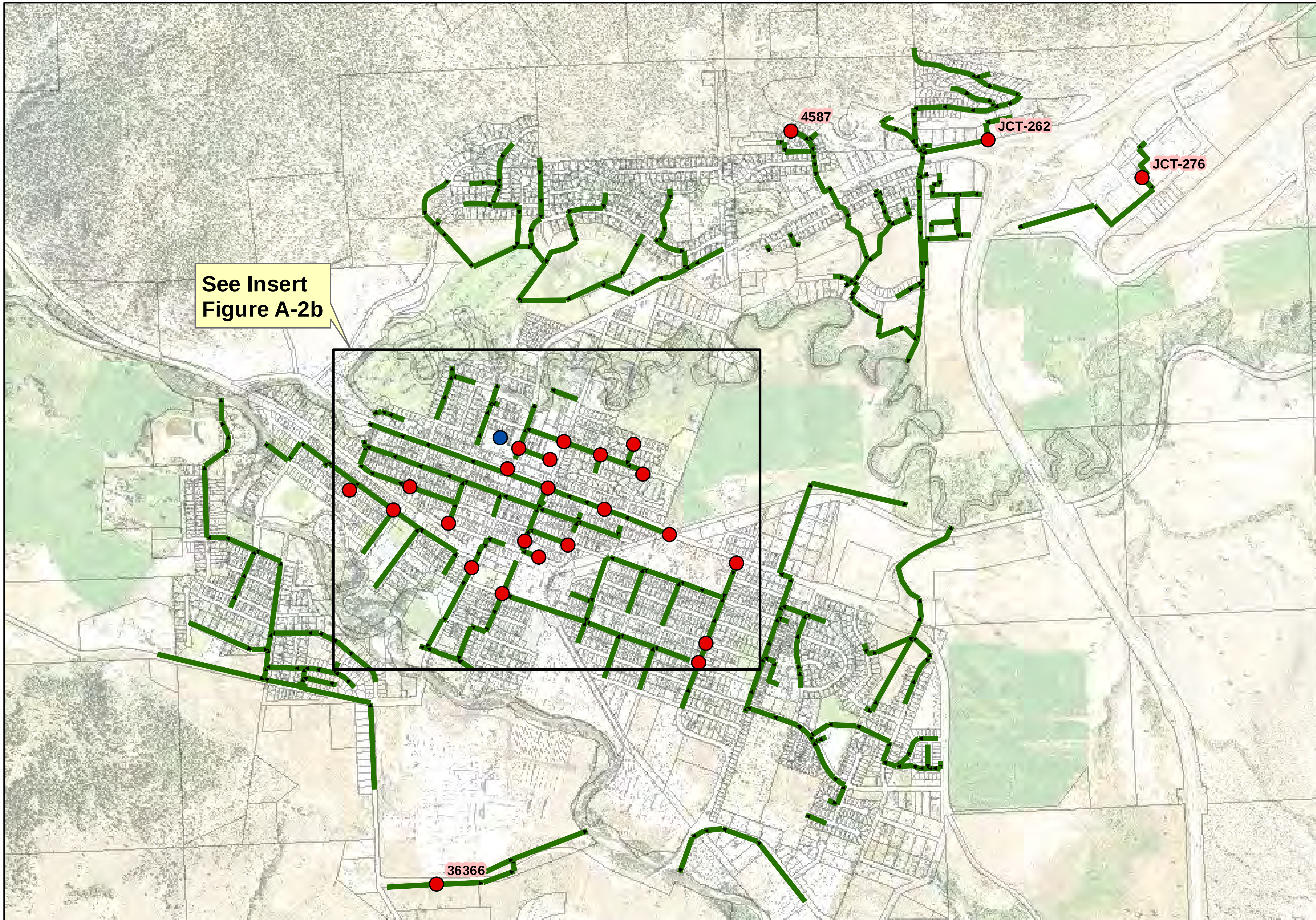
Figure A-1b

Table A-2: Junction Floodloss Volume (100-year Event)

Junction ID	Floodloss Volume (m^3)
JCT-230	1,895
JCT-124	569
5113	413
JCT-110	379
4912	319
4908	191
JCT-120	191
JCT-100	181
36366	162
JCT-216	159
JCT-82	109
4992	109
JCT-122	89
4974	83
5072	65
JCT-84	51
5040	50
JCT-98	30
4971	26
JCT-262	22
4906	17
4587	17
4903	11
JCT-276	6
4942	3
4998	2

Table A-3: Dry Well Floodloss Volume (100-year Event)

Dry Well ID	Floodloss Volume (m^3)
STU-06	528



City of Merritt

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (100-Year Event)

Flooding Junctions & Dry Wells

GeoAdvice Engineering Inc.

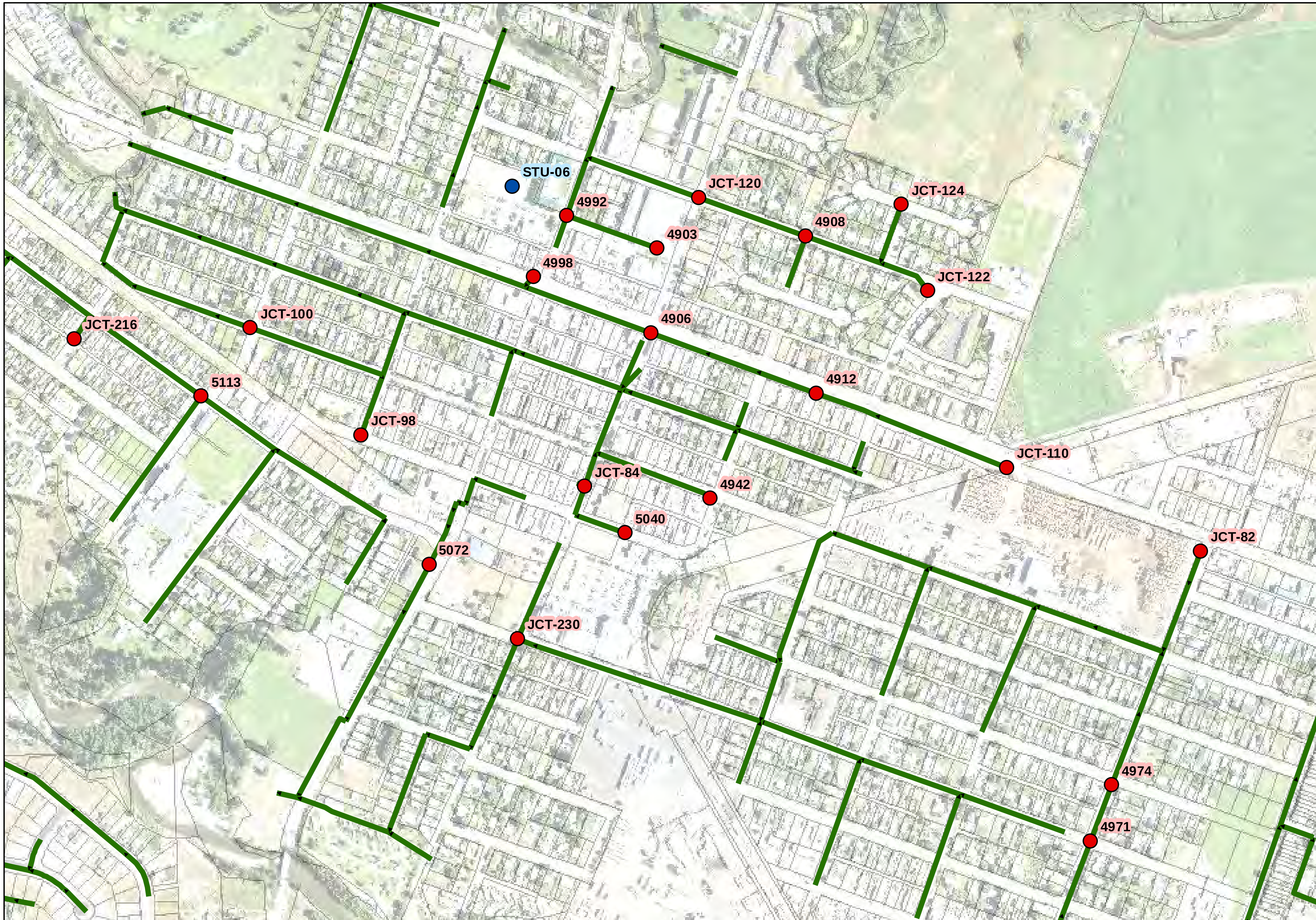
0 0.5 1
Kilometers

Project: City of Merritt ISMP
Model Development and System Analysis

Project ID: 2012-038-MER

Date: May 2013

Figure A-2a



City of Merritt

Legend

- Conduit
- Flooding Junction
- Flooding Dry Well

Engineering base plan provided by Summit Environmental Consultants Inc.

Future System Performance (100-Year Event)

Flooding Junctions & Dry Wells

GeoAdvice Engineering Inc.

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N W E S

0 0.15 0.3
Kilometers

Project: **City of Merritt ISMP Model Development and System Analysis**

Project ID: 2012-038-MER

Date: May 2013

Figure A-2b

Appendix G - Long Term Capital Improvements

Technical Memorandum

City of Merritt

City of Merritt ISMP
Long Rage Capital Improvements

June 2013

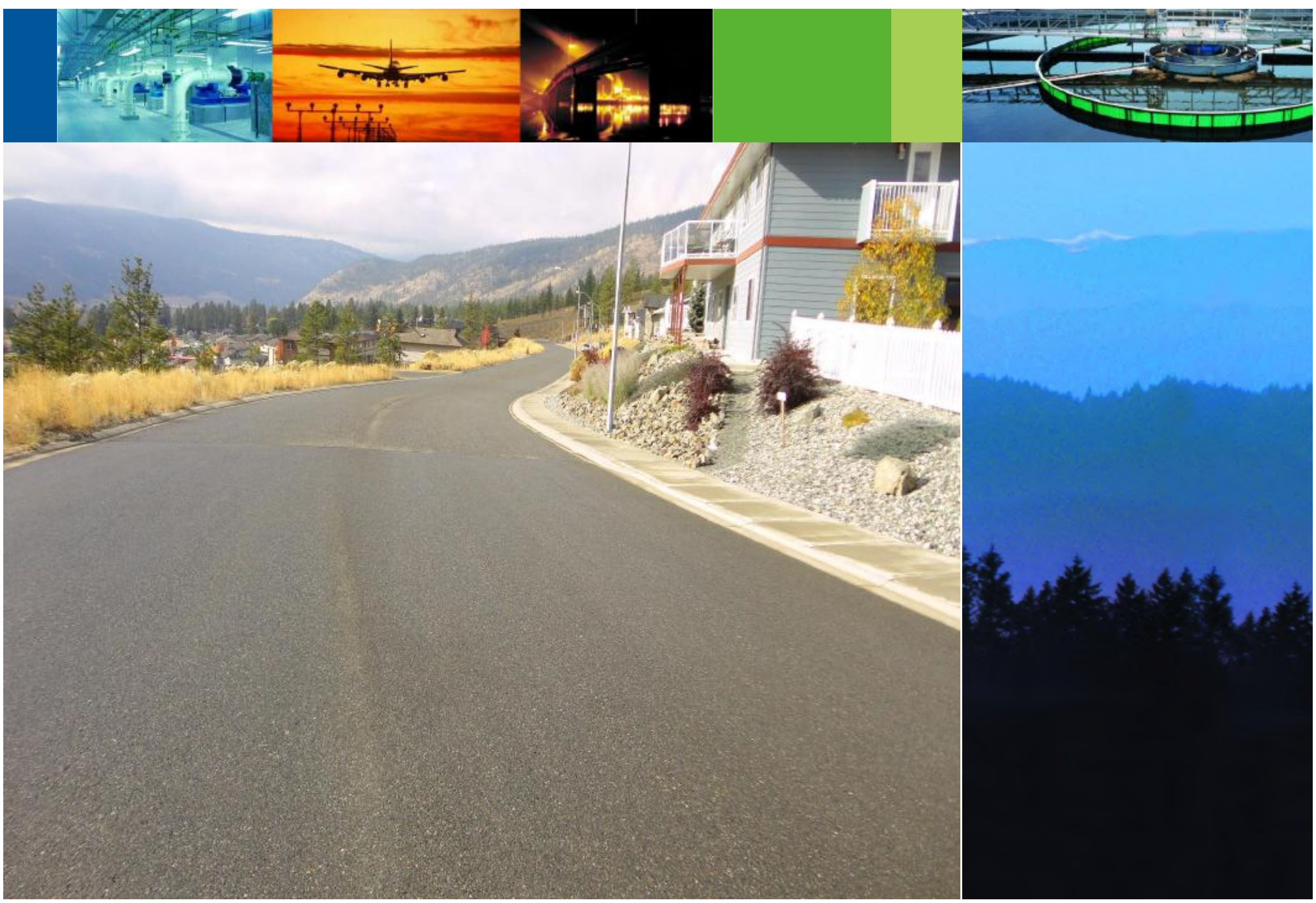

Table of Contents

TECHNICAL MEMORANDUM

1 General

1.1 Introduction

Associated Engineering (AE) has prepared an Integrated Storm water Management Plan (ISMP) for the City of Merritt. Summit Environmental investigated and reported on topics ranging from Aquatic and Terrestrial Species and Habitat Review, Desktop Hydrogeological Assessment, Natural Hazard Review, and Water Quality Review; each topic having recommendations to implement. GeoAdvice then produced an InfoSWMM model and analyse the required capacity of storm water facilities required in the City to safely pass storm water flows today and into the future. This report provides detail of projects recommended for long range capital improvements, as well as cost estimates associated with those improvements.

1.2 Objectives

Several mitigation measures were investigated to meet the objectives of the town. These objectives are:

- Drainage Objectives - Minimize threat to life and destruction of property from flooding.
- Stream Protection Objectives - Protect and Enhance Aquatic Habitat and Stream Corridors
- Water Quality Objectives – Remediate existing and potential water quality problems including protect and enhance local aquifer (therefore drinking water supply).

Under current conditions if development continues without appropriate mitigation measures put in place it would be expected that there would be several undesirable outcomes from this:

- Decrease in surface water quality in the Coldstream River and Nicola River
- Increased storm flows from town into the surface rivers
- Decrease in aquifer water quality due to infiltration into dry wells within the aquifer infiltration zones.
- Increased erosion of ditches and sloped embankments
- Increased sediment loading in the storm water to both river outlets and drywells
- Increased flooding hazards in low lying areas, especially those with no storm system available to them.
- Increase in surficial flows on road surfaces

With each improvement they will be evaluated based on several objectives/measuring points. A concise list of these objectives is listed below:

- Analyze measures and their effectiveness
- Recommended strategies for implementation
- Initial and long term cost of constructing and operating
- Prioritize the measures with respect effectiveness and cost associated.

2 Proposed Remedial Work Items

This list of alternative remedial measures reviewed follows with some of the storm system improvements run in the InfoSWMM model for verification of effectiveness. Each item has been evaluated for its relative effectiveness and cost.

1. Collettville Storm System
2. Midday Valley Road Storm System Upgrades
3. Downtown East un-serviced area
4. Silt Banks bordering the golf course
5. Several ditch/swale/piping installations to improve and control flow
6. Construction of Storm pond at Voght St Park
7. Construction of Storm pond at end of Douglas road
8. Combining outfalls at Nicola Ave and provide treatment for storm flow prior to release.
9. Removal of drywells in aquifer sensitive areas
10. Replacement of surcharged pipes
11. Development and servicing bylaws revisions
12. OCP revisions
13. Requirements for future developments
14. Monitoring program.

2.1 Collettville Storm System

Collettville is a low lying area in the south west corner of the community. It is bounded by the Coldwater River to the north. Currently road surfaces have low slopes along their lengths with significant depth ditches to manage the storm flows in this area and prevent flooding of properties throughout this neighborhood. From the inspections completed it was noted that a large percentage of the crossing culvert inlets are significantly blocked with soil and/or vegetation. We investigated potential options to install storm water piping and controls in this area and these options are described below.

Option 1

Install storm piping at between 1.5m and 2.0m of cover and outlet to the Coldwater though the city owned property west of the Main St Bridge. There is also potential to construct a storm water detention pond in this property that would improve the system in several ways. First of all it would act as a settlement point for any sediment in the water prior to release to the river. Secondly it would provide a buffer in the case of a spill occurring in the drainage area, and allow crews to stop flow into the river prior to the contaminant leaving the town's storm system. Thirdly it would provide a location to re-establish some aquatic, riparian habitat, improving the environmental conditions.

The piping system through Collettville could be placed at low slopes (range of 0.2% to 0.5% slopes) depending on surface ground slopes.

Option 2

The basic system in the neighborhood would remain the same as with option 1 but the outlet to the Coldwater River though Pine Street. There would also be potential to construct a storm water detention pond near the outlet to the river to improve the system in several ways. First of all it would act as a settlement point for any sediment in the water prior to release to the river. Secondly it would provide a buffer in the case of a spill occurring in the drainage area, and allow crews to stop flow into the river prior to the contaminant leaving the town's storm system. Thirdly it would provide a location to re-establish some aquatic, riparian habitat, improving the environmental conditions.

The benefit to this option is that additional slope of the outlet and therefor the backup of the water up the storm line in the event of a river flood or storage in the pond. The outlet in this case would be approximately 3m below the elevation of the majority of the system to be installed. This would be advantageous in the case of flooding of the river or other high storm flow event where the outfall pipe is submerged. There would also be additional properties and streets that could be connected that would not be able to be with option 1. The disadvantage of this solution is the potential availability of an easement or access to the river for a storm pond and discharge.

The recommended option is option 2 with the additional elevation and length of pipe allowing for increased flexibility in design, increased area of incorporation and improved flows at times of river high water levels as well as having an increased potential locations for a storm detention pond prior to the outlet.

Description	Quantity	Unit Cost	Estimated Cost
450Ø Pipe - 2 – 3 m depth	2085 m	$350/m	$730,000
525Ø Pipe - 2 – 3 m depth	624 m	$350/m	$220,000
Pond	1 each	$50,000/each	$50,000
		Subtotal	$1,000,000
		10% engineering and 10% contingency	$200,000
		Total	$1,200,000

2.2 Midday Valley Road Storm System Improvements

Currently there are 2 ponds that occur next to Midday Road at low points about halfway between the Houston Road intersection and the Vought Road intersection. There is an artesian spring that flows year round upstream of the Houston road intersection that flows to the west side pond. There is also a culvert and ditch that crosses Houston Road and flows to the east side pond. Several levels of mitigation measures are proposed. Firstly the storm piping at the intersection of Houston Road and Midday Road will be redirected to the east to transfer the artesian spring flow to the east along the south side of Houston Road. And will cross Houston at the second culvert into the large existing ditch that flows to the east and eventually the Coldwater River. The ditch on the south side of Houston Road is to be re-graded to improve flows and reduce ponding.

Secondly the culvert that flows to the east side pond is to be capped and abandoned. This will cut off the majority of the flow to the east side. This flow will be directed along the same ditch as the water above, to the east then towards the Coldwater River. Thirdly a storm pipe is proposed on Midday Road from the low point to the north. This pipe is to be installed at a minimum cover and slope to control the depth at the intersection of Voght and Midday Road. Two options were investigated in depth:

Option 1

The pipe could be directed east at a minimum slope and outlet to a ditch on Voght Street which would then flow to the Coldwater River and outlet from the ditch. This is the most direct path to get the storm flows into the river, and has a minimum amount of piping necessary; this direction would also impact the lowest number of public due to increased storm flows. This route has a potential storm pond location near the outlet, which is already an unplanned pond that could be developed into a pond with a controlled outlet to the river.

Option 2

The second option is to direct the pipe west and tie into the proposed storm system in Collettville. This option would be closely linked to the development of the storm system in Collettville. This pipe could also be installed and outfall into the Collettville storm system ditches currently in place if the Collettville Storm System Improvements is not completed prior to the Midday Road Storm System Improvements. The benefit of this solution would be the added settlement time of the water prior to release into the river, as well as the increased time available if a spill or other emergency was to occur in which then crews would have more time to cut-off the pollution prior to release to the river. Another benefit of this option is that protection measures could be focused on this outlet instead of having to duplicate protection measures or releasing without these measures.

Description	Quantity	Unit Cost	Estimated Cost
New 450Ø Storm Sewer			
2 – 3 m depth	1000 m	$350/m	$350,000
600Ø Pipe culvert			
Midday and Houston	20m	$500/m	$10,000
Ditch re-grading	600m	$50/m	$30,000
		Subtotal	$380,000
		10% engineering and 10% contingency	$76,000
		Total	$456,000

2.3 Downtown East Storm System Installation

In the area east of downtown there are difficulties managing the current storm flows effectively. Currently the storm flows are trapped in this area due to minimal to 0% road slopes, very few drywells, no storm piping, or ditches to remove the water in heavy storm flow events, therefore the water ponds and causes flooding of residences. Installing a piping system in this area is a viable option, though the pipe would be required to be laid at a minimum slope and minimum cover to ensure tie-ins. For connection we investigated two potential options.

Option 1

First is to head north, to make a tie in at the end of Douglas Road and the current storm pipe that flows to the north. The suspected issues/difficulty with this route is that it will be difficult to find a suitable route to tie in at the far north end of Douglas road while maintaining slope and cover. This option was determined not to be viable due to lack of grade and depth to construct the tie in pipe.

Option 2

The second is to head southwest to tie in on Voght Street and the current storm pipe. This direction appears to have more slopes which will help the installation of the connection pipe but the capacity and tie-in location will need to be investigated further, as the pipe that flows south along Voght Street is very flat and may not have capacity to accommodate additional flows. This option was investigated using the InfoSWMM model and was determined that some downstream upgrades would also be required to accommodate the increased flows. This pipe would need to be increased to a 900 diameter pipe to avoid surcharging during storm events.

The future investigation using InfoSWMM also determined that several other pipes in the existing network would require upsizing to prevent surcharging. See Figure 4-1a and 4-1b in Geoadvice's Technical Memo – Future System Performance Analysis.

Description	Quantity	Unit Cost	Estimated Cost
New Storm Sewer			
450Ø 2 – 3 m depth	800m	$350/m	$280,000
600Ø 2 – 3 m depth	1056m	$350/m	$370,000
750Ø 2 – 3 m depth	370m	$400/m	$148,000
Replacement of Existing storm sewer			
375Ø 2–3 m depth	400m	$350/m	$140,000
525Ø 2–3 m depth	300m	$350/m	$105,000
900Ø 2–3 m depth	580m	$400/m	$232,000
		Subtotal	$1,275,000
		10% engineering and 10% contingency	$255,000
		Total	$1,530,000

2.4 Silt Banks above the Golf Course

In the silt banks along the north and west edges of the golf course and baseball diamonds some significant erosion is occurring due to increased storm flows onto the top of the banks from storm pipes. There are a number of potential solutions to mitigate this risk as if it continues it is inevitably going to continue to erode the slope and will someday threaten properties at the top of the banks. The increase sediment loading in the storm water should also be mitigated.

Option 1 - Rip Rap

One solution would be to rip rap the slopes along the length of the slope. This option is not recommended as we would still expect erosion beneath the riprap as the water flows down the steep slope. Also installation of the riprap may cause to be problematic as the silt banks are steep and any equipment on the slopes may increase the erosion.

Option 2 - Extend pipes to base of slope

A second solution would be to extend the pipes to near the base of the slope then to riprap the outfall structure. This is the recommended solution as the pipe could be laid by hand, decreasing the disturbance to the natural slope and the cost would be kept to a minimum. Minimum cover on the pipe would not be required as there would not be any traffic over this area.

Option 3 - Remove trees over growing outfalls

This is another recommended maintenance task that should be completed to ensure that flow in the pipe is adequate. It was reported by the maintenance crew that they have been starting to have this problem on some of these pipes.

Description	Quantity	Unit Cost	Estimated Cost
Riprap	100 m^3	$100/$m^3$	$100,000
Remove problem trees	5 each	$10,000 each	$50,000
		Subtotal	$150,000
		10% engineering and 10% contingency	$30,000
		Total	$180,000

Description	Quantity	Unit Cost	Estimated Cost
Extend Storm Pipe	50 m	$200/m	$100,000
Remove problem trees	5 each	$10,000 each	$50,000
		Subtotal	$150,000
		10% engineering and 10% contingency	$30,000
		Total	$180,000

2.5 Miscellaneous Storm Controls

There are several areas within the community that have minor storm water control problems in storm events. Most of these are due to improper or inadequate flow routing. Thus we have investigated the addition, and rework of several areas in town to mitigate these issues. The base of these improvements is shown in figure ___. These additions should alleviate much of the ponding in low spots in the areas shown. These locations are:

1. Voght Street, near the RCMP station
2. Nicola Ave, east of Juniper Drive
3. Nicola Aver, near Coldwater Road intersection

At location #1 it would appear as though some surface swales and curb breaks (or pipes installed in the sidewalks) could correct the ponding problem that exists at this location during storm events. With the large expanse of park land immediately to the west, this could prove to be a simple solution without major costs associated.

At location #2, there are a few potential options to mitigate the ponding on the road. One option would be to construct infiltration ditches that would provide some storage for the excess storm water from the road and infiltration into the groundwater and therefore the river as this location is close to the river. Another option would be drywells as this area is downslope from the town's wells. But since the groundwater table would be expected to be quite shallow, might be unnecessary.

At location #3 it was noted that some flows from the irrigated field across the road are permeating to the subdivision to the west. A potential solution would be to construct a ditch that would allow storm flow to route to the north and towards the river outfall. This may alleviate the groundwater problems that are currently occurring.

Description	Quantity	Unit Cost	Estimated Cost
Reworking Ditches	500 m	$50/m	$25,000
Extend Pipe	250 m	$500/m	$125,000
Remove problem trees	5 each	$10,000 each	$50,000
		Subtotal	$200,000
		10% engineering and 10% contingency	$40,000
		Total	$240,000

2.6 Construction of Storm Pond at Voght Street Park

The storm outlet at Voght Street Park next to the school is currently in a state of need and repairs. We have looked at the potential of construction a storm pond, low sloped sides with minimal slopes, should keep the pond above the water table. It would also allow the city to isolate the flows in the case of a spill in town, prior to it reaching and discharging into the river. This will be exceptionally important if the area of downtown east is tied into this discharge as this increased area will also increase the risk of hazards flowing into the river.

This park is mostly naturally graded at the current time consisting of aspens, and other river edge plants and trees. The pond would be located in the flood zone so appropriate measures would need to be taken to ensure that the pond is appropriately designed for this.

Another mitigation measure that should be investigated is the implementation of an oil/grit separator or jellyfish type of structure to manage the flows under typical conditions. These products work well in areas of low flows and in the case of high flows allow water to pass through without limiting the flow.

Description	Quantity	Unit Cost	Estimated Cost
Construct Pond	1 each	$150,000 each	$150,000
		Subtotal	$150,000
		10% engineering and 10% contingency	$30,000
		Total	$180,000

2.7 Construction of Storm Pond at End of Douglas Road

This remedial measure has been considered to provide a wet pond at the Douglas Road outlet. Currently the outfall flows in to a disconnected oxbow of the Nicola River. What is being considered is to construct this area as a wet pond with the ability to cut off the flow into the river in the event of an emergency. As this is already a disconnected oxbow this would be relatively simple to do as one would strive to keep it as the natural habitat, it would simply formalize this area and put it on the maintenance checklist for the city crews.

Description	Quantity	Unit Cost	Estimated Cost
Construct Pond	1 each	$50,000 each	$50,000
		Subtotal	$50,000
		10% engineering and 10% contingency	$10,000
		Total	$60,000

2.8 Combining Outfalls at Nicola Ave and Pre-Treatment

This remedial measure entails combining the outfalls into major outfalls to allow treatment options to be provided at the major areas rather than having several small outfalls all needing treatment or going into the river system without any checks. This remedial measure maybe difficult to complete due to the locations of the outfalls, their elevations and the slope of the pipe required to tie them together. This is still a valid solution that should be investigated if/when doing work around multiple outfalls. In the case of the outfalls at Nicola St. and Nicola River there are 3 outfalls within 200m, if these outfalls could be combined into 1 outfall with a "Stormceptor" and/or storm pond the level of service that would be able to be provided would increase significantly for a minimal capital cost when compared to installing 3 storm water quality units.

Description	Quantity	Unit Cost	Estimated Cost
600Ø storm sewer 2 – 3m deep	200m	$500/m	$100,000
Construct Pond/"Stormceptor"	1 each	$50,000 each	$50,000
		Subtotal	$100,000
		10% engineering and 10% contingency	$20,000
		Total	$120,000

2.9 Removal of Drywells in Aquifer Sensitive Areas

This mitigation measure is in reference the hydrogeological study. The underlying aquifer, in which the town receives most of its potable water, is also the area that seems to have been chosen as the ideal location to install dry wells. This works well from a storm water disposal situation as the water flows away quite freely after it enters the dry well. The problem is that any hazardous substances that were present in the stormwater have now entered directly into the aquifer in which the town gets its drinking water. These wells are typically close to the drywell locations and therefore don't have much of a chance to dilute the pollutants prior to being sucked up as drinking water. The majority of the dry wells are located in the Coldwater area of town.

Description	Quantity	Unit Cost	Estimated Cost
450Ø storm water pipe 2 – 3m deep	1000m	$500/m	$500,000
		Subtotal	$500,000
		10% engineering and 10% contingency	$100,000
		Total	$600,000

2.10 Replacement of Surcharged Pipes

After modelling the system with InfoSWMM, Geoadvice determined several pipe networks throughout town that surcharged in the 10 year storm event. The solution to fix the surcharged pipes is to put a capital improvements plan in place to replace and upsize these pipes over time. All these pipes are located in-between the Coldwater and Nicola River in the low lying areas. For evaluation we have separated the areas for improvements into 2 areas:

- Downtown
- North of downtown

Description	Quantity	Unit Cost	Estimated Cost
North of Downtown			
450Ø storm sewer			
2 – 3m deep	989m	$350/m	$346,000
Downtown			
450-525Ø storm sewer			
2 – 3m deep	2482m	$350/m	$869,000
375Ø storm sewer			
2 – 3m deep	500m	$350/m	$175,000
		Subtotal	$1,390,000
		10% engineering and 10% contingency	$278,000
		Total	$1,668,000

2.11 Development and Servicing Bylaw Revisions

Revisions should be made to the bylaws to improve future development impacts on the city. Coordination with areas outside the city should also be ongoing as storm water enters the city boundaries from outside areas and these areas need to be ensuring they are following the best management practices as well. Future developments need to be designed not to the current system but to the system that will be in place in 5, 10 or 20 years.

2.12 OCP revisions

We would suggest reviewing the current OCP and ensuring that the OCP and bylaws are in line and they consider the environment as a key factor in development.

3 Recommendations

Based on this analysis, we suggest the following sequence of projects:

0 – 2 years

- OCP revisions
- Monitoring Program
- Development and servicing bylaws revisions
- Silt Banks bordering the golf course 180,000
- Midday Road Storm System Upgrades (ditch and redirection east) 50,000

Estimated Cost: $350,000 (230,000 plus admin)

2 – 5 years

- Downtown East un-serviced area 1,530,000
- Construction of Storm pond at Voght St Park 180,000
- Construction of Storm pond at end of Douglas road 60,000
- Removal of drywells in aquifer sensitive areas 600,000

Estimated Cost: $2,370,000

5 - 10 years

- Collettville Storm System 1,200,000
- Midday Road Storm System Upgrades. (piping to north) 350,000
- Several ditch/swale/piping installations to improve and control flow 120,000+834000

Estimated Cost: $2,504,000

10 – 20 years

- Requirements for future developments
- Several ditch/swale/piping installations to improve and control flow 120,000
- Combining outfalls at Nicola Ave and provide treatment for storm flow prior to release 120,000+834000

Estimated Cost: $1,074,000

Appendix A -