Rocky View County

Bragg Creek Master Drainage Plan

FINAL REPORT

SEPTEMBER 2025

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1.0 Executive Summary

1.1 Geographic Location and Boundaries

The study area encompasses the Hamlet of Bragg Creek, located within southwest Rocky View County (RVC) on the Elbow River, near Highway 22. It is bounded by the Tsuut'ina Nation Reserve #145 to the east, Banded Peak School to the south, and Bragg Creek Provincial Park to the west as shown in Figure 1.0.

1.2 Purpose of the Study

This Master Drainage Plan (MDP) provides a comprehensive framework for managing surface water and flood risk within the Hamlet of Bragg Creek. The plan addresses existing drainage deficiencies, evaluates the impacts of future development, and establishes a strategic plan for sustainable stormwater management. The primary driver for this MDP is the need to balance development pressure with the significant flood risk posed by the Elbow River, which includes both seasonally high groundwater and the acute, rapid rise of the water table during major flood events.

1.3 Summary of Key Findings

- The primary flood risk to the Bragg Creek Hamlet is not from rainfall-runoff alone, but from the rapid rise of groundwater levels directly connected to the Elbow River during high flow events. The (draft) Hydrogeological Study (WSP, 2025) quantifies this risk, indicating that induced groundwater seepage can propagate 50 to 100 metres inland from the flood berm during a 1:100-year event.
- The Elbow River flood barrier mitigates overland river flooding but does not prevent groundwater from surcharging the ground surface within the Hamlet, particularly within the 50 to 100-metre zone of influence identified in the hydrogeological assessment.
- The Hamlet currently lacks an engineered stormwater system, relying on informal ditches, culverts, and overland flow, resulting in nuisance ponding and an uncontrolled pathway for floodwaters. This MDP formalizes the public road and ditch network as the foundational major system, designed to convey both rainfall runoff and emergent groundwater safely.
- A historical overland flood channel exists, spilling north across Balsam Avenue. This is the natural and critical emergency escape route for extreme floodwaters.
- Future development is constrained by high groundwater. A major system-focused (overland) approach is required, as a traditional, Hamlet-wide minor (underground pipes) system is not feasible or practical. New development requires a dedicated outfall solution.
- The identified emergency spill route across Balsam Avenue currently follows a pre-existing natural overland path across private property. The plan does not create a new spill channel; it documents the existing path for clarity and emergency planning. Evaluation of this spill route, and if warranted, securing overland drainage easements to formalize access and maintenance is recommended.
- Because the flood berm interrupts overland drainage to the Elbow River, stormwater is impounded on the landward side during high river and groundwater conditions. The Master Plan therefore identifies lift stations and force mains as critical enabling infrastructure to maintain controlled releases when infiltration is unavailable due to river-driven groundwater rise

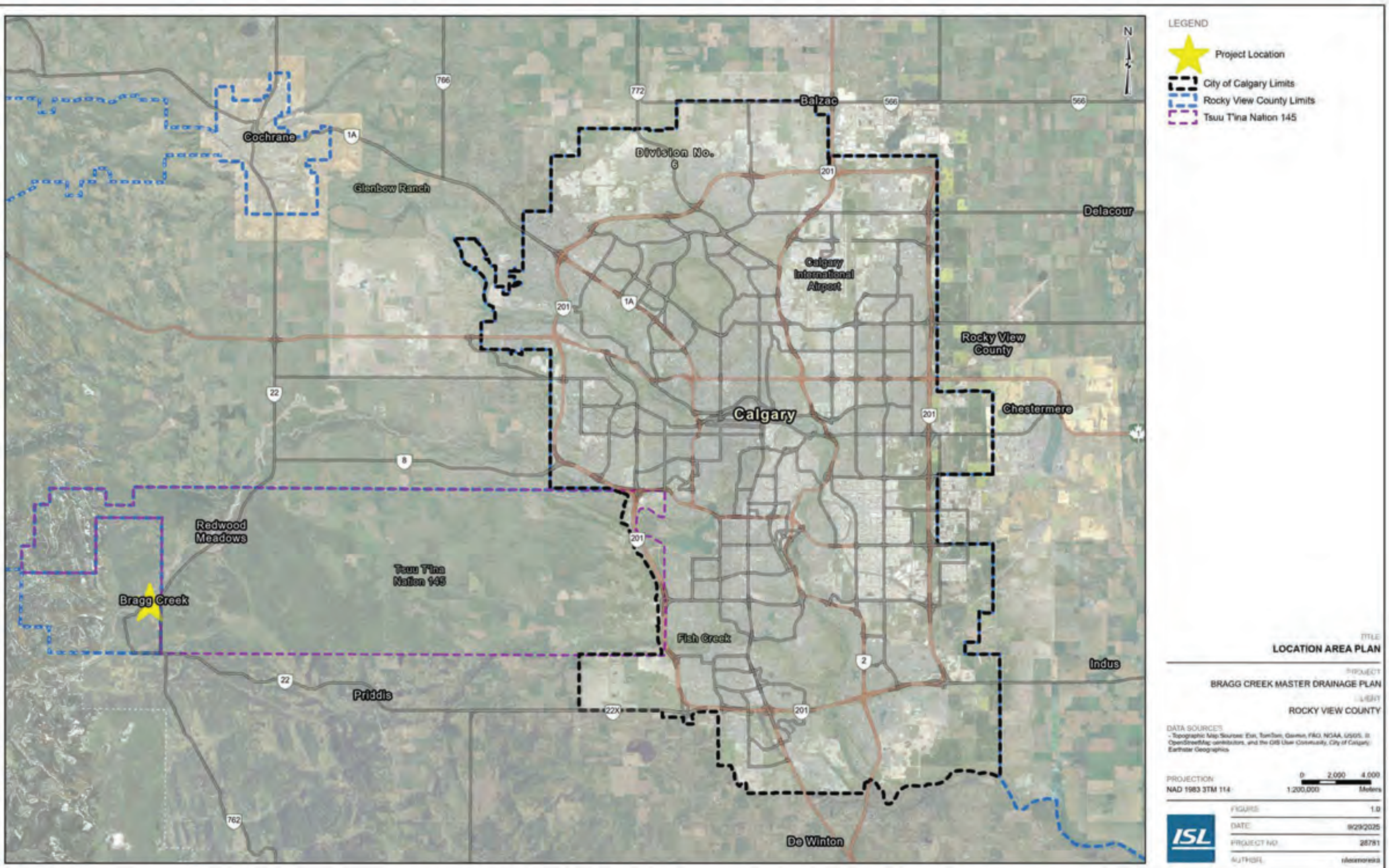
1.4 Recommended Strategies

Given the lack of technical feasibility for a traditional piped storm sewer system, this MDP recommends a practical strategy focused on managing surface water and adapting to the Hamlet's unique hydrogeological conditions.

1. The most critical and cost-effective action is to immediately adopt and enforce a robust set of Development Drainage Guidelines. This ensures all new construction is resilient to known flood risks from the outset by mandating Minimum Building Elevations (MGs), requiring positive lot grading to the public right-of-way, and restricting inappropriate foundation design in high-risk zones. This prevents new problems from being created and shifts the primary responsibility for property protection to individual developments.
2. New, dense development in the Hamlet core cannot be serviced by the existing informal system. Therefore, approval for such projects will be conditioned on the developer designing, funding, and constructing a self-contained, engineered stormwater system, including a centralized Stormwater Management Facility (SWMF) and a lift station to provide a reliable, positive outfall to the Elbow River.
3. To address existing drainage deficiencies and formalize a safe conveyance path for extreme flood events and emergent groundwater, it is recommended that the County consider implementing a long-term capital program for Major System Enhancements. This would involve systematic re-grading and improvement of the public road and ditch network to create a continuous and functional overland drainage system that directs water safely to the designated outlets throughout the Hamlet.

1.5 Implementation Considerations

Implementation will be phased. The highest priority is the establishment of the Development Drainage Guidelines to ensure all new construction is resilient. The Hamlet-wide road and ditch improvements can be implemented over time through the County's capital improvement program.


LEGEND
Project Location
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Rocky View County Limits
Tsuu T'ina Nation 145
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Cochrane
1A
766
772
Balzac
566
566
Division No. 6
Glenbow Ranch
201
Delacour
Calgary International Airport
201
1A
Rocky View County
22
Calgary
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8
Redwood Meadows
201
Tsuu T'ina Nation 145
Bragg Creek
Fish Creek
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762
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TITLE
LOCATION AREA PLAN
PROJECT
BRAGG CREEK MASTER DRAINAGE PLAN
CLIENT
ROCKY VIEW COUNTY
DATA SOURCES
- Topographic Map Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Calgary, Earthstar Geographics
PROJECTION
NAD 1983 3TM 114
0 2,000 4,000
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Meters
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FIGURE 1.0
DATE 9/29/2025
PROJECT NO. 28781
AUTHOR

2.0 Introduction

2.1 Project Background

The Hamlet of Bragg Creek, located in southwest RVC, is experiencing significant pressure for redevelopment and new growth, including the Gateway Village project, densification along Balsam Avenue, and development of designated expansion lands, as shown in Figure 2.0. This growth occurs within the context of significant environmental constraints, most notably the Hamlet's location within the historical floodplain of the Elbow River.

The major flood event of June 2013 caused extensive damage and highlighted the community's vulnerability. In response, significant flood mitigation efforts have been undertaken, including the design and construction of the Elbow River Flood Barrier. However, recent hydrogeological investigations have confirmed that the permeable alluvial aquifer beneath the Hamlet is directly and rapidly influenced by river levels. This means that even with the flood barrier in place, a major river flood event will cause groundwater levels to rise and potentially flood the area from below. This understanding has been further detailed and quantified by the draft *Hydrogeological Development Suitability Study* (WSP, 2025), which provides a comprehensive assessment of the hydrogeological factors influencing development suitability and flood risk in the Hamlet.

This MDP builds upon previous work, including the 2013 Master Drainage Plan by MPE Engineering, the 2020 ISL Servicing Feasibility Study, the 2016 Amec Foster Wheeler flood dike analysis, and the findings of the provincial Bow and Elbow River Hazard Study (WSP, 2025a; WSP, 2025b), which provides detailed hydraulic modeling, quantifies assets at risk, and establishes the official Design Flood Hazard mapping for the Elbow River and Bragg Creek.

2.2 Study Objectives

The primary objectives of this MDP are to:

- Assess existing drainage conditions and identify system deficiencies.
- Characterize the flood risk from both surface runoff and groundwater surcharge.
- Develop a comprehensive stormwater management strategy that supports future development as outlined in the Bragg Creek Area Structure Plan (ASP).
- Establish clear drainage guidelines for new development and redevelopment.
- Provide a strategic implementation plan for RVC.

2.3 Scope of Work Overview

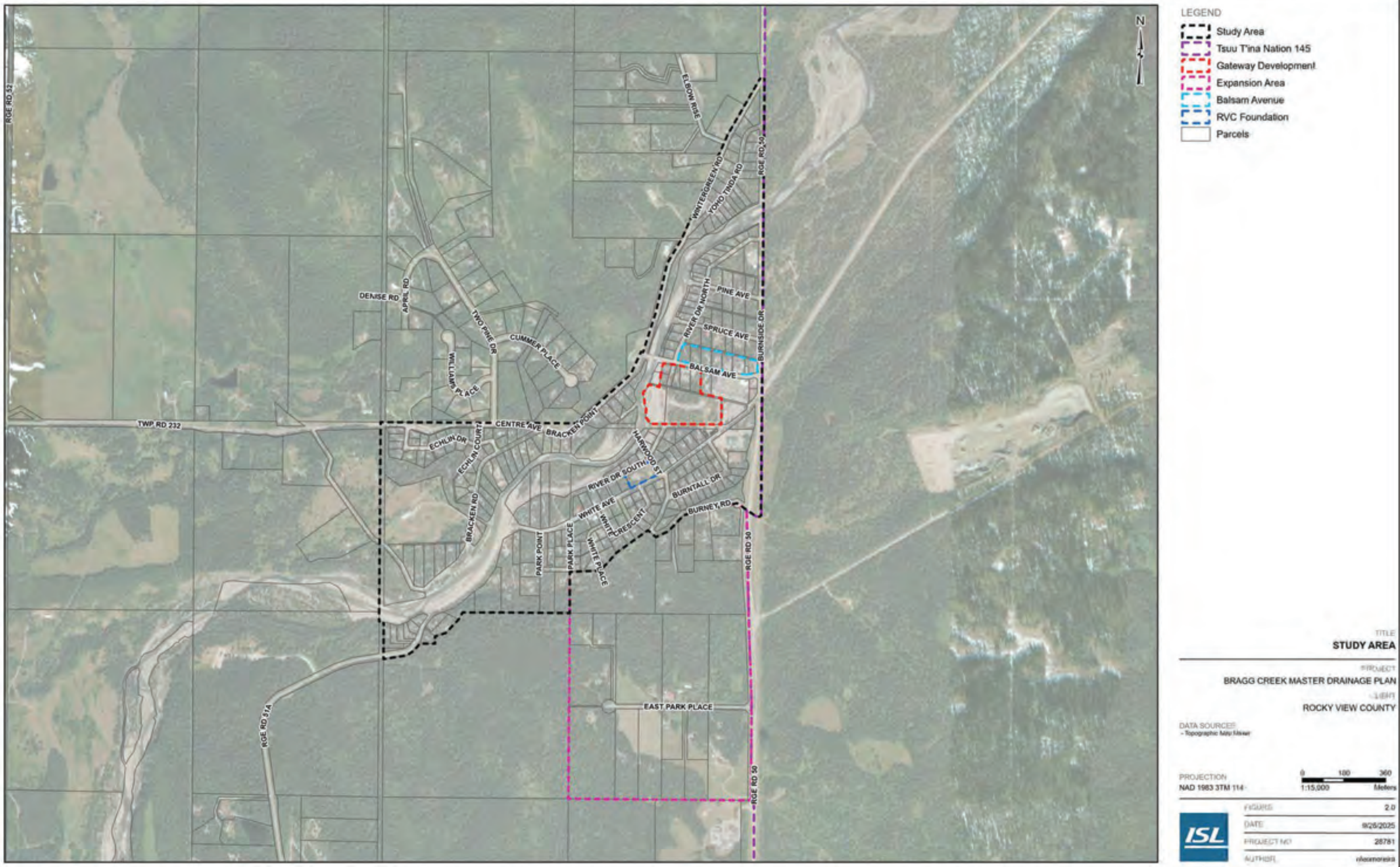
The scope of this MDP includes a review of all available data, development of integrated strategic hydrologic and hydraulic models to simulate existing and future conditions, a detailed flood risk assessment, evaluation of mitigation strategies, and the development of a conceptual design and implementation strategy.

2.4 Regulatory Context and Framework

This plan has been developed in accordance with the standards and guidelines of Rocky View County and Alberta Environment and Protected Areas (AEPA). Key documents include the Rocky View County Servicing Standards, AEPA's (formerly AEP) Stormwater Management Guidelines, The City of Calgary Stormwater Management Manual, and water license requirements associated with the Elbow River.

2.5 Stakeholder Engagement Overview

This MDP has been developed for Rocky View County as the primary client. It is understood that the findings and recommendations of this report will be used to inform future engagement with developers, residents of Bragg Creek, and other relevant stakeholders to ensure the successful implementation of the proposed drainage strategy.



TITLE

STUDY AREA

PROJECT

BRAGG CREEK MASTER DRAINAGE PLAN

CLIENT

ROCKY VIEW COUNTY

DATA SOURCES
- Topographic Map Viewer

PROJECTION
NAD 1983 3TM 114

0 100 360
1:15,000 Meters

FIGURE	2.0
DATE	9/26/2025
PROJECT NO	28781
AUTHOR	rfeomoreira

3.0 Study Area Description

3.1 Watershed Characteristics

The Hamlet lies within the Elbow River watershed. The local topography generally drains from the west and south towards the Elbow River, a naturally braided river, which flows from southwest to northeast through the study area and serves as a critical raw water supply for the City of Calgary. Elevations range from a high point of approximately 1,350 m to a low point at the Elbow River of approximately 1,300 m. The area is characterized by a wide floodplain and underlying deposits of highly permeable alluvial sands and gravels, creating a direct hydraulic connection with the river. This formation, known as the Elbow River's alluvial aquifer, is a key characteristic of the watershed and is the primary mechanism for the groundwater-driven flood risk addressed in this plan.

3.1.1 Hydrogeological Setting

The hydrogeological conditions of the study area, as detailed in the WSP (2025) report, are the primary drivers of flood risk and development constraints. The surficial geology consists primarily of highly permeable Pleistocene-aged fluvial and glaciofluvial deposits of sand and gravel adjacent to the Elbow River. These deposits form a shallow, unconfined alluvial aquifer that is in direct hydraulic connection with the river.

The study confirms that during periods of high river discharge, the hydraulic gradient can reverse, causing rapid and significant groundwater level rise across the floodplain. In contrast, higher elevation areas, particularly in the Hamlet Expansion Area, are characterized by less permeable, fine-textured glaciolacustrine and till deposits. While these areas are less susceptible to river-induced groundwater flooding, they present different constraints such as lower infiltration capacity and susceptibility to frost heave.

Bedrock aquifers, composed of alternating shale and sandstone, are the primary source for domestic groundwater use but are less significant to the surface flooding dynamic (WSP, 2025). This direct and rapid groundwater response to river levels means the entire Hamlet is susceptible to flooding from below, a mechanism that operates independently of local rainfall and is not prevented by the presence of surface flood berms.

3.2 Existing Development and Land Use

Bragg Creek currently consists primarily of low-density residential properties, with commercial and public service uses concentrated along Balsam Avenue and Burnside Drive. The area north of the Hamlet, known as Elkana, is also comprised of low- and medium-density residential development. Table 3.1 below summarizes the existing land uses. The total existing developed footprint within Bragg Creek and Elkana includes approximately 327.3 ha with an estimated population of 714 people. Existing land use is detailed in Figure 3.0.

Table 3.1: Existing Land Use Summary

Land Use	Area (ha)		
	Bragg Creek Hamlet	Expansion Area	Elkana
Residential	130.1	50.2	76.6
Commercial	23.7	0.0	0.0
Public Service	3.9	0.0	0.0
Agricultural Holding	0.0	40.5	0.0
Direct Control	2.3	0.0	0.0
Total	**160.0**	**90.7**	**76.6**

3.3 Future Development and Land Use

Future development within Bragg Creek is guided by the ongoing Bragg Creek Area Structure Plan Hamlet Review. The growth strategy focuses on densification within the Hamlet's core and expansion into designated lands to the south. The timing of this growth is broken into two main horizons: short term and long term.

- **Short Term Development:** This phase focuses on densification within the existing Hamlet boundaries and includes the Gateway Village, Balsam Avenue, and RVC Foundation development areas.
- **Long Term Development:** This phase involves the build-out of the Expansion Area south of the current Hamlet, which is planned primarily for residential development.

At full build-out, the population of the Bragg Creek study area is projected to increase from approximately 714 to 2,523 people. This significant increase in population and development density is a primary driver for this Master Drainage Plan, as it will alter the area's hydrology and increase the number of people and assets at risk from flooding. Approximate future land use areas are outlined in Table 3.2 and in Figure 3.1. Refer to the servicing study for further details on potential scenarios regarding densities and land uses considered.

Table 3.2: Future Land Use Summary

Area	Residential Area	Commercial Area	Institutional Area
	ha	ha	ha
Bragg Creek	130.1	23.7	6.2
Elkana	50.2	0.0	0.0
Existing Total	**180.3**	**23.7**	**6.2**
Gateway Village	1.3	0.0	0.0
Balsam Avenue	2.1	0.0	0.0
RVC Foundation	0.8	0.0	0.0
Short Term	**4.2**	**0.0**	**0.0**
Short Term Total	**184.5**	**23.7**	**6.2**
Expansion Area	8.3	0.0	0.0
Long Term	**8.3**	**0.0**	**0.0**
Long Term Total	**192.8**	**23.7**	**6.2**

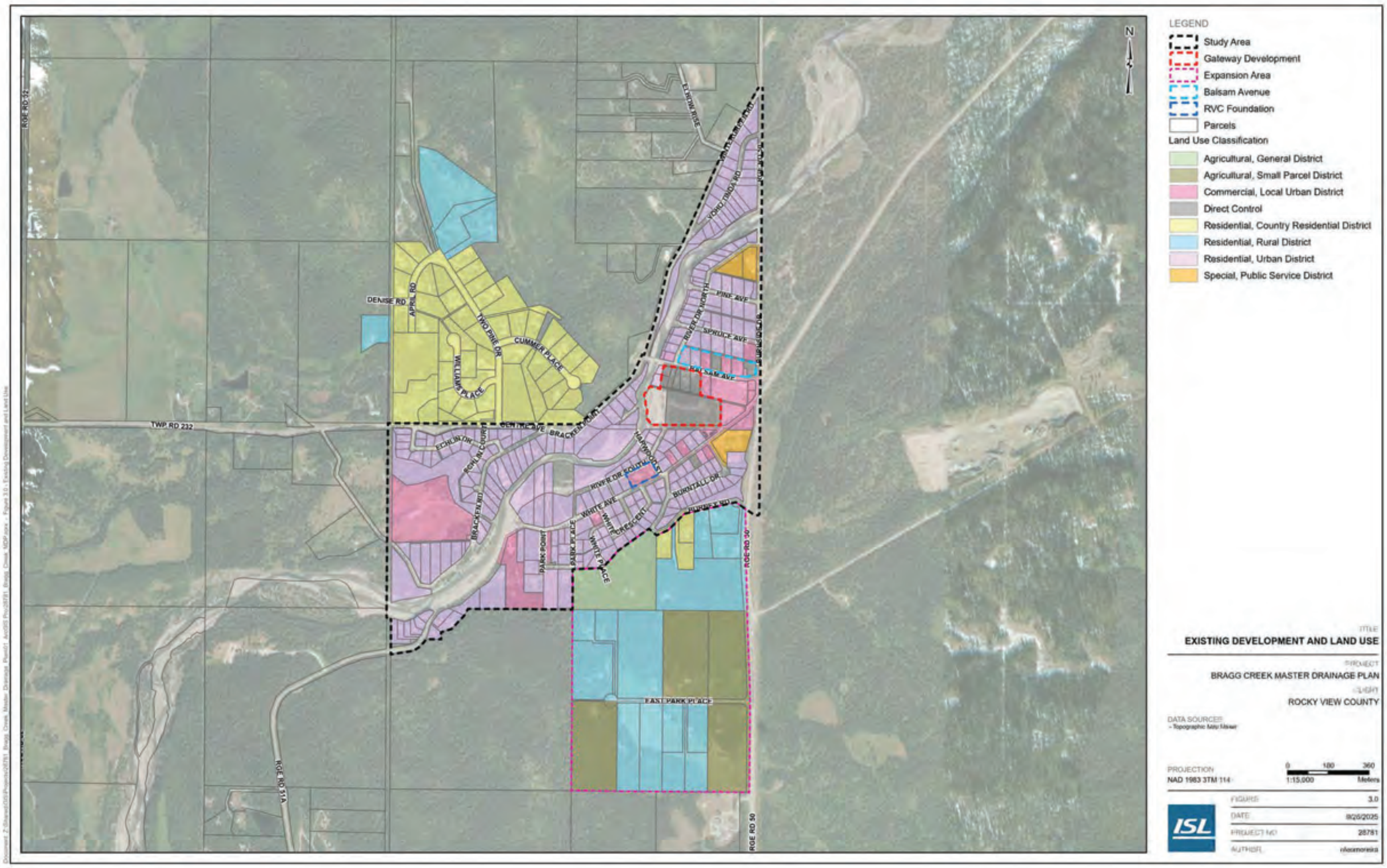
3.4 Environmental and Ecological Features

The environmental sensitivity of the greater region is well-documented. The 2013 Master Drainage Plan included a detailed inventory identifying over 500 hectares of wetlands in the surrounding area, with fens being the most common type. The protection of these downstream water bodies and the water quality of the Elbow River is a key driver for implementing a formal, engineered stormwater management strategy within the Hamlet. The 2013 Master Drainage Plan is included in Appendix A.

3.5 Infrastructure Overview (Stormwater, Roads, Utilities)

Water, wastewater and stormwater are interdependent in Bragg Creek. Fire flow storage/loops, lift station corridors and grading decisions materially affect stormwater conveyance and emergency routing. This report includes context and interfaces only; detailed servicing requirements are in the Bragg Creek Servicing Study

- **Water System:** The Hamlet is serviced by a Water Treatment Plant (WTP) drawing raw water from an infiltration gallery on the Elbow River. The system includes the Bragg Creek Reservoir and the Elkana Reservoir, and a distribution network of HDPE, PVC, and AC pipes.
- **Wastewater System:** Wastewater is collected via an HDPE low-pressure force main system, which conveys sewage from individual lot lift stations to the Wastewater Treatment Plant (WWTP). This sealed system is designed to prevent inflow and infiltration, a critical feature given the high groundwater table.
- **Stormwater System:** There is currently no formal, engineered stormwater collection and conveyance system within the Hamlet. Drainage relies on informal overland flow via ditches and swales, with runoff ultimately infiltrating into the ground or flowing to the Elbow River.



TWP RD 232
RGE RD 50
RGE RD 51A
RGE RD 52
DENISE RD
APRIL RD
TWO PINE DR
CUMMER PLACE
WILLIAMS PLACE
PINE AVE
SPRUCE AVE
BALSAM AVE
BURNTALL DR
WHITE AVE
WHITE CRESCENT
WHITE PLACE
PARK POINT
EAST PARK PLACE
N
LEGEND
Study Area
Gateway Development
Expansion Area
Balsam Avenue
RVC Foundation
Parcels
Land Use Classification
Agricultural, General District
Agricultural, Small Parcel District
Commercial, Local Urban District
Direct Control
Residential, Country Residential District
Residential, Rural District
Residential, Urban District
Special, Public Service District
TITLE
EXISTING DEVELOPMENT AND LAND USE
PROJECT
BRAGG CREEK MASTER DRAINAGE PLAN
CLIENT
ROCKY VIEW COUNTY
DATA SOURCES
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FIGURE 3.0
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PROJECT NO 28781
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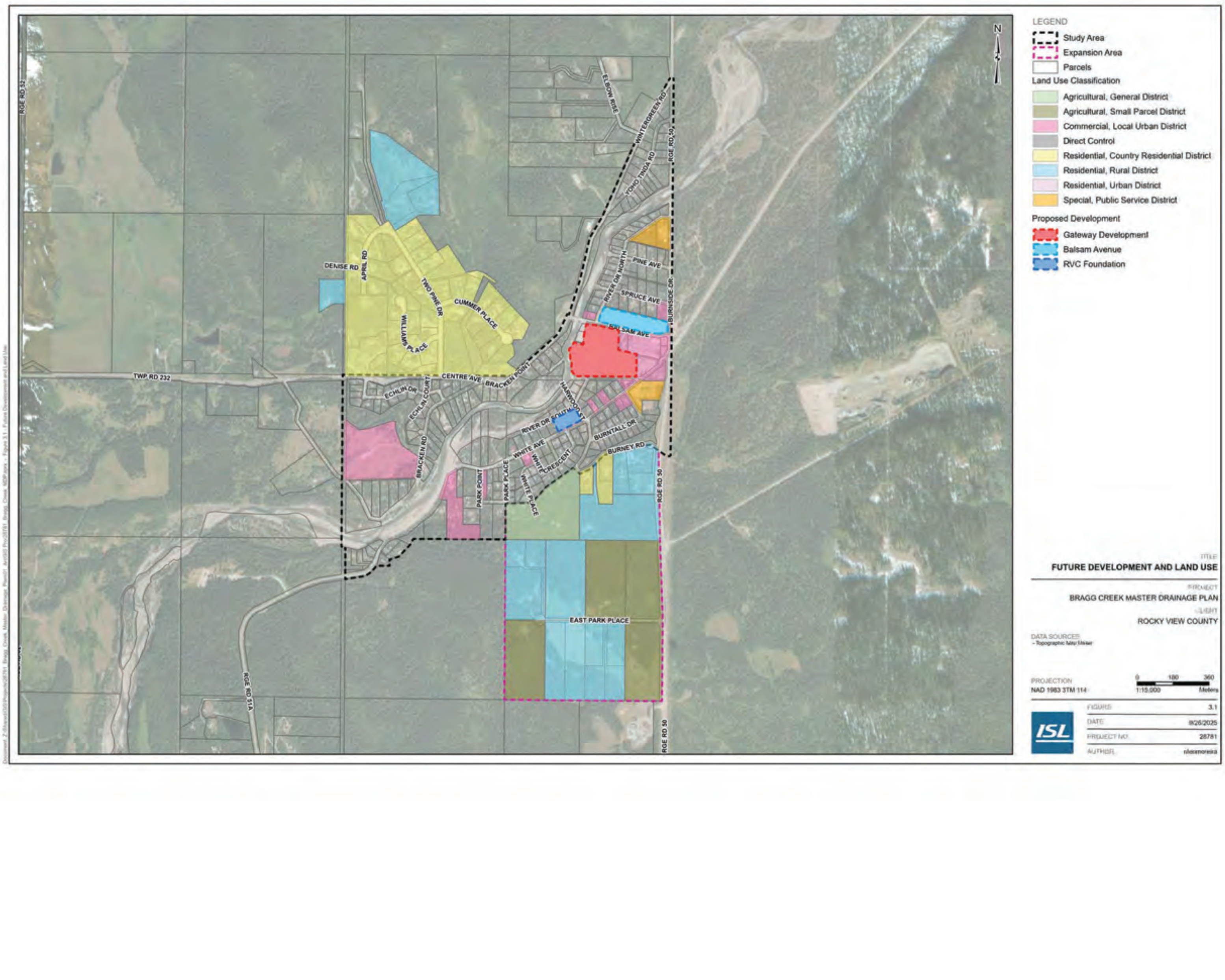
LEGEND
Study Area
Expansion Area
Parcels
Land Use Classification
Agricultural, General District
Agricultural, Small Parcel District
Commercial, Local Urban District
Direct Control
Residential, Country Residential District
Residential, Rural District
Residential, Urban District
Special, Public Service District
Proposed Development
Gateway Development
Balsam Avenue
RVC Foundation
TWP RD 232
RGE RD 52
RGE RD 51A
RGE RD 50
DENISE RD
APRIL RD
TWO PINE DR
CUMMER PLACE
WILLIAMS PLACE
ELBOW RISE
WINTERGREEN RD
YOHO TINDA RD
PINE AVE
SPRUCE AVE
BALSAM AVE
BURNSIDE DR
CENTRE AVE
BRACKEN POINT
ECHLIN DR
ECHLIN COURT
BRACKEN RD
RIVER DR SOUTH
BURNTALL DR
BURNEY RD
WHITE AVE
WHITE CRESCENT
WHITE PLACE
PARK POINT
PARK PLACE
EAST PARK PLACE
TITLE
FUTURE DEVELOPMENT AND LAND USE
PROJECT
BRAGG CREEK MASTER DRAINAGE PLAN
CLIENT
ROCKY VIEW COUNTY
DATA SOURCES
PROJECTION
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1:15,000 Meters
FIGURE 3.1
DATE 8/26/2025
PROJECT NO. 28781
AUTHOR(S)

4.0 Review of Existing Information

4.1 Previous Studies and Reports

This MDP is informed by several key technical documents:

- **Bragg Creek Hamlet Expansion ASP Servicing Feasibility Study (ISL, 2020):** Provided a baseline assessment of water and wastewater infrastructure capacity and identified future servicing needs and design parameters.
- **Impacts of Proposed Flood Protection Dikes at Bragg Creek on Flood Conditions at Redwood Meadows (Amec Foster Wheeler, 2016):** Contains detailed hydraulic modeling of the Elbow River, confirming the presence of a natural flood spillway (flow split) at Balsam Avenue and providing critical data on flood elevations.
- **Hydrogeological Investigation for Gateway Village (ISL, 2021):** A critical study confirming the high permeability of the alluvial aquifer and its direct hydraulic connection to the Elbow River. The investigation documented the rapid response of groundwater to changes in river stage, observing a lag time of only approximately half a day, and concluded that groundwater levels across the site will likely rise to match the 1:100-year flood elevation of the river.
- **Stormwater Management for Gateway Village in Bragg Creek (ISL, 2022):** Outlined a site-specific stormwater management strategy for a major development, highlighting the challenges of groundwater rise and the necessity of a lift station for positive drainage. Gateway Developments Ltd. has granted ISL Engineering permission to include information from the Stormwater Management Report for Gateway Village within this document.
- **Bragg Creek Area Structure Plan Hamlet Review (Rocky View County, ongoing):** Provides the land use and planning vision for future growth that this MDP is designed to support.
- **Hydrogeological Development Suitability Study (WSP, 2025):** This is the foundational hydrogeological assessment for the MDP. It characterizes the surficial and bedrock geology, analyzes groundwater conditions, and provides a detailed assessment of groundwater seepage and flooding risks. The study concludes that induced groundwater seepage during a 1:100-year flood event may propagate 50 to 100 m inland from the river and flood berm, confirming that groundwater management is the central challenge for drainage and development in Bragg Creek.
- **Bow and Elbow River Hazard Study – Flood Risk Inventory and Assessment Report (WSP, 2025a):** This provincial study provides a detailed inventory of land parcels, buildings, infrastructure, and population at risk from various flood events (2-year to 1,000-year). For Bragg Creek, it specifically quantifies infrastructure vulnerabilities, noting that the Bracken Road bridge is overtopped starting at the 50-year flood event and Highway 22 is impacted starting at the 75-year event. Crucially, it also confirms that the Bragg Creek Water Treatment Plant is not affected by any of the modeled open water flood events.
- **Bow and Elbow River Hazard Study – Design Flood Hazard Mapping Report (WSP, 2025b):** This report establishes the official regulatory flood hazard zones for the Hamlet based on the 100-year design flood. It formally delineates the Floodway, Flood Fringe, High Hazard Flood Fringe, and Protected Flood Fringe areas. The "Protected Flood Fringe" designation applies to the areas behind the new flood barriers, acknowledging the residual risk from groundwater or a potential berm failure. This MDP officially adopts these flood hazard classifications.

4.2 Historical Flood Events and Records

The June 2013 flood is the defining historical event for the study area. This event caused widespread inundation from both overland river flow and significant groundwater-related flooding throughout the Hamlet. Anecdotal and recorded evidence from 2013 validated the long-held understanding that the community's flood risk is a complex interaction between the river and the underlying aquifer.
While the subsequent construction of the Elbow River Flood Barrier provides protection against overland river flow for a specific design event, the hydrogeological mechanism observed in 2013 remains.

The Hydrogeological Development Suitability Study (WSP, 2025) was commissioned to analytically quantify this subsurface flood risk. The study's key finding is that a direct hydraulic connection between the river and the shallow alluvial aquifer will cause significant groundwater to rise behind the flood berm during a major flood. The modeling shows that during a 1:100-year event, the zone of impact from this induced groundwater seepage is expected to extend 50 to 100 meters inland from the river and flood berm. Within this zone, groundwater is predicted to "daylight" (emerge at the surface) and cause significant hydrostatic pressure on subsurface structures like basements.

Figure 4.0 (taken from the draft hydrogeological study by WSP, 2025) illustrates the predicted extent of groundwater daylighting and potential seepage impacts to basements during a 1:100-year flood. This analytically confirmed inundation map is foundational to this MDP, reinforcing that the primary drainage challenge is not preventing water from entering the "protected" area, but rather managing the groundwater that will inevitably rise from below.

4.3 Available Survey and Mapping Data

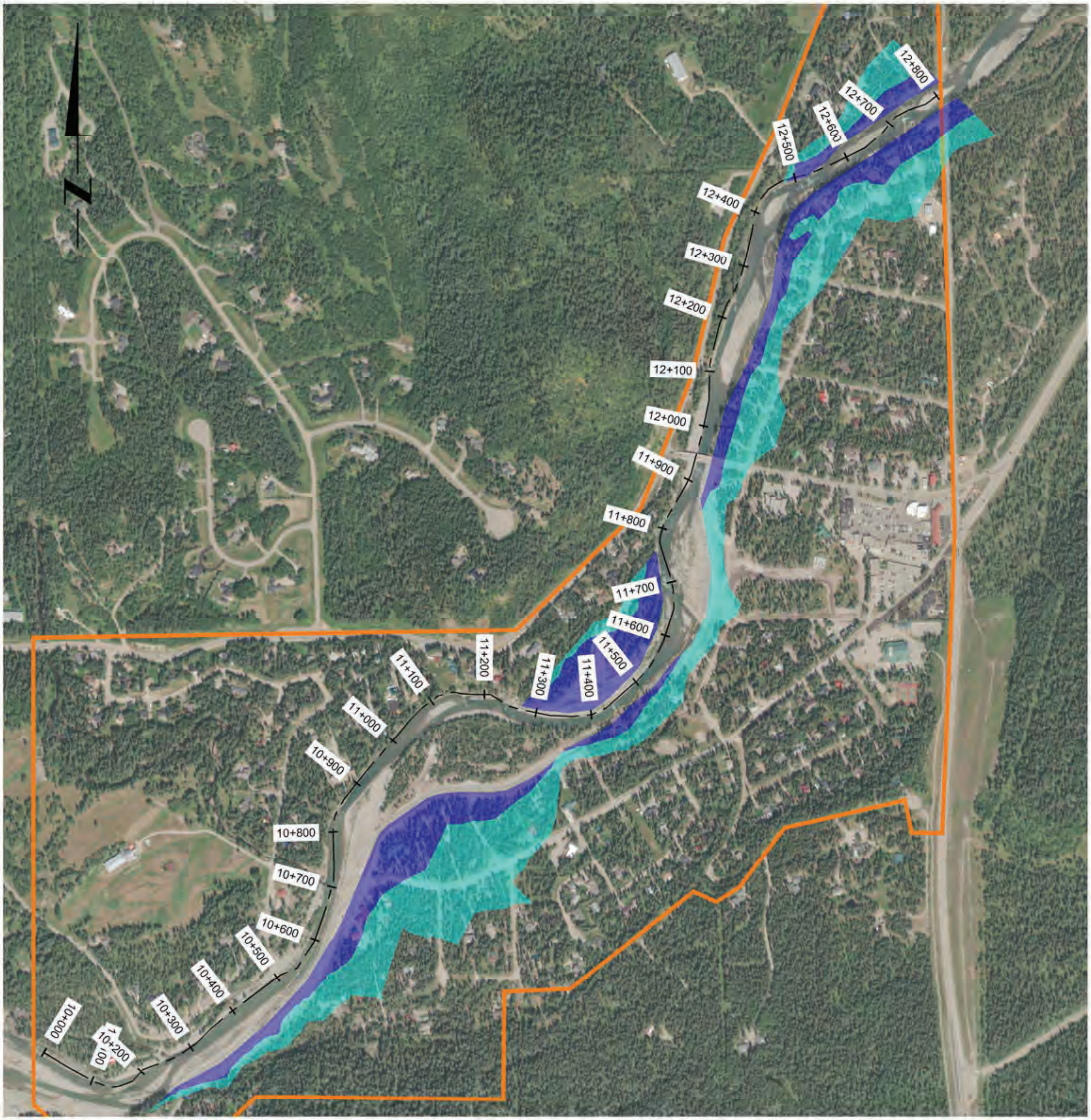
The analyses in this Master Drainage Plan are based on a comprehensive set of survey, mapping, and infrastructure data specifically relevant to surface water drainage. The primary data sources included:

- **Topographic Data:** Recent Light Detection and Ranging (LiDAR) data covering the entire study area. This high-resolution dataset was used to create the Digital Elevation Model (DEM) that defines overland flow paths, delineates catchment areas, and models the existing ditches and swales for the hydraulic analysis.
- **Aerial Photography:** High-resolution aerial imagery was used to assess land cover, vegetation density, and estimate surface imperviousness (e.g., roads, rooftops, gravel lots). This information was critical for assigning runoff parameters in the hydrologic model.
- **Infrastructure Records:** An inventory of existing surface drainage features was compiled from Rocky View County's GIS database and a review of as-built drawings, where applicable. Mapping provided building footprints and road outlines, which are critical for defining hydraulic obstructions and roughness areas in the 2D model.
- **Field Survey Data:** Site-specific field investigations were conducted to validate the LiDAR data and confirm key infrastructure details.

4.4 Review of Relevant Policies and Standards

The design criteria and recommendations in this report adhere to the Rocky View County Servicing Standards and the Alberta Environment and Protected Areas (AEPA, formerly AEP) Stormwater Management Guidelines.

File Name: C:\Users\wds_james.r.hughes\DC\ACCDocs\WSP Canada projects (AMER)\Canada Water-Small Projects\Project Files\CA0048988.7843 Bragg Creek Seepage\1 Deliverables\2 Figures\CA0048988.7843_FIG-01_E-0001.dwg Saved By: Hughes, James Plot Date: 250730 1:13 PM ANSI A 279mm x 216mm



LEGEND:

- Potential Groundwater Daylighting - 1:100 year flood
- Potential Seepage Impacts to Basements - 1:100 year flood
- HAMLET GROWTH AREA

SCALE
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DRAFT

wsp	PROJECT NAME BRAGG CREEK HYDROGEOLOGICAL DEVELOPMENT STUDY	PROJECT NUMBER CA0048988
CLIENT ROCKY VIEW COUNTY	SHEET TITLE Groundwater Seepage Assessment - 1:100 Year Flood	FIGURE NUMBER 9 ISSUE/REVISION A

5.0 Data Collection and Field Investigations

5.1 Topographic and LiDAR Data Acquisition

A recent LiDAR dataset provided the basis for the Digital Elevation Model (DEM) used in the hydraulic and hydrologic modeling, defining overland flow paths and delineating catchment areas. Existing topographic map of the study area is detailed in Figure 5.0.

5.2 Infrastructure Inventory and Condition Assessments

A comprehensive inventory of the existing surface drainage infrastructure was conducted to establish a baseline for the hydraulic analysis. The process integrated a desktop review of Rocky View County's GIS database and available as-built records with a detailed analysis of high-resolution LiDAR data. This data was used to create a Digital Elevation Model (DEM) that delineated the network of informal roadside ditches, swales, and the dominant overland flow paths that constitute the Hamlet's de facto major drainage system.

The inventory revealed that the Hamlet relies on an ad-hoc collection of infrastructure with several key deficiencies. Many roadside ditches and swales are discontinuous, terminating at property lines or driveways without a clear connection to a downstream path, which is a primary cause of nuisance ponding.

Crucially, the overland flow path analysis confirmed that topography naturally directs major flows from the Hamlet's core northward across Balsam Avenue. This corridor functions as the community's unofficial but critical emergency spillway. Additionally, it is important to note that the Balsam Avenue Bridge is the only access point for West Bragg Creek. This makes the bridge a critical piece of infrastructure for both daily access and emergency response, especially during flood events when alternative routes may be unavailable.

5.3 Site Visits and Photographic Documentation

An initial site visit was conducted in August 2025 to observe current site conditions, verify the status of recent flood mitigation works, and document key features of the existing informal drainage system within the Hamlet.

The recently constructed Elbow River Flood Barrier was observed to be complete and functional, with the berm and associated rip-rap installed as per design. Key components of the system, including outfalls and drainage swales/culverts along the land side of the berm, were also noted.

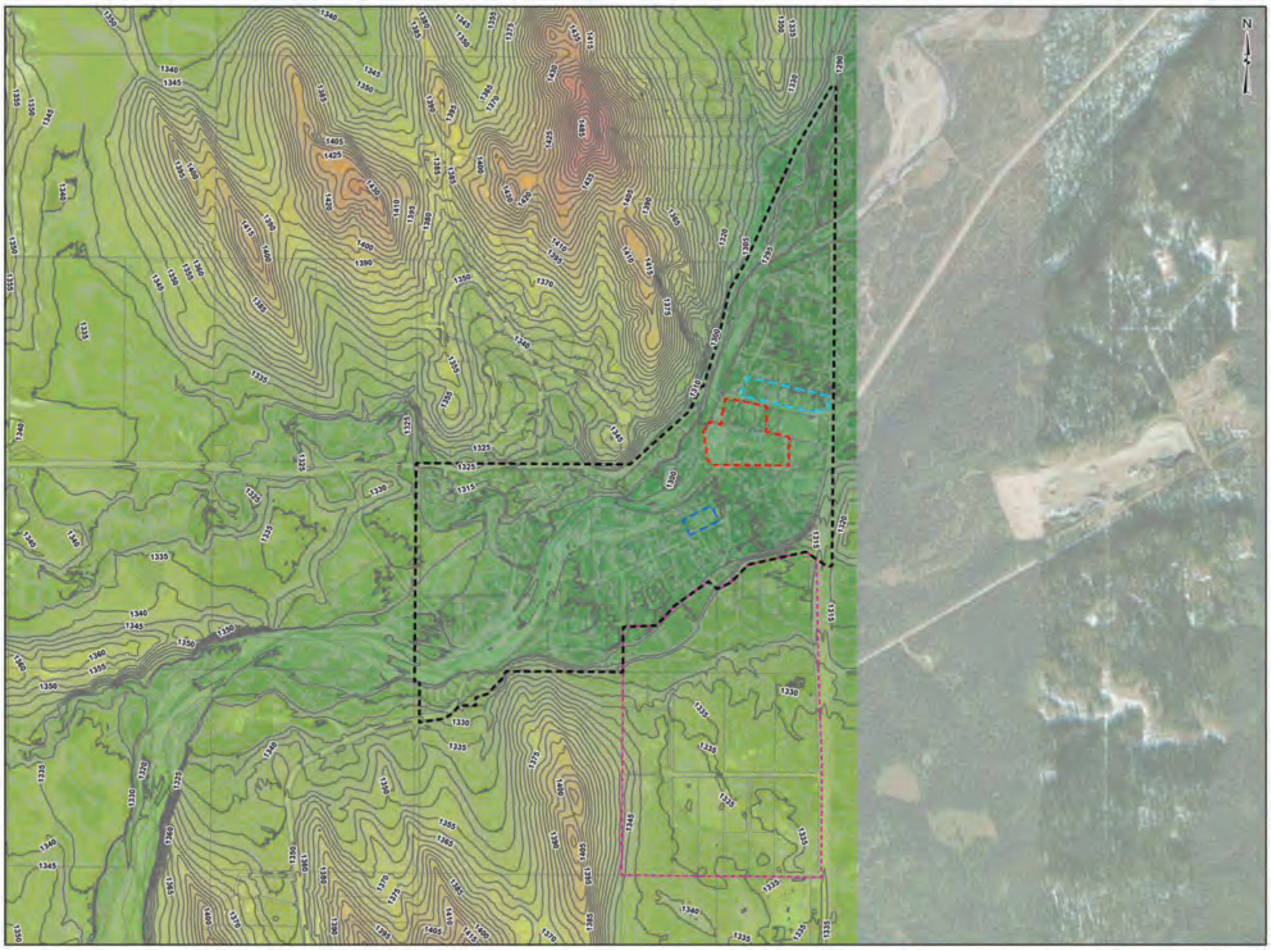
Observations within the Hamlet's core, away from the new flood barrier, identified significant deficiencies in the existing informal drainage system. Numerous culverts under roadways and driveways were found to be partially or fully blocked with sediment and debris. In several locations, culverts were noted to be partially crushed or damaged, severely restricting their hydraulic capacity (see Figure 5.0, below).

Figure 5.0: Crushed or Damaged Culverts

Similarly, many of the roadside swales were heavily overgrown with vegetation, which impedes flow and reduces conveyance capacity. These swales require significant vegetation removal and, in many cases, re-grading to restore their intended function. A common issue identified was a lack of positive drainage connectivity; swales along individual properties or driveways frequently terminate without a clear connection to a downstream swale or culvert, creating areas of localized ponding (see Figure 5.1, below) These field observations confirm the need for a formalized major drainage system to effectively convey stormwater.

Additional site visits may be warranted following the completion of the hydraulic modeling and upon receipt of feedback from the County. Such visits would serve to ground-truth specific model outputs or investigate areas of concern identified during the review process. This section will be updated as required for the final report submission.

Figure 5.1: Localized Ponding Area



TITLE
EXISTING TOPOGRAPHY

PROJECT
BRAGG CREEK MASTER DRAINAGE PLAN

CLIENT
ROCKY VIEW COUNTY

DATA SOURCE(S)
- Topographic Map Mosaic

PROJECTION
NAD 1983 3TM 114

0 180 360
1:15,000 Meters

FIGURE	5.2
DATE	8/29/2025
PROJECT NO	28781
AUTHOR	rdesmoreira

6.0 Hydraulic Analysis

6.1 Model Set-Up

The model used for assessing the Bragg Creek stormwater system was PCSWMM Version 7.4 developed by Computational Hydraulics International (CHI). The software was chosen due to its ability for 2-D integrated modeling combined with its powerful GIS integration in addition to its 1-D modelling capabilities. Some of the capabilities of PCSWMM that were an asset for this project are summarized below:

- Effective in urban and rural applications, PCSWMM is a popular modelling software utilized by numerous municipalities across the country.
- Ease with applying differential cell sizing.
- Rain on Mesh option is available, meaning that overland flow path assumptions are not necessarily required upfront.
- Triangular mesh elements mean that the surface can be modelled with extreme accuracy; • Ability for terrain sensitive meshing, ensuring that changes in topography are reflected in the mesh.
- Ability to account for building footprints.
- Compatible with ArcGIS.

A 2-D model was built for Bragg Creek to assess the existing conditions of Bragg Creek. The 2-D model was constructed by utilizing all available data combined with survey, limited record drawings, and certain assumptions. Section 6.2 describes the process that was undertaken to develop the 2-D model, including a discussion of the features and parameters that were required as input into the mesh development process, and a summary of the mesh generation itself.

6.2 Major System (2D) Development

The major system consists of all overland drainage components listed in section 3.0. The following parameters have been considered to develop a mesh, which ultimately represents the overland drainage system:

- Boundary Layer
- Roughness
- Resolution
- Seepage (infiltration)
- Obstruction layer

The bounding layer represents the boundary in which the 2D analysis will occur and is digitized to be a simplified version total catchment area for Bragg Creek. 2D nodes are created within the boundary layers by sampling elevations from a digital elevation model (DEM) layer. A 2D mesh is created from the 2D nodes. The mesh represents the surface with hexagons as mesh elements, each with their own unique elevation. Together with other mesh elements, a surface is formulated. The number of mesh elements has a direct impact on simulation run times. Various parameters can be considered when developing a mesh. For the model that has been developed as part of the MDP, these parameters include the resolution, roughness, and seepage for each boundary layer.

The mesh zone specifies different mesh element densities for various zones, to either increase or decrease the resolution of a zone depending on its importance. For example, in order to capture pertinent features such as the crowns of roads or curb and gutters, roadways are generally defined by denser, smaller elements. Alternatively, greenfields that do not impact existing developments could be considered for larger mesh elements.

The roughness zone allows various Manning's n roughness values for different parts of the mesh. A roughness value is assigned to each mesh element depending on which roughness zone that mesh element is a part of. The roughness zone allows for a more accurate representation of different surfaces within the model.

Seepage is another parameter for the bounding layer which defines the seepage rate for generating the mesh. The seepage rate allows for varying infiltration parameters across the mesh, depending on the different surfaces that are apparent within the mesh. Each boundary layer is designated a seepage rate, using the Horton Method for infiltration. For this study, due to potentially high groundwater interactions, a low seepage rate was used to remain conservative.

Default mesh, roughness and seepage parameters were defined in the boundary layer to represent impervious areas such as roadways and buildings. These default parameters are stipulated below in Tables 6.1, 6.2, and 6.3.

The boundary layer parameters are based on ISL's experience using PCSWMM, optimizing both model simulation time and level of detail. The roughness zone parameters are based on engineering best practices, and are consistent with past projects completed by ISL. The seepage parameters are based on a combination of the runoff coefficients stipulated in the Stormwater Management and Design Manual (City of Calgary, 2011) with the goal of maintaining conservative values due to the mentioned shallow water tables and shallow bedrock in the area.

Table 6.1: Mesh Zone Parameter Per Land Use Type

Land Use	Resolution	Style
Grassed Area	8	Hexagonal
Roads	8	Hexagonal
Commercial	8	Hexagonal

Table 6.2: Roughness Zone Parameters Per Land Use Type

Land Use	Roughness Coefficient
Grassed Area	0.04
Roads	0.011
Commercial	0.081

Table 6.3: Infiltration Zone Parameters Per Land Use Type

Land Use	Seepage Rate (mm/hr)
Grassed Area	1.016
Roads	0
Commercial	0

Incorporating buildings into the 2D model was a major consideration. Ultimately, as the models utilize mesh ideology, the most conservative and effective approach was found to represent the buildings on an obstruction layer, meaning the buildings are not a part of the mesh. In addition, the existing berm was also modeled as an obstruction. The berm and building footprints were digitized based on the available engineering drawings and aerial imagery.

6.3 Channel and Overland Flow Path Analysis

The hydraulic model developed for this MDP confirms that under extreme flood conditions, the primary overland flow path within the downtown Bragg Creek area is north across Balsam Avenue as shown in Figure 14.0. This result is directly consistent with the independent hydraulic modeling performed by Amec Foster Wheeler (2016), which identified this corridor as a natural "flow split" in the Elbow River's flood fringe. This overland path exists over private lands and represents the natural topographic spillway for the area, not a constructed channel.

6.4 Culvert and Bridge Capacity Assessments

The hydraulic performance of key crossings was assessed in the provincial *Bow and Elbow River Hazard Study* (WSP, 2025a). The study concluded that while the Centre Avenue bridge has sufficient capacity, the Bracken Road bridge is overtopped during a 50-year flood event and would be overtopped by 1.1 meters during the 100-year design flood. This crossing is a significant hydraulic constriction and a known high-risk area.

6.5 Floodplain Mapping and Extent

Floodplain mapping for this MDP is based on the official Design Flood Hazard Mapping Report for the Bow and Elbow River Hazard Study (WSP, 2025). The area within the Hamlet protected by the Elbow River Flood Barrier is officially classified as a Protected Flood Fringe, acknowledging the residual flood risk from groundwater surcharge and potential berm failure.

7.0 Design Criteria

The design criteria for the Bragg Creek stormwater system are based on the Rocky View County Servicing Standards, AEPA Stormwater Management Guidelines, The City of Calgary's Stormwater Management and Design Manual, and best engineering practices adapted for the unique hydrogeological conditions of the site.

7.1 Design Rainfall Events

The design storms applied in this study are based on The City of Calgary's adjusted Meteorological Service of Canada (MSC) intensity-duration-frequency (IDF) curves, consistent with regional practice.

Major System Design: The overland flow system (roadways) and the SWMF are designed to manage the 1:100 year, 24-hour Chicago design storm.

Table 7.1: City of Calgary's Adjusted MSC IDF Curve – Intensity Summary (mm/hr)

Time	Return Frequency					
Minutes	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
5	58.80	87.60	106.80	132.00	150.00	168.00
60	13.70	19.40	23.20	28.00	31.60	35.10
720	2.59	3.50	4.09	4.85	5.41	5.97
1440	1.55	2.13	2.52	3.00	3.37	3.73

Table 7.2: City of Calgary's Adjusted MSC IDF Parameters

Parameter	Return Frequency					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
a	243.0	353.5	429.1	522.6	594.9	663.1
b	2.710	2.290	2.160	1.960	1.940	1.870
c	0.695	0.703	0.707	0.709	0.711	0.712

Table 7.3: Climate Change Adjusted IDF Parameters (RCP 4.5 - 2050 Horizon)

Parameter	Return Frequency					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
a	16.2	23.2	28.8	36.9	44.0	53.0
b	0.054	0.064	0.076	0.095	0.119	0.143
c	0.730	0.757	0.772	0.784	0.794	0.803

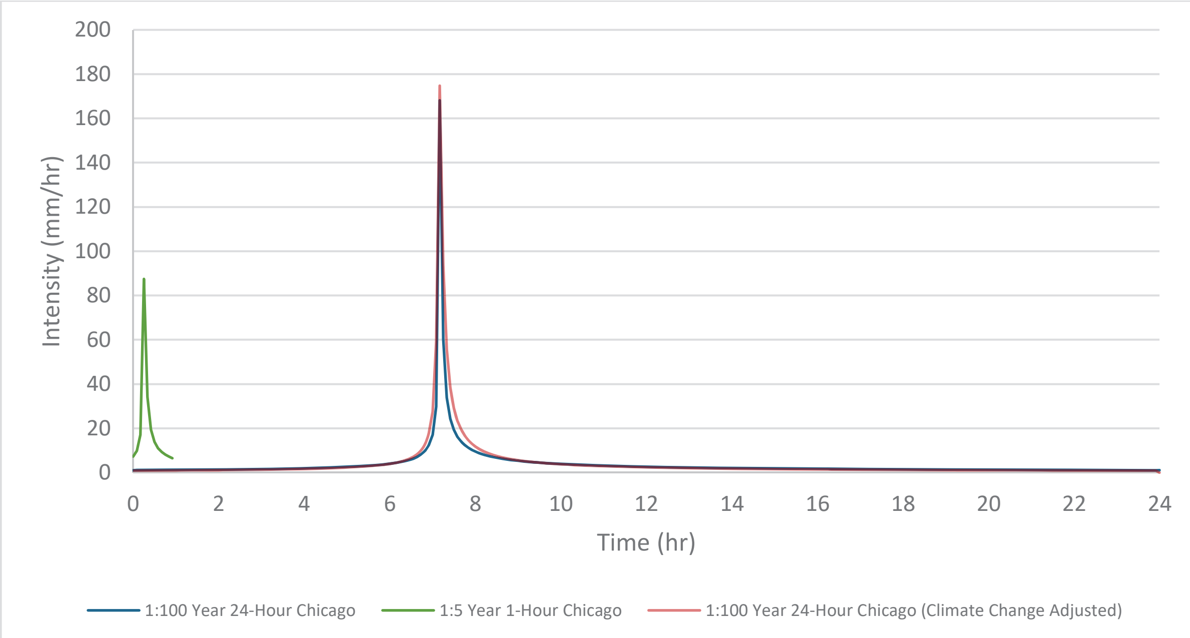


Figure 7.1: Design Rainfall Event Hydrographs

7.2 Assessment Criteria

In assessing the storm drainage system in an area, typically a 1:5 year storm is used to assess the minor (piped) drainage system under short duration, high intensity rainfall events. This is followed by analysis with a large volume storm to test the system under large flow volumes once the system is saturated, which would typically be a 1:100 year, 24-hour event. Given the existing system is entirely overland drainage, only the 1:100 year storm was assessed in the 2D model.

7.2.1 2D Assessment Criteria

To present and evaluate 2D assessment model results, model files were reviewed, and results data was extracted for both depth and velocity at the maxima, for the 1:100 year event. The complete model file contains velocity and depth properties at any time step within the simulation in the event they are required. Additionally, different storm events can be applied to the model to allow Rocky View County to explore different scenarios, if required.

To increase public safety, the Province of Alberta has stipulated permissible depths for submerged objects in relation to water velocity. This guideline, Stormwater Management Guidelines for the Province of Alberta, 1999, was implemented to ensure that a 20 kg child would be able to withstand the force of moving water, thus preventing possible tragedies. Figure 7.2 indicates these requirements.

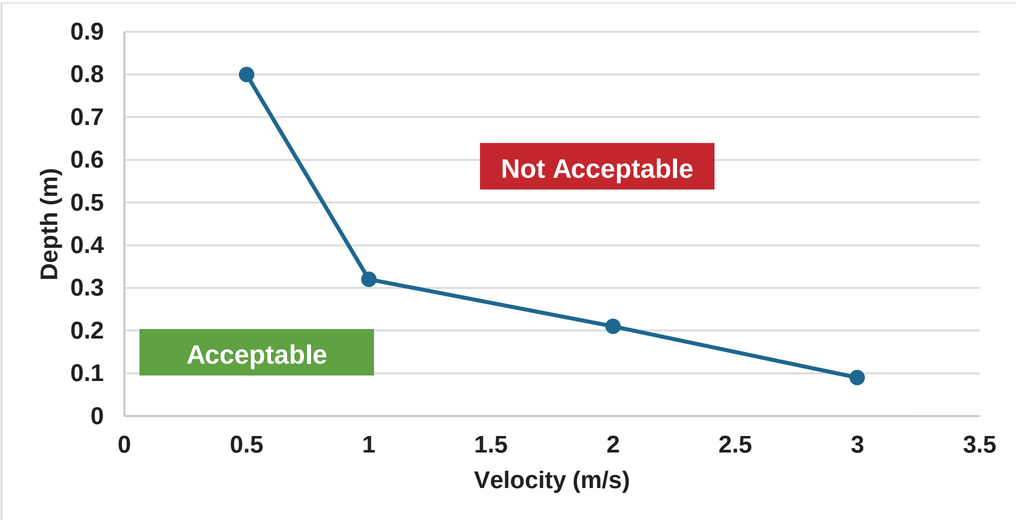


Figure 7.2: Permissible Depth vs. Velocity

8.0 Existing System Assessment

The existing system was assessed using the design criteria stipulated above. The existing system was assessed under the City of Calgary 1:100 year 24-hour Chicago design storm. Simulation results are described in Section 8.1 below.

8.1 Hamlet Area - 1:100 Year Event 2D Model Results Summary

To assess Bragg Creek's existing overland drainage system, model results were extracted at the maxima for both water depth relative to the LiDAR surface and surface flow velocity. It is noted that the maxima represent the peak depth/velocity value of each mesh element at a specific point in time. The water depth and surface flow velocity results are illustrated in Figures 8.2 and 8.3, respectively.

The results shown on Figures 8.1 indicate that Bragg Creek largely meets the Provincial depth vs. velocity criteria. Figure 8.1 plots model results compared to the province's requirements, with very few mesh elements exceeding the criteria.

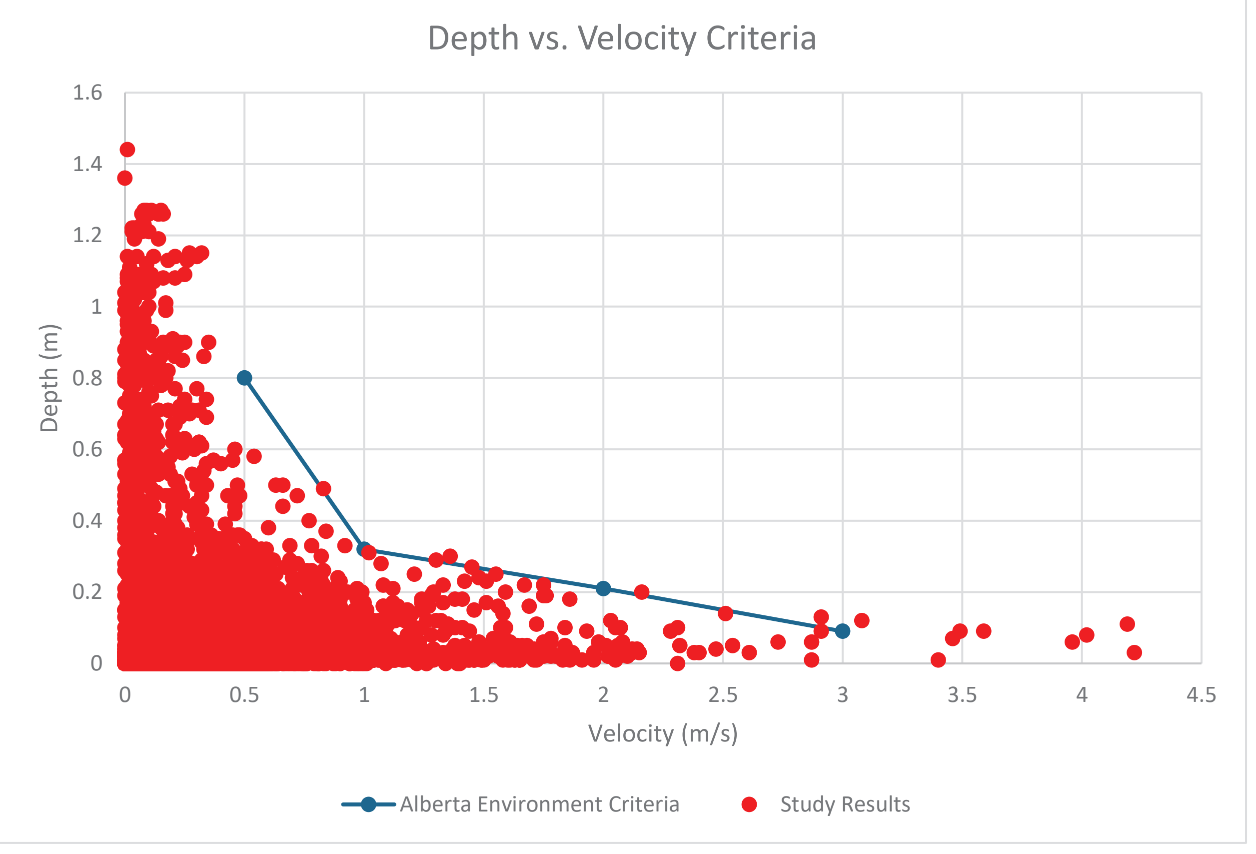
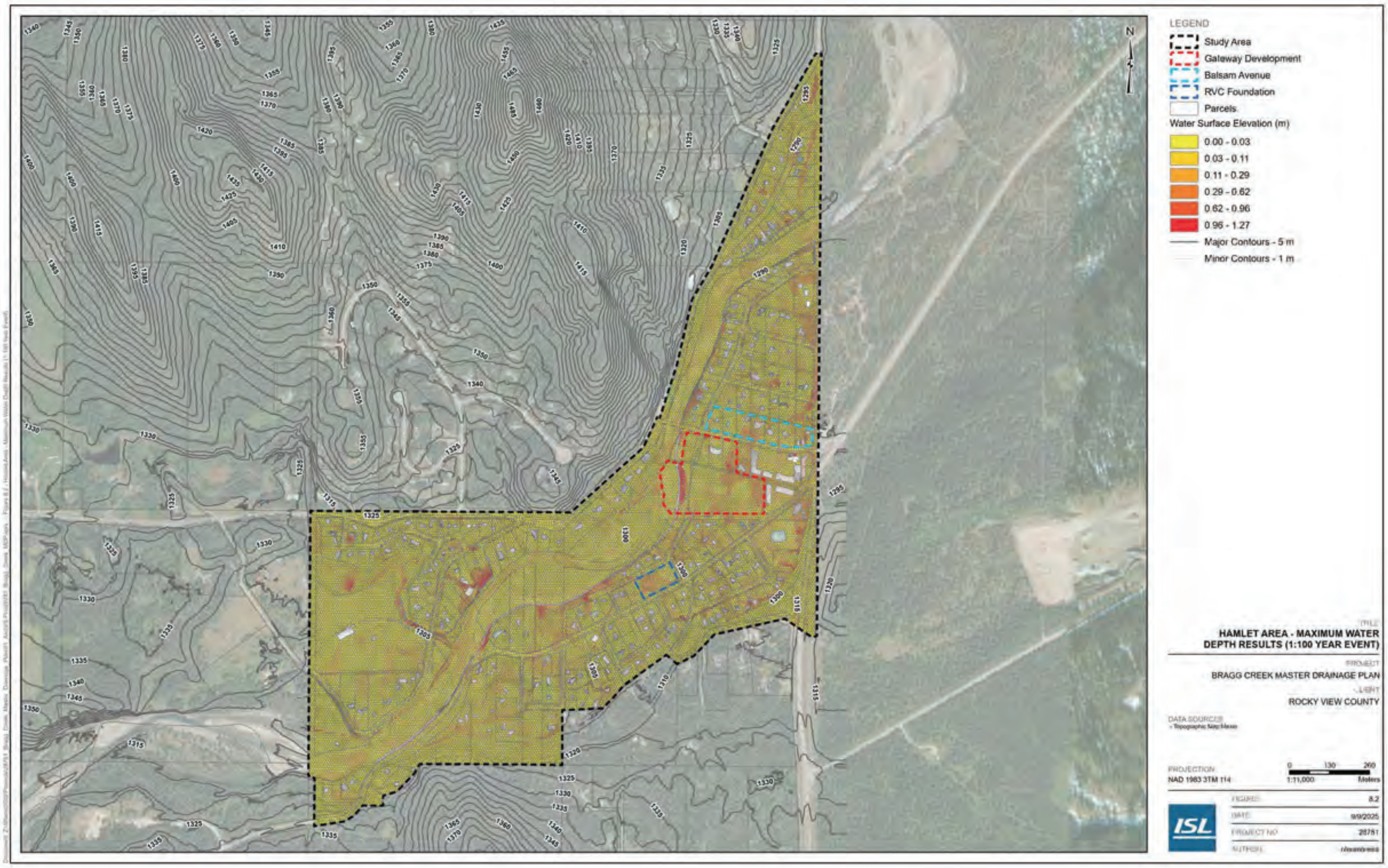


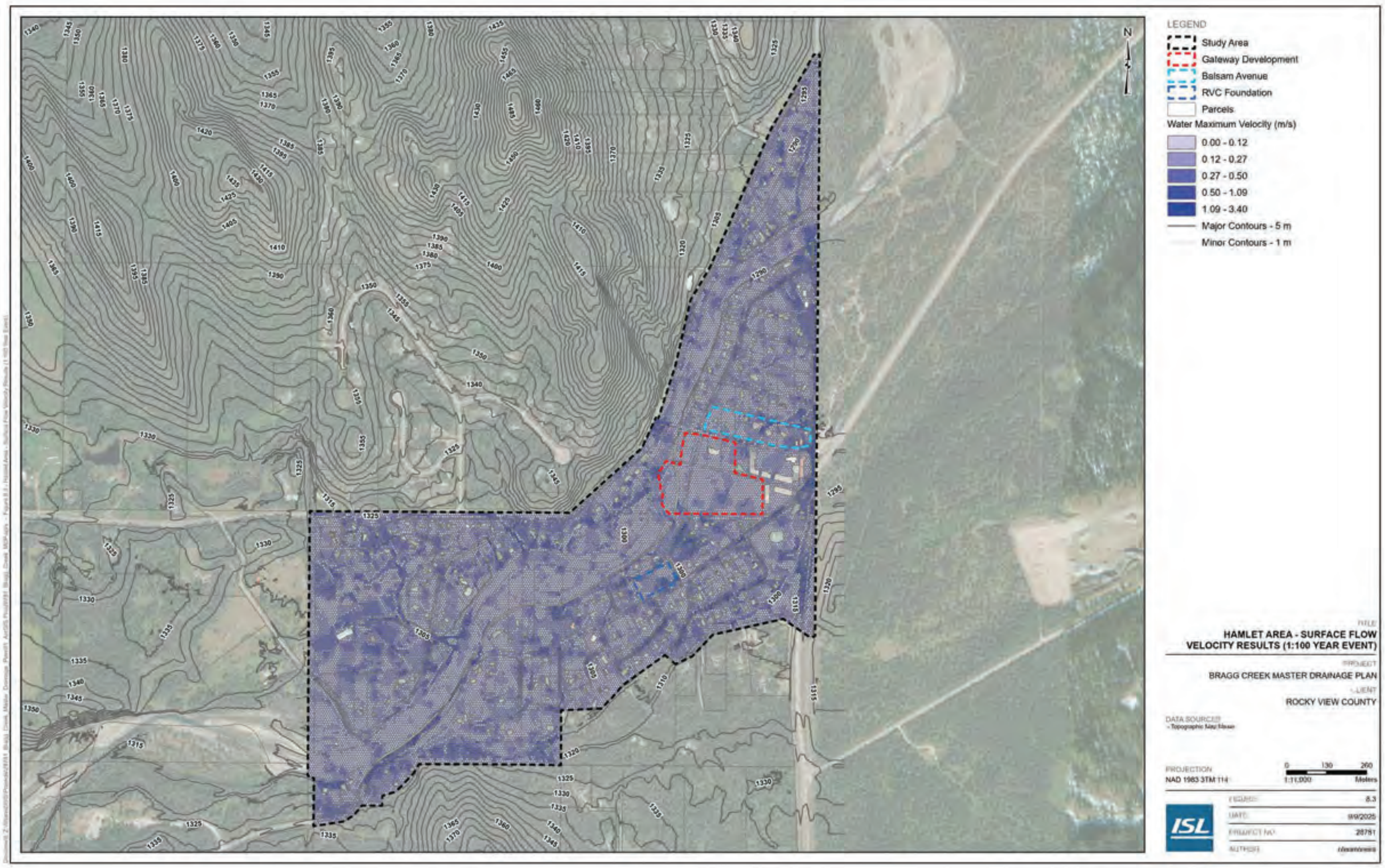
Figure 8.1: Hamlet Area - Modelling Results for Depth vs. Velocity

8.2 Hamlet Area - Observations and Recommendations

Based on the initial findings of the 1:100 year 24-hour Chicago storm 2D simulation, the following general observations, and recommendations to address the surface drainage issues in Bragg Creek are described as follows:

- There are certain areas on the surface side of the berm where overland drainage may pond, resulting in excessive depths. Some of these are listed below.
  - The highest depths observed during the 2D simulation were observed north of Bracken Road Bridge, where the “West Barrier North” was constructed. Upstream flows pond on the surface side of the barrier and struggle to drain around the modeled obstruction. Drainage improvements should be made either through an outlet into the Creek, or through potential swale improvements north of the barrier to divert as much drainage as possible prior to its arrival to the barrier. Note: though the WSP drawings show a “groundwater control outlet”, no additional details were provided in the WSP drawings (making it not clear if it was a surface or below-ground outlet), and the area was inaccessible during the site visit for visual confirmation, so a potential outlet for this area was omitted in the 2D model, and the entire barrier length was modeled as an obstruction.
  - There are intermittent areas along “East Barrier South” that indicate some ponding. These areas could be improved through improving the nearby drainage ditches that direct flow towards the nearby surface drainage outlets.


LEGEND
Study Area
Gateway Development
Balsam Avenue
RVC Foundation
Parcels
Water Surface Elevation (m)
0.00 - 0.03
0.03 - 0.11
0.11 - 0.29
0.29 - 0.62
0.62 - 0.96
0.96 - 1.27
Major Contours - 5 m
Minor Contours - 1 m
TITLE
HAMLET AREA - MAXIMUM WATER DEPTH RESULTS (1:100 YEAR EVENT)
PROJECT
BRAGG CREEK MASTER DRAINAGE PLAN
CLIENT
ROCKY VIEW COUNTY
DATA SOURCES
- Topographic Map Mosaic
PROJECTION
NAD 1983 3TM 114
0 130 260
1:11,000
Meters
FIGURE 8.2
DATE 9/9/2025
PROJECT NO 28781
ISL


LEGEND
Study Area
Gateway Development
Balsam Avenue
RVC Foundation
Parcels
Water Maximum Velocity (m/s)
0.00 - 0.12
0.12 - 0.27
0.27 - 0.50
0.50 - 1.09
1.09 - 3.40
Major Contours - 5 m
Minor Contours - 1 m
N
HAMLET AREA - SURFACE FLOW VELOCITY RESULTS (1:100 YEAR EVENT)
BRAGG CREEK MASTER DRAINAGE PLAN
ROCKY VIEW COUNTY
DATA SOURCE
PROJECTION
NAD 1983 3TM 114
0 130 260
1:11,000
Meters
8.3
ISL

8.3 Expansion Area - 1:100 Year Event 2D Model Results Summary

To assess Bragg Creek's expansion area drainage system, model results were extracted at the maxima for both water depth relative to the LiDAR surface and surface flow velocity. It is noted that the maxima represent the peak depth/velocity value of each mesh element at a specific point in time. The water depth and surface flow velocity results are illustrated in Figures 8.5 and 8.6, respectively.

The results shown on Figures 8.4 indicate that there are certain locations within the expansion area exceeding the provincial criteria, though most locations meet the requirements.

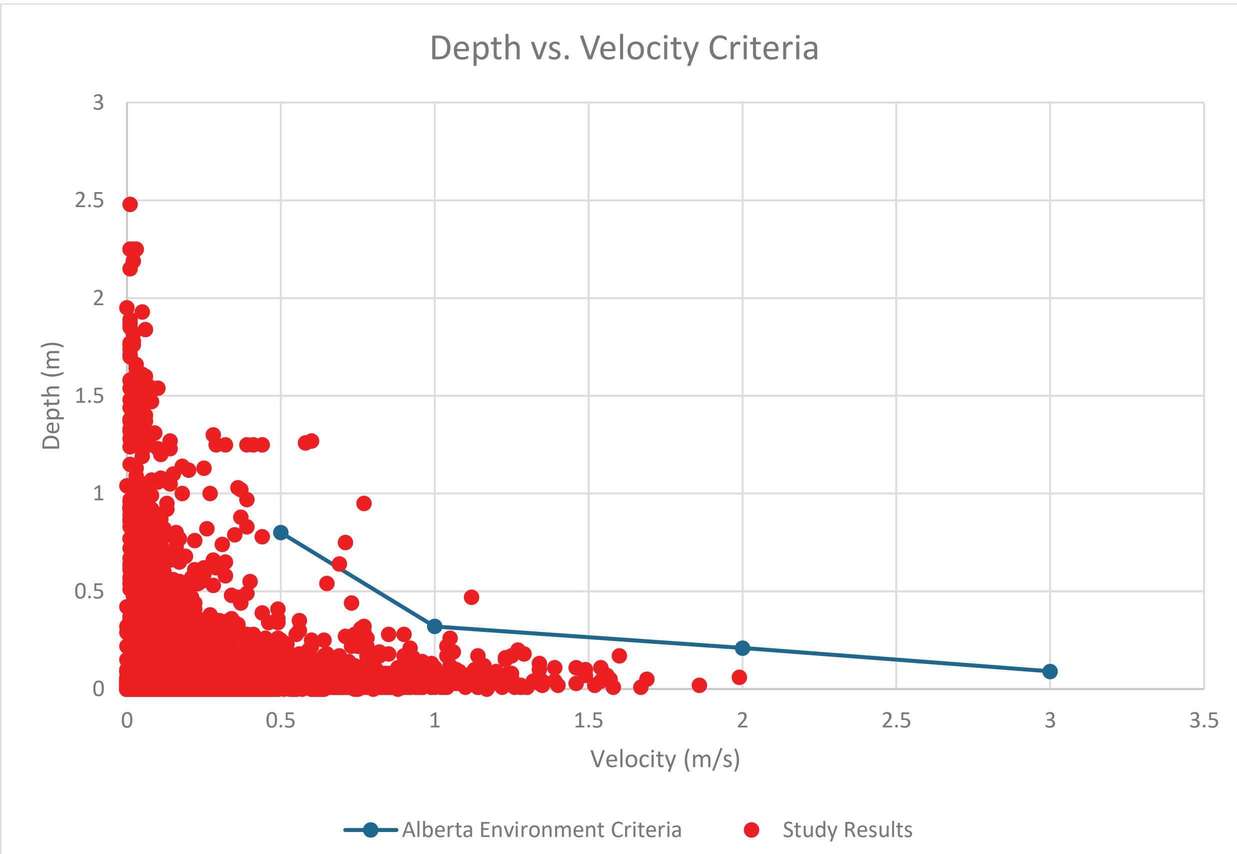
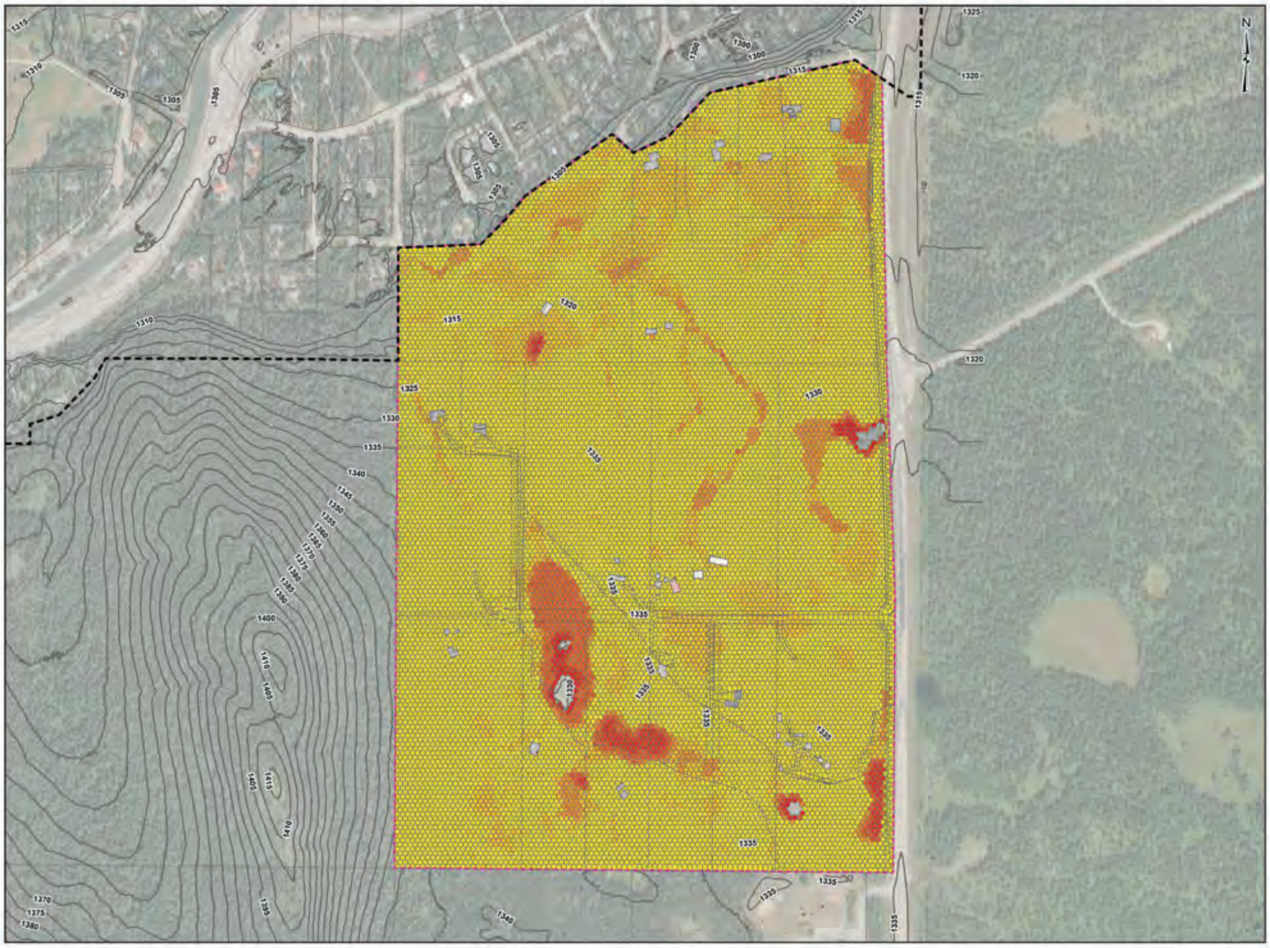


Figure 8.4: Expansion Area - Modelling Results for Depth vs. Velocity

8.4 Expansion Area - Observations and Recommendations

Based on the initial findings of the 1:100 year 24-hour Chicago storm 2D simulation, the following general observations, and recommendations to address the surface drainage issues in the expansion area are described as follows:

- There is an existing low spot north of 50095 E Park Pl where the 2D simulation indicates significant ponding. Certain locations around this area also indicate high velocities, which may be where most of the depth vs. velocity criteria is exceeded as noted above. This area would likely serve as a potential stormwater facility location for the future expansion area.
- There is some significant ponding north of the intersection between E Park Pl and Highway 22, indicating that the drainage ditch leading north is not necessarily functioning as intended. This area requires some re-grading of the ditch to ensure the flow direction is maintained to avoid ponding.



LEGEND

Study Area

Expansion Area

Parcels

Water Surface Elevation (m)

	0.00 - 0.03
	0.03 - 0.11
	0.11 - 0.29
	0.29 - 0.62
	0.62 - 0.96
	0.96 - 1.27

Major Contours - 5 m

Minor Contours - 1 m

TITLE

EXPANSION AREA - MAXIMUM WATER DEPTH RESULTS (1:100 YEAR EVENT)

PROJECT

BRAGG CREEK MASTER DRAINAGE PLAN

CLIENT

ROCKY VIEW COUNTY

DATA SOURCES

- Topographic Nearmap

PROJECTION

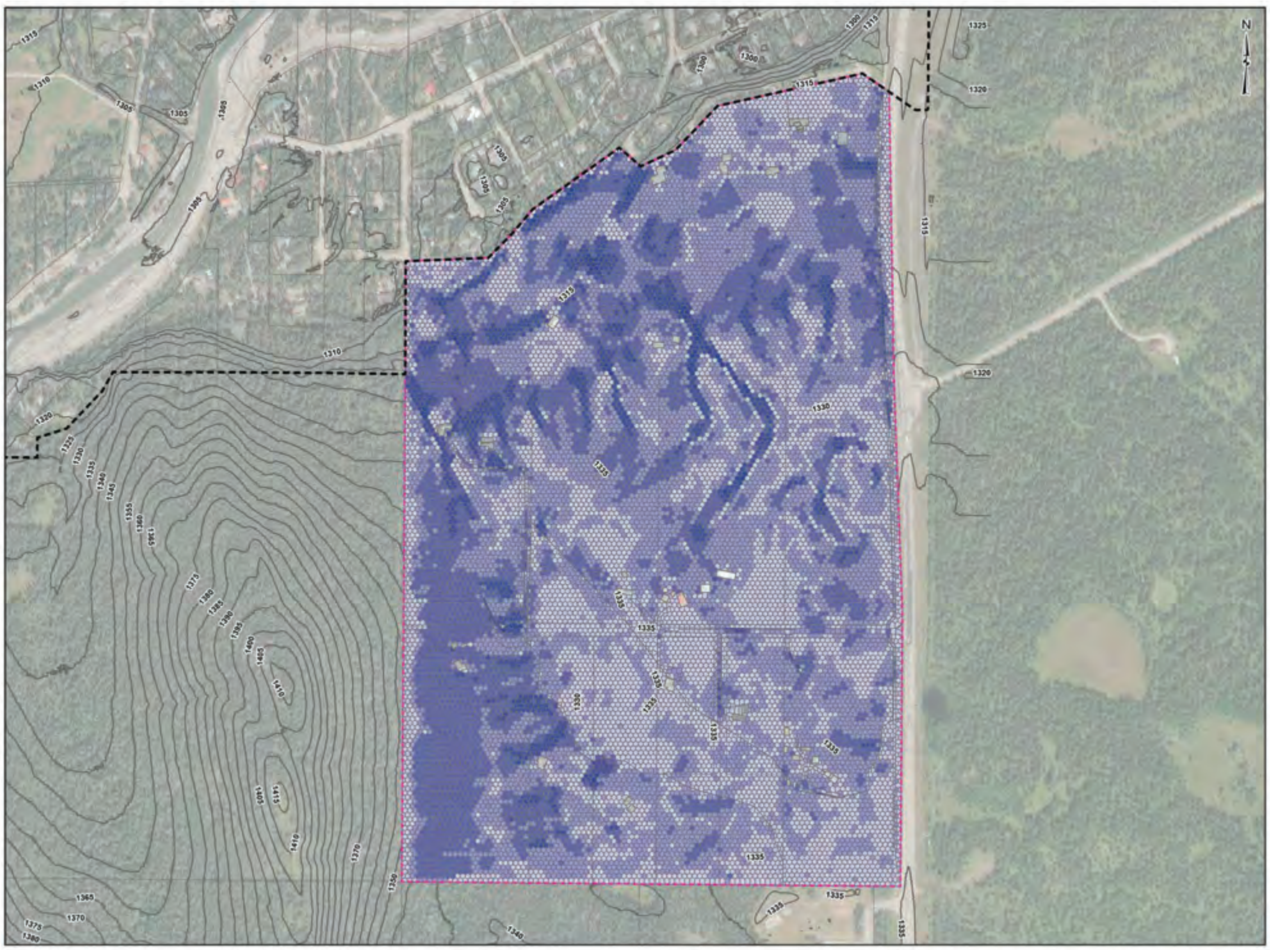
NAD 1983 3TM 114

0 70 140

1:6,000 Meters

ISL

FIGURE	8.5
DATE	9/29/2025
PROJECT NO	28781
AUTHOR	[illegible]



TITLE
EXPANSION AREA - SURFACE FLOW VELOCITY RESULTS (1:100 YEAR EVENT)

PROJECT
BRAGG CREEK MASTER DRAINAGE PLAN

CLIENT
ROCKY VIEW COUNTY

DATA SOURCES
- Topographic Map Esri

PROJECTION
NAD 1983 3TM 114

0 70 140
1:6,000 Meters

FIGURE	8.6
DATE	9/29/2025
PROJECT NO	28781
AUTHOR	rfaomoreira

9.0 Flood Risk Assessment

9.1 Identification of High-Risk Areas

The entire Hamlet area is considered to have a high risk of flooding due to its proximity to the Elbow River and the confirmed hydrogeological conditions, though the southern portion of the Hamlet is at highest risk, as it is topographically lower and will experience the most significant groundwater surcharge and longest ponding durations. This is displayed in both the previously shown Figure 4.0 as well as Figure 9.0 (taken from the Bow and Elbow River Hazard Study by WSP, 2025).

9.1.1 Groundwater Seepage Risk

While the flood berm protects against overland flow, the draft hydrogeological study by WSP (2025) study provides a quantitative assessment of the risk from groundwater seepage. Analytical modeling indicates that during a 1:100-year flood event on the Elbow River, impacts from induced groundwater seepage can propagate between 50 to 100 meters laterally inland from the river channel and berm.

This seepage will manifest as daylighting of groundwater on the surface and significant hydrostatic pressure on subsurface structures like basements within this zone. The calculated seepage fluxes are significant, estimated to be between 8 and 9 m^3/day per linear meter of riverbank at 50m from the river/berm interface. This finding analytically confirms that a portion of the Hamlet's area will experience direct inundation from groundwater during a major flood, reinforcing the strategy to manage this water within an enhanced major system rather than attempting to prevent it. The water daylighting and seepage extents are displayed in Figure 4.0 (WSP, 2025).

9.2 Understanding of the Flood Berm

The Elbow River Flood Barrier is a critical piece of infrastructure that significantly reduces the risk of catastrophic overland flooding in Bragg Creek. However, it is essential for planning, development, and emergency response to have a clear understanding of its function, design limitations, and the types of flood risk that remain.

9.2.1 Berm Function and Limitations

The flood berm is designed to prevent surface water from the Elbow River from flowing overland into the community up to its design capacity. It functions as a dam. Its critical limitation, dictated by the area's geology, is that it does not stop groundwater flow. The highly permeable alluvial aquifer beneath the Hamlet allows groundwater levels on the "dry" side of the berm to equalize with the elevated river levels on the "wet" side during a flood. This results in groundwater surcharging the ground surface.

9.2.2 Design Level of Service

The Elbow River Flood Barrier in Bragg Creek was designed and mapped to provide protection against the 1:100-year open water flood, which is the design flood standard used for the entire study area (*Bow and Elbow River Hazard Study - Design Flood Hazard Mapping Report, Report 1, Section 3.1*).

While the official design level is the 1:100-year event, the flood risk assessment data suggests the berms are overtopped or fail in a flood scenario between the 1:200-year and 1:350-year recurrence interval. At the 1:350-year flood level, the area behind the berm transitions entirely from being mapped as a "protected flood fringe" to an area of "direct inundation" (*Bow and Elbow River Hazard Study - Flood Risk Inventory and Assessment Report, Report 2, Tables 23 & 25*).

9.2.3 Flood Frequency vs. Inundation Extent

The extent and depth of surface water inundation are directly related to the magnitude of the river flood. While the community is protected from direct overland flow during the 1:100-year design flood, larger and rarer floods will result in more severe impacts. The design flood hazard maps illustrate these increasing risks by showing the incremental inundation extents for floods larger than the design standard (*Bow and Elbow River Hazard Study - Design Flood Hazard Mapping Report, Report 1, Executive Summary*).

- 1:100-Year Event: Inundation from groundwater seepage is predicted to extend 50-100 meters inland, as shown in Figure 4.0.
- Events > 1:100-Year (e.g., 1:200-Year & 1:500-Year): A larger flood produces a higher river level, resulting in a greater extent of overland flooding in unprotected areas. The hazard maps specifically illustrate the areas at risk for the regulated 1:200-year and 1:500-year floods to show this escalating risk (*Bow and Elbow River Hazard Study - Design Flood Hazard Mapping Report, Report 1, Section 4.3.1*).

9.2.4 Residual Risk: Berm Failure or Overtopping

A residual risk always exists for any flood mitigation structure. The area behind the Bragg Creek berm is mapped as a "Protected Flood Fringe" to illustrate this risk, which could be realized in the event of a flood that exceeds the berm's capacity or a structural failure (a breach) (*Bow and Elbow River Hazard Study - Design Flood Hazard Mapping Report, Report 1, Executive Summary & Section 3.3*).

In such a failure scenario, the consequences would be severe. This would result in overland flooding characterized by conditions similar to a "Floodway"—the zone of highest hazard where flows are described as "deepest, fastest, and most destructive" (*Bow and Elbow River Hazard Study - Design Flood Hazard Mapping Report, Report 1, Section 3.2*). This highlights the berm's critical importance for life safety by preventing destructive, high-velocity overland flow from entering the community during the design flood.

9.2.5 Official Flood Hazard Designation

In recognition of the residual risk from groundwater, the *Design Flood Hazard Mapping Report* (WSP, 2025b) officially classifies the area behind the flood berm as a **Protected Flood Fringe**. This provincial designation aligns with the findings of this MDP and reinforces the need for an internal drainage strategy focused on managing groundwater surcharge.

9.3 Designated Emergency Spillway

The primary overland flow path for extreme flood events within the Hamlet is north across Balsam Avenue. This corridor is formally recognized as the community's designated emergency spillway. It is critical to understand that the identified emergency spill route across Balsam Avenue follows a pre-existing natural overland path across private property. This MDP does not create a new spill channel; it documents the existing, topographically controlled path for clarity, risk management, and emergency planning.

The function of this corridor as a natural low point and "flow split" in the Elbow River's flood fringe was confirmed analytically in the Amec Foster Wheeler (2016) hydraulic model. The spill is initiated when water levels in the Hamlet's core exceed an approximate elevation of 1297.8 m. The drainage strategy in this MDP is fundamentally designed to preserve and formalize the conveyance towards this natural outlet. Any development or infrastructure must not obstruct this critical corridor.

9.4 Infrastructure Vulnerability Assessment

Provincial studies allow for a detailed assessment of specific assets. The findings highlight critical vulnerabilities in the transportation network but also confirm the resilience of key utility infrastructure.

- **Transportation Network:** The transportation network is the most vulnerable public asset, with flood impacts that threaten community access and safety. The *Bow and Elbow River Hazard Study - Flood Risk Inventory and Assessment Report (Report 2)*, Executive Summary and Section 4.3.5, detail extensive road inundation at various flood levels, including primary access routes like Highway 22.
- **Bracken Road Bridge:** The quantitative assessment identifies this bridge as a primary hydraulic constriction. It will be overtopped during a 1:50-year flood event (WSP, 2025a). During a 1:100-year event, it would be submerged by over a meter of water, effectively acting as a dam. This will exacerbate upstream flooding in the Hamlet’s core and sever an important local transportation link. *Bow and Elbow River Hazard Study - Flood Risk Inventory and Assessment Report, Table 13*, shows the clearance for the Bracken Road bridge is **-0.3 m** at the 50-year flood and **-1.1 m** at the 100-year flood.
- **Highway 22:** The study shows that sections of Highway 22 between Bragg Creek and Highway 8 will be inundated during a 1:75-year flood event (WSP, 2025a). As the primary access route, the inundation of Highway 22 would **isolate the Hamlet**, severely compromising emergency response (ingress for fire/ambulance, egress for evacuation). *Bow and Elbow River Hazard Study - Flood Risk Inventory and Assessment Report, Section 4.3.5*, explicitly states: "Highway 22 between Bragg Creek and its intersection with Highway 8 starting at the **75-year flood”**.
- **Bragg Creek Water Treatment Plant:** The provincial risk assessment confirmed that the Water Treatment Plant is not expected to be affected by open water flood events (WSP, 2025a). This is a significant positive finding, indicating that the community’s potable water supply is likely to remain secure and operational during a major flood.

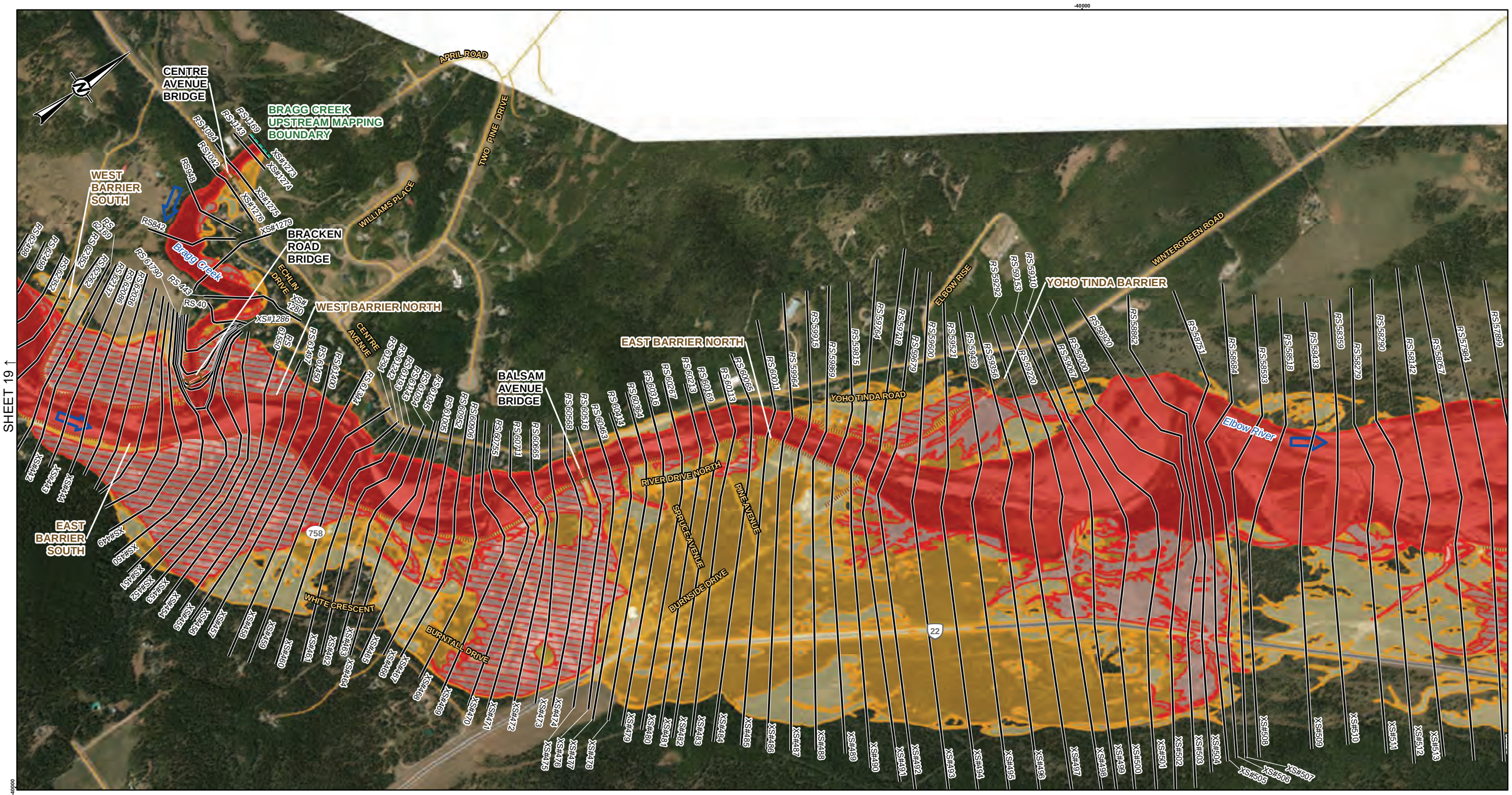
9.5 Impacts on Private Property and Public Assets

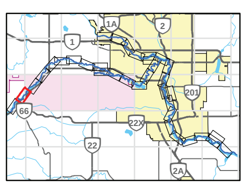
The primary threat to private property is not from berm failure, but from the inevitable rise of groundwater behind it. As established in the Hydrogeological Study (WSP, 2025) and reinforced by the provincial "Protected Flood Fringe" designation, future development will be at high risk without a comprehensive drainage plan.

- **Groundwater Inundation:** During a 1:100-year event, groundwater is expected to "daylight" (emerge at the surface) within 50 to 100 metres of the flood berm. This will cause direct surface flooding on private lots, regardless of local rainfall.
- **Structural and Property Damage:** Properties within this zone will experience significant hydrostatic pressure on foundations, leading to a high risk of basement flooding, structural damage, and destruction of mechanical/electrical systems located below grade.
- **Public Safety:** Uncontrolled surface flooding contained within private lots and depressions creates unpredictable hazards.

9.6 Flood Hazard Mapping and Classification

The official flood hazard maps for the Hamlet of Bragg Creek are those produced as part of the Bow and Elbow River Hazard Study – Design Flood Hazard Mapping Report (WSP, 2025b). These maps define the regulatory Floodway, Flood Fringe, High Hazard Flood Fringe, and Protected Flood Fringe areas. As illustrated in the official Design Flood Hazard Map for Bragg Creek (Figure 9.0), the area behind the flood berm is designated as a Protected Flood Fringe. The delineation of the regulatory floodway is based on a technical assessment of flood depth and velocity, as shown in the Floodway Criteria Map (see Figure 9.1).





LEGEND

- CROSS SECTION
- XS#100 CROSS SECTION NUMBER
- RS 304 RIVER STATION (M)
- STUDY BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PATHWAY
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- RAILWAY
- FLOOD CONTROL STRUCTURE

HYDRAULIC STRUCTURES

- CULVERT
- DAM
- OTHER
- WEIR
- BRIDGE

- FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- PROTECTED FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
ELBOW RIVER ABOVE SPRINGBANK CREEK = 840 M^3/S (NAT)
BRAGG CREEK = 48.1 M^3/S (NAT)

0 200 400
1:10,000 METRES

REFERENCE(S)

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IMAGERY CAPTURED MAY 2016 BY GEODESY GROUP INC. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 114

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

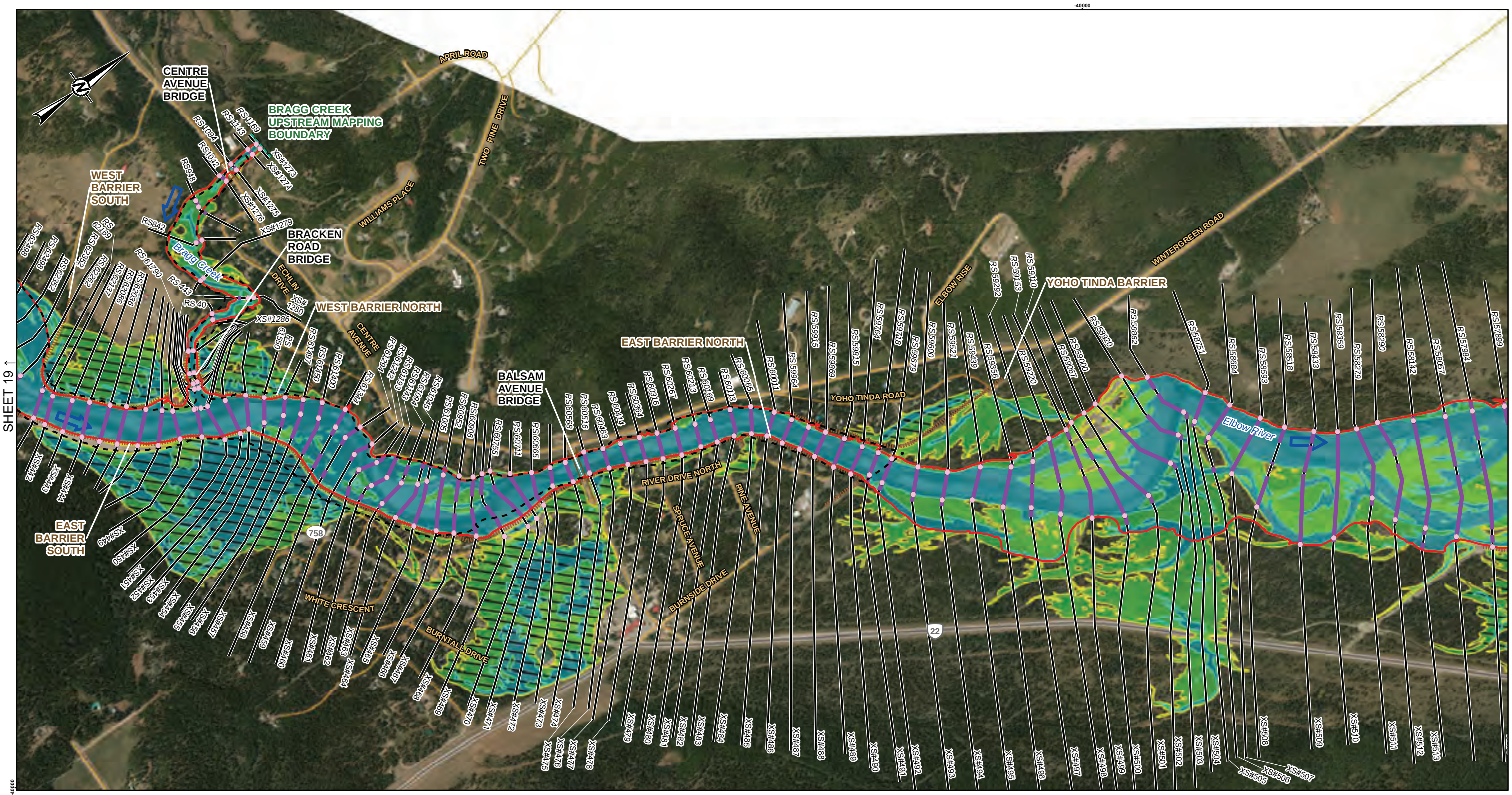
CONSULTANT

YYYY-MM-DD	2025-05-08
DESIGNED	GT
PREPARED	SP
REVIEWED	WP
APPROVED	WP

PROJECT
BOW AND ELBOW RIVER HAZARD STUDY

TITLE
GOVERNING DESIGN FLOOD HAZARD MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0045476.0426	5	0	20 of 34



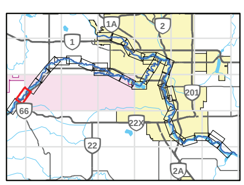
LEGEND

- CROSS SECTION
- XS#10 CROSS SECTION NUMBER
- RS 4994 RIVER STATION (M)
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- FLOOD CONTROL STRUCTURE

HYDRAULIC STRUCTURES

- CULVERT
- DAM
- OTHER
- WEIR
- BRIDGE
- PROPOSED FLOODWAY BOUNDARY
- BANK STATION
- PREVIOUS FLOODWAY
- DEPTH ≥ 1 M
- 100-YEAR DESIGN FLOOD EXTENT
- PROTECTED FLOOD AREA
- VELOCITY ≥ 1 M/S

DESIGN DISCHARGE
ELBOW RIVER ABOVE SPRINGBANK CREEK = 840 M^3/S (NAT)
BRAGG CREEK = 48.1 M^3/S (NAT)



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1:10,000 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS
Alberta Government

CONSULTANT
wsp

YYYY-MM-DD	2025-05-08
DESIGNED	GT
PREPARED	PT
REVIEWED	WP
APPROVED	

REFERENCE(S)
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DATUM: NAD 83 CSRS PROJECTION: 3TM 114

PROJECT
BOW AND ELBOW RIVER HAZARD STUDY

TITLE
OPEN WATER FLOODWAY CRITERIA MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0045476.0426	5	0	20 of 34

10.0 Future Stormwater Assessment

The stormwater management strategies for future development in Bragg Creek must be tailored to the distinct hydrogeological conditions of two separate areas: the Hamlet core and the designated Expansion Area. The Hamlet core is severely constrained by its proximity to the Elbow River and high groundwater, necessitating an engineered, pumped system for new dense development. In contrast, the topographically higher Expansion Area is suitable for a conventional gravity-based system integrated with Low Impact Development (LID) practices.

This section outlines the distinct stormwater management concepts for these two fundamentally different development areas.

10.1 Interim Fire Suppression

In addition to stormwater management, any SWMF, in either the Hamlet or Expansion Area, must be designed to serve as an interim water source for fire suppression. Until regional fire protection upgrades are complete, developments may use stormwater facilities as fire ponds with dry hydrants designed to RVC standards, including winter/ice cover operational provisions and access/offsets to satisfy Fire Code requirements at the Development/Building Permit stage.

This aligns with Section 7010.2 of the Rocky View County Servicing Standards. The developer will be responsible for incorporating these features into the SWMF design and securing all necessary approvals from the County Fire Service.

10.2 Hamlet Area

Unlike the Expansion Area, future development and redevelopment within the Hamlet's core are severely constrained by the area's hydrogeology. As established in the Hydrogeological Study (WSP, 2025), the shallow alluvial aquifer is in direct and rapid hydraulic connection with the Elbow River. During high river stages, this results in a high water table and the potential for groundwater to surcharge the ground surface, regardless of local rainfall.

This direct hydraulic connection means that a reliable gravity outlet does not exist during high river stages, rendering traditional storm sewers ineffective. Furthermore, it requires a specialized approach to Low Impact Development (LID), as simple infiltration systems can become sources of groundwater intrusion when the water table rises. Therefore, the stormwater management strategy for the Hamlet core must focus on positive conveyance, a reliable engineered outfall, and facilities designed for two-way hydraulic interaction with the subsurface.

10.2.1 Centralized System for New Developments

As a condition of approval, new high-density developments (such as the Gateway Village and Balsam Avenue projects) will be required to design, fund, and construct a self-contained, engineered stormwater system. This approach ensures that new growth can be serviced safely without relying on a non-existent gravity outfall. The key components of this system are:

- A dedicated facility (e.g., a wet pond) to provide water quality treatment and attenuate post-development runoff to the approved release rate, with a mechanical pumping station to provide a positive, reliable outfall to the Elbow River, as a gravity connection would be compromised by high river levels and groundwater.
- The default stormwater release rate for Bragg Creek as well as the Expansion Area is 6.0 L/s/ha, consistent with the 2013 regional Master Drainage Plan. However, proponents of new major developments have the option to establish a higher, site-specific rate through a detailed pre-development analysis, acknowledging that the baseline rate can be overly stringent for near-river parcels with unique hydrogeological conditions. This approach is based on the methodology successfully utilized and approved for the Gateway Village Stormwater Management Report (ISL, 2022). To establish an alternative rate, proponents will be required to develop a detailed hydrologic model (e.g., PCSWMM or similar software) to simulate the site's pre-development runoff conditions. The analysis must rigorously account for site-specific characteristics, including:
  - High-resolution topographic data.
  - The high gravel and alluvial soil composition, which promotes significant infiltration.
  - Existing vegetation, tree cover, and initial pervious depression losses.

The use of continuous simulation modeling is required to accurately capture the influence of infiltration and antecedent moisture conditions, which is critical in the area's permeable soils. The analysis must provide a clear, defensible rationale, consistent with Alberta Environment and Protected Areas (AEPA) guidelines for why a higher release rate is appropriate. This justification typically relies on the site's direct proximity to the Elbow River, which minimizes routing effects and results in non-coinciding peak flows between the site runoff and the river.

Based on the approved analysis for the Gateway Village site (likely being the closest development possible to the Elbow River), the maximum permissible site-specific release rate that will be considered under this policy is 34 L/s/ha. Any proposed rate up to this maximum must be rigorously justified by the proponent's analysis and is subject to review and approval by the County. All modeling files, engineering drawings and documents, as well as supporting documentation must be submitted as part of the development application.

10.2.2 Reliance on the Major System for Infill and Existing Areas

For smaller infill projects and the existing developed area, stormwater management will continue to rely on the formalized major system. This involves directing surface runoff to the enhanced network of roads and ditches, which are designed to convey flows safely to the Balsam Avenue emergency spillway. The Development Drainage Guidelines, particularly the enforcement of Minimum Building Elevations and positive lot grading, are the primary tools for ensuring resilience in these areas. The already approved Gateway development could potentially serve as a regional stormwater facility for infill of existing areas, though these additional contributing areas would need to be decided on prior to the commencement of construction and in negotiation with the developer.

10.3 Expansion Area

The future development of the Expansion Area, located south of the Hamlet at a significantly higher elevation, is not constrained by the Elbow River or its associated alluvial aquifer. Consequently, the stormwater management strategy for this area can rely on a gravity-based system. However, it must still adhere to the regional principles established in the 2013 Bragg Creek Master Drainage Plan to protect downstream watercourses by ensuring post-development runoff mimics pre-development hydrological conditions.

This will be achieved through a "treatment train" hierarchy that prioritizes source controls through Low Impact Development (LID) before conveyance to a central Stormwater Management Facility (SWMF).

It is the responsibility of the developer, in consultation with Rocky View County, to assess and confirm that the downstream receiving system has sufficient capacity to safely convey post-development flows. All proposed stormwater management solutions must be supported by detailed hydrological and hydraulic analyses and must be reviewed and approved by the County prior to implementation.

10.3.1 Low Impact Development (LID) Integration

In full alignment with the principles of the 2013 Master Drainage Plan, and in contrast to the hydro-geologically constrained Hamlet core, the Expansion Area presents an ideal opportunity for the integration of Low Impact Development (LID) practices. The objective of incorporating LIDs is to manage rainfall where it falls, promoting infiltration, filtration, and evapotranspiration to reduce the overall volume and improve the quality of stormwater runoff before it reaches the SWMF.

Developers will be required to incorporate a suite of LID practices into their site design. Based on the suitability assessment in the 2013 MDP, the following practices are considered highly applicable to the Expansion Area:

- **Maintaining Natural Areas:** Preserving significant portions of the site's existing natural vegetation, particularly tree stands and native grasslands, to maintain natural hydrological function.
- **Absorbent Landscapes:** Designing lot-level landscaping with thickened topsoil and native vegetation to capture and absorb runoff from rooftops and driveways. This is one of the most effective and reliable lot-level LIDs.
- **Vegetated Swales and Bioswales:** Utilizing grass-lined swales and engineered bioswales in place of traditional curb and gutter for roadway drainage. These features slow runoff, promote infiltration, and provide effective water quality treatment.
- **Better Planning Practices:** Employing site design techniques that minimize impervious surfaces, such as reducing road widths and using shared driveways where feasible, and orienting lots to maximize overland flow across vegetated areas.

The primary benefit of this integrated LID approach is the reduction in the overall runoff volume and peak flow rates that must be managed by the downstream SWMF. This can lead to a more efficient and potentially smaller facility, reducing overall infrastructure costs. Therefore, the Stormwater Management Plan for the Expansion Area shall include a dedicated section detailing the proposed implementation of LID practices at the planning, community, and lot level.

10.3.2 Stormwater Management Facility

While LIDs will manage a portion of runoff, a central SWMF is still required to provide quantity and quality control for the fully developed area.

The default stormwater release rate for the Expansion Area SWMF is 6.0 L/s/ha, consistent with the regional target established in the 2013 Bragg Creek Master Drainage Plan. This rate is considered the baseline for protecting downstream conveyance systems and watercourses.

However, the County may consider a higher, site-specific release rate if the proponent can rigorously demonstrate through detailed engineering analysis that the downstream conveyance system has sufficient and safe capacity to accommodate the proposed flows. To justify a release rate higher than the default, the proponent must undertake a comprehensive hydraulic analysis of the entire downstream drainage system to the ultimate outfall. This analysis, submitted as part of the Stormwater Management Plan, must prove to the satisfaction of the County that the proposed release rate for the 1:100-year event will not cause:

- Adverse flooding impacts on upstream, adjacent, or downstream public or private property.
- Erosion, scour, or instability in downstream ditches, swales, or watercourses.
- Exceedance of permissible depth and velocity criteria in publicly accessible areas.
- Surcharging of existing culverts or other infrastructure beyond their design capacity.

10.3.3 Outfall Capacity Assessment

This justification will form a key component of the mandatory outfall capacity assessment. As part of the detailed design for the Expansion Area, the proponent will be required to undertake this comprehensive study to determine a viable outfall path and its maximum safe conveyance capacity. The study must evaluate, at a minimum, the following two options:

- Option 1: Northern Outfall (Towards the Hamlet/Elbow River): This option involves directing flow north along existing ditches towards the Elbow River. The hydraulic model must confirm that all downstream ditches, swales, and culverts have sufficient capacity to safely convey the proposed 1:100-year post-development flow without causing adverse impacts within the existing Hamlet.
- Option 2: Southern Outfall (Towards Priddis Creek): This option involves directing flow south along existing ditches, which ultimately discharge to Priddis Creek. The hydraulic analysis must confirm the capacity of the downstream conveyance system to the ultimate outlet and assess any potential impacts on Priddis Creek, ensuring compliance with all environmental and flow rate requirements for that water body.

The final approved release rate for the Expansion Area SWMF will be dictated by the results of this detailed capacity analysis and is subject to the review and approval of the County. While the proponent may justify a rate higher than the 6.0 L/s/ha default, in no case shall the approved release rate exceed the demonstrated safe capacity of the downstream drainage system. The full cost and execution of this analysis, as well as the design, construction, and long-term maintenance of the SWMF and any required downstream conveyance improvements needed to support the approved release rate, will rest with the developer of the Expansion Area lands as a condition of development approval.

11.0 Mitigation Options and Evaluation

The mitigation strategy for Bragg Creek must acknowledge that a traditional, Hamlet-wide piped storm sewer system is not a feasible option due to cost, challenging terrain, and the overwhelming influence of groundwater. While infiltration into the area's permeable soils is a key hydrological process, the design of stormwater facilities must account for the dynamic, two-way exchange of water with the subsurface. During high river stages, a rising groundwater table can reverse the hydraulic gradient, causing simple infiltration systems to become sources of groundwater exfiltration. Therefore, this MDP requires a strategy that leverages infiltration when conditions allow but also provides positive conveyance and engineered controls to manage groundwater interaction. The focus shifts to managing water on the surface and providing targeted, resilient solutions for areas of new, concentrated development.

11.1 Structural Mitigation Alternatives

11.1.1 Conveyance Improvements

- **Option 1: Hamlet-Wide Road and Ditch Re-Grading (Recommended Major System Enhancement):** This is the foundational strategy for the existing community. It involves a systematic program to improve existing roadways and adjacent ditches to create a functional and continuous overland drainage system for both rainfall runoff and emergent groundwater. Swales and shallow ditches would be graded to eliminate low spots and direct flow efficiently towards the Balsam Avenue spillway. This option improves day-to-day drainage and provides a controlled path for 1:100-year floodwaters.
- **Option 2: Centralized SWMF with Lift Station (Recommended for New Developments):** This option is specifically for new, dense development areas like within the existing Hamlet core. As detailed in site-specific stormwater studies (ISL, 2022), a reliable gravity outlet does not exist during high Elbow River stages, as backwater from the river and high groundwater would prevent discharge. Therefore, a lift station is required to provide positive drainage and pump treated water to the Elbow River. This self-contained system ensures new development can be serviced effectively without burdening the surrounding area.

11.1.2 Property Acquisition and Setbacks

The hydraulic analysis confirms that the historical flood channel north of Balsam Avenue is the Hamlet's natural and critical emergency spillway. The primary goal is to preserve this overland flow path's hydraulic capacity in perpetuity to ensure a safe exit route for extreme floodwaters. While wholesale property acquisition is not envisioned, a combination of targeted land use policies, zoning tools, and development setbacks is required.

Defining the Spillway Corridor

The first step is to formally delineate the spillway. The basis for this delineation will be the overland flow path identified in the hydraulic models from this Master Drainage Plan and the Amec Foster Wheeler (2016) study.

Land Use Policy and Zoning Mechanisms

Once defined, the spillway corridor must be protected through formal planning tools.

- **Area Structure Plan (ASP) Designation:** The Bragg Creek Area Structure Plan must be amended to explicitly identify the Balsam Avenue Emergency Spillway as a critical piece of public infrastructure and an environmental constraint. The ASP should include policies that prohibit development within the spillway and guide appropriate land use on adjacent parcels.
- **Land Use Bylaw Zoning:** A specific zone should be applied to the legally defined spillway corridor. This zoning would have highly restrictive regulations, such as:
  - **Prohibited Uses:** All permanent structures, buildings, and residential uses.
  - **Restricted Uses:** Fencing, significant landscaping, storage of materials, or any activity that would impede flow or alter grade would be prohibited or require specific engineering review to prove no negative hydraulic impact.
  - **Permitted Uses:** Open space, natural areas, or passive recreational uses that do not require grading or structures.

Development Setbacks and Floodproofing

For properties *adjacent* to, but not within, the designated spillway, specific development regulations are necessary to mitigate risk.

- **Development Setbacks:** A mandatory development setback from the edge of the legally defined spillway corridor shall be established in the Land Use Bylaw. This setback creates a buffer to prevent encroachment and provide space for potential future maintenance or minor enhancements to the spillway.
- **Minimum Building Elevations (MGs):** Parcels adjacent to the spillway are at a higher risk of shallow flooding. All new construction on these parcels must adhere to the Minimum Building Elevations.

11.2 Non-Structural Mitigation Alternatives

11.2.1 Policy and Regulation Changes

- **Policy and Regulation Changes (Highly Recommended):** This is the most critical component for ensuring long-term community resilience.
  - **Minimum Building Elevations (MGs):** Enforce strict MGs for all new construction, set with a safe freeboard above the 1:100-year flood/groundwater elevation. This elevates properties above the predicted water level in the major system.
  - **Lot Grading Policies:** Require all new and redeveloping lots to have a lot grading plan that demonstrates positive drainage to the public right-of-way (the road/ditch system) without impacting neighbours.
- **Emergency Response Planning:** An EOP remains critical, focused on the operational reliability and failure protocol for the developer-owned lift station and public notification procedures during a major flood event.

11.2.2 Emergency Response Planning

An Emergency Operations Plan (EOP) must be developed. A key component of this EOP will be the response protocol for a lift station failure during a major storm event, outlining procedures for monitoring, public notification, and potential deployment of temporary pumping solutions. Furthermore, the EOP must include protocols related to the interim use of the SWMF as a fire suppression resource, including procedures for ensuring year-round access and operational readiness, particularly during winter/ice conditions.

11.3 Screening and Evaluation Criteria

Options were evaluated on technical feasibility, public safety, cost-effectiveness for the County, and operational sustainability. The unfeasibility of a Hamlet-wide minor system was a primary screening factor. The evaluated options were screened based on the following criteria:

- **Public Safety:** Ability to protect life and property from flooding.
- **Technical Feasibility:** Effectiveness given the high groundwater and river interaction.
- **Economic Viability:** Capital and long-term operational costs.
- **Environmental Impact:** Effects on water quality and the Elbow River ecosystem.
- **Operational Reliability:** Resilience and maintenance requirements.

11.4 Preferred Options and Rationale

The preferred strategy is a pragmatic, hybrid approach that is both effective and financially viable:

4. **For the Existing Hamlet:** Implement Major System Enhancements (Option 1) over time to improve existing drainage and provide a controlled flood conveyance network.
5. **For New Major Development:** Require the construction of a Centralized SWMF with a Lift Station (Option 2) as a condition of development approval.
6. **For All Development:** Immediately implement and enforce the recommended Non-Structural Policies (MGs, lot grading) to ensure all new construction is resilient.

This strategy provides an improved level of service for the entire community through major system upgrades while placing the responsibility for managing the significant impact of new, dense development directly on the developer.

12.0 Conceptual Design of Recommended Improvements

The conceptual design aims to achieve the following:

- To improve surface drainage throughout the Hamlet to reduce nuisance ponding from routine storm events.
- To establish a continuous and defined major system (roads and ditches) capable of conveying the 1:100-year design flood event while protecting adjacent private properties.
- To ensure new development manages its 1:100-year post-development runoff on-site and provides a reliable, positive outfall via a lift station.

12.1 Preliminary Layouts and Typical Sections

The conceptual design for the Hamlet-wide major system improvements is based on establishing a network of formalized roadways and ditches that function predictably during all rainfall events. The design basis for these improvements shall be derived from established municipal engineering standards, such as those provided by Rocky View County. Relevant RVC Standards are included in Appendix B.

12.1.1 Roadway and Ditch Cross-Sections

The re-grading and formalization of Hamlet roads and ditches are the foundational components of this MDP. The typical cross-sections shown in the RVC standard drawings provide a template for these enhancements, ensuring proper surface drainage and conveyance capacity.

- In general, the design should follow the principles outlined in the standard templates within Appendix B. Key features to be incorporated include a properly crowned road surface (2-3% cross-slope) to direct runoff efficiently to the shoulders and into a formalized ditch with a minimum depth of 0.80 meters and stable side slopes (max 3:1).

12.1.2 Driveway Crossings

A critical finding of this study is that discontinuous ditches at private driveway crossings are a primary cause of localized ponding and system failure. To create a continuous major drainage system, all new and reconstructed driveway crossings must be standardized.

The design shown in Rocky View County Servicing Standards - Figure 400.14: Typical Rural Road Approach Design Criteria provides the necessary standard. Key requirements include:

- A properly sized culvert (minimum 450mm diameter) to pass design flows.
- Smooth, flared transitions between the ditch and the culvert entrance/exit. In accordance with Table 400-D within the standards
- Stable side slopes (e.g., 4:1 for Secondary Highways & 3:1 for Local Roads) that seamlessly connect the ditch on either side of the driveway, eliminating obstructions.

Standardizing driveway crossings is essential to achieving the uninterrupted conveyance required for the major system to function as designed.

12.2 Hydraulic Performance Expectations

- **Major System (Roads/Ditches):** The enhanced system will be designed to convey smaller storm events within the ditch capacity. During the 1:100-year event, flow will be contained within the road right-of-way (ditch and road surface), with depths not exceeding 0.30m on the roadway itself while maintaining freeboard to MG's. For more frequent storms, such as the 1:5-year event, at least one lane of traffic in each direction must be free of flooding.
- **Centralized SWMF**: The developer-funded SWMF will provide water quality treatment and attenuate post-development flows to 34 L/s/ha via the lift station. This pre-development rate is based on the specific conditions of the infill development lands and differs from the broader regional target of 6.0 L/s/ha recommended in the 2013 Master Drainage Plan, which was established for the conversion of large, undeveloped rural parcels and is not directly applicable to a densified Hamlet scenario requiring a pumped outfall. The facility will include emergency storage for the 1:100-year event in case of pump failure.

12.3 Land Requirements and Constraints

The major system improvements will be contained within existing public road rights-of-way. The centralized SWMF will be located on private land as part of a new development. It is recommended that subsurface investigations assessing geotechnical / hydrogeological parameters for future developments should be conducted at a time when seasonal groundwater is potentially at its highest (i.e., late spring to early summer).

13.0 Implementation Strategy

13.1 Phasing Recommendations

A phased implementation is recommended to align with development timing, capital budget planning, and immediate risk reduction priorities.

- Immediate Priority: Policy Adoption
  - Action: Adopt the Development Drainage Guidelines (Section 14.0) into the County's Land Use Bylaw and Servicing Standards.
  - Rationale: This is the most critical and cost-effective first step. It ensures that all new construction is resilient to known flood risks and contributes positively to the overall drainage strategy, preventing the creation of new problems.
- Phase 1: Core Area Servicing
  - Action: The design and construction of the centralized Stormwater Management Facility (SWMF) and lift station will be a condition of approval for the Gateway Village development or any other major new development in the Hamlet's core.
  - Rationale: This places the responsibility for servicing new, dense development directly on the benefiting parties, ensuring a robust and engineered outfall is in place before significant new impervious surfaces are created.
- Phase 2: Major System Enhancements
  - Action: The Hamlet-wide road and ditch improvements should be prioritized and implemented over multiple years through the County's capital budget.
  - Rationale: This long-term program addresses existing drainage deficiencies. Priority should be given to areas with known repetitive flooding issues and those sections critical to establishing the main conveyance path to the Balsam Avenue emergency spillway.

13.2 Prioritization of Major System Enhancements

To ensure funds are used effectively, the multi-year program for Major System Enhancements should be prioritized based on the following criteria, in order of importance:

1. The highest priority shall be given to any work required to protect, preserve, and enhance the hydraulic function of the Balsam Avenue emergency spillway. This includes removing any identified obstructions and formalizing the conveyance paths that lead directly to it.
2. Priority should be given to projects that create a continuous, connected flow path. Improvements should begin at the downstream end and work upstream, ensuring that improved sections have a functional outlet.
3. Projects that address areas with a documented history of repetitive nuisance flooding and property impacts should be prioritized to provide tangible benefits to existing residents.
4. Drainage improvements should be coordinated with other planned capital projects (e.g., road repaving, utility upgrades) to maximize cost-efficiency and minimize public disruption.

13.3 Regulatory Approval Pathways

The implementation of this MDP, particularly the construction of physical infrastructure, will require a multi-jurisdictional approvals process. Early and frequent engagement with all regulatory bodies is essential to ensure project success and avoid delays.

13.4 Municipal Approvals (Rocky View County)

- **Land Use Bylaw and Servicing Standards Amendments:** To formally adopt the Development Drainage Guidelines (Section 14.0) and the designation of the Balsam Avenue emergency spillway.
- **Development Permits:** All new developments will be reviewed for compliance with the updated standards as part of the standard Development Permit process.
- **Capital Project Approvals:** The phased major system improvements will require annual approval through the County's capital budget process.

13.5 Provincial Approvals (Alberta Environment and Protected Areas – AEPA)

Provincial approvals are primarily governed by the *Environmental Protection and Enhancement Act (EPEA)* and the *Water Act*.

- SWMF and Lift Station (Developer Responsibility): The construction and operation of a stormwater system that discharges directly into the Elbow River will require a formal *EPEA Approval*. This is a comprehensive process that will require the proponent to submit a detailed application demonstrating that the system will protect water quality and the aquatic environment.
- Major System Ditch Improvements (County Responsibility): While much of the re-grading work may occur within the existing municipal right-of-way, any activities that involve altering a water body, working within the bed and banks of a tributary to the Elbow River, or creating a new drainage outlet may require an approval under the *Water Act*. The County must consult with AEPA prior to initiating detailed design to confirm the specific regulatory requirements for the major system enhancement program.
- Public Lands Act: Any work on the bed and banks of the Elbow River, such as the construction of the SWMF outfall, occurs on Crown land and will require a disposition (e.g., a License of Occupation) under the *Public Lands Act*.

13.6 Operation and Maintenance Considerations

A robust operation and maintenance (O&M) plan is critical, particularly for the lift station. Key O&M activities will include:

- **Centralized SWMF:** The O&M for the SWMF and lift station will be the responsibility of the developer or a subsequent homeowners/condominium association, secured through an agreement with the County.
- **Major System:** The County will be responsible for the O&M of the public road and ditch network, including routine inspections, sediment removal from ditches, and ensuring culverts remain clear.

13.7 Monitoring and Adaptive Management

The ongoing groundwater monitoring program is critical. Data should be reviewed annually to confirm that the assumptions in this MDP remain valid and to adapt the design of future phases of the major system improvements as needed.

13.8 Land Rights and Easement Considerations

A foundational finding of this MDP is the formal identification of the natural overland spillway north of Balsam Avenue. As this critical emergency path crosses private property, a long-term strategy to secure public interest is recommended.

While the immediate priority is to protect the spillway's function through land use regulation and development setbacks, the County should consider a more formal approach over time. It is recommended that Rocky View County's administration evaluate the long-term feasibility and necessity of securing overland drainage easements or a similar right-of-way along the defined spill alignment.

Such instruments would formalize the County's right to access the corridor for inspection and maintenance activities, should they ever be required, and provide greater legal certainty for the County, Hamlet, and affected landowners. This evaluation should be undertaken as part of the long-term capital planning for the Hamlet.

14.0 Development Drainage Guidelines

These guidelines are designed to address the specific and complex flood risks within the Hamlet of Bragg Creek, which are dominated by the direct hydraulic connection between the Elbow River and the underlying alluvial aquifer. A traditional piped stormwater system is not feasible; therefore, these guidelines prioritize a major system-focused (overland) strategy to build community resilience.

The primary objectives are to ensure new development is protected from both local rainfall-runoff and river-induced groundwater surcharge, to prevent adverse impacts on adjacent properties, and to protect the water quality of the Elbow River. All new developments and significant redevelopment within the Bragg Creek study area shall prepare a detailed Stormwater Management Plan demonstrating compliance with the following guidelines.

14.1 Flood Protection and Building Resilience

1. Minimum Building Elevations (MGs): The underside of the floor system for the lowest habitable space (e.g., main floor of a slab-on-grade or crawlspace building) shall be set a minimum of 0.5 m above the higher of:
   a. The 1:100-year design flood elevation from river inundation.
   b. The 1:100-year groundwater surcharge elevation as defined in the official Hydrogeological Study (WSP, 2025), included in Appendix C.
   c. The 1:100-year major system (overland) flood elevation from local rainfall-runoff modeling.

The 1:100-year design flood elevation for Bragg Creek is established by the Bow and Elbow River Hazard Study – Design Flood Hazard Mapping Report (WSP, 2025b), which is adopted by Rocky View County as the official regulatory flood mapping.

2. Regulatory Groundwater Elevation Map: To provide a clear and enforceable basis for setting building grades, all development applications must reference the official hydraulic gradient profile.

Figure 14.1: Hydraulic Gradient Profile – Hamlet of Bragg Creek (Source: WSP, 2025)
Note: Where the final figure from the WSP Hydrogeological Study is not yet available for public use, the provision of a site-specific analysis to establish this minimum elevation, consistent with the methodology of the broader study, becomes a prerequisite for a complete development application.

3. Foundations and Subsurface Structures in High-Risk Zones: The area within 100 meters of the Elbow River Flood Barrier is identified as a zone of high risk for groundwater daylighting and significant hydrostatic pressure.
   a. The construction of basements or any habitable below-grade space is strongly discouraged within this zone.
   b. Any proposal for subsurface structures in this area will require a site-specific hydrogeological and geotechnical assessment, prepared by a qualified professional, demonstrating that the foundation is designed to withstand full hydrostatic pressures and prevent seepage without reliance on permanent mechanical dewatering systems.
   c. On-site septic systems are not permitted in this zone.

14.2 Site Drainage and the Major System

1. All properties must be graded to direct surface runoff from rainfall and potential groundwater daylighting away from buildings and towards the public major drainage system (i.e., the road right-of-way, ditches, or swales). A detailed Lot Grading Plan is required for all new development, demonstrating that site grading will not cause adverse impacts on adjacent properties.
2. The Hamlet's road network is formally recognized as a component of the major system, designed to serve as a controlled shallow conveyance channel for emergent groundwater during high river stages.
   a. Site grading must preserve continuous, unobstructed flow paths along the road right-of-way.
   b. The Hamlet's road network, including its adjacent ditches and swales, is formally recognized as a critical component of the major drainage system. Roadways may serve as controlled shallow conveyance for emergent groundwater where grading maintains continuous road-edge flow paths; building finished grades shall exceed adjacent road elevations to maintain protection and flow continuity. This system is designed to convey both local rainfall runoff and river-induced groundwater surcharge, directing flows safely to designated outlets.
3. All new developments must manage rainfall runoff generated on-site. Post-development runoff release rates for the 1:100-year storm event must be controlled to pre-development levels or to a rate specified by the County for the receiving system, in accordance with the policies in this report. The default stormwater release rate for the Hamlet is 6.0 L/s/ha, as established in the 2013 regional Master Drainage Plan. For new major developments, proponents may propose a higher, site-specific release rate if supported by a detailed pre-development analysis. This recognizes that the default rate may be overly conservative for near-river parcels with unique hydrogeological conditions, and allows flexibility where justified by site-specific studies and subject to County approval.
4. Design for Infiltration and Exfiltration: All stormwater facilities and Low Impact Development (LID) practices in the Hamlet core must be designed to accommodate the two-way exchange of water with the subsurface, recognizing that rising groundwater can reverse the hydraulic gradient.
   a. Infiltration from facilities into the ground is encouraged during normal and low groundwater conditions to reduce runoff volumes.
   b. Exfiltration management is required. Designs must include provisions to safely manage groundwater that may enter the facility from below when the external water table is high. This shall be achieved through design elements such as:
      i. Underdrains or relief drains to collect and convey emergent groundwater to a controlled outlet.
      ii. Impermeable liners or cut-off trenches where necessary to limit the rate of groundwater intrusion into critical infrastructure.
      iii. Simple, unlined infiltration systems (e.g., soakaway pits, infiltration trenches without underdrains) that lack controls for exfiltration are not permitted. All facilities must demonstrate a controlled conveyance pathway to the major system or a pumped outfall to manage both surface runoff and potential groundwater intrusion.

14.3 Requirements for Major and Core Area Development

1. Centralized Stormwater Management Facility (SWMF) and Lift Station: New high-density developments within the Hamlet's core do not have a reliable gravity outfall during flood conditions. As a condition of development approval, these projects will be required to design and construct a self-contained, centralized SWMF and lift station to provide positive drainage to the Elbow River.
2. Operational Responsibility: The ongoing operation, maintenance, and long-term replacement of the SWMF and lift station shall be the responsibility of the developer or a subsequent homeowners/condominium association, secured through a legally binding agreement with the County. An Emergency Operations Plan for the lift station must be developed and approved by the County.

14.4 Protection of the Major System and Emergency Spillway

1. **Major Drainage System (Ditches and Swales):** The Bragg Creek road and ditch network serves as the formal major drainage system. No development shall obstruct, alter, or fill any public ditch, swale, or overland flow path without the express approval of the County. Any development directing overland drainage towards the major drainage system must ensure that the outlet has downstream continuity to the final discharge location.
2. Balsam Avenue Emergency Overland Flow Path: Hydraulic analysis confirms that the natural topography north of Balsam Avenue creates a critical overland flow path for extreme flood events. This is not a well-defined channel but a broad flow regime that crosses multiple private properties, as shown in Figure 14.0. As a formally delineated boundary is not feasible, the following performance-based requirements shall apply to preserve this essential hydraulic function:
   a) No Adverse Impact Requirement: All new development, redevelopment, or significant site alteration (including the placement of fill, fences, or large accessory buildings) on properties located generally north of Balsam Avenue must demonstrate through a detailed engineering analysis that the proposed changes will not obstruct or negatively impact the overland flow of floodwaters.
   b) Hydraulic Analysis: The required engineering analysis must, at a minimum, show the pre-development and post-development site grading and prove to the satisfaction of the County that the development will not cause an increase in flood levels or a redirection of flow that would adversely affect upstream, downstream, or adjacent properties. The fundamental principle is to maintain the existing overland conveyance capacity throughout the area.

14.5 Infrastructure Design Standards

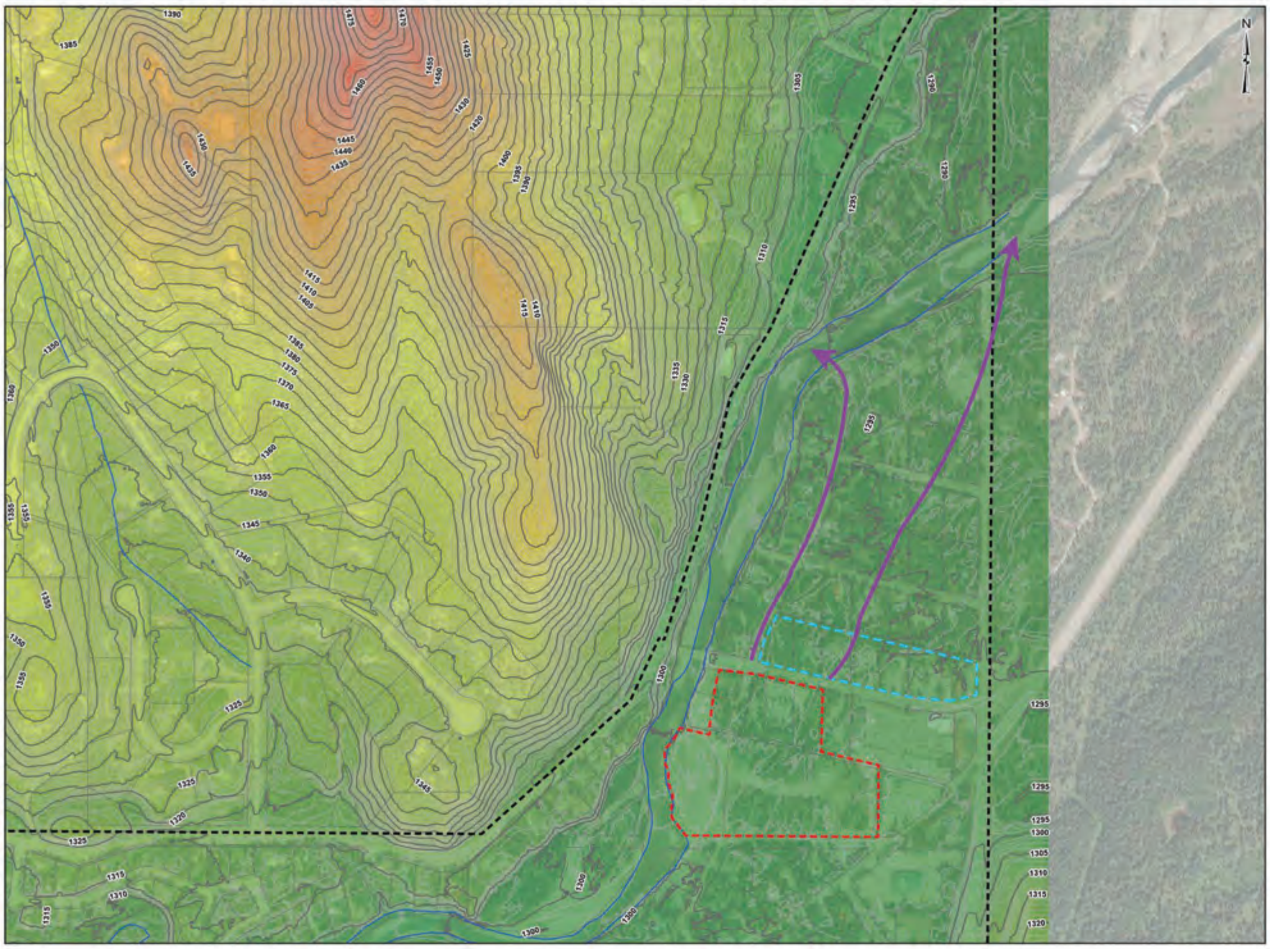
To ensure consistency, durability, and hydraulic function, all new and reconstructed public and private infrastructure within the study area shall conform to the County's most current Servicing Standards. In the absence of a specific County standard, the following shall be used as the design basis:

1. Roads and Ditches: Cross-sections for new or reconstructed roads and adjacent drainage ditches shall be designed in accordance with the principles outlined in the Rocky View County Servicing Standards for Country Residential (Figure 400.1) and Rural Low Volume (Figure 400.5).
2. Driveway Crossings: All new or replaced driveway crossings over public ditches or swales must include a properly sized culvert and be constructed in accordance with the principles of the Rocky View County Servicing Standards for Typical Rural Road Approach Design Criteria (Figure 400.14): to ensure continuous and unobstructed conveyance in the major system.

14.6 Infrastructure Design Standards

Until such time as regional piped fire protection upgrades fully service a development area, all new SWMFs shall be designed to provide dual use as an interim water source for fire suppression.

Until regional fire protection upgrades are complete, developments may use stormwater facilities as fire ponds with dry hydrants designed to RVC standards, including winter/ice cover operational provisions and access/offsets to satisfy Fire Code requirements at Development/Building Permit. This requirement is consistent with Section 7010.2 of the Rocky View County Servicing Standards, and the final design must be approved by the County Fire Service.



LEGEND

- Study Area
- Gateway Development
- Balsam Avenue
- Parcels
- Overland Spillway
- Surface Water
- Major Contours - 5 m
- Minor Contours - 1 m

Ground Elevation (m)

1495.21

1285.8

TITLE

OVERLAND SPILLWAY

PROJECT

BRAGG CREEK MASTER DRAINAGE PLAN

CLIENT

ROCKY VIEW COUNTY

DATA SOURCE(S)

- Topographic Map Mosaic

PROJECTION

NAD 1983 3TM 114

0 70 140

1:6,000 Meters

ISL

FIGURE	14.0
DATE	9/29/2025
PROJECT NO	28781
AUTHOR	rkoomoreira

15.0 Stormwater Management Report Submission Requirements

All development applications within the Bragg Creek study area must be accompanied by a comprehensive Stormwater Management Report (SWMR). The report shall be prepared, sealed, and signed by a qualified Professional Engineer registered in the Province of Alberta.

The purpose of the SWMR is to demonstrate that the proposed development complies with all policies and technical requirements outlined in this Master Drainage Plan (MDP), particularly the Development Drainage Guidelines, as well as the Rocky View County Servicing Standards and relevant provincial guidelines. The report must provide sufficient detail for the County to conduct a thorough technical review of the proposed stormwater management strategy.

To ensure completeness and consistency, all SWMR submissions shall follow the format and include all items detailed in the checklist provided in Appendix D of this MDP. The checklist is based on the comprehensive submission standards of the City of Calgary. A completed copy of the checklist must be included with every SWMR submission.

16.0 Conclusions and Recommendations

16.1 Summary of Findings

This Master Drainage Plan (MDP) provides a comprehensive framework for managing surface water and mitigating flood risk within the Hamlet of Bragg Creek. The analyses and strategies herein are driven by the Hamlet's unique and challenging hydrogeological setting, which dictates a departure from conventional stormwater management approaches. The following conclusions and recommendations are intended to guide Rocky View County in implementing a resilient and sustainable drainage strategy that supports planned future growth.

1. The foundational finding, supported by the Hydrogeological Study (WSP, 2025), is that the Hamlet's primary flood risk is not from local rainfall but from river-induced groundwater surcharge. The direct hydraulic connection between the Elbow River and the underlying alluvial aquifer means that during a 1:100-year river flood, groundwater will rise and emerge at the surface ("daylight") within 50 to 100 meters of the flood berm, causing widespread inundation from below.
2. Due to the high water table and the overwhelming influence of the river, a traditional, Hamlet-wide piped storm sewer system is technically and financially unfeasible. The community's flood resilience must be built upon a major system-focused (overland) strategy that manages inevitable surface water rather than attempting to prevent it.
3. The Hamlet's network of roads and ditches is its de facto major drainage system. This network must be formalized and enhanced to safely convey both local stormwater and emergent groundwater to a stable outfall. The strategy requires that building finished grades be set above adjacent road elevations to preserve longitudinal flow paths along the right-of-way and protect private property.
4. A historical overland flood channel north of Balsam Avenue functions as the Hamlet's natural and critical emergency spillway. The preservation of this corridor's hydraulic capacity is essential for community safety during extreme flood events.
5. The Hamlet's core lacks a reliable gravity outlet during flood conditions due to high river levels. New, dense development cannot be safely serviced by the existing informal system and requires a self-contained, engineered solution, including a centralized Stormwater Management Facility (SWMF) and a lift station to provide a positive outfall.

16.2 Recommended Actions

To address these findings and support the sustainable growth of Bragg Creek, it is recommended that Rocky View County take the following strategic actions:

1. Adopt this MDP as the guiding framework for all future stormwater management, land use planning, and capital works within the Bragg Creek study area.
2. Immediately prioritize the adoption of the Development Drainage Guidelines into the County's Land Use Bylaw and Servicing Standards. This is the most critical and cost-effective action to ensure all new construction is resilient, protected from known flood risks, and contributes positively to the overall drainage strategy.
3. Condition the approval of any major new development within the Hamlet's core on the developer-funded design, construction, and long-term operational agreement for a self-contained SWMF with a lift station outfall, as outlined in this report.

4. Initiate a formal process to secure the long-term function of the Balsam Avenue emergency spillway. Recognizing this pathway crosses private property, the County should evaluate and, if warranted, secure overland drainage easements or similar legal instruments to formalize public interest and ensure access for potential future maintenance.
5. Establish a multi-year capital improvement program for the phased implementation of Hamlet-wide road and ditch enhancements. This program should prioritize works that establish a continuous and functional conveyance path toward the Balsam Avenue emergency spillway, followed by areas with a documented history of nuisance flooding.
6. Formally designate and protect the Balsam Avenue emergency spillway through amendments to the Area Structure Plan and Land Use Bylaw, incorporating zoning regulations, development setbacks, and land use restrictions to ensure its hydraulic capacity is preserved in perpetuity.

16.3 Next Steps for the County

To move this plan from strategy to implementation, the following immediate next steps are recommended for the County:

1. **Initiate Bylaw and Standards Amendments:** Begin the statutory process required to amend the Land Use Bylaw and County Servicing Standards to formally incorporate the Development Drainage Guidelines.
2. **Develop a Prioritized Capital Plan:** Task administration with developing a prioritized, multi-year capital plan, complete with cost estimates, for the major system road and ditch improvements, to be considered in the next municipal budget cycle.
3. **Utilize the MDP for Current Reviews:** Immediately begin using the policies, guidelines, and technical requirements of this MDP to inform the review of all current and future development applications within the Hamlet of Bragg Creek, ensuring no new risks are created while formal amendments are underway.

17.0 References

- Amec Foster Wheeler. (2016). Impacts of Proposed Flood Protection Dikes at Bragg Creek on Flood Conditions at Redwood Meadows. Edmonton, AB.
- ISL Engineering and Land Services Ltd. (2020). *Bragg Creek Hamlet Expansion ASP Servicing Feasibility Study.* Rocky View County, AB.
- ISL Engineering and Land Services Ltd. (2021). Memorandum: Hydrogeological Investigation for Gateway Village Development at Bragg Creek – Preliminary Findings.
- ISL Engineering and Land Services Ltd. (2022). Memorandum: Stormwater Management for Gateway Village in Bragg Creek.
- Rocky View County. (2013). *County Servicing Standards.*
- Province of Alberta. (1999). Stormwater Management Guidelines for the Province of Alberta.
- City of Calgary. (2011). *Stormwater Management & Design Manual.* Calgary, AB.
- MPE Engineering Ltd. (2013). *Rocky View County Bragg Creek Master Drainage Plan*. Rocky View County, AB.
- WSP Canada Inc. (2025). *Hydrogeological Development Suitability Study, Greater Bragg Creek Area Structure Plan Review*. Submitted to Rocky View County. Calgary, AB.
- WSP Canada Inc. (2025a). *Bow and Elbow River Hazard Study – Flood Risk Inventory and Assessment Report*. Prepared for Alberta Environment and Protected Areas. Calgary, AB.
- WSP Canada Inc. (2025b). *Bow and Elbow River Hazard Study – Design Flood Hazard Mapping Report*. Prepared for Alberta Environment and Protected Areas. Calgary, AB.

APPENDIX
Bragg Creek Master Drainage Plan
(HAB-TECH Environmental, 2013)

A

HAB-TECH environmental

MPE Engineering Ltd.

Final Report for:

ROCKY VIEW COUNTY

BRAGG CREEK MASTER DRAINAGE PLAN

Submitted to: Rocky View County
Date: October 2013
(2285-033-00)

Suite 260, East Atrium
2535 - 37 Avenue NE
Calgary, AB T1Y 5Z6
Phone: 403-250-1362
1-800-351-0929
Fax: 403-250-1518

MPE Engineering Ltd.

Rocky View County
911 – 32nd Avenue N.E.
Calgary, Alberta
T2E 6X6

October 29, 2013
File: N:\22\85\033\Bragg Creek MDP.R01

Attention: Mr. Vince Diot
Municipal Engineering Technologist

Dear Vince:

Re: Bragg Creek Master Drainage Plan – Final Report

We are pleased to submit the Bragg Creek Master Drainage Plan report as requested by Rocky View County. This will enable you to provide clear guidance to prospective developers and the community on the management of stormwater for the Greater Bragg Creek Region.

Please contact the undersigned for any questions that you may have.

Yours truly,

MPE ENGINEERING LTD.

David Seeliger, P.Eng.
Senior Water Resources Engineer

DLP/mw

Enclosure

CORPORATE AUTHORIZATION

This report has been prepared by MPE Engineering Ltd. under authorization of Rocky View County. The material in this report represents the best judgment of MPE Engineering Ltd. given the available information. Any use that a third party makes of this report, or reliance on or decisions made based upon it is the responsibility of the third party. MPE Engineering Ltd. accepts no responsibility for damages, if any, suffered by a third party as a result of decisions made or actions taken based upon this report.

MPE ENGINEERING LTD.

PERMIT TO PRACTICE
MPE ENGINEERING LTD.
PERMIT NUMBER: P 3680
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

EXECUTIVE SUMMARY

The residents of the Bragg Creek community typically have a strong affinity with the natural environment and they desire the values and character of the region to be protected. Rocky View County in association with the local community, finalized the Greater Bragg Creek Area Structure Plan (ASP) in 2007, which sets the overall framework for future development in the region. A key focus of the ASP involved the management of stormwater and it recommended this Master Drainage Plan (MDP) be prepared to determine requirements to protect and enhance the sensitive wetlands and riparian areas from future development impacts.

The Study Area covers approximately 4,900 ha and is mostly situated in the Elbow River sub-basin, but also has small areas situated in the Bow River and Fish Creek sub-basins. Significant upstream catchments drain through the Study Area in the Elbow River and Fish Creek sub-basins. Approximately 26% of the Study Area has been subdivided for low density residential development. As in most parts of the County, much of the existing development has adopted rural stormwater management practices, incorporating culverts, ditches, and natural conveyance systems.

Development, including low density residential areas and other land uses, results in environmental impacts to the downstream wetlands and riparian areas. In addition, the Elbow River is an important multi-use tributary river of the Bow River Basin supporting many uses, including raw water supply for the City of Calgary through the Glenmore Reservoir, irrigation for crops and golf courses, stock watering, terrestrial wildlife, native flora and aquatic ecosystems, resource extraction, and numerous recreation activities. Therefore setting objectives and policies to protect wetlands, riparian areas and the water quality for the downstream users are some of the important considerations in developing the MDP.

This MDP provides policy and implementation strategies to ensure sustainable and orderly development of future growth in the Bragg Creek region. It identifies opportunities, constraints, and design parameters for managing existing and future drainage infrastructure and provides key strategies to address environmental sensitivities of existing wetlands and riparian zones as well as protection of the Elbow River Basin as a regional resource. In addition, it provides an overview of Low Impact Development (LID) practices and their effectiveness within the Bragg Creek region.

The key methods and analyses involved during the preparation of this MDP involved the following:

- Assessment of the condition and capacity constraints for existing drainage infrastructure.
- Preparation of an inventory and assessment of existing wetlands.
- Setting stormwater management control targets for peak flow, volume and water quality.
- Review of suitable Low Impact Development (LID) practices for the Bragg Creek region.
- Hydrologic modelling to assess detention storage requirements and the effectiveness of LID practices.
- Stakeholder consultation to understand current drainage/stormwater problems within the Study Area and receive feedback for future drainage policy strategies.
- Constraints and opportunities analysis and preparation of drainage policy implementation strategies.

The key recommendations for this study are summarized as follows:

<u>Stormwater Management Policies for Development Outside of the Bragg Creek Hamlet</u>

- All proposed development should prepare a Stormwater Management Plan which addresses the following:
  - LID practices and constructed wetlands with detention storage to be adequately sized to restrict discharges to meet the maximum unit flow rate of 6 L/s/ha or lower where downstream constraints exist.
  - LID practices and constructed wetland surface areas should be adequately sized, using evaporative losses only, to ensure that post development runoff volumes are equal to pre-development runoff volumes.
  - Development should be positioned and arranged to not adversely impact the hydraulic regime of existing wetlands and watercourses.
  - Development applications provide field verification of existing downstream constraints and capacity restrictions.
- However, small infill developments, where the above requirements may be impractical or not desirable to fully implement, proposed development applications must demonstrate that:

   - Runoff volumes and peak flows are managed using adequately sized and positioned LID practices that are suitable for the site.
   - Downstream impacts are negligible.
- Required setbacks from riparian and flood risk zones are adopted.
- Existing wetlands and riparian areas are protected.

Stormwater Management Policies for Development in the Bragg Creek Hamlet

- All proposed significant developments should provide:
   - Appropriately sized wet ponds with detention storage to restrict discharges to meet the maximum unit flow rate of 6 L/s/ha or lower where downstream constraints exist.
   - Stormwater infrastructure sized to meet the water quality targets of AENV stormwater guidelines and the ERBWMP.
   - Appropriate LID practices should be encouraged wherever possible.
   - Appropriate outfall measures to protect existing development from flooding.
- Minor development (i.e. up to two lots) or redevelopment should adopt LID practices to manage stormwater on site to meet the objectives of the MDP.

General Development Recommendations

- Stormwater reuse should be encouraged for lawn irrigation to reduce potable water for irrigation purposes.
- Prior consultation with AENV is required for future subdivision development proposals if any storm outfalls or constructed wetlands, stormwater management ponds, or stormwater treatment system (e.g., oil/grit separator) are to be constructed.
- Any proposed stormwater infrastructure within the plan area must follow environmental, municipal developmental, and site specific policy and design guidelines.
- Any future developments within the Study Area provide water quality improvement/enhancement practices to meet AENV and ERBWMP guidance.

Low Impact Development Practices

LID practices have been evaluated to identify their suitability for the Bragg Creek Region. The suitability of individual practices will depend on whether they are located on municipal or private property and the type of development they are being proposed for. The key LID practices for the Bragg Creek region are provided in the following table together with a suitability rating based on their hydraulic effectiveness, cost effectiveness and long term reliability.

Suitability of LID Practices

LID Practice	Development Type					Maintenance by Municipal /Private
	Hamlet	Infill	Cluster	Small # of lots	Large # of lots	
Better Planning Practices	M	H	H	H	H	N/A
Maintain Natural Areas	L	H	M	H	H	P
Absorbent Landscape	M	H	H	H	H	P
Permeable Pavement	M	L	L	L	L	P / M
Rain Garden	H	M	M	M	M	P / M
Vegetated Swales	M	×	M	H	H	M
Bio-swales	H	×	M	H	H	M
Rain Barrel/Tank with Reuse	L	L	L	L	L	P
Constructed Wetlands[a]	×	×	M	L	H	M
Wet Ponds[a]	M	×	L	L	M	M

Notation: L – Low, M – Medium, H –High, × - not suitable, M – Municipal, P - Private

a) end of pipe stormwater treatment measure

The most applicable LID practices for the Bragg Creek area have found to include:

- Better Planning Practices
- Maintain Natural Areas
- Absorbent Landscapes

The following LID practices have not been highly rated due to the high installation costs and the medium to long term reliability and serviceability issues:

- Permeable Paving
- Rain Barrel and Reuse

The County should develop policies and guidance related to the implementation and management of Stormwater infrastructure, including:

- Vesting ownership and management of constructed wet ponds and wetlands with the County.
- Develop policies and procedure to ensure LID practices required at the lot level are implemented in conformance with the requirements of the planning approval (i.e. at the building permit approval stage).
- Providing guidance on the design, installation and maintenance of key LID practices for private lots.

Stormwater Management Recommendations for Existing Infrastructure

- Develop strategies to manage/rectify existing drainage issues that have been identified in the MDP.
- Investigate opportunities to rectify existing capacity constraints as a component of future development proposals.
- Provide periodic review of existing infrastructure to assess the condition and structural adequacy of major culvert and bridge structures under County roads.

TABLE OF CONTENTS

MAPS

1.0 INTRODUCTION

1.1 Background

The community members in the Bragg Creek region have developed a strong affinity for the existing natural environment. As part of the ASP, a Master Drainage Plan (MDP) is needed to ensure stormwater created by future development can and will be managed effectively.

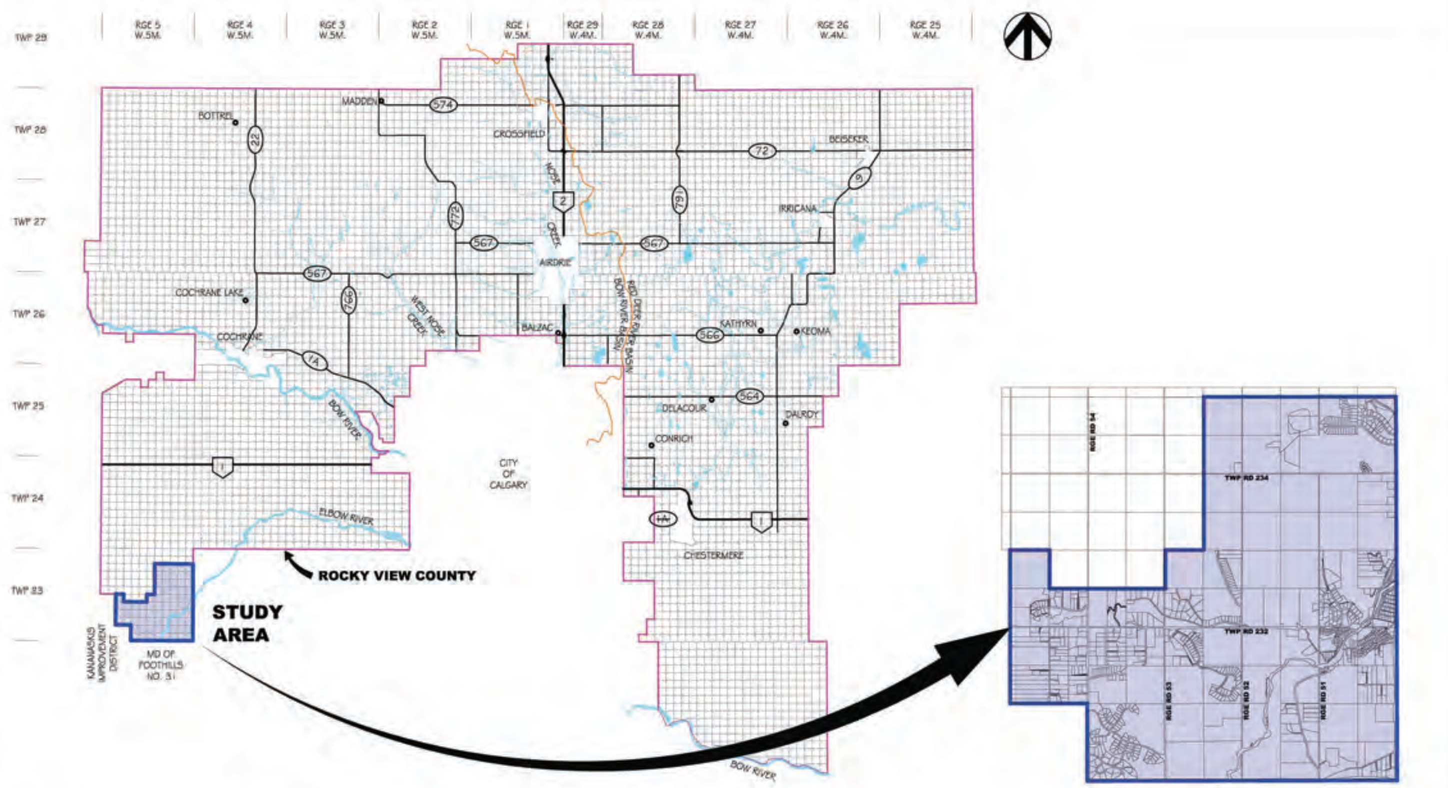
Rocky View County (RVC) retained MPE Engineering Ltd. (MPE) to complete a MDP for the Greater Bragg Creek region of the County as recommended by the Greater Bragg Creek Area Structure Plan (ASP).

This MDP is aimed to serve as a guiding tool to establish parameters for preservation of drainage corridors and implementation strategies to ensure sustainable and orderly development of future growth in the Bragg Creek region.

It identifies opportunities, constraints, and design parameters for existing and future drainage issues and provides key strategies to address environmental sensitivities of wetlands and riparian zones as well as protection of the Elbow River Basin as a regional resource. In addition, it provides an overview of Low Impact Development (LID) practices and their effectiveness and suitability within the Bragg Creek region.

1.2 Study Area

The Study Area is located approximately 30 km southwest of the City of Calgary, with a total area of ±4,900 ha within the County lands (***Figure 1***). It is an enclave within the County: bounded on the west by Kananaskis Improvement District, on the south by the Municipal District (MD) of Foothills No. 31/Highway 22, on the east by the Tsuu T'ina Reserve/Wintergreen Road, and on the north by a significant block of provincially-owned lands that are leased to private individuals for grazing purposes. It lies at the foot of the eastern slopes of the Rocky Mountains, within the upper reaches of the Elbow River. Both the Hamlet of Bragg Creek and Bragg Creek Provincial Park lie within the Study Area.



NOTES

1. RANGE DESIGNATIONS WEST OF 4TH MERIDIAN
2. BASE MAP FROM M.D. OF ROCKYVIEW MAY 2004.

LEGEND

- STUDY AREA
- 27 PRIMARY HIGHWAY
- 838 SECONDARY HIGHWAY
- RAILWAY
- MUNICIPAL BOUNDARY

MPE Engineering Ltd.

ROCKY VIEW COUNTY
Cultivating Communities

BRAGG CREEK MASTER DRAINAGE PLAN
STUDY AREA

SCALE: 1:400 000	DATE: NOVEMBER 2013	JOB: 2285-033-00	FIGURE: 1

1.3 Scope of Work

The following points summarize the overall scope of work for this study:

- Review existing background information and previous reports.
- Conduct field reconnaissance of wetlands and drainage conveyance infrastructure (culverts, bridges, swales/ditches, flow control structures, etc.)
- Delineate and characterize the sub-basins and sub-catchments within the Study Area.
- Identify constraints on existing drainage courses/paths, road culvert sizes, existing depressions/wetlands, and the environmental sensitivities of wetlands and riparian zone.
- Review existing LID practices in the Bragg Creek region to determine their effectiveness and align with the objectives of the Elbow River Basin Water Management Plan (ERBWMP).
- Prepare a case study to evaluate potential LID and stormwater recycling Best Management Practices (BMPs) that are adaptable to the Bragg Creek region and assess their effectiveness in improving water quality and reducing runoff volumes.
- Conduct event based and continuous hydrologic modelling simulations to derive release rates, volumes, and effectiveness of source control practices.
- Recommend stormwater unit release rates and runoff volume criteria for the Bragg Creek region.
- Evaluate drainage constraints and issues relating to new drainage routes and facilities, particularly potential impacts on the alluvial aquifer and existing wetlands.
- Prepare probable cost estimates for proposed storm drainage infrastructure.

1.4 Previous Studies

The following documents provide an overview of planning framework and physical, environmental, and natural characteristics of the Bragg Creek region:

- Greater Bragg Creek Area Structure Plan (ASP), M.D. of Rocky View No. 44, Adopted February 27, 2007. This document being the key planning document, sets legislative framework, describes natural characteristics of the plan area, and underlines plan philosophy and goals. It provides policy framework for the natural environment, infrastructure, future physical forms, community development, and implementation strategies.

- Elbow River Basin Water Management Plan, Prepared by Elbow River Watershed Partnership, Revised January 16, 2009 (M.D. of Rocky View No. 44 Council Endorsed January 13, 2009). This is a guidance document and planning tool pertaining to water management plan objectives, outcomes, physical characteristics of the Elbow River watershed, measurable impacts on water quality, and recommendations for implementation.
- Greater Bragg Creek Sub-basin Study for the Greater Bragg Creek ASP, Prepared by David Lagore, P.Eng., M. D. of Rocky View No. 44, November 2004. This document was prepared in support of the Greater Bragg Creek ASP. It broadly covers drainage catchments, unit area release rates, water quality risks associated with land use practices and some field observations, ecological land use planning approach to emphasize LID practices; need of precipitation, water quality, and streamflow monitoring stations; and recommendations for a MDP for the Bragg Creek region to address drainage issues while maintaining water quality.
- Elbow River at Bragg Creek Hydraulic Study, Prepared by UMA Engineering Ltd. (UMA) for Alberta Environment (AENV), March 1992. This document was prepared as per the guidelines of the Canada-Alberta Flood Damage Reduction Program and has addressed the historic flooding on the Elbow River and Bragg Creek. Flood Risk Maps covering the Hamlet of Bragg Creek were developed for the 1:100 year and smaller return period events.
- Bragg Creek Floodplain Management Study, Prepared by JN Mackenzie Engineering Ltd. (JN Mackenzie) and W-E-R Engineering Ltd. (WER) for AENV, March 1987. This document was prepared to identify flood hazard areas within the Hamlet of Bragg Creek in response to development pressures on the valley flat. The study documents the potential damages and risks associated with flooding by the Elbow River through the Hamlet, and recommendations for flood damage reduction alternatives.
- Bragg Creek Floodplain Study, Prepared by River Engineering Branch of Alberta Environment (AENV), May 1984. This document was prepared to delineate floodplain boundaries through the Hamlet of Bragg Creek in response to development pressures on the valley flat. It also provides historical review of flooding in the Bragg Creek region.

2.0 EXISTING CONDITIONS

2.1 Existing Drainage Catchments

The Study Area consists of portions of the Elbow River, Bow River, Fish Creek, and Bragg Creek Sub-basins. The Study Area has been divided into six sub-basins, namely Bragg Creek, Iron Creek, Elbow River North, Elbow River South, Fish Creek Tributary, and the Bow River Tributary (see ***Map 1***). Immediate upstream sub-catchments that drain via the Study Area form the part of each sub-basin. The Elbow River South Sub-basin is not completely shown in ***Map 1***, which extends to the southwest of the Study Area boundary of the upper Elbow River basin within the Kananaskis Country.

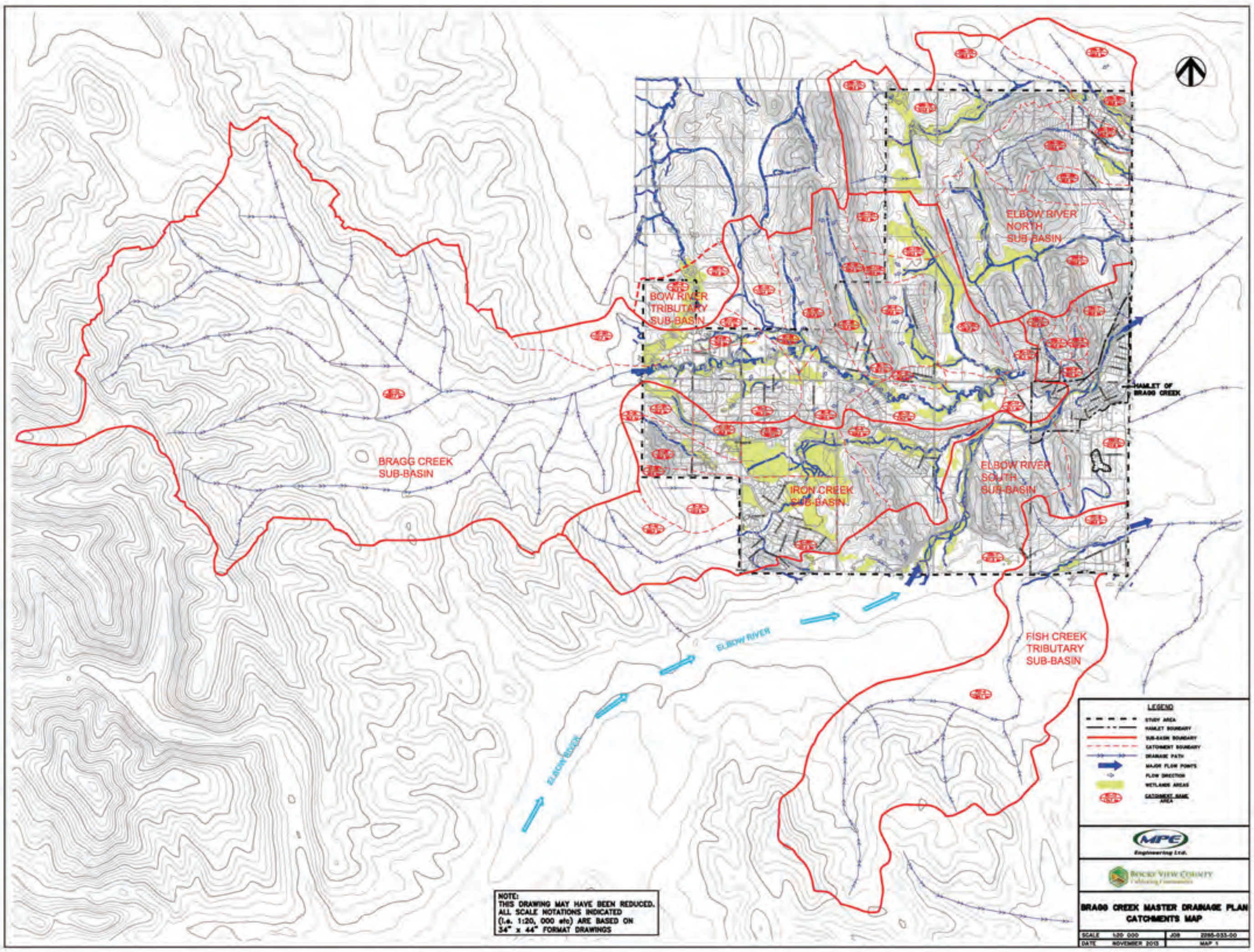
The following sub-section provides an overview of each major sub-basin. A summary of both on-site and off-site area and average slope for each sub-catchment is presented in ***Table 1*** in ***Appendix A*** and all the sub-catchments are shown in ***Map 2***.

2.1.1 Bragg Creek (BC) Sub-Basin

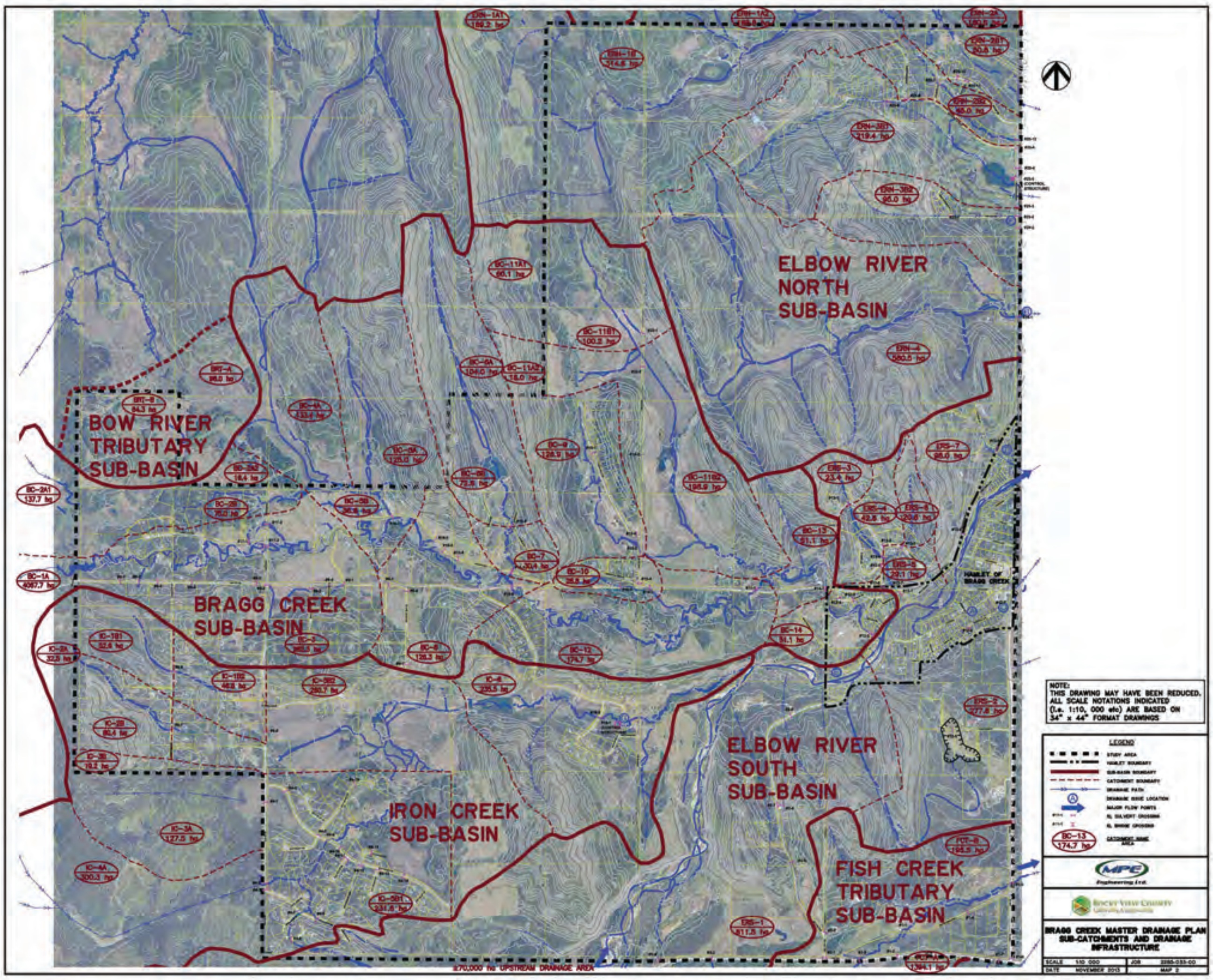
Bragg Creek (BC) Sub-basin is the second largest sub-basin having a total drainage area of approximately 6,000 ha with about 1,345 ha located in the Study Area. Land use in this sub-basin is characterized mainly by forested zones, clear-cut areas, wetlands, some acreage developments, and small sub-divisions. Township Road 232 traverses through this sub-basin from east to west and a large portion of this sub-basin is located to the west of the Study Area.

2.1.2 Iron Creek (IC) Sub-Basin

The Iron Creek (IC) Sub-basin has a total drainage area of approximately 1,400 ha with about 970 ha located within the Study Area before joining the Elbow River about 700 m west of the Hamlet of Bragg Creek boundary. Land use in this sub-basin is mainly characterized by subdivisions and wetlands with some forested areas, pasture lands, and acreage developments.



BRAGG CREEK SUB-BASIN
BOW RIVER TRIBUTARY SUB-BASIN
ELBOW RIVER NORTH SUB-BASIN
HAMLET OF BRAGG CREEK
IRON CREEK SUB-BASIN
ELBOW RIVER SOUTH SUB-BASIN
ELBOW RIVER
FISH CREEK TRIBUTARY SUB-BASIN
LEGEND
STUDY AREA
HAMLET BOUNDARY
SUB-BASIN BOUNDARY
CATCHMENT BOUNDARY
DRAINAGE PATH
MAJOR FLOW POINTS
FLOW DIRECTION
WETLANDS AREAS
CATCHMENT NAME AREA
MPE Engineering Ltd.
ROCKY VIEW COUNTY
NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:20, 000 etc) ARE BASED ON 34" x 44" FORMAT DRAWINGS
BRAGG CREEK MASTER DRAINAGE PLAN
CATCHMENTS MAP
SCALE 1:20 000
JOB 2266-033-00
DATE NOVEMBER 2013
MAP 1



BOW RIVER TRIBUTARY SUB-BASIN
ELBOW RIVER NORTH SUB-BASIN
BRAGG CREEK SUB-BASIN
ELBOW RIVER SOUTH SUB-BASIN
IRON CREEK SUB-BASIN
FISH CREEK TRIBUTARY SUB-BASIN
HAMLET OF BRAGG CREEK
NOTE: THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:10, 000 etc) ARE BASED ON 34" x 44" FORMAT DRAWINGS
LEGEND
BRAGG CREEK MASTER DRAINAGE PLAN SUB-CATCHMENTS AND DRAINAGE INFRASTRUCTURE
270,000 ha UPSTREAM DRAINAGE AREA

2.1.3 Elbow River North (ERN) Sub-Basin

The Elbow River North (ERN) Sub-basin has a total drainage area of approximately 1,800 ha with about 1,300 ha located within the Study Area. The sub-basin discharges, via two main tributaries, to the Elbow River to the east of Wintergreen Road. Land use in this sub-basin is characterized by forested areas, pasture lands/clear-cut area, subdivisions, some acreage developments, Wintergreen Golf Course, and wetland areas.

2.1.4 Elbow River South (ERS) Sub-Basin

The Elbow River South (ERS) Sub-basin is the largest sub-basin having an area in the order of approximately 70,000 ha (700 km^2) forming the upper reach of the Elbow River located mostly in Kananaskis Country. An area of about 1,100 ha is located within the study boundary with the Elbow River flowing in a northeasterly direction through the Hamlet of Bragg Creek. Land use in the Study Area of this sub-basin is characterized by forested zones, valley lands, some acreage developments and the Hamlet of Bragg Creek. This sub-basin is bounded by Highway 66/M.D. of Foothills No. 31 on the south and Highway 22/Wintergreen Road on the east.

2.1.5 Fish Creek Tributary (FCT) Sub-Basin

The Fish Creek Tributary (FCT) Sub-basin has a total drainage area of approximately 1,600 ha, with about 180 ha located within the southwestern portion of the Study Area. This sub-basin is an unnamed tributary of Fish Creek, crossing the southeast corner of the Study Area before crossing Highway 22. Land use in this sub-basin is characterized by forested zones mostly south of Highway 66, pasture lands, and some acreage developments.

2.1.6 Bow River Tributary (BRT) Sub-Basin

The Bow River Tributary (BRT) Sub-basin, with a drainage area of approximately 160 ha drains through the far western portion of the Study Area and discharges northwards to an unnamed tributary of the

Bow River. Land use in this sub-basin is characterized by some forest, pasture lands/clear-cut areas, and wetlands.

2.2 Characteristics of the Elbow River Watershed

The Elbow River is an important multi-use tributary river in the Bow River basin supporting many uses, including raw water supply for the City of Calgary through the Glenmore Reservoir, irrigation for crops and golf courses, stock watering, resource extraction, and numerous recreation activities. The Elbow River watershed, which consists of several tributaries and occupies an area of 1,235 km^2, is currently experiencing development pressures from rural and urban activities, particularly in the lower reaches (ERBWMP, 2009).

2.2.1 Physical

The Elbow River watershed originates in Alberta's eastern slopes of the Rocky Mountains at Elbow Lake and flows approximately 120 km through mountainous terrain, foothills, and prairie grasslands before it empties into the Bow River near the Calgary Zoo. As reported in the ERBWMP, the majority of the watershed (780 km^2, 63%) lies within Kananaskis Country, mostly zoned forest reserve and the remainder (455 km^2, 37%) lies in the Tsuu T'ina Nation and prairie lands. Approximately 264 km^2 (22%) of the watershed is within RVC. The river drops about 1,000 m elevation from source to mouth with an average slope of about 1% (ERBWMP, 2009; Valeo *et al*, 2007).

2.2.2 Geomorphology and Hydrology

The Elbow River is a naturally braided river, which includes a number of channels of relatively transitory gravel bars or islands (Kellerhals *et al*, 1972). The Elbow River changes the river course on a regular basis and changes in channel characteristics are often evident following periods of high flows. The Elbow River bed is known to be unstable even during low flows with measurable bed movement occurring at flows of 34 m^3/s.

The majority of total annual discharge in the Elbow River occurs in May, June, and July with a large portion of flow during these three months being generated upstream of Bragg Creek. As confirmed in the Bragg Creek Floodplain Management Study (JN Mackenzie and WER, 1987), floods in the Elbow River are generally caused by snowmelt or snowmelt combined with rain. Flooding in the Elbow River contributes to recharging the alluvial aquifer system, improving the riparian function through deposition and flushing of sediments and plant materials, and enhances the fish habitat through deposition of woody debris (ERBWMP, 2009).

2.2.3 Alluvial Aquifer

The Elbow River aquifer refers to the shallow, unconfined gravel and sand deposits formed by current and historic river processes (Manwell, 2005). It was formed by alluvial (river) deposition and is very permeable resulting in a high level of hydraulic connection with the Elbow River. Groundwater from the alluvial aquifer flows into the river during periods of low flow and river water flows into the aquifer during periods of high flows. Water withdrawal from groundwater in the alluvial aquifer is considered to be surface water and is licensed as such by AENV under the *Water Act*. As shown on ***Figures 3 and 4*** of the ERBWMP, the alluvial aquifer is mostly located downstream of Bragg Creek on both sides of the Elbow River with varying widths and falls within the central reach. Approximately 58 km^2 or 5% of the land area is occupied by this alluvial aquifer (ERBWMP, 2009).

2.2.4 Flood Risk and Historical Flooding

Portions of the Hamlet of Bragg Creek are subject to flooding from the Elbow River. Historically, the first bridge across the Elbow River at Bragg Creek was washed out in 1915. Major floods in the region include the following years: 1879, 1884, 1897, 1902, 1913, 1923, 1929, 1932, 1963, 1967 and 2005. Since the major flood in 1967, urban expansion pressures on the valley flat or within the flood risk area prompted a need to identify the potential flood hazard area map within the Hamlet. In 1984, AENV carried out the Bragg Creek Floodplain Study to determine the 1:100 year flood event hazard map for a reach of the river extending 3.2 km through the Hamlet. The 1987 study assessed the extent and magnitude of potential flood damages and suggested various flood damage reduction alternatives.

The June 2005 flood was the most recent significant event in the Bragg Creek region. It has been reported that four large culverts across Bracken Road were washed out during the June 7-9, 2005 flood event and were carried about one km downstream of the Elbow River Bridge from Balsam Avenue. The flood of 1932 was the most significant of recorded flows, with an estimated peak flow of 774 m^3/s in the Elbow River at Bragg Creek.

A hydrology study of the Elbow River and Bragg Creek was conducted by the Hydrology Branch of AENV in 1990. The study derived the flood frequency distribution for peak flows in both the Elbow River and Bragg Creek. The results of the study are summarized in ***Table 1*** below.

Table 1

Elbow River and Bragg Creek Flood Peak Flows for Various Return Periods

Return Period (Years)	Flood Peak Flows at Bragg Creek (m^3/s)	
	Elbow River [1]	Bragg Creek [1,2]
2	52.2	2.4
5	185	10.0
10	318	17.8
20	466	26.6
25	516	29.5
50	676	38.9
100	842	48.9

Notes:

1. The drainage area at the Elbow River at Bragg Creek Station 05BJ004 of Water Survey of Canada is 791 km^2. These flood peak flow estimates have been adopted in the *Elbow River at Bragg Creek Hydraulic Study* completed by UMA Engineering in 1992.
2. Drainage Area for Bragg Creek Sub-basin at the mouth of Bragg Creek is 60 km^2 based on areas of sub-catchments draining to main stem Bragg Creek.

2.3 Existing Land Use

The natural landscape of the Bragg Creek region offers opportunities for regional and provincial recreational amenities. Bragg Creek Provincial Park and the Wintergreen Golf Course are located within the Study Area. Kananaskis Country, a significant year-round provincial recreational area, lies immediately west of the Study Area.

The Greater Bragg Creek ASP document identifies that approximately 26% of the Greater Bragg Creek region outside the Hamlet has been subdivided into country residential acreages in a somewhat incremental subdivision pattern that has, over time, responded to natural environmental constraints. These developments are surrounded by privately-owned, open landscapes characterized by undeveloped agricultural lands. These open landscapes are expected to shrink over time due to future development.

2.4 Existing Drainage Infrastructure

The existing drainage infrastructure within the Study Area includes: natural drainage courses, road ditches, constructed swales, culverts, bridges, constructed dams and ponds and natural wetlands and riparian areas. The use of vegetated ditches/swales has been the preferred drainage conveyance method rather than hard engineered storm sewer pipes in the neighborhood subdivision developments and within the Hamlet of Bragg Creek. The majority of the Hamlet has no formal drainage but relies on infiltration into the underlying aquifer and some minor drainage ditches to dissipate stormwater runoff. Drainage conveyance through vegetated swales in Bragg Creek region has provided basic level of water quality protection before discharging into adjacent streams or wetlands.

2.4.1 Infrastructure Condition

Site inspections were carried out to determine the size and condition of culverts crossing public roads and the general condition and arrangement of drainage ditches and swales within the existing developed areas of Bragg Creek. The culverts that were inspected mostly cross RVC roads, however some cross Alberta Transportation Roads (AT) and some are located in privately-owned property like those along Saddle Ridge. The crossings are mainly CSP culverts but a number of older timber bridges and concrete box culverts cross Bragg Creek and a concrete arch culvert is located on the main stream of the Fish Creek sub-basin. The majority of the crossings are in good or reasonable condition; however, a number of them are in poor condition and have been plugged or blocked by thick vegetation.

Plugged culverts have occurred on a number of AT highway crossings and local RVC roads. They mostly occur due to erosion of the upstream catchment or through damage of the stream from livestock access, resulting in damage to the existing banks and silting of the watercourse.

The locations of blocked or damaged culverts have been provided in a culvert summary presented in ***Appendix B*** with culvert locations being shown on ***Map 2***.

A number of potential flooding issues have been identified during the site inspection, meeting with RVC operations staff and from the public through the Open House. The main areas where issues have been identified on ***Map 2*** include:

- **White Avenue Area (Location A)**
    - Drainage relies on infiltration to the underlying alluvial aquifer.
    - Is not effective under heavy rainfall, high Elbow River levels or rain or snow on frozen ground.
    - Stormwater tends to pond on or adjacent to the footpath and flow over the road.
- **Winter Green Road Culvert # 24-1 (Location B)**
    - Upgraded high level culvert crossing incomplete.
    - Downstream culvert outlet does not have erosion protection.
- **Burntall Drive (Location C)**
    - Stormwater tends to overflow to Burntall Drive and behind the community centre.
- **Yoho Tinda Road (Location D)**
    - Area has poor drainage due to local springs and service trenches causing local flooding problems.

- **Bracken Road (Location E)**
  - Levee constructed to protect properties from flooding of the Elbow River does not have adequate drainage to relieve the local catchment.
- **Township Road 234 (Location F)**
  - Section of Golf Course near Winter Green Road is regularly inundated.
- **Wild Rose Close (Location G)**
  - Overflow culvert taking flow from the upstream wetland has limited capacity.
  - The road has been overtopped on a number of occasions.
  - In the 2005 flood, significant overtopping occurred which nearly lead to the failure of the embankment.
- **East Park Place (Location H)**
  - The low point in the road and adjacent land are located in a natural depression serving an area of approximately 100 ha.
  - Adjacent landholders observe that water ponds on the low lying land during periods of heavy and extended rainfall.
  - The ponded water dissipates over time, mainly through infiltration.
  - The natural depression area is a potential flood risk to adjacent properties, particularly if the catchment is developed though expansion of the Hamlet.

2.4.2 Infrastructure Hydraulic Capacity Assessment

A preliminary hydraulic capacity assessment of culverts and bridges identified within the Study Area (see ***Map 2***) was carried out based on field reconnaissance. Culvert inverts, constructed slopes, lengths, road/driveway centerline elevations, upstream, and downstream channel conditions were estimated based on information gained during the site inspection and examination of the LIDAR contour data. Hydraulic assessments for culverts were performed using the Culvert Master Software. Similarly, bridge cross-sections, channel roughness, and channel geometry were determined from the site inspection and LIDAR contours were used to estimate the hydraulic capacity using the Flow Master Software. A summary of preliminary hydraulic assessment of the most significant culverts and bridges within the Study Area is presented in ***Table 2*** and ***Table 3*** respectively. Please refer to ***Appendix B*** for preliminary capacities of culverts and bridges at various locations. The approximate design standard of each culvert or bridge was estimated by comparing the unit area flow rate with the flow estimates for Bragg Creek in ***Table 1*** after converting to a unit area basis.

Based on the preliminary capacity assessment results, it has been found that some culverts have reasonable and some have a fairly low capacity. For example, the 2 x 825 mm Corrugated Steel Pipe (CSP) culvert at Boyce Ranch Road (Culvert ID # 1-1) is quite undersized and considered as a bottleneck for drainage conveyance. Culverts that may require potential upgrades are discussed further in Section 6.4.

In general, bridges on secondary and primary highways are designed to handle major flood flows, typically the 1:50 and 1:00 year return period events respectively. Based on flood frequency analysis, it has been reported that the 1:50 and 1:100 year return event flood peak flows at the mouth of Bragg Creek can be approximately 39 and 49 m^3/s respectively (UMA, 1992). It appears from the preliminary capacity assessment results that Bragg Creek Bridge at Township Road 232 (Bridge ID # 11-1 see ***Map 2***) has a hydraulic capacity somewhere around the 1:50 year return period event. Anecdotal evidence of the recent flood event of June 2005 has shown that the second bridge along the West Bragg Creek was found to be quite vulnerable with flood stage reaching almost 90 to 95% of the bridge capacity.

Table 2

Summary of Hydraulic Assessment of Selected Culverts

<table>
<tr><th>Culvert ID</th><th>Road Name</th><th>Diameter (mm)</th><th>Estimated Capacity(L/s)</th><th>Gross Drainage Area (ha)</th><th>Unit Area Flow Rate (L/s/ha)</th><th>Approx. Design Standard (1:Y years)</th></tr>
<tr><td>4-1</td><td>Range Road 54</td><td>2x600</td><td>1,330</td><td>150</td><td>9.1</td><td>100</td></tr>
<tr><td>4-2</td><td>Range Road 54</td><td>900</td><td>1,880</td><td rowspan="2">300</td><td rowspan="2">9.2</td><td rowspan="2">100</td></tr>
<tr><td>4-3</td><td>Range Road 54</td><td>600</td><td>890</td></tr>
<tr><td>4-6</td><td>Elk Valley Drive</td><td>2x600</td><td>1,170</td><td>390</td><td>3.0</td><td>10</td></tr>
<tr><td>15-3</td><td>Range Road 52</td><td>450</td><td>380</td><td>130</td><td>3.0</td><td>5</td></tr>
<tr><td>10-1</td><td>Wild Rose Close</td><td>1200</td><td>3,200</td><td>1,290</td><td>2.5</td><td>2</td></tr>
<tr><td>25-3</td><td>Wintergreen Rd</td><td>900</td><td>1,280</td><td rowspan="2">220</td><td rowspan="2">13.6</td><td rowspan="2">100</td></tr>
<tr><td>25-4</td><td>Wintergreen Rd</td><td>2x600</td><td>1,700</td></tr>
<tr><td>24-1A</td><td rowspan="3">Wintergreen Road</td><td>600</td><td>740</td><td rowspan="3">560</td><td rowspan="3">7.2</td><td rowspan="3">50</td></tr>
<tr><td>24-1B</td><td>450</td><td>320</td></tr>
<tr><td>24-1C</td><td>1350</td><td>3,000</td></tr>
<tr><td>13-7</td><td>Township Road 232</td><td>600</td><td>640</td><td>115</td><td>5.5</td><td>25</td></tr>
<tr><td>1-1</td><td>Boyce Ranch Road</td><td>2x825</td><td>1,920</td><td>1,400</td><td>1.4</td><td>2</td></tr>
<tr><td>1-2</td><td>Highway 66</td><td>2400</td><td>12,130</td><td rowspan="2">1,395</td><td rowspan="2">18.7</td><td rowspan="2">>100</td></tr>
<tr><td>1-3</td><td>Highway 66</td><td>2x1800</td><td>14,000</td></tr>
</table>

Table 3

Summary of Hydraulic Assessment of Selected Bridges

Bridge ID	Road Name	Approximate Size	Estimated Capacity (L/s)	Gross Drainage Area (ha)	Unit Area Flow Rate (L/s/ha)	Approx. Design Standard (1:Y years)
17-3	Bragg Creek @ Range Rd 54	5m Bx1.8m Risex10m Span	27,500	4,210	6.5	50
15-6	Bragg Creek @ Twp Rd 232	5m Bx1.9m Risex12m Span	28,000	5,190	5.4	25
11-1	Bragg Creek @ Twp Rd 232	6m Bx2m Risex12m Span	38,000	5,390	7.0	50
15-7	Saddle Road	1.3m Risex2.4m Span	7,800	210	37	> 100

2.4.3 Adaptability of Existing Drainage Features to Meet Low Impact Development Practices

Low Impact Development (LID) involves incorporating a range of practices that tries to mimic the natural hydraulic pathways of holding rainfall on site and slowly releasing any flows that do manage to exceed that hydraulic capacity of these systems. The nature of existing development in the Greater Bragg Creek region lends itself to the implementation of LID practices to manage stormwater runoff due to its low development density. Actually, many of the past practices align with what LID practices propose to achieve. In this study we have undertaken a qualitative review of past practices and discuss what types of practices should be encouraged.

The key LID that is implemented across much of Bragg Creek involves maintaining a significant area of undisturbed natural land. These undisturbed areas have a significant natural capacity to infiltrate and absorb runoff from impervious areas, whereas disturbed and trafficked areas become quickly compacted, reducing infiltration and generating runoff during more frequent rainfall events.

The other main LID practice involves the use of grass lined ditches or swales to convey stormwater runoff from the development areas. These swales, normally located on each side of the road right-of-way (ROW), collect runoff from the upland areas on the high side of the road and the road itself. A number of different swale forms and maintenance regimes have been identified and are described below.

Photo #2-1 shows a well grassed swale on a steep slope which provides good erosion protection and resistance to slow down flows and encourage infiltration and settling out suspended solids. ***Photo #2-2*** is an example where a stone weir is used to slow the flow in a steeply graded swale to reduce soil erosion.

Photo #2-3 gives an example of an infiltration zone along a swale. This ditch feature probably resulted from improper grading of the downstream pipe or from a buildup of silt at the culvert. Wetland type plants have been established which provide an opportunity for further stormwater treatment. It is appropriate that these areas are not mowed to improve the water quality treatment effectiveness of the swale.

Photo #2-1 Well grassed swale

Photo #2-2 Stone drop/weir

Photo #2-3 Sedge swale with infiltration capacity

Photo #2-4 shows a well maintained swale which looks good for the adjacent residences, however this form of swale provides less water quality treatment through reduced resistance to flow than the swale in ***Photo #2-1***.

Photo #2-4 Mowed grass swale

Photo #2-5 shows a swale with a concrete lined base. This construction detail provides the least desirable form to satisfy LID type systems as it does not promote the settling out of silt and reduces the opportunity for infiltration into the underlying subsurface. It appears that runoff in this swale contains high levels of nutrients due to the formation of algae in the stagnant water, probably from the overuse of fertilizers within the development.

Photo #2-5 Swale with concrete lined base

2.5 Streamflow Analysis and Pertinent Release Rates in the Region

2.5.1 Rationale

The Bragg Creek region consists typically of steeper natural wooded up slopes and flatter wide floodplains with significant flood storage. Typical stormwater models such as SWMHYMO for event based simulation and QHM for continuous simulation typically are used for urban catchments and are not easily adapted to large pervious catchments for a number of reasons. Firstly, SWMHYMO uses idealized rainfall and temporal patterns and suitable abstractions are needed to mimic antecedent moisture conditions in order to achieve realistic results. QHM avoids needing to estimate antecedent moisture conditions but still needs to estimate properties related to soil abstractions over time. Both models are poor at modelling the physical processes such as water movement down the upslope and accounting for the floodplain storage within the wetlands without discretely modelling such storage. These factors result in an overestimation of peak flows using these types of models without detailed model development and calibration to simulate the physical process as best as possible.

Alternative approaches such as a single station stream flow analysis can perfectly represent the physical characteristics of a gauged catchment, however long continuous records of stream flow are required to estimate a peak flow for a 100 year event with confidence. The main limitation of a single station analysis is that the actual points of interest are likely to not have gauged data. Regional analysis can be used by combining the analysis of a number of catchments that have similar hydrologic characteristics. This can provide increased confidence in the flood estimate using these methods. This type of analysis typically provides estimates on the lower side of the expected range of flow, which is preferred when establishing predevelopment flow rates.

Considering the basin characteristics information and enormous level of effort required to calibrate the hydrologic models for the offsite catchments and the Study Area, regional historic peak runoff rates were determined using the alternate method known as the Regional Flood Frequency Analysis, to estimate the Unit Area Flow Rate (UAFR) in L/s/ha for the predevelopment condition. This alternate method has been typically used in establishing predevelopment peak runoff rates in the region to the west of Calgary (McElhanney, 2008; Golder, 2006; Westhoff, 2004; MPE, 2009). In this method, estimation of the predevelopment peak runoff rate for the Study Area is based on interpretation of regional streamflow analysis results and the catchment characteristics of the Water Survey of Canada (WSC) gauging stations. For these studies, UAFRs have been recommended for numerous new developments and existing developed areas in the region as summarized in ***Table 4***.

Table 4

Unit Area Flow Rate Recommendations in the Region

Other Similar Studies in the Region	Approximate Distance from Study Area (km)	1:100 Y UAFR (L/s/ha)
Greater Bragg Creek ASP Sub-basin Study, MDRV, 2004	0	8.5
Pirmez Creek Development, Golder, 2007	15	5.2
Springbank Airport SMP, McElhanney, 2008	25	4.8
Highway 2A ASP, MPE, 2009	75	5.0

2.5.2 Streamflow Analysis

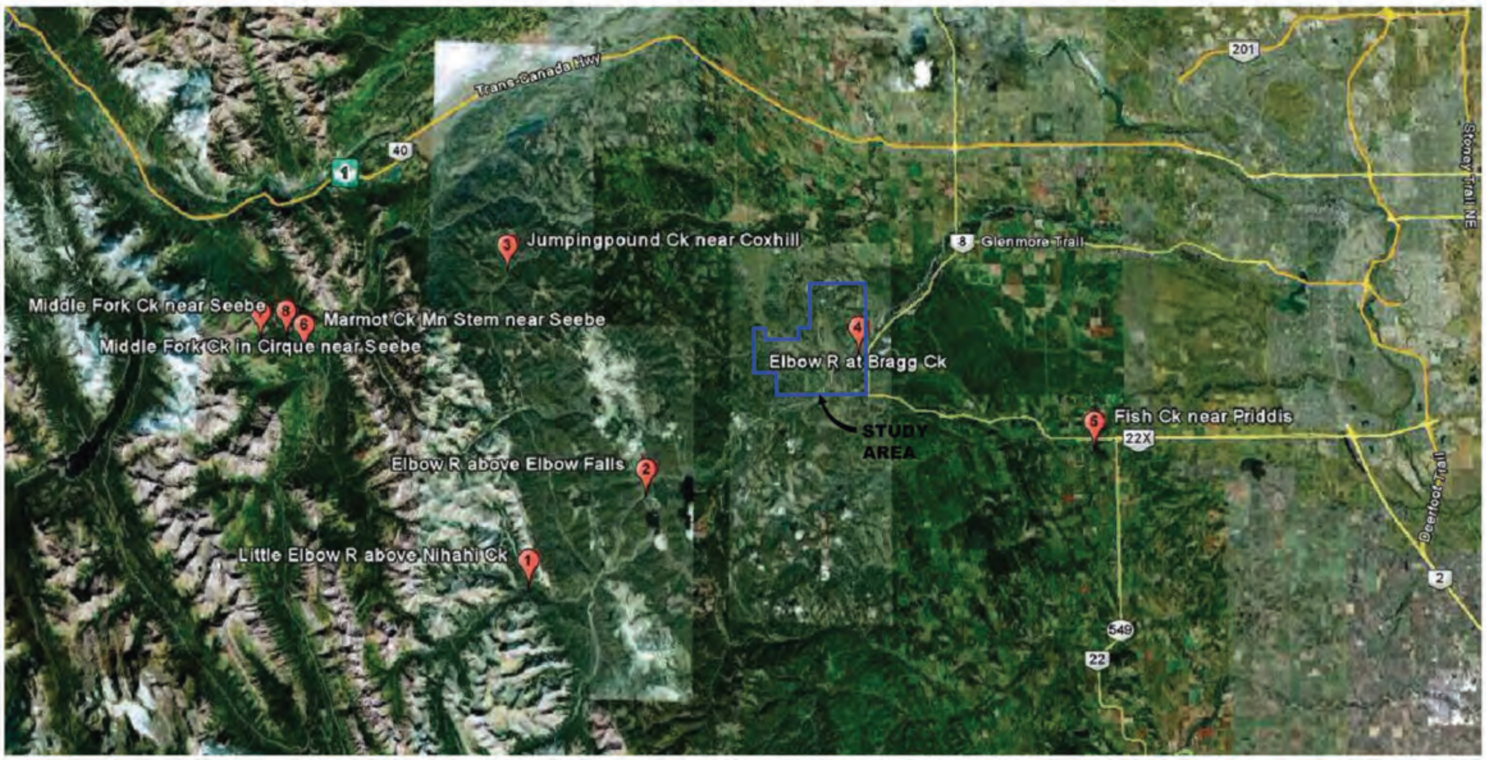
Streamflow analysis was conducted using the historic instantaneous peak flow data at eight WSC Hydrometric Stations near the Study Area. The location of WSC Hydrometric Stations selected for this analysis is presented in ***Figure 2*** and other pertinent station details are presented in ***Table 5***.

Table 5

Hydrometric Stations used for Regional Frequency Analysis

Station No.	Station Name	Location		Drainage Area (km^2)	Period of Record
		Latitude	Longitude		
(1) 05BJ009	Little Elbow River above Nihahi Creek	50.795° N	114.916° W	129	1978-1995
(2) 05BJ006	Elbow River above Elbow Falls	50.855° N	114.794° W	437	1967-1995
(3) 05BH013	Jumpingpound Creek near Cox Hill	51.002° N	114.938° W	37	1977-2009
(4) 05BJ004	Elbow River at Bragg Creek	50.948° N	114.571° W	791	1935-2009
(5) 05BK001	Fish Creek near Priddis	50.885° N	114.326° W	260.5	1911-2009
(6) 05BF016	Marmot Creek Main Stem near Seebe	50.950° N	115.153° W	9.1	1962-2009
(7) 05BF020	Middle Fork Creek in Cirque near Seebe	50.958° N	115.198° W	1.2	1966-1986 (1978,79 & 82 missing)
(8) 05BF017	Middle Fork Creek near Seebe	50.959° N	115.171° W	2.8	1963-1986

Note: (1) refers to station numbers show in Figure 2.



MPE Engineering Ltd.

ROCKY VIEW COUNTY
Cultivating Communities

BRAGG CREEK MASTER DRAINAGE PLAN
WSC HYDROMETRIC STATIONS

SCALE:	DATE: NOVEMBER 2013	JOB: 2285-033-00	FIGURE: 2

For each of these stations, a frequency analysis was performed on maximum annual instantaneous flows using the industry standard software, Hydrofreq1 developed in Alberta (Hydro Tools Software, 2000). Since the streamflow data did not have annual instantaneous flows for all the years in record, a regression analysis was used to derive instantaneous flows from the annual maximum daily flows for the missing years. The peak flow results associated with the return period events were then converted into the UAFR values by dividing the peak flow by the gross drainage area of each gauging station to allow easier comparison and use in the analysis. The 1:2, 1:5, and 1:100 year return period UAFRs typically used for minor and major drainage system design are presented in ***Table 6***. The peak flows for typical return period events and gross drainage areas of the hydrometric stations were used to perform regression analysis between drainage area and peak flows.

Table 6

Regional Streamflow Analysis Results

WSC Gauge	Drainage Area (ha)	No. of Years of Data	Unit Area Flow Rates (UAFR) for Various Return Period Events		
			1:100 Y (L/s/ha)	1:5 Y (L/s/ha)	1:2 Y (L/s/ha)
Little Elbow River above Nihahi Creek	12,900	18	6.7	2.4	1.3
Elbow River above Elbow Falls	43,700	29	5.2	1.6	0.9
Jumpingpound Creek near Cox Hill	3,700	33	12.0	2.9	1.3
Elbow River at Bragg Creek	79,100	75	5.9	1.6	0.8
Fish Creek near Priddis	26,100	60	13.3	2.4	0.6
Marmot Creek Main Stem near Seebe	910	48	4.0	1.7	1.1
Middle Fork Creek in Cirque near Seebe	120	18	4.3	2.3	1.7
Middle Fork Creek near Seebe	290	24	3.0	2.0	1.5

A review of the Regional Streamflow Analysis results (***Table 6***) obtained for the Study Area was conducted and a 1:100 year UAFR of 6 L/s/ha provides a reasonable allowable release rate. The 6 L/s/ha rate is the average UAFRs of the three WSC Hydrometric stations that are along the Elbow River from its headwaters towards downstream at Bragg Creek and is consistent with other adopted UAFR in the region as shown in ***Table 4***.

Therefore, 6 L/s/ha is recommended as the maximum release rate for the Study Area.

3.0 REGULATORY FRAMEWORK

3.1 Greater Bragg Creek Area Structure Plan

The Area Structure Plan (ASP) sets legislative framework, describes natural characteristics of the Plan Area, and underlines plan philosophy and goals. It provides policy framework for the natural environment, infrastructure, future physical forms, community development, and implementation strategies.

3.1.1 Policy Areas

The ASP proposed four distinct policy areas considering common relationships with existing transportation routes, current local land use, subdivision potential and the land's natural capacity to support further development. The four policy areas as shown on ***Figure 3*** (Section 4.4 in the ASP document) are identified as follows:

- Hamlet of Bragg Creek Policy Area
- West Bragg Creek Policy Area
- North Bragg Creek Policy Area
- South Bragg Creek Policy Area

3.1.2 Policy Framework for Natural Environment

The policy framework in the document outlines numerous preservation and protection measures for the natural environment. Some of the key excerpts (Sections 5.1.3, 5.1.4, 5.1.5, and 5.1.6 in the ASP document) relevant to this MDP are listed below.

- A riparian Buffer Policy shall be implemented within the ASP area in order to restrict and/or regulate development within the riparian buffer of all surface drainage features including wetlands.

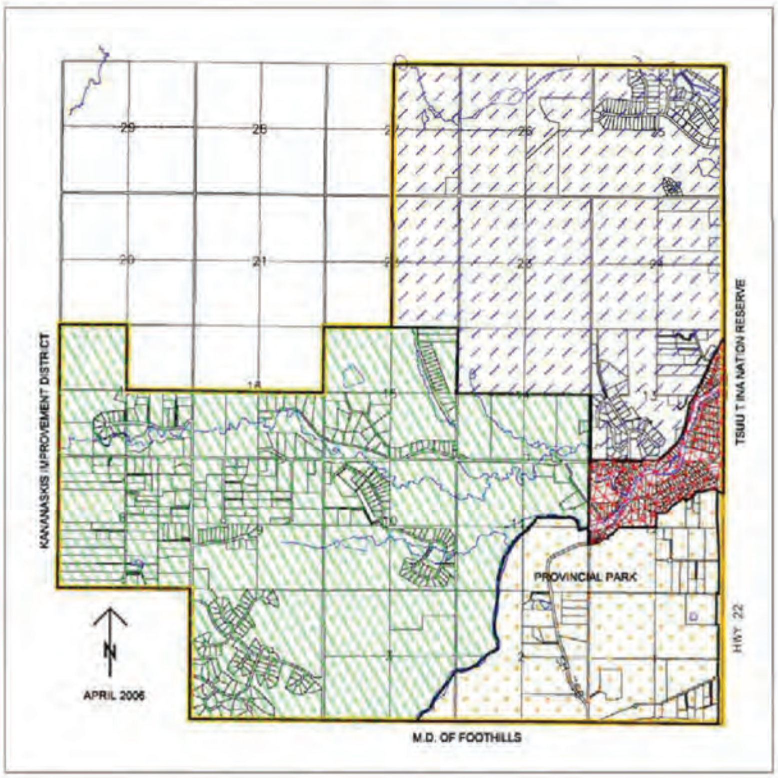


FIGURE 6:
POLICY AREAS

- PLAN AREA
- AREA WITHIN THE EXISTING HAMLET OF BRAGG CREEK BOUNDARY
- NORTH BRAGG CREEK
- WEST BRAGG CREEK
- SOUTH BRAGG CREEK

GREATER BRAGG CREEK
AREA STRUCTURE PLAN

MPE Engineering Ltd.		ROCKY VIEW COUNTY	
		BRAGG CREEK MASTER DRAINAGE PLAN POLICY AREAS	
SCALE:	DATE: NOVEMBER 2013	JOB: 2285-033-00	FIGURE: 3

- For lands outside of the Hamlet, the riparian buffer for the Elbow River is a 50 meter strip that extends outside of the active flood plain. For all other streams, tributaries and wetlands, the riparian buffer is defined as a 30 meter strip on both sides of the stream or edge of the wetland, measured from the high water mark.
- Within the Hamlet of Bragg Creek, the riparian buffer for the Elbow River is a 50 meter strip that extends beyond the floodway, as shown on the Bragg Creek Flood Risk Map, and the riparian buffer for Bragg Creek is a 30 meter strip that extends beyond the floodway, as shown on the Bragg Creek Flood Risk Map (***Refer Appendix C***).
- Subdivision development shall be prohibited within the floodway and restricted within the flood-fringe of the Elbow River and its tributaries. Development within the flood fringe should only be permitted when minimal negative impact to the Elbow River's drainage system can be demonstrated.
- If developments are considered within flood-fringe areas, appropriate flood proofing measures should be provided for all buildings, in conformity with the Land Use Bylaw.
- Developments on slopes steeper than 15% shall be discouraged.
- Areas of unstable slopes should be dedicated as Environmental Reserve (or Environmental Reserve Easement).
- To preserve the land's natural ability to provide for groundwater recharge, stormwater management and to reduce negative impacts of erosion and siltation within downstream areas, retaining at least 65% of natural vegetation within developed areas should be encouraged.
- Ongoing opportunities for public education programs designed to promote an understanding and awareness of local watershed and surface drainage issues should be encouraged.
- Responsible agricultural management practices that preserve the integrity of riparian areas should be encouraged.

3.1.3 Source Control and Water Quality Enhancement

In the ASP document, a brief discussion about the stormwater management strategies including MDP and site implementation plan requirements has been presented. Some of the key excerpts (Section 6.1.4 in the ASP document) pertinent to future development philosophy are listed below.

- Low Impact Development (LID) practices should be considered within all future subdivision and/or developments to encourage the retention of 65% native vegetation, 10% maximum impervious surfaces and 0% effective impervious surfaces (impervious surfaces flow over pervious areas such as LID practices).
- Wherever possible, natural surface drainage systems should be incorporated within all developments located in the Hamlet service area as opposed to “hard-engineered” stormwater control solutions, such as underground drainage systems.
- Implementation of absorbent landscaping and xeriscaping techniques and best management practices for stormwater control should be encouraged to reduce the use of potable water for irrigation purposes.
- The use of fertilizers, pesticides and herbicides (other than to control noxious weeds) shall be discouraged within the ASP area to improve water quality in the receiving water bodies (the Elbow River, Bragg Creek).

3.1.4 Future Residential Development Policy

The evolution of local subdivision and its resulting settlement pattern within the ASP area outside of the Hamlet can be characterized by one of three categories: *Built Out Residential Areas*, *Infill Residential Areas*, and *New Residential Areas* as illustrated on ***Figure 4****.* Some of the key excerpts (Section 7.4 in the ASP document) pertinent to future residential development are listed below.

- *Built Out Residential Areas* consist of existing planned subdivisions, with parcels that are two acres in size (on average), that were comprehensively developed and are considered “end subdivisions”, without potential for further subdivision. Further subdivision can occur where parcels currently have a land use designation that allows subdivision; otherwise no further subdivision is likely.

- *Infill Residential Areas* refer to parcels that have already experienced subdivision greater than eight lots per quarter. These areas typically contain a subdivision pattern that appears somewhat incrementally planned with parcels typically ranging in size between four to 20 acres. Future subdivision densities in *Infill Residential Areas* should be calculated on the basis of a ratio of lots per acre of Gross Developable Area (GDA). GDA is the remainder of the land once areas that represent constraints to development have been subtracted from the titled gross area.
- *New Residential Areas* contain larger tracts of land that are generally being used for a mix of agricultural uses and natural areas. Future development in these areas should follow policies established in this Plan to create and protect areas of Open Space.
- The General Residential Policies pertaining to future development within either Infill or New Development Areas as it relates to stormwater impacts are as follows:
    - Future subdivision should be evaluated based on the land's ability to accommodate additional development and not negatively impact the natural environment.
    - Areas that represent constraints to development, either being unstable or due to environmental sensitiveness, should be protected from development. These areas include: slopes in excess of 15%, water bodies and wetlands, and riparian buffer.
- Lands between the southern Hamlet boundary and the Hamlet Expansion Lands (see ***Figure 3***) should accommodate future expansion of the Hamlet for residential development and appropriate commercial uses.
- Parcel sizes within New Residential Areas in West and North Bragg Creek should not be less than 0.25 acres (11,000 ft^2), and not greater than two acres, with an overall density of not greater than one lot per four acres of GDA.
- Parcel sizes within New Residential Areas in South Bragg Creek should not be less than 0.25 acres (11,000 ft^2), and not greater than two acres, with an overall density of not greater than one lot per three acres of GDA.

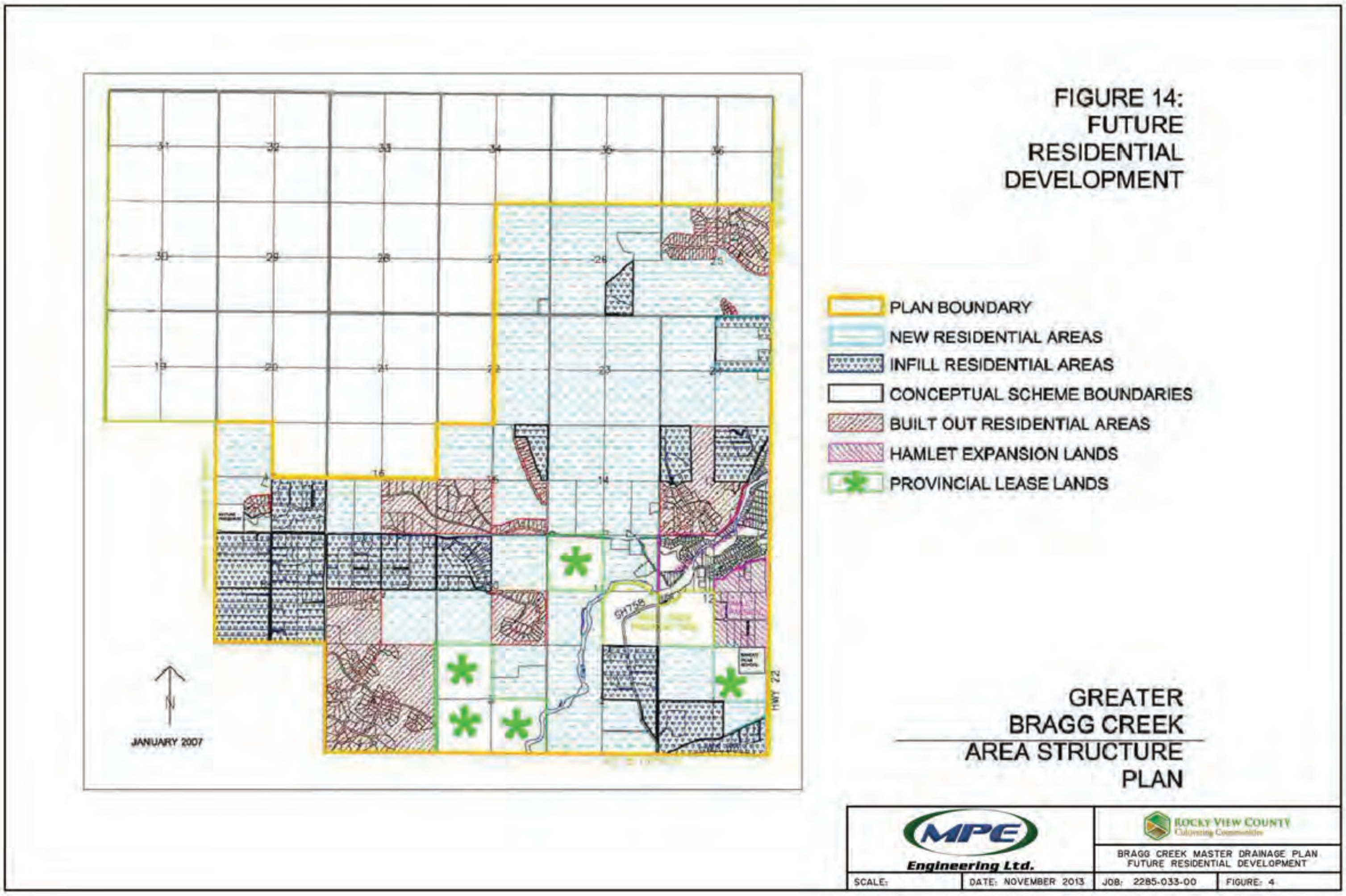


FIGURE 14:
FUTURE
RESIDENTIAL
DEVELOPMENT
PLAN BOUNDARY
NEW RESIDENTIAL AREAS
INFILL RESIDENTIAL AREAS
CONCEPTUAL SCHEME BOUNDARIES
BUILT OUT RESIDENTIAL AREAS
HAMLET EXPANSION LANDS
PROVINCIAL LEASE LANDS
JANUARY 2007
HWY 22
SH758
GREATER
BRAGG CREEK
AREA STRUCTURE
PLAN
MPE Engineering Ltd.
ROCKY VIEW COUNTY
BRAGG CREEK MASTER DRAINAGE PLAN
FUTURE RESIDENTIAL DEVELOPMENT
SCALE:
DATE: NOVEMBER 2013
JOB: 2285-033-00
FIGURE: 4

3.2 Elbow River Basin Water Management Plan

This is a guidance document and planning tool pertaining to water management plan objectives, outcomes, physical characteristics of the Elbow River watershed, measurable impacts on water quality, and recommendations for implementation.

For water management planning, the Elbow River Watershed is divided into three distinct river reaches:

- The *upper reach* within the Kananaskis Improvement District,
- The *central rural reach* within Rocky View County and Tsuu T'ina Lands, and
- The *lower urban reach* within the City of Calgary boundary upstream of Glenmore Dam.

The Study Area falls within the *central rural reach,* where the land uses are primarily agriculture, recreation and rural residential, including the Hamlet of Bragg Creek.

The four desired outcomes to be achieved with the implementation of the ERBWMP are as follows:

- Safe, secure drinking water supply,
- Healthy aquatic ecosystems,
- Reliable, quality water supplies for a sustainable economy, and
- Inclusive, integrated and committed stewardship of the river and watershed.

Based on the above desired outcomes, the following two objectives were established.
Objective #1: Recommend water quality objectives.
Objective #2: Provide decision making advice within the Elbow River watershed for federal, provincial and municipal authorities.

To achieve Objective #1, all jurisdictions and stakeholders adopt the water quality objectives and associated indicators for the Elbow River and its tributaries. The water quality objectives, warning levels and targets for biological (i.e. Attached Algae, Dissolved Oxygen, *E. Coli*, Fecal Coliforms, Total Coliforms, *Giardia* Pathogen), chemical (i.e. Nitrate plus Nitrite as N, Total Ammonia, Total Dissolved Phosphorous, Total Phosphorous, Total Organic Carbon, Pesticides and Degradation Products), and physical (e.g. Total

Suspended Solids) properties of the river water and environmental condition of the river system (i.e. Water Temperature, Riparian Condition, Soil Erosion) are outlined in ***Appendix B*** of the ERBWMP.

To achieve Objective #2, the following land use stewardship strategies are recommended:

- Manage water source areas to maintain or improve water quality in the Elbow River and its tributaries.
- Manage riparian areas and wetlands to maintain or improve water quality.
- Limit new development on the alluvial aquifer to those that improve water quality in the *central urban* and *central rural reaches* and those that maintain or improve water quality in the *upper reach*.
- Modify existing developments on or within the alluvial aquifer to ensure water quality objectives are met (e.g. improvements to wastewater and stormwater systems).
- No new direct stormwater discharge to the river.
- Reduce the risk of spills and potential contamination in the design, construction, operation and maintenance of stream/river crossings so that water quality is not adversely affected.
- Implement Best Management Practices (e.g. Low Impact Development Practices, Environmental Farm Plans).

3.3 Alberta Environment

Stormwater from the Study Area currently flows to Bragg Creek, Elbow River or their tributaries via natural streams or constructed swales. There are no formal constructed stormwater ponds for water quality treatment and water quantity control. Any future stormwater management facilities such as stormwater ponds and constructed wetlands and underground culvert outfalls within the Study Area would need to be authorized and regulated by Alberta Environment under the *Water Act* (*WA*) and *Environmental Protection and Enhancement Act (EPEA)*. Prior consultation with AENV is required for future subdivision development proposals within the Study Area if any storm outfalls or stormwater management ponds or stormwater treatment system (e.g. oil/grit separator) are to be constructed.

In addition, Alberta's *Water Act* requires that an approval be obtained before undertaking a construction activity in a wetland. Currently, Alberta's priority is to reduce loss of wetlands by:

- Avoiding impacts to the wetland;
- Minimizing impacts and requiring applicable compensation; and
- Compensating for impacts that cannot be avoided or minimized.

The approval process and the use of wetland compensation are summarized as follows:

- Applicants should discuss their proposal, including options to avoid or minimize the impact on the wetland, with a wetlands specialist or restoration agency and the local municipality (i.e. Rocky View County) before applying for *Water Act* approval.
- Applicants should also consult with Alberta Sustainable Resource Development's Public Lands and Forest Division.
- An assessment and classification of the affected wetland must be completed if the wetland is to be destroyed or altered.

3.4 Alberta Transportation

Alberta Transportation (AT) is responsible for primary and secondary highways, and associated bridge infrastructures in the Study Area. The care of water with respect to road and bridge infrastructure includes stormwater, irrigation water, and natural stream/river flows. Prior consultation with AT is required for future subdivision development proposals within the Study Area if any drainage infrastructure (e.g. bridge, culverts) across primary and secondary highways is impacted, needs replacing or upgrading.

3.5 Tsuu T'ina

Tsuu T'ina land is located on the eastern side of the Study Area and it accepts flow directly from a number of the Greater Bragg Creek sub-basins and the Elbow River. Tsuu T'ina Nation should be consulted whenever development or stormwater infrastructure upgrades have an impact or potential impact on their lands.

4.0 WETLANDS INVENTORY AND ASSESSMENT

4.1 Wetland Classification and Mapping

Wetlands in the Greater Bragg Creek region were classified and mapped based on elements of the Canadian Wetland Classification System (1997) and Alberta Wetland Inventory (Halsey et al. 2003). Site visits were conducted on the 15th and 22nd of October, 2010. A total of 52 wetland sampling sites were visited. Photographs were taken at each sampling site in addition to botanical information sufficient to identify wetland class (e.g. bog versus fen) and dominant vegetation association(s) and physiognomy. Wetland boundaries at another 26 reconnaissance sites (in accessible areas) were delineated/classified in the field on a 1:20,000 scale orthophoto (spring 2010). Ground truth information from sampling and reconnaissance sites was used in combination with visual signatures from 1:5,000 scale orthophotos and wet areas mapping from the Greater Bragg Creek ASP to delineate wetland polygons according to seven wetland types.

Seven different wetland types were classified and mapped as follows:

- Treed fen — 97.6 ha (50 map polygons)
- Shrubby fen — 254.1 ha (73 map polygons)
- Graminoid fen — 87.8 ha (50 map polygons)
- Graminoid wetland — 0.4 ha (11 map polygons)
- Shallow open water wetland — 12.0 ha (29 map polygons)
- Constructed wetland — 20.5 ha (35 map polygons)
- Dammed wetland — 29.0 ha (10 map polygons)

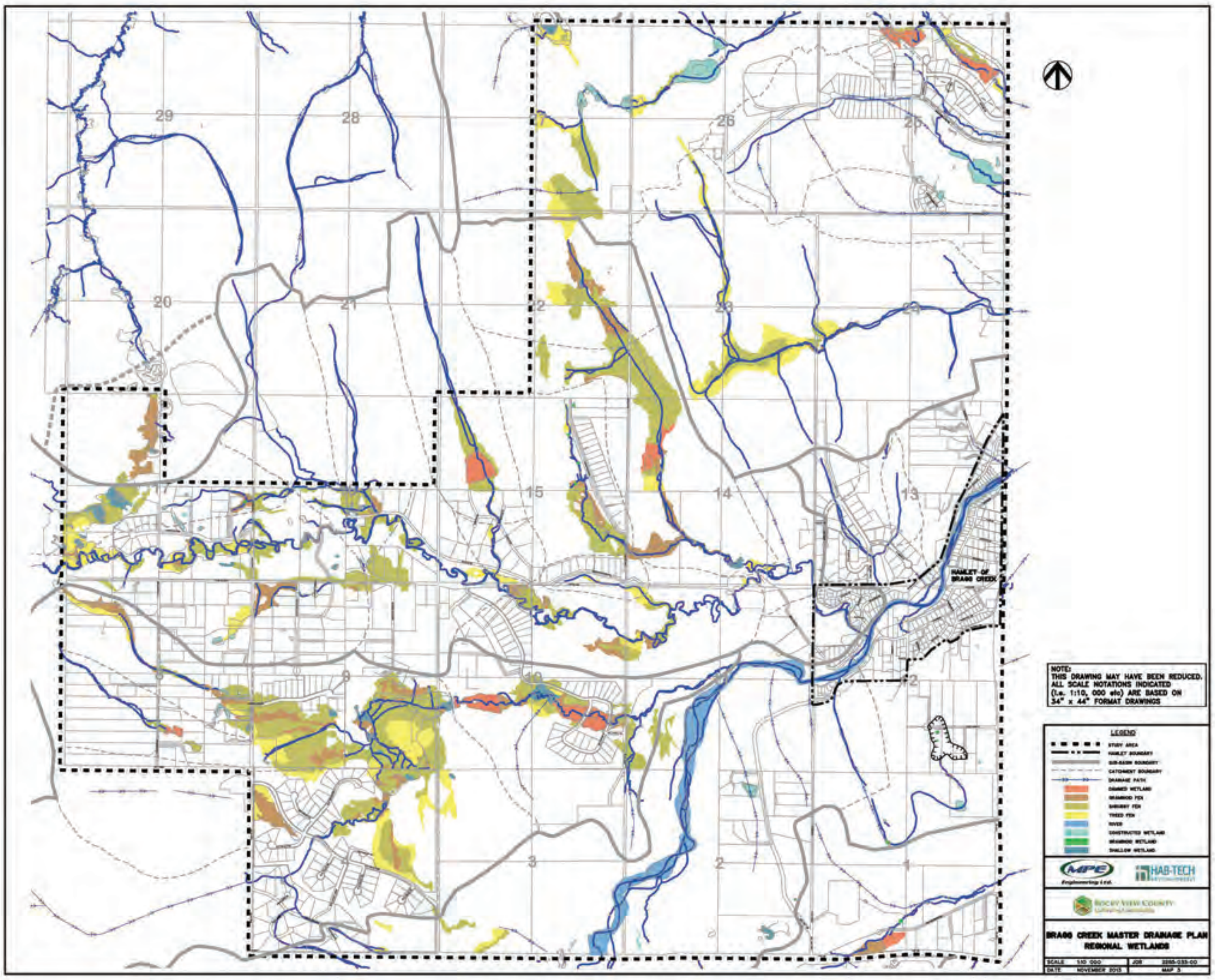
The classified wetlands occupy approximately 502 ha (10%) of the Greater Bragg Creek area (***Map 3***). The Elbow River and its active floodplain cover another 48.5 ha. Naturally occurring fens are the most common wetland class, comprising 439.6 ha (88%) of total wetland landscapes in the Study Area. Fens dominated by shrubs (willow, bog birch, white spruce, black spruce) are most common (254.1 ha). Fens dominated by trees (mainly white spruce) and graminoid (sedges, marsh reed grass, red canary grass) fens occupy 97.6 ha and 87.8 ha respectively. Human-created wetlands developed either by impeding water flow (“dammed wetland”) or by excavation and contouring (“constructed wetlands”) comprise 29 ha and 20.5 ha of the Study Area respectively. The majority of wetlands in the Greater Bragg Creek area occur in association with stream channels such as Bragg Creek, Iron Creek and their tributaries. Field visits noted very few sites with significant cover of black spruce trees, sphagnum moss or ericaceous shrubs. This, combined with the abundant cover of sedges, willows, dwarf birch and brown, golden and tufted mosses indicates that fens are much more abundant than bogs in this region.

4.2 Wetland Type Descriptions

Fens

Fens are wetlands characterized by fluctuating water table, flowing water and alkaline, mineral/nutrient rich site conditions (CWCS, 1997). Fens occupy level and depressional areas where moving water is at or near the soil surface for varying portions of the growing season (Beckingham et al. 1996). Water input into fens comes from precipitation falling directly onto the fen, surface runoff from surrounding slopes, and groundwater. Soils are dominated by decomposing sedges, golden, tufted and brown mosses. Vegetation in fens is influenced primarily by water table depth and water chemistry.

Graminoid Fens in the Greater Bragg Creek area comprise 87.8 ha and were mapped in 50 different locations (***Map 3***). Sedges and mosses dominate vegetation in graminoid fens. These fens occur where the water table is at or above the ground surface. The wettest fens in the Study Area are sedge rich fens (Lawrence *et al*. 2005) characterized by coarse sedges (*Carex aqualitis, C. rostrata*), marsh reedgrass (*Calamagrostis canandensis*) sausage moss (*Scorpidium* spp.), brown moss (*Drepanocladus* spp.) and marsh cinquefoil (*Potentilla palsutris*). Sedge rich fens are flooded for most of the growing season and occur in the lower, inner portions of larger fen complexes (***Photo #4-1***). Slightly drier portions of graminoid fens are dominated by a marsh reedgrass slough community (Lawrence *et al*. 2005). This plant community occurs on the fringes of marshes and sedge meadows (***Photo #4-2***). This wetland type is flooded only in the spring and early summer. Characteristic plants include marsh reedgrass, horsetail (*Equisetum arvense*), tufted hairgrass (*Deschampsia caespitosa*), fowl bluegrass (*Poa palustris*), slough grass (*Beckmannia syzigachne*) and reed canary grass (*Phalaris arundinacea*).


29
28
26
25
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HAMLET OF BRAGG CREEK
9
10
12
3
2
1
NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED.
ALL SCALE NOTATIONS INDICATED
(i.e. 1:10, 000 etc) ARE BASED ON
34" x 44" FORMAT DRAWINGS
LEGEND
STUDY AREA
HAMLET BOUNDARY
SUB-BASIN BOUNDARY
CATCHMENT BOUNDARY
DRAINAGE PATH
TREED FEN
RIVER
SHALLOW WETLAND
MPE Engineering Ltd.
HAB-TECH
ROCKY VIEW COUNTY
BRAGG CREEK MASTER DRAINAGE PLAN
REGIONAL WETLANDS
SCALE 1:10 000
JOB
DATE NOVEMBER 2013
MAP 3

Shrubby Fens in the Greater Bragg Creek area occupy 254 ha distributed among 73 distinct map polygons. This is the most common wetland type in the Study Area. Significant shrub cover occurs in drier fens where the water table is lower and moving water is at or near the surface for only a portion of the growing season. In large fen complexes, shrubby fens are transitional between wetter graminoid fens and drier treed fens, which they often lie in between. A willow-bog birch/water sedge plant association (Lawrence *et al.* 2005) occurs in the wettest portions of shrubby fens in the Bragg Creek area (***Photo #4-3****)*. This wetland plant community occurs along the edges of sedge meadows and in moist depressions. Characteristic plants include willow, bog birch, coarse sedge (*Carex aquatilis, C. rostrata*), slough grass, wire rush (*Juncus balticus*), marsh reedgrass, field horsetail, purple avens (*Geum rivale*), and wild strawberry (*Fragaria virginiana*). Drier portions of shrubby fens support more bog birch and less willow, limited coarse sedge and greater representation of fine sedges (e.g. *Carex atherodes, C. praegracilis*), and more marsh reedgrass, tufted hairgrass, wheatgrass (*Agropyron* spp.), and fowl bluegrass. ***Photo #4-4*** provides an example of a drier shrubby fen.

Photo #4-1 Sedge rich graminoid fen in lower middle portion of photo

Photo #4-2 Tufted hairgrass-marsh reedgrass-fine sedge graminoid fen

Photo #4-3 Willow-coarse sedge shrubby fen

Photo #4-4 Extensive bog birch/fine sedge-tufted hairgrass shrubby fen

Treed Fens in the Greater Bragg Creek area occupy 97.6 ha distributed among 50 distinct map polygons. In large fen complexes, trees occur on the driest sites where microtopographic features such as moss hummocks provide habitats as much as 20 cm above the water table (CWCS 1997). These sites most often occur on the outer edges of larger channel fens. White spruce trees are most prevalent in treed fens in the Greater Bragg Creek Study Area. Black spruce and tamarack trees, typical of poor and rich tree fens in northern and central Alberta, are very rare in southern Alberta's east slopes. Treed fens in the Study Area occur mainly as open or semi-open white spruce/bog birch-willow/sedge meadows on the outer fringes of large channel fen complexes (***Photo #4-5***). They also occur as closed canopy white spruce/willow-sedge associations in ribbons along the bottoms of narrow stream channels (***Photo #4-6***).

Natural Open Water Wetlands/Marshes

Naturally occurring open water wetlands and marshes are uncommon in the Greater Bragg Creek area. Our preliminary mapping delineated just 12.4 ha (0.3% of Study Area) of these wetlands among 40 map polygons. These are wetlands that support shallow water for much of the year. Water levels fluctuate daily, seasonally or annually due to flooding, evapotranspiration, groundwater recharge, or seepage losses. Open water in these wetlands results from topographic position, basin shape, high water table, or natural damming (i.e. beavers). This class of wetland is divided into two types – graminoid wetlands (shallow marshes) and shallow open water wetlands.

Graminoid Wetlands or shallow marshes are formed in depressions in the landscape where water runs through channels or where water collects as standing pools. The water table usually remains at or below the surface, but soil water remains within the rooting zone for most of the growing season. In the Greater Bragg Creek area, marshes are rare (0.4 ha and 11 map polygons) and very small, often occurring as isolated, complete entities found in shallow basins (***Map 3 and Photo #4-7***). Most marshes in the Study Area are shallow marshes which experience water level draw-downs that result in basins drying up and exposing sediments. Deep marshes with well-developed emergent zones of cattail and bulrush are rare in the Study Area. Marshes receive water from the surrounding catchment as surface runoff, stream inflow, precipitation, and/or groundwater discharge. Vegetation occurring in shallow marshes in the Study Area include: coarse and fine sedges, slough grass, and rushes.

Shallow Open Water Wetlands are semi-permanent or permanent wetlands that usually maintain surface water throughout the spring and summer and frequently maintain open water during fall and winter. Water levels are seasonally stable, permanently flooded, or intermittently exposed during droughts or low flows (CWSC 1997). Open shallow water comprises the majority of the surface area of a confined basin or saturated zone. These wetlands are created and maintained by either groundwater upwelling (***Photo #4-9***) or dam construction by beavers (***Photo #4-10***).

Photo #4-5 Open white spruce/bog birch-willow/fine sedge treed fen

Photo #4-6 Closed white spruce-willow sedge treed fen in narrow stream channel

Photo #4-7 Isolated shallow marsh with standing water and sedges

Photo #4-8 Shallow marsh in open water phase in stream channel

Photo #4-9 Shallow open water wetland in northern portion of Study Area

Photo #4-10 Shallow open water wetland created by beaver dam – Iron Creek

Constructed/Dammed Wetlands

These are wetlands where water regimes were artificially manipulated by construction of dams, reservoirs, impoundments and dugouts. Two types of 'artificial' wetlands were mapped in the Greater Bragg Creek area – dammed wetlands and constructed wetlands. Depending on the situation, some of these sites have over time evolved into naturally functioning wetland systems.

Dammed Wetlands comprise 29.0 ha among 10 map polygons in the Study Area (***Figure 1***). These wetlands arise primarily from impeding natural water flow through construction of roads and other earthen berms. Such dams have resulted in permanent open water with levels subject to drought and storm events. The "naturalness" or native ecological integrity of dammed wetlands depends on water depth, the age of the dam and the amount of vegetation manipulation along shores of the wetland. ***Photos #4-11*** and ***#4-12*** show two different outcomes of damming of Iron Creek by a residential road. The degree of naturalness of the wetland in ***Photo #4-11*** greatly exceeds that of the wetland in ***Photo #4-12***, which lies immediately adjacent and across the road. The wetland in ***Photo #4-12*** has been excavated and the shorelines partially mowed, whereas the wetland in ***Photo #4-11*** was created by damming and flooding with no excavation or vegetation removal.

Constructed Wetlands comprise 20.5 ha among 35 map polygons in the Greater Bragg Creek area. This type of wetland is usually found in association with country residential or recreational (e.g. golf course) properties. They are created usually by excavation and subsequent ponding by groundwater and additional surface water input. These wetlands could alternatively be termed residential or recreational ponds. Constructed wetlands are small averaging 0.6 ha and ranging in size from 0.04 ha to 6.0 ha. A wide range of levels of naturalness occur among constructed wetlands. Most wetlands support limited native ecological integrity and limited emergent vegetation (***Photo #4-13***). Some constructed wetlands support a narrow emergent zone of 1 meter or less.

Photo #4-11 Naturally functioning wetland created by damming of Iron Creek

Photo #4-12 Wetland adjacent to Photo #11 with modified basin and shoreline

Photo #4-13 Constructed wetland with limited emergent vegetation

Photo #4-14 Constructed wetland with partial emergent zone

4.3 Relative Importance of Wetland Types

According to Alberta's *Water Act,* all wetlands in the province are important ecological and socio-economic features, regardless of class or type. This is reflected in the strict wetland policy that requires an approval and/or license to affect a water body including dredging, filling, diverting, and drainage. Rocky View County adopted policies in 2010 with the purpose of conserving and managing wetlands and riparian lands. These policies help the County to fulfill its legislative mandate through meeting legal and statutory requirements for the protection of provincial water resources.

The definition of a water body in the *Water Act* is as follows:

> *"Water body means any location when water flows or is present, whether or not the flow or the presence of water is continuous, intermittent or occurs only during flood, and includes but is not limited to wetlands and aquifers".*

The importance of individual wetlands is often measured using the concept of wetland functionality (Brinson 1993, Clairain 2002, Fennessy *et al*. 2004, City of Calgary 2004). Wetland function assessments are often applied to assess the relative importance of specific wetlands for impact assessment purposes. Factors used to measure relative functional value of wetlands include: flood and stormwater storage, surface/groundwater quality protection, erosion and sediment control, fisheries habitat suitability and aquatic biological diversity, wildlife habitat suitability and terrestrial biological diversity, species at risk potential, plant community function, ecologically significant area potential, educational/research value, open space/recreational value, and cultural/heritage value.

Assessment of the relative importance of individual wetlands lies outside of the scope of this project and is, in fact, not applicable to this level of sub-regional planning and wetland classification. There are however some inherent differences in the level of ecological importance of the seven wetland types mapped in ***Map 3*** and described above. These include: 1) regional rarity; 2) wetland genesis/native ecological integrity; 3) plant and wildlife biodiversity potential; 4) size; and 5) connectivity.

The rarest wetlands in the Study Area from a land area perspective are graminoid wetlands (shallow marshes) and shallow open water wetlands. The interspersed standing water and emergent zone elements of these habitat types also enhance their potential to support a wide range of plant and vertebrate wildlife species including “at risk” species. Large fen complexes offer secure ‘core’ areas for certain wetland species but tend to support less structural and compositional diversity than shallow marshes and open water wetlands. Constructed wetlands generally offer less biological diversity although some dammed wetlands in the Study Area have evolved into natural open water wetlands with well-developed emergent zones and strong combined hydrological, biological and socio-economic function.

4.4 Potential Impacts of Stormwater Drainage on Wetlands

Some of the potential impacts of stormwater drainage and management on wetlands in the Study Area include:

- Increased surface water runoff because of impervious surfaces;
- Contaminants, sediments and nutrients entering wetlands affects water quality and aquatic and semi-aquatic wildlife and fish habitat;
- Erosion of stream banks and creation of erosion channels in the wetland;
- Reduced floodwater storage capacity;
- Altering plant composition and wildlife habitat.

Changes in water regime and water permanence have the greatest potential to alter wetland plant structure and composition and therefore wildlife habitat and populations. Increased water input into wetlands will generally result in reductions in shrubs, trees and grasses, and increases in sedges and open water. This is not necessarily a negative outcome given the limited representation of open water wetlands and shallow marshes in the Study Area. Ideally, best management practices commonly known as Source Control Practices (SCPs) or LID will make it feasible to manage stormwater while at the same time limit impacts on water regime and physical alteration of wetland habitat.

Section 7 and 8 of this report recommend measures to mitigate wetland impacts.

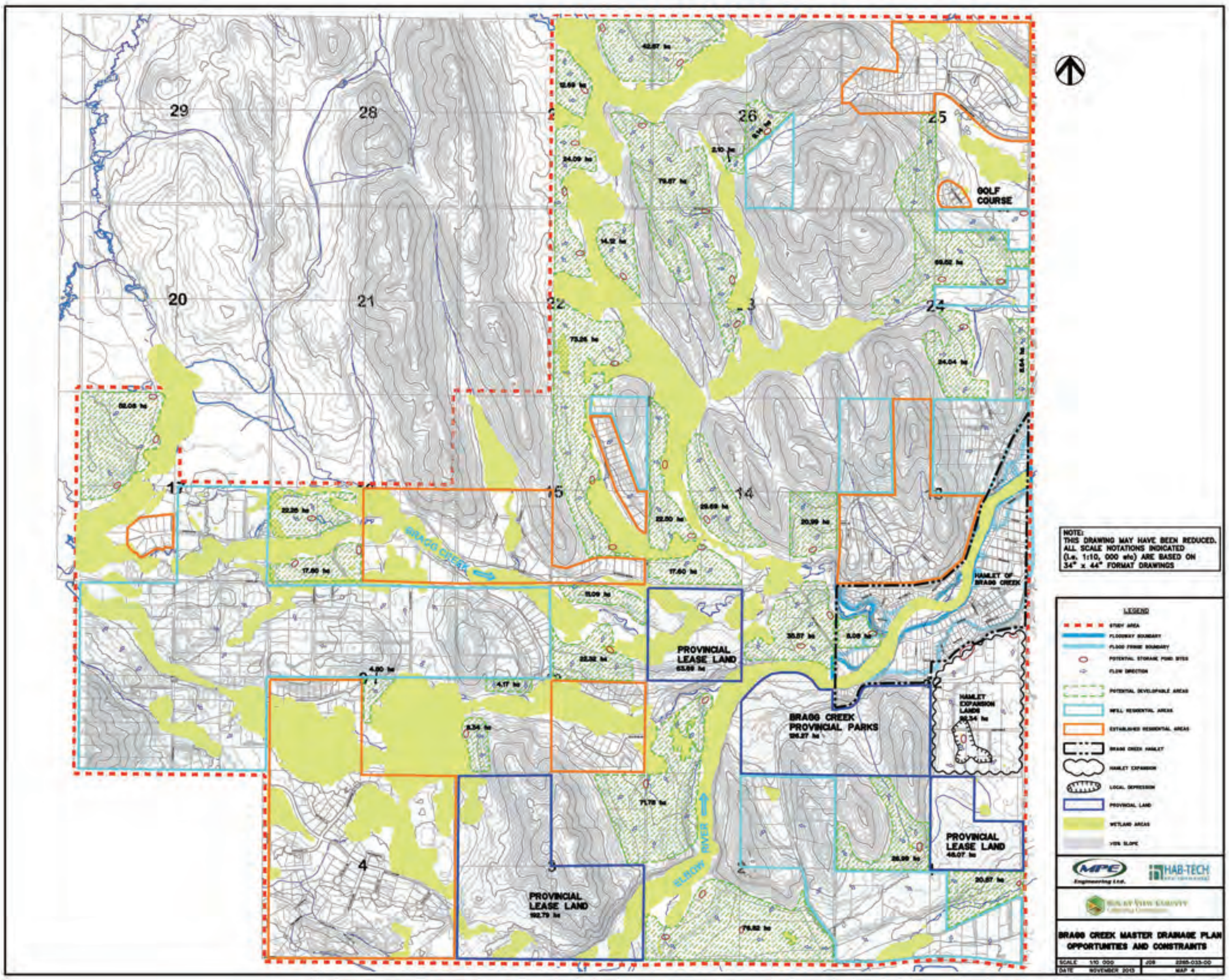
5.0 OPPORTUNITIES, CONSTRAINTS, AND DESIGN ISSUES

5.1 Background

Identification of future potential development parcels is guided by several factors including environmental and policy related issues. Environmental issues include: unstable slopes, forested areas, wetlands, wildlife corridors, flood risk areas, riparian buffer zones, alluvial aquifer zones, parks and recreation lands. Policy related issues include: type of development (e.g. low density, country residential acreage, infill development), lot size, developable area (DA), impacts to existing agricultural operations/practices, impacts to transportation infrastructure, lot servicing requirements (utilities, sanitary, water supply, drainage), and impact to natural environment. The following sections will describe future development opportunities, constraints, and design issues related to slope and stormwater management issues.

5.2 Potential Residential Development Parcels and Constraints

A constraint map was created first using the LIDAR data derived contours, existing wetlands as per the ASP document, wetlands inventory and assessment as part of this MDP, provincial park lands, floodway and flood fringe lines within the Hamlet, the Hamlet boundary and the existing subdivisions. This map identifies regions where potential future development is unsuitable in such areas with ground slope more than 15%, flood hazard areas, wetland areas, riparian areas, Environmental Reserve (ER) areas, and park areas. Based on consultations with the community residents, the County staff, and the wetland inventory and assessment completed by Hab-Tech Environmental, a map with opportunities and constraints was prepared (***see Map 4***). Potential storm pond locations have been provided considering the areas that could potentially be developed and the associated slope towards existing creeks and wetland areas. Actual locations of future storm ponds will depend on the area selected to be developed and other physical constraints, such as vegetation, in the area.



NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:10, 000 etc) ARE BASED ON 34" x 44" FORMAT DRAWINGS
LEGEND
STUDY AREA
FLOODWAY BOUNDARY
FLOOD FRINGE BOUNDARY
POTENTIAL STORAGE POND SITES
FLOW DIRECTION
POTENTIAL DEVELOPABLE AREAS
INFILL RESIDENTIAL AREAS
ESTABLISHED RESIDENTIAL AREAS
BRAGG CREEK HAMLET
HAMLET EXPANSION
LOCAL DEPRESSION
PROVINCIAL LAND
WETLAND AREAS
MPE Engineering Ltd.
HAB-TECH
BRAGG CREEK MASTER DRAINAGE PLAN
OPPORTUNITIES AND CONSTRAINTS
SCALE 1:10 000
JOB 2285-033-00
DATE NOVEMBER 2013
MAP 4
GOLF COURSE
HAMLET OF BRAGG CREEK
HAMLET EXPANSION LANDS
PROVINCIAL LEASE LAND
BRAGG CREEK PROVINCIAL PARKS
PROVINCIAL LEASE LAND
PROVINCIAL LEASE LAND
BRAGG CREEK
ELBOW RIVER

5.3 Future Development Stormwater Management Measures and Associated Design Issues

Potential developments will need to be planned and sited to minimize the potential impacts on environmentally sensitive areas such as wetlands, streams and areas of high value flora and fauna. The MDP looks primarily at the stormwater issues in respect to riparian and wetlands areas together with implementing practices that enable development to occur without adversely impacting these environmentally sensitive areas. Policies have been developed and recommended to control the peak flow and volume and to improve water quality from a development.

The key stormwater management recommendations include:

- Adoption of Low Impact Development (LID) practices to reduce runoff volumes and controlling peak flows.
- Provision of constructed wetlands, or wet ponds in the Hamlet, with detention storage to control peak flows to a maximum discharge rate of 6L/s/ha.
- Provision of LID practices and constructed wetlands to maintain flow volumes at predevelopment levels.
- Locating and arranging development to maintain the hydraulic regime of adjacent wetlands and watercourses.

By complying with the above objectives, significant improvements to runoff water quality will be achieved for new development, resulting in the downstream water quality condition being maintained or even enhanced. The level of improvement or otherwise that is achieved above existing background water quality levels will depend on the land use that existed prior to development. Areas of relatively undisturbed land are unlikely to have improved water quality outcomes, however areas that are currently used for various agricultural and grazing uses should see improved water quality outcomes to the receiving streams.

6.0 STORMWATER MANAGEMENT MEASURES FOR DEVELOPMENT

Hydrological modelling of the Study Area assessed the impacts of future development on the downstream watercourses and wetlands and determined what stormwater management practices are likely to be required to meet the recommended peak flow and volume control targets. The size of detention storage associated with wetlands and wet ponds and the potential benefits of incorporating LID practices and wetlands to achieve annual runoff volume and water quality targets were determined.

6.1 Gross Developable Area and Development Size

The Greater Bragg Creek ASP proposes policy guidance of future residential development including maximum size and number of lots within a Gross Developable Area (GDA). Gross Developable Area (GDA) is the amount of land that remains once areas that represent constraints to development have been subtracted from the titled area (Gross Area). Constraints include wetlands and streams and their riparian set backs and steeply sloped areas. The ASP sets maximum number of lots irrespective of the allotment density, i.e. whether at the maximum lot size or cluster style development. The ASP only permits 50% of the GDA will be taken as lots where a development uses the maximum lot size. Under a cluster style development 6.3% of the GDA will be taken up as lots where the smallest lot size is used. However, as lot sizes are typically not equal, a lot size of 0.33 of an acre is considered a reasonable average lot size for a cluster style development, which would take up 8.4% of the GDA. Concept size of detention storage volume to determine the predevelopment flows was determined for a maximum lot size and the cluster development lot size of 0.33 of an acre. The modelling parameters used and the imperviousness calculations are presented in ***Appendix D.***

6.2 Hydrologic Modelling for Storage Requirements

The SWMHYMO event based model and the continuous simulation QHM model was used to determine concept level storage volume requirements for specific unit area release rates. Estimated costs to construct the various wetland sizes were determined using standard rates for earthworks associated components. For planning purposes, the storage-release rate-pond cost charts for both the maximum 2.0 and 0.33 acre lot size for various sizes of Gross Developable Area are presented in ***Figure 5*** and

Figure 6 respectively. Further details of the modelling undertaken have been included in the Bragg Creek Hydrological Modelling Analysis report provided in ***Appendix D***.

Figure 5: Storage Volume – Release Rate – Pond Cost for Two Acre Lot Size

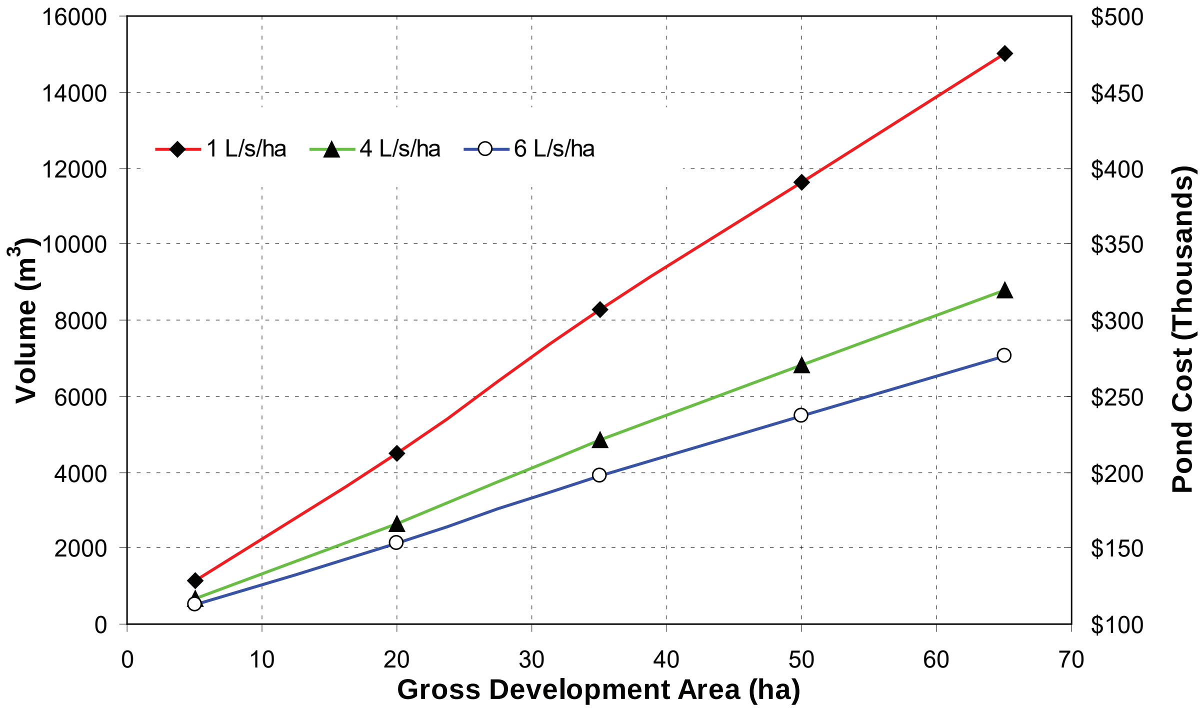
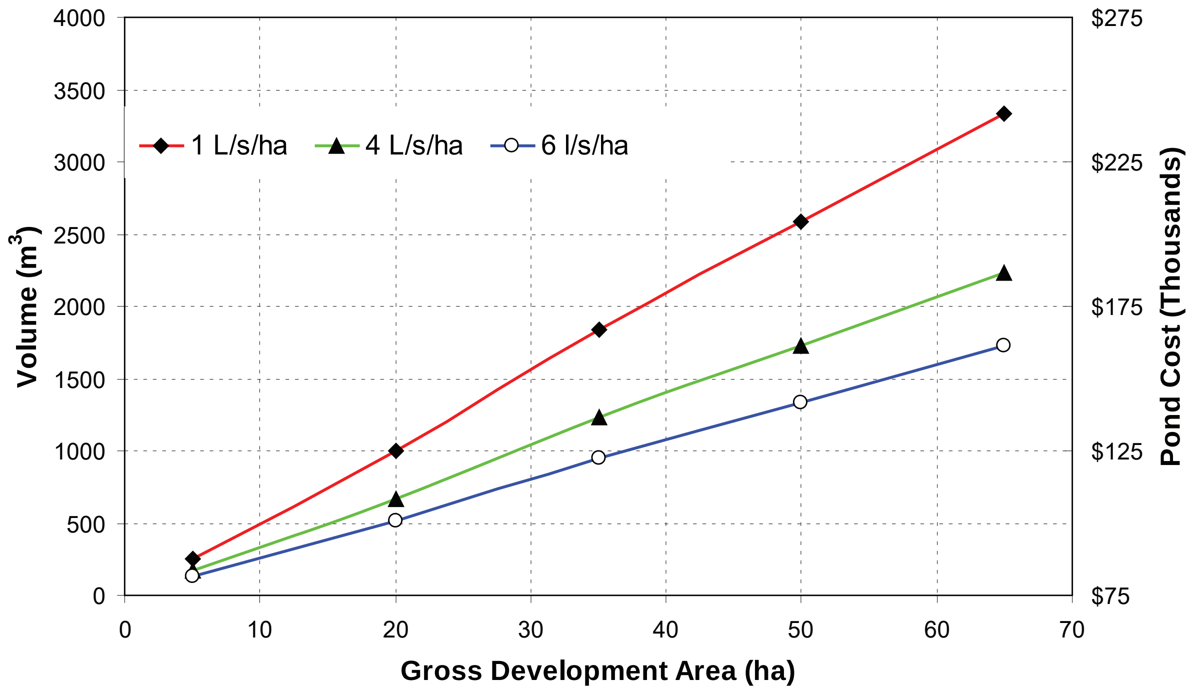


Figure 6: Storage Volume – Release Rate – Pond Cost for 0.33 Acre Average Size Lot



The pond costs have been based on typical construction rates for the key elements for constructing a constructed wetland or pond, including excavation, inlets and outlets and landscaping. No land cost allowance has been included.

6.3 Bragg Creek Hamlet Stormwater Management

The Hamlet of Bragg Creek is mostly located on an alluvial aquifer which is hydraulically connected to the adjacent Elbow River. The drainage in the Hamlet typically relies on the high permeability of the underlying ground to dissipate and infiltrate stormwater. Therefore, no formal surface drainage system exists for the majority of the area. Specific conditions such as a high river levels or a sizable runoff volume generated from a Chinook or spring melt while the ground is still frozen limits this infiltration capacity, resulting in localized flooding. There is also the possibility that the infiltration capacity is reduced in local depressions due to sealing off of the surface by fine silts and clays. The potential for infill and some large scale development within the Hamlet and the possible expansion to the south will mean a more integrated approach to managing stormwater is needed. This approach should ensure that new development does not adversely impact existing drainage systems but can also provide a means for providing overall improvements.

6.3.1 Development in the Existing Hamlet

Proposed development within the Hamlet should incorporate LID practices as the primary method to manage stormwater runoff. Stormwater practices such as bioretention and bioswales should be promoted as they can take advantage of the underlying natural capacity to infiltrate stormwater. These types of systems also provide a filter between the polluted surface stormwater and the underlying aquifer. However the stormwater systems will still need to account for conditions such as high river levels and Chinook snow melts by providing adequate storage and safe overland flow paths in addition to setting appropriate minimum floor levels for development. Providing new outfalls can also be used in combination with the above methods; however any direct discharge into the Elbow River will require appropriate upstream treatment measures and regulatory approvals.

6.3.2 Hamlet Expansion Lands

Approximately sixty percent of the land identified for future Hamlet expansion slopes towards the existing developed area of the Hamlet and therefore future development is constrained by the lack of drainage infrastructure that is available. Approximately forty percent of the area drains to a local depression which serves a catchment area of approximately 100 ha to the south and west. Stormwater management strategies in addition to implementing LID practices have been identified for these areas as follows:

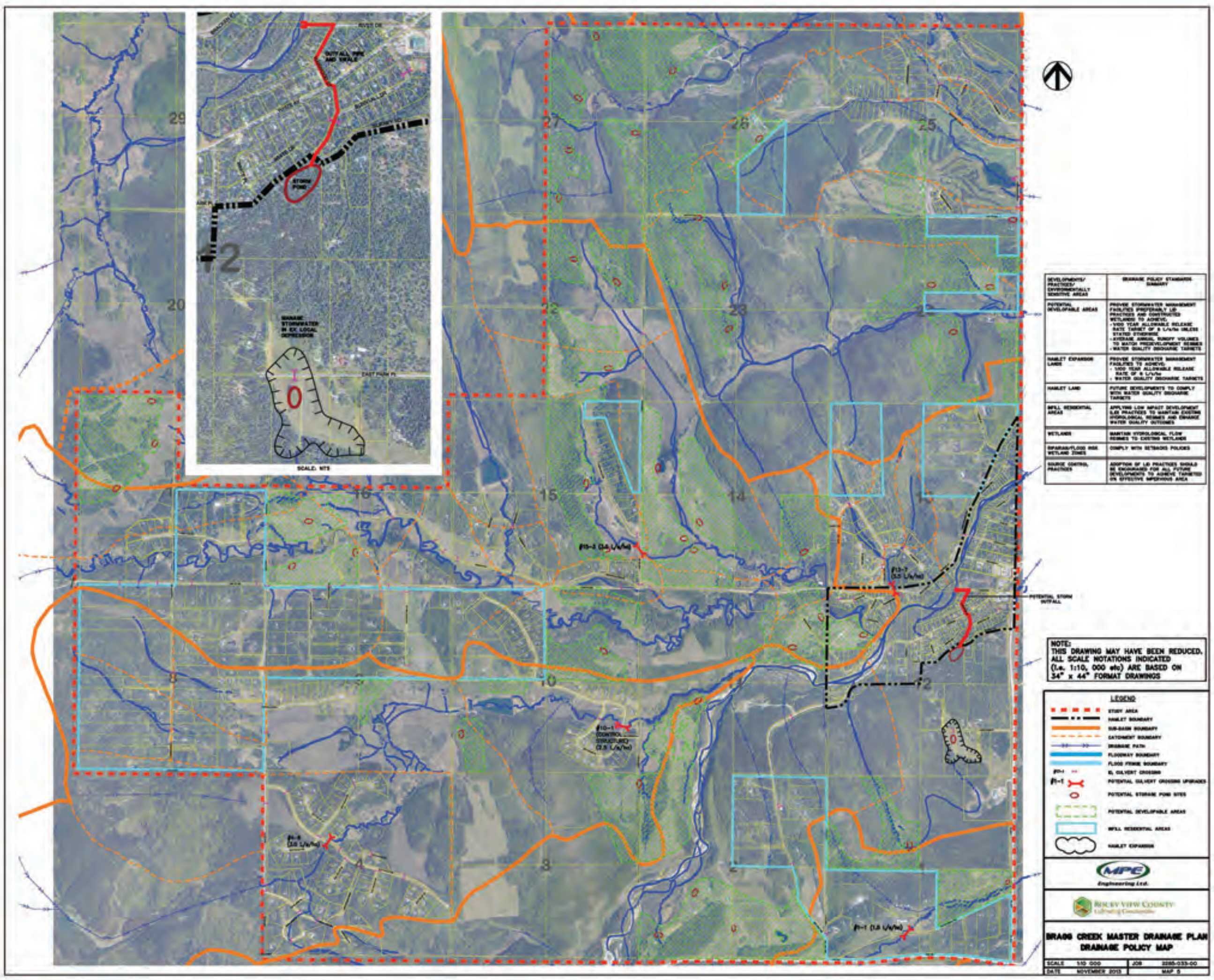
<u>Development within the Southern Depression Catchment</u>

Stormwater runoff of any proposed development within this catchment should be managed within the local depression as a reasonable rate of infiltration is observed after significant runoff events. A stormwater management study would be required to understand the hydrological regime of the depression, assess impacts to existing infrastructure and ensure new development is situated outside and is a minimum of 0.5m above the 1 in 100 year and extreme event (June 2005) flood levels.

Development Draining to Existing Hamlet

The majority of the future expansion area that drains towards the Hamlet can be graded towards a point to the north of Burney Road. This area is a relatively flat bench above the floodplain but below the majority of the developable catchment. It is proposed that a stormwater wet pond for treatment and detention storage could be constructed in this location with an outfall directing overflows towards the Elbow River (Refer Enlargement on ***Map 5***). The outfall would need to be a pipe for steeply graded areas or where flows need to be directed against grade. However a swale could be provided for sections of the outfall depending on the existing constraints along potential alignments. A swale may be preferred for some sections as it should be built at a lower cost and conform to the ASP policy recommendations of not providing formal hard engineered solutions in the Hamlet. One of the key limitations to constructing a swale will be available space along any potential alignment. Detailed survey and further investigations would be required to determine how the outfall could be built. For this study, an underground outfall was sized and construction costs estimated to provide a budget cost for providing an outfall.

The size of the wet pond component was estimated using current Alberta Environment criteria of providing a volume equal to 25mm of runoff over the contributing catchment. The required detention storage volume to mitigate flow down to the maximum discharge rate of 6L/s/ha was estimated based on the hydrological modelling. It was assumed that development will have an average impervious area of 40 percent and only a single stormwater basin has been provided for the expansion area. The outfall pipe was sized to accommodate the 360 L/s capacity from the development to the river.


DEVELOPMENTS/ PRACTICES/ ENVIRONMENTALLY SENSITIVE AREAS
DRAINAGE POLICY STANDARDS SUMMARY
POTENTIAL DEVELOPABLE AREAS
PROVIDE STORMWATER MANAGEMENT FACILITIES (PREFERABLY LID PRACTICES AND CONSTRUCTED WETLANDS) TO ACHIEVE:
- 1/100 YEAR ALLOWABLE RELEASE RATE TARGET OF 8 L/s/ha UNLESS STATED OTHERWISE
- AVERAGE ANNUAL RUNOFF VOLUMES TO MATCH PREDEVELOPMENT REGIMES
- WATER QUALITY DISCHARGE TARGETS
HAMLET EXPANSION LANDS
PROVIDE STORMWATER MANAGEMENT FACILITIES TO ACHIEVE:
- 1/100 YEAR ALLOWABLE RELEASE RATE OF 8 L/s/ha
- WATER QUALITY DISCHARGE TARGETS
HAMLET LAND
FUTURE DEVELOPMENTS TO COMPLY WITH WATER QUALITY DISCHARGE TARGETS
INFILL RESIDENTIAL AREAS
APPLYING LOW IMPACT DEVELOPMENT (LID) PRACTICES TO MAINTAIN EXISTING HYDROLOGICAL REGIMES AND ENHANCE WATER QUALITY OUTCOMES
WETLANDS
MAINTAIN HYDROLOGICAL FLOW REGIMES TO EXISTING WETLANDS
RIPARIAN/FLOOD RISK WETLAND ZONES
COMPLY WITH SETBACKS POLICIES
SOURCE CONTROL PRACTICES
ADOPTION OF LID PRACTICES SHOULD BE ENCOURAGED FOR ALL FUTURE DEVELOPMENTS TO ACHIEVE TARGETED ON EFFECTIVE IMPERVIOUS AREA
POTENTIAL STORM OUTFALL
OUTFALL PIPE AND SWALE
STORM POND
MANAGE STORMWATER IN EX. LOCAL DEPRESSION
EAST PARK PL
SCALE: NTS
NOTE:
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:10, 000 etc) ARE BASED ON 34" x 44" FORMAT DRAWINGS
LEGEND
STUDY AREA
HAMLET BOUNDARY
SUB-BASIN BOUNDARY
CATCHMENT BOUNDARY
DRAINAGE PATH
FLOODWAY BOUNDARY
FLOOD FRINGE BOUNDARY
EL CULVERT CROSSING
POTENTIAL CULVERT CROSSING UPGRADES
POTENTIAL STORAGE POND SITES
POTENTIAL DEVELOPABLE AREAS
INFILL RESIDENTIAL AREAS
HAMLET EXPANSION
MPE Engineering Ltd.
ROCKY VIEW COUNTY
BRAGG CREEK MASTER DRAINAGE PLAN
DRAINAGE POLICY MAP
SCALE 1:10 000
JOB 2285-033-00
DATE NOVEMBER 2013
MAP 5

The sizing of the stormwater pond and the outfall together with an indicative cost to construct the infrastructure is provided in ***Table 7***. The cost may vary significantly depending on the final location of the stormwater pond and the catchment characteristics that are being proposed.

Table 7

Stormwater Infrastructure for Hamlet Expansion

Wet Pond Volume (m^3)	15,000
Detention Volume (m^3)	20,000
Pond Cost ($)	$600,000
Outfall size (mm)	525
Outfall Cost	$500,000
Total Estimated Cost	$1,100,000

The proposed alignment of the outfall passes a number of areas that are known areas of ponding and localized flooding. The outfall could also be designed to accept additional flows from these locations with bio-swales and rain gardens potentially being used to filter the stormwater before entering the outfall. Such pretreatment measures may be more acceptable to the approving authorities when discharging to the Elbow River. However, issues such as frozen ground and high river levels will also need to be examined when considering the design.

6.4 Upgrade Requirements for Existing Drainage Infrastructure

A review of the existing culverts and bridges summarized in ***Table 2 and 3*** indicates a number of culverts have a low servicing standard before they are overtopped. As they are existing culverts, the priority to upgrade depends on the culverts' level of service and consequences if their capacity is exceeded. If culvert or bridge overflows resulted in unsafe conditions or damage to infrastructure or property, it is recommended that they are prioritized within the overall works program of the County. However, if the culverts provide an acceptable level of service, the upgrades could be deferred to align the upgrade with future development works impacting the culvert or future road upgrades.

The culverts identified in ***Table 8*** have been reviewed to determine if any action is required to determine if they should be included as a priority culvert upgrade. The review generally identifies no upgrades are needed unless required by future development proposals. However there may be a number of culverts that require maintenance, as identified in the culvert assessment given in ***Appendix B*** or upgrades due to minor drainage issues.

Table 8

Culvert/Bridge Capacity Upgrade Review

Culvert / Bridge #	Ex. Design Standard	Action Required	Comments
10-1	2	N	Investigation by MPE (2007) identified that existing outlet structure is satisfactory provided the County accepted undertaking repair due to scour from overtopping and the potential for failure of the embankment during an extreme event.
1-1	2	N	Upstream channel has five to ten year capacity, remaining flood flow inundate wide area and safely overtop the road. Any future development proposal should consider the extent of the 100 year flood plain and how it should be managed.
15-3	5	N	Safely overtops local road.
13-7	25	Y	Overtops main road for brief periods during significant events. Investigate if overtopping in a 100 year event could result in damage to downstream property.
4-6	10	N	Culvert safely overtops Elk Valley Drive.
15-6	25	N	Infrequently overtops road with shallow flow, no adjacent properties exist. 100 year flood plain to be assessed for proposed development.

6.5 Low Impact Development Case Study

The effectiveness of LID techniques to retain runoff from development was determined using a case study for several development scenarios that are expected to be encountered within the Bragg Creek region. The **M**odel for **U**rban **S**tormwater **I**mprovement **C**onceptualisation (MUSIC) water quality model was used to assess the potential for LIDs to achieve the requirement to not change the runoff volumes and regimes that existed prior to development. This section summarizes the findings of the case study. Further details of calibration of the MUSIC model and associated analysis is included in Bragg Creek Hydrological Modelling Analysis report provided in ***Appendix D*.**

6.5.1 Infill Development with LID Modelling

A typical infill development was modeled to assess the potential increase in runoff due to development and assess the size of LIDs required to mitigate against any increase in volume. A four lot development with a 1.6 ha (four acre) lot size was considered in the model and is shown in ***Figure 7***. A model was developed for the pre-developed area, the developed area, and the developed area with the application of LIDs. The total site area was 6.4 ha with an impervious area of 6.3% consisting of roofed areas, paving and driveways. The model also assumed that 75% of the site was not disturbed or modified during or after the development of the lots.

Table 9 gives the changes in runoff from each condition. LIDs that were selected for the modelling included rain barrels/tanks used to irrigate landscaped areas and absorptive landscaped to hold runoff from adjacent paved areas. The irrigated areas assume an application rate of 130mm per year based on the moisture deficit between the average monthly evaporation and rainfall. The absorptive landscape is assumed to increase the holding capacity of the soil by 100mm and all losses are assumed to occur through evapo-transpiration. Any infiltration losses that would actually occur are most likely to re-enter the downstream wetlands/stream and therefore not reduce the runoff volume. ***Table 10*** gives the LID sizing required to meet the ‘no effective increase in runoff volume’ recommendation.

Figure 7 **Infill Development with Application of LIDs**

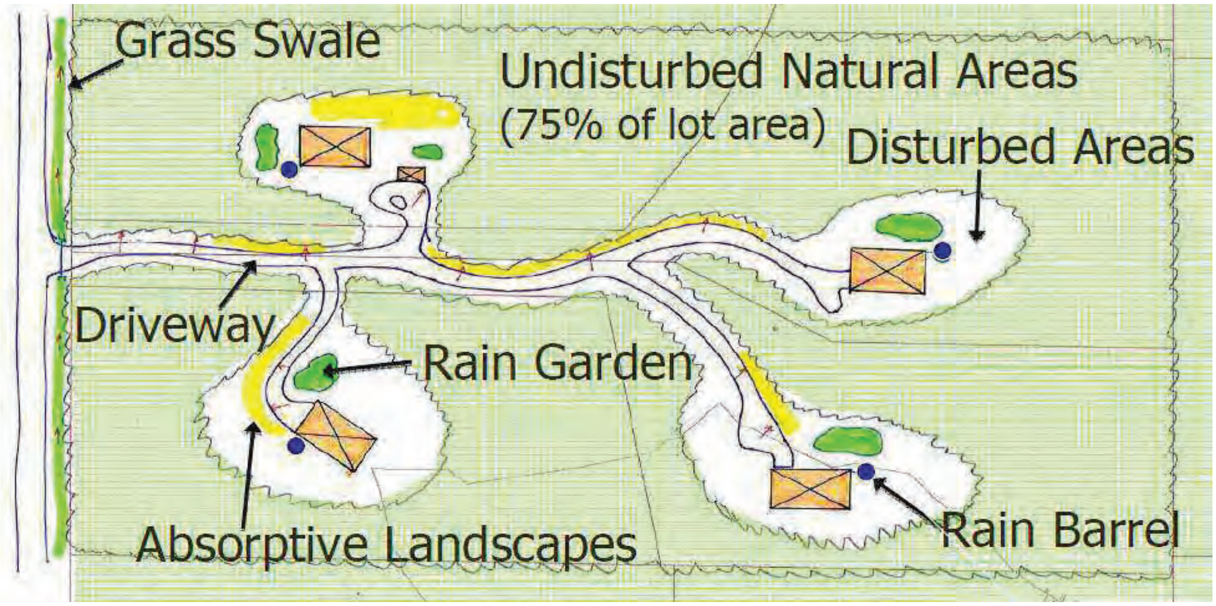


Table 9

Runoff from Three Typical Scenarios (Infill Development)

Condition	Runoff	Increase above Predevelopment
Predeveloped	13,100 m^3/yr	-
Developed	14,400 m^3/yr	10 %
Developed with LIDs	13,300 m^3/yr	2%

Table 10

Required Size /Total Water Use of Typical LID Methods (Infill Development)

LID	Size	Total Estimated Water Use
Absorbent Landscape	300 m^2 per lot 1,200 m^2	660 m^3/yr
Rain Barrel	5 m^3 per lot 20 m^3	236 m^3/yr
Landscape Irrigation	700 m^2 per lot 2,800 m^2	1,300 m^3 per ha irrigation rate

6.5.2 Development LID and Wetland Modelling

A typical development was modeled to assess the potential increase in runoff due to development and assess the size of LIDs and wetland required to mitigate against any increase in volume. A 22 lot development with a 0.8 ha (two acre) lot size was considered in the model and is shown in ***Figure 8*** with the components of the area shown in ***Table 11***. A model was developed for the pre-developed area, the developed area, and the developed area with the application of LIDs and wetlands. The total modelled site area of 24.6 ha was assumed from a GDA area of 35 ha with an impervious area of approximately 10% consisting of roofed areas, paving, driveways and service roads. It was assumed that 65% of the allotment area had no disturbance or modification. The remaining undeveloped area was not modeled as it was assumed to be undisturbed and therefore meets the predevelopment conditions.

Figure 8: Development with Application of LIDs and Wetland

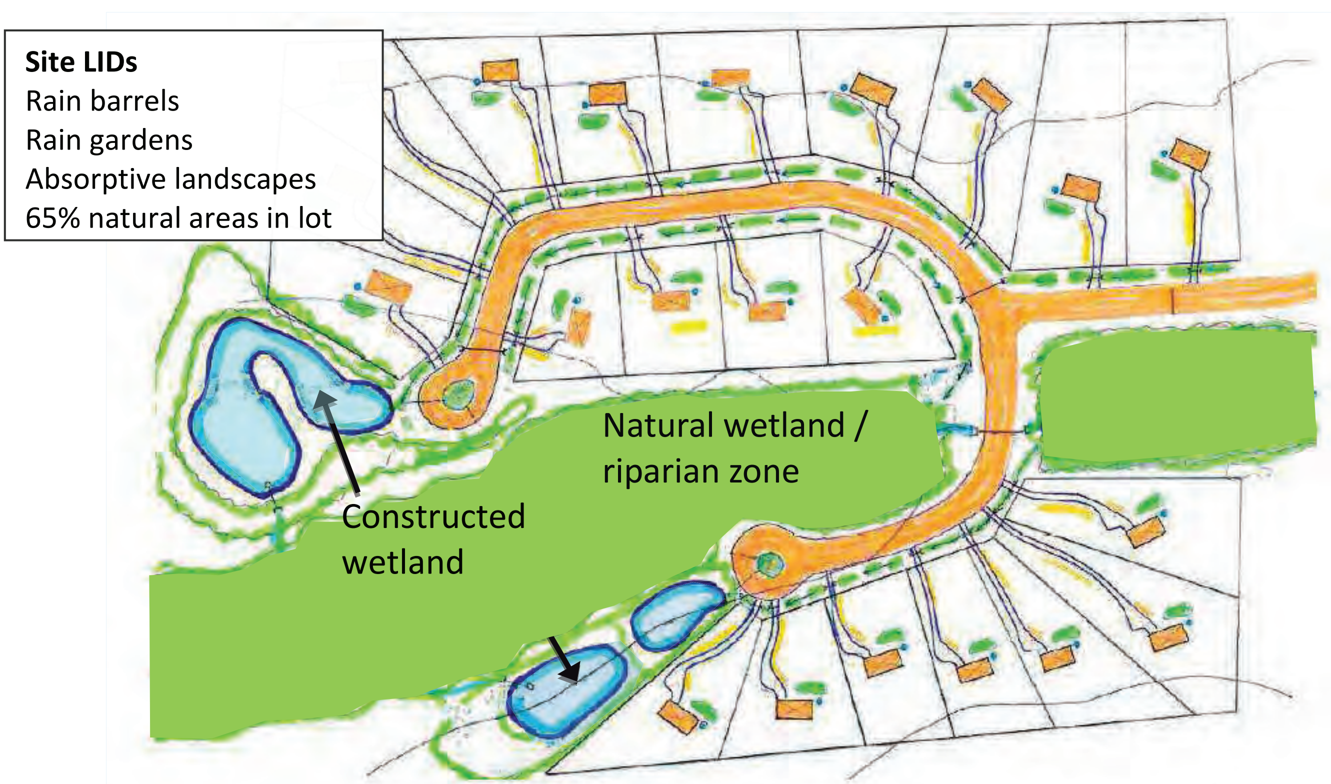


Table 11

New Development Assumed Catchments

	Total	Lots	Roof	Lot Paving	Road ROW	Natural	Offsite
Area (ha)	24.6	17.8	0.7	0.54	2.67	12.5	4.1
Impervious (%)	10.5	7.0	100	100	50	0	0

It was found that the development increased the runoff volume by 17% as shown in ***Table 12***. The LID practices and wetland sizing required to meet the no effective increase in runoff volume is shown in ***Tables 13***.

Table 12

Runoff from New Development Scenario

Condition	Runoff	Increase above Predevelopment
Predeveloped	50,200 m^3/yr	
Developed	58,600 m^3/yr	17%
Developed & LID	49,600 m^3/yr	-1.2%

Table 13

Combined LID and Wetland sizing for New Development

LID	Size	Estimated Total Development Water Use
Absorptive Landscape	200 m^2 per lot 4,400m^2	2,350 m^3/yr
Rain Barrel	4m^3 per lot 88m^3	980 m^3/yr
Landscape Irrigation	500m^2 per lot 10,500m^2	1,300 m^3 per ha irrigation rate
Wetlands	8,000m^2	4,400 m^3/yr

The same development was modeled without any LID practices other than swales to convey flow to the stormwater wetlands as shown in ***Figure 9***. The area of the wetland had to increase to achieve no net increase in the volume of runoff from the development. The wetland size required, provided in ***Table 14***, needed to be 75% larger than the wetland required when combined with LIDs. The incorporation of more extensive on site LID practices than identified in ***Table 13*** would further reduce the size of wetlands required to meet the runoff volume targets.

Table 14

Wetland sizing with and without LIDs

Case	Wetland Size	Estimated Wetland Water use
Wetland & LIDs	8,000m^2	4,400 m^3 /yr
Wetlands Only	14,000m^2	7,600 m^3 /yr

Figure 9: Development with Wetland Only

6.6 Review of LID Practices

LID practices provide a range of benefits from the retention of incident rainfall and runoff from adjacent impervious surfaces to the treatment of runoff to improve water quality. The effectiveness of the various practices will depend on the level of maintenance and compliance that is achieved. Therefore, in order to identify suitable LID practices for Bragg Creek, a number of factors need to be considered including function i.e. volume reduction/water quality treatment capabilities, operation and maintenance requirements and located on public or private land. The performance of potential LID practices has been summarized in the ***Table 15*** and further description of individual LIDs and discussion on their suitability for the Bragg Creek region is given in ***Table 16****.*

Table 15

LID Performance Matrix

LID Practice	Pollutant Removal	Volume Reduction	Peak Flow Reduction	Maintenance Requirements	Cost	Operational Requirements	Located on Private Land	Located on Public Land
Better Planning Practices	M	M	M	N/A	L	N/A	N/A	N/A
Maintain Natural Areas	H	H	H	L	L	✗	✓	✗
Absorbent Landscape	H	H	M	L	L	✗	✓	✗
Rain Garden	H	M	M	H	M	✗	✓	✓
Permeable Pavement	M	L	M	M	H	✗	✓	✓
Rain Barrel & Irrigation	L	M-H	M	M	L-M	✓	✓	✗
Bio Swales	M	M	M	M	M	✗	✗	✓
Swales	M	L	L	M	L	✗	✗	✓
Constructed Wetlands	H	M	H	H	H	✗	✗	✓

Notation: L – Low, M – Medium, H – High, N/A – Not Applicable, ✓ - yes, ✗ - no

Table 16

LID Description and Discussion

LID	Description, Key Benefits/Disadvantages
Better Planning Practices	The positioning of the development within the GDA, the road and lot layout and the arrangement of buildings on a lot can significantly influence the hydraulic and water quality performance of a development. In addition to managing the increase in runoff volume, care needs to be taken not to significantly change the hydraulic loading of adjacent wetlands, including reducing or increasing the runoff volume they receive. Particular attention should also be given to minimizing the interception or redirection of groundwater away from wetlands that are fed primarily from upslope groundwater movements. Best practice should be used to avoid these issues at the planning and the design phase of a development.
Maintain Natural Areas	Natural undisturbed areas have higher infiltration capacity than disturbed areas. Natural areas provide a higher capacity to hold direct rainfall and runoff from more impervious areas. They will be most effective where runoff from impervious areas is evenly distributed over these natural areas. This practice is one of the key practices that should be implemented for development in Bragg Creek.
Absorbent Landscape	Absorbent landscapes is thickened topsoil or soil media which have the capacity to absorb and hold direct rainfall and distributed runoff from adjacent impervious areas such as paving and roofs. They also promote infiltration similar to the original natural areas. Absorbent landscape areas would complement the desire of most property owners to beautify the property. Absorbent landscapes would be normally located on the low side of a dwelling, which is typically the direction of the vista or focus of a property. The material for these types of landscape would ideally come from the topsoil stripping process for the building, where suitable, or from imported materials. Site grading and spreading of surface runoff from impervious areas are important components but the construction and maintenance of these practices is relatively straightforward. Therefore, absorbent landscaping is considered the most practical and reliable LID practice.
Rain Garden	Rain gardens can provide a similar function to absorbent landscapes. If no under-drain is needed below the filtration media, it will act like a soakaway area. If an under-drain is needed, it will provide more of a runoff filtration process with a lower absorption capacity. Rain gardens are typically designed to accept concentrated runoff and therefore are more suited to accepting runoff from roofs and large paved areas. As rain gardens have a higher hydraulic loading, they need higher levels of design input and have higher construction and maintenance requirements as they are more likely to fail, whether it is due to the plant selection not matching wetting regime or become waterlogged, etc. It is important that rain gardens be properly designed and receive regular maintenance to prevent problems. Rain gardens would be highly suited to the Hamlet and other areas with high underlying infiltration rates.

Table 16

LID Description and Discussion (continued)

LID	Description, Key Benefits/Disadvantages
Permeable Pavement	Permeable pavements can reduce runoff from hard surfaces by allowing rainfall to infiltrate the surface and be stored in the open underlying pavement to then percolate further into the ground or evaporate back through the surface. Surface examples include gravel areas, concrete pavers and asphalt surfaces. Permeable paving for high trafficked areas have high design, installation and maintenance specifications and are costly to install and maintain and would not typically be recommended for roads and private lots in the Bragg Creek area. Gravel surfaces instead of pavement on private property are recommended to reduce the impervious surfaces. Permeable pavement should be encouraged for low use pedestrian or vehicle areas, but may not be reliable over the long term due to clogging and issues in climates subject to frequent freeze/thaw cycles.
Rain Barrel & Irrigation	Rain barrels or tanks store water from impervious surfaces such as roofs and can be used for domestic non-potable uses. Stored water should be utilized regularly to be an effective LID practice e.g. irrigation and toilet flushing. Therefore, LID practices require the water balance to be actively managed either through an automatic system or users/owners that are dedicated to reusing rainwater. These systems require regular maintenance for efficient and continued operation. Considering these issues, it is likely that such installations are prone to neglect and may not be relied upon for long term management of runoff.
Vegetated Swales	A vegetated swale's main function is to convey runoff in a manner that allows infiltration and some water quality treatment while providing flood protection capacity during a significant rainfall event. The slope and vegetation cover are important components to encourage siltation and minimize erosion. Development in the Bragg Creek region currently relies on these types of systems to convey runoff from developed areas. The swales should be designed to reduce interception of the natural groundwater movement and limit the redirection of runoff that could significantly change the natural flow patterns of the existing wetlands.
Bio Swales	Bio Swales have a similar function to vegetated swales but provide additional treatment capacity through the use of a filtration media with and without an underdrain. The effective use may be somewhat limited in low lying areas or where groundwater interception would occur.
Wetlands with Detention	Wetlands provide the key functions of retention, detention and pollution removal in addition to providing increased habitat, amenity and a buffer zone to adjacent wetlands and streams. Wetlands are ideally located at the downstream end of a development and provide the last opportunity to minimize development impacts; particularly from roads as there is limited ability for the swales to manage runoff compared to LIDs located on allotments.

6.7 Maintenance of Stormwater Management Facilities

LID practices have shown to be effective in achieving the volume control objectives set for the Greater Bragg Creek region either on its own or in combination with wetlands. Many of the preferred LID practices are mainly located on private lots, which raises questions on their long term operation and performance. Therefore consideration should be given to how acceptable specific LIDs are and the likelihood that they will remain operational. Consideration is also given to what potential mechanisms or encouragement can be provided to ensure they remain operational over the longer term.

6.7.1 Communal Stormwater Management Facilities

Where communal facilities such as wetlands and wet ponds are proposed, it is recommended that maintenance and management of these facilities be vested in RVC, through the subdivision approval process to ensure they function as intended. Ownership and operation of stormwater management facilities should be in accordance with County policy.

6.7.2 Onsite LID Practices

A summary of the most suitable site LID practices have been assessed considering how effective they are likely to be over the long term, based on a number of factors as shown in ***Table 17***. The LIDs have been ranked, based on this assessment.

Table 17

Private LID Assessment

Site LID	Design / Install Expertise	Maintenance Requirements	Required to be Operated	Nuisance Potential	Difficulty to Relocate	Aesthetic Value	LID Ranking
Maintain Natural Areas	N/A	L	×	L	N/A	H	1
Absorbent Landscape	L	L	×	L	L	H	2
Rain Garden	M	M	×	M	M	H	3
Porous Pavement	H	H	×	M	M	L	4
Rain Barrel & Irrigation	H	M	✓	H	H	L	5

6.8 Suitability Assessment of LID Practices and Facilities

The suitability of LID practices being applied to various types of development within the Study Area has been presented in ***Table 18.***

The most applicable LID practices for the Bragg Creek area have been found to include:

- Better Planning Practices
- Maintain Natural Areas
- Absorbent Landscapes

The following LID practices have not been highly rated due to the high installation costs and the medium to long term reliability and serviceability issues:

- Permeable Paving
- Rain Barrel and Irrigation

Table 18

Applicability of LID Practices

LID Practice	Development Type						Maintenance by Municipal /Private
	Hamlet Residential	Hamlet Commercial	Infill	Cluster	Small # of lots	Large # of lots	
Better Planning Practices	M	L	H	H	H	H	N/A
Maintain Natural Areas	L	L	H	M	H	H	P
Absorbent Landscape	M	L	H	H	H	H	P
Constructed Wetlands[a]	×	×	×	M	L	H	M
Wet Ponds[a]	M	M	×	M	L	M	M
Rain Garden	H	M	M	M	M	M	P / M
Vegetated Swales	M	L	×	M	H	H	M
Bio-swales	H	M	×	M	H	H	M
Permeable Pavement	M	M	L	L	L	L	P / M
Rain Barrel & Reuse	L	H	L	L	L	L	P

Notation: L – Low, M – Medium, H –High, × - not suitable, M – Municipal, P - Private

a) end of pipe stormwater treatment measure

7.0 IMPLEMENTATION STRATEGIES

7.1 Stormwater Management Policies and Principles for Existing and Future Development

The Greater Bragg Creek area is a unique region whose hamlet development has co-existed with significant areas of forest, wetlands, and agricultural land uses. If development and land use practices are not managed carefully, they can result in negative impacts to wetlands, watercourses, riparian zones, groundwater recharge areas and the associated natural habitat.

To preserve and maintain the environmental integrity of the Elbow River Basin, a set of stormwater management objectives and guiding principles have been developed to assist the sustainable development and management of the region. Practical strategies are discussed to further assist developers and landholders to manage their land for the benefit and preservation of the environment. These policies should be reviewed and amended as necessary, should development densities be higher than assumed in this report.

Objectives

The development of the Greater Bragg Creek area should be managed in ways to achieve the following key environmental protection and stormwater management objectives:

Objective 1 *Management of watercourses, floodplains, and wetlands to protect and maintain:*

a) water quality
b) flow regime
c) environmental values (biodiversity, species at risk) and ecological functions of watercourse habitat
d) the movement or migration of aquatic, semi-aquatic and terrestrial wildlife

Objective 2 *Watercourses, wetlands, and floodplains are protected against:*

a) pollution
b) erosion
c) habitat alteration and removal
d) diversion of, or obstruction to natural stream flow
e) activities that compromise water quality and ecosystem health

Objective 3 *Promote development which:*

a) ensures the management of stormwater that promotes the maintenance of natural flow regimes, natural storage areas, native vegetation and wildlife, and existing drainage characteristics
b) prevents soil erosion and water pollution
c) protects water quality and riparian zones by providing adequate setback distances from watercourses and wetlands
d) minimizes the disturbance of native vegetation, soils and the area of the development footprint
e) protects alluvial aquifers, particularly recharge zones and their dependent ecosystems
f) encourages stormwater reuse to reduce potable water consumption
g) meets the Greater Bragg Creek ASP guidelines
h) meets Rocky View County, City of Calgary and Alberta Environment Stormwater guidelines

Objective 4 *Integrate stormwater management hierarchically to achieve the objectives at the:*

a) catchment level
   i. water quality of the Elbow River
   ii. protection of wetlands and water courses
b) development and drainage system level
   i. minimizes impacts on existing hydrological pathways

   ii. development meets the maximum unit flow rate objectives in this report or a lesser unit flow rate given existing downstream constraints
   iii. development meets the overall volume control objectives
   iv. prevents erosion

c) lot level
   i. reduces runoff volume
   ii. mitigates peak flows
   iii. minimizes pollution generation

Objective 5 *Provide stormwater management facilities that:*

a) minimizes public and private operation and maintenance requirements
b) provides long term compliance for practices and facilities located on private land
c) vests the ownership and maintenance of communal facilities with RVC
d) maintains infrastructure in a serviceable and safe state

Principles

The following Principles should be incorporated into the planning, design, construction and management of new developments within the Greater Bragg Creek area specifically related to the protection of existing wetland and riparian ecosystems and the integration of stormwater management strategies.

1. *Watercourses, floodplains, wetlands and associated riparian zones should be protected and enhanced by:*

   a) maintaining hydrological pathways
   b) encouraging the maintenance of natural riparian zones and existing wetland system
   c) restricting uncontrolled livestock access
   d) adopting required setbacks
   e) developing and promoting public awareness on local watershed, surface, and sub-surface drainage issues

2. *Land developments to:*

a) be located outside the 1:100 year flood risk area
b) provide riparian buffers to wetlands and watercourses
c) minimize disruption of the natural hydrological pathways
d) retain 65% of the native vegetation on the site
e) encourage stormwater use for lawn irrigation and other aesthetic needs
f) promote lot layout plans that encourage the adoption of LIDs to filter site runoff through absorptive landscapes and natural undisturbed areas
g) provide water quality improvement/enhancement practices as recommended by AENV and ERBWMP

3. *Stormwater management systems should be designed and located to:*

a) improve or maintain the current quality of receiving waters
b) protect existing wetlands and watercourses
c) prevent erosion
d) protect receiving waters by adopting allowable release rates
e) minimize adverse impact of impervious surfaces by mitigating increases in runoff volume and peak flow

4. *Development should incorporate stormwater management techniques and strategies where appropriate that:*

a) encourages the onsite retention and use of stormwater (may require AENV approval)
b) directs runoff from impervious surfaces onto absorptive landscapes, infiltration and natural undisturbed areas
c) uses the lands' natural capacity to manage and hold stormwater runoff
d) conveys excess stormwater runoff from developed areas as much as possible using bio-swales, constructed road ditches, and culverts in rural and infill development areas
e) uses wetlands to retain, polish and detain stormwater to maintain hydrologic regimes and enhance water quality (requires AENV approval)
f) meets predevelopment peak flow and volume recommendations, including:

i. detaining the 1:100 year flood event to a maximum release rate of 6.0 L/s/ha for the entire Greater Bragg Creek Study Area
ii. detaining the 1:100 year flood event to a lower release rate where the downstream constraints have been identified as a bottleneck in drainage conveyance (refer to **Map 5** for currently identified locations). Where developments propose a higher release rate, applicants must provide field verification that higher release rates (up to the maximum release rate in i. above) will work with the upstream and downstream conditions/constraints
iii. retaining runoff by incorporating LID practices and wetland surface areas of adequate size, using evaporative losses only, to ensure that post development runoff volumes meet pre-developed runoff volume conditions

5. *Stormwater wetlands and associated detention facilities should be designed to:*

a) mimic, merge with and support adjacent natural wetland systems
b) provide water quality treatment
c) promote infiltration and minimize interception of underlying groundwater table
d) be used in combination with LID features to meet the required hydrological flow regimes/release rates
e) provide wetland pond areas that match the reduction of flow volumes required to meet predevelopment runoff volume conditions
f) provide detention storage to meet flow rate recommendations
g) prevent erosion and impacts to the downstream watercourses and wetlands
h) maximize wetland wildlife productivity and diversity
i) meet Rocky View County, City of Calgary, and AENV guidelines

6. *Development within the Hamlet of Bragg Creek shall manage stormwater by:*

   a) adopting LID practices
   b) incorporating natural surface drainage systems more suitable as opposed to “hard-engineered” stormwater control solutions
   c) providing water quality treatment devices on commercial sites to remove oil, grit and sediment
   d) providing wet ponds to control release rates and meet water quality objectives
   e) meeting water quality discharge requirements of Alberta Environment for direct discharges to the Elbow River

7. *For small infill developments, where these guidelines may be impractical or not desirable to fully implement, development applications must demonstrate that:*

   a) downstream impacts are negligible
   b) upstream drainage areas have been taken into account
   c) required setbacks from riparian and flood risk zones are adopted
   d) existing wetlands have been protected
   e) LID methods are promoted in infill development areas for stormwater quality and quantity controls

8. *Installation, Maintenance, Operation & Compliance of Stormwater Management Infrastructure:*

   a) LID practices specified on private lots shall be enforced through the building application process
   b) constructed wetlands and wet ponds shall be vested to RVC
   c) practical advice and guidelines on the installation and maintenance of the most promising LID practices should be provided to homeowners
   d) consider policies and bylaws which encourage or enforce compliance of private onsite facilities
   e) develop strategies to manage/rectify existing drainage issues that have been identified in the MDP

f) investigate opportunities to rectify existing capacity constraints as a component of future development proposals

g) provide periodic review of existing infrastructure to assess the condition and structural adequacy of major culvert and bridge structures under County roads

9. *The Municipality should develop an enforcement and maintenance program to:*

a) annually inspect, monitor and document drainage facility operation

b) carry out minor maintenance of conveyance systems such as removal of debris and sediment accumulation from culverts

c) allocate funding for major maintenance of stormwater facilities (i.e. silt removal)

d) monitor long term performance and compliance of private onsite facilities

e) develop minimum performance guidelines for property owners

10. *Planning Policy Considerations*

a) policy implications of this MDP should be considered within the context of the Greater Bragg Creek Area Structure Plan

b) policies be reviewed and amended as necessary, should development densities be higher than assumed in this report

8.0 REFERENCES

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Websites

http://www.braggcreek.ca/braggcreek/highwater.htm (accessed December 23, 2010)

MAPS

APPENDIX A

SUB-CATCHMENT CHARACTERISTICS

Appendix A: Sub-basins and Sub-catchment Areas

	Offsite Contributing Area			Onsite Contributing Area			
Sub-Basin	**Catchments Name**	**Ave Slope (%)**	**Area (ha)**	**Catchments Name**	**Ave Slope (%)**	**Area (ha)**	**Total Area (ha)**
Bragg Creek (BC)	BC-1A	5.1	4067.7				
	BC-2A1	9.1	137.7	BC-2B	1.4	75.0	
	BC-2A2	1.7	16.4	BC-3	3.7	262.3	
	BC-4A	2.7	133.4				
	BC-5A	7.4	125.0	BC-5B	6.2	36.8	
	BC-6A	3.4	104.0	BC-6B	3.4	72.6	
				BC-7	8.3	30.4	
				BC-8	15.8	126.3	
				BC-9	5.0	126.9	
				BC-10	1.2	28.8	
	BC-11A1	15.6	60.1	BC-11B1	2.1	100.2	
	BC-11A2	14.3	18.0	BC-11B2	1.8	198.9	
				BC-12	2.7	174.7	
				BC-13	3.6	61.1	
				BC-14	5.0	51.1	
Sub-Total			**4,662.3**			**1,345.1**	**6,007.4**
Iron Creek (IC)				IC-1B1	3.3	52.6	
				IC-1B2	2.5	46.8	
	IC-2A	4.5	32.5	IC-2B	14.5	60.4	
	IC-3A	11.0	127.5	IC-3B	13.3	19.2	
	IC-4A	8.1	300.3				
				IC-5B1	3.6	231.6	
				IC-5B2	9.0	260.7	
				IC-6	7.5	235.5	
Sub-Total			**460.3**			**906.8**	**1,367.1**
Elbow River North (ERN)	ERN-1A1	8.7	169.2				
	ERN-1A2	5.0	168.8	ERN-1B	1.2	314.6	
	ERN-2A	2.3	160.8	ERN-2B1	8.0	50.8	
				ERN-2B2	3.7	45.0	
				ERN-3B1	5.2	219.4	
				ERN-3B2	10.6	95.0	
				ERN-4	2.9	560.5	
Sub-Total			**498.8**			**1,285.3**	**1,784.1**
Elbow River South (ERS)				ERS-1	4.7	611.5	
				ERS-2	3.7	277.6	
				ERS-3	10.0	23.4	
				ERS-4	12.8	42.6	
				ERS-5	15.0	29.1	
				ERS-6	14.0	20.6	
				ERS-7	16.2	98.0	
Sub-Total						**1102.8**	**1102.8**
Fish Creek Tributary (FCT)	FCT-A	2.8	**1394.1**	FCT-B	8.7	**195.5**	**1589.6**
Bow River Tributary (BRT)	BRT-A	2.5	**96.0**	BRT-B	3.5	**64.3**	**160.3**
TOTAL			**7,111.5**			**4,900**	**12,011**

APPENDIX B

CULVERT AND BRIDGE HYDRAULIC ASSESSMENT SUMMARY

&

SITE PHOTOGRAPHS

Appendix B1: Summary of Hydraulic Assessment of Culverts

Section	Culvert ID	Road Name	Dia/Size & Material (mm)	Estimated U/S Inv (m)	Estimated D/S Inv (m)	Estimated Length (m)	Road Top/ Spill Depth (m)	CulvertMaster Computed- Q (cms) Inlet Control	CulvertMaster Computed- Q (cms) Outlet Control	Drainage Area (ha)	Unit Area Flow Rate, UAFR (L/s/ha)	Comments Size identified to upgrade to 100 year standard
8	8-1	Twp Rd 232	600 CSP	1386.30	1386.00	20.00	2.00		0.79			
8	8-2	Twp Rd 232	600 CSP	1380.50	1379.50	20.00	1.60	0.79				
8	8-3	Twp Rd 232	To be determined									could not be located
8	8-4	Twp Rd 232	To be determined									could not be located
8	8-5	Twp Rd 232	750 CSP	1371.50	1371.00	30.00	2.40		1.36			
8	8-6	Forestry Way	1200 CSP	1391.00	1390.70	25.00	5.50		6.31	52.6	**120.0**	
8	8-7	Forestry Way	1250 CSP	1402.80	1402.50	25.00	2.80		4.8	86.8	**55.3**	
8	8-8	Range Road 54	750 CSP	1374.50	1374.30	25.00	2.30		1.3			
17	17-1	Hawk Eye Road	450 CSP	1369.25	1369.00	30.00	2.00		0.35			
17	17-2	Range Road 54	250 CSP	1368.50	1368.25	20.00	0.50		0.08			
9	9-1	Twp Rd 232	To be determined									
9	9-2	Breezewood Bay	450 CSP	1369.50	1369.20	30.00	1.20		0.26			
9	9-3	Range Road 54	750 CSP	1371.00	1369.70	30.00	1.50	1.11				inlet partially blocked by vegetation
9	9-4	Forest Park Place	500 CSP	1368.50	1368.00	20.00	0.90	0.41				
9	9-5	Twp Rd 232	600 CSP	1364.00	1363.50	25.00	1.20		0.6			
9	9-6	Meadow View Road	450 CSP	1364.00	1363.50	35.00	0.80		0.23			
9	9-7	Meadow View Road	450 CSP	1374.00	1373.50	25.00	0.80		0.26			
4	4-1	Range Road 54	2x600 CSP	1380.25	1380.00	20.00	1.50		1.33	146.7	**9.1**	damage to one u/s CSP inlet
4	4-2	Range Road 54	900 CSP	1405.25	1405.00	20.00	2.00		1.88	300.3	**9.2**	
4	4-3	Range Road 54	600 CSP	1405.25	1405.00	20.00	2.50		0.89			
4	4-4	Elk Valley Drive	800 CSP	1382.25	1382.00	30.00	1.30		1.06			
4	4-5	Elk Valley Crescent	600 CSP	1383.25	1383.00	30.00	1.20		0.51			slight damage to u/s inlet
4	4-6	Elk Valley Drive	2x600 CSP	1382.25	1382.00	30.00	1.50		1.17	387	**3.0**	duplicate with 2 - 600 dia CSP
4	4-7	Highlands Boulevard	600 CSP	1409.50	1409.00	30.00	1.00		0.52			
4	4-8	Highlands TC	450 CSP	1423.50	1423.00	35.00	2.30		0.37			
4	4-9	Highlands Boulevard	600 CSP	1410.50	1408.50	35.00	1.50		0.6			
4	4-10	Elk Valley Drive	600 CSP	1381.50	1381.00	35.00	1.30		0.56			
4	4-11	Elk Valley Bay	600 CSP	1382.00	1381.50	30.00	1.00		0.43			
4	4-12	8972 Rocky View	600 CSP	1383.00	1382.80	35.00	1.00		0.41			
4	4-13	Elk Valley Gate	600 CSP	1383.40	1383.00	35.00	1.00		0.47			
4	4-14	Elk Valley Drive	600 CSP	1376.50	1376.00	35.00	1.30		0.56			
4	4-15	Elk Valley Grove	600 CSP	1376.50	1376.00	35.00	1.40		0.58			
4	4-16	Elk Valley Crescent	600 CSP	1374.50	1374.00	25.00	1.50		0.67			
16	16-1	Saddle Road	1200 CSP	1353.00	1352.50	25.00	1.20	1.55				
16	16-2	Saddle Road	375 CSP	1352.50	1352.00	25.00	0.50		0.14			damage to u/s CSP inlet
16	16-3	Saddle Road	375 CSP	1352.00	1351.50	25.00	0.40		0.10			
22	22-1	Range Road 52	1250 CSP	1344.00	1343.90	35.00	2.80		3.52	160.3	**22.0**	
22	22-2	Range Road 52	600 CSP	1343.10	1343.00	35.00	1.00		0.38			
15	15-1	Fawn Hills Drive	600 CSP	1350.25	1350.00	30.00	1.10		0.48			
15	15-2	Range Road 52	450 CSP	1350.25	1350.00	20.00	1.10		0.29			
15	15-3	Range Road 52	450 CSP	1336.00	1335.90	20.00	2.00		0.38	126.9	**3.0**	duplicate with 450 dia CSP
15	15-4	Range Road 52/Mountain View Park	450 CSP	1337.30	1337.00	25.00	0.50		0.17			CSP inlet filled with gravel, 50% blocked
15	15-5	Fawn Hills Drive	600 CSP	1538.50	1538.00	30.00	1.30		0.60			
15	15-7	Saddle Road (Box Culvert)	2400x1300 Conc	1345.25	1345.00	30.00	1.80	8.31				
15	15-8	Saddle Ridge	1200 CSP	1356.90	1356.00	25.00	1.60	2.40				
15	15-9	Saddle Road	375 CSP	1351.50	1351.00	25.00	0.50		0.14			
10	10-1	Wild Rose Close	1200 CSP with Outlet Control	1333.15	1332.50	35.00	5.50	2.5				limited capacity, has overtopped road in 2010
10	10-1	Wild Rose Close	1200 CSP Weir Flow (Sharp-Crested) [2]					4.2 [4]		1287	**2.5**	1200 dia CSP duplicate
10	10-2	Wild Rose Close	unknown / submerged									
10	10-3	Twp Rd 232	To be determined									could not be located?

Appendix B1: Summary of Hydraulic Assessment of Culverts

Section	Culvert ID	Road Name	Dia/Size & Material (mm)	Estimated U/S Inv (m)	Estimated D/S Inv (m)	Estimated Length (m)	Road Top/ Spill Depth (m)	CulvertMaster Computed- Q (cms) Inlet Control	Outlet Control	Drainage Area (ha)	Unit Area Flow Rate, UAFR (L/s/ha)	Comments Size identified to upgrade to 100 year standard
25	25-1	Wintergreen Way	900 CSP	1308.00	1307.50	25.00	1.40	1.47				
25	25-2	Wintergreen Road	2x600 CSP	1293.00	1292.80	35.00	1.00		0.83			some rock blocking inlet
25	25-3	Wintergreen Road	900 CSP	1293.00	1292.80	35.00	1.50		1.28	219.4	**13.6**	d/s vegetation blocking outlet
25	25-4	Wintergreen Road	2x600 CSP	1294.50	1294.30	35.00	3.30		1.70			
25	25-5	Wintergreen Road	1400 CSP Orifice Flow [1]					2.9 [3]				
25	25-5	Wintergreen Road	1400 CSP Weir Flow (Sharp-Crested) [2]					3.31 [4]				
25	25-6	Wintergreen Road	450 CSP	1293.50	1293.30	35.00	1.50		0.22			some vegetation blocking inlet
25	25-7	Squirrel Crescent	600 CSP	1305.00	1304.50	40.00	2.30		0.71			
25	25-8	Mountain Lion Place	450 CSP	1311.50	1311.00	35.00	1.50		0.30			vegetation blocking inlet
25	25-9	Mountain Lion Drive	900 CSP	1313.00	1312.50	40.00	1.70		1.52			culvert out of shape
25	25-10	Moose Drive	600 CSP	1304.00	1303.80	35.00	1.20		0.47			
25	25-11	Coyote Close	450 CSP	1305.00	1304.80	30.00	1.00		0.23			
25	25-12	Wintergreen Road	600 CSP	1292.50	1292.30	35.00	2.10		0.65			vegetation 20% blocked
24	24-1A	Wintergreen Road	600 CSP	1290.18	1289.80	26.50	4.81		0.74			
24	24-1B	Wintergreen Road	450 CSP	1290.85	1290.40	26.50	4.14		0.32	**560.5**	**7.2**	
24	24-1C	Wintergreen Road	1350 CSP	1290.50	1290.00	30.00	3.70	3.00				d/s outlet incomplete
24	24-2	Wintergreen Road	450 CSP	1291.00	1290.50	30.00	2.30		0.40			u/s & d/s blocked by vegetation
13	13-1	April Road	1200 CSP	1348.40	1348.00	30.00	4.00		5.06	23.4	**216.2**	
13	13-2	Cummer Place	450 CSP	1336.40	1336.00	30.00	1.00		0.26			
13	13-3	Cummer Place	1200 CSP	1342.40	1342.00	30.00	2.60		3.85	20.6	**186.9**	
13	13-4	Two Pine Drive	600 CSP	1327.40	1327.00	30.00	2.10		0.74			
13	13-5	Williams Place	600 CSP	1326.40	1326.00	30.00	1.40		0.60			
13	13-6	Two Pine Drive	600 CSP	1309.40	1309.00	30.00	1.00		0.50			
13	13-7	Twp Rd 232	600 CSP	1308.40	1308.00	30.00	1.60		0.64	115.7	**5.5**	
13	13-8	Elbow Ridge	450 CSP	1292.40	1292.30	20.00	1.00		0.25			blocked by vegetation 20%
13	13-9	Wintergreen Road	600 CSP	1300.50	1300.00	30.00	1.40		0.61			damage to culvert inlet, 80% pugged with silt
12	12-1	Bracken Road	900 CSP	1304.40	1304.00	20.00	1.40		1.47			
12	12-3	Echlin Drive	450 CSP	1319.40	1319.30	20.00	0.70		0.20			culvert pugged 80%
12	12-4	Echlin Drive	375 CSP	1319.40	1319.00	20.00	0.70		0.17			
12	12-5	East Park Place	600 CSP	1318.40	1318.20	20.00	0.80		0.42			heavy u/s veg + 60% plugged
12	12-6	Harwood Street	450 CSP	1301.40	1301.20	20.00	1.00		0.26			
12	12-7	Burntall Drive	450 CSP	1300.40	1300.20	20.00	0.70		0.21			
1	1-1	Boyce Ranch Road	2x825 CSP	1318.40	1318.10	30.00	1.10		1.92	1400	**1.4**	minor damage to one CSP inlet
1	1-2	Highway 66	2400 CSP	1330.50	1330.00	40.00	2.80		12.13	1394.1	**18.7**	requires significant upgrades when future
1	1-3	Highway 66	2x1800 CSP	1330.50	1330.00	40.00	2.30		14.00			is being proposed
1	1-4	Boyce Ranch Road	600 CSP	1317.40	1317.00	30.00	0.80		0.44			
1	1-5	Highway 22	3000 CSP	1310.50	1310.00	40.00	3.50	21.14				
1	1-6	Highway 22	1050 CSP	1320.50	1320.00	40.00	4.00		3.54			
1	1-7	Highway 66	600 CSP	1320.50	1320.00	40.00	4.00		0.95			80% plugged by cattle accessing drain
2	2-1	Secondary Highway 758	600 CSP	1336.50	1335.50	30.00	0.80	0.43				
2	2-2	Range Road 51	600 CSP	1348.50	1347.50	25.00	0.80	0.43				
2	2-3	Highway 66	600 CSP	1346.50	1346.00	40.00	4.00		0.93			80% plugged
2	2-4	Highway 66	1200 CSP	1344.50	1344.00	40.00	1.50		2.46			
2	2-5	Secondary Highway 758	450 CSP	1375.40	1375.00	30.00	1.20		0.28			
2	2-6	Lot	450 CSP	1375.40	1375.00	20.00	0.60		0.22			inlet blocked with rock, damage to CSP
2	2-7	Cul-de-sac	450 CSP	1374.50	1374.00	25.00	0.60		0.22			
2	2-8	Secondary Highway 758	600 CSP	1330.50	1330.20	30.00	3.00		0.88			inlet blocked 80% by thick woody vegetation

Notes:

[1] Orifice Flow Contraction Coefficient (Cd) was taken as 0.6 (Fluid Mechanics for Engineers by Bruce, p. 133)

[2] Weir Flow Discharge Coefficient (Cd) was taken as 1.837 for Sharp Crested Weir (Smith, C.D. Hydraulic Structures, 1995, p.11-3)

[3] With 1 m of head and assuming 30 % blockage by grates

[4] With 0.8 m and 0.7m of head for 10-1 and 25-5 control strcuturtes repectively and assuming 30 % blockage by grates


Wild Rose Cl near 10-1 L West 5.jpg


Wild Rose Cl near 10-1 L West.jpg


Wild Rose Cl near 10-2 L NWest-2.jpg


Wild Rose Cl near 10-2 L NWest-3.jpg


Wild Rose Cl near 10-2 L NWest.jpg


Williams Pl Swale L east.jpg


Williams Pl swale SW bend.jpg


Winter Green Rd Nth TWP 234 DW.jpg

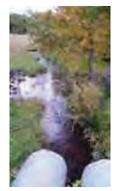

Winter Green Wy L Nth 2.jpg


Winter Green Wy L Nth 3.jpg


Winter Green Wy L Nth.jpg


1-1 ds creek.jpg


1-1 ds.jpg


1-1 us creek.jpg


1-1 us culvert.jpg


1-2 ds creek.jpg


1-2 ds.jpg

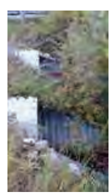

1-2 us creek.jpg

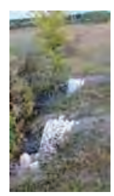

1-2 us.jpg


1-3 ds 2.jpg


1-3 ds 3.jpg

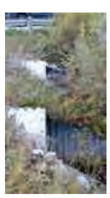

1-3 ds.jpg


1-3 us 2.jpg


1-3 us 3.jpg


1-3 us L Sth culvert 2.jpg


1-3 us L Sth culvert.jpg


1-3 us.jpg


1-4 ds.jpg


1-4 L East.jpg


1-4 L West.jpg


1-4 us.jpg


4-1 culvert L East.jpg


4-1 culvert L Nth.jpg


4-1 culvert L Sth-2.jpg


4-1 culvert L Sth.jpg


4-1 ds culvert-2.jpg


4-1 ds culvert L Nth.jpg


4-1 ds culvert L nth.jpg


4-1 ds culvert.jpg


4-1 ds inlet L East 2.jpg


4-1 ds inlet L East.jpg


4-1 us culvert.jpg


4-1 us inlet-2.jpg


4-1 us inlet L nth 2.jpg


4-1 us inlet L nth.jpg

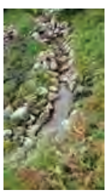

4-1 us inlet L sth 2.jpg


4-1 us inlet L sth.jpg


4-1 us inlet.jpg


4-4 ds L NE.jpg


4-4 ds swale 2.jpg


4-4 ds swale.jpg

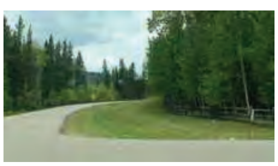

4-4 L NE.jpg

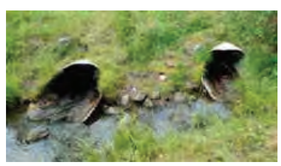

4-4 us culvert 2.jpg

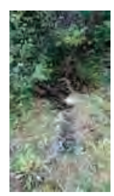

4-4 us culvert.jpg


4-4 us L SW.jpg


4-5 us inlet.jpg


4-5 us swale.jpg


4-6 us inlet.jpg


4-7 us culvert.jpg


4-9 ds culvert .jpg


4-9 L East.jpg

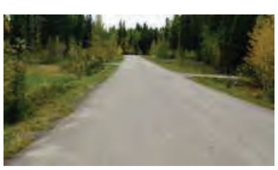

4-9 L West.jpg


4-9 us inlet.jpg


4-10 ds.jpg

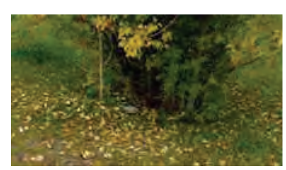

4-10 us.jpg


4-11 ds.jpg


4-11 L Sth.jpg


4-11 us .jpg


4-13 ds L East.jpg


4-13 ds.jpg

4-13 L Sth Elk Valley Gate.jpg

4-13 us.jpg

4-14 ds.jpg

4-14 us 2.jpg

4-14 us.jpg

4-15 ds.jpg

4-15 us 2.jpg

4-15 us.jpg

4-16 L East 2.jpg

4-16 L East.jpg

4-16 L West.jpg

4-16 us culvert.jpg

8-2 sth side Rd L East.jpg

8-2 Sth side Rd L West.jpg

8-5 us culvert L West.jpg

8-5 us L Nth.jpg

8-7 us culvert.jpg

9-3 inlet .jpg

9-3 us culvert.jpg

9-3 us side East.jpg

9-4 ds culvert.jpg

9-4 ds swale.jpg

9-4 us swale.jpg

9-5 us inlet.jpg

9-6 ds culvert-2.jpg

9-6 ds culvert.jpg

9-6 us L East.jpg

9-7 ds culvert.jpg

9-7 L Sth.jpg

9-7 L SWest.jpg

9-7 us culvert.jpg

10-1 inlet.jpg

10-1 outlet .jpg

11-1 us bridge 3.jpg

12-1 ds 2.jpg


12-1 ds.jpg


12-1 us 2.jpg


12-1 us 3.jpg

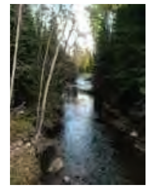

12-1 us.jpg


12-2 Bridge 3.jpg


12-2 Bridge 4.jpg


12-2 Bridge 5.jpg


12-2 Bridge 6.jpg


12-2 Bridge L ds.jpg


12-2 Bridge L nth 2.jpg


12-2 Bridge L us.jpg


12-2 L Nth.jpg


12-3 ds.jpg


12-3 us.jpg


12-5 ds.jpg


12-5 L East.jpg


12-5 L nth.jpg


12-5 L Sth.jpg


12-5 L West.jpg

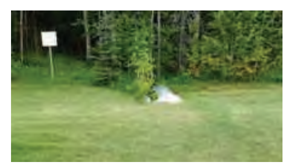

12-5 us.jpg


12- 3 ds 2.jpg


13-2 us L Sth.jpg


13-2 us swale adj Cummer Pl L East.jpg


13-2 us swale adj Two Pine Dr.jpg


13-3 ds culvert.jpg


13-3 L east.jpg


13-3 L west.jpg


13-4 us culvert 2.jpg


13-4 us culvert L us.jpg


13-4 us culvert.jpg


13-5 ds outlet.jpg


13-5 ds swale L sth 2.jpg


13-5 ds swale L sth.jpg


13-5 us inlet.jpg


13-5 us swale L nth.jpg


13-6 us.jpg


13-7 Bragg Ck adj outlet.jpg


13-7 Bragg Ck L West 2.jpg


13-7 Bragg Ck L West.jpg


13-7 ds .jpg


13-7 ds.jpg


13-7 us 2.jpg


13-7 us inlet 2.jpg


13-7 us inlet.jpg


13-7 us.jpg


13-8 ds 2.jpg


13-8 ds 3.jpg

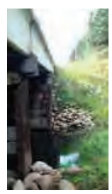

13-8 ds.jpg

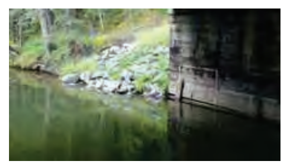

13-8 us 2.jpg

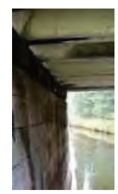

13-8 us swale.jpg

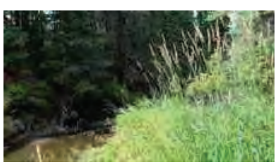

14-1 ds bridge 2.jpg

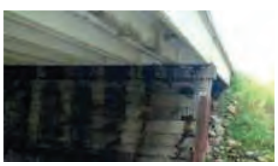

14-1 ds bridge 3.jpg

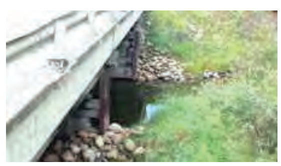

14-1 ds bridge 4.jpg


14-1 ds bridge 5 L us.jpg


14-1 ds bridge 6 L us.jpg


14-1 ds bridge looking ds.jpg


14-1 ds bridge West abutment.jpg


14-1 ds bridge.jpg


15-1 ds adjacent outlet .jpg


15-1 ds outlet.jpg


15-1 us .jpg


15-3 ds outlet 2.jpg


15-3 ds outlet 3.jpg


15-3 ds outlet.jpg


15-3 us inlet 2.jpg


15-3 us inlet.jpg


15-3 us wetland 2.jpg


15-3 us wetland 3.jpg


15-3 us wetland.jpg


15-4 ds inlet.jpg


15-5 us inlet.jpg


15-5 us L West.jpg


15-6 Bridge ds 2.jpg


15-6 Bridge ds 3.jpg


15-6 Bridge ds.jpg


15-7 Bridge ds.jpg


15-7 Bridge L us.jpg


15-7 Bridge us L ds.jpg


15-7 Bridge us.jpg


15-8 ds 2.jpg


15-8 ds.jpg


16-2 us.jpg


16-3 ds outlet.jpg

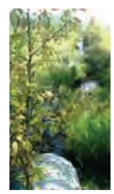

16-3 us outlet.jpg


17-3 ds bridge.jpg

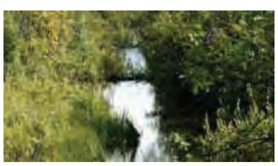

17-3 us bridge 1.jpg


17-3 us bridge 2.jpg


17-3 us bridge west .jpg


22-1 ds 2.jpg


22-1 ds 3.jpg


22-1 ds 4.jpg


22-1 ds 5.jpg

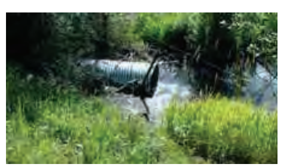

22-1 ds.jpg


22-1 RRd 52 L South.jpg


22-1 RRd 52 L West 2.jpg


22-1 RRd 52 L West 3.jpg


22-1 RRd 52 L West.jpg


22-1 us.jpg


24-1 ds 1.35m steel culvert 2.jpg


24-1 ds 1.35m steel culvert.jpg

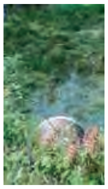

24-1 ds .jpg


24-1 ds L NE 2.jpg

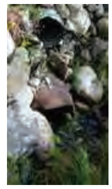

24-1 ds L NE.jpg


24-1 L Nth.jpg


24-1 L Sth.jpg


24-1 us 1.35m steel culvert.jpg


24-1 us grate.jpg


24-1A us twin culvert.jpg


24-1A us twin culverts.jpg


24-2 outlet L East 2.jpg


24-2 outlet L East.jpg


25-1 adjacent path.jpg


25-1 ds channel.jpg


25-1 outlet 3.jpg


25-1 outlet L Nth.jpg


25-1 outlet.jpg


25-1 us channel.jpg


25-1 us inlet.jpg


25-1 us L Nth.jpg


25-2 inlet.jpg


25-2 outlet L Nth-2.jpg


25-2 outlet L Nth.jpg


25-2 outlet L.jpg


25-2 TWP Rd 234 L West.jpg


25-2 us inlet L NEast.jpg


25-2 us inlet L Nth.jpg


25-3 inlet 2.jpg


25-3 inlet L Sth.jpg


25-3 inlet.jpg

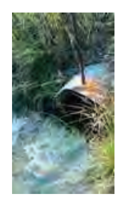

25-3 outlet .jpg


25-3 outlet L Sth.jpg


25-4 us swale L Nth.jpg


25-6 ds L East.jpg

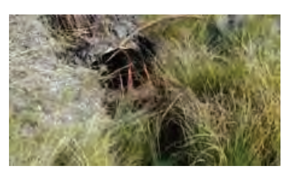

25-6 ds L nth.jpg


25-6 ds.jpg


25-6 Nth Mt Lion L West.jpg


25-6 us L Sth.jpg


25-6 us L West.jpg


25-6 us.jpg


25-7 ds-2.jpg


25-7 ds.jpg

25-7 outlet.jpg

25-7 us inlet.jpg

25-7 us L Nth.jpg

25-8 ds culvert.jpg

25-8 ds L East.jpg

25-8 ds L nth.jpg

25-8 us L Nth.jpg

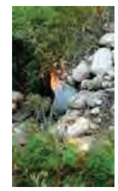
25-8 us swale.jpg

25-8 us.jpg

25-9 ds 3.jpg

25-9 ds 4.jpg

25-9 ds 5.jpg

25-9 ds 7.jpg

25-9 ds.jpg

25-9 L East.jpg

25-9 L West.jpg

25-9 us 2.jpg

25-10 inlet .jpg

25-10 outlet.jpg

25-10 us L East.jpg

25-10 us L West.jpg

25-11 ds cul.jpg

25-11 us inlet.jpg

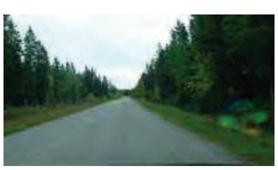
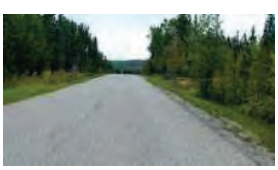
25-11 us swale L SE.jpg

25-11 us swale L SW.jpg

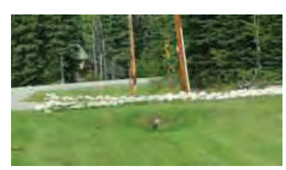
adj 15-4 L East.jpg

adj 15-4 L NEast.jpg

adj 22-1 L West.jpg

Adj 24-2 L West.jpg

Boyce Ranch Rd L E.jpg

Breezway Rd L Nth.jpg

Breezway Rd L Sth.jpg

bugs in WG Lake ds swale.jpg

Coyote Cl L nth.jpg


Coyote Cl L Sth dw cul.jpg


Echlin Dr adj Echlin Ct.jpg


Echlin Dr L E to 12-3.jpg


Echlin Dr L W.jpg


Elk Valley Bay 2.jpg


Elk Valley Bay 3.jpg


Elk Valley Bay 4.jpg


Elk Valley Bay .jpg


Elk Valley Cres 1a L Nth.jpg


Elk Valley Cres 2.jpg


Elk Valley Cres 3.jpg

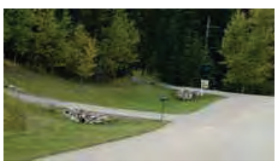

Elk Valley Cres 4.jpg


Elk Valley Cres 5.jpg


Elk Valley Cres 5A.jpg


Elk Valley Cres 6.jpg

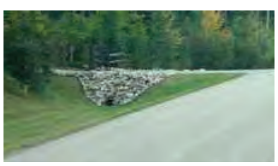

Elk Valley Cres Nth EV Ct.jpg

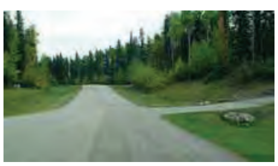

Elk Valley Ct 2.jpg


Elk Valley Ct 3.jpg


Elk Valley Ct 4.jpg

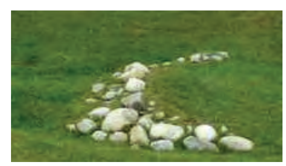

Elk Valley Ct 5.jpg


Elk Valley Ct 6.jpg


Elk Valley Ct.jpg


Elk Valley Gate 1.jpg


Elk Valley Gate 3 E.jpg


Elk Valley Gate 4 E.jpg

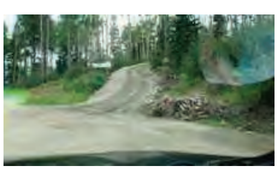

Elk Valley Gate 5 W.jpg


Elk Valley Gate 7 W.jpg

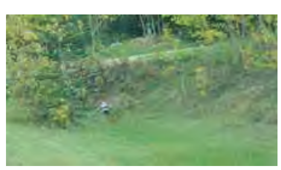

Elk Valley Gate 10 E.jpg


Elk Valley Gate 11 W.jpg

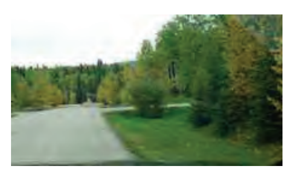

Elk Valley Pl 2 W.jpg


Elk Valley Pl 2.jpg


Elk Valley Pl 3 W.jpg


Elk Valley Pl 4 W.jpg


Elk Valley Pl 5 E.jpg


Elk Valley Pl 6 E.jpg


Elk Valley Pl W.jpg


Elk Valley Rd 2.jpg


Elk Valley Rd NW 4-5.jpg


Elk Valley Rd SE 4-4.jpg


Elk Valley Rd.jpg


Fawn Hills Dr L Nth-2.jpg


Fawn Hills Dr L Nth West.jpg


Fawn Hills Dr L Nth.jpg


Fawn Hills Dr West end L SE -2.jpg


Fawn Hills Dr West end L SE.jpg


Fawn Hills Dr West end L Sth 2.jpg


Fawn Hills Dr West end L Sth.jpg


Forest Park Pl L Sth.jpg


Forest Wy L West Twp Rd 232.jpg


Forestry Wy Adj Twp Rd 232 L SE.jpg

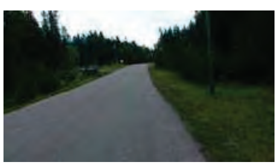

Forestry Wy L Nth.jpg


Forestry Wy Looking nth.jpg

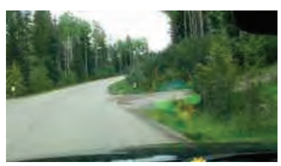

Forestry Wy south end L East.jpg

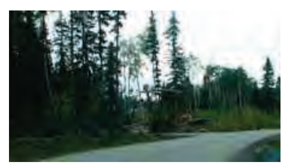

Golf course TWP 234 2.jpg

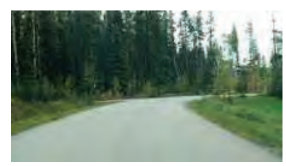

Golf course TWP 234.jpg

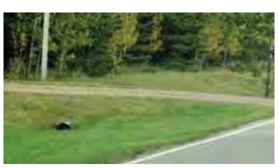

Hawk Eye Rd L East.jpg

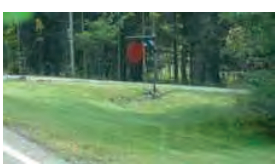

Hawk Eye Rd L west.jpg


Highlands Bv L NW.jpg


Highlands Tce L Nth.jpg


Highlands Tce L NW.jpg

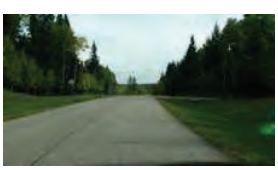

Moose Dr 5.jpg


Moose Dr 6.jpg


Moose Dr from Squirrel.jpg


Moose Dr L SE 2.jpg

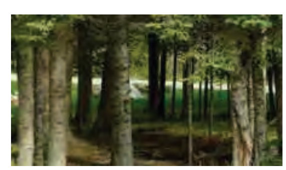

Moose Dr L SE 3.jpg


Moose Dr L SE 4.jpg


Moose Dr L SE 5-2.jpg


Moose Dr L SE 5.jpg


Moose Dr L SE.jpg


Mt Lion Dr L Nth swale.jpg


Mt Lion Dr L NWest 2.jpg

Mt Lion Dr L NWest 3.jpg

Mt Lion Dr L NWest 4.jpg

Mt Lion Dr L NWest.jpg

Mt Lion Dr L West.jpg

Mt Lion Pl 2.jpg

Mt Lion Pl 3.jpg

Mt Lion Pl 4.jpg

Mt Lion Pl 5.jpg

Mt Lion Pl 7.jpg

Mt Lion Pl -2.jpg

Mt Lion Pl -3.jpg

Mt Lion Pl .jpg

Mt View Pk & TWP 232 ds.jpg

Mt View Pk & TWP 232 L E.jpg

Near 13-8 L nth.jpg

near 13-8 L Sth.jpg

RRd 52 near 15-2 L East.jpg

RRd 52 near 15-2 L Sth E.jpg

Squirrel Cr dw cul East side.jpg

Squirrel Cr dw cul West side.jpg

Squirrel Cr L Nth.jpg

Squirrel Cres cul.jpg

TWP rd 232 at RRd 52 L NE 2.jpg

TWP rd 232 at RRd 52 L NE.jpg

TWP Rd 232 W Rge Rd 54 LW.jpg

WG GC Lake 2.jpg

WG GC Lake 3.jpg

WG GC Lake 4.jpg

WG GC Lake 5.jpg

WG GC Lake 6.jpg

WG GC Lake 7.jpg

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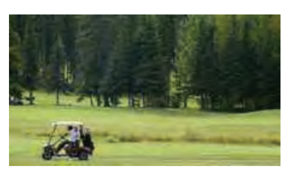
WG GC Mt Lion Dr.jpg

WG GC.jpg

WG Lake ds swale.jpg

WG Lake high culvert.jpg

WG Lake inet.jpg

WG Lake inlet 2.jpg

WG Lake pump house.jpg

WG Lake swale L Sth 2.jpg

WG Lake swale L Sth.jpg

WG Lake valve.jpg

WG way L Sth 2.jpg

WG way L Sth.jpg

WG Way swale L Nth 2.jpg

WG Way swale L Nth.jpg

APPENDIX C

BRAGG CREEK 100 YR FLOOD RISK MAP

FIGURE 7

SCHEDULE 2

BRAGG CREEK FLOOD RISK MAP

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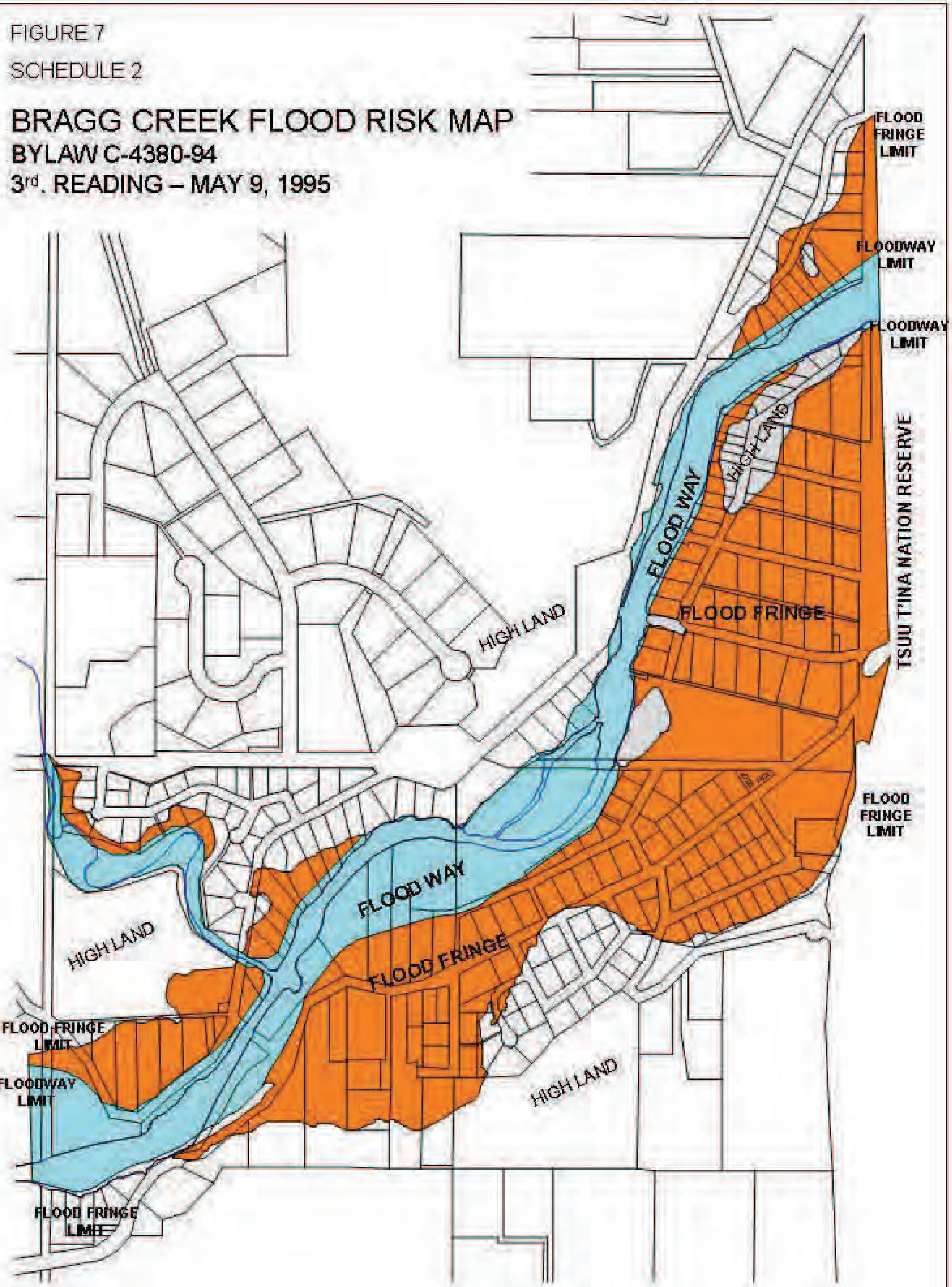
3rd. READING – MAY 9, 1995



APPENDIX D

BRAGG CREEK HYDROLOGIC MODELLING ANALYSIS

BRAGG CREEK HYDROLOGIC MODELLING ANALYSIS

1.0 INTRODUCTION

Hydrologic modelling analysis for this study involves three components.

- Determination of order of magnitude peak runoff rates for several pilot catchments within the Study Area using both event based and continuous simulations to establish suitable hydrology model input parameters,
- Determination of storage requirements for new low density and cluster developments within the Study Area at recommended release rates using both event based and continuous simulations, and
- Determination of effectiveness of Low Impact Development (LID) practices for the Bragg Creek region using continuous daily rainfall simulations.

2.0 HYDROLOGICAL MODELLING FOR PEAK FLOW

2.1 Rainfall Records and Precipitation Event

The Calgary International Airport (YYC) meteorological station data is typically used in the Calgary region, including Bragg Creek. The 1:100 year Intense Stormwater Event using the Chicago Storm hyetograph distribution represents approximately 90 mm with a maximum rainfall intensity of about 168 mm/hour within a 24 hour period. The closest Environment Canada meteorological station for the Study Area is Elbow Ranger Station (ERS), which is about 30 km southwest from Bragg Creek. Based on historic precipitation data at the YYC and ERS, it has been found that Bragg Creek receives approximately 25 to 40% more annual precipitation than Calgary (Valeo *et. al*, 2007; Lagore, 2004). There are no suitable records of an Intensity-Duration-Frequency (IDF) Curves at ERS to generate a local Intense Stormwater Event for Bragg Creek. Therefore a brief review of the hydrological modeling methods used for modeling the catchments at Bragg Creek and discussion on the appropriateness of using the YYC IDF curves for single event analysis and rainfall data for continuous rainfall simulation is provided in the following subsections.

2.1.1 Methods of Applying Rainfall in hydrological Models

The Chicago Storm hyetograph is a design storm distribution widely used by practicing drainage engineers in the USA and Canada for assessing runoff from smaller predominantly urban catchments. This distribution was originally proposed by Keifer and Chu in 1957. While developing this storm distribution pattern, they preserved the maximum volume of water falling within a specified duration, the average amount of rainfall before the peak intensity, and the relative time of the peak intensity. To preserve these characteristics, Keifer and Chu (1957) developed the Chicago Storm hyetograph from empirical Intensity Duration Frequency (IDF) relationships. By using the IDF relationships, they made procedures and concepts familiar to engineers and simple to obtain and therefore, the Chicago Storm has become widely accepted for use in Engineering Practice (Greenland Engineering, 1997).

The single event model requires the estimation of rainfall losses or abstraction to ensure the design rainfall produces an equivalent peak flow for a specific Average Recurrence Interval (ARI) event. For small catchments, an event model using the Chicago Storm Event generally produces higher peak flows for design events (e.g., one hour or less) in comparison to frequency analysis of peak flows derived from continuous rainfall simulations. This is due to the Chicago Storm hyetograph being an idealized attempt to accommodate shorter storm events within the overall design storm duration, compared to a more realistic rainfall temporal patterns that occur in continuous simulation methods.

Continuous rainfall simulation modelling applies rainfall time series over a significant period of at least 30 to 50 years. This allows the model to take account of the variability in the antecedent moisture conditions through the modelling process to combine with the incident rainfall to produce peak flows and runoff volumes. Therefore this type of simulation can provide a more realistic estimate of runoff volumes, which is particularly important when assessing or sizing detention basins and other assessment where the flood volume is an important consideration. The limitation with this type of modelling includes inadequate rainfall data, poor understanding of catchment soil parameters and the extra effort required to determine peak flows and volumes for each element of interest in the model using frequency analysis.

2.1.2 Historic Monthly Rainfall Comparisons

Historic monthly precipitation data available for the ERS from Environment Canada climate records were obtained and plotted. As shown in **Figure 1**, the highest monthly precipitation occurred in the years 1963, 1969, 1981, 1993, and 2005. Monthly precipitation data at the ERS shows that over the past 49 years of record, the June 2005 event gave the highest monthly precipitation at 506 mm. It is evident from **Figure 1** that the June 2005 rainfall total in the Bragg Creek region represents over two times that of the Calgary area (see **Figure 2**). Further comparison of June 2005 data for ERS and YYC (**Figures 1** & **2**) revealed that monthly maximums for the two stations do not match well, hence precipitation patterns and totals are relatively different in Calgary and Bragg Creek. This difference in monthly rainfall often does not translate into significantly different IDF values for short duration thunderstorm type events which typically govern for estimating the magnitude of significant flood events on small urbanized catchments. With continuous simulation methods, the statistical differences in rainfall over the 6, 12 and possibly 24 hour periods are more important than monthly comparisons. If the frequency and intensity of those events were typically higher, then the hydrological analysis using the YYC data would give lower volumes for detention storage sizing. However, the modeling parameters and approaches used for assessing low density development typically produces conservative detention basin storage sizing when limiting flow to the recommended unit area release rate due to the following factors:

1. Most models have a tendency to overestimate peak flows from a natural catchment
2. Developments are usually located on the upslope of a catchment resulting in higher flows than would be observed further downstream in the catchment after being routed by the riparian and wetland storage
3. The adopted unit area release rates have been based on flood frequency analysis which incorporates all the in stream storage routing of a catchment

The use of standard modelling methods with YYC rainfall data should give adequately conservative estimates of detention storage sizing to meet predevelopment conditions. Even if the differences in rainfall distribution of the local Bragg Creek region compared to YYC rainfall data was understood and incorporated into the modelling, the sizing would likely be still be adequate if the conservativeness of a number of other assumptions is reduced.

Since the IDF data for Intense Stormwater Event and hourly data for continuous simulation were not available for the Bragg Creek region, both the Intense Storm Event and continuous simulation precipitation data of the Calgary International Airport were used in hydrologic model simulations for this study will be recommended.

2.2 Hydrologic Modelling – Peak Flow Analysis

Typical stormwater models such as SWMHYMO for event based and QHM for continuous simulation were not suitable models to represent the large upstream catchments and the Study Area. However, these two models are commonly used to assist in the stormwater analysis for small sub-division developments in urban and semi-urban areas in Alberta. Keeping in mind that these models will probably be used to assess future development proposals within the Study Area, both the SWMHYMO and QHM modelling simulation runs were made for a few pilot sub-catchments that fall within the Elbow River North and Elbow River South sub-basins. These pilot sub-catchments were selected, considering potential for new developments in the Elbow River North sub-basin and infill developments in the Elbow River South sub-basins as suggested in the Greater Bragg Creek ASP.

As part of determining the existing peak runoff rates, hydrologic modelling was done for the pilot sub-catchments. Catchment parameters were estimated based on existing land use and soil conditions. The pilot sub-catchments were modelled to estimate the 1:2, 1:5, and 1:100 year peak flow rates that would occur under existing (pre-development) conditions using the computer programs SWMHYMO Version 4.02/July 1999 and QHM Version 3.1. The SWMHYMO modelling is completed using a single (discrete) storm event while the QHM modelling is completed using historic rainfall data. The “Chicago” synthetic design storm parameters for the City of Calgary were used to model SWMHYMO 1:2, 1:5 and 1:100 year storm events. Continuous precipitation data from 1960 to 2007 (48 years) at the Calgary International Airport were used for the QHM model. The statistical analysis program, HydroFreq1 version 1.0, was used to process the QHM output data to determine the 1:2, 1:5, and 1:100 year runoff rates.

Figure 1: Monthly Precipitation at Elbow Ranger Station

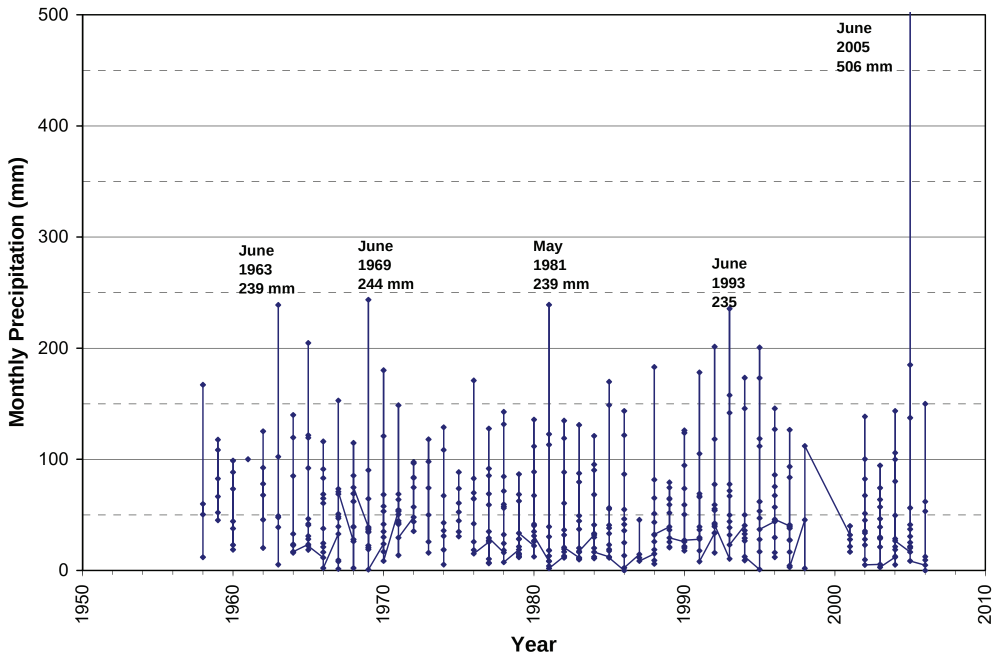
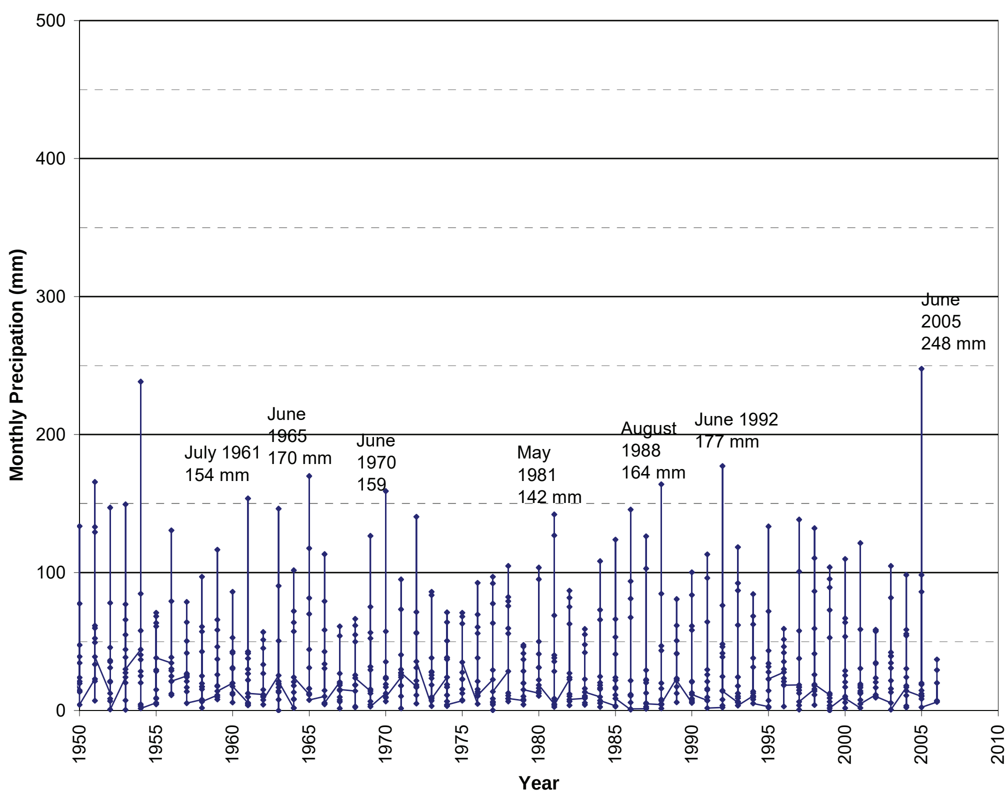


Figure 2: Monthly Precipitation at Calgary International Airport



The modelling approach and parameters used in this analysis are based upon soil conditions obtained from AGRASID soils map of Alberta, a combination of locally accepted practices, Alberta Environment and the City of Calgary Guidelines, as well as past experience in the Calgary Region. A summary of SWMHYMO modelling parameters is presented in **Table 1**.

Table 1
Summary of SWMHYMO Modelling Parameters

Pilot Sub-catchment	Existing Land Use	Area (ha)	CN	Pervious Area		
				IAper (mm)	SLPP (%)	Tp (hrs)
ERN-4	Forested & clear-cuts	542	72	15	2.6	1.8
ERS-3	Forested & residential lots	18	73	15	7.5	0.3
ERS-4&5	Forested & residential lots	58	74	15	5.5	0.6
ERS-6	Forested & residential lots	21	72	15	15.0	0.4

The modelling parameters shown in **Table 1** are briefly explained as:

CN = Runoff Curve Number, a function of hydrologic soil group and land use,
IAper = Initial Abstraction (wetting losses) from pervious surfaces,
SLPP = Average pervious surface slope over which runoff travels, and
Tp = Time to peak of the unit hydrograph

Table 2 provides the summary of hydrologic modelling (SWMHYMO and QHM) results for the existing condition.

The analysis demonstrates typical stormwater models such as SWMHYMO for event based simulation and QHM for continuous simulation typically are used for urban catchments and are not easily adapted to large pervious catchments for a number of reasons. Firstly, SWMHYMO uses idealized rainfall and temporal patterns and suitable abstractions are needed to mimic antecedent moisture conditions in order to achieve realistic results. QHM avoids needing to estimate antecedent moisture conditions but still needs to estimate properties related to soil abstractions over time. Both models are poor at modelling the physical processes such as water movement down the upslope and accounting for the floodplain storage within the wetlands without discretely modelling such storage. These factors result in an overestimation of peak flows using these types of models without detailed model development and calibration to simulate the physical process as best as possible.

Table 2
Existing Condition Hydrologic Modelling Results for Pilot Sub-catchments

Pilot Sub-catchment	Drainage Area (ha)	SWMHYMO Peak Runoff Rates and Unit Area Flow Rates (UAFR)					
		1:100 Y 24 h Q_{peak} (L/s)	1:100 Y 24 h UAFR (L/s/ha)	1:5 Y 24 h Q_{peak} (L/s)	1:5 Y 24 h UAFR (L/s/ha)	1:2 Y 24h Q_{peak} (L/s)	1:2 Y 24 h UAFR (L/s/ha)
ERN-4	542	6,309	11.6	1,479	2.7	508	0.9
ERS-3	18	695	38.6	124	6.9	29	1.6
ERS-4&5	58	1,520	26.2	302	5.2	84	1.4
ERS-6	21	680	32.4	124	5.9	31	1.5
		QHM Peak Runoff Rates and Unit Area Flow Rates (UAFR)					
Pilot Sub-catchment	Drainage Area (ha)	1:100 Y 24 h Q_{peak} (L/s)	1:100 Y 24 h UAFR (L/s/ha)	1:5 Y 24 h Q_{peak} (L/s)	1:5 Y 24 h UAFR (L/s/ha)	1:2 Y 24h Q_{peak} (L/s)	1:2 Y 24 h UAFR (L/s/ha)
ERN-4	542	3,890	7.2	2,080	3.8	860	1.6
ERS-3	18	240	13.3	100	5.6	50	2.8
ERS-4&5	58	860	14.8	370	6.4	210	3.6
ERS-6	21	220	10.5	100	4.8	50	2.4

2.3 Hydrologic Modelling - Storage Requirements

The Greater Bragg Creek Area Structure Plan proposes policy guidance of future residential development including maximum size and number of lots with a Gross Developable Area (GDA). The ASP sets maximum number of lots irrespective of the allotment density, ie. whether at the maximum lot size or cluster style development. Therefore, only 50% of the GDA will be taken as lots with a development set at the maximum lot size down to 6.3% at the smallest permitted lot size. However as all lots are typically not equal, a lot size of 0.33 of an acre is considered a reasonable average lot size for a cluster style development, which would take up 8.4% of the GDA. Concept size of detention storage volume to determine the predevelopment flows were determined for a maximum lot size and the cluster development size of 0.33 of an acre. The modelling parameters used and the imperviousness calculations are presented in **Appendix A**.

Both the event based and continuous hydrologic models discussed in Section 2.2 have been used to determine concept level storage - release rate - pond cost charts for any new developments within the Study Area. For planning purposes, the storage - release rate - pond cost charts for both the maximum 2-acre and for an average lot size of 0.33-acre is presented in **Figure 3** and **Figure 4** respectively. It should be noted that the storage volumes estimated for the 2 acre lot size development is significantly higher than the 0.33 acre lot size development. The following factors should be considered to understand why this occurs:

1. The number of lots per gross development area for each lot size is the same; therefore it is likely that the impervious area of the 2 acre lot development will be higher due to longer roads and driveways required to service the properties.
2. The hydrological models used to estimate the peak flows typically give higher peak flows from the undeveloped catchment than the recommended unit area release rate of 6L/s/Ha. Therefore the significantly larger pervious area of the 2 acre lots will further increase the detention storage volumes required for this type of development.

Figure 3: Storage Volume – Release Rate – Pond Cost Estimate for 2 Acre Lot Size

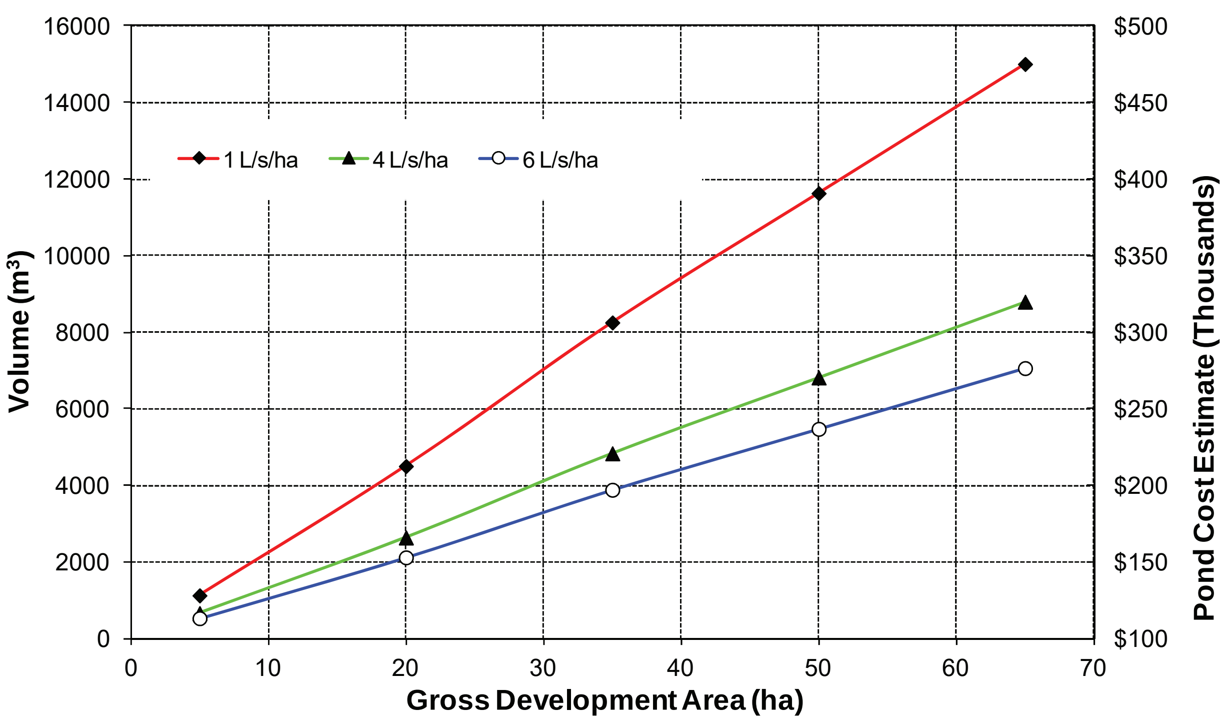
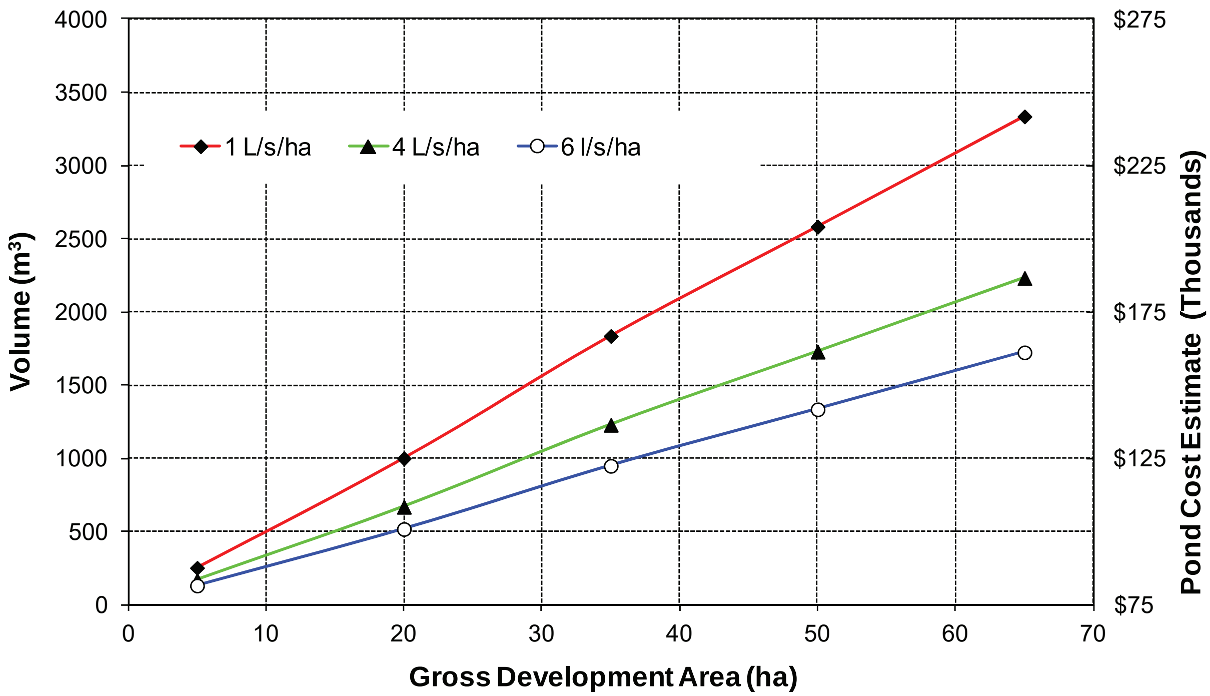


Figure 4: **Storage Volume – Release Rate – Pond Cost for 0.33 Acre Average Lot Size**



3.0 HYDROLOGIC MODELLING - DEVELOPMENT WITH LID PRACTICE CASE STUDY

The effectiveness of Low Impact Development (LID) practices to retain runoff from development was determined using a case study for several development scenarios that are expected to be encountered within the Bragg Creek region. The **M**odel for **U**rban **S**tormwater **I**mprovement **C**onceptualisation (MUSIC) water quality model was used to assess the potential for LID practices to achieve the requirement to not change the runoff volumes and regimes that existed prior to development. This section discusses the approach taken and summarizes the findings of the case study.

3.1 Meteorological and Hydrological Data

Rainfall, streamflow, temperature and evaporation data will be needed to provide data inputs to the MUSIC modelling. This data was collected from the nearest WSC Gauging Stations (GS) to Bragg Creek to provide data that is representative to what would typically be experienced in the Bragg Creek catchment area as provided in **Table 3**.

Table 3
Meteorological and Hydrological Data Source

Data	Station Name	Station No	Comments
Precipitation	Elbow RS	3052270	Missing data filled using Kananaskis station
Temperature	Kananaskis	3053600	estimate snow accumulation and snow melt
Evaporation	AENV Calgary data	-	AENV monthly evaporation data for Calgary adjusted to suit lower evaporation rates for the Bragg Creek region
Gauged Flow	Elbow Falls & Bragg Ck GS	05BJ006 05BJ004	Used both GS to estimate the typical runoff characteristics of the Bragg Creek region

A daily precipitation data set from 1958 to 2009 was developed from the Elbow RS with missing data filled from the adjacent Kananaskis weather station. The average annual precipitation was 645 mm at Elbow RS and 638 mm at Kananaskis, based on the climate normal derived from the years 1971 to 2000. The data set was further modified to incorporate a snow accumulation and melt process with snow melt being calculated using the equation described in Watt (1989) as follows:

$$M = M_f (T_i - T_b)$$

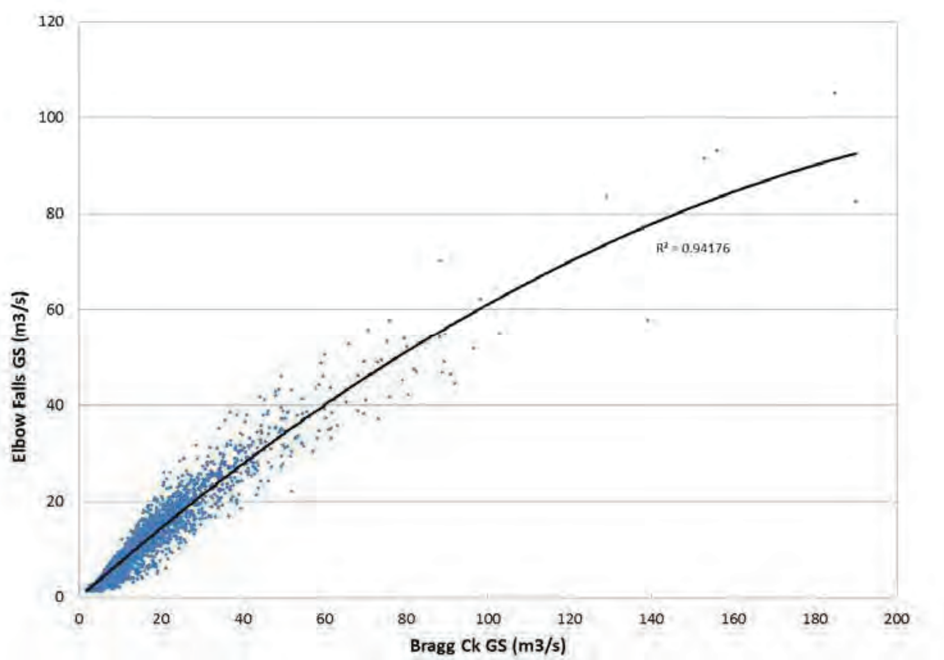
Where M_f is the degree-day melt factor in mm/degC/day, T_i is the index temperature assumed to be average daily temperature at the Kananaskis weather station and T_b is the base temperature, usually freezing point.

Average monthly evaporation data from the Calgary International Airport was modified to reflect the lower evaporation rates that occur at Bragg Creek. A range of reductions were trialed based on literature (Worley Parsons, 2010) and to match the stream flow gauging estimates. An annual evaporation rate of 545 mm appeared to provide reasonable runoff rates when validating the MUSIC model parameters.

Stream flow calibration data was derived for the modelling by subtracting flows at Elbow Falls RS from the flows at the Elbow River Station at Bragg Creek. Stream flow data was missing from either gauging station for significant periods of time over the simulation period, particularly at Elbow Falls. A relationship between the flows at Elbow River and Bragg Creek GS was derived from a line of best fit as shown in **Figure 5**. The catchment between the two gauging stations has an area of 354 km^2 and has an average annual runoff of 72,000,000 m^3 or about 30 percent of the annual average precipitation of the catchment.

Figure 5:

Relationship Between Peak Flows at Bragg Creek and Elbow Falls GS



3.2 Model Calibration

The MUSIC model was calibrated against the runoff characteristics of the gauged flow generated between the Bragg Creek and Elbow Falls stations. The model input parameters for the soil moisture store and groundwater components were derived to provide a reasonable match with the gauged data as shown in **Figures 6a, 6b & 6c**. The calibrated model generated average annual runoff of 73,000 dam^3 which was within 2% of the gauged catchment flows. The model tended to overpredict the peak flows from the more significant storm events, which is expected as the model assumes surface runoff will reach the gauge station on the day that the precipitation falls on the catchment. In reality, the runoff will reach the gauge station spread over a number of days.

The modelling indicated that a significant portion of the runoff generated in the Bragg Creek Area results from groundwater flow in the vadose zone. This is consistent with the finding discussed with the wetland assessment section of this report which found that the wetlands are fed from groundwater.

Figure 6a: MUSIC Model Calibration Results (1978-1982)

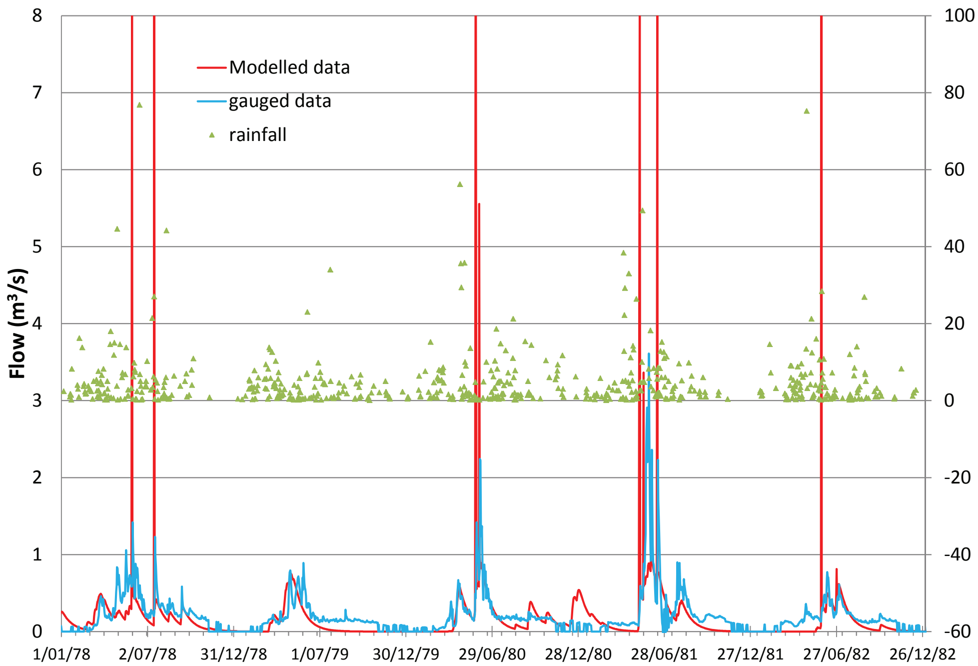


Figure 6b: MUSIC Model Calibration Results (1991-1995)

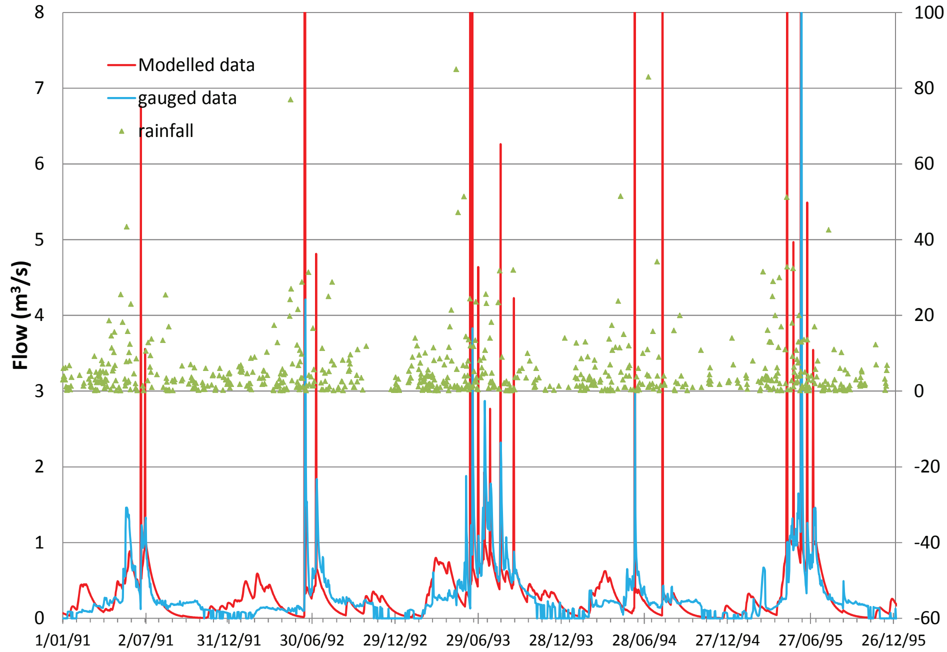
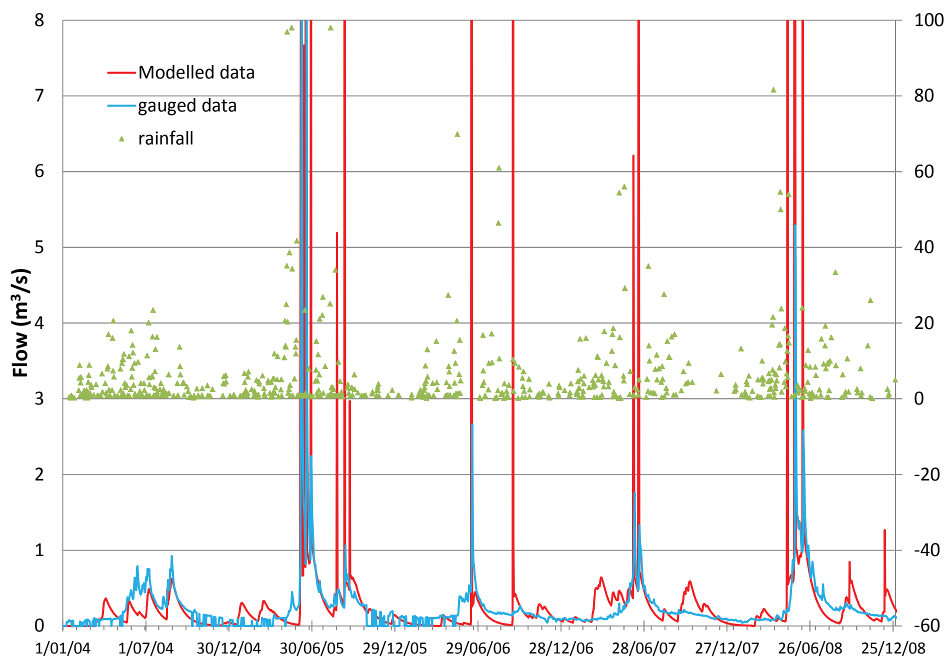


Figure 6c: MUSIC Model Calibration Results (2004-2008)



3.3 Infill Development with LID Practices

A typical infill development was modelled to assess the potential increase in runoff due to development and assess the size of LID practices required to mitigate against any increase in volume. A four lot development with a 1.6 ha (4 acre) lot size was considered in the model and is shown in **Figure 7**. A model was developed for the pre-developed area, the developed area, and the developed area with the application of LID practices. The total site area was 6.4 ha with an impervious area of 6.3% consisting of roofed areas, paving and driveways. The model also assumed that 75% of the site was not disturbed or modified during or after the development of the lots.

Figure 7: Infill Development with Application of LID Practices

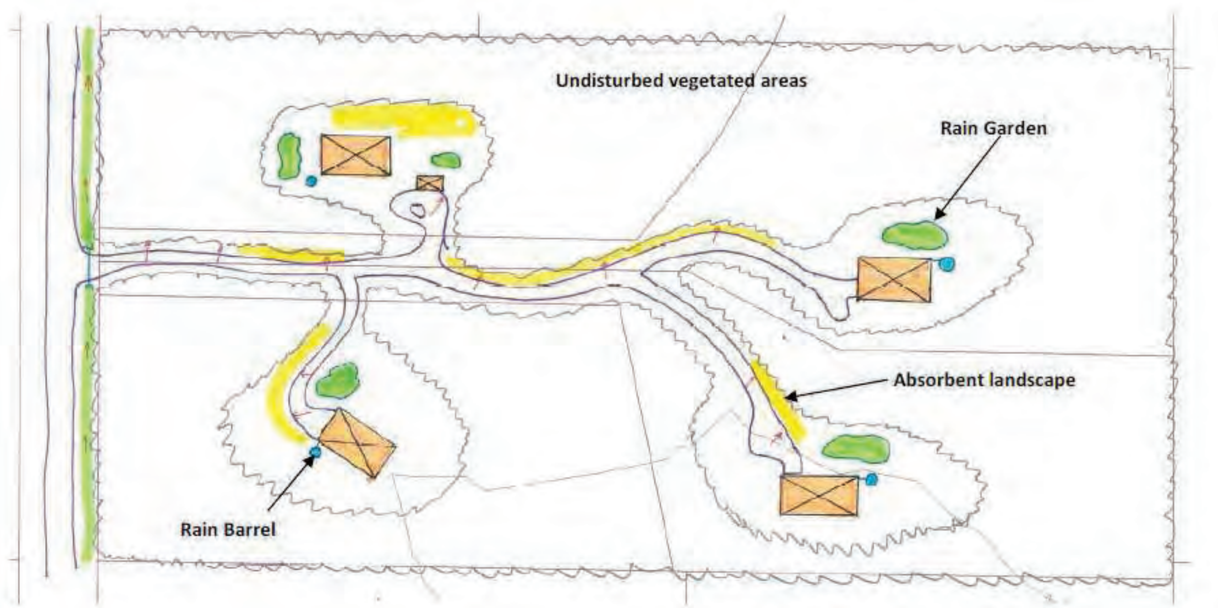


Table 4 gives the changes in runoff from each condition. LID practices that were selected for the modelling included rain barrels/tanks used to irrigate landscaped areas and absorbent landscape to hold runoff from adjacent paved areas. The irrigated areas assume an application rate of 130mm per year which adjusts the application to take into account daily rainfall. The absorbent landscape is assumed to increase the holding capacity of the soil by 100mm and all losses are assumed to occur through evapo-transpiration. Any infiltration losses that would actually occur are most likely to reenter the downstream

wetlands/stream and therefore not reduce the runoff volume. **Table 5** gives the LID sizing required to meet the no effective increase in runoff volume policy.

Table 4
Runoff from Three Typical Scenarios (Infill Development)

Condition	Runoff	Increase above predevelopment
Predeveloped	13,100 m^3/yr	-
Developed	14,400 m^3/yr	10 %
Developed with LID's	13,300 m^3/yr	2%

Table 5
Approximate Area/Volume for Three Typical LID Methods (Infill Development)

LID	Size	Estimated Water use
Absorptive Landscape	300 m^2 per lot 1200m^2	660 m^3 /yr
Rain Barrel	5m^3 per lot 20m^3	236 m^3 /yr
Landscape Irrigation	700m^2 per lot 2,800m^2	1,300 m^3 per ha irrigation rate

3.4 Development LID and Wetland Modelling

A typical development was modelled to assess the potential increase in runoff due to development and assess the size of LID's and wetland required to mitigate against any increase in volume. A 22 lot development with a 0.8 ha (2 acre) lot size was considered in the model and is shown in **Figure 8** with the components of the area shown in **Table 6**. A model was developed for the pre-developed area, the developed area, and the developed area with the application of LIDs and wetlands. The total site area of 24.6 ha was assumed from a GDA area of 35 ha with an impervious area of approximately 10% consisting of roofed areas, paving, driveways and service roads. It was assumed that 65% of the allotments remained in a natural state.

Table 6
New Development Assumed Catchments

	Total	Lots	Roof	Lot Paving	Road ROW	Natural	Offsite
Area (ha)	24.6	17.8	0.7	0.54	2.67	12.5	4.1
Imperviousness (%)	10.5	7.0	100	100	50	0	0

It was found that the development increased the runoff volume by 17% as shown in **Table 7**. **Table 8** gives the LID and wetland sizing required to meet the no effective increase in runoff volume policy.

Table 7
Runoff from New Development Scenario

Condition	Runoff	Increase above Predevelopment
Predeveloped	50,200 m^3/yr	
Developed	58,600 m^3/yr	17%

Figure 8: Development with application of LID Practices and Wetland

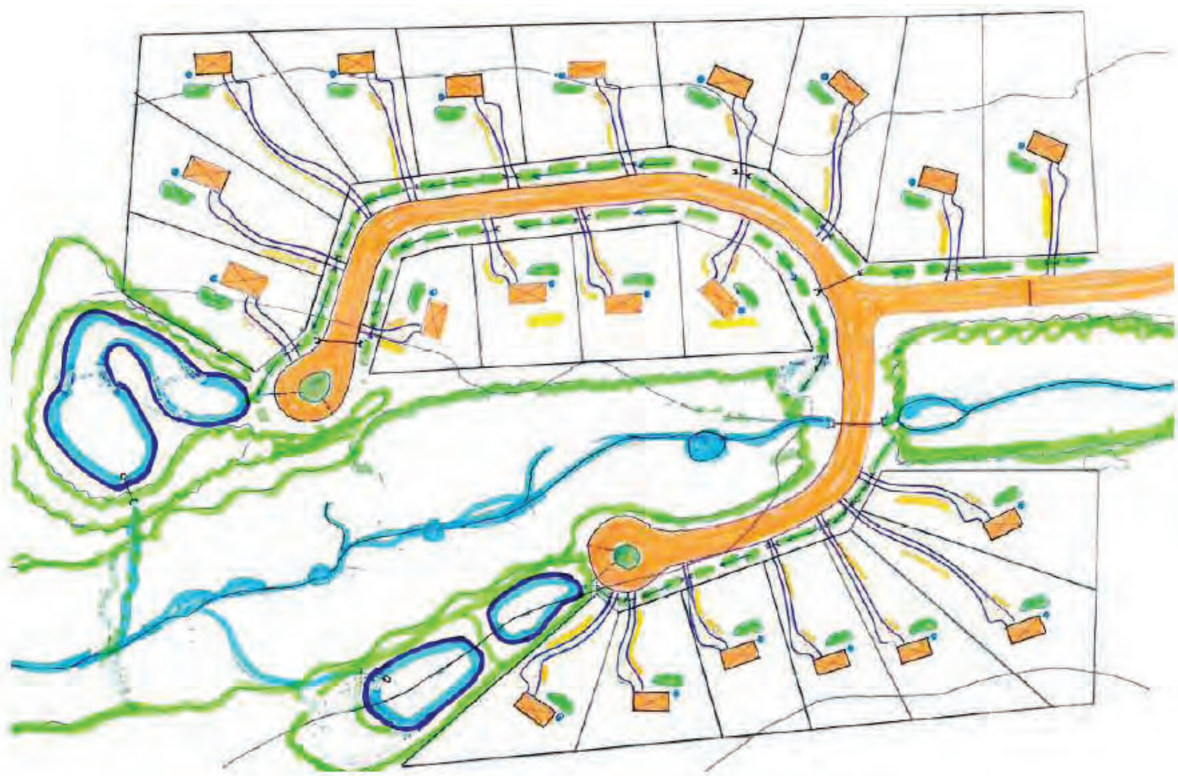


Table 8
Sizing of LID Practices and Wetland for New Development

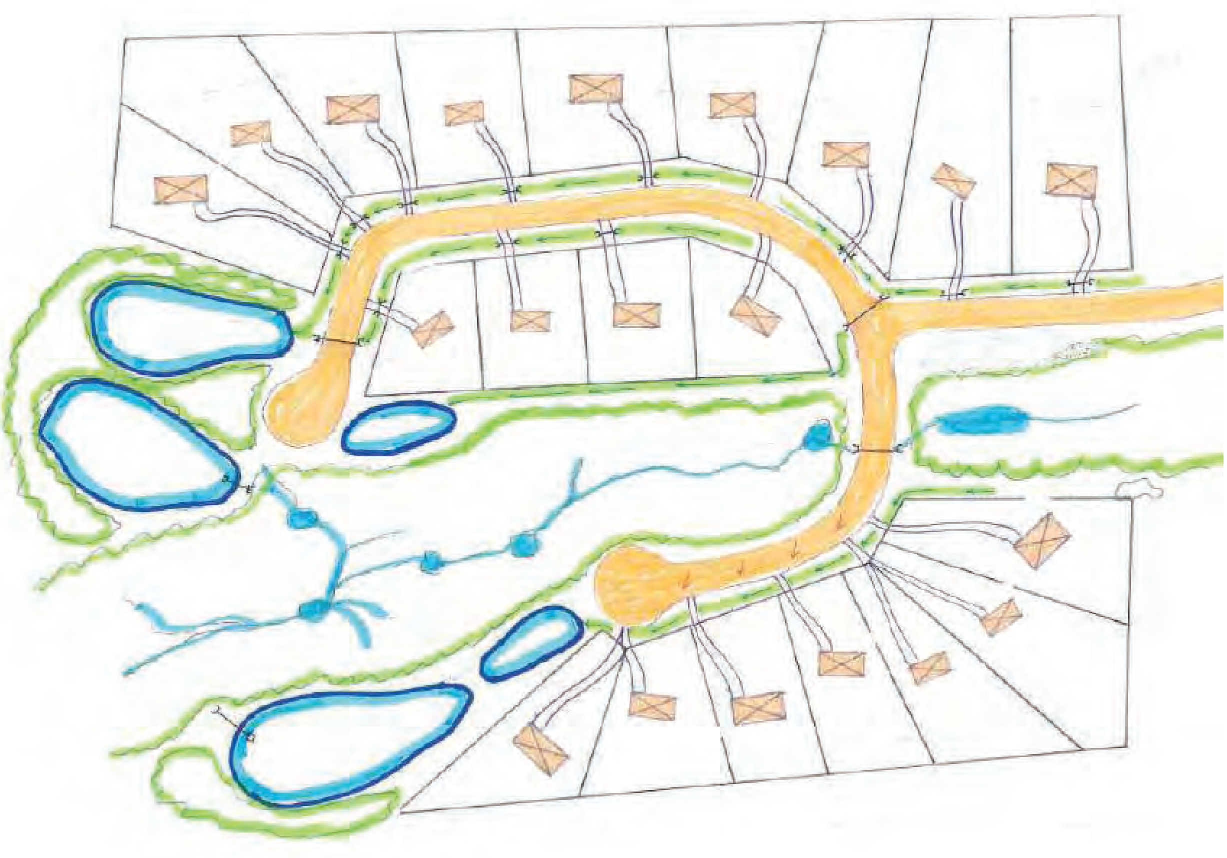
LID	Size	Estimated Water use
Absorptive Landscape	200 m^2 per lot 4,400m^2	2,350 m^3 /yr
Rain Barrel	4m^3 per lot 88m^3	980 m^3 /yr
Landscape Irrigation	700m^2 per lot 2,800m^2	1,300 m^3 per ha irrigation rate
Wetlands	8,000m^2	4,400 m^3 /yr

The same development was modelled without any LID practices other than swales to convey flow to the stormwater wetlands as shown in **Figure 9**. The area of the wetland had to increase to achieve no net increase in the volume of runoff from the development. The wetland size required, provided in **Table 9**, needed to be 75% larger than the wetland required when combined with LID practices.

Table 9
Wetland sizing with and without LID Practices

Case	Wetland Size	Estimated Wetland Water use
Wetland & LID practices	8,000m^2	4,400 m^3/yr
Wetlands Only	14,000m^2	7,600 m^3/yr

Figure 9: Development with Wetland Only



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APPENDIX-A

HYDROLOGIC MODELLING PARAMETERS AND IMPERVIOUSNESS ESTIMATION

Appendix A: Estimation of Percent Imperviousness for New Large Lot and Cluster Developments

A) Large Lot New Development CN = 72 IAper = 15 mm IAimp = 1.7 mm

								Assumed		Assumed		Assumed	
Gross Development Area, GDA (ha)	# of Lots [1]	Lot Area (ha) [2]	Roads (ha) [3]	Offsite Area (ha) [4]	Total Area (ha) [5]	Total Impervious Area (ha) [6]	Imperviousness (%)	L(m)	W(m)	SLPP (%)	SLPI (%)	LGP (m)	LGI (m)
5	3	2.43	0.36	0.56	3.35	0.32	10%	259	129	2	2	30	40
20	12	9.72	1.46	2.24	13.41	1.29	10%	518	259	2.5	2	30	50
35	22	17.82	2.67	4.10	24.59	2.36	10%	701	351	2.5	2.5	30	70
50	31	25.11	3.77	5.78	34.65	3.32	10%	832	416	3	2.5	30	120
65	40	32.4	4.86	7.45	44.71	4.29	10%	946	473	3	2.5	30	200

NOTES:
[1] Assuming 1 Lot = 4 acres (1.6 ha) as GDA
[2] Developable Area (DA) per lot = 2 acres (0.81 ha)
[3] Roads = 15 % of Lot Area (DA)
[4] Typical Offsite Area = 20 % of Lot Area and Roads
[5] Total Area = Lot Area + Roads + Offsite Area
[6] Total Impervious Area = 50 % of Roads Area + 465 sq m of Lot Area as hard surface as per RVC's RFP Document

B) Cluster New Development CN = 72 IAper = 15 mm IAimp = 1.7 mm

								Assumed		Assumed		Assumed	
Gross Development Area, GDA (ha)	# of Lots [1]	Lot Area (ha) [2]	Roads (ha) [3]	Offsite Area (ha) [4]	Total Area (ha) [5]	Total Impervious Area (ha) [6]	Imperviousness (%)	L(m)	W(m)	SLPP (%)	SLPI (%)	LGP (m)	LGI (m)
5	3	0.39	0.06	0.09	0.54	0.18	33%	104	52	2	2	20	40
20	12	1.56	0.23	0.36	2.15	0.71	33%	207	104	2.5	2	20	50
35	22	2.86	0.43	0.66	3.95	1.30	33%	281	140	2.5	2.5	20	60
50	31	4.03	0.60	0.93	5.56	1.83	33%	334	167	3	2.5	20	80
65	40	5.2	0.78	1.20	7.18	2.37	33%	379	189	3	2.5	20	100

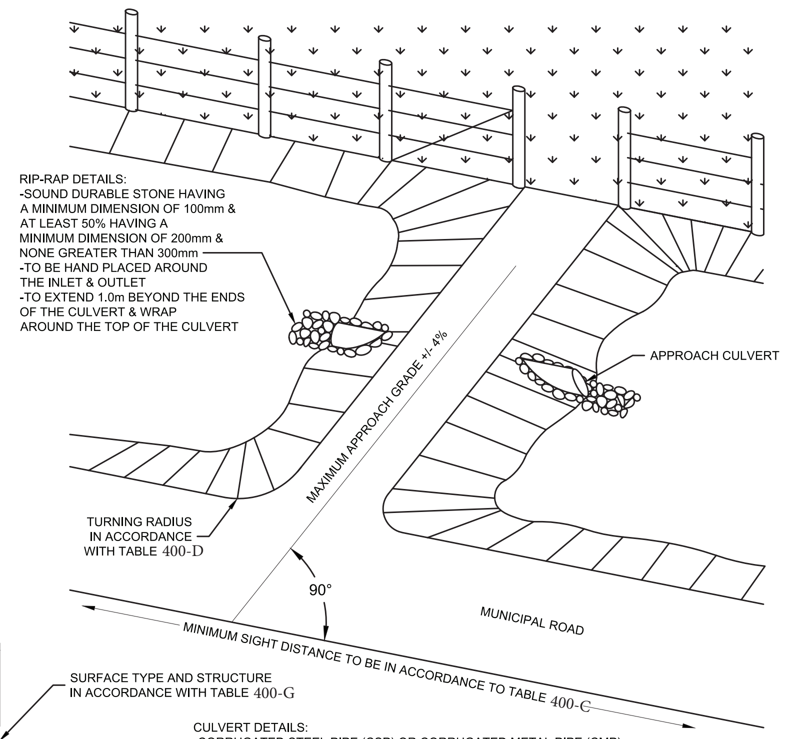
NOTES:
[1] Assuming 1 Lot = 4 acres (1.6 ha) as GDA
[2] Developable Area (DA) per lot = 0.33 acres (0.13 ha)
[3] Roads = 15 % of Lot Area (DA)
[4] Typical Offsite Area = 20 % of Lot Area and Roads
[5] Total Area = Lot Area + Roads + Offsite Area
[6] Total Impervious Area = 65 % of Roads Area + 465 sq m of Lot Area as hard surface as per RVC's RFP Document

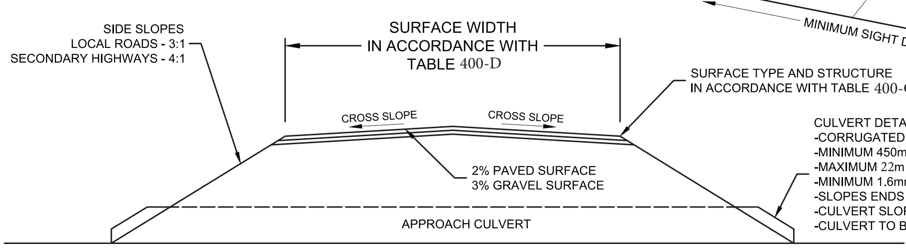
APPENDIX
Rocky View County Typical Sections

B

TABLE 400-D - ROAD APPROACH DESIGN CRITERIA

TYPE OF APPROACH	SURFACE WIDTH (m)	TURNING RADIUS (m)	SIDE SLOPE	SURFACE STRUCTURE
-COMMERCIAL -INDUSTRIAL	10	9	4:1	BASED ON SOAKED CALIFORNIA BEARING RATIO. AT MINIMUM MUST MATCH STRUCTURE OF ROAD PROVIDING ACCESS TO LOT
-AGRICULTURAL -RECREATIONAL -UTILITY -RESOURCE	8	6	3:1	GRAVEL RD: -75mm DES 4 CL 20 CRUSHED GRAVEL OVER 150mm DES 6 CL 80 PIT-RUN PAVED / CHIPSEALED RD: -90mm CITY OF CALGARY TYPE 'B' ACP OVER 200mm DES 2 CL 20 GRAVEL
-RESIDENTIAL: SINGLE/ MUTUAL	6.1 / 7.0	3	3:1	GRAVEL RD: -75mm DES 4 CL 20 CRUSHED GRAVEL PAVED / CHIPSEALED RD: -75mm CITY OF CALGARY TYPE 'B' ACP OVER 200mm DES 2 CL 20 GRAVEL
-FIELD	8	6	3:1	GRAVEL RD: -100mm DES 4 CL 20 CRUSHED GRAVEL PAVED / CHIPSEALED RD: -75mm CITY OF CALGARY TYPE 'B' ACP OVER 200mm DES 2 CL 20 GRAVEL
-TEMPORARY	USE ROAD APPROACH GEOMETRY AS NOTED ABOVE FOR EQUIVALENT PERMANENT APPROACH			





APPROACH CROSS SECTION

CULVERT DETAILS:
-CORRUGATED STEEL PIPE (CSP) OR CORRUGATED METAL PIPE (CMP)
-MINIMUM 450mm DIAMETER (18in)
-MAXIMUM 22m LENGTH UNLESS PERMITTED OTHERWISE
-MINIMUM 1.6mm WALL THICKNESS
-SLOPES ENDS ARE REQUIRED AS PER SECTION 404.6 OF THE COUNTY SERVICING STANDARDS
-CULVERT SLOPE TO BE 0.5% OR DITCH GRADE, WHICHEVER IS GREATER
-CULVERT TO BE INSTALLED AT DITCH BOTTOM OR COUNTERSUNK UP 50mm BELOW DITCH BOTTOM

DETAIL

400.14 FIGURE NO.

DESIGN BY:	--
DRAWN BY:	BM
CHECKED BY:	--
DATE:	11/2024
SCALE:	NTS

FIGURE NO.

400.14

PLANNING & DEVELOPMENT

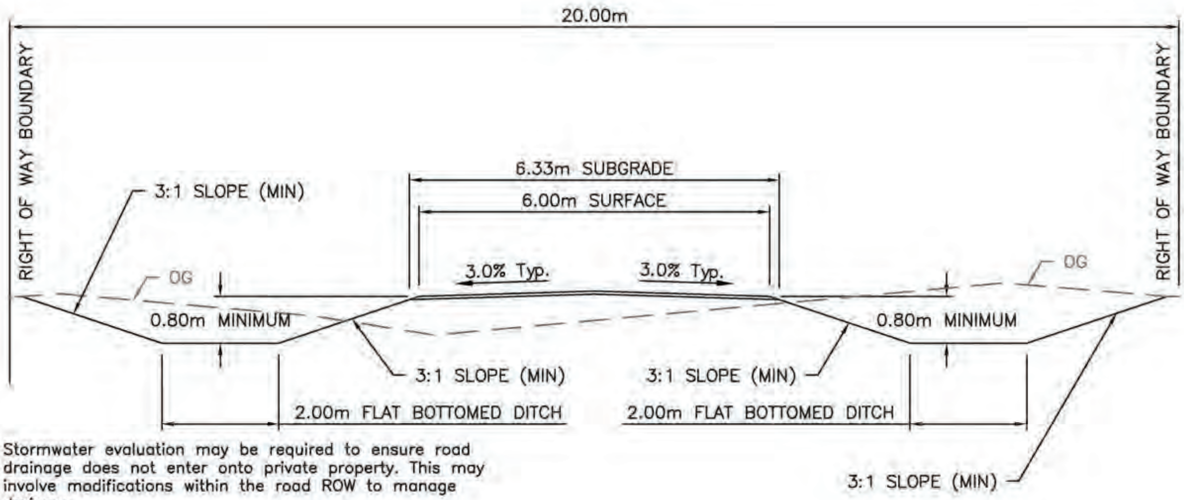
TITLE

TYPICAL
RURAL ROAD APPROACH
DESIGN CRITERIA

No.	YY/MM/DD	ISSUE/REVISION DESCRIPTION	DRN	DES	CHK	APP'D
-	-	-	-	--	-	--
-	-	-	-	--	-	--
1	24/11/29	-	BM	--	-	--

REVISIONS

ROCKY VIEW COUNTY



Stormwater evaluation may be required to ensure road drainage does not enter onto private property. This may involve modifications within the road ROW to manage drainage.

Notes:

For local roads with less than 50 vehicles per day.

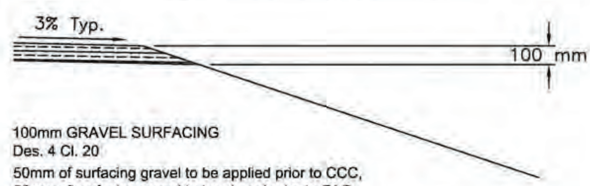
All roadway structure depths shall be certified by the Geotechnical engineering consultant and be acceptable to the County based on soaked subgrade CBR values obtained from the actual subgrade road material, prior to entering the Development Agreement or Road Construction Agreement.

Backsloping agreement or extra ROW required must be obtained by the developer at their sole cost.

Slopes may be increased or decreased under exceptional circumstances if approved by the municipality in writing.

All ditch slopes and ditch bottoms requires topsoil dressing and seed.

ROAD STRUCTURE DETAIL



100mm GRAVEL SURFACING
Des. 4 Cl. 20
50mm of surfacing gravel to be applied prior to CCC,
50mm of surfacing gravel to be placed prior to FAC.

FIGURE NO.	400.5
DESIGN BY:	—
DRAWN BY:	BM
CHECKED BY:	—
DATE:	11/2024
SCALE:	1:100
FIGURE NO.	400.5

ENGINEERING SERVICES

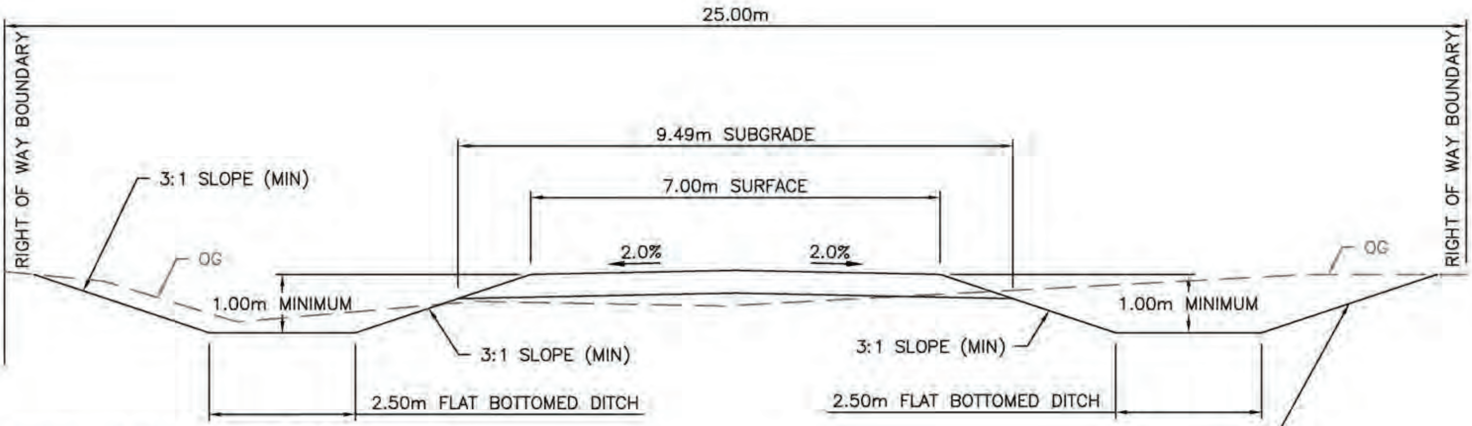
TITLE

RURAL
LOW VOLUME
(RLV)
20.00 m R/W 6.00 m ROAD

No.	YY/MM/DD	ISSUE/REVISION DESCRIPTION	DRN	DES	CHK	APP'D
–	–	–	–	–	–	–
–	–	–	–	–	–	–
1	24/11/29	–	BM	–	–	–

REVISIONS

ROCKY VIEW COUNTY



Stormwater evaluation may be required to ensure road drainage does not enter onto private property. This may involve modifications within the road ROW to manage drainage.

Notes:

All roadway structure depths shall be certified by the Geotechnical engineering consultant and be acceptable to the County based on soaked subgrade CBR values obtained from the actual subgrade road material, prior to entering the Development Agreement or Road Construction Agreement.

Backsloping agreement or extra ROW required must be obtained by the developer at their sole cost.

Slopes may be increased or decreased under exceptional circumstances if approved by the municipality in writing.

All ditch slopes and ditch bottoms requires topsoil dressing and seed.

ROAD STRUCTURE DETAIL

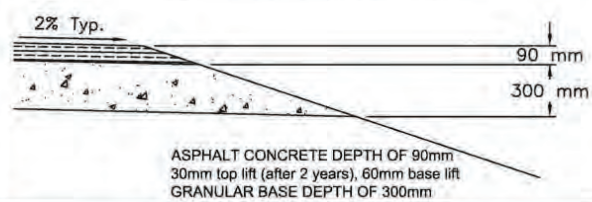


FIGURE NO. 400.1

DESIGN BY: __
DRAWN BY: BM
CHECKED BY: __
DATE: 11/2024
SCALE: 1:100
FIGURE NO.
400.1

ENGINEERING SERVICES

TITLE
COUNTRY RESIDENTIAL (CR)
25.00 m R/W 7.00 m ROAD

NO.	YY/MM/DD	ISSUE/REVISION DESCRIPTION	DRN	DES	CHK	APP'D
–	–	–	–	–	–	–
–	–	–	–	–	–	–
1	24/11/29	–	BM	–	–	–

REVISIONS

ROCKY VIEW COUNTY

APPENDIX
Hydrogeological Study (WSP, 2025)

C

ISSUED FOR REVIEW

REPORT

Hydrogeological Development Suitability Study

Greater Bragg Creek Area Structure Plan Review

Submitted to:

Rocky View County

262075 Rocky View Point
Rocky View County, AB, T4A 0X2

Submitted by:

WSP Canada Inc.

3300 237 4th Avenue SW

Calgary, AB

T2P 4K3

CA0048988.7843

Client Ref: PO 32354

July 31, 2025

Distribution List

1 e-copy: Rocky View County

1 e-copy: WSP Canada Inc.

ISSUED FOR REVIEW

August 8, 2025

Reference No. PO 32354

Dalia Wang, Planner
Rocky View County
262075 Rocky View Point
Rocky View County, AB
T4A 0X0

Dear Dalia:

As per the request by Rocky View County, we have prepared this report of the Hydrogeological Suitability Study for the Bragg Creek Development and Expansion Areas. We hope it meets your needs and expectations.

This deliverable is currently at the draft stage. We look forward to engaging with yourself and other interested parties for feedback.

We appreciate the opportunity to work on such an interesting and important project.

Yours sincerely,

WSP Canada Inc.

David Parsons, M.Sc., P.Geol.
Lead Hydrogeologist

DP/jr

WSP ref: CA0048988.7843

Table of Contents

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

WSP Canada was retained by Rocky View County (the County) to complete a Hydrogeological Development Suitability Study, which will contribute to informing the development of an updated Area Structure Plan (ASP) for the Greater Bragg Creek area. The existing ASP lays a foundation that addresses community values, environmental integrity, and sustainable growth. However, with evolving environmental, infrastructure, and population dynamics, there is a need for an updated ASP. This study will underpin the new ASP by assessing hydrogeological and geotechnical factors that directly influence development suitability across the plan area. The hydrogeological assessment consists of multidisciplinary fields to determine areas suitability for development and identifying areas where additional precautions or restrictions are necessary due to environmental sensitivity or geological challenges. The study focused on:

- Flood and Groundwater Management - assessing flood risks, drainage patterns, and groundwater levels to develop effective flood mitigation strategies and protect water resources.
- Geotechnical Suitability - evaluating soil conditions, stability, and potential geohazards to ensure safe and cost-effective construction and foundation design.
- Environmental Preservation - identifying key natural resources and implementing strategies to minimize ecological impact, preserve habitats, and comply with environmental regulations.
- Potable Water and Wastewater Infrastructure Feasibility - analyzing the capacity of existing water supply and wastewater systems to meet demand and evaluating options for sustainable infrastructure development.

2 BACKGROUND AND OBJECTIVES

The primary objective of this study is to deliver a detailed assessment of hydrogeological conditions within the Bragg Creek Hamlet Growth Area and Expansion Area (the Study Area), the boundaries of which are illustrated on Figure 1. This involved determining areas suitable for development and identifying areas where additional precautions or restrictions are necessary due to potential environmental sensitivity or geological challenges, based on desktop assessment. The overall scope of work encompassed the following key components:

- Data Collection and Review – Compilation of previous hydrogeological, geotechnical, and environmental studies, including the assessment of relevant records from the Bragg Creek Hamlet Expansion Strategy and other publicly available resources on the County’s website.
- Hydrogeological Analysis – Surface and groundwater conditions within the Study Area were assessed, taking into account the extent and yield capabilities of aquifers, groundwater flow regimes, and recharge and discharge areas, particularly in relation to seasonal variations in water levels and flood risk. Historical data and analytical methods were used to visualize and evaluate existing conditions and potential impacts on areas identified for future development.
- Geotechnical Evaluation – WSP identified areas where subsurface geological materials could limit development potential due to risks such as slope instability or subsidence. The analysis incorporated data such as subsurface composition, groundwater conditions, and topography to pinpoint areas requiring specialized construction techniques or those deemed unsuitable for development.

- Impact Assessment and Mitigation Strategies – The preliminary assessment evaluated potential impacts of the proposed development on water resources, infrastructure, and the environment. Mitigation measures were recommended for sensitive areas, aligned with the ASP's environmental goals and informed by Rocky View County's low-impact development principles and Alberta's Water for Life Strategy.

3 HYDROGEOLOGICAL STUDY

3.1 Groundwater Resource Evaluation and Aquifer Assessment

3.1.1 Area Geology

The bedrock geology and surficial deposits within the Study Area are shown on Figure 2.

3.1.1.1 Bedrock Geology

The bedrock geology in the Study Area is a complex series of repeated units formed by northwest-southeast trending thrust faults and folds of the Foreland Fold and Thrust Belt (Rocky Mountain Thrust Belt). Bedrock formations broadly sub-crop parallel to the regional deformation structures. The bedrock units in this area are Upper and Lower Cretaceous in age. The Upper Cretaceous units are identified as the Wapiabi Formation and Cardium Formation, and the Lower Cretaceous unit consists of the Blairmore Group (Figure 1).

The geological formations are described by Prior et al. as follows:

Upper Cretaceous

- Wapiabi Formation – shale, mudstone, silty shale, argillaceous siltstone, and siltstone (some platy, some with rusty-brown weathering, some calcareous); local bentonite layers and local siderite concretions (isolated or along horizons, locally abundant); includes fine-grained, massive to cross-bedded sandstone of the Marshybank Member (lower part of formation) and the fine- to coarse-grained sandstone and argillaceous siltstone of the Chungo Member (upper part of formation); rare, thin chert-pebble layers; marine to locally nonmarine deposits.
- Cardium Formation – Quartz sandstone (commonly thick bedded to massive), silty sandstone, siltstone, shale, and pebble conglomerate; marine deposits.

Lower Cretaceous

- Blairmore Group – Conglomerate and quartzose sandstones at the base, grades to sandstone, siltstone, mudstone, and limestone in the overlying formations.

3.1.1.2 Surficial Geology

The surficial geology of the Bragg Creek area consists primarily of Pleistocene-aged glacial deposits, with moraine, fluvial, and glaciolacustrine deposits being the dominant units (Figure 2). Fluvial deposits, including a mix of poorly to well-sorted, stratified to massive sand, gravel, silt, clay, and organic sediments are found beneath areas of low surface elevations adjacent to the Elbow River. In some areas, fluvial deposits incorporate a significant amount of colluvial material. Glacial moraine deposits consist of diamicton (till) deposited directly by glacial ice, which includes a mixture of clay, silt, and sand, along with minor pebbles, cobbles, and boulders (AGS 2024). These deposits include blocks of bedrock, stratified sediments, or lenses of glaciolacustrine and/or glaciofluvial material in some locations (AGS 2024). Lastly, the glaciolacustrine deposits, include sediments that are rhythmically laminated to massive fine sand, silt, and clay, sometimes containing debris released by melting floating ice. Littoral sediments are typically massive to stratified, well-sorted silty sand, pebbly sand, and minor gravel, commonly found in beaches, bars, and deltas (AGS 2024)

3.1.2 Water Wells and Groundwater Licences in Project Area

A total of 179 records were identified within the Study Area through a review of the Alberta Water Well Information Database (AWWID, Appendix A). Table 1 presents a summary of Domestic use wells, and Table 2 summarizes Observation, Municipal, and Unknown use wells.

It should be noted that the total number of records does not directly correspond to the number of active water wells, as the dataset includes entries related to water quality sampling, decommissioned wells, reconditioned or deepened wells, and test holes. Additionally, some active wells may not be captured due to incomplete reporting at the time of drilling. After filtering out records unlikely to represent active wells, the estimated number of active wells within the Project Area is approximately 70 to 80. Furthermore, the mapped well locations should be considered approximate, as many records provide location data only to the legal subdivision or quarter section level.

There is one active groundwater diversion licence, as shown in Table 3. The licence serves various purposes and allocates an annual groundwater volume of 1,230 m^3/year to the Bavarian Inn. It is assumed that the rest of the water wells in the Study Area are operated under exemptions to the *Water Act* for household use or traditional agricultural use of groundwater. These types of exemptions limit diversions to 1,250 m^3/year and 6,250 m^3/year, respectively.

Numerous springs have been identified in the surrounding areas by Borneuf (1980) and others. Only one spring is recorded in the water well database for the Study Area, in the NW quarter of Section 12. The precise location of this spring is unknown based on the available information; however, it is likely that it occurs as a contact spring at the base of a slope, either in the vicinity of Park Place/Park Pointe, or on the north side of the Elbow River, south of Centre Avenue.

3.1.3 Potential Aquifers in Study Area

Groundwater in the Study Area is primarily stored in shallow alluvial aquifers adjacent to the Elbow River. These aquifers exhibit seasonal variations in groundwater flow direction, which are closely tied to river discharge levels. During periods of low river discharge, groundwater tends to flow sub-parallel to the river, while during high discharge periods, the flow direction can shift, indicating complex interactions between surface water and groundwater systems.

Sandstone units within the Upper and Lower Cretaceous deposits are the primary bedrock aquifers in the Study area. Deformation of bedrock units resulted in sub horizontal and near-vertical orientation of depositional units as well as truncations of aquifer units by faulting can limit the lateral continuity and therefore yield capacity of these aquifers. Drilling reports from AWWID indicate that bedrock units with a well-developed fracture network (typically near the top of bedrock) may also act as secondary bedrock aquifers.

The locations of water wells, historical boreholes and hydrogeological cross-section lines are shown on Figure 3. Hydrogeological cross-sections A-A’ (Figure 4), B-B’ (Figure 5), and C-C’ (Figure 6), show the distributions of geological materials, well screen intervals, and water levels in selected boreholes and water well records in the Study Area.

3.1.3.1 Surficial Aquifers

Surficial aquifers are typically within shallow fluvial and glaciofluvial units composed of sands and gravels; these aquifers are expected to have limited lateral and vertical extents in the Study Area due to the topography and nature of the depositional environment. Surficial deposits and associated aquifers generally occur at depths of less than 17 metres below ground level (mGL). Thirty-seven AWWID records have been interpreted as being completed in the surficial aquifers. Sand and gravel deposits of varying depths were noted above bedrock across the Study Area. Recommended or tested flow rates from 25 wells completed within surficial aquifers ranged from 1.1 to 114 L/min, with an average of approximately 34 L/min.

Mapped groundwater yields in surficial aquifers in the Study Area range between 5 and 25 imperial gallons per minute (igpm), or 30 to 160 m^3/d (Borneuf 1980, HCL 2002). The Bow River basin, of which the Elbow River is a tributary, is closed to new surface water allocations. This includes groundwater that is considered directly connected to surface water, so groundwater diversions from alluvial aquifers in the Bragg Creek townsite are limited to existing allocations and may be subject to holdbacks.

In the Hamlet Expansion Area, extensive surficial sand and gravel-bearing deposits of up to 40 m depth covered by a thin veneer of fine-grained materials are indicated in the water well records and may represent buried paleochannel or glacial meltwater lake deposits within sandy tills that are/were connected to channels that drain southeast to Priddis Creek (Figure 2). A gravel pit is located to the west of the Study Area in NE Section 07, and SE Section 18 of Twp 23 Rng 4 W5M and appears to also represent similar deposits connected to the Priddis Creek sub-watershed (Figure 2). Limited water level measurements from the water wells completed in these deposits are available; however, the data that is available indicate a deep local water table and deep saturated intervals of limited thickness within these granular deposits immediately above the bedrock. The AWWID records indicate the wells in the Hamlet Expansion Area are mostly screened in the underlying bedrock sandstones.

3.1.3.2 Bedrock Aquifers

Sandstone units within the Blairmore and the Alberta Group deposits are expected to be the primary bedrock aquifers in the Study Area; however, drilling reports from AWWID indicate that fine-grained bedrock units with a well-developed fracture network may also act as secondary aquifers. Due to the complex regional folding and faulting of the bedrock in the Study Area, the low permeability units are expected to act as confining layers and barriers to groundwater flow. Hydraulic connectivity between sandstone units will be controlled by the extent of fracture development within the low permeability units. Mapped groundwater yields from the Study Area (Borneuf 1980, HCL 2002) are between 1 igpm and 5 igpm (0.1 to 0.4 L/s, 5 to 30 m^3/d) in the bedrock aquifers. Data from the AWWID records indicates the following about wells completed within the bedrock:

- Water well depths ranged from 18 to 90 m, with an average depth of 35 m; the majority of the wells are installed to withdraw groundwater from interbedded shale and sandstone bedrock units.
- Water well pumping rates were assessed in records from 1966 – 2022; recommended pumping rates (as indicated in the records by the water well drillers) range from 1.14 to 90.92 L/min, with an average rate of 18.95 L/min. The approximate locations of these groundwater wells and their recommended pumping rates are shown on Figure 7. Water well records are included in Appendix A and Tables 1 and 2.

- Across the Study Area, there are multiple sets of records that show a combination of test holes, dry holes, or new wells have been drilled near one another and terminated at various depths; indicating that the depth to viable aquifers is inconsistent across the Study Area. A comparison of drilled well depths and recommended pumping rate data further indicated that there is no apparent correlation between well depth and recommended pumping rates.

3.1.3.3 Groundwater Recharge

Of the 179 well records in the Bragg Creek Hamlet Growth and Expansion Areas, approximately 143 have data to indicate the depth of screened, open, or perforated intervals, in addition to lithology logs. Disregarding decommissioned wells, it is estimated there are on the order of 70 to 80 active water wells in the Study Area. Other than the single licensed water well for the Bavarian Inn, it is assumed that the active water wells in the Study Area are operated under exemptions to the *Water Act* for household use or traditional agricultural use of groundwater. These types of exemptions limit diversions to 1,250 m^3/year and 6,250 m^3/year, respectively. If a volume of 1250 m^3/year is being diverted from 80 of these wells, that represents an annual groundwater requirement of approximately 100,000 m^3/year. This estimated volume only includes water wells within the boundaries of the Study Area; however, it is unlikely that all of these wells are fully active and being used constantly throughout the year. It is also possible that many are not being used at all or have been abandoned.

The catchment area for Bragg Creek (waterbody), Iron Creek, and areas of the Study Area and adjacent areas that drain to the Elbow River represent approximately 60 km^2. Average annual precipitation in Bragg Creek is approximately 410 mm/year, and therefore equates to a volume of almost 24,000,000 m^3/year in the catchment area. An assumption of 10% groundwater recharge equals over 2,400,000 m^3/year, which well exceeds the estimated groundwater usage for the Study Area. This proportion of groundwater recharge (10%) was previously assumed for the Jumpingpound Creek watershed to the north and was comparable to separate estimates of recharge obtained from baseflow separations for that area (AMEC, 2011). This estimate also does not include potential recharge occurring further upstream of the Study Area boundaries within the Elbow River catchment.

3.1.4 Water Quality

The Greater Bragg Creek Area was evaluated for water quality using laboratory results administered by Alberta Health Services (AHS) for private well water (Appendix B). Groundwater samples were collected from private wells between 2002 and 2018, with the wells categorized by depth into surficial and bedrock aquifers. What are classified as surficial aquifer wells in the Study Area generally include those with depths ranging from 0.0 to 17 mGL, while wells deeper than 17 mGL are likely installed in a bedrock aquifer and extend to depths up to 54 m. The water quality results included various groundwater parameters, including major ions and general chemistry analytes, trace metals, and bacteria.

The average pH for the surficial aquifer was 8.09, while the bedrock aquifer had a similar but slightly higher average pH of 8.23. Total Dissolved Solids (TDS) concentrations averaged 490 mg/L for the surficial aquifer and 436 mg/L for the bedrock aquifer. Electrical conductivity (EC) averaged 877 µS/cm for the surficial aquifer and 786 µS/cm for the bedrock aquifer. Chloride concentrations were 60.0 mg/L in the surficial aquifer and 39.5 mg/L in the bedrock aquifer, both of which are within typical ranges, although slightly elevated compared to background values.

The water type in the surficial aquifer is primarily Calcium Bicarbonate, with minor contributions from Calcium Chloride, Sodium Bicarbonate, Calcium Sulphate, and Sodium Chloride waters. The bedrock aquifer, in contrast, contains a more even mix of Calcium Bicarbonate and Sodium Bicarbonate water type, with lower relative concentrations of other major ions. Figure 8 presents a Piper plot illustrating the geochemical composition of the groundwater samples, categorized by their respective sources.

Overall, the water quality in the Study Area can be considered suitable for domestic consumption, agriculture, and other development-related uses; however, there are concerns regarding groundwater hardness, which may impact well screens, plumbing fixtures and other infrastructure, and may be of concern to individuals with health issues related to bones and joints.

The Sodium Absorption Ratio (SAR) of local groundwater was assessed using the equation below

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Analyte concentrations were obtained from Alberta Health Services and converted from mg/L to meq/L. The Sodium Adsorption Ratio (SAR) for the surficial aquifer was calculated at 1.11 meq/L, and for bedrock aquifer, at 1.89 meq/L. These values reflect the relative proportion of sodium to calcium and magnesium in both shallow and groundwater sources. SAR values of this magnitude are considered low, indicating minimal risk of sodium-related impacts on subsurface soils and ground structures. SAR greater than 8 may be conducive to reduced permeability of surface soils over time which would impact the function of disposal fields or stormwater infiltration features (AENV, 1996).

To evaluate the potential for scaling and corrosion in water systems that divert and convey local groundwater, the Langelier Saturation Index (LSI) and Ryznar Stability Index (RSI) were calculated. The LSI estimates whether water will precipitate or dissolve calcium carbonate: a positive LSI indicates a tendency for scaling, while a negative value points to potential corrosion. The RSI is derived from water chemistry parameters including pH, calcium, TDS, bicarbonate, and temperature; assumed temperatures were 15°C for the surficial aquifer and 10°C for the bedrock aquifer.

The calculated RSI for the surficial aquifer was 6.4, suggesting the water is stable with low likelihood for corrosion. Similarly, the bedrock aquifer showed an RSI of 6.8, indicating only a slight difference from the surficial aquifer and similarly low risk. The LSI for the surficial aquifer was calculated at 0.83, while the bedrock aquifer had an LSI of 0.73. These positive values indicate that both water sources are supersaturated with respect to calcium carbonate, suggesting a moderate tendency to form scale buildup on surfaces such as piping, fixtures, and well casings/screens.

3.2 Site Suitability for Development

Site Suitability for Development is generally determined by the composition and drainage capacity of the natural surficial materials and soils, severity of surface slopes, and depths to water table and bedrock. As discussed above, surficial geological materials that characterize the Study Area include:

- Fine- and coarse-grained alluvial sands and gravels, occurring in the valley bottoms and in adjacent areas as terraces.

- Thin, fine-textured glaciolacustrine deposits on top of bedrock (Bayrock et. al. 1980). Scheelar and Veauvy (1977) interpret these materials to be morainal blanket deposits of glacial origin. These generally occur on the higher ground to the south of the Elbow River (including most of the Hamlet Expansion Area).
- At elevated areas to the north and southwest of the Elbow River, surface materials are mainly comprised of sandy till (Moraine) deposits on top of bedrock, and colluvium consisting of soil and rock creep materials occurs at the highest elevations. The occurrence of these deposits is very limited within the Study Area.

Figure 2 shows the general distribution of the surficial materials described above. The following subsections discuss the suitability for development in the areas where each of them occurs.

3.2.1 Fine and Coarse Textured Alluvial Deposits

The alluvial deposits in the region occur in and along the river channels and in adjacent terraces and are typically 2 to 7 m thick (Bayrock et al. 1980). Drilling data in the Study Area indicate typical thicknesses of alluvial sands and gravels of between 2 m and 5 m. Floodplain-deposited silty sands at ground level and overlying the coarser fluvial channel material are also commonly found at the low elevations adjacent to the river in the valley bottom. The areas where these occur are characterized by:

- Shallow water table due to low elevation and proximity to the Elbow River.
- High permeability, which gives them a high infiltration/drainage capacity and low risk for frost heave, however, these materials also are conducive to seepage induced by flooding. Drainage is also limited by shallow water tables and shallow bedrock in the area.
- The gravel deposits in these areas can be a source of aggregate, where practical (Shetsen 1981).
- The fine and coarse alluvial and floodplain deposits may be suitable as road fill.
- They generally occur on level- to gently sloping topography on the valley bottom and terraces near the base of adjacent slopes.

Due to the risks from shallow water tables and seepage/flooding risks, these areas are not generally recommended for homes with basement levels, on-site septic systems, or passive stormwater or low impact development (LID) facilities. These areas may be more suitable for recreation areas, limited agriculture, and non-residential buildings and roadways. Buildings/residential developments could be considered for higher elevation areas further from the river and/or using added fill on top of grade, slab on grade or raised foundations, or flood protection structures where practical. Excavations in these noncohesive granular materials can be prone to sloughing/caving as well (Scheelar and Veauvy, 1977).

To the south of the river valley and floodplain, in the Hamlet Expansion Area (SE ¼, Section 12), there are surficial granular deposits of possible fluvial/glaciofluvial or lacustrine origin extending to depths of up to 40m. These deposits appear to represent an abandoned/buried paleochannel or meltwater lake deposits potentially connected to tributary streams flowing to the southeast toward Priddis Creek. Aerial imagery shows that there is a gravel pit located to the east of the Hamlet Expansion Area, in an area of local sand and gravel deposits mapped by Shetsen (1981), which also appears to be connected to Priddis Creek drainage. Water tables in this area appear to be much deeper below ground level, and the areas where the granular surficial materials occur are likely well-drained. Topography is gently to moderately sloping and some areas may require cut/fill grading to permit residential development in some locations.

3.2.2 Fine Textured Glaciolacustrine/Till Deposits

The silty, relatively thin surficial materials deposited above bedrock at the higher elevations to the south and north of the valley bottom range from 3 to 6 m thick (Bayrock et. al 1980). They generally consist of clayey silt with minor sand and gravel. The high elevation areas where these deposits occur are characterized by:

- High fines content and low permeability may be below ideal infiltration capacity for stormwater, infiltration, and septic facilities in some areas; Scheelar and Veauvy (1977) describe the deposits as moderately well-draining.
- They generally occur on gently to moderately sloping topography.
- The local bedrock depth is variable and the water table is relatively deep, but perched conditions may exist in some areas.
- The silty composition of the deposits may make these materials prone to frost heave.

Slopes, moderate drainage and susceptibility to frost heave represent some risk for buildings, roadways, stormwater or septic facilities, and landfills in certain areas. For recreation sites and agriculture, the areas where these surficial deposits occur are generally suitable. Cut/fill/levelling would be required in some cases for expanded residential development. Excavations may be limited by shallow bedrock at higher elevations. Perched water tables may occur in some locations creating wet conditions and possible need to manage seepage during and after construction.

3.2.3 Sandy Till (Moraine) Deposits and Colluvium

Sandy till and colluvium deposits occur along the steeper slopes to the north and southwest of the Elbow River and are of limited extent and occurrence within the Study Area boundaries. These are characterized as sandy till/morainal veneer deposits consisting of approximately 50% sand. Colluvium occurs at the highest elevations with a 1.5 to 3 m thickness consisting of rock creep and weathered bedrock material directly above shale, siltstone, and sandstone bedrock. These deposits:

- Are generally well-drained and of relatively high permeability.
- Occur on moderate to steep slopes.
- Occur where bedrock is shallow. The water table where these deposits occur is generally deep, but perched conditions may exist.

The steep slopes and thin deposits above bedrock generally make these areas unsuitable for development, however, some developments may be sited where slopes are moderate. They may be suitable for limited use for recreation sites and agriculture. The occurrence of the surficial deposits that characterize these areas are of limited areal extent in the Hamlet Growth Area and are more common in areas further north and southwest of the Study Area boundaries.

3.3 Seepage Assessment and Risks Due to Flooding

Groundwater seepage was previously assessed by Amec Foster Wheeler (2017) to estimate potential underseepage beneath proposed flood berms along the Elbow River, to evaluate the necessary capacity of proposed drainage systems, and to determine the likelihood and extent of groundwater seepage appearing at surface in a 1:100-year flood event. Historical borehole and test pit data have been compiled to characterize the subsurface and the alluvial aquifer in the area of the Elbow R-river channel and flood plain to re-assess the extent of flooding due groundwater seepage beneath the flood berms. The previous assessment was based on the information available at the time from the immediate area and some simplifying assumptions. Here, underseepage during flood conditions will be reassessed using additional, more up-to-date information and revised assumptions.

It is understood that there have been instances of greater incursion of groundwater in some areas adjacent to the Elbow River than expected at times during the annual water cycle. This is believed to be partly due to the presence of the berm which has effectively narrowed and deepened the river channel in some areas, possibly resulting in higher local rise in the river level than expected during peak flows in spring. In addition, the permeable sand and gravel deposits are conducive to rapid seepage of flood water through the surficial deposits and under the berm that can reappear at ground surface.

Groundwater seepage rates and water table displacement were evaluated based on the hydraulic head changes produced by the expected rise and rate of change in the river level in a 1:100-year flood condition using river and flood stationing data from Amec Foster Wheeler (2017). The seepage estimates are determined based on one-dimensional flow in an unconfined aquifer developed by Edelman (1947), as described by Huisman and Olsthoorn (1983).

The calculations used for seepage estimates are as follows:

$u = 0.5*\sqrt{(S_y/Kb)}*(x/\sqrt{t})$ (1a)

$s_x = s_o*\text{erfc}(u)$ (1b)

$q_o = (s_o/\sqrt{(\pi)}) * (\sqrt{(Sy*K*b)})*(1/\sqrt{(t)})$ (1c)

$E_2 = e^{-uu}$ (1d)

$q_x = q_o * E_2$ (1e)

Where:

S_y = specific yield
K = hydraulic conductivity (m/s)
b = aquifer thickness (m),
x = distance from flood-berm interface (m)
t = time (d)
s_o = river level rise (3.6 to 4.4 m) and s_x = head change at distance x from the interface (L)
q_o = seepage rate at the interface, and q_x = seepage rate at distance x (L^3/t)

Some assumptions were made to simplify the analytical calculations:

- The transition to the flood condition is instantaneous and the peak flood persists for up to 3 days.
- The surficial geology consists of a single layer of material, as described above, with a typical thickness observed in borehole logs of 4.0 m.
- Hydraulic conductivity (K) estimates for the sand/gravel surficial materials in the immediate area range from 5.0×10^{-5} to 8.5×10^{-4} m/s, based on particle size and slug test data collected during previous investigations.
- Distances (x) at which water table rise and seepage rates are calculated are relative to the flood/berm interface which is considered to be located at the stream-side toe of the berm.

- All seepage flux is assumed to be horizontal and parallel to the plane of section (orthogonal to the river channel).

The calculations produced multiple estimates of seepage flux and water table displacement for 2D sections through the river and floodplain area at the selected stationing locations. The calculations were automated using a spreadsheet. The results were calculated at various time steps, which are within the range that peak flooding would be expected to persist (approximately three days). Sensitivity of the calculations to uncertainty in parameters such as hydraulic conductivity and flood duration were assessed as well.

3.3.1 Results

Table 4 and Figure 9 present the estimated extent of daylighting of groundwater underseepage during flood conditions and extent of potential impacts to subsurface structures such as basements. The assessment neglects the potential barrier effects of materials such as road pavements or preferential pathways created by underground utilities. It also disregards collection and potential infiltration of direct surface precipitation and runoff.

The theoretical seepage calculations and results are included in Appendix C. The analysis indicates that impacts due to induced groundwater seepage in a 1:100year flood event may propagate between 50 to 100m laterally from the river channel and berm within a typical flood advance timeframe of 2 to 3 days.

Seepage fluxes in the subsurface at a distance of 50m from the river/berm interface (as calculated from equations 1c to 1e and summarized in Appendix C) are mostly between 8 and 9 m^3/d per lateral metre orthogonal to the direction of flow. Groundwater seepage reaching subsurface structures would represent a significant portion of these fluxes, depending on the depth/elevation of the structure relative to the water table rise and the configuration of the structure.

4 CONCLUSIONS

Bedrock aquifers composed of alternating shale and sandstone represent the primary source of domestic groundwater use in the area. Groundwater yield mapping and recharge estimates indicate that sufficient groundwater resources capable of providing provincially mandated domestic water volumes appear to exist across the Study Area; however, due to the complex regional folding and faulting of the bedrock geology, the depth and continuity of water bearing units may vary widely and productivity of water bearing units also is expected to vary.

Groundwater quality in bedrock aquifers in the Study Area is of generally acceptable quality and within guidelines for domestic consumption. Sodium Absorption Ratios in surficial and bedrock aquifers were within a range suggesting they were suitable for stormwater infiltration facilities and septic fields; however, other site suitability factors would also need to be favourable. It was also determined that groundwater hardness and carbonate stability indices indicate that scaling of plumbing and fixtures is a potential problem for new developments, and water hardness may also be of concern for individuals with health issues related to bones and joints.

Site suitability for new developments is variable across the Hamlet Growth and Expansion Areas, and all areas have some combination of shallow water tables, shallow bedrock depths, steep slopes, poorly draining surface soils, and risks of groundwater flooding that may be detrimental to development activities without cut and fill levelling, raised / pile-supported foundations or other interventions. The most desirable areas for residential developments are likely in the lowland valley area at distances of greater than 100m from the Elbow River, and in parts of the Hamlet Expansion Area (SE ¼ Section 12) where soils are well-draining and slopes are relatively moderate.

An updated assessment of the extent of flooding impacts due to induced groundwater seepage during a 1:100 year flood condition indicate that, provided the flood berms are effective at preventing overland flooding, possible daylighting of groundwater and basement seepage would be limited to a distance of between 50 and 100 m inland from the Elbow River flood berm in most areas, assuming direct precipitation and runoff contributions are relatively minor.

5 DATA GAPS AND RECOMMENDATIONS FOR FURTHER EFFORTS

The most significant data gaps are associated with the subsurface characterization of the Hamlet Expansion Area in SE-12-23-05 W5M. A field verified water well survey to confirm the existence and location of water wells and springs in that area should be conducted to provide additional detail to future hydrostratigraphic conceptual models. Also, a limited drilling programme and/or geophysical survey may be necessary to delineate/confirm the local stratigraphy, and areal distribution and thickness of fine- and coarse-grained surficial materials.

A number of geotechnical and groundwater monitoring boreholes and instrumentation have been installed in the past in the Hamlet of Bragg Creek, generally focussed on small areas including a gauging station site, and the water treatment plant. Data associated with these investigations was collected in various years and times of the year. It is recommended to conduct a field programme to fill gaps in these existing data sets by completing the following:

- Borehole drilling to further characterize the geology in the Hamlet Expansion Area.
- Conducting surface geophysical surveys where feasible, to supplement the drilling programme.
- Water level monitoring and in-situ testing for assessment of hydraulic parameters, including slug tests and / or pumping tests.

Assessment of the extent of flooding impacts may be refined by developing a 2D or 3D numerical surface water-groundwater model(s) for the area. Such models, in comparison to the analytical calculations described above, may better incorporate and account for the complexities of area geology, as well as timing of both flood advance and recession, and inputs from precipitation and runoff.

Installation and testing of water wells in proposed areas of development can be conducted to assess the feasibility of community or individual household water wells in new residential developments, the capabilities of local aquifers, and potential impacts on existing groundwater users in adjacent areas.

6 CLOSURE

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WSP Canada Inc.

Prepared by:

David Parsons, M.Sc., P.Geol.
Lead Hydrogeologist

Nishat Rahman, B.Sc., G.I.T.
Hydrogeologist in Training

Reviewed by:

Alyssa Barker, P.Geo.
Group Manager / Lead Hydrogeologist

Ali Samadi, P.Eng.
Principal Geotechnical Engineer

NR/AB/AS/jr

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This limitations statement is considered an integral part of this report.

TABLES

Table 1: Well Records - Domestic

Well ID	Landowner	Date Completed	Total Drilled Depth (mGL)	Listed Well Type	Static Water Level (m)	Test Rate (L/min)	Test Rate (m^3/day)	Outer Well Diameter (cm)
Surficial								
341415	HERRON EST	1998-06-08	12.19	Test Hole-Decommissioned	2.83	9.09	13.09	0.00
341416	HERRON EST	1998-06-08	12.19	Test Hole-Decommissioned	2.65	1.14	1.64	0.00
349515	MERRITT, CARL	1987-02-09	12.19	Deepened	3.05	2.27	3.27	16.81
357782	ARCHER, CAREN/STEVE	1987-07-29	17.07	New Well	2.44	13.64	19.64	16.81
359886	THOMPSON, AL	1991-07-16	13.11	New Well	2.44	54.55	78.55	16.81
364932	GLASSFORD, A.R.	1992-05-14	15.24	New Well	10.97	36.37	52.37	16.81
379701	BUMSTEAD, BRIAN	1995-10-18	13.41	New Well	3.51	9.09	13.09	16.81
387456	MCARUTHER, JAMES	1966-09-07	5.18	New Well	1.52	113.65	163.66	15.57
387458	GRAVES, G.	1968-06-11	16.76	New Well	1.22	2.27	3.27	0.00
387459	ELSDON	1977-07-05	17.07	New Well	3.35	9.09	13.09	17.78
387464	COCKING, JIM	1981-11-02	12.50	New Well	4.57	43.19	62.19	14.12
387504	EARLY, JOHN	1975-06-11	12.19	New Well	2.74	18.18	26.18	13.97
387508	BISHOP, ROBIN	1969-09-01	6.71	New Well-Decommissioned	1.83	45.46	65.46	12.70
387510	CHALLICE, C.	1972-06-01	11.89	New Well	6.10	13.64	19.64	0.00
387511	B&G CONSTR	1972-11-01	9.14	New Well	2.44	90.92	130.92	15.24
387519	NEWLANDS, B.	1974-11-04	9.14	New Well	0.00	22.73	32.73	16.84
387520	KUNES, VUCLAV	1975-06-21	12.80	New Well	3.05	31.82	45.82	11.43
387625	RICHTER, PAUL	1974-01-01	10.06	New Well	3.05	4.55	6.55	15.88
387626	GRAHAM, E.	1970-11-01	11.28	New Well	4.88	45.46	65.46	0.00
387627	TEGHTMEYER, ROB	1975-02-24	9.45	New Well	3.35	68.19	98.19	0.00
387633	KOGMA, J.	1971-04-01	8.84	New Well	3.35	113.65	163.66	12.40
387635	JONES, COLIN	1970-11-01	6.40	New Well	3.66	27.28	39.28	15.24
418094	RIDLEY, HAROLD	1974-05-27	12.19	New Well	2.44	6.82	9.82	15.24
Bedrock								
341256	DALRYMPLE, LORNE #3832	1999-09-03	50.29	New Well	11.49	9.09	13.09	16.81
341491	FRENCH, KIM #3696	1999-03-31	24.38	New Well	11.89	22.73	32.73	16.81
349187	RUBEN, P. PALMER K.	1992-11-17	30.48	New Well-Decommissioned	10.67	6.82	9.82	16.81
349188	RUBEN P/PALMER K.	1992-11-23	19.81	New Well	9.75	18.18	26.18	16.81
349754	CARRUTHERS, BARRY 2673	1995-05-17	29.57	New Well	0.00	13.64	19.64	16.81
349764	AVERY, SUSAN #2698	1995-06-05	27.43	New Well	2.53	10.68	15.38	16.81
349765	AVERY, SUSAN #2695	1995-06-01	28.04	New Well	9.36	18.18	26.18	16.81
349769	HARE,RICHARD #2723 SITE 3	1995-06-29	32.00	New Well	19.29	36.37	52.37	16.81

Table 1: Well Records - Domestic

Well ID	Landowner	Date Completed	Total Drilled Depth (mGL)	Listed Well Type	Static Water Level (m)	Test Rate (L/min)	Test Rate (m^3/day)	Outer Well Diameter (cm)
349817	HARR, RICHARD #2680	1995-06-15	36.58	New Well	22.40	9.09	13.09	16.81
349818	HARE, RICHARD #2747	1995-07-28	33.53	New Well	20.70	22.73	32.73	16.81
351846	MCCLOY, TERRY	1990-07-07	32.00	New Well	12.19	9.09	13.09	14.12
352206	EAGER, ALAN	1990-09-18	44.20	New Well	3.05	13.64	19.64	16.81
357974	SHOULTS, IDA # 1599	1991-05-27	32.00	New Well	3.05	18.18	26.18	16.81
364931	GLASSFORD, A.R.	1992-06-05	18.90	New Well	11.58	27.28	39.28	16.81
387390	KLEIBER, W.	1970-11-01	19.81	New Well	4.88	7.96	11.46	16.51
387392	NEUFELD, VIC	1974-11-07	50.90	Deepened	17.98	9.09	13.09	15.88
	NEUFELD, VIC	1974-11-07	50.90	Deepened	27.13	45.46	65.46	15.88
387395	ALBERTSON	1968-06-06	28.96	New Well	10.36	13.64	19.64	13.97
387457	MCKEAGUE, D.	1967-09-08	36.58	Deepened	6.10	2.27	3.27	0.00
387463	KABATOFF, ALEX	1979-07-31	33.53	New Well	3.05	2.27	3.27	14.12
387490	KELLY, LAWRENCE	1976-07-03	18.29	New Well	1.98	13.64	19.64	17.78
387503	LOVE, H.G.	1968-06-04	18.29	New Well	3.05	4.55	6.55	15.24
387509	BISHOP, ROBIN	1969-09-01	21.34	New Well	2.13	45.46	65.46	12.70
387514	MCLENNAN, BOB	1977-03-07	34.75	New Well	13.72	4.55	6.55	14.12
387515	BRAUN, ERV	1976-07-06	25.91	New Well	4.88	10.23	14.73	14.12
387517	TRAVIS, STEVE	1979-07-08	21.34	New Well	4.57	45.46	65.46	14.12
387521	MCARTHUR, ARNOLD	1985-05-28	30.18	New Well	4.27	18.18	26.18	16.84
387591	ARCHER, STEVE #1	1987-07-28	28.96	Test Hole	2.44	4.55	6.55	16.84
387607	PEARMAIN, KEITH	1975-03-04	31.09	New Well	2.80	18.18	26.18	0.00
387617	DICK, LEO	1975-02-26	21.34	New Well	2.44	45.46	65.46	14.12
387628	WRATHALL, G.M.	1967-09-20	21.34	New Well	2.74	2.27	3.27	16.84
387631	BLAKLY, W.E.	1971-06-01	34.14	New Well	14.33	90.92	130.92	13.16
387645	BRAGG CREEK TRADING POST	1981-02-01	28.04	New Well	3.66	2.27	3.27	0.00
390232	LERNER, DENNIS	1968-06-21	29.26	New Well	3.35	9.09	13.09	0.00
458941	HOLSCHUH, CHARLIE#3338	2001-10-10	36.58	Deepened	3.35	2.27	3.27	16.81
491217	DEAN, DON	1998-07-14	24.38	New Well	1.52	90.92	130.92	16.81
1020214	RENAUD, ALAIN	1998-09-30	30.48	New Well	2.41	11.37	16.37	16.81
1021522	MCKEAGUE, DOUG	2007-08-07	49.68	New Well	0.00	18.18	26.18	16.81
1611155	FRENCH, KIM	2022-09-05	28.96	New Well	11.40	34.10	49.10	16.84
2066214	MACALLISTER, EDITH	2018-10-25	53.34	New Well	2.32	27.28	39.28	16.83
9546320	MINTY, DEV	2017-09-03	41.15	New Well	2.83	6.82	9.82	16.81
350053	MCHUGH, DAN	2016-08-30	89.92	Deepened	51.82	2.27	3.27	16.84
350053	EATON, LES #3359	1998-01-30	67.06	New Well	12.59	9.09	13.09	16.81

Table 1: Well Records - Domestic

Well ID	Landowner	Date Completed	Total Drilled Depth (mGL)	Listed Well Type	Static Water Level (m)	Test Rate (L/min)	Test Rate (m^3/day)	Outer Well Diameter (cm)
350053	MCHUGH, DAN	2007-09-10	71.63	Deepened	19.81	1.14	1.64	16.81
1022750	WAKEFIELD, DAVE & IRIS	2016-05-24	65.53	New Well	16.52	4.55	6.55	16.84

Table 2: Well Records - Miscellaneous

Well ID	Landowner	Date Completed	Total Drilled Depth (mGL)	Listed Well / Record Type	Static Water Level (m)	Test Rate (L/min)	Test Rate (m^3/day)	Outer Well Diameter (cm)
Surficial								
387504	EARLY, JOHN	1975-06-11	12.19	New Well	2.74	18.18	26.18	13.97
387623	KLINE, ROGER	1967-09-11	9.14	New Well	3.35	-	0.00	16.84
387633	KOGMA, J.	1971-04-01	8.84	New Well	3.35	113.65	163.66	12.40
465414	REID, CROWTHER & PARTNERS LTD	-	0.00	Spring	-	-	0.00	0.00
Bedrock								
387455	ELKANA RANCH LTD	1966-06-15	48.77	Dry Hole	-	-	0.00	12.70
387512	MCKEAQUE, D.K.	1981-07-08	48.77	Dry Hole	-	-	0.00	0.00
387591	ARCHER, STEVE #1	1987-07-28	28.96	Test Hole	2.44	4.55	6.55	16.84
387615	SHLAHT, ALF	1973-07-01	33.22	Dry Hole	-	-	0.00	0.00
2095057	MASCH, KLAUS	1961-07-01	21.34	Well Inventory	21.34	-	0.00	-

mGL = metres below ground level

Table 3: Water Licences

Allocation #	Priority	Licensee	Purpose	Diversion Quantity (m^3)	Diversion Rate (m3/day)	Allocation Type
10751	1981-01-19-0001	Wintergreen Woods Water Utility Ltd.	Recreation	201,060	4924.8	Surface Water
13959	1976-07-30-0002	Rocky View County	Municipal	39,470	1382.4	Surface Water
14981	1974-08-20-0002	Elkana Residents Water Co-op Limited	Municipal	86,350	172.8	Surface Water
201198	2009-08-17-0002	Elkana Residents Water Co-op Limited	Municipal	0	864	Surface Water
16120	1981-04-10-0003	Bavarian Inn	Recreation	1,230	0.65	Groundwater
230328	1969-05-16-0001	Alberta Environment and Portected Areas	Government Holdback	617	86.4	Surface Water
237535	2009-08-17-0002	Alberta Environment and Portected Areas	Government Holdback	0	0	Surface Water
237537	1974-08-20-0002	Alberta Environment and Portected Areas	Government Holdback	0	0	Surface Water
DRALOC0011584	2009-08-17-0002	Rocky View County	Municipal	0	864	Surface Water
DRALOC0015195	1981-04-21-0001	G.S. Barbecue Steak Pit Ltd.	Commercial	18,500	86.4	Surface Water
DRALOC0015910	1964-10-21-0002	Rocky View County	Water Management	0	0	Surface Water

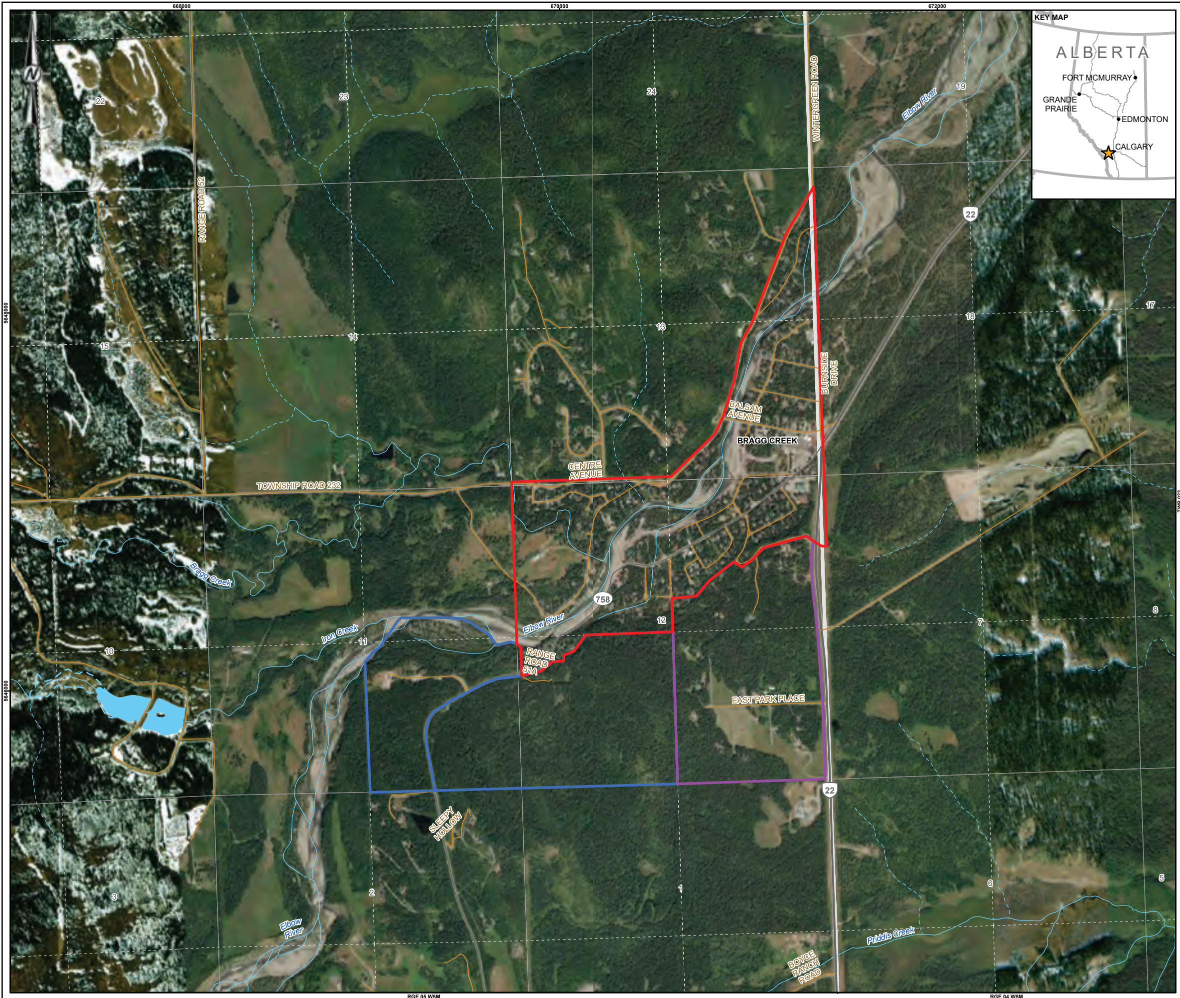
Table 4: Estimated Extent of Elbow River Flood Impacts (1:100 year event).

River Centerline Stationing (Figure 9)	Non-Flood River Level (masl)	Rise in River Level – 1:100 year flood (m)	Ground Surface Elevation (masl – approx.)	Distance (x) From River Flood Interface (m)	Phreatic Surface Elevation at 'x' (masl)		
					Base Case	Sensitivity Analysis	
					K = 8.0 x 10^{-4} m/s, S_y = 0.2, t = 3 d	Lower K K = 1 x 10^{-4} m/s	Less time (t = 2 d)
10+150	1307.5	3.8	1323	10	1310.96	-	1310.89
				50	1309.71	-	1309.40
				100	1308.53	-	1308.17
				150	1307.87	-	1307.66
				200	1307.60	-	1307.52
				300	1307.50	-	1307.50
10+700	1303	4.3	1306	10	**1306.92**	**1306.25**	**1306.84**
				50	**1305.50**	1303.51	**1305.15**
				100	**1304.17**	1303.01	1303.76
				150	1303.42	1303	1303.18
				200	1303.12	1303	1303.03
				300	1303.00	1303	1303
11+000	1301.5	4.1	1305	10	**1305.24**	**1304.60**	-
				50	**1303.89**	1301.99	-
				100	1302.61	1301.51	-
				150	1301.90	1301.50	-
				200	1301.61	1301.50	-
				300	1301.50	1301.50	-
11+550	1297.5	3.7	1302	10	**1300.87**	-	-
				50	1299.65	-	-
				100	1298.50	-	-
				150	1297.86	-	-
				200	1297.60	-	-
				300	1297.50	-	-
12+100	1293	4.0	1297.5	10	**1296.65**	-	-
				50	**1295.33**	-	-
				100	1294.08	-	-
				150	1293.39	-	-
				200	1293.11	-	-
				300	1293.00	-	-
12+450	1290.5	4.4	1294.5	10	**1294.51**	-	-
				50	**1293.06**	-	-
				100	1291.69	-	-
				150	1290.93	-	-

River Centerline Stationing (Figure 9)	Non-Flood River Level (masl)	Rise in River Level – 1:100 year flood (m)	Ground Surface Elevation (masl – approx.)	Distance (x) From River Flood Interface (m)	Phreatic Surface Elevation at 'x' (masl)		
					Base Case	Sensitivity Analysis	
					K = 8.0 x 10^{-4} m/s, S_y = 0.2, t = 3 d	Lower K K = 1 x 10^{-4} m/s	Less time (t = 2 d)
				200	1290.62	-	-
				300	1290.50	-	-
12+800	1287.1	4.2	1290.5	10	**1290.93**	-	-
				50	**1289.54**	-	-
				100	1288.24	-	-
				150	1287.51	-	-
				200	1287.21	-	-
				300	1287.10	-	-

Note: **bold type** = water table rise at or near ground surface (within 2.2m bgs) at given distance, x.

FIGURES



LEGEND

- HAMLET GROWTH AREA
- HAMLET EXPANSION AREA
- BRAGG CREEK PROVINCIAL PARK
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- LOCAL ROAD
- INDEFINITE WATERCOURSE
- WATERCOURSE
- INTERMITTENT WATERBODY
- WATERBODY

DRAFT

0 500 1,000

1:20,000 METRES

REFERENCE(S)

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PROJECTED COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N

CLIENT
ROCKY VIEW COUNTY

PROJECT
HYDROGEOLOGICAL DEVELOPMENT SUITABILITY STUDY
GREATER BRAGG CREEK

TITLE
PROJECT LOCATION

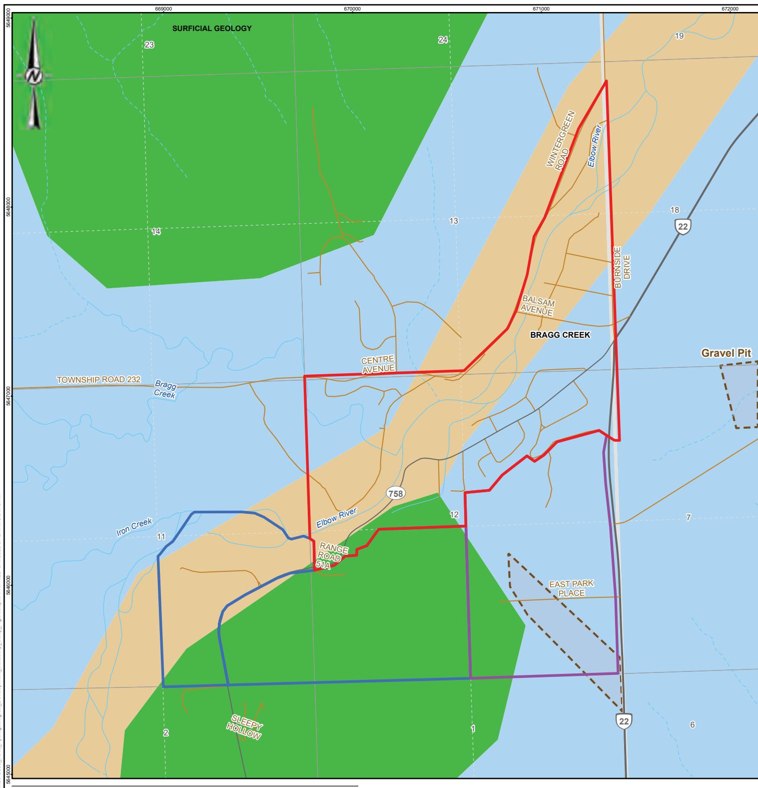
CONSULTANT

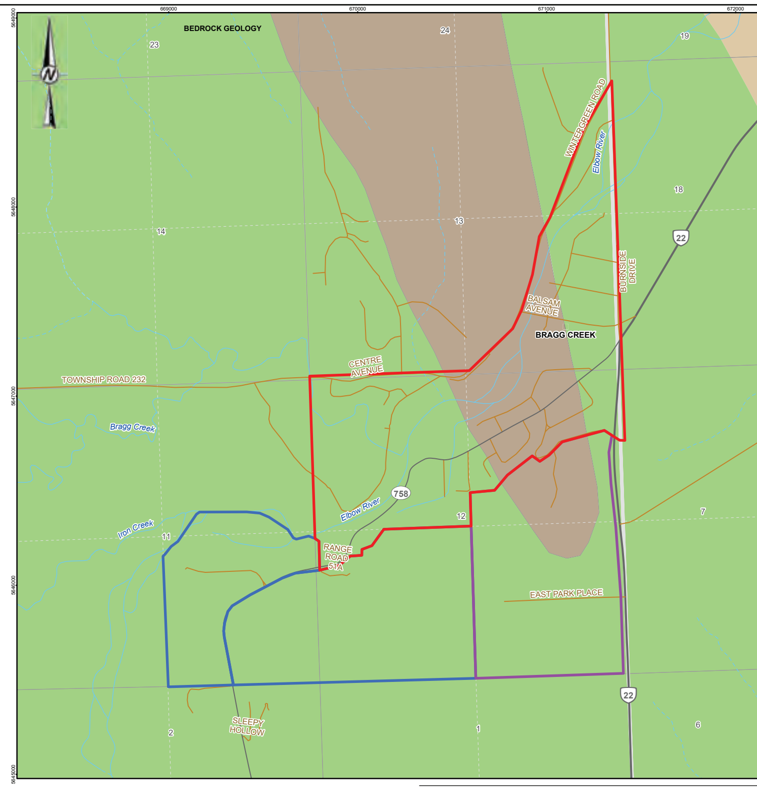
YYYY-MM-DD	2025-04-16
DESIGNED	NR
PREPARED	PMT
REVIEWED	
APPROVED	

PROJECT NO. CA0048988.7843 REV. A FIGURE 1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm





LEGEND

- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- LOCAL ROAD
- INDEFINITE WATERCOURSE
- WATERCOURSE
- HAMLET OF BRAGG CREEK
- HAMLET EXPANSION AREA
- BRAGG CREEK PROVINCIAL PARK

SURFICIAL GEOLOGY

- GLACIOLACUSTRINE DEPOSITS (LG)
- INFERRED EXTENT OF IDENTIFIED COARSE GRANULAR DEPOSITS
- FLUVIAL DEPOSITS (F)
- MORAINE (M)

BEDROCK GEOLOGY

- BRAZEAU FORMATION
- ALBERTA GROUP (WAPIABI FORMATION, CARDIUM FORMATION, BLACKSTONE FORMATION)
- LUSCAR, BLAIRMORE, BULLHEAD AND FORT ST. JOHN GROUPS

DRAFT

0 500 1,000

1:20,000 METRES

REFERENCE(S)

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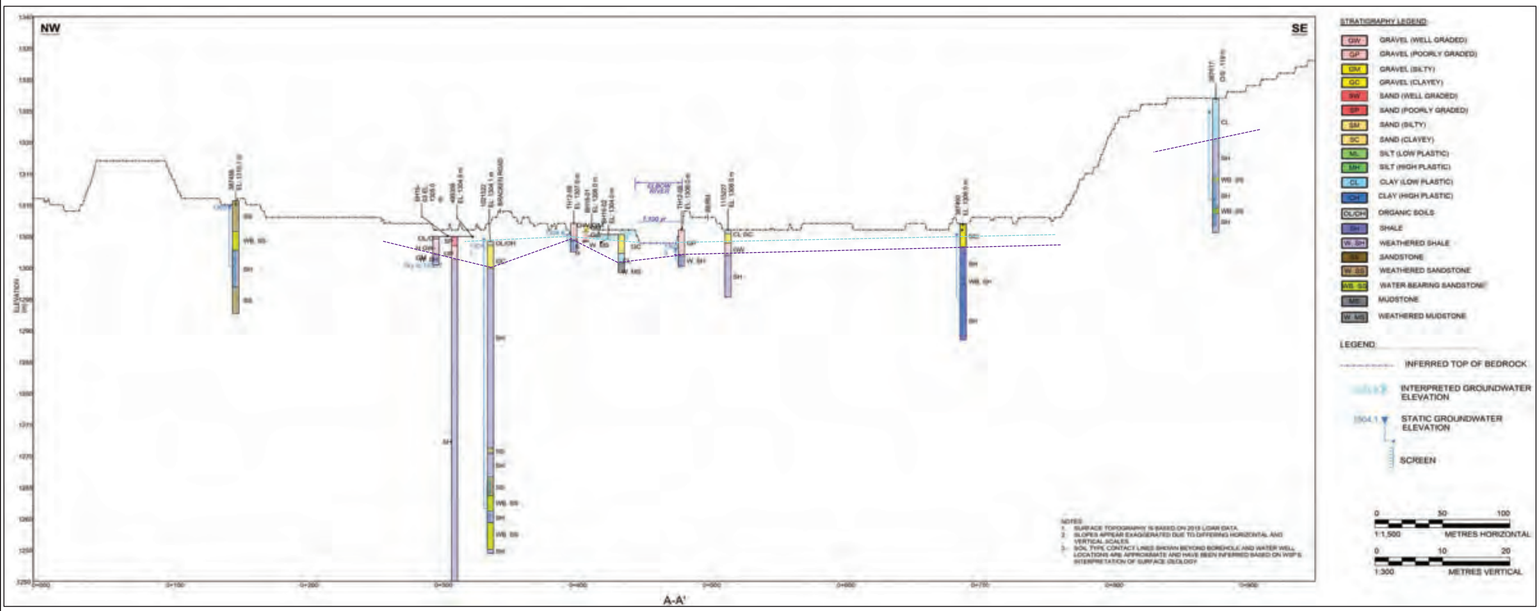
PROJECTED COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N

CLIENT	ROCKY VIEW COUNTY
PROJECT	HYDROGEOLOGICAL DEVELOPMENT SUITABILITY STUDY GREATER BRAGG CREEK
CONSULTANT	wsp
YYYY-MM-DD	2025-07-24
DESIGNED	NR
PREPARED	PMT
REVIEWED	
APPROVED	
TITLE	**BEDROCK AND SURFICIAL GEOLOGY**
PROJECT NO.	CA0048988.7843
REV.	A
FIGURE	2

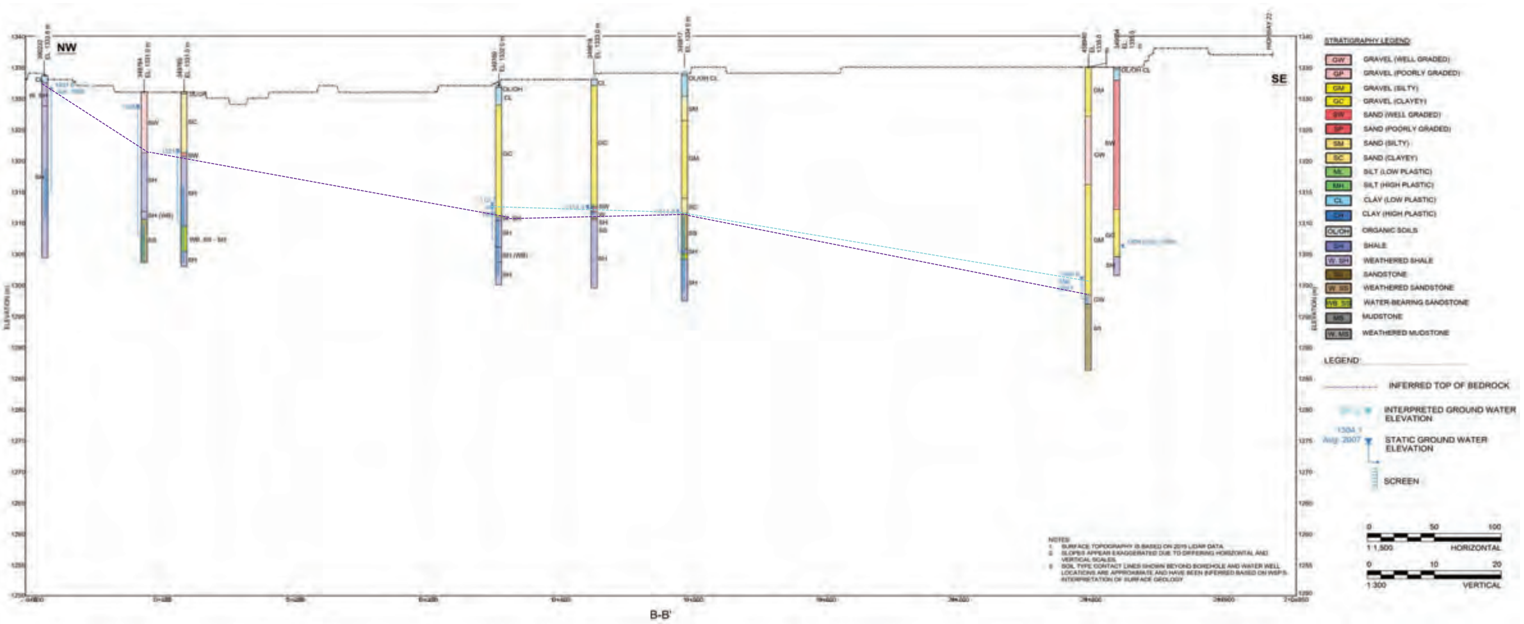
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

wsp	PROJECT: **Bragg Creek Hydrogeological Development Suitability**
CLIENT: **Rocky View County**	TITLE: **Airphoto Borehole Plan**

DATE:	JOB No.:	FILE:	FIGURE No.:	REV.
June 2025	CA0048988	Figure-Section Plan.xlsx	3	A



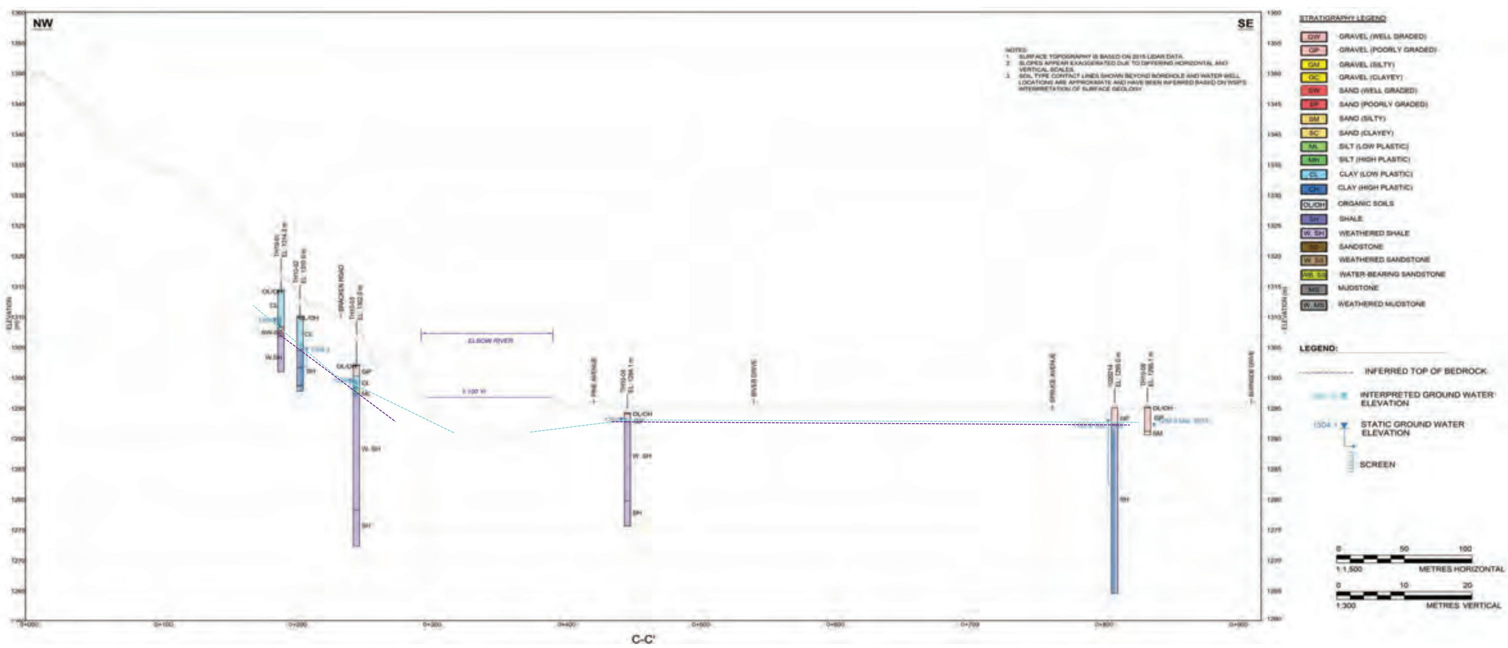
wsp		PROJECT: Bragg Creek Hydrogeological Study			
		TITLE: Cross-Section A-A'			
CLIENT: ROCKY VIEW COUNTY	DATE: July 2025	JOB No.: CA0048988	FILE: Cross-Sections_11x17_landscape.xlsx	FIGURE No.: 4	REV.: A



wsp

CLIENT: ROCKY VIEW COUNTY

PROJECT:	Bragg Creek Hydrogeological Study			
TITLE:	Cross-Section B-B'			
DATE: July 2025	JOB No.: CA0048988	FILE: Cross-Sections_11x17_landscape.xlsx	FIGURE No.: 5	REV.: A

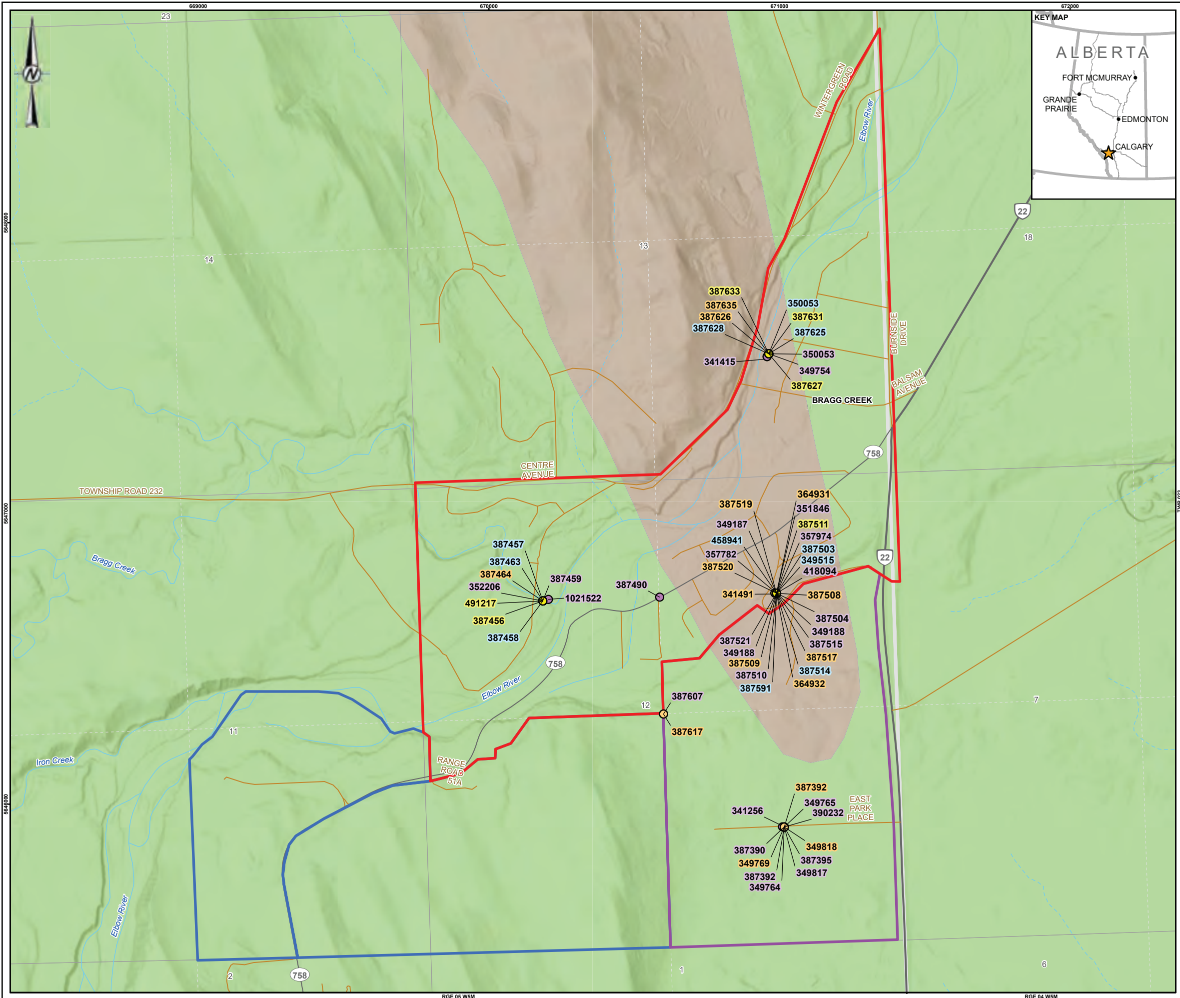


wsp

CLIENT:

ROCKY VIEW COUNTY

PROJECT:	**Bragg Creek Hydrogeological Study**			
TITLE:	**Cross-Section C-C'**			
DATE: July 2025	JOB No.: CA0048988	FILE: Cross-Sections_11x17_landscape.xlsx	FIGURE No.: 6	REV.: A



LEGEND

GROUNDWATER WELL - POST 1990 DEEPENED/NEW (RECOMMENDED RATE)

- 0.0 – 4.6 (L/min)
- 4.6 – 18.5 (L/min)
- 18.6 – 45.5 (L/min)
- 45.5 + (L/min)
- HAMLET OF BRAGG CREEK
- HAMLET EXPANSION AREA
- BRAGG CREEK PROVINCIAL PARK

BEDROCK GEOLOGY

- BRAZEAU FORMATION
- ALBERTA GROUP (WAPIABI FORMATION, CARDIUM FORMATION, BLACKSTONE FORMATION)
- LUSCAR, BLAIRMORE, BULLHEAD AND FORT ST. JOHN GROUPS

- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- INDEFINITE WATERCOURSE
- WATERCOURSE

DRAFT

0 300 600

1:13,000 METRES

REFERENCE(S)

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PROJECTED COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N

CLIENT
ROCKY VIEW COUNTY

PROJECT
HYDROGEOLOGICAL DEVELOPMENT SUITABILITY STUDY
GREATER BRAGG CREEK

TITLE
GROUNDWATER WELLS - RECOMMENDED RATES

CONSULTANT

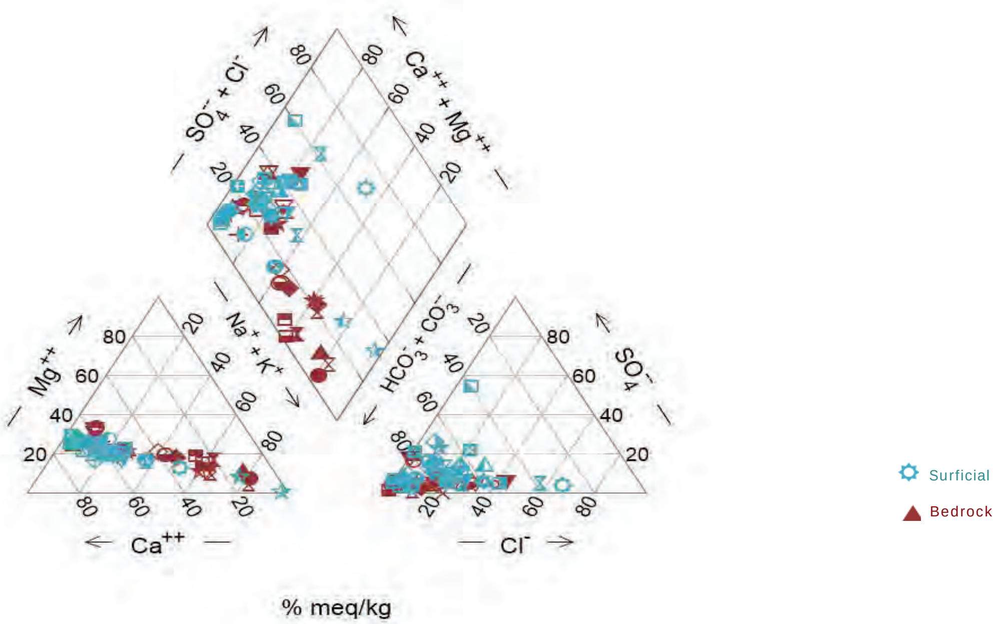
wsp

YYYY-MM-DD	2025-04-16
DESIGNED	NR
PREPARED	PMT
REVIEWED	
APPROVED	

PROJECT NO.	REV.	FIGURE
CA0048988.7843	A	7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm



LEGEND

NOTE(S)

REFERENCE
NA

CLIENT
Rocky View County

CONSULTANT

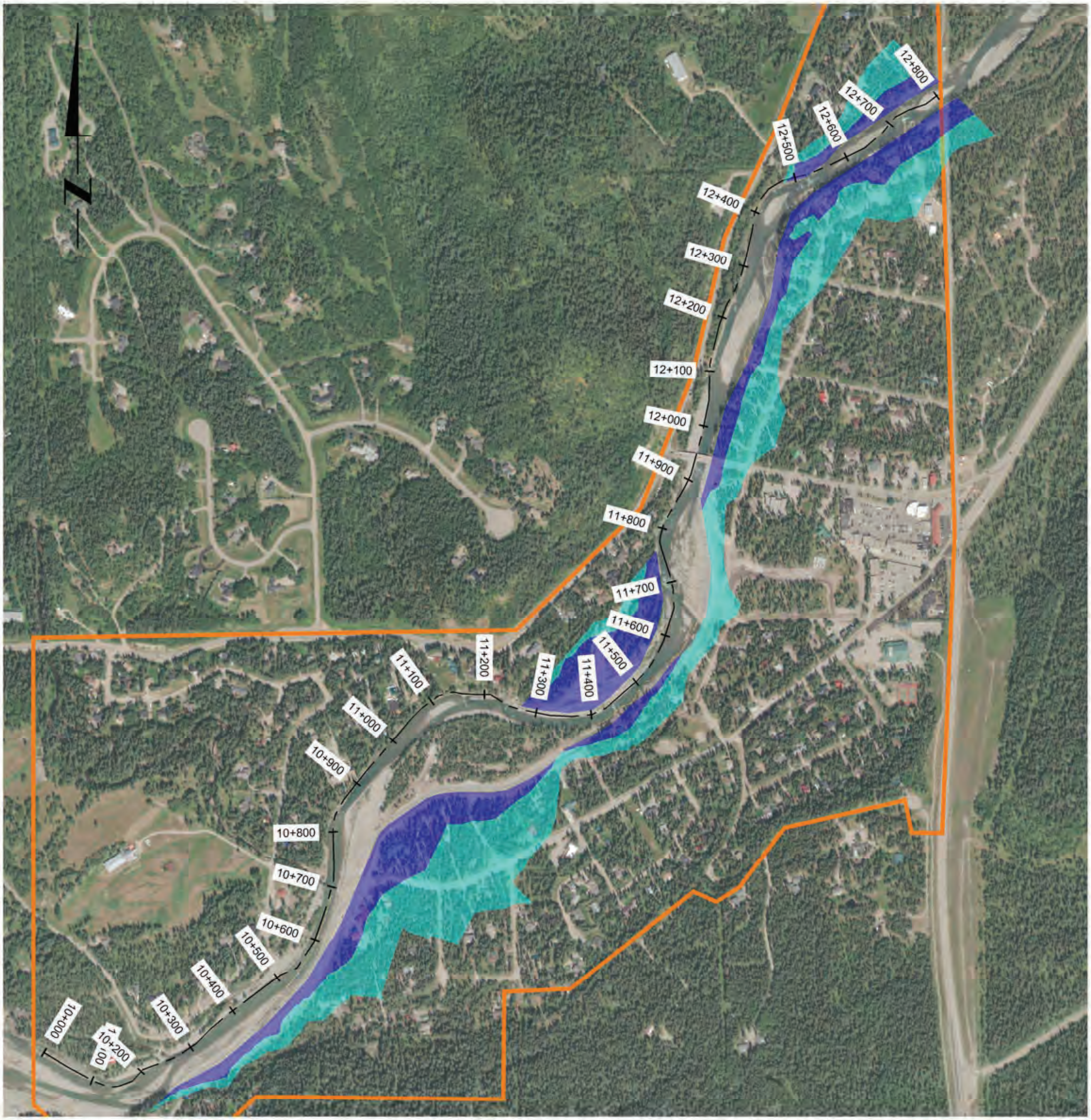
YYYY-MM-DD	2023-09-14
PREPARED	NR
DESIGN	NR
REVIEW	DP
APPROVED	DP

PROJECT
Hydrogeological Development Suitability Study Greater Bragg Creek

TITLE
Piper Plot - Shallow and Bedrock Aquifers

PROJECT No.	PHASE	Rev.	FIGURE
CA0048988.7843	2	A	8

File Name: C:\Users\wds_james.r.hughes\DC\ACCDocs\WSP Canada projects (AMER)\Canada Water-Small Projects\Project Files\CA0048988.7843 Bragg Creek Seepage\1 Deliverables\2 Figures\CA0048988.7843_FIG-01_E-0001.dwg Saved By: Hughes, James Plot Date: 250730 1:13 PM ANSI A 279mm x 216mm



LEGEND:

Potential Groundwater Daylighting - 1:100 year flood

Potential Seepage Impacts to Basements - 1:100 year flood

HAMLET GROWTH AREA

SCALE
1:10 000
0 100 200 m

DRAFT

wsp	PROJECT NAME BRAGG CREEK HYDROGEOLOGICAL DEVELOPMENT STUDY		PROJECT NUMBER CA0048988
CLIENT ROCKY VIEW COUNTY	SHEET TITLE Groundwater Seepage Assessment - 1:100 Year Flood		FIGURE NUMBER 9
			ISSUE/REVISION A

APPENDIX A

Water Well Reports

Alberta

Reconnaissance Report

View in Imperial

Export to Excel

Groundwater Wells

Please click the water Well ID to generate the Water Well Drilling Report.

GIC Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	CHM	LT	PT	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)	SC_DIA (cm)
341256	SE	12	23	5	5	AARON DRILLING INC.	1999-09-03	50.29	New Well	Domestic		11	5	DALRYMPLE, LORNE #3832	11.49	9.09	16.81
341415	SE	13	23	5	5	AARON DRILLING INC.	1998-06-08	12.19	Test Hole-Decommissioned	Domestic		4		HERRON EST	2.83	9.09	0.00
341416	SE	13	23	5	5	AARON DRILLING INC.	1998-06-08	12.19	Test Hole-Decommissioned	Domestic		6		HERRON EST	2.65	1.14	0.00
341491	NE	12	23	5	5	AARON DRILLING INC.	1999-03-31	24.38	New Well	Domestic		9	6	FRENCH, KIM #3696	11.89	22.73	16.81
349187	NE	12	23	5	5	AARON DRILLING INC.	1992-11-17	30.48	New Well-Decommissioned	Domestic		6		RUBEN, P. PALMER K.	10.67	6.82	16.81
349188	NE	12	23	5	5	AARON DRILLING INC.	1992-11-23	19.81	New Well	Domestic		7		RUBEN P/PALMER K.	9.75	18.18	16.81
349188	NE	12	23	5	5	AARON DRILLING INC.	1992-11-23	19.81	New Well	Domestic		7	7	RUBEN P/PALMER K.	9.75	18.18	16.81
349241	SE	13	23	5	5	AARON DRILLING INC.	1988-07-13	30.48	New Well-Decommissioned	Domestic		3		DON JOY MGMT			0.00
349515	NE	12	23	5	5	AARON DRILLING INC.	1987-02-09	12.19	Deepened	Domestic		2		MERRITT, CARL	3.05	2.27	16.81
349754	SE	13	23	5	5	AARON DRILLING INC.	1995-05-17	29.57	New Well	Domestic		7	33	CARRUTHERS, BARRY 2673	0.00	13.64	16.81
349764	SE	12	23	5	5	AARON DRILLING INC.	1995-06-05	27.43	New Well	Domestic		5	16	AVERY, SUSAN #2698	2.53	10.68	16.81
349765	SE	12	23	5	5	AARON DRILLING INC.	1995-06-01	28.04	New Well	Domestic		6	40	AVERY, SUSAN #2695	9.36	18.18	16.81
349769	SE	12	23	5	5	AARON DRILLING INC.	1995-06-29	32.00	New Well	Domestic		7	40	HARE,RICHARD #2723 SITE 3	19.29	36.37	16.81
349817	SE	12	23	5	5	AARON DRILLING INC.	1995-06-15	36.58	New Well	Domestic		14	16	HARR, RICHARD #2680	22.40	9.09	16.81
349818	SE	12	23	5	5	AARON DRILLING INC.	1995-07-28	33.53	New Well	Domestic		7	10	HARE, RICHARD #2747	20.70	22.73	16.81
349819	SE	12	23	5	5	AARON DRILLING INC.	1995-07-31	45.72	New Well-Decommissioned	Domestic		7		HARE,RICHARD #2733	21.03		16.81
349820	SE	12	23	5	5	AARON DRILLING INC.	1995-07-31	45.72	New Well-Decommissioned	Domestic		6		HARE, RICHARD #2716			16.81
349936	SE	13	23	5	5	AARON DRILLING INC.	1996-09-09	45.72	New Well-Decommissioned	Domestic		7		MOON, TOM #TH1	0.00		0.00
350053	SE	13	23	5	5	AARON DRILLING INC.	2016-08-30	89.92	Deepened	Domestic		6	18	MCHUGH, DAN	51.82	2.27	16.84
350053	SE	13	23	5	5	AARON DRILLING INC.	1998-01-30	67.06	New Well	Domestic		2	13	EATON, LES #3359	12.59	9.09	16.81

Reconnaissance Report

View in Imperial

Export to Excel

GIC Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	CHM	LT	PT	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)	SC_DIA (cm)
350053	SE	13	23	5	5	AARON DRILLING INC.	2007-09-10	71.63	Deepened	Domestic		2	1	MCHUGH, DAN	19.81	1.14	16.81
351846	NE	12	23	5	5	BAKER WATER WELLS	1990-07-07	32.00	New Well	Domestic		4		MCCLOY, TERRY	12.19	9.09	14.12
352206	NW	12	23	5	5	DOLOMITE DRILLING	1990-09-18	44.20	New Well	Domestic		12		EAGER, ALAN	3.05	13.64	16.81
354349	SE	12	23	5	5	UNKNOWN DRILLER		29.26	Chemistry	Domestic				PROUD, KELLY			0.00
357782	NE	12	23	5	5	KRIEGER DRILLING LTD.	1987-07-29	17.07	New Well	Domestic		5		ARCHER, CAREN/STEVE	2.44	13.64	16.81
357974	NE	12	23	5	5	AARON DRILLING INC.	1991-05-27	32.00	New Well	Domestic		5		SHOULTS, IDA # 1599	3.05	18.18	16.81
359886	1	13	23	5	5	ALBERTA SOUTHERN EXPLORATION DRILLING LTD.	1991-07-16	13.11	New Well	Domestic		2		THOMPSON, AL	2.44	54.55	16.81
361443	NE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				KLEPACKI, CYNTHIA R			0.00
361444	NE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				MAGEE, MIKE/JOANNE			0.00
363237	SE	13	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				BUCONJIC, APRIL/GORDAN			0.00
363666	NE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				BRISCO, STUART/PHILIPPA			0.00
364931	NE	12	23	5	5	WATKINS DRILLING	1992-06-05	18.90	New Well	Domestic		3	28	GLASSFORD, A.R.	11.58	27.28	16.81
364932	NE	12	23	5	5	WATKINS DRILLING	1992-05-14	15.24	New Well	Domestic		3	9	GLASSFORD, A.R.	10.97	36.37	16.81
379701	9	12	23	5	5	ALBERTA SOUTHERN EXPLORATION DRILLING LTD.	1995-10-18	13.41	New Well	Domestic		5	16	BUMSTEAD, BRIAN	3.51	9.09	16.81
387385	SE	12	23	5	5	UNKNOWN DRILLER		25.91	Chemistry	Domestic				NEUFELD, VIC	25.91		0.00
387389	SE	12	23	5	5	UNKNOWN DRILLER		60.96	Chemistry	Domestic				MACLELLAN, GLEN	33.53		0.00
387390	SE	12	23	5	5	DEL'S DRILLING	1970-11-01	19.81	New Well	Domestic		9		KLEIBER, W.	4.88	7.96	16.51
387392	SE	12	23	5	5	DEL'S DRILLING	1974-11-07	50.90	Deepened	Domestic		4		NEUFELD, VIC	17.98	9.09	15.88
387392	SE	12	23	5	5	DEL'S DRILLING	1974-11-07	50.90	Deepened	Domestic		4		NEUFELD, VIC	27.13	45.46	15.88
387395	SE	12	23	5	5	PARSONS DRLG	1968-06-06	28.96	New Well	Domestic		6		ALBERTSON	10.36	13.64	13.97

Alberta

Reconnaissance Report

View in Imperial

Export to Excel

GIC Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	CHM	LT	PT	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)	SC_DIA (cm)
387398	SE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				JARDINE, DAVID			0.00
387400	2	12	23	5	5	UNKNOWN DRILLER		6.10	Chemistry	Domestic				WILSON, VERN O.C.	6.10		0.00
387452	NW	12	23	5	5	UNKNOWN DRILLER		8.53	Chemistry	Unknown				WEBSTER, EARL	4.27		0.00
387453	NW	12	23	5	5	UNKNOWN DRILLER		19.51	Chemistry	Domestic				ELSDON, S.			0.00
387454	NW	12	23	5	5	UNKNOWN DRILLER		18.29	Chemistry	Unknown				ECHLIN, R.			0.00
387455	NW	12	23	5	5	PARSONS DRLG	1966-06-15	48.77	Dry Hole			3		ELKANA RANCH LTD			12.70
387456	NW	12	23	5	5	PARSONS DRLG	1966-09-07	5.18	New Well	Domestic		3		MCARUTHER, JAMES	1.52	113.65	15.57
387457	NW	12	23	5	5	ADAIR D	1967-09-08	36.58	Deepened	Domestic		2		MCKEAGUE, D.	6.10	2.27	0.00
387458	NW	12	23	5	5	ADAIR D	1968-06-11	16.76	New Well	Domestic		5		GRAVES, G.	1.22	2.27	0.00
387459	NW	12	23	5	5	DEL'S DRILLING	1977-07-05	17.07	New Well	Domestic		4		ELSDON	3.35	9.09	17.78
387460	NW	12	23	5	5	UNKNOWN DRILLER		3.05	Chemistry	Domestic				DOCKER, C.	2.44		0.00
387461	NW	12	23	5	5	DEL'S DRILLING	1979-06-27	18.29	Dry Hole	Domestic		4		PAREL, A.J.			0.00
387462	NW	12	23	5	5	DEL'S DRILLING	1979-06-28	27.43	Dry Hole	Domestic		3		KABATOFF, ALEC			0.00
387463	NW	12	23	5	5	DEL'S DRILLING	1979-07-31	33.53	New Well	Domestic		3		KABATOFF, ALEX	3.05	2.27	14.12
387464	NW	12	23	5	5	KRIEGER DRILLING LTD.	1981-11-02	12.50	New Well	Domestic		7		COCKING, JIM	4.57	43.19	14.12
387465	NW	12	23	5	5	UNKNOWN DRILLER		18.29	Chemistry	Domestic				WORKMAN, RHONDA			0.00
387466	NW	12	23	5	5	UNKNOWN DRILLER		10.67	Chemistry	Domestic				SUKOVIEFF, D.F.			0.00
387467	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				CLARK, KIMBERLEY			0.00
387468	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				BAVARIAN INN			0.00
387469	NW	12	23	5	5	UNKNOWN DRILLER		9.14	Chemistry	Domestic				PENMAN, CHERYL/DAVE			0.00

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387470	NW	12	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic				HIND, PETER			0.00
387471	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				MCKEAGUE, DOUG			0.00
387472	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				SPRING, G.			0.00
387473	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				EDWARDS, NORM/KATHLEEN			0.00
387474	NW	12	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic	1			WINNITOY, W.			0.00
387476	NW	12	23	5	5	UNKNOWN DRILLER		1.83	Chemistry	Domestic				MCDOUGALL, R.			0.00
387477	NW	12	23	5	5	UNKNOWN DRILLER		46.33	Chemistry	Domestic				VARADI, JOSEF			0.00
387478	NW	12	23	5	5	UNKNOWN DRILLER		3.05	Chemistry	Domestic				COULAN			0.00
387480	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				DUNFORD, J.			0.00
387482	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				HARTFORD, CRAIG			0.00
387483	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				PERRY, LINDA			0.00
387484	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				SIMMERLING, KARL/CAROL ANNE			0.00
387485	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Unknown				FORMAN, ELAINE/RAYMOND			0.00
387486	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Unknown				CLEASE, HELEN/DENNIS			0.00
387487	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Unknown				LINDSKOG, CHRISTIE			0.00
387488	11	12	23	5	5	UNKNOWN DRILLER		18.29	Chemistry	Domestic				RAVENHILL, ROY D.			0.00
387489	NH	12	23	5	5	UNKNOWN DRILLER		8.84	Chemistry	Domestic				KOZMA, JOHN	3.35		0.00
387490	NH	12	23	5	5	DEL'S DRILLING	1976-07-03	18.29	New Well	Domestic		4		KELLY, LAWRENCE	1.98	13.64	17.78
387491	NH	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				SHERIN, RICHARD D.			0.00
387492	NH	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				MCKINLEY			0.00

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387493	NH	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				REDMAN, D.			0.00
387494	NH	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				THE STEER INN			0.00
387495	NH	12	23	5	5	UNKNOWN DRILLER		10.67	Chemistry	Domestic				SUKCRIEFF, D.			0.00
387496	NH	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				PERROTT, STAN			0.00
387497	NE	12	23	5	5	ADAIR D	1968-05-21	30.48	New Well	Domestic		4		CANNIFF, ANDY	11.28		15.24
387498	NE	12	23	5	5	UNKNOWN DRILLER		3.96	Chemistry	Domestic				SHOULTS, GORDON			0.00
387499	NE	12	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic				JENSEN, ROBERT			0.00
387500	NE	12	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic				ADES, R.G.	3.20		0.00
387501	NE	12	23	5	5	UNKNOWN DRILLER		10.67	Chemistry	Domestic				KLOKEID, J.F.	1.83		0.00
387502	NE	12	23	5	5	UNKNOWN DRILLER		1.52	Chemistry	Domestic				KLOKEID, J.F.	0.76		0.00
387503	NE	12	23	5	5	ADAIR D	1968-06-04	18.29	New Well	Domestic		4		LOVE, H.G.	3.05	4.55	15.24
387504	NE	12	23	5	5	C.H. NELSON DRILLING LTD.	1975-06-11	12.19	New Well	Unknown		7		EARLY, JOHN	2.74	18.18	13.97
387505	NE	12	23	5	5	UNKNOWN DRILLER		16.76	Chemistry	Unknown				SYMES, W.E.	3.66		0.00
387506	NE	12	23	5	5	UNKNOWN DRILLER		9.75	Chemistry	Unknown				FULLERTON, STEVE	3.05		0.00
387507	NE	12	23	5	5	UNKNOWN DRILLER		5.18	Chemistry	Domestic				MCLENNAN, ROBERT	0.91		0.00
387508	NE	12	23	5	5	WATKINS DRILLING	1969-09-01	6.71	New Well-Decommissioned	Domestic		2		BISHOP, ROBIN	1.83	45.46	12.70
387509	NE	12	23	5	5	WATKINS DRILLING	1969-09-01	21.34	New Well	Domestic		4		BISHOP, ROBIN	2.13	45.46	12.70
387510	NE	12	23	5	5	OTHER	1972-06-01	11.89	New Well	Domestic		5		CHALLICE, C.	6.10	13.64	0.00
387511	NE	12	23	5	5	OTHER	1972-11-01	9.14	New Well	Domestic		4		B&G CONSTR	2.44	90.92	15.24
387512	NE	12	23	5	5	DEL'S DRILLING	1981-07-08	48.77	Dry Hole	Unknown		6		MCKEAQUE, D.K.			0.00

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387513	NE	12	23	5	5	UNKNOWN DRILLER		10.67	Chemistry	Domestic				EARLY, JOHN F.	3.66		0.00
387514	NE	12	23	5	5	DEL'S DRILLING	1977-03-07	34.75	New Well	Domestic		6		MCLENNAN, BOB	13.72	4.55	14.12
387515	NE	12	23	5	5	DEL'S DRILLING	1976-07-06	25.91	New Well	Domestic		6		BRAUN, ERV	4.88	10.23	14.12
387516	NE	12	23	5	5	UNKNOWN DRILLER		6.10	Chemistry	Domestic				KERS, MARIE	4.57		0.00
387517	NE	12	23	5	5	WARD E DRLG CO LTD	1979-07-08	21.34	New Well	Domestic		3		TRAVIS, STEVE	4.57	45.46	14.12
387518	NE	12	23	5	5	UNKNOWN DRILLER		18.29	Chemistry	Domestic				BALL, MARILYN			0.00
387519	NE	12	23	5	5	GOODISON WATER WELL DRILLING	1974-11-04	9.14	New Well	Domestic		2		NEWLANDS, B.	0.00	22.73	16.84
387520	NE	12	23	5	5	ZIEGLER BROS. DRILLING LTD.	1975-06-21	12.80	New Well	Domestic		3		KUNES, VUCLAV	3.05	31.82	11.43
387521	NE	12	23	5	5	KRIEGER DRILLING LTD.	1985-05-28	30.18	New Well	Domestic		11		MCARTHUR, ARNOLD	4.27	18.18	16.84
387586	NE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				DAVID, J.			0.00
387587	NE	12	23	5	5	UNKNOWN DRILLER		19.81	Chemistry	Domestic				HARDAGE, ROGER/VICKI			0.00
387589	NE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				MICHOR, A.			0.00
387590	NE	12	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				HOMESTEAD ANTIQUES			0.00
387591	NE	12	23	5	5	KRIEGER DRILLING LTD.	1987-07-28	28.96	Test Hole	Observation		8		ARCHER, STEVE #1	2.44	4.55	16.84
387593	NE	12	23	5	5	UNKNOWN DRILLER		12.19	Chemistry	Domestic				JANKE, ED			0.00
387594	NE	12	23	5	5	UNKNOWN DRILLER		9.14	Chemistry	Domestic				TREASURY BRANCH			0.00
387595	NE	12	23	5	5	UNKNOWN DRILLER		22.86	Chemistry	Domestic				DAVIDS, PERRY			0.00
387596	NE	12	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic				SWALES, M.	2.44		0.00
387597	NE	12	23	5	5	UNKNOWN DRILLER		70.10	Chemistry	Unknown				STUPNYCKYJ, LINDA/OLEH			0.00
387598	NE	12	23	5	5	ALBERTA SOUTHERN EXPLORATION DRILLING LTD.	1989-06-08	54.86	New Well	Domestic		21		DEFRAINE, BILL	0.00		16.84

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387601	10	12	23	5	5	UNKNOWN DRILLER		36.58	Chemistry	Domestic				GRIFFIN, E.D.	6.10		0.00
387605	SE	12	23	5	5	OTHER	1974-01-01	7.32	New Well	Domestic		5		B&G CONSTR			15.24
387607		12	23	5	5	GOODISON WATER WELL DRILLING	1975-03-04	31.09	New Well	Domestic		5		PEARMAIN, KEITH	2.80	18.18	0.00
387615	15	12	23	5	5	DEL'S DRILLING	1973-07-01	33.22	Dry Hole	Unknown		7		SHLAHT, ALF			0.00
387617	SE	12	23	5	5	DEL'S DRILLING	1975-02-26	21.34	New Well	Domestic		9		DICK, LEO	2.44	45.46	14.12
387619		12	23	5	5	UNKNOWN DRILLER		3.05	Chemistry	Domestic				BRAGG CREEK SHOPPING CENTRE			0.00
387620	SE	13	23	5	5	UNKNOWN DRILLER		2.74	Chemistry	Domestic				WHITE, R.H.	2.44		0.00
387621	SE	13	23	5	5	UNKNOWN DRILLER		30.48	Chemistry	Domestic				DEGROOT, H.			0.00
387623	SE	13	23	5	5	ADAIR D	1967-09-11	9.14	New Well	Unknown		2		KLINE, ROGER	3.35		16.84
387625	SE	13	23	5	5	OTHER	1974-01-01	10.06	New Well	Domestic		4		RICHTER, PAUL	3.05	4.55	15.88
387626	SE	13	23	5	5	DEL'S DRILLING	1970-11-01	11.28	New Well	Domestic		4		GRAHAM, E.	4.88	45.46	0.00
387627	SE	13	23	5	5	DEL'S DRILLING	1975-02-24	9.45	New Well	Domestic		3		TEGHTMEYER, ROB	3.35	68.19	0.00
387628	SE	13	23	5	5	ADAIR D	1967-09-20	21.34	New Well	Domestic		2		WRATHALL, G.M.	2.74	2.27	16.84
387631	SE	13	23	5	5	PARSONS, DELBERT	1971-06-01	34.14	New Well	Domestic		9		BLAKLY, W.E.	14.33	90.92	13.16
387633	SE	13	23	5	5	PARSONS, DELBERT	1971-04-01	8.84	New Well	Unknown		4		KOGMA, J.	3.35	113.65	12.40
387635	SE	13	23	5	5	WATKINS DRILLING	1970-11-01	6.40	New Well	Domestic		1		JONES, COLIN	3.66	27.28	15.24
387637	SE	13	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic				COX, HAROLD	2.44		0.00
387639	SE	13	23	5	5	UNKNOWN DRILLER		21.95	Chemistry	Domestic				BISHOP, R.E.	0.40		0.00
387641	SE	13	23	5	5	UNKNOWN DRILLER		12.19	Chemistry	Domestic				COX, HAROLD	3.05		0.00
387642	SE	13	23	5	5	UNKNOWN DRILLER		15.24	Chemistry	Domestic				MERRYFIELD, G.J.	4.88		0.00

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387644	SE	13	23	5	5	UNKNOWN DRILLER		22.86	Chemistry	Domestic				DUNFORD, J.O.H.	6.10		0.00
387645	1	13	23	5	5	DEL'S DRILLING	1981-02-01	28.04	New Well	Domestic		5		BRAGG CREEK TRADING POST	3.66	2.27	0.00
387646	SE	13	23	5	5	UNKNOWN DRILLER		6.10	Chemistry	Domestic				ELSDON, M.S.			0.00
387647	SE	13	23	5	5	UNKNOWN DRILLER		4.27	Chemistry	Domestic				MERRYFIELD			0.00
387649	SE	13	23	5	5	UNKNOWN DRILLER		3.66	Chemistry	Domestic				TEGHTMEYER, ROB L.			0.00
387650	SE	13	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				FUSSEL, H.			0.00
387652	SE	13	23	5	5	UNKNOWN DRILLER		0.00	Chemistry	Domestic				KING, TAMMY			0.00
387653	SE	13	23	5	5	UNKNOWN DRILLER		3.96	Chemistry	Domestic				NICHOL, E.			0.00
387660	SE	13	23	5	5	UNKNOWN DRILLER		3.05	Chemistry	Domestic				PIKE, BOB			0.00
387661	SE	13	23	5	5	UNKNOWN DRILLER		3.96	Chemistry	Domestic				RODGER, BRUCE			0.00
387663	SE	13	23	5	5	UNKNOWN DRILLER		60.96	Chemistry	Domestic				SHOULTS, H.			0.00
389410	15	12	23	5	5	UNKNOWN DRILLER		6.10	Chemistry	Domestic	1			GIBSON, DEBBIE			0.00
389420	SE	12	23	5	5	UNKNOWN DRILLER		24.38	Chemistry	Domestic	1			BAR-B-QUE STEAK PIT	15.24		0.00
390232	SE	12	23	5	5	PARSONS DRILLING	1968-06-21	29.26	New Well	Domestic		3		LERNER, DENNIS	3.35	9.09	0.00
394246	SE	13	23	5	5	UNKNOWN DRILLER		4.57	Chemistry	Domestic	1			PERRY, R.T.			0.00
418094	NE	12	23	5	5	INTERPROVINCIAL DRILLING CONTRACTORS	1974-05-27	12.19	New Well	Domestic	2	5		RIDLEY, HAROLD	2.44	6.82	15.24
458941	NE	12	23	5	5	AARON DRILLING INC.	2001-10-10	36.58	Deepened	Domestic		7		HOLSCHUH, CHARLIE#3338	3.35	2.27	16.81
465414	NW	12	23	5	5	UNKNOWN DRILLER		0.00	Spring	Municipal				REID, CROWTHER & PARTNERS LTD			0.00
491217	NW	12	23	5	5	BAKER WATER WELLS	1998-07-14	24.38	New Well	Domestic		5	22	DEAN, DON	1.52	90.92	16.81
494766	NE	12	23	5	5	ALKEN BASIN DRILLING LTD.	1999-11-16	24.38	Test Hole-Decommissioned	Domestic		4		MILLS, ROBERT			0.00

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499358	NW	12	23	5	5	ALKEN BASIN DRILLING LTD.	2001-08-28	30.48	Test Hole-Decommissioned	Domestic		2		ODELL, RANDY			0.00
499359	NW	12	23	5	5	ALKEN BASIN DRILLING LTD.	2001-08-28	60.96	Test Hole-Decommissioned	Domestic		3		ODELL, RANDY			0.00
1020214	1	13	23	5	5	DEL'S REGIONAL DRILLING	1998-09-30	30.48	New Well	Domestic		5	2	RENAUD, ALAIN	2.41	11.37	16.81
1020215	SE	13	23	5	5	AARON DRILLING INC.	2005-07-26	30.48	Existing Well-Decommissioned	Domestic		1		DOMANIC OILFIELD SERV	2.44		
1021522	NW	12	23	5	5	AARON DRILLING INC.	2007-08-07	49.68	New Well	Domestic		20	13	MCKEAGUE, DOUG	0.00	18.18	16.81
1022408	15	12	23	5	5	AARON DRILLING INC.	2014-02-10		Existing Well-Decommissioned	Unknown				SHEPERD, BILL			16.81
1022750	9	13	23	5	5	AARON DRILLING INC.	2016-05-24	65.53	New Well	Domestic		19	7	WAKEFIELD, DAVE & IRIS	16.52	4.55	16.84
1022840	9	13	23	5	5	AARON DRILLING INC.	2016-11-13	149.96	Dry Hole-Decommissioned	Unknown		21		LENNOX, PAIGE			
1023283	16	12	23	5	5	AARON DRILLING INC.			Existing Well-Decommissioned	Unknown				KING MAKER DEVELOPMENTS			
1023312	15	12	23	5	5	AARON DRILLING INC.			Existing Well-Decommissioned	Unknown				KINGMAKER DEVELOPMENTS			
1023313	16	12	23	5	5	AARON DRILLING INC.			Existing Well-Decommissioned	Unknown				KINGMAKER DEVELOPMENTS			
1023314	SE	12	23	5	5	AARON DRILLING INC.			Existing Well-Decommissioned	Unknown				KING MAKER DEVELOPMENTS			
1023374	16	12	23	5	5	AARON DRILLING INC.			Existing Well-Decommissioned	Unknown				KING MAKER DEVELOPMENTS			
1115227	NW	12	23	5	5	BAKER WATER WELLS	2011-09-22	10.67	Dry Hole-Decommissioned	Domestic		4		RIVERSIDE CHATEAU			
1611155	16	12	23	5	5	PETER NIEMANS WATER WELL DRILLING	2022-09-05	28.96	New Well	Domestic		6	26	FRENCH, KIM	11.40	34.10	16.84
2066214	14	12	23	5	5	WELL DONE WATERWELLS INC.	2018-10-25	53.34	New Well	Domestic		6	26	MACALLISTER, EDITH	2.32	27.28	16.83
2095057	SE	12	23	5	5	UNKNOWNDRILLINGCOMP11	1961-07-01	21.34	Well Inventory	Domestic & Stock		1		MASCH, KLAUS	21.34		
2096008	NE	12	23	5	5	UNKNOWNDRILLINGCOMP11		3.66	Well Inventory	Domestic		1		MCAUTHUR, ARNOLD G.			
9546320	14	12	23	5	5	AQUACLEAR DRILLING INC.	2017-09-03	41.15	New Well	Domestic		7	18	MINTY, DEV	2.83	6.82	16.81

APPENDIX B

Groundwater Chemistry

Appendix B - Groundwater Chemistry 2001-2004

SampleID	Date	Source	WellDepth	Alkalinity	Bicarbonat	Calcium	Carbonate	Chloride	Conductivity	Fluoride	Hardness	Hydroxide	Magnesium	Nitrate	Nitrite	pH	Potassium	Iron	Sodium	Sulfate	TDS	Latitude	Longitude	STRM
T017733	28-Aug-02	Well	100	304.4	371.3	91.37	0	13.3	602	0.1	310.55	0	20.01	1.5	0	7.73	1.41	0.18	6.62	14.6	331.46	50.943148	-114.571721	S12T23R5M5
T017619	7-Oct-02	Well	45	350.9	428.1	113.1	0	102.1	1045	0.2	371.52	0	21.64	3.4	0	7.93	4.5	0.22	62.67	34.6	552.69	50.943148	-114.571721	S12T23R5M5
T017670	6-Mar-03	Well	30	311.2	379.7	119.9	0	19.9	843	0.4	418.32	0	28.88	0.1	0	8.08	1.67	0.05	21.73	113.5	492.76	50.943148	-114.571721	S12T23R5M5
T031474	8-Jan-04	Well	29	276.3	337.1	160.1	0	292.8	1544	0.2	550.57	0	36.62	0	0	8.16	12.38	0.0078	81.95	30.4	780.16	50.943148	-114.571721	S12T23R5M5
T000015	10-Feb-02	Well	10	240.1	292.9	3.1	0	23.4	679	0.3	10.83	0	0.75	0.07	0	8.14	0.15	0.11	163.5	79.5	414.82	50.957696	-114.571717	S13T23R5M5
T002890	16-Jul-02	Well	10	377.2	460.2	125.3	0	46	955	0.2	427.73	0	27.89	2	0	7.95	2.26	0	34.71	67.9	532.52	50.957696	-114.571717	S13T23R5M5
T017584	25-Nov-02	Well	74	304.1	371	80.98	0	47	766	0.08	287.99	0	20.83	0	0	8.11	1.07	0.98	46.19	27.8	406.36	50.957696	-114.571717	S13T23R5M5
T017624	4-Dec-02	Well	160	318.1	354.4	14.9	16.5	2.1	615	1.9	60.97	0	5.77	0.46	0	8.63	0.81	0.5	126.7	10.8	354.29	50.957696	-114.571717	S13T23R5M5
T023258	24-Jan-03	Well	75	354.5	406	18.02	13	11.5	709	1	85.12	0	9.74	0	0	8.52	0.77	0.03	132.2	24.1	409.98	50.957696	-114.571717	S13T23R5M5
T024061	8-May-03	Well	56	358.7	437.6	86.61	0	22.9	732	0.8	321.97	0	25.67	0.06	0	8.03	1.68	0.61	30.3	16.8	400.01	50.957696	-114.571717	S13T23R5M5
T031534	24-Feb-04	Well	6	267.1	325.9	120.47	0	108	1048	0.3	397.55	0	23.49	9.3	0	8.04	3.22	0.2	56.61	62.8	544.43	50.957696	-114.571717	S13T23R5M5

Appendix B - Groundwater Quality - 2004-2006

SampleID	Date	Source	WellDepth	Alkalinity	Bicarbonate	Calcium	Carbonate	Chloride	Conductivity	Fluoride	Hardness	Hydroxide	Magnesium	Nitrate	Nitrite	pH	Potassium	Iron	Sodium	Sulfate	TDS	Latitude	Longitude	STRM
T041651	30-Apr-04	Well	10	306.5	373.9	112.3	0	60.5	822	0.2	372.86	0	22.45	0.3	-0.03	8.2	1.64	-0.01	31.5	41.4	454.14	50.943148	-114.571721	S12T23R5M5
T050758	3-Nov-04	Well	6	233.2	284.5	80.85	0	24.6	594	0.2	281.36	0	19.3	0.3	-0.03	8.01	1.21	0.31	15.71	46.4	328.46	50.943148	-114.571721	S12T23R5M5
T047230	3-Jun-05	Well	70	259.1	316.1	109.1	0	157.1	1072	0.2	382.95	0	26.84	4.1	-0.03	8.23	2.57	0.03	51.56	30.6	537.58	50.943148	-114.571721	S12T23R5M5
T052549	21-Sep-05	Well	17	379.4	462.8	105.1	0	108.2	1102	0.1	348.91	0	21	3.7	-0.03	8.02	4.42	-0.01	95.18	22.9	588.21	50.943148	-114.571721	S12T23R5M5
T062871	24-Nov-05	Well	90	271.6	327.7	42.65	1.8	28.6	595	0.3	161.1	0	13.26	-0.23	-0.03	8.3	0.86	0.05	69.42	8.6	326.63	50.943148	-114.571721	S12T23R5M5
T063518	16-Oct-06	Well	25	384.5	469.1	32.69	0	87.1	1043	0.5	127.62	0	11.17	-0.23	-0.03	8.1	1.09	0.02	201.1	24.9	589.31	50.943148	-114.571721	S12T23R5M5
T075388	7-Nov-06	Well	15	268.8	298	79.57	14.8	1	503	0.2	276.93	0	19	-0.23	-0.03	8.56	1.1	0.21	6.79	12.6	281.56	50.943148	-114.571721	S12T23R5M5
T031598	18-May-04	Well	65	359.4	438.5	114.1	0	58.4	901	0.7	430.97	0	35.47	-0.23	-0.03	8.06	1.43	0.11	25.92	46.4	498.09	50.957696	-114.571717	S13T23R5M5
T053923	23-Aug-05	Well	120	309.1	344.4	25.61	16.1	4.5	600	0.5	117.4	0	12.98	-0.23	-0.03	8.6	7.66	0.14	88.4	14.4	339.57	50.957696	-114.571717	S13T23R5M5
T063552	3-Apr-06	Well	-50	294.8	359.7	418.6	0	1507.5	5280	-0.1	1523.76	0	116.2	-0.23	-0.03	8.06	5.64	3.75	471.8	114.3	2810.93	50.957696	-114.571717	S13T23R5M5
T064199	3-Apr-06	Well	74	298.8	364.5	84.39	0	63	800	0.1	297.74	0	21.13	-0.23	0.1	8.12	1.32	0.05	51.12	22.5	422.96	50.957696	-114.571717	S13T23R5M5
T063790	11-Jun-06	Well	26	353	430.6	117.7	0	44	872	0.1	405.12	0	27.01	1.3	-0.03	8.11	2.55	0.04	29.18	48.3	482	50.957696	-114.571717	S13T23R5M5

Appendix B - Groundwater Chemistry - 2007 -2009

SampleID	Date	Source	WellDepth	Alkalinity	Bicarbonate	Calcium	Carbonate	Chloride	Conductivity	Fluoride	Hardness	Hydroxide	Magnesium	Nitrate	Nitrite	pH	Potassium	Iron	Sodium	Sulfate	TDS	Latitude	Longitude	STRM
T075430	23-Jan-07	Well	7	268.4	327.5	79.48	0	1.1	531	0.2	273.7	0	18.27	-0.23	-0.03	7.66	1.23	-0.01	7.01	18.3	286.57	50.943148	-114.571721	S12T23R5M5
T082730	28-Jan-08	Well	12	268.1	327.1	184.4	0	29.9	1193	0.2	637.31	0	42.95	1.7	-0.03	8.08	3.38	-0.01	22.89	348.7	795.01	50.943148	-114.571721	S12T23R5M5
T086275	16-Apr-08	Well	10	254.8	310.8	80.05	0	8.7	546	0.2	280.97	0	19.69	-0.23	-0.03	8.04	0.67	-0.01	8.21	26.5	296.94	50.943148	-114.571721	S12T23R5M5
T053999	23-Apr-08	Well	50	323.7	394.9	105.5	0	10.4	640	0.1	355.96	0	22.47	0.5	-0.03	8.15	2.03	0.02	5.91	10	351.08	50.943148	-114.571721	S12T23R5M5
T086274	27-May-08	Well	10	187.8	229.1	57.66	0	5	403	0.2	202.95	0	14.32	-0.23	-0.03	8.06	0.55	-0.01	4.8	15.9	211.18	50.943148	-114.571721	S12T23R5M5
T098724	14-Nov-08	Well	43	320.7	391.3	105.2	0	64.7	847	0.4	350.93	0	21.43	2.4	-0.03	7.84	5.5	2.9	45.2	24.3	461.55	50.943148	-114.571721	S12T23R5M5
T098851	22-Jan-09	Well	16	328.7	401	153.7	0	521	2280	0.3	519.64	0	32.99	9.7	-0.03	8.14	5.14	-0.01	257.7	38.6	1216.33	50.943148	-114.571721	S12T23R5M5
T085844	13-May-09	Well	10	272.5	332.4	115.5	0	114	889	0.3	379.91	0	22.22	1	-0.03	8.25	1.68	-0.01	40.54	24.6	483.29	50.943148	-114.571721	S12T23R5M5
T079835	3-Jun-07	Well	-50	292.1	356.4	80.97	0	-1	611	0.9	296.03	0	22.79	-0.23	-0.03	7.9	1.43	0.02	13.47	36.6	331.79	50.957696	-114.571717	S13T23R5M5
T082518	6-Sep-07	Well	25	350.1	427.1	141.2	0	40	919	0.1	477.15	0	30.25	1.5	-0.03	8.14	2.67	0.03	39.88	76.4	542.04	50.957696	-114.571717	S13T23R5M5
T085843	8-Feb-08	Well	-50	379.3	462.7	122.8	0	56.2	918	0.1	409.09	0	24.88	-0.23	-0.03	8.26	3.59	0.03	30.35	25.4	491.01	50.957696	-114.571717	S13T23R5M5
T065070	16-Jun-08	Well	105	389.8	475.6	54.73	0	80	974	0.2	206.46	0	16.95	-0.23	-0.03	8.14	0.74	0.01	150	-1	537.1	50.957696	-114.571717	S13T23R5M5
T075414	11-Aug-09	Well	80	364.8	445.1	91.46	0	10.9	711	0.8	329.31	0	24.51	0.3	-0.03	8.14	1.53	0.13	25.91	22	396.29	50.957696	-114.571717	S13T23R5M5

Appendix B - Groundwater Chemistry - 2010-2012

SampleID	Date	Source	WellDepth	Alkalinity	Bicarbonate	Calcium	Carbonate	Chloride	Conductivity	Fluoride	Hardness	Hydroxide	Magnesium	Nitrate	Nitrite	pH	Potassium	Iron	Sodium	Sulfate	TDS	Latitude	Longitude	STRM
T107478	11-Jan-10	Well	-50	267.3	326.2	126.5	0	209.5	1290	0.2	421.09	0	25.55	8	-0.03	8.28	4.3	-0.01	79.55	48.5	662.49	50.943148	-114.571721	S12T23R5M5
T115396	10-May-10	Well	120	336	385.6	35.35	12	6.2	621	0.5	151.64	0	15.39	-0.23	-0.03	8.5	1.34	0.2	84.26	10.3	355.23	50.957696	-114.571717	S13T23R5M5
T110532	27-May-10	Well	82	284.8	347.4	77.38	0	7.5	634	0.7	305.97	0	27.38	-0.23	-0.03	8.03	9.52	0.58	9.87	55.1	358.33	50.957696	-114.571717	S13T23R5M5
T125625	15-Nov-10	Well	-50	236.8	288.9	67.3	0	13.9	506	-0.1	254.69	0	21.04	0.8	-0.03	7.88	1.9	0.01	6.12	8.5	261.65	50.943148	-114.571721	S12T23R5M5
T125568	14-Mar-11	Well	74	305	372.1	92.11	0	90.1	856	-0.1	327.72	0	23.73	-0.23	-0.03	8.26	1.3	0.04	54.98	19.9	465.49	50.957696	-114.571717	S13T23R5M5
T115440	13-Apr-11	Well	39	313.4	382.4	97.96	0	22.4	656	-0.1	332.11	0	21.25	0.7	-0.03	8.13	1.78	0.02	6.95	9.7	348.86	50.943148	-114.571721	S12T23R5M5
T115386	18-Apr-11	Well	85	282.4	344.5	79.19	0	1.1	621	0.7	310.98	0	27.5	-0.23	-0.03	8.23	1.57	2.47	14.16	61.4	355.06	50.957696	-114.571717	S13T23R5M5
T119002	20-Apr-11	Well	-50	357	416.6	-0.1	9.3	7.2	704	0.9	0.33	0	-0.1	-0.23	-0.03	8.53	0.4	0.02	170.8	12.4	405.99	50.957696	-114.571717	S13T23R5M5
T115382	21-May-11	Well	30	228.8	279.1	50.42	0	15.7	511	0.2	170.62	0	10.86	0.3	-0.03	7.95	6.72	-0.01	42.48	18	282.01	50.943148	-114.571721	S12T23R5M5
T109243	10-Jun-11	Well	-50	267.5	326.3	90.9	0	71	793	0.2	326.8	0	24.24	-0.23	-0.03	8.22	1.23	0.15	41.05	31.8	421.01	50.943148	-114.571721	S12T23R5M5
T126753	12-Jun-12	Well	20	161.5	194.4	58.63	1.3	1.3	383	0.3	208.52	0	15.08	-0.23	-0.03	8.33	0.56	-0.01	2.13	40.3	215.27	50.943148	-114.571721	S12T23R5M5

Appendix B - Groundwater Chemistry - 2013-2015

SampleID	Date	Source	WellDepth	Alkalinity	Bicarbonate	Calcium	Carbonate	Chloride	Conductivity	Fluoride	Hardness	Hydroxide	Magnesium	Nitrate	Nitrite	pH	Potassium	Iron	Sodium	Sulfate	TDS	Latitude	Longitude	STRM	Well ID
T156851	8-Jan-13	Well	165	383.6	468	52.6	0	62	898	0.2	183.96	0	12.77	-0.23	-0.03	7.89	1.02	0.14	146.49	20.3	525.48	50.943148	-114.571721	S12T23R5M5	U
T134146	21-Jan-13	Well	160	411.2	499.2	50.06	1.2	59.7	897	0.2	171.79	0	11.36	-0.23	-0.03	8.3	1.13	0.9	147.44	19.7	536.29	50.943148	-114.571721	S12T23R5M5	U
T156840	28-Feb-13	Well	10	285.8	348.7	117.53	0	78	920	0.2	401.08	0	26.13	3.8	-0.03	8.25	2.86	0.01	48.51	104.1	552.62	50.957696	-114.571717	S13T23R5M5	U
T150802	4-Mar-13	Well	26	343.8	419.5	112.66	0	30.4	777	0.2	381.23	0	24.26	1	-0.03	8.16	2.29	-0.01	29.6	68.1	474.78	50.957696	-114.571717	S13T23R5M5	U
T150868	29-Apr-13	Well	-50	309.1	377.1	118.95	0	53.1	903	0.2	413.5	0	28.29	2.5	-0.03	8.26	3.17	-0.01	37.64	95.6	524.86	50.957696	-114.571717	S13T23R5M5	U
T152756	15-Jul-13	Well	-50	297.9	363.4	110.23	0	61.4	774	-0.1	361.9	0	21.04	-0.23	-0.03	8.09	2.29	-0.01	50.34	17.7	441.75	50.957696	-114.571717	S13T23R5M5	U
T162288	28-Jan-14	Well	160	349.4	412.3	59.28	6.9	51.2	824	0.2	206.12	0	14.11	-0.23	-0.03	8.41	1.1	0.05	145.54	21.5	502.52	50.943148	-114.571721	S12T23R5M5	U
T162318	19-Feb-14	Well	15	301.5	348.5	107.77	9.5	59.3	792	0.2	357.19	0	21.39	3.5	-0.03	8.47	5.92	-0.01	37.44	23.5	439.87	50.943148	-114.571721	S12T23R5M5	U
T162580	2-Apr-14	Well	130	370.2	435.3	40.48	8	2.4	661	0.7	161.97	0	14.78	-0.23	-0.03	8.43	1.36	0.06	108.91	3.5	394.28	50.943148	-114.571721	S12T23R5M5	U
T163568	16-Jun-14	Well	-50	324.3	395.6	31.29	0	9.7	631	0.2	110.66	0	7.9	0.6	-0.03	8.23	1.18	-0.01	117.66	10.2	373.19	50.943148	-114.571721	S12T23R5M5	U
T163547	18-Aug-14	Well	115	356.5	429.9	58.69	2.5	30	726	0.2	223.2	0	18.62	-0.23	-0.03	8.32	0.58	0.31	78.98	13.5	414.46	50.957696	-114.571717	S13T23R5M5	U
T150828	30-Sep-14	Well	50	429.4	523.8	190.2	0	104.9	1249	0.2	596.75	0	29.58	2.1	-0.03	7.7	4.26	-0.01	55.29	85.2	729.34	50.957696	-114.571717	S13T23R5M5	U
T161541	12-May-15	Well	10	328.4	400.7	139.37	0	86	897	0.2	456.23	0	26.28	0.6	-0.03	8.05	2.02	-0.01	24.15	44.9	520.65	50.943148	-114.571721	S12T23R5M5	U
T139027	22-Jun-15	Well	100	377.9	461	139.94	0	129	1158	0.7	511.16	0	39.27	0.3	-0.03	7.87	0.63	0.02	27.88	31.2	595.63	50.957696	-114.571717	S13T23R5M5	U
T139045	10-Aug-15	Well	74	294.8	359.7	110.97	0	93.9	873	0.1	373.11	0	23.32	-0.23	-0.03	7.8	5.2	-0.01	54.39	22.7	487.68	50.957696	-114.571717	S13T23R5M5	U

Appendix B - Groundwater Chemistry 2016-2018

SampleID	Date	Source	WellDepth	Alkalinity	Bicarbonate	Calcium	Carbonate	Chloride	Conductivity	Fluoride	Hardness	Hydroxide	Magnesium	Nitrate	Nitrite	pH	Potassium	Iron	Sodium	Sulfate	TDS	Latitude	Longitude	STRM	Well ID
T176835	16-Dec-15	Well	-50	361	440	83.8	0	2.6	706	0.4	337	0	31.1	-0.23	-0.03	8.1	1.3	0.24	39.6	30	405	50.943148	-114.571721	S12T23R5M5	U
T180597	25-Jan-16	Well	75	311	380	112	0	46.7	773	0.2	379	0	24.5	2.4	-0.03	8.1	1.7	-0.01	32.4	23.6	430	50.943148	-114.571721	S12T23R5M5	U
T139097	21-Mar-16	Well	115	333	406	59.8	0	26.1	733	0.1	225	0	18.4	-0.23	-0.03	8.1	0.59	0.16	78.2	11.6	395	50.957696	-114.571717	S13T23R5M5	350901
T190402	25-Apr-16	Well	8	325	396	116	0	55.4	900	0.2	392	0	25.1	2.2	-0.03	8	3.1	-0.01	31.8	59.1	487	50.957696	-114.571717	S13T23R5M5	U
T220769	11-Jul-16	Well	-50	220	269	90.6	0	3.4	556	0.3	305	0	19.1	0.3	-0.03	8	0.62	-0.01	2.8	73.8	323	50.943148	-114.571721	S12T23R5M5	U
T201833	6-Sep-16	Well	10	424	518	148	0	57.9	1030	0.2	501	0	32.1	1.2	-0.03	7.8	3.1	0.03	39.8	55.9	592	50.957696	-114.571717	S13T23R5M5	U
T207335	10-Apr-17	Well	14	231	282	89	0	128	882	0.1	322	0	24.1	-0.23	-0.03	8.2	1.3	0.02	51.6	18.7	452	50.957696	-114.571717	S13T23R5M5	U
T221306	30-May-17	Well	90	298	357	96.9	3.3	23.5	659	0.12	327	0	20.6	1.1	-0.03	8.3	1.8	0.06	8.8	15.6	347	50.943148	-114.571721	S12T23R5M5	U
T194280	26-Jun-17	Well	100	378	461	154	0	139	1175	0.6	589	0	49.4	-0.23	-0.03	8.2	0.53	0.04	31.7	30.2	633	50.957696	-114.571717	S13T23R5M5	U
T201765	24-Jul-17	Well	10	298	364	101	0	26	724	0.31	356	0	25.3	0.53	0.04	8.2	1.5	0.05	27.5	62.2	423	50.943148	-114.571721	S12T23R5M5	U
T150799	24-Oct-17	Well	120	276	315	59.6	10.5	23.5	607	0.33	227	0	19	-0.23	-0.03	8.6	1.3	0.04	68.8	17.1	355	50.957696	-114.571717	S13T23R5M5	1020257
T198753	13-Aug-18	Well	74	285	348	120	0	145	1017	-0.1	404	0	25.6	-0.23	-0.03	8.3	1.4	-0.01	54.6	19.9	538	50.957696	-114.571717	S13T23R5M5	U
T193134	28-Sep-18	Well	12	323	391	123	1.5	79	966	0.26	408	0	24.5	1	-0.03	8.3	2	0.01	45.1	69	537	50.943148	-114.571721	S12T23R5M5	U
T223650	5-Nov-18	Well	175	345	398	20.7	11.5	27.1	726	0.58	67.8	0	3.9	-0.23	-0.03	8.6	0.58	1.3	151	1.7	412	50.943148	-114.571721	S12T23R5M5	2066214

APPENDIX C

Analytical Calculations

Project: Bragg Creek
Location: Section 10+150

River Elev. = **1307.5**

Unsteady one-dimensional flow **Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.**

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$
$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$
$E_1 = erfc(u)$ $E_2 = e^{-u^2}$
$s = S_o*E_1$ $q = q_o*E_2$

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	10
b(m)=	4	x_2(m)=	20
S_y=	0.2	x_3(m)=	30
S_o(m)=	3.8	x_4(m)=	**50** *
t(day)=	3	x_5(m)=	75
q_o =	**0.00010653** m³/s		**9.20439** m³/d

				Head Change (s_n at distance x_n)		Elev.			Seepage rate per metre			
										m³/s	m³/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1=	3.467754	**1310.968**	E_2=	0.99399	q_1=	0.000105892	9.149069741	6.353521
u_2=	0.155282498	E_1=	0.826181	s_2=	3.139486	**1310.639**	E_2=	0.976176	q_2=	0.000103994	8.985100592	6.239653
u_3=	0.232923748	E_1=	0.74185	s_3=	2.819032	**1310.319**	E_2=	0.947192	q_3=	0.000100907	8.718322956	6.054391
u_4=	0.388206246	E_1=	0.583001	s_4=	2.215404	**1309.715**	E_2=	0.860102	q_4=	9.16286E-05	7.916714474	5.497718
u_5=	0.582309369	E_1=	0.410218	s_5=	1.558829	**1309.059**	E_2=	0.712422	q_5=	7.5896E-05	6.557413021	4.553759

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	100
b(m)=	4	x_2(m)=	150
S_y=	0.2	x_3(m)=	200
S_o(m)=	3.8	x_4(m)=	**300** *
t(day)=	3	x_5(m)=	400
q_o =	**0.00010653**		**9.20439** m³/d

				Head Change (s_n at distance x_n)					Seepage rate per metre			
										m³/s	m³/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1=	1.034355	**1308.534**	E_2=	0.547268	q_1=	5.83017E-05	5.037268707	3.498103
u_2=	1.164618738	E_1=	0.099554	s_2=	0.378305	**1307.878**	E_2=	0.257603	q_2=	2.7443E-05	2.371075298	1.64658
u_3=	1.552824984	E_1=	0.02809	s_3=	0.106742	**1307.607**	E_2=	0.089702	q_3=	9.55613E-06	0.825649391	0.573368
u_4=	2.329237477	E_1=	0.000988	s_4=	0.003753	**1307.504**	E_2=	0.004404	q_4=	4.69119E-07	0.040531864	0.028147
u_5=	3.105649969	E_1=	1.12E-05	s_5=	4.27E-05	**1307.5**	E_2=	6.47E-05	q_5=	6.89738E-09	0.000595934	0.000414

Project: Bragg Creek
Location: Section 10+700

River Elev. = 1303

Unsteady one-dimensional flow

Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$
$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$
$E_1 = erfc(u)$ $E_2 = e^{-u^{\wedge}2}$
$s = S_o*E_1$ $q = q_o*E_2$

Parameters		Distance	
K(m/s)=	8.00E-04	x_1(m)=	10
b(m)=	4	x_2(m)=	20
S_y=	0.2	x_3(m)=	30
S_o(m)=	4.3	x_4(m)=	**50** *
t(day)=	3	x_5(m)=	75

q_o = 0.00012055 m^3/s 10.4155 m^3/d

				Head Change (s_n at distance x_n)	Elev.			Seepage rate per metre m^3/s	m^3/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1= 3.924038	**1306.924**	E_2=	0.99399	q_1= 0.000119825	10.35289471	7.18951
u_2=	0.155282498	E_1=	0.826181	s_2= 3.552577	**1306.553**	E_2=	0.976176	q_2= 0.000117678	10.16735067	7.06066
u_3=	0.232923748	E_1=	0.74185	s_3= 3.189957	**1306.19**	E_2=	0.947192	q_3= 0.000114184	9.865470713	6.851021
u_4=	0.388206246	E_1=	0.583001	s_4= 2.506904	**1305.507**	E_2=	0.860102	q_4= 0.000103685	8.958387431	6.221102
u_5=	0.582309369	E_1=	0.410218	s_5= 1.763938	**1304.764**	E_2=	0.712422	q_5= 8.58823E-05	7.420230524	5.152938

Parameters		Distance	
K(m/s)=	8.00E-04	x_1(m)=	100
b(m)=	4	x_2(m)=	150
S_y=	0.2	x_3(m)=	200
S_o(m)=	4.3	x_4(m)=	300
t(day)=	3	x_5(m)=	400

q_o = 0.00012055 10.4155 m^3/d

				Head Change (s_n at distance x_n)				Seepage rate per metre m^3/s	m^3/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1= 1.170455	**1304.17**	E_2=	0.547268	q_1= 6.5973E-05	5.700067222	3.95838
u_2=	1.164618738	E_1=	0.099554	s_2= 0.428082	**1303.428**	E_2=	0.257603	q_2= 3.10539E-05	2.68305889	1.863235
u_3=	1.552824984	E_1=	0.02809	s_3= 0.120787	**1303.121**	E_2=	0.089702	q_3= 1.08135E-05	0.934287468	0.648811
u_4=	2.329237477	E_1=	0.000988	s_4= 0.004247	**1303.004**	E_2=	0.004404	q_4= 5.30845E-07	0.045865004	0.031851
u_5=	3.105649969	E_1=	1.12E-05	s_5= 4.83E-05	**1303**	E_2=	6.47E-05	q_5= 7.80493E-09	0.000674346	0.000468

Project: Bragg Creek
Location: Section 11+000

River Elev. = **1301.5**

Unsteady one-dimensional flow **Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.**

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$

$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$

$E_1 = erfc(u)$ $E_2 = e^{-u^2}$

$s = S_o*E_1$ $q = q_o*E_2$

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	10
b(m)=	4	x_2(m)=	20
S_y=	0.2	x_3(m)=	30
S_o(m)=	4.1	x_4(m)=	**50** *
t(day)=	3	x_5(m)=	75

q_o = **0.00011494 m³/s** **9.93105 m³/d**

				Head Change (s_n at distance x_n)		Elev.			Seepage rate per metre			
										m³/s	m³/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1=	3.741525	**1305.242**	E_2=	0.99399	q_1=	0.000114252	9.871364721	6.855114
u_2=	0.155282498	E_1=	0.826181	s_2=	3.387341	**1304.887**	E_2=	0.976176	q_2=	0.000112204	9.694450639	6.732257
u_3=	0.232923748	E_1=	0.74185	s_3=	3.041587	**1304.542**	E_2=	0.947192	q_3=	0.000108873	9.40661161	6.532369
u_4=	0.388206246	E_1=	0.583001	s_4=	2.390304	**1303.89**	E_2=	0.860102	q_4=	9.88625E-05	8.541718248	5.931749
u_5=	0.582309369	E_1=	0.410218	s_5=	1.681894	**1303.182**	E_2=	0.712422	q_5=	8.18878E-05	7.075103523	4.913266

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	100
b(m)=	4	x_2(m)=	150
S_y=	0.2	x_3(m)=	200
S_o(m)=	4.1	x_4(m)=	300
t(day)=	3	x_5(m)=	400

q_o = **0.00011494** **9.93105 m³/d**

				Head Change (s_n at distance x_n)					Seepage rate per metre			
										m³/s	m³/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1=	1.116015	**1302.616**	E_2=	0.547268	q_1=	6.29045E-05	5.434947816	3.774269
u_2=	1.164618738	E_1=	0.099554	s_2=	0.408171	**1301.908**	E_2=	0.257603	q_2=	2.96096E-05	2.558265453	1.776573
u_3=	1.552824984	E_1=	0.02809	s_3=	0.115169	**1301.615**	E_2=	0.089702	q_3=	1.03106E-05	0.890832237	0.618633
u_4=	2.329237477	E_1=	0.000988	s_4=	0.004049	**1301.504**	E_2=	0.004404	q_4=	5.06154E-07	0.043731748	0.030369
u_5=	3.105649969	E_1=	1.12E-05	s_5=	4.6E-05	**1301.5**	E_2=	6.47E-05	q_5=	7.44191E-09	0.000642981	0.000447

Project: Bragg Creek
Location: Section 11+550

River Elev. = **1297.5**

Unsteady one-dimensional flow **Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.**

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$
$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$
$E_1 = erfc(u)$ $E_2 = e^{-u^{\wedge}2}$
$s = S_o*E_1$ $q = q_o*E_2$

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	10
b(m)=	4	x_2(m)=	20
S_y=	0.2	x_3(m)=	30
S_o(m)=	3.7	x_4(m)=	**50** *
t(day)=	3	x_5(m)=	75

q_o = 0.00010373 m^3/s **8.96217 m^3/d**

				Head Change (s_n at distance x_n)		Elev.			Seepage rate per metre		
									m^3/s	m^3/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1=	3.376498	**1300.876**	E_2=	0.99399	q_1= 0.000103105	8.908304748	6.186323
u_2=	0.155282498	E_1=	0.826181	s_2=	3.056868	**1300.557**	E_2=	0.976176	q_2= 0.000101258	8.748650577	6.075452
u_3=	0.232923748	E_1=	0.74185	s_3=	2.744846	**1300.245**	E_2=	0.947192	q_3= 9.82511E-05	8.488893405	5.895065
u_4=	0.388206246	E_1=	0.583001	s_4=	2.157104	**1299.657**	E_2=	0.860102	q_4= 8.92174E-05	7.708379882	5.353042
u_5=	0.582309369	E_1=	0.410218	s_5=	1.517807	**1299.018**	E_2=	0.712422	q_5= 7.38987E-05	6.384849521	4.433923

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	100
b(m)=	4	x_2(m)=	150
S_y=	0.2	x_3(m)=	200
S_o(m)=	3.7	x_4(m)=	300
t(day)=	3	x_5(m)=	400

q_o = 0.00010373 **8.96217 m^3/d**

				Head Change (s_n at distance x_n)					Seepage rate per metre		
									m^3/s	m^3/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1=	1.007135	**1298.507**	E_2=	0.547268	q_1= 5.67675E-05	4.904709005	3.406048
u_2=	1.164618738	E_1=	0.099554	s_2=	0.36835	**1297.868**	E_2=	0.257603	q_2= 2.67208E-05	2.30867858	1.603249
u_3=	1.552824984	E_1=	0.02809	s_3=	0.103933	**1297.604**	E_2=	0.089702	q_3= 9.30465E-06	0.803921775	0.558279
u_4=	2.329237477	E_1=	0.000988	s_4=	0.003654	**1297.504**	E_2=	0.004404	q_4= 4.56774E-07	0.039465236	0.027406
u_5=	3.105649969	E_1=	1.12E-05	s_5=	4.15E-05	**1297.5**	E_2=	6.47E-05	q_5= 6.71587E-09	0.000580251	0.000403

Project: Bragg Creek
Location: Section 12+100

River Elev. = **1293**

Unsteady one-dimensional flow

Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$

$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$

$E_1 = erfc(u)$ $E_2 = e^{-u^{\wedge}2}$

$s = S_o*E_1$ $q = q_o*E_2$

Parameters		**Distance**		
K(m/s)=	8.00E-04	x_1(m)=	10	
b(m)=	4	x_2(m)=	20	
S_y=	0.2	x_3(m)=	30	
S_o(m)=	4	x_4(m)=	**50**	*
t(day)=	3	x_5(m)=	75	

q_o = 0.00011214 m^3/s **9.68883 m^3/d**

				Head Change (s_n at distance x_n)		**Elev.**			**Seepage rate per metre** m^3/s	m^3/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1=	3.650268	**1296.65**	E_2=	0.99399	q_1= 0.000111465	9.630599728	6.687916
u_2=	0.155282498	E_1=	0.826181	s_2=	3.304723	**1296.305**	E_2=	0.976176	q_2= 0.000109468	9.458000624	6.568056
u_3=	0.232923748	E_1=	0.74185	s_3=	2.967402	**1295.967**	E_2=	0.947192	q_3= 0.000106217	9.177182059	6.373043
u_4=	0.388206246	E_1=	0.583001	s_4=	2.332004	**1295.332**	E_2=	0.860102	q_4= 9.64512E-05	8.333383657	5.787072
u_5=	0.582309369	E_1=	0.410218	s_5=	1.640873	**1294.641**	E_2=	0.712422	q_5= 7.98905E-05	6.902540023	4.793431

Parameters		**Distance**		
K(m/s)=	8.00E-04	x_1(m)=	100	
b(m)=	4	x_2(m)=	150	
S_y=	0.2	x_3(m)=	200	
S_o(m)=	4	x_4(m)=	**300**	*
t(day)=	3	x_5(m)=	400	

q_o = 0.00011214 **9.68883 m^3/d**

				Head Change (s_n at distance x_n)					**Seepage rate per metre** m^3/s	m^3/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1=	1.088795	**1294.089**	E_2=	0.547268	q_1= 6.13702E-05	5.302388113	3.682214
u_2=	1.164618738	E_1=	0.099554	s_2=	0.398216	**1293.398**	E_2=	0.257603	q_2= 2.88874E-05	2.495868735	1.733242
u_3=	1.552824984	E_1=	0.02809	s_3=	0.11236	**1293.112**	E_2=	0.089702	q_3= 1.00591E-05	0.869104622	0.603545
u_4=	2.329237477	E_1=	0.000988	s_4=	0.00395	**1293.004**	E_2=	0.004404	q_4= 4.93809E-07	0.04266512	0.029629
u_5=	3.105649969	E_1=	1.12E-05	s_5=	4.49E-05	**1293**	E_2=	6.47E-05	q_5= 7.2604E-09	0.000627298	0.000436

Project: Bragg Creek
Location: Section 12+450

River Elev. = **1290.5**

Unsteady one-dimensional flow **Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.**

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$
$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$
$E_1 = erfc(u)$ $E_2 = e^{-u^2}$
$s = S_o*E_1$ $q = q_o*E_2$

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	10
b(m)=	4	x_2(m)=	20
S_y=	0.2	x_3(m)=	30
S_o(m)=	4.4	x_4(m)=	**50** *
t(day)=	3	x_5(m)=	75

q_o = 0.00012335 m^3/s 10.6577 m^3/d

				Head Change (s_n at distance x_n)		**Elev.**			**Seepage rate per metre**		
									m^3/s	m^3/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1=	4.015295	**1294.515**	E_2=	0.99399	q_1= 0.000122612	10.5936597	7.356708
u_2=	0.155282498	E_1=	0.826181	s_2=	3.635195	**1294.135**	E_2=	0.976176	q_2= 0.000120414	10.40380069	7.224862
u_3=	0.232923748	E_1=	0.74185	s_3=	3.264142	**1293.764**	E_2=	0.947192	q_3= 0.000116839	10.09490026	7.010347
u_4=	0.388206246	E_1=	0.583001	s_4=	2.565204	**1293.065**	E_2=	0.860102	q_4= 0.000106096	9.166722022	6.365779
u_5=	0.582309369	E_1=	0.410218	s_5=	1.80496	**1292.305**	E_2=	0.712422	q_5= 8.78796E-05	7.592794025	5.272774

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	100
b(m)=	4	x_2(m)=	150
S_y=	0.2	x_3(m)=	200
S_o(m)=	4.4	x_4(m)=	300
t(day)=	3	x_5(m)=	400

q_o = 0.00012335 10.6577 m^3/d

				Head Change (s_n at distance x_n)					**Seepage rate per metre**		
									m^3/s	m^3/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1=	1.197675	**1291.698**	E_2=	0.547268	q_1= 6.75073E-05	5.832626924	4.050435
u_2=	1.164618738	E_1=	0.099554	s_2=	0.438038	**1290.938**	E_2=	0.257603	q_2= 3.17761E-05	2.745455608	1.906566
u_3=	1.552824984	E_1=	0.02809	s_3=	0.123596	**1290.624**	E_2=	0.089702	q_3= 1.1065E-05	0.956015084	0.663899
u_4=	2.329237477	E_1=	0.000988	s_4=	0.004345	**1290.504**	E_2=	0.004404	q_4= 5.4319E-07	0.046931632	0.032591
u_5=	3.105649969	E_1=	1.12E-05	s_5=	4.94E-05	**1290.5**	E_2=	6.47E-05	q_5= 7.98644E-09	0.000690028	0.000479

Project: Bragg Creek
Location: Section 12+800 (NW and SE sides)

River Elev. = **1287.1**

Unsteady one-dimensional flow **Huisman, L. and T.N. Olsthoorn (1983) *Artificial Groundwater Recharge*. Pittman: London. 320pp.**

$u = 0.5*(sqrt(S_y/Kb))*(x/sqrt(t))$
$q_o = (s_o/sqrt(\pi)) * (sqrt(S_y*K*b))*(1/sqrt(t))$
$E_1 = erfc(u)$ $E_2 = e^{-u^2}$
$s = S_o*E_1$ $q = q_o*E_2$

Parameters		**Distance**		
K(m/s)=	8.00E-04	x_1(m)=	10	
b(m)=	4	x_2(m)=	20	
S_y=	0.2	x_3(m)=	30	
S_o(m)=	4.2	x_4(m)=	**50**	*
t(day)=	3	x_5(m)=	75	

q_o = 0.00011775 m^3/s **10.1733 m^3/d**

				Head Change (s_n at distance x_n)		**Elev.**			**Seepage rate per metre**			
										m^3/s	m^3/d	L/min
u_1=	0.077641249	E_1=	0.912567	s_1=	3.832781	**1290.933**	E_2=	0.99399	q_1=	0.000117039	10.11212971	7.022312
u_2=	0.155282498	E_1=	0.826181	s_2=	3.469959	**1290.57**	E_2=	0.976176	q_2=	0.000114941	9.930900655	6.896459
u_3=	0.232923748	E_1=	0.74185	s_3=	3.115772	**1290.216**	E_2=	0.947192	q_3=	0.000111528	9.636041162	6.691695
u_4=	0.388206246	E_1=	0.583001	s_4=	2.448604	**1289.549**	E_2=	0.860102	q_4=	0.000101274	8.750052839	6.076426
u_5=	0.582309369	E_1=	0.410218	s_5=	1.722916	**1288.823**	E_2=	0.712422	q_5=	8.3885E-05	7.247667024	5.033102

Parameters		**Distance**	
K(m/s)=	8.00E-04	x_1(m)=	100
b(m)=	4	x_2(m)=	150
S_y=	0.2	x_3(m)=	200
S_o(m)=	4.2	x_4(m)=	300
t(day)=	3	x_5(m)=	400

q_o = 0.00011775 **10.1733 m^3/d**

				Head Change (s_n at distance x_n)					**Seepage rate per metre**			
										m^3/s	m^3/d	L/min
u_1=	0.776412492	E_1=	0.272199	s_1=	1.143235	**1288.243**	E_2=	0.547268	q_1=	6.44387E-05	5.567507519	3.866325
u_2=	1.164618738	E_1=	0.099554	s_2=	0.418127	**1287.518**	E_2=	0.257603	q_2=	3.03317E-05	2.620662172	1.819904
u_3=	1.552824984	E_1=	0.02809	s_3=	0.117978	**1287.218**	E_2=	0.089702	q_3=	1.0562E-05	0.912559853	0.633722
u_4=	2.329237477	E_1=	0.000988	s_4=	0.004148	**1287.104**	E_2=	0.004404	q_4=	5.185E-07	0.044798376	0.03111
u_5=	3.105649969	E_1=	1.12E-05	s_5=	4.72E-05	**1287.1**	E_2=	6.47E-05	q_5=	7.62342E-09	0.000658663	0.000457

wsp.com

APPENDIX
Stormwater Management Report Submission Requirements

D

Report Template #1:
Stormwater Management Report

Subdivision (SB) # __________

Outline Plan # ____-____ or DP # ____-____

Prepared for:
Name of client developer / landowner

This template applies to both subdivision (public systems) and DSSP (private systems) submissions, and to conventional submissions without Source Control Practices. Not all information and tables will be relevant for all submissions. The consultant is responsible to ensure that all applicable information relevant to the design has been included.

Please provide the report with reinforced, plasticized or plastic front and back covers. The binding shall be cerlox; spiral bound reports or reports in binders will be returned.

A digital version (Word document) of this template can be obtained from _________________.

Name of consultant
Address of consultant
E-mail address of consultant

Date

Consultant file number

Add plastic sleeve for future correspondence

Add relevant checklists

- Checklist #2: Development Site Servicing Plan (DSSP) and
- Checklist #3: Subdivision Stormwater Management Report (SWMR).
- Checklist #4: XP-SWMM Models.
- Checklist for Oil/Grit Separators.

Add cover letter

- Highlight in cover letter unresolved issues or areas where guidelines cannot be met.
- Explicitly state that all details conform to the City of Calgary Standard Specifications and Stormwater Management Design Manual, or explicitly state items that have to be addressed prior to report approval.

Consider including a (Executive) Summary for reports describing complex systems.

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

Give a brief introduction for the report:

- In support of design drawings for subdivision or DSSP approval.
- Outline Plan #____-____, SB # ___________ or DP #____-____.
- Name of the project and phase.
- Client developer/landowner.
- Land location (legal description).
- **Figure 1** (8½ x 11) showing site location within City of Calgary, showing major roadways.
- State overall objectives.

Example:

1. *Peak flows in the storm sewers are to be controlled to allowable limits based on design flows and capacities of individual segments.*

2. *Overland flows are to be in accordance with Alberta Environment's guidelines (January 1999) with respect to ponding depths and flow velocities in streets.*

2.0 SITE DESCRIPTION AND DESIGN CRITERIA

Description of the study area:

- **Figure 2** (8½ x 11 or 11 x 17) showing the overall study area boundary, site phase boundary and adjacent phases – identifying section numbers and major roadways.
- **Figure 3** showing catchment boundaries in relationship to site phase boundary. Also show contours of adjacent properties.
- Type of development (residential, industrial, commercial, etc.).
- Future external development areas included in the study area, if applicable.
- Total site area, including external areas.
- Identify overland drainage direction, downstream storm ponds and outfalls.

  Also show contours/grades of adjacent properties.
- Identify all stormwater quality treatment facilities or Source Control Practices in this phase or development.

2.1 Design Objectives

Reference the relevant MDP report or previous SWM reports for adjacent phases that provide the basis for setting the objectives.

State the site specific design objectives:

- Criterion used for sizing the minor system (e.g. Unit Area Release Rate method or Rational Method).
- Allowable minor system discharges from upstream areas into previous, now downstream phases (**Table 1**).
- Allowable overland spill from upstream areas into previous, now downstream phases (**Table 2**).
- State if non-surcharge conditions are used or if surcharge is allowed with justification.
- Overland flow depths and velocities to meet depth-velocity criterion (**Table 3**).
- Identify water quality objectives.

Table 1 Minor System Boundary Conditions – Inflows into previous phases

Location	Manhole Number	Area Size (ha)	Flow Rate		Runoff Volume		HGL (m)	Design Storm	Source of Information
			(L/s)	(L/s/ha)	(m^3)	(mm)			

Table 2 Major System Boundary Conditions – Inflows into previous phases

Location	Area Size (ha)	Flow Rate		Runoff Volume		Design Storm (type and duration)	Source of Information
		(L/s)	(L/s/ha)	(m^3)	(mm)		

Table 3 Permissible Depth and Velocities of Overland Flow

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

For non-serviced sites (with Deferred Servicing Agreements) the report shall address both interim (e.g., with an evaporation pond) and ultimate development scenarios.

For linear roadway, projects (e.g. for TI), the report shall address both short-term and long-term, full build-out scenarios to ensure that the drainage system has adequate flexibility to allow for future widening.

For roadways, clearly identify the relationship with adjacent lands, e.g., show contours/grades, low- and high-point elevations, and line assignments.

3.0 ANALYSIS METHODOLOGY AND DATA

3.1 Design Storm

Describe the design storm used:

- Example: 1:100 year event, Chicago distribution (Appendix 2).

3.2 Computer Model

Describe the computer model used:

- Example: SWMHYMO, DDSWMM, XPSWMM, QHM, etc.
- Dual Drainage (major-minor) system approach.
- Reference the User's Manual.
- Reference model input and output data appended to the report.

  Hardcopy to be provided in the Appendix.

The numbering system shall be logical. Preferably, catchment, street segment, and storm sewer identification numbers shall relate to the phase and manhole number. For instance, manhole 5-8D, located in Phase 5, receives runoff from catchments 5-8A through 5-8E, street segments 5-8-1 and 5-8-2, and trap low 5-8.

3.3 Major - Minor System

- Describe the data used for modeling the major and minor system (as applicable) - Appendix 3.
- If spreadsheet analysis is used for minor system analysis, describe approach and assumptions.
- State that areas and location of **overland inflows** from external areas match all relevant, preceding reports. Provide supplemental information to rationalize changes to boundary conditions. Identify in cover letter as well.
- State that areas and location of **minor system inflows** from external areas match all relevant, preceding reports. Provide supplemental information to rationalize changes to boundary conditions. Identify in cover letter as well.

  If neither of these conditions is met, identify impacts on previous phases, if applicable. Submit under separate cover summary of impacts and consequences relative to affected previous phases. Identify in cover letter as well.

3.4 Catchment Areas

Describe briefly how the model computes surface runoff and abstraction losses:

- CN or Horton approach.
- For SWMHYMO describe IUH routines used.
- Abstraction loss parameters.
- Manning 'n' values.
- Tabulate the key catchment parameters (area, % impervious, etc.) – see **Table 4**.

Table 4 Catchment Parameters and Imperviousness (Imp.) Ratio

Catchment ID	Area (ha)	Total Imp. (%)	Directly Connected Imp. (%)
17-3A	1.340		
17-4A	0.278		
17-4B	0.232		
17-4C	0.571		
17-5A	0.560		
17-6A	0.760		
17-6B	0.288		
E-6B	0.169		
17-7A	0.452		

3.5 Minor System Capture

Describe the methodology used for minor system capture:

- For SWMHYMO describe DIVERT HYD and/or COMPUTE DUALHYD routines used.
- Basis for inlet capture (unit rate design flow, hydraulic capacity, ICD, etc.).
- Describe the basis for determining the capture curves.

3.6 Storage

- Describe the methodology used for storage routing (trap-lows, minor system (underground) storage and/or storm ponds).
- Describe emergency spill routes: type and destination.
- Describe the appropriate model routines used. Show relevant information for ponds if applicable, see **Tables 5 through 8**.

Table 5 Common Characteristics for Main Cell of Pond

Parameter	Unit	Value
Bottom Elevation	m	65.75
Normal Water Level (NWL)	m	66.50
High Water Level (HWL)	m	68.25
Invert Elevation of Orifice in control structure	m	65.75
Pond Depth below NWL	m	0.75
Active Pond Depth (NWL to HWL)	m	1.75

Table 6 Common Characteristics for Forebay

Parameter	Unit	Value
Bottom Elevation	m	65.156
Normal Water Level (NWL)	m	67.156
High Water Level (HWL)	m	68.50
~~Invert Elevation of control structure~~	~~m~~	~~67.156~~
Pond Depth below NWL	m	2.00
Active Pond Depth (NWL to HWL)	m	1.344

Data for ponds shall be included when the pond is modelled in the report. This information shall match the data presented in the preceding Staged Master Drainage Plan report or Pond Report.

Table 7 Stage-Area-Storage-Discharge Relationship for Main Cell of Pond

Elevation (m)	Depth ~~above NWL~~ (m)	Area (m^2)	Total Storage Volume (m^3)	Active Storage Volume (m^3)	Discharge (L/s)	
65.75	0	1,949.0	0	0	0	Bottom
66.00	0.25	2,447.0	548.0	0	0	
66.25	0.50	4,049.0	1,352.0	0	0	
66.50	0.75	5,650.0	2,559.0	0	0	**NWL**
66.75	1.00	7,122.0	4,152.0	1,593.0	25.80	
67.00	1.25	8,178.0	6,063.0	3,504.0	41.10	
67.25	1.50	8,999.0	8,209.0	5,650.0	52.00	
67.50	1.75	9,204.0	10,484.0	7,926.0	61.10	
67.75	2.00	10,044.0	12,890.0	10,331.0	68.90	
68.00	2.25	10,848.0	15,501.0	12,942.0	76.00	
68.25	2.50	11,578.0	18,303.0	15,744.0	82.40	**HWL**
68.80	3.05	xx,xxx	xx,xxx	xx,xxx	xx.xx	**Freeboard**

In case the discharge is composed of multiple components (e.g., orifice and overflow weir or multiple outlets), the discharge relationship for the individual components shall be presented.

Table 8 Stage-Area-Storage-Discharge Relationship for Forebay

Elevation (m)	Depth ~~above NWL~~ (m)	Area (m^2)	Total Storage Volume (m^3)	Active Storage Volume (m^3)	Discharge (L/s)	
65.156	0	13.0	0	0	0	**Bottom**
65.50	0.344	67.0	13.0	0	0	
66.00	0.844	217.0	80.0	0	0	
66.50	1.344	460.0	245.0	0	0	
67.00	1.844	626.0	516.0	0	0	
67.156	2.00	714.0	620.0	0	0	**NWL**
67.50	2.50	908.0	898.0	278.0	761.0	
68.00	3.00	1,272.0	1,441.0	820.0	2,926.0	
68.50	3.50	1,677.0	2,176.0	1,556.0	5,407.0	**HWL**
69.00	4.00	x,xxx	x,xxx	x,xxx	x,xxx	**Freeboard**

4.0 RESULTS

4.1 Overland Flows

- Confirm that the combination of the depth and velocity of flow meets Alberta Environment guidelines.
- Confirm that all drainage gutters / swales fully contain 1:100 year peak flow rate without overtopping / spillover.
- Tabulate overland flow data (major segment number, 1:100 flow, 1:100 depth, 1:100 velocity), see **Table 9**.
- **Figure 4** (8½ x 11) showing overland flows compared to depth-velocity criterion.
- State whether or not the overland flows leaving a phase or site meet the specific objectives (Section 3.3), and justify where they do not meet the objective.

Summary of overland flows to include spill segments and concrete or vegetated drainage gutters/swales. Spillover into natural areas such as ravines shall be avoided. Appropriate erosion protection shall be provided if unavoidable.

Table 9 Overland Flow Assessment

Street Segment Number	Peak Discharge (L/s)	Maximum Depth (mm)	Maximum Velocity (m/s)	Specific Energy (mm)	Gutter Type and Depth
S #1	52	51	0.79		
Traplow #1 – Spill	0	0	0.00		
S #2	112	64	1.08		
Traplow #2 - Spill	0	0	0.00		

Only needs to be provided for concrete drainage gutters/swales in back of or between lots.

- Summarize major system flows exiting the phase or development, see **Table 10**.

All overland runoff should be fully contained on-site up to a 1:100 year event for private sites.

Table 10 Major System Boundary Conditions – Outflows

Location	Area Size (ha)	Flow Rate		Runoff Volume	
		(L/s)	(L/s/ha)	(m^3)	(mm)

- Summarize assumed major system flows entering the phase or development, see **Table 11**.

Table 11 Major System Boundary Conditions – Assumed Inflow from External Areas

Location	Area Size	Flow Rate		Runoff Volume		Design Storm
	(ha)	(L/s)	(L/s/ha)	(m^3)	(mm)	

4.2 Inlet Restrictions

- Tabulate the ICD locations (MH number, ICD type, number of ICDs, capture rate), see **Table 12**.
- For standard ICDs, reference City of Calgary Standard 452.1002.031.
- **Figure 5** (8½ x 11) showing details for special ICDs or for DSSP sites (if applicable).

Table 12 Results of Minor System Analysis

Manhole Number		Pipe Design Method						Actual Flow Comparison							
		Area Number	Incremental Area	Cumulative Area	UARR Method Unit Area Release Rate	Incremental Flow	Cumulative Flow	Type Catchbasin	Location	Type Inlet Control Device	Incremental Inlet Peak Flow	Cumulative Inlet Peak Flow	Cumulative Hydraulic Model Routed Flow	Pipe Capacity	Spare Capacity
From	To		(ha)	(ha)	(L/s/ha)	(L/s)	(L/s)				(L/s)	(L/s)	(L/s)	(L/s)	(L/s)
E-5	E-6	External Area	268.000		2.40	643.2		Permissible Release Rate			643.2				
		Malpais	4.833		57.25	276.7		Permissible Release Rate			276.7				
		Shangri-La	12.603		38.66	487.2		Allocated Permissible Release Rate			554.7				
	Sub-Total		285.436	285.436			1407.1				1474.6	1474.6		1574.6	100.0
17-D6	E-6	17-6A	0.760		38.66	29.4		Single C	East	ICD R30	18.8				
		17-6B	0.288		38.66	11.1		Single K2	West	ICD R30	20.9				
	Sub-Total		1.048	1.048			40.5				39.7	39.7	39.7	169.4	129.7
E-6	E-7	E-6A	0.630		38.66	24.4		Single K2	North	No ICD	51.9				
		E-6B	0.169		38.66	6.5		Single C	West	No ICD	14.9				
	Sub-Total		0.799	287.283			1478.5				66.8	1581.1	1346.5	1574.6	228.1
E-7	17-D7		0.000		38.66	0.0					0.0				
	Sub-Total		0.000	287.283			1478.5				0.0	1581.1	1346.8	1772.1	425.3
17-D3	17-D4	17-3A	1.340		38.66	51.8		Single C	Northwest	R30	18.9				
								Single K2	Southeast	R30	20.9				
		17-4A	0.278		38.66	10.7		Single C	Park	No ICD	26.9				
	Sub-Total		1.618	1.618			62.6				66.7	66.7	66.3	108.2	41.9
17-D4	17-D5	17-4B	0.232		38.66	9.0		Single C	Southwest	ICD R30	18.0				
		17-4C	0.571		38.66	22.1		Single K2	Northeast	ICD R30	20.1				
	Sub-Total		0.803	2.421			93.6				38.1	104.8	101.3	165.4	64.1
17-D5	17-D7	17-5A	0.560		38.66	21.6		Single C	Northeast	ICD R30	16.0				
								Single K2	Southwest	ICD R30	18.0				
	Sub-Total		0.560	2.981			115.2				34.0	138.8	134.3	187.9	53.6
17-D7	E-8	17-7A + 17-7B	0.991		38.66	38.3		Single K2	North	No ICD	49.7				
	Sub-Total		0.991	291.255			1632.1				49.7	1769.6	1486.3	1772.1	285.8
E-8	16-D5	E-8A	0.470		38.66	18.2		Single K2	South	No ICD	54.7				
	Sub-Total		0.470	291.725			1650.3				54.7	1824.3	1505.1	2333.0	827.9
16-D5	E-9	Existing Phase 16	4.870		38.66	188.3		Allocated Permissible Release Rate			248.5				
	Sub-Total		4.870	296.595			1838.5				248.5	2072.8	1753.1	2333.0	579.9

This example is for an older system that was designed prior to the release of the December 2000 Stormwater Management & Design Manual
Current design criteria call for a minimum unit area release rate of 70 L/s/ha!

4.3 Storage

- Tabulate pond and/or trap low results (storage number, capacity at spill, spill depth, spill elevation, 1:100 volume, 1:100 depth, 1:100 elevation, MG Elevation). See **Table 13**.
- Note where RMG is required.
- State if the maximum ponding depths are within the Alberta Environment guideline of 0.5 m, and if not, then justify.
- Tabulate permissible discharge rates and on-site storage requirements for private sites if applicable (see **Table 14**).

Table 13 Results of Traplow Analysis

Number[1]	Low Point Elevation	Spill Conditions			1:100 Year Event Results				MG Elevation[3]	R[4]
		Capacity	Depth	Elevation	Storage Volume[2]	Spillover Volume	Depth	Elevation		
		m^3	m	m	m^3	m^3	m	m		
17-3	1084.198	128	0.323	1084.521	190.0	77.0	0.358	1084.556	1084.856	R
17-4	1083.977	203	0.348	1084.325	150.0	0.0	0.305	1084.282	1084.625	R
17-5	1083.935	272	0.353	1084.288	60.0	0.0	0.164	1084.099	1084.588	R
17-6	1084.692	128	0.368	1085.060	120.0	0.0	0.359	1085.051	1085.360	R

(1) Locations are indicated on Overland Drainage Drawing.

(2) At maximum 1:100 year depth of ponding.

(3) MG denotes Minimum Building Opening Elevation.

(4) R designates that a Restrictive Covenant is required.

The spill conditions shall correspond to the critical, i.e. the highest downstream location, even if it is located outside the phase or development in question.

Table 14 Permissible Discharge Rates and Preliminary On-site Storage Requirements for Private Sites

Location	Manhole Number	Invert	Obvert or Top	HGL	Area	Discharge Rate		Storage Volume	
		(m)	(m)	(m)	(ha)	(L/s/ha)	(L/s)	(m^3/ha)	(m^3)

4.4 Minor System Flows

- Tabulate the minor system flows (segment number, design flow, full flow capacity, and model analysis results) – see **Table 12**.
- State if results are within the rated hydraulic capacities of the individual segments or identify where surcharge conditions occur.
- Comment on the impact of surcharge within the development and downstream system.
- Tabulate HGL results for surcharging (MH number, HGL elevation, depth of surcharge, freeboard relative to surcharge and LTF) – **Figure** showing HGL (see **Table 15**).

  Compare the minor system flows entering and leaving the site relative to the specific objectives (Section 2.1), and justify where they do not meet the objective.

- Summarize assumed minor system flows exiting the phase or development, see **Table 16**.
- Summarize assumed minor system flows entering the phase or development, see **Table 17**.

Table 15 Summary of Surcharge Conditions

Manhole Number	Location	Elevations			LTF	HGL	Surcharge	Freeboard relative to	
		Invert (m)	Obvert (m)	Ground (m)	(m)	(m)	(m)	Ground (m)	LTF (m)

Table 16 Minor System Boundary Conditions – Outflows

Location	Manhole Number	Area Size (ha)	Flow Rate		Runoff Volume	
			(L/s)	(L/s/ha)	(m^3)	(mm)

Table 17 Minor System Boundary Conditions – Assumed Inflow from External Areas

Location	Manhole Number	Invert (m)	Obvert or Top (m)	HGL (m)	Area Size (ha)	Flow Rate		Runoff Volume		Design Storm
						(L/s)	(L/s/ha)	(m^3)	(mm)	

5.0 SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Explicitly state that all details conform to the City of Calgary Standard Specifications and Stormwater Management Design Manual, or explicitly state items that have to be addressed prior to report approval.

FIGURES

Figure 1 Site Location

- 8½ x 11.
- Project location within City of Calgary.

Figure 2 Study Area

- 8½ x 11.
- Study area boundary, site phase boundary, adjacent phases.
- Show contours/grades/elevations and flow directions.
- Show pond locations (if applicable).
- Show alignment storm trunks (if applicable).

Figure 3 Flow Depth-Velocity Results

- 8½ x 11.
- Overland flows compared to depth-velocity criterion.

Figure 4 Details for Special ICDs or for DSSP Sites

DATAFILES

- Use header with the following info: project name, page x of y.
- Use footer with following info: filename / date-time.
- Use a colored sheet to separate data files.
- Text in data files should not wrap at end of line – consider using “Courier New” font in WORD.

CORPORATE AUTHORIZATION

We agree and certify that all requirements on this template have been reviewed and properly identified as part of this submission. We understand that this template will be used as a tool for review and approval of stormwater management reports and accept responsibility and liability for the designs in this submission.

Show stamp or provide Corporate Authorization number **CORPORATE AUTHORIZATION**	Show stamp of Professional Engineer **RESPONSIBLE ENGINEER**

APPENDICES

APP 1 Computer Model Schematic, data (input and output files)

- Size commensurate with the number of model segments.
- Model routing order for of subcatchments, minor segments, major segments and major-minor storage
- Adding or splitting flows.
- Segment reference numbers.
- **APP 1-1** Show Computer Model Schematic (size commensurate with number of model elements).

Ensure that the model identification numbering system matches the Overland Drainage and Storm Drainage drawings to the greatest extent possible. That is, manhole numbers shall include phase number and subcatchment identification shall relate to manhole number.

APP 2 Design Storm

- Design storm parameters.
- Duration.
- Time increments.

APP 3 Major - Minor System

- Tabulate the minor system data (segment number, size, length, slope, material type, Manning ‘n’).
- Tabulate the major system data (segment number, geometry, length, slope, Manning ‘n’).

APP 4 Minor System Capture

- Inlet types (K2, C, grated-top MH, special CB, etc.).
- Tabulate the rating data used for the various inlet types.
- Tabulate the rating data used for ICDs.

APP 5 Storage

- Tabulate the rating data (Storage number, capture/discharge rate, type of hydraulic control, storage volume, spill condition, etc.).

Table 18 Minor System

Pipe Design

Sement ID	U/S MH	D/S MH	Number of Barrels	Shape	U/S Invert Elevation (m)	D/S Invert Elevation (m)	U/S Manhole Rim Elevation (m)	D/S Manhole Rim Elevation (m)	Length (m)	Slope (%)	Material	Roughness (Manning n)	Nominal Size (mm)	Actual Size (mm)	Entrance Loss (-)	Exit Loss (-)
	61	56							99.169	0.500	PVC	0.011	450	447.9		
	56	57							65.252	3.400	CON	0.013	525	533.0		
	57	58							109.710	2.000	CON	0.013	600	610.0		
	60	62							86.750	1.500	PVC	0.011	300	299.4		
	62	63							56.731	1.000	PVC	0.011	375	366.4		
	63	64							51.588	1.750	PVC	0.011	375	366.4		
	65	58							84.747	0.840	CON	0.013	525	533.0		
	58	59							88.927	3.054	CON	0.013	600	610.0		
	66	67							82.500	1.150	PVC	0.011	300	299.4		
	67	68							40.500	0.300	CON	0.013	525	533.0		
	68	69							92.880	0.200	CON	0.013	675	686.0		
	69	69a							6.427	0.500	CON	0.013	675	686.0		
	69a	59							59.747	0.200	CON	0.013	675	686.0		
	59	110B							83.190	0.220	CON	0.013	1200	1219.0		

Base Flow

Drainage Area	Size (ha)	UARR (L/s/ha)	Total Flow (L/s)	To MH
P	6.058	69.0	418.0	56
Fut ER	2.534	18.5	47.0	EX2

Culverts

Segment ID	U/S ID	D/S ID	Number of Barrels	Shape	Inlet Type	Length (m)	US/ Invert Elevation (m)	D/S Invert Elevation (m)	Longitudinal slope (%)	Material	Roughness (Manning n)	Nominal Size (mm)	Actual Size (mm)	Entrance Loss (-)	Exit Loss (-)	Spillover Elevation (m)

Table 19 Major System

Flow Segment Types

Segment ID	Flow Path					Shoulder		Max Depth
	Half Width (m)	Cross Slope (%)	Curb Height (mm)	Roughness (Manning n)	Longitudinal Slope (%)	Cross Slope (%)	Manning n	(m)
1	4.50	2.0	140	0.015	1.5	2.0	0.250	0.3
2	4.50	2.0	140	0.015	4.0	2.0	0.250	0.3
3	4.50	2.0	140	0.015	5.4	2.0	0.250	0.3
4	4.75	2.0	140	0.015	4.0	2.0	0.250	0.3
5	4.75	2.0	140	0.015	6.0	2.0	0.250	0.3
6	7.40	2.0	140	0.015	8.0	2.0	0.250	0.3
7	11.70	2.0	140	0.015	8.0	2.0	0.250	0.3
8	0.01	-0.1	0	0.250	10.0	0.1	0.250	0.3

Storage Inlets

Drainage Area	Trap Low #	Spill Volume (m^3)	Capture at Spill Depth (L/s)
A	1	87	40.6
D	2	282	43.0
E	3	82	172
G	4	195	169.1
H	5	214	42.2
U	6	100	44.9

Swales/Ditches

Segment ID	Width (m)	Longitudinal Slope (%)	Roughness (Manning n)	Left Side Slope (H:V)	Right Side Slope (H:V)	Max Depth (m)

Drainage Areas

Drainage Area	Size (ha)	Percent Total Imperviousness (%)	Percent Directly Connected Imperviousness (%)	Average Length (m)	Average Width (m)	Average Slope (%)	Manning n Impervious	Manning n Pervious
17-5A	0.80	69	30	200	40	3.0	0.015	0.25
17-5B	1.81	65	24	180	100	2.0	0.015	0.25
17-6A	0.77	70	30	200	40	6.0	0.015	0.25
17-7A	1.26	65	25	150	40	2.0	0.015	0.25
17-7B	1.56	65	25	50	40	3.0	0.015	0.25
17-7C	0.99	65	25	75	80	3.0	0.015	0.25
17-9A	0.88	72	35	125	60	2.0	0.015	0.25
17-10A	1.87	63	20	75	125	4.0	0.015	0.25
17-10B	1.52	65	25	100	100	4.0	0.015	0.25
17-12A	0.90	64	23	100	60	2.0	0.015	0.25
17-12B	0.71	70	25	170	40	4.5	0.015	0.25

DRAWINGS

All plans submitted include quarter section lines and street names. Pertinent information on the plans uses legible font sizes.

DR 1 Overland Drainage

Provide full size Overland Drainage drawing (identical to drawing in construction set), including:

- Professional Engineer’s stamp which has been signed and dated.
- Subdivision phase and construction boundary.
- Q,v,d’s for critical segments.
- Trap low storage table.
- Trap low location and outline at spill elevation.
- ICDs, catch basin types, and interconnected CBs.
- Details/cross-sections for spills as required.
- Overland escape routes (arrow) must be clearly delineated.
- Concrete drainage gutter locations and details for deep or non-standard gutter sections.
- Direction of drainage flow (arrow) including slopes, high points and low points.
- Catchment I.D’s.
- Original ground contour lines.

DR 2 Storm Drainage

Full size Storm Drainage drawing (identical to drawing in construction set), including:

- Professional Engineer’s stamp which has been signed and dated.
- Drainage area boundary lines.
- Drainage area sizes and release rates.
- Minor system table that follows a logical flow pattern.
- ICDs, catch basin types, and interconnected CBs.
- Pipe layout including pipe sizes and manhole numbers.
- Overall drainage plans if applicable.
- Pipe numbering system if applicable.

DR 3 Storm Pond (if applicable)

DR 4 Source Control Practices (if applicable)

REFERENCES

- Computer model User's Manual.
- City of Calgary *Stormwater Management & Design Manual.*
- MDP report or SWM reports which provide the basis for the design objectives.