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Millet Flood Study

Main Report

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CREDITS AND ACKNOWLEDGEMENTS

The Millet Flood Study was completed by the Government of Alberta under the provincial Flood Hazard Identification Program, the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. The study was co-funded by the Government of Canada through the federal Flood Hazard Identification and Mapping Program. NHC would like to thank Government of Alberta and Government of Canada for funding this project.

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- Tachara Larocque — River Hazard Specialist, Project Manager

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EXECUTIVE SUMMARY

In March 2024, Alberta Environment and Protected Areas (EPA) enlisted the services of Northwest Hydraulic Consultants Ltd. (NHC) to complete a flood study for areas along 15 km of Pipestone Creek, 4 km of Eyot Creek, and 2 km of Snake Drain through the town of Millet and Wetaskiwin County No. 10. This initiative was conducted under the Flood Hazard Identification Program (FHIP) with the goals of enhancing public safety and mitigating potential flood damages in the province.

The Millet Flood Study is comprised of five major components: 1) survey and base data collection; 2) open water hydrology assessment; 3) open water hydraulic modelling; 4) open water flood inundation mapping; and 5) design flood hazard mapping. This report summarizes the work of all five components, and together they include the following details:

- descriptions of survey procedures and methodology
- documentation of the collected survey and base data
- summary of flood history
- open water flood frequency flow estimations
- construction of the hydraulic model
- calibration and validation of the hydraulic model
- computation of flood frequency water levels
- a model sensitivity analysis
- associated inundation mapping
- computation of design flood profiles
- floodway criteria and hazard mapping

The survey program was completed in May 2024. The objective of the survey program was to survey river cross sections and hydraulic structures along the Pipestone Creek, Eyot Creek, and Snake Drain study reaches to support the development of a one-dimensional (1D) hydraulic model. In addition to this, data such as Digital Terrain Model (DTM), aerial imagery, and other mapping features were gathered for model development and flood mapping efforts. The model calibration and validation data, including highwater marks (HWMs), were collected for the April 1974 flood. In addition, NHC measured discharges and surveyed the corresponding water levels for Pipestone Creek and Eyot Creek as part of their May 2024 survey program.

Open water flood frequency estimates were completed at multiple locations along Pipestone Creek, Eyot Creek, and Snake Drain. Flood magnitudes for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year events were estimated based on regional analysis. The current flood frequency estimates are higher than previous flood frequency estimates developed by AENV (2003). However, the current estimates are considered more accurate due to the use of

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longer and more recent data series, the inclusion of additional homogeneous gauges in the regional analysis, and improved drainage basin delineation using the latest topographic data.

The open water hydraulic modelling task involved the creation, calibration, and validation of a hydraulic model, computation of flood levels, and conducting of a model sensitivity analysis. A 1D hydraulic model was developed based on the survey data and DTM. The model was then calibrated using HWMs collected during the April 1974 flood at Pipestone Creek, with channel Manning's roughness selected as the primary calibration parameter. The calibration results showed good agreement at most reliable HWM measurement points; however, the available HWM data were limited to four points and did not cover Eyot Creek or Snake Drain. To address this limitation, channel roughness parameters were determined through a detailed review of literature, analysis of channel geomorphic characteristics, and NHC's experience from the 2003 study and similar studies in the region. Overbank roughness parameters were assigned based on land use and literature-prescribed values, while other hydraulic parameters were selected based on literature, professional judgment, and to produce reasonable results. The calibrated model was then used to generate water surface profiles for 13 flood scenarios, ranging from the 2-year to the 1000-year open water flood events. Finally, a sensitivity analysis was performed by varying discharges, downstream boundary conditions, channel and overbank roughness values, and roadway weir coefficients revealing that the model was most sensitive to changes in discharge and channel roughness.

The computed flood levels were then used to determine the extent of inundation for each of the respective flood scenarios and are presented as a set of flood inundation maps for each scenario (the flood inundation map library). This library is intended primarily for stakeholders to use in emergency response planning and preparation. The maps indicate that no residential houses will be impacted by the simulated floods; however, some out buildings on residential lots, playgrounds, and golf courses may be affected as early as the 5- to 20-year flood events. Of the 22 hydraulic structures within the study reaches, 14 are expected to be impacted by the 100-year flood, and 17 by the 1000-year flood. None of the wastewater lagoon dikes located adjacent to the creek are expected to be affected by any of the modelled flood events.

The design flood hazard mapping component provided a design flood hazard map – a key deliverable for this flood study. The design flood hazard map depicts the floodway and flood fringes (including high hazard areas) for the open water design flood. The supporting rationale for the flood hazard map is depicted on the open water floodway criteria map. The methods used to develop the flood hazard map follow the provincial Flood Hazard Identification Program guidelines, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta. The floodway criteria and flood hazard maps show no notable overbank areas within the floodway.

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ABBREVIATIONS

Acronym / Abbreviation	Definition
1D	One-Dimensional
2D	Two-Dimensional
3TM	Three-Degree Transverse Mercator
AFETUW	Alberta Flow Estimation Tool for Ungauged Watershed
ASCM	Alberta Survey Control Monuments
AT	Alberta Transportation
ATS	Alberta Township System
BF	Bridge File
CGVD28	Canadian Geodetic Vertical Datum of 1928
CSRS	Canadian Spatial Reference System
DTM	Digital Terrain Model
EGBC	Engineers and Geoscientists British Columbia
EPA	Alberta Environment and Protected Areas
FHIP	Flood Hazard Identification Program
GNSS	Global Navigation Satellite Systems
HEC-RAS	Hydrologic Engineering Center River Analysis System
NAD83	North American Datum 1983
HWM	Highwater Mark
NHC	Northwest Hydraulic Consultants Ltd.
PFRA	Prairie Farm Rehabilitation Administration
PPP	Precise Point Positioning
PXS	Planned Cross Section
RTK	Real-Time Kinematic
TEC	Alberta Transportation and Economic Corridors
TIN	Triangular Irregular Network
TOB	Top of Bank

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Acronym / Abbreviation	Definition
WSC	Water Survey of Canada
WSE	Water Surface Elevation

SYMBOLS AND UNITS OF MEASURE

Symbol / Unit of Measure	Definition
°	degree
±	plus or minus
%	percent
cm	centimetre
km	kilometre
km^2	square kilometre
m	metre
m^3	cubic metre
m/s	metres per second
m^3/s	cubic metres per second
m/m	metres per metre

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1 INTRODUCTION

This section provides comprehensive insights into the background of the Millet flood study, outlines its specific objectives, and furnishes a detailed description of the study area and its reaches.

1.1 Study Background

In March 2024, Alberta Environment and Protected Areas (EPA) retained Northwest Hydraulic Consultants Ltd. (NHC) to complete a flood study for areas along approximately 15 km of Pipestone Creek, 4 km of Eyot Creek, and 2 km of Snake Drain through the town of Millet and Wetaskiwin County No. 10. This study is being undertaken as part of Alberta's Flood Hazard Identification Program (FHIP), which is intended to enhance public safety and reduce future flood damages in the province. Results from this study are also intended to inform local land use planning decisions, flood mitigation projects, and emergency response planning.

The Millet Flood Study is comprised of five major components: 1) survey and base data collection; 2) open water hydrology assessment; 3) open water hydraulic modelling; 4) open water flood inundation mapping; and 5) design flood hazard mapping.

A previous provincial flood hazard mapping study was completed for the Millet area by NHC in 2003; however, the present study covers an expanded study reach and represents an update to the prior work.

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1.2 Study Objectives

The study objectives include the following primary services and deliverables:

- Conduct stream cross section surveys.
- Collect data on hydraulic structures.
- Conduct a field survey and integrate data from the digital terrain model (DTM).
- Document flood history.
- Conduct open water hydrology assessment to determine flood frequency estimates.
- Develop a one-dimensional (1D) open water hydraulic model.
- Simulate open water floods for 13 return periods and create water surface profiles throughout the study reach.
- Perform sensitivity analysis on selected modelling parameters.
- Produce flood inundation maps for selected return periods.

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- Determine floodway criteria and boundary line.
- Produce floodway criteria and design flood hazard maps.

1.3 Study Reach

Figure 1.1 shows the location and boundaries of the study area, which includes:

- 15 km of Pipestone Creek extending from Range Road 250 to the eastern boundary of NW 15-47-24-W4M.
- 4 km of Eyot Creek extending from the north boundary of Wetaskiwin County No.10 to its confluence with Pipestone Creek.
- 2 km of Snake Drain extending from the western boundary of NE/SE 31-47-24-W4M to its confluence with Eyot Creek.

River cross section surveys were extended beyond these boundaries to accommodate hydraulic modelling and inundation mapping requirements.

There are no active streamflow gauges within the study reaches. A discontinued Water Survey of Canada (WSC) gauge station, 05FA007 (Pipestone Creek near Millet), was previously located within the study reach. This station reported only daily flow measurements in April and early May of 1925.

1.4 River and Basin Settings

Pipestone Creek is a major tributary of the Battle River, which is a tributary of the North Saskatchewan River. The creek is a prairie stream flowing through central Alberta. It originates east of Pigeon Lake and flows generally east for approximately 35 km to the town of Millet. From there, it flows southeast for approximately 20 km to Coal Lake, which discharges to the Battle River south of Gwynne, Alberta.

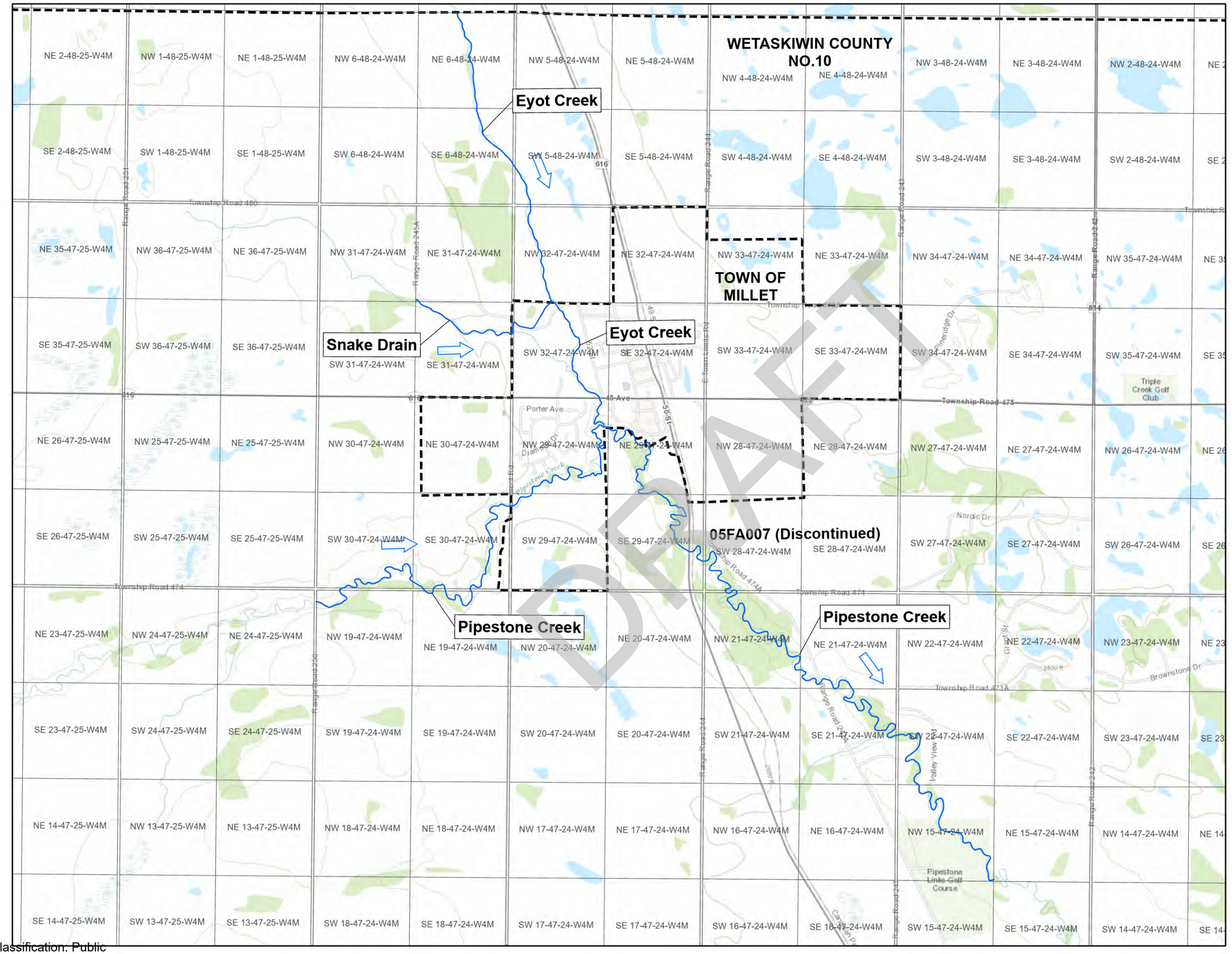
Eyot Creek is a tributary of Pipestone Creek. It flows in a southerly direction through the town of Millet before joining Pipestone Creek.

Snake Drain conveys runoff from land immediately west of the town of Millet and joins Eyot Creek at the north boundary of the town. Snake Drain's present-day alignment was characterized by its realignment and excavation in the mid-1970s and the alignment within the town's limits differs from its characterization in the base map shown in Figure 1.1.

Figure 1.2 provides an overview of the study basin, illustrating the drainage areas for Pipestone Creek (325 km^2), Eyot Creek (118 km^2), and Snake Drain (4.84 km^2) within the study area. These areas were determined using data from the WSC stations, the Prairie Farm Rehabilitation Administration (PFRA) Watersheds project (Version 8), LiDAR 7.5 m digital elevation model (DEM), and the Alberta Flow Estimation Tool for Ungauged Watersheds (AFETUW).

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- FLOW DIRECTION
- STUDY REACH
- WSC GAUGE STATION
- MUNICIPAL & COUNTY BOUNDARIES
- ALBERTA TOWNSHIP QUARTER SECTION BOUNDARY

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 1 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

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MMM	LS	RBA

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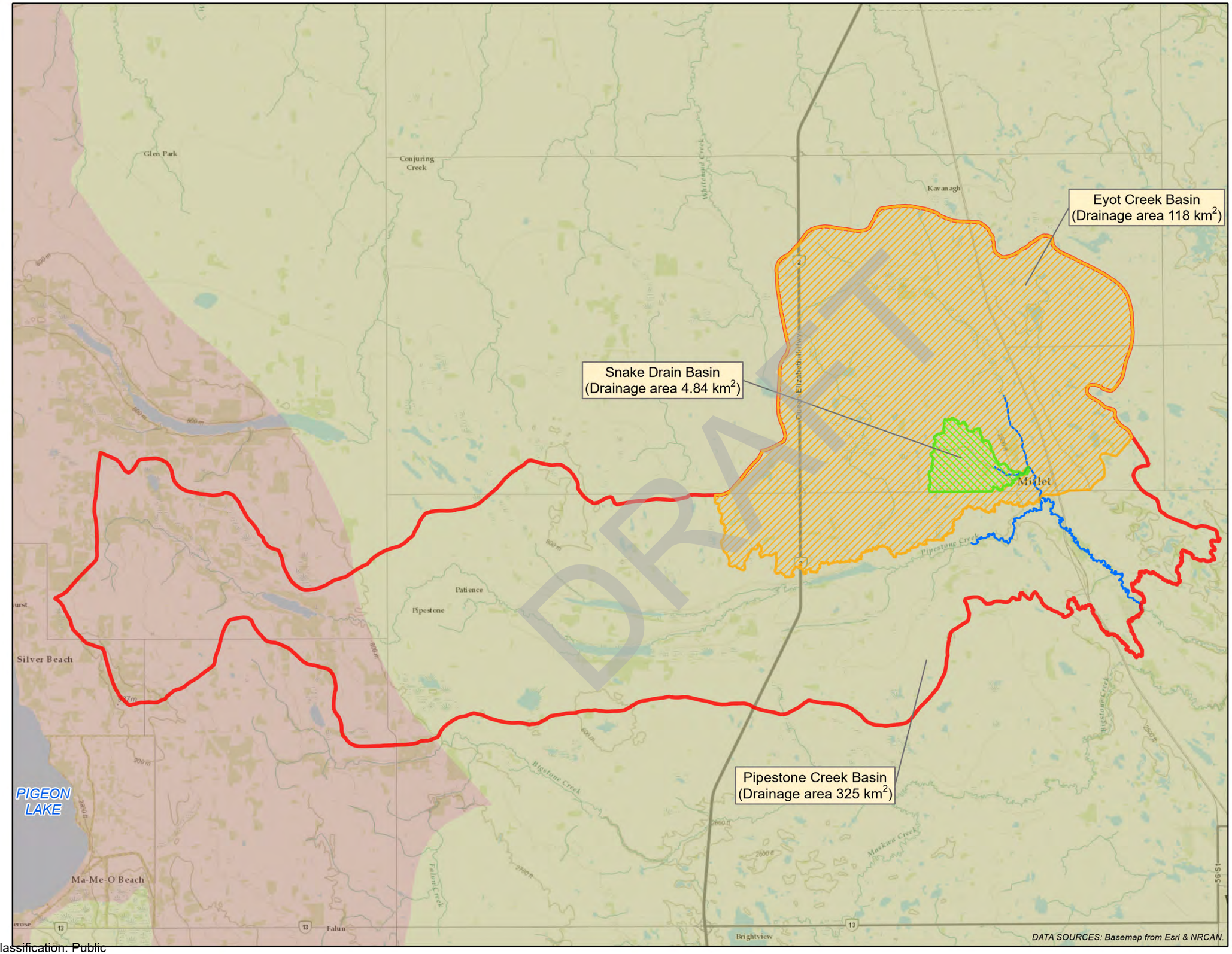
MILLET FLOOD STUDY

FLOOD STUDY AREA

FIGURE 1.1

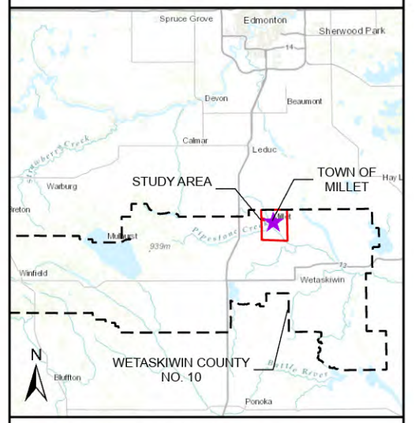
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- STUDY REACH
- PIPESTONE CREEK BASIN
- EYOT CREEK BASIN
- SNAKE DRAIN BASIN
- CENTRAL PARKLAND NATURAL SUBREGION
- DRY MIXEDWOOD NATURAL SUBREGION

SCALE - 1:120,000

0 2 4 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	LS	RBA

Job Number	Date
1008862	02-APR-2025

MILLET FLOOD STUDY

STUDY BASIN OVERVIEW

FIGURE 1.2

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Figure 1.2 also presents the study basin areas overlaying Alberta's natural subregions (Natural Regions Committee, 2006). Alberta's land classification system divides the province into six natural regions and 21 subregions, which are defined geographically based on landscape patterns, notably the vegetation, soils, and physiographic features reflecting the combined influence of climate, hydrology, topography, and geology. Most of the study basin areas are located within the Central Parkland natural subregion. Only the upper portion of the Pipestone Creek basin lies in the Dry Mixed-Wood natural subregion. Generally, the Central Parkland subregion is slightly warmer and receives slightly less precipitation than the Dry Mixed-Wood subregion. Additionally, the Central Parkland subregion is more cultivated than the Dry Mixed-Wood subregion. The study basin areas also feature relatively flat terrain with many undrained or intermittently draining wetlands and sloughs, which are typical physiographic features for prairie stream basins. Land use in these basin areas is dominated by agriculture.

2 SURVEY AND BASE DATA COLLECTION

2.1 Survey Procedures and Methodology

The main survey program was completed between 6 and 14 May 2024. The objective was to survey channel cross sections along the study reach to support the development of a 1D hydraulic model. Prior to the survey, a site visit was carried out on 29 April 2024, to inspect the study reach, assess the overall condition of the river channel and floodplain, and plan the survey program. After the site visit, the survey plan was submitted to and approved by EPA.

Ground positioning for the survey was measured using Global Navigation Satellite Systems (GNSS) and Trimble R10 and R12 Real Time Kinetic (RTK) GNSS receivers. Elevations in the channel and on the ground along the channel banks and in floodplains were directly measured with the RTK GNSS receiver attached to a survey rod. The surveyed cross sections included the riverbanks and extended into the floodplain, overlapping with the DTM provided by EPA.

The Trimble RTK GNSS receivers used in the survey can provide an accuracy of ±0.02 metres under optimal conditions when mounted on a tripod with a clear view of the sky, sufficient satellites, and proper static data collection. Additional errors may occur if the receiver is off-level, obstructed by trees or vegetation, or if the receiver height is incorrectly recorded. The expected accuracy of ground-based survey points is ±0.05 metres, except in rare cases where points are surveyed in tree cover or near large vertical banks, resulting in poor satellite coverage. The accuracy of the survey data collected falls within the tolerance specified in the FHIP Flood Study Technical Guidelines (AEP, 2022).

2.1.1 Coordinate System and Datum

Horizontal positions were referenced to the three-degree Transverse Mercator (3TM) projection with a central meridian of 114°W. The 3TM projection is part of the Canadian Spatial Reference

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System (CSRS) North American Datum of 1983 (NAD83); it is a three-dimensional grid on which the position of an object or feature can be precisely pinpointed. Orthometric heights are based on the Canadian Geodetic Vertical Datum of 1928 (CGVD28) and HTv2.0 hybrid geoid model.

2.1.2 Control Network

A control point network was established from local Alberta Survey Control Monuments (ASCMs), and GNSS surveying to provide a spatial reference for the survey program. Five Alberta Survey Control Markers (ASCM), three NHC project survey control points, and two Can-Net RTK network towers were tied into the survey. A list of the control point coordinates is provided in Table 2.1. The coordinates for ASCM and NHC project survey control points in the table are NHC survey coordinates, while the coordinates for the two Can-Net RTK network towers were obtained from Natural Resources Canada (NRCan).

Table 2.1 Control point summary

Name	Type	Easting (m)	Northing (m)	Elevation (m)	Measurement Type
NHC Control 1	Project Control Point	34292.888	5887852.649	754.843	Static Measurement (NHC)
NHC Control 2		34261.186	5883766.301	763.485	
NHC Control 3		37673.936	5880333.814	752.367	
Leduc Tower (LED4)	Can-Net RTK Network Towers	30022.152	5903119.346	735.313	Coordinates from NRCan
Wetaskiwin Tower (WET2)		42072.487	5871373.251	769.667	
ASCM 489161	ASCM Benchmark	34250.712	5883755.385	762.831	RTK Measurement (NHC)
ASCM 459420		35109.111	5885075.136	752.718	
ASCM 349746		35905.789	5885038.197	755.835	
ASCM 649558		37324.851	5879450.603	758.387	
ASCM 115626		39151.185	5883836.392	769.378	

The coordinates for three of the NHC control points were determined by running the GNSS receivers simultaneously in static mode for over three hours at each control point. This was done to obtain precise point positioning (PPP) results from the Canadian Spatial Reference System (CSRS). The data were then post-processed using Trimble Business Center software to adjust the

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network by establishing baselines between control points. The coordinates for two Can-Net RTK network towers were obtained from NRCan directly. These towers have continuous occupation time to generate PPP results from the CSRS.

The adopted coordinates were constrained to Leduc and Wetaskiwin Can-Net RTK network towers, which had had the longest occupation time. The CSRS-PPP results estimated the total standard deviation (95%), accounting for both PPP and epoch transformation uncertainties. At Leduc tower, the total horizontal uncertainty was determined to be 0.024 m (easting) and 0.034 m (northing), with a total vertical uncertainty of 0.023 m. Similarly, at Wetaskiwin Tower, the total horizontal uncertainty was determined to be 0.022 m (easting) and 0.032 m (northing), with a total vertical uncertainty of 0.023 m. The horizontal and vertical errors at the other three control points, after post-processing and adjustment to the reference CSRS-PPP values, are summarized in Table 2.2. The largest horizontal error was 0.0040 metres, and the largest vertical error was 0.0115 metres.

Table 2.2 Control network errors

Name	Easting (m)	Northing (m)	Elevation (m)
NHC Control 1	0.0040	0.0038	0.0115
NHC Control 2	0.0040	0.0037	0.0111
NHC Control 3	0.0039	0.0038	0.0098
LED4 (Constrained)	N/A	N/A	N/A
WET2 (Constrained)	N/A	N/A	N/A

A comparison between the surveyed elevations (after post-processing and adjustment) and published ASCM elevations is provided in Table 2.3. The mean of the elevation residuals is −0.036 m, which indicates good vertical agreement between the control network and local benchmarks.

Table 2.3 Comparison between surveyed and published local benchmark coordinates

Name	Residuals (Surveyed Minus Published)		
	Easting (m)	Northing (m)	Elevation (m)
ASCM 649558	-0.025	-0.002	-0.009
ASCM 489161	-0.086	0.052	-0.015
ASCM 459420	-0.067	0.032	-0.012
ASCM 349746	-0.040	0.063	-0.010
ASCM 115626	-0.051	0.031	-0.134

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Among the five ASCM points compared in Table 2.3, ASCM 115626 exhibited a relatively high elevation residual. During the survey, NHC observed that this point was located in a farmer's field and appeared not to be maintained. However, since the other four ASCM points showed very low elevation residuals, NHC is confident in the accuracy of the survey and can confirm that it meets the expected standards outlined in the FHIP Flood Study Technical Guidelines (AEP, 2022).

2.2 Digital Terrian Model

For this study, a non-hydro-flattened DTM was provided by EPA in August 2024, constructed from airborne LiDAR data gathered in the fall of 2023.

Elevations extracted from the DTM were compared with selected ground survey points collected by NHC on roads, wastewater lagoon dikes, and other high ground. On average, the elevation difference between the DTM and ground survey points was approximately 0.07 m within the sampled data. However, a small positive bias was noted in the DTM, meaning it generally shows higher elevations compared to ground survey points. Despite this positive bias, the overall average error falls within an acceptable range, and the DTM was deemed suitable for model development.

2.3 Aerial Imagery

Aerial imagery was acquired for EPA by OGL Engineering on 10 October 2023. Fully processed orthophoto mosaics were provided by EPA in October 2024.

2.4 Cross Sections and Bathymetry

Cross section locations were selected to ensure adequate representation of the channel geometry in the hydraulic model with consideration of repeating cross section locations from the last flood risk mapping study (NHC, 2003), as appropriate. During the planning process for the survey, each cross section was assigned a planned cross section (PXS) identifier to organize the cross sections sequentially and to associate survey point data with a PXS. The cross sections were surveyed between 06 and 14 May 2024. The PXS cross section and survey point locations are shown on maps provided in **Appendix A**.

A total of 186 cross sections were surveyed along the study reach. The survey was extended 2 km beyond the downstream study limit to reduce the uncertainties in hydraulic modelling results within the study reaches caused by downstream boundary condition parameters. Details on minimum, maximum and average spacing of the cross sections surveyed in each reach can be found in Table 2.4.

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Classification: Public

Table 2.4 Cross section survey summary

River	River Length (km)	Number of Cross Sections	Average Spacing (m)	Minimum Spacing (m)	Maximum Spacing (m)
Pipestone Creek	18.4	119	156	2	629
Eyot Creek	4.2	41	104	4	259
Snake Drain	1.5	26	60	1	212

The average surveyed cross section spacing for Pipestone Creek was 156 m. The minimum spacing, found at multiple locations, was 2 m, occurring between cross sections on either side of small bridges. The maximum spacing was 629 m between PXS-7 (RS 2,015 m) and PXS-6 (RS 1,386 m), which is beyond the downstream study boundary.

The average cross section spacing for Eyot Creek was 104 m. The minimum spacing, found at multiple locations, was 4 m, occurring between cross sections on either side of pedestrian bridges. The maximum spacing was 259 m between PXS-153 (RS 3,118 m) and PXS-152 (RS 2,859 m), situated along a straight, flat reach upstream of the town boundary.

The average cross section spacing for Snake Drain was 60 m. The minimum spacing, found at multiple locations, was 1 m, occurring between cross sections on the upstream and downstream sides of multiple gabions drop structures within the Snake Drain study reach downstream of Range Road 245A. The maximum spacing was 212 m between PXS-180 (RS 997 m) and PXS-179 (RS 785 m), located along a straight muskeg reach with deep pool of water created by multiple beaver dams.

All the survey point data were assembled and provided in the digital file submission.

2.5 Hydraulic Structures

The hydraulic structures measured as part of the survey program include eighteen bridge crossings, three culvert crossings and one overhead pipeline crossing as listed in Table 2.5, which also includes the corresponding Alberta Transportation and Economic Corridors (TEC) bridge file numbers when available. The locations of these structures are shown in survey overview maps provided in **Appendix A**. Survey data collected for the bridge included: span length; deck width; top of curb or solid guardrail elevation; low chord elevation; number, width, type, shape, and location of piers; top of deck elevation; and photographs of the bridge. Information collected for the culvert included: culvert type; shape; dimensions and length; entrance condition; upstream and downstream invert elevation; crest elevation; and photographs of the culvert. In addition, bridge and culvert design drawings were collected as available to complement the survey data. Details on each hydraulic structure are provided in **Appendix B**.

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Classification: Public

Table 2.5 Hydraulic structure survey summary

River	River Station (m)	Crossing Description	Structure Type	TEC Bridge File No.
Pipestone Creek	18,357	Range Road 250 Bridge	Bridge	496
	17,704	Private Crossing Bridge	Bridge	N/A
	15,803	Township Road 474 Bridge	Bridge	N/A
	14,465	Range Road 245/Govt. Road Culvert	Culvert	9139
	13,308	Pedestrian Bridge	Bridge	N/A
	12,677	Pedestrian Bridge	Bridge	N/A
	12,398	Pedestrian Bridge	Bridge	N/A
	11,930	Overhead Pipeline Crossing	Pipeline	N/A
	9,791	Highway 2A Bridge	Bridge	72548
	9,756	CP Rail Bridge	Bridge	N/A
	8,375	Private Crossing Bridge	Bridge	N/A
	7,908	Private Crossing Bridge	Bridge	N/A
	7,816	Private Crossing Bridge	Bridge	N/A
	6,581	Range Road 243A Bridge	Bridge	359
	6,345	Private Crossing Bridge	Bridge	N/A
	94	Range Road 242 Bridge	Bridge	727
Eyot Creek	1,401	53 Avenue Bridge	Bridge	70461
	1,215	Private Crossing Bridge	Bridge	N/A
	749	Pedestrian Bridge	Bridge	N/A
	405	45 Avenue Bridge	Bridge	910
Snake Drain	1,127	Private Crossing Culvert	Culvert	N/A
	473	Range Road 245A Culvert	Culvert	N/A

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Classification: Public

2.6 Flood Control Structures

The FHIP Guidelines (AEP, 2022) describe flood control structures as a permanent barrier or engineering system that keep water from entering and flooding an area up to a designed water level and can be overtopped if flood levels exceed the height of the berms at one or more locations. These flood control structures are mostly earth berms but can be other types of flood barriers constructed of concrete, steel, or other materials.

Dedicated flood control structures, such as berms, typically require regulatory approval prior to construction, are owned, operated, and maintained by a local authority or other government entity, and are officially recognized by EPA and local authorities as flood management infrastructure.

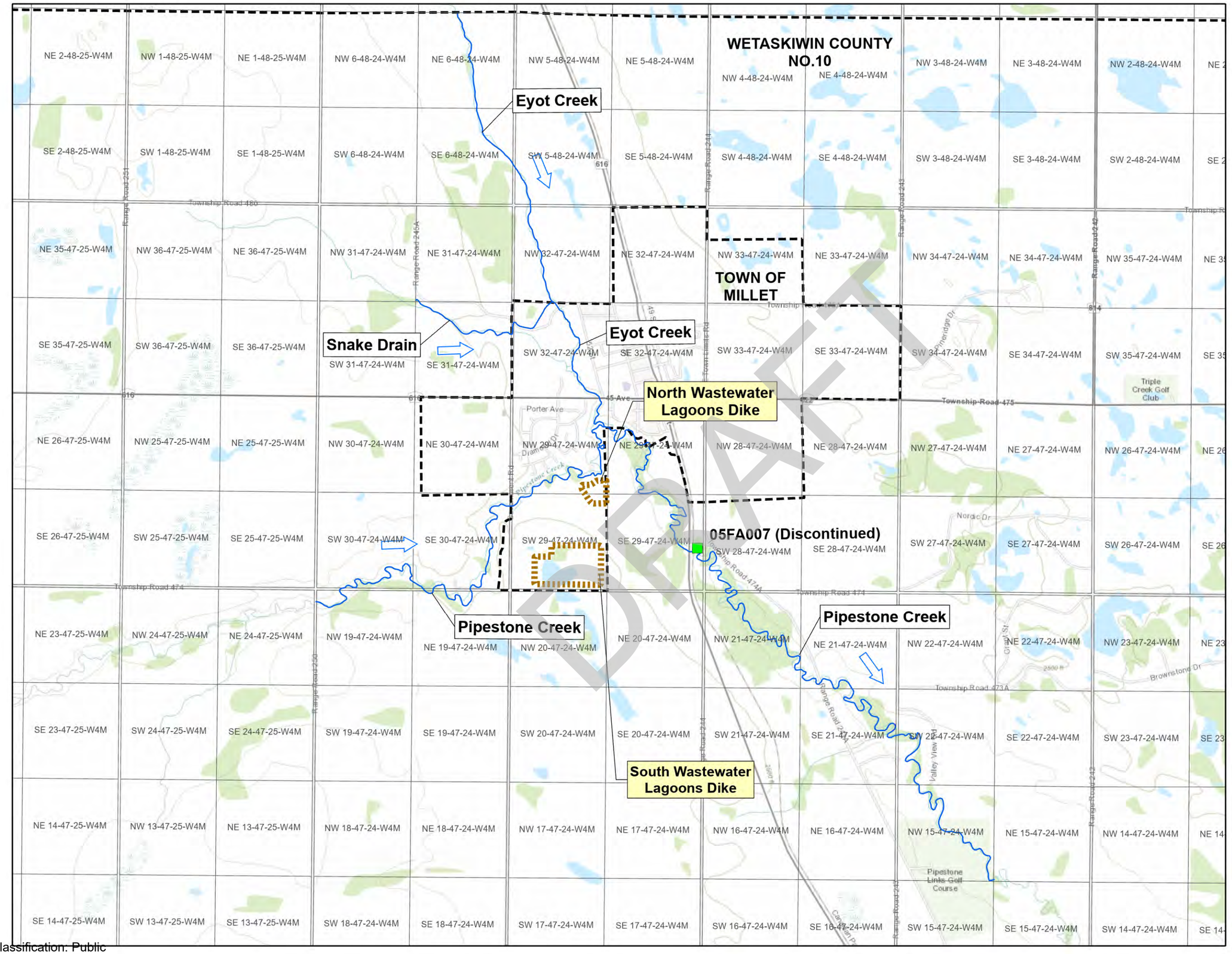
Some road and railway embankments or berms may perform as flood barriers and affect the river hydraulics but may not be dedicated flood control structures. Railroad embankments are typically assumed to be permeable and are not treated as natural ground features or dedicated flood control structures in flood studies.

Following the site visit, survey, and discussions with EPA and the town of Millet, NHC concluded that there are no specifically designated flood control structures within the study area. Nevertheless, the town has containment dikes in place for their wastewater lagoons. These containment dikes are located alongside Pipestone Creek within the study area and adjacent to the west town boundary.

The containment dikes surrounding wastewater lagoons are impervious barriers constructed to control and contain wastewater within each cell. These dikes are assumed to be designed to withstand natural events such as heavy rain or flooding. Therefore, they were regarded as flood control structures in this study and are illustrated in Figure 2.1.

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Classification: Public





FLOW DIRECTION

FLOOD CONTROL STRUCTURES

STUDY REACH

WSC GAUGE STATION

MUNICIPAL & COUNTY BOUNDARIES

ALBERTA TOWNSHIP QUARTER SECTION BOUNDARY

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 1 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY/MMM	RBA

Job Number	Date
1008862	16-MAR-2025

MILLET FLOOD STUDY

FLOOD STUDY REACH AND FLOOD CONTROL STRUCTURES LOCATIONS

FIGURE 2.1

J:\Y\1_Projects (Active)\1008862 Millet Flood Study\90_GIS\SURVEY\MILLET FS SURVEY.aprx

DRAFT

Classification: Public

A summary of the flood control structures is presented in Table 2.6 below.

Table 2.6 Flood control structure summary

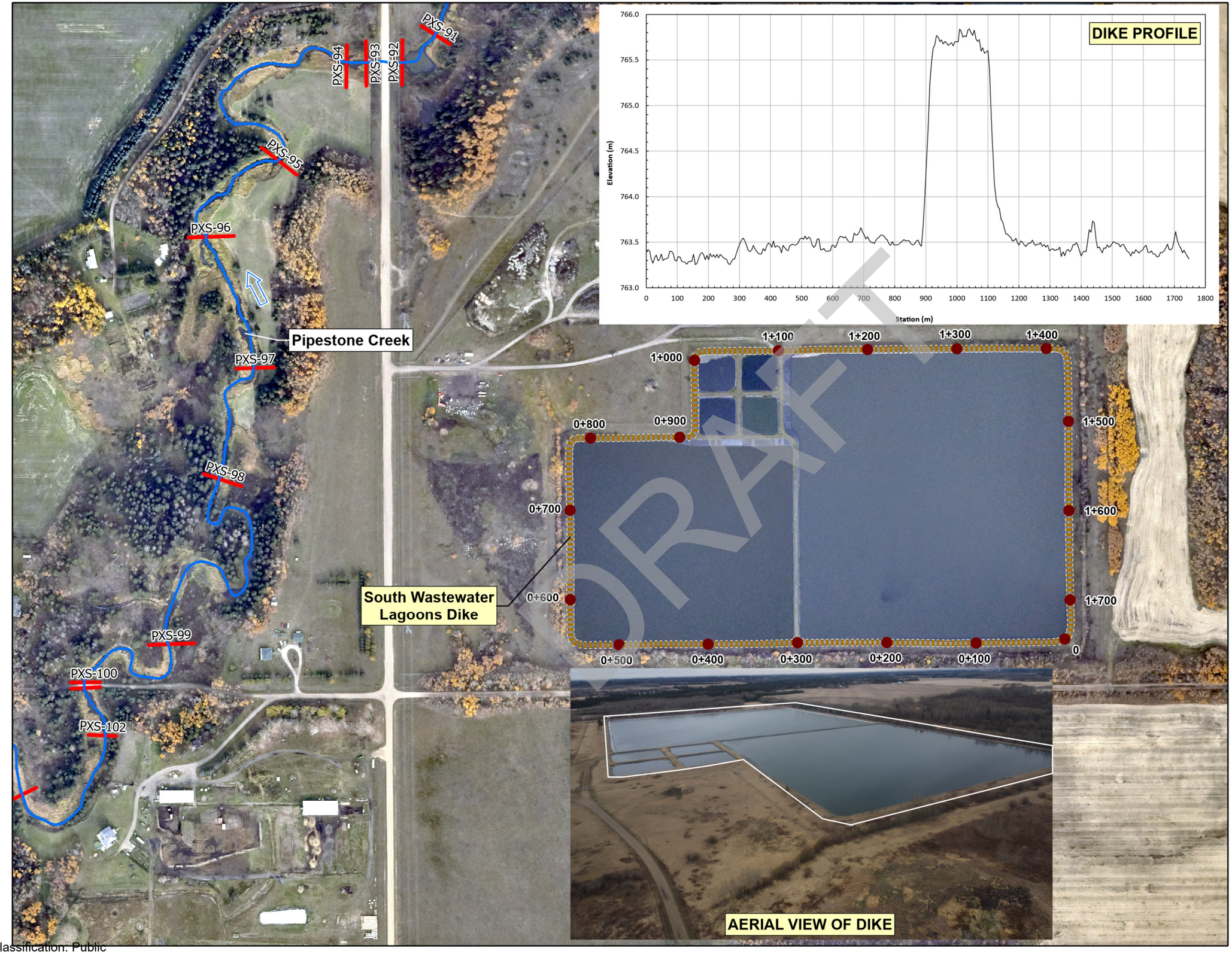
Name	Owner	Stream	Upstream Survey XS	Downstream Survey XS	Crest Length (m)	Minimum Crest Elevation (m)
South Wastewater Lagoons Dike	Town of Millet	Pipestone Creek	PXS-99	PXS-95	1,750	763.254
North Wastewater Lagoons Dike			PXS-86	PXS-81	700	752.225

Since these dikes are not conventional flood control structures, no design drawings were readily available. NHC conducted a survey to determine the crest elevation profiles for the dikes. These survey points were compared with the DTM to assess the accuracy of the DTM at the dike site. The average variance stands at 0.01 m, falling within the acceptable tolerance range.

The surveyed profiles, along with plan views and photographs of the dikes surrounding the south and north wastewater lagoons, are presented in Figure 2.2 and Figure 2.3, respectively.

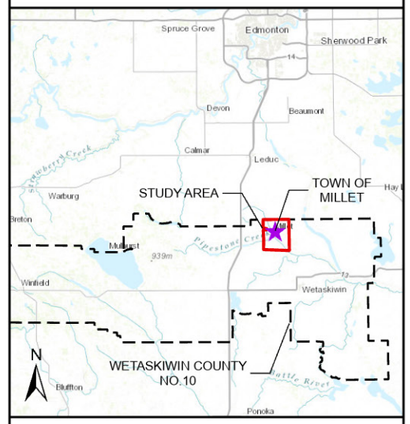
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Classification: Public



Alberta Canada

nhc



FLOW DIRECTION
DIKE STATION MARKER
FLOOD CONTROL STRUCTURES
SURVEY CROSS SECTIONS
STUDY REACH

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:4,000
0 100 Meters
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY/MMM	RBA

Job Number	Date
1008862	02-APR-2025

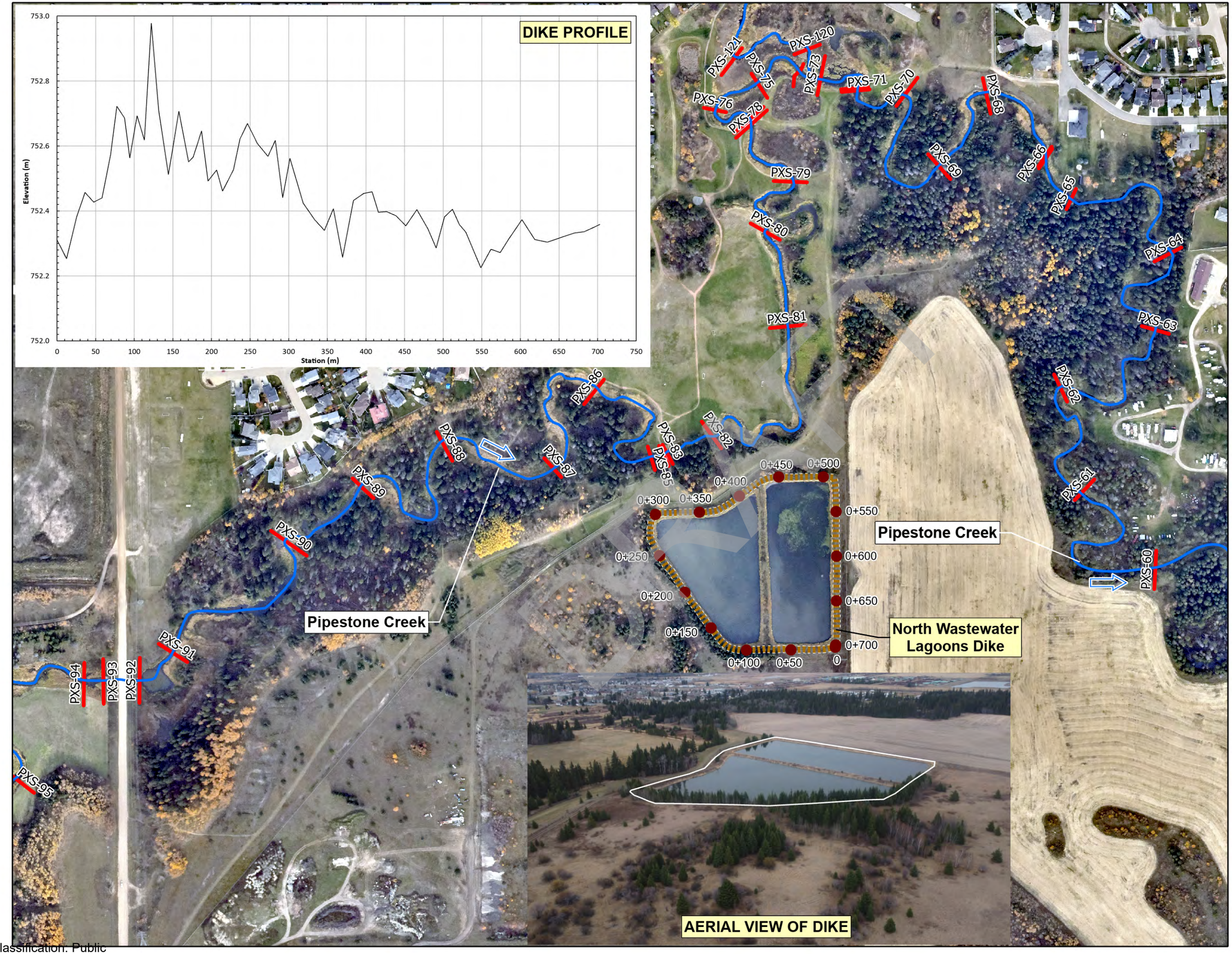
MILLET FLOOD STUDY

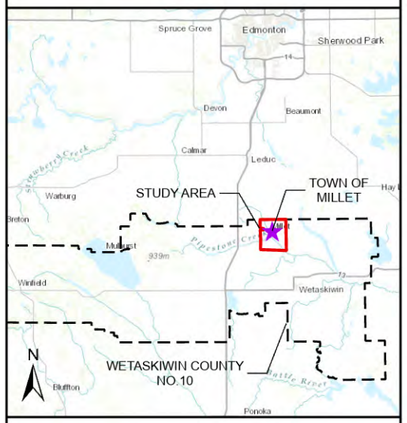
SOUTH WASTEWATER LAGOONS DIKE DETAILS

FIGURE 2.2

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Classification: Public





FLOW DIRECTION
DIKE STATION MARKER
FLOOD CONTROL STRUCTURES
SURVEY CROSS SECTIONS
STUDY REACH

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:4,000
0 100 Meters
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY/MMM	RBA

Job Number	Date
1008862	02-APR-2025

MILLET FLOOD STUDY

NORTH WASTEWATER LAGOONS DIKE DETAILS

FIGURE 2.3

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Classification: Public

2.7 Additional Data

Additional data comprises site photographs, gathered during the site visit and survey, encompassing both ground shots and aerial drone shots. Hydraulic structure drawings and base mapping features were also collected as integral components of the project.

2.7.1 Discharge and Water Level Measurements

As part of the survey program, NHC has measured discharge and corresponding water levels at the Pipestone Creek and Eyot Creek study reaches. Discharge measurements were taken at three selected transects—two along Pipestone Creek and one along Eyot Creek. Due to the muskeg terrain and stagnant water, discharge measurements were not feasible for Snake Drain. Water levels were recorded throughout Pipestone Creek and Eyot Creek in conjunction with the discharge measurements.

Discharge measurements were done using a Sontek FlowTracker Acoustic Doppler velocimeter (ADV) mounted to a wading rod. The ADV reports velocity measurements to an accuracy of ±2.5 mm/s. Table 2.7 summarizes the discharge measurements for Pipestone Creek and Eyot Creek carried out on 07 and 08 May 2024.

Table 2.7 Summary of discharge measurements

River	Reach	Date	Discharge Measurement (m^3/s)	Location Remarks
Pipestone Creek	Above Eyot Creek	07 May 2024	0.02	Upstream of Eyot Creek confluence
	Below Eyot Creek	08 May 2024	0.41	Range Road 242
Eyot Creek	Below Snake Drain	07 May 2024	0.21	45 Avenue

Unfortunately, all measured discharges were significantly low and not representative of flood conditions. At the Pipestone Creek transect above Eyot Creek, the flow was nearly unmeasurable at just 0.02 m^3/s. Field observations indicated mostly stagnant water in the creek with minimal surface flow. However, this may only reflect conditions at the selected discharge measurement site and may not be representative of the entire Pipestone Creek above Eyot Creek study reach.

2.7.2 Site Photographs

Appendix C provides annotated reach representative photographs obtained during the site inspection and survey program. The location, time, and other metadata information are embedded in the electronic images included as part of the digital file submission.

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Classification: Public

2.7.3 Hydrometric Gauging Station Information

There is no active WSC gauging station within the study reach of Pipestone Creek, Eyot Creek, and Snake Drain. Thus, no WSC benchmarks are available to compare against the control network.

2.7.4 Hydraulic Structure Design Drawings

NHC requested design drawings for bridges and culverts through EPA, TEC, and Town of Millet. Information was obtained for the following structures:

- 45 Avenue Bridge at Eyot Creek (BF910)
- Highway 2A Bridge at Pipestone Creek (BF72548)
- Range Road 245/Gov't. Road Culvert at Pipestone Creek (BF9139)

2.7.5 Base Mapping Features

In addition to the datasets listed above, other base mapping data were obtained to support modelling and mapping for the study, including road network, hydrography, administrative boundaries, topographic maps, and Alberta Township System (ATS) grids within the study area.

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3 FLOOD HYDROLOGY

This section provides a summary of flood hydrology for the study. A more detailed assessment of open water hydrology is provided in the Open Water Hydrology Assessment Memorandum in **Appendix D**.

3.1 Flooding History

A description of local flood history was prepared to provide context for the hydraulic model creation and calibration. This flood history documentation summarizes information related to open water flooding that has been documented and observed.

NHC explored and reviewed the following sources to document major flood events in the study area:

- Millet Flood Risk Mapping Study (NHC, 2003)
- TEC bridge file for Highway 2A bridge crossing (BF 72548)
- Discussion with local people and stakeholders

Classification: Public

3.1.1 General Information

Long-term flow data are not available within the study reaches. The only WSC gauge station within the study reach, 05FA007 (Pipestone Creek near Millet), was discontinued and provides only daily flows measured in April and early May of 1925. However, long-term Pipestone Creek flow monitoring data are available downstream of the study area. Currently, WSC operates a gauging station on Pipestone Creek about 10 km downstream of the study area, which has been in operation from 1972-1979, and from 1990 to the present (WSC Station 05FA012 – Pipestone Creek near Wetaskiwin, drainage area = 1,030 km^2). Additionally, a now discontinued gauging station was operated 3 km upstream of the current gauge from 1979 to 1990 (Station 05FA022 - Pipestone Creek below Bigstone Creek, drainage area = 1,020 km^2). The data from these two gauges are transferable due to the similarity of the drainage areas.

Both WSC Station 05FA012 and 05FA022 are located close to the study area, but their drainage areas are about three times as large as the Pipestone Creek study basin area, due to a major tributary, Bigstone Creek, joining Pipestone Creek just downstream of the study area. Despite the difference in the drainage area size, data from WSC Stations 05FA012 and 05FA022 can be used to describe the flood characteristics for the current study area due to their similar climate and physiographic conditions.

Most annual peak flows in Pipestone Creek occur between March and May, primarily due to snowmelt or rain-on-snow events, though some peak flows have resulted from summer rainfall in certain years. The combined 53-year data record from stations 05FA012 and 05FA022 provides discharge measurements and the timing of annual maximum flows. Of the ten largest recorded floods, seven occurred in April and early May, likely driven by snowmelt runoff, while the remaining three took place in July, resulting from summer rainfall.

3.1.2 Open Water Floods

Recent and Recorded Open Water Floods

The three largest floods on record are described as follows.

1974 Flood Event

The largest flood on record was observed in the spring of 1974, with an instantaneous peak of 98 m^3/s at WSC Station 05FA012 – Pipestone Creek near Wetaskiwin. The 1974 flood is the largest peak flood by a significant margin across many basins in central and northern Alberta, including the Pipestone Creek basin.

Figure 3.1 illustrates the impacts of the 1974 flooding event on the old Highway 2 Bridge, prior to the current bridge's construction in 1990, situated within the study reach.

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1925 Flood Event

The 1925 spring flood is the second largest event on record for the Pipestone Creek basin. WSC Station 05FA007 – Pipestone Creek near Millet reported a maximum daily discharge of 37.7 m^3/s on April 13, 1925. On the same day, WSC Station 05FA008 – Bigstone Creek near Bigstone recorded the maximum daily discharge of the year as 19.3 m^3/s. Accordingly, the daily discharge of April 13, 1925, for Pipestone Creek near Wetaskiwin was estimated as 61.0 m^3/s, which is greater than all annual maximum daily discharges reported for this gauge except the 1974 value.

The precipitation data suggest that the 1925 spring event was likely the largest event in the period from 1925 to 1971. Therefore, the 1925 spring event might be the second largest flood event in the Pipestone Creek basin within the period from 1925 to 2023, next to the 1974 spring flood.

1990 Flood Event

The 1990 flood event was the third largest flood in the record. The flood occurred in July with an instantaneous peak of 48.1m^3/s at WSC Station 05FA012 – Pipestone Creek near Wetaskiwin.

Historical and Observed Open Water Floods

Historic floods refer to major floods that occurred prior to the period of hydrometric data collection and systematic recording of water level and discharge.

According to TEC bridge file #72548, which includes the history and observed flood levels at the Highway 2A bridge, a significant flood occurred in June 1954. This flood was likely a summer flood. No peak discharge estimate is available for this flood.

Figure 3.2 presents images captured at old Highway 2 bridge during the 1954 flood event following the peak flow.

3.1.3 Ice Jam Floods

Ice jams have not been a cause of flooding in the study area, based on the information available.

3.2 Flood Frequency Analysis

An open water flood frequency analysis was carried out to determine estimates of flood frequencies for a range of return periods up to 1000 years. Details on the flood frequency analysis are provided in the Open Water Hydrology Assessment Memorandum in **Appendix D**.

DRAFT

Classification: Public



(a)



(b)

DRAFT

Notes:
1. (a) View of old Highway 2 Bridge (replaced in 1990) looking downstream from the right bank - 23 April 1974 12:20 pm.
2. (b) View looking upstream at the old Highway 2 Bridge estimated high water level is approximately 0.03 m higher than water level shown.

Alberta Canada		MILLET FLOOD STUDY
nhc		**1974 FLOOD PHOTOGRAPHS**
	Job: 1008862 *Date: 02-APR-2025*	FIGURE 3.1

Classification: Public



DRAFT

Notes: 1. View of old Highway 2 Bridge (replaced in 1990) looking at southwest abutment – estimated high water level 742.7 m - June 1954.

Alberta Canada		MILLET FLOOD STUDY
nhc		**1954 FLOOD PHOTOGRAPHS**
	Job: 1008862 *Date: 02-APR-2025*	FIGURE 3.2

Classification: Public

3.2.1 Flood Frequency Flow Estimates

Flood frequency estimates from the 2- to 1000-year floods were developed for Pipestone Creek, Eyot Creek and Snake Drain. The flood frequency flows were estimated based on the regional analysis. The adopted flood frequency estimates are presented in Table 3.1 along with their 95% confidence limits.

Table 3.1 Flood frequency estimates from regional analysis

Return Period (years)	Peak Instantaneous Discharge (m^3/s)									
	Pipestone Creek above Eyot Creek (Site 1)		Pipestone Creek at downstream study boundary (Site 2)		Eyot Creek above Snake Drain (Site 3)		Eyot Creek at the mouth (Site 4)		Snake Drain at the mouth (Site 5)	
	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit
1000	46.4	55.1 40.2	66.8	79.4 57.9	33.2	39.4 28.7	35.3	41.9 30.6	4.7	5.6 4.1
750	44.1	52.4 38.2	63.6	75.5 55.1	31.6	37.5 27.3	33.6	39.9 29.1	4.5	5.3 3.9
500	40.8	48.4 35.4	58.8	69.8 51.0	29.2	34.7 25.3	31.1	36.9 26.9	4.2	4.9 3.6
350	38.1	45.1 33.0	54.9	65.0 47.6	27.2	32.3 23.6	29.0	34.3 25.1	3.9	4.6 3.4
200	33.6	39.7 29.2	48.4	57.2 42.0	24.0	28.4 20.9	25.5	30.2 22.2	3.4	4.0 3.0
100	28.2	33.3 24.5	40.6	47.9 35.3	20.2	23.8 17.6	21.5	25.3 18.7	2.9	3.4 2.5
75	26.1	30.7 22.7	37.6	44.3 32.7	18.7	22.0 16.2	19.8	23.4 17.3	2.7	3.1 2.3
50	22.9	27.0 20.0	33.0	38.9 28.8	16.4	19.3 14.3	17.5	20.5 15.2	2.3	2.7 2.0
35	20.3	23.9 17.7	29.3	34.4 25.5	14.5	17.1 12.7	15.5	18.2 13.5	2.1	2.4 1.8
20	16.2	19.0 14.1	23.4	27.4 20.4	11.6	13.6 10.1	12.4	14.5 10.8	1.7	1.9 1.4
10	11.5	13.5 9.8	16.5	19.4 14.2	8.2	9.7 7.0	8.7	10.3 7.5	1.2	1.4 1.0
5	7.1	8.6 5.7	10.2	12.4 8.2	5.1	6.2 4.1	5.4	6.6 4.3	0.7	0.9 0.6
2	2.5	3.9 1.0	3.6	5.6 1.4	1.8	2.8 0.7	1.9	2.9 0.7	0.3	0.4 0.1

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Classification: Public

3.2.2 Comparison to Previous Studies

The flood frequency estimates for Pipestone Creek, Eyot Creek, and Snake Drain were compared against the estimates from two previous studies (EPEC, 1983 and AENV, 2003). The comparison is shown in Table 3.2 for four sites: Pipestone Creek above Eyot Creek (Site 1), Eyot Creek above Snake Drain (Site 3), Eyot Creek at the mouth (Site 4), and Snake Drain at the mouth (Site 5). No comparisons were made for Pipestone Creek at downstream study boundary (Site 2) as the previous studies did not include this location.

Table 3.2 Comparison with previous flood frequency estimates

Return Period (years)	Pipestone Creek above Eyot Creek (Site 1)			Eyot Creek above Snake Drain (Site 3)			Eyot Creek at the mouth (Site 4)			Snake Drain at the mouth (Site 5)		
	This Study	AENV (2003)	EPEC (1983)	This Study	AENV (2003)	EPEC (1983)	This Study	AENV (2003)	EPEC (1983)	This Study	AENV (2003)	EPEC (1983)
	Drainage Area (km^2)											
	182	**166**	**184**	**107**	**125**	**-**	**118**	**-**	**114**	**4.84**	**3.96**	**-**
100	28.2	21.59	26.5	20.2	16.51	-	21.5	-	18.5	2.9	0.55	-
50	22.9	16.25	-	16.4	12.34	-	17.5	-	-	2.3	0.40	-
20	16.2	10.53	-	11.6	7.96	-	12.4	-	-	1.7	0.26	-
10	11.5	7.36	-	8.2	5.55	-	8.7	-	-	1.2	0.18	-
5	7.1	4.88	-	5.1	3.67	-	5.4	-	-	0.7	0.12	-
2	2.5	2.35	-	1.8	1.78		1.9	-	-	0.3	0.06	-

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The current study provides higher estimates than both previous studies for all corresponding sites and return periods. For example, the 100-year flood peak estimates for Pipestone and Eyot creeks from the current study are 22% to 31% higher than those from AENV (2003), and 6% to 16% higher than those from EPEC (1983). For Snake Drain, the current 100-year flood estimate is 2.9 m^3/s, significantly higher than the value of 0.55 m^3/s from AENV (2003).

The primary difference between the current study and AENV (2003) is the selection of gauging stations for the regional analysis. The regional analysis of AENV (2003) relied on two stations: WSC Station 05FA012 (Pipestone Creek near Wetaskiwin, infilled with 05FA022) and WSC Station 05FA014 (Maskwa Creek No. 1 above Bearhills Lake). Among these two basins, the Maskwa Creek basin appears to have a lower runoff potential than the other basins in the region, as discussed in **Appendix D** (Open Water Hydrology Assessment). As such, AENV's method has the tendency to underestimate flood peaks at the study sites. The current study includes seven additional regional stations with a greater variety of drainage areas. The runoff potentials of these regional basins are slightly higher than Maskwa Creek while consistent with Pipestone Creek near Wetaskiwin. So, the regional analysis of the current study tends to produce higher estimates at the study sites with reduced uncertainties in comparison with AENV (2003).

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EPEC (1983) does not present the data that their analysis was based on. So, the reason for their lower estimates cannot be evaluated.

In addition, the current study used longer flow records that include data for more recent years and benefited from the latest topographic datasets including LiDAR DEM data for basin delineation. So, the flood frequency estimates from the current study would bear lower uncertainties than the previous studies.

Overall, the differences between the current and previous studies reflect the impact of updated data and improved methodologies on flood frequency estimates.

4 HYDRAULIC MODELLING

This section provides an overview of the hydraulic modelling relevant to this study. It includes discussions on the data used in the modelling, the characteristics of the streams and valleys, the model development and calibration process, the results obtained from the model, and the model sensitivity analysis.

4.1 Available Data

Data pertinent to the development of a hydraulic model include basin hydrology, current high-resolution terrain data representing the floodplain, survey data, existing hydraulic models, and calibration data. The data available for this study are summarized below.

4.1.1 Survey and Base Data

The hydraulic modelling utilized the following survey and base data:

- cross section survey data gathered by NHC
- survey data on hydraulic structures such as bridges and culverts, collected by NHC
- hydraulic structure design drawings
- water level survey data collected by NHC throughout the study reach

In addition, the non-hydro-flattened DTM received in August 2024 was used for constructing the model. For additional details regarding the acquired survey and base data, refer to Section 2.

4.1.2 Previous Models

In 2003, NHC conducted a flood risk mapping study for the provincial government and developed a hydraulic model for Pipestone Creek, Eyot Creek, and Snake Drain at Millet. This model covered segments of these three creeks within the current study area. During the

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development of the hydraulic model for this study, parameters from the 2003 NHC model were referenced and compared with those selected for the present analysis. This comparison serves as a validation check for the parameters used in the current study.

4.1.3 Highwater Marks

Highwater mark observations serve as documentation of the highest water levels reached at specific locations during a particular flood event. These observations are instrumental in calibrating and validating hydraulic models, as they allow for comparisons between simulated water levels and actual highwater mark elevations along the study reach. To gather highwater mark data, various sources such as previous studies, the EPA database, flood history documentation from TEC, and local historical archives were thoroughly searched. Table 4.1 lists the HWM elevation data reported for the May 1948, June 1954, and April 1974 flood events along Pipestone Creek. Unfortunately, no HWM data was found for Eyot Creek or Snake Drain. Additionally, some HWMs in Pipestone Creek were associated with old bridges that have since been replaced, making it impossible to determine their geodetic elevations and has been excluded from Table 4.1. The locations for each HWM were shown in Figure 4.1 and were approximated using information specific to each HWM observation site (e.g. site photographs or comments on their location with respect to other features like bridges).

Table 4.1 Summary of available HWMs

Event	Location Description	River	Reach	River Station	Discharge (m^3/s)	HWM Elevation (m)
May 1948	Highway 2A Bridge	Pipestone Creek	Below Eyot Creek	9,800	Unknown	743.8
June 1954	Highway 2A Bridge			9,800	Unknown	742.7
23 April 1974	Range 245/Gov't. Road Culvert (Upstream Side)		Above Eyot Creek	14,486	32.1[1]	752.8
	Range Road 245/Gov't Road Culvert (Downstream Side)			14,445		750.6
	Highway 2A Bridge		Below Eyot Creek	9,800	46.2[1]	743.3
	On a farmland (estimated from flood photographs)			9,112		742.0

1. The discharge value was estimated based on NHC's Open Water Hydrology Assessment.

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No discharge measurements are available for Pipestone Creek within the study reach for any of the three events with recorded HWM data. However, discharge data is available for Pipestone Creek near Wetaskiwin (WSC Station 05FA022) for April 1974, located downstream of the study area. The recorded peak instantaneous discharge for this event at WSC Station 05FA022 was 98 m^3/s, with an estimated return period of approximately 165 years, based on NHC's current open water hydrology assessment. For detailed information, please refer to **Appendix D**.

Based on the estimated 165-year return period and the flood frequency curves developed using the Pearson Type III (P3) distribution for Pipestone Creek study reaches (as illustrated in Figure 4.2), the peak instantaneous discharge was estimated at 32.1 m^3/s for Pipestone Creek above Eyot Creek and 46.2 m^3/s for Pipestone Creek below Eyot Creek.

Only the HWM data from April 1974 was used for hydraulic model calibration.

4.1.4 2024 Surveyed Low Flow Water Levels

The water levels corresponding to the flow measurements (described in Section 2.7.1) along Pipestone Creek and Eyot Creek were surveyed on May 7–8, 2024. These surveys were conducted to represent the entire study reach. The locations of the surveyed water levels along with the flow measurement locations were illustrated in Figure 4.1.

4.1.5 Gauge Data and Rating Curves

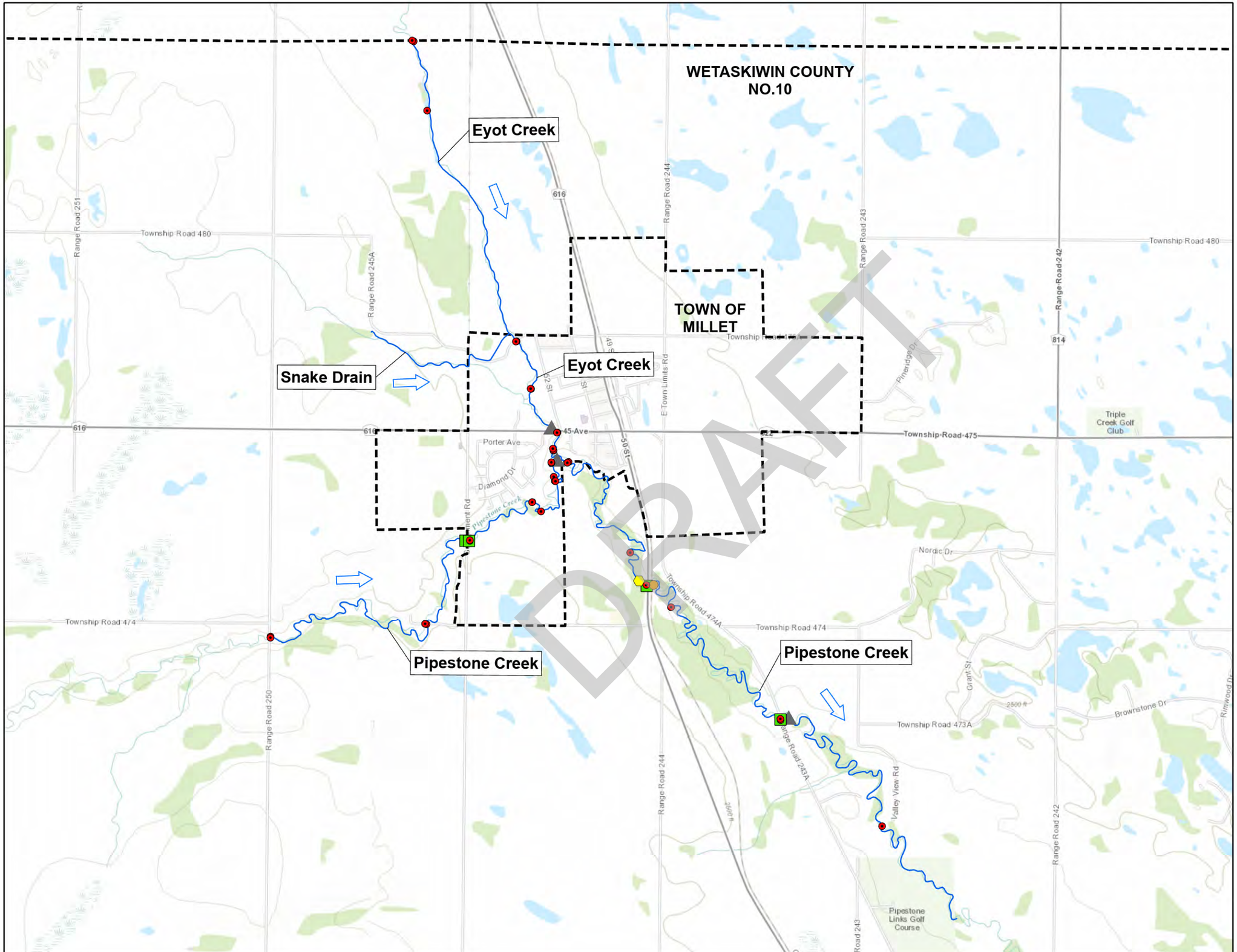
The relationship between stage (water height) and discharge at a gauging station is established by the WSC using recorded stage data and direct discharge measurements. This relationship is represented by a curve fitted to the observed data, commonly known as a rating curve. However, since there are no WSC gauges within the study reaches, no rating curve data is available for this study.

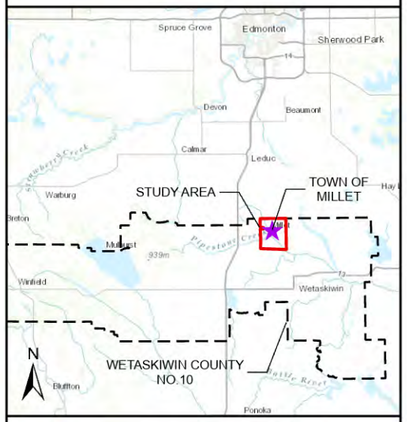
4.1.6 Flood Photography

Ground flood photos are available for some major floods in the area including the 1954 and 1974 open water floods. These photographs are referenced in the flood history section (Section 3.1).

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FLOW DIRECTION
07 AND 08 MAY 2024 SURVEYED WATER LEVEL
APRIL 1974 HWM
JUNE 1954 HWM
MAY 1948 HWM
07 AND 08 MAY 2024 NHC DISCHARGE MEASUREMENT
STUDY REACH
MUNICIPAL & COUNTY BOUNDARIES

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 1 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	LS	RBA

Job Number	Date
1008862	16-MAR-2025

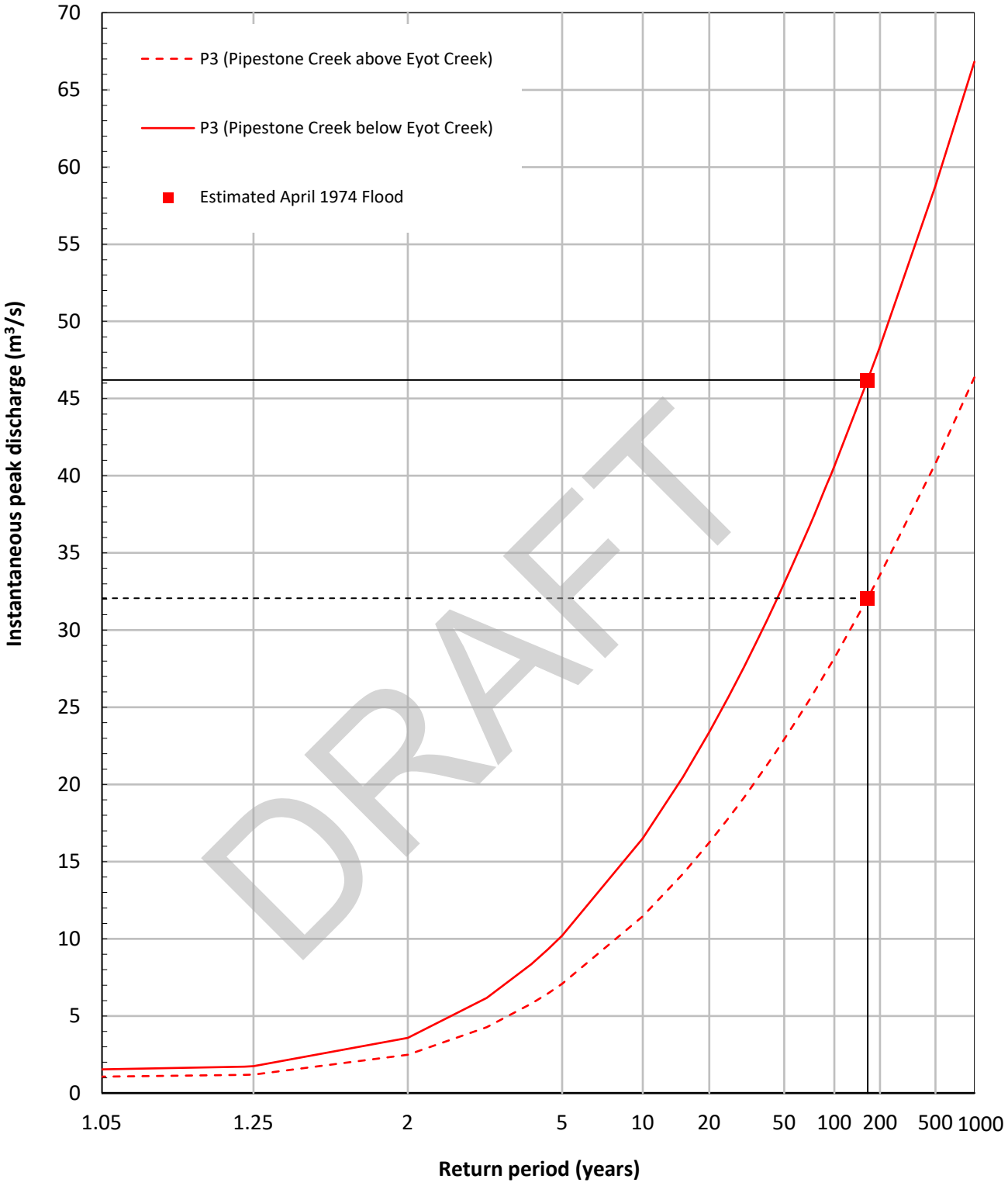
MILLET FLOOD STUDY

LOCATION OF AVAILABLE HWMs AND 2024 SURVEYED WATER LEVEL

FIGURE 4.1

J:\Y_P_Projects (Active)\1008862 Millet Flood Study\90_GIS\REPORT FIGURES\1008862 Millet FS Figures.aprx

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SCALE – AS SHOWN

UNITS: AS SHOWN

Job: 1008862

Date: 02-APR-2025

MILLET FLOOD STUDY

ADOPTED FLOOD FREQUENCY CURVES FOR PIPESTONE CREEK

FIGURE 4.2

Classification: Public

4.2 River and Valley Features

This section talks about the channel and floodplain characteristics of Pipestone Creek, Eyot Creek and Snake Drain within the study area.

4.2.1 General Description

Pipestone Creek is a prairie stream in central Alberta that generally flows eastward through the Town of Millet before turning south after its confluence with Eyot Creek. Eyot Creek flows from north to south, joining Pipestone Creek at the town's southern boundary. Snake Drain flows west to east, meeting Eyot Creek at the town's northern boundary.

4.2.2 Channel Characteristics

The Pipestone Creek study reach is a grass-lined channel with an irregular meander pattern. Upstream of its confluence with Eyot Creek, the channel has light vegetation, including some weeds and stones. By contrast, the downstream section features denser vegetation, heavy weed growth, and deep pools. Beaver dams and meander cutoffs are visible throughout the study reach. The creek bed material has been identified as sandy gravel silt (NHC, 2003).

The Eyot Creek study reach consists of a flat, wide, relatively straight grass-lined channel with weeds, stones, and sections of ineffective slopes. Its characteristics are believed to be similar to those of Pipestone Creek upstream of the Eyot Creek confluence.

The Snake Drain study reach includes both a natural channel and a man-made ditch. The natural channel, located upstream of Range Road 245A, is wide and contains dense vegetation, weeds, and fallen trees, along with deep pools and a few beaver dams observed during the site visit. Downstream of Range Road 245A, Snake Drain transitions into a straight, excavated ditch with three gabion drop structures.

The slopes and top of bank width for Pipestone Creek, Eyot Creek and Snake Drain vary by reach, but the average slope and top of bank width for each reach are summarized in Table 4.2.

Table 4.2 Summary of average channel slopes within the study reaches

River	Reach	Average Channel Slope (m/m)	Average Channel Width (m)
Pipestone Creek	Above Eyot Creek	0.0022	9.0
	Below Eyot Creek	0.0013	11.0
Eyot Creek	Above Snake Drain	0.0005	15.0
	Below Snake Drain	0.0012	9.0
Snake Drain	Main	0.0094	9.0

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4.2.3 Floodplain Characteristics

Outside the Town, the floodplains of all creeks primarily consist of farmland and pastureland, covered with medium to short grasses. Within the Town, the floodplain is mainly occupied by parks and recreational areas.

4.2.4 Anthropogenic Features

The study area encompasses the Town of Millet and a portion of Wetaskiwin County, featuring several key anthropogenic features:

- Twenty two crossings, consisting of 18 bridges, 3 culverts and 1 overhead pipe crossing, are distributed along the study reach.
- These crossings serve roads, railways, pedestrian paths, and private land access.
- Recreational amenities such as playgrounds, parks, golf courses, soccer fields, and baseball fields are located within the study area.
- Various residential, commercial, and industrial buildings are situated along the study reach.
- The Town's wastewater lagoons are adjacent to Pipestone Creek, with containment dikes around these facilities.

4.3 Model Construction

This section discusses the hydraulic model development, calibration, model parameter selections, model results, and model sensitivity analysis.

4.3.1 General Methodology

The U.S. Army Corps of Engineer's Hydrologic Engineering Center River Analysis System (HEC-RAS) computer program (Version 6.5, 2024) was used to perform hydraulic modelling for this study. The basic inputs required by HEC-RAS are cross sections spaced throughout the study reach that represent the geometry of river channel and floodplain, roughness coefficients for the channel and overbank areas at each cross section, and upstream and downstream boundary conditions. HEC-RAS can perform one-dimensional (1D), two-dimensional (2D), or combined 1D and 2D hydraulic calculations for a network of channels with or without hydraulic structures. For this study, a 1D model was constructed to compute water surface profiles for steady-state flows. The computational procedure for steady flow calculations is based on the solution of the 1D energy equation. Energy losses due to friction and expansion/contraction between cross sections are calculated.

The analytical approach employed by HEC-RAS has the following assumptions and potential limitations:

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- Flow is gradually varied and boundary friction losses between cross sections are estimated by Manning's equation using section-average parameters.
- The geometry is assumed to be fixed; therefore, changes in the channel and floodplain geometry (e.g. erosion or scour) that may occur during a flood are not accounted for.
- Each model cross section is apportioned into three separate conveyance components representing the main channel, left overbank, and right overbank; and the water level is assumed to be constant across all three conveyance components.
- The flow is one-dimensional (1D); therefore, only the velocity component in the principal direction of flow is accounted for in the model.

Supplementary 2D Modelling

A supplementary 2D model was developed for the study area (including Pipestone Creek, Eyot Creek, and Snake Drain) based on the DTM. The model was preliminary in nature and was only used to guide the initial 1D model construction, such as defining overbank cross section alignments, overbank flow paths, and ineffective flow areas.

1D Geometric Layout

NHC employed the following approach to develop key components of the model's geometric layout:

- Defined the channel centreline along the middle of the main channel and digitized it using ArcGIS tools and by visual referencing the DTM, hillshade, and aerial imagery.
    - Created a single, continuous centreline to represent each modelled reach.
    - Extended the study reach 2 km downstream beyond the study limit, resulting in a total modelled reach of approximately 26 km.
- Digitized the model cross section transects at each surveyed cross section as follows:
    - Digitized the main channel section over the surveyed channel and bank point data.
    - Extended the main channel portion left and right across the floodplain (overbank areas).
    - Aligned the overbank portions perpendicular to the anticipated path of the floodplain flows based on preliminary 2D modelling results and projected them far enough to extend beyond the 1000-year flood inundation extents.
    - Projected cross section elevation values from the survey point data onto the cross section lines using the RAS Mapper toolset through a conflation process.
    - Determined elevations in the overbank areas by extracting elevation values from the underlying DTM along the cross section polylines.

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- Determined the left and right banks (referred to as bank stations) by examining the geometry of cross sections and analyzing the DTM, aerial imagery, and survey data. These bank stations were strategically positioned to delineate the boundaries of the modelled left overbank, main channel, and modelled right overbank sections of the cross sections. Additionally, they were placed to reflect variations in roughness within both the channel and floodplains. It's important to note that while these model bank stations serve to represent hydraulic conditions within the channel and floodplain, they may not align with the actual banks of the main channel. Their primary function is to simulate the hydraulic behavior of the channel and its surrounding floodplains within the model framework.
- Created flow paths coincident with the river centreline and along the left and right floodplains, representing the length of the main channel, left overbank, and right overbank flow paths.
- Measured distances between cross sections along flow path lines. The model requires these distances for calculating energy losses between cross sections within the main channel and the left and right overbank areas.

Channel and Overbank Roughness

Manning's roughness values were used to simulate roughness in the modelled reaches. A minimum of three (one channel and two overbank) roughness values were used within each cross section. Manning's roughness is an empirical coefficient used to account for energy losses due to a combination of factors including surface roughness and channel sinuosity. Manning's roughness also varies somewhat with discharge and this situation could be simulated by a flow roughness factor in hydraulic modelling. The Manning's roughness values adopted for the present study are discussed further in Section 4.3.4.

Expansion and Contraction Coefficients

To account for the effect of flow contraction or expansion losses on the energy balance between successive cross sections, HEC-RAS multiplies the absolute difference in velocity head by a coefficient. These coefficients range from 0.10 for gradual transitions to 0.80 for abrupt transitions (Brunner, 2016).

Boundary Conditions

Boundary conditions are required at the inflow (upstream) and outflow (downstream) boundaries of the model. The inflow boundary condition for this model is the discharge. The outflow boundary condition can be a water level or a friction slope with which the water level will be calculated by HEC-RAS assuming a normal depth condition. NHC used a normal depth friction slope as the downstream boundary condition for this study.

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Ineffective Flow Areas

Ineffective flow areas can be specified within portions of cross sections where water will pond but there is no appreciable flow. One common example of using ineffective flow area is in cross sections upstream and downstream of a bridge or culvert where flow is obstructed by elevated road embankments. In HEC-RAS, ineffective flow areas can be defined as either a permanent or non-permanent type. Permanent ineffective flow areas stay ineffective regardless of the water surface elevation, whereas temporary ineffective flow areas become effective when water surface elevation exceeds a defined elevation. The configuration of ineffective flow areas depends on site-specific circumstances and engineering judgement.

4.3.2 Geometric Database

The geometric database provides all the components of the HEC-RAS model geometry, including cross sections, internal hydraulic structures, and boundary conditions. Each component is described below. Additional information and data are provided as part of the electronic deliverables of the study.

Cross Section Data

A total of 186 cross sections were created and used to construct the model for this study. The steps taken to generate the cross section data were as follows:

- Cross section alignments within the channel were established generally following the alignments of the cross section survey (Section 2.4). The overbank portions were aligned perpendicular to the anticipated flow direction based on preliminary 2D models. The cross section alignments were extended beyond the anticipated 1000-year flood inundation extents.
- Two separate station-elevation data sets were created for each cross section.
- The first data set was created by projecting surveyed data points perpendicularly onto the channel portion of the cross section line.
- The second data set was created by extracting elevation values from the DTM along the cross section lines excluding the channel portion covered by the survey data.
- The two station-elevation data sets were combined. For each cross section, the number of elevation points for the overbanks were reduced using the minimize-area-change point filter option in HEC-RAS, so that the total number of the points is within the HEC-RAS limit of 500 points.
- Distances between consecutive cross sections were established within the HEC-RAS model following the established channel centreline and central flow paths for the left and right overbank areas.

Cross section details are provided in **Appendix E**.

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Hydraulic Structures

The constructed model comprises 18 bridges, 3 culvert crossings and 1 overhead pipeline crossing. The alignments and positions of all other hydraulic structures were determined based on survey data and existing design drawings (as available). Hydraulic structure details are tabulated in **Appendix B.**

Key design information for these structures that was incorporated into the model is tabulated in **Appendix E**. For bridges, this includes high and low chord elevations defining the bridge deck and the superstructure, and the arrangement, shape, and dimensions of the piers. For culverts, parameters include the length of the barrel, the shape including span and rise, and the upstream and downstream invert elevations. The road profile at each hydraulic structure crossing was extracted using DTM data along the road centreline.

4.3.3 Model Calibration

This section discusses the general model calibration methodology, high flow calibration, and low flow calibration.

Methodology

Calibration Parameters

Model calibration involves the selection and adjustment of model parameters such that calculated flood levels agree well with observed flood levels. Calibration parameters could include:

- Manning's roughness coefficient for the channel and floodplain
- friction slope associated with the downstream normal depth boundary condition
- ineffective flow areas
- expansion and contraction coefficients

NHC selected Manning's roughness as the primary calibration parameter for this study; however, other model parameters from the list were also selected within plausible limits to achieve reasonable results.

Roughness Calibration Challenges and Limitations

Roughness calibration is associated with the following challenges and limitations:

- accuracy of HWM elevations
- improper identification of HWMs
- uncertainties in estimates of instantaneous flood peak discharge for the calibration event

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- presence of a hydraulic control between model cross sections

Main Channel Manning's Roughness

NHC's general calibration approach involved adjusting Manning's roughness values to ensure computed water levels closely matched observed levels during the selected high flow calibration event. These roughness adjustments were made on a reach-averaged basis through comparison of computed and observed water levels. A single calibrated model was developed to represent both high and low flow conditions.

Overbank / Floodplain Roughness

NHC characterized roughness in the floodplain areas (model overbanks) using land cover type determined by ground observations, collected aerial drone videos, and visual inspection of aerial imagery. These overbank and floodplain roughness values were not adjusted during the model calibration process.

High Flow Calibration

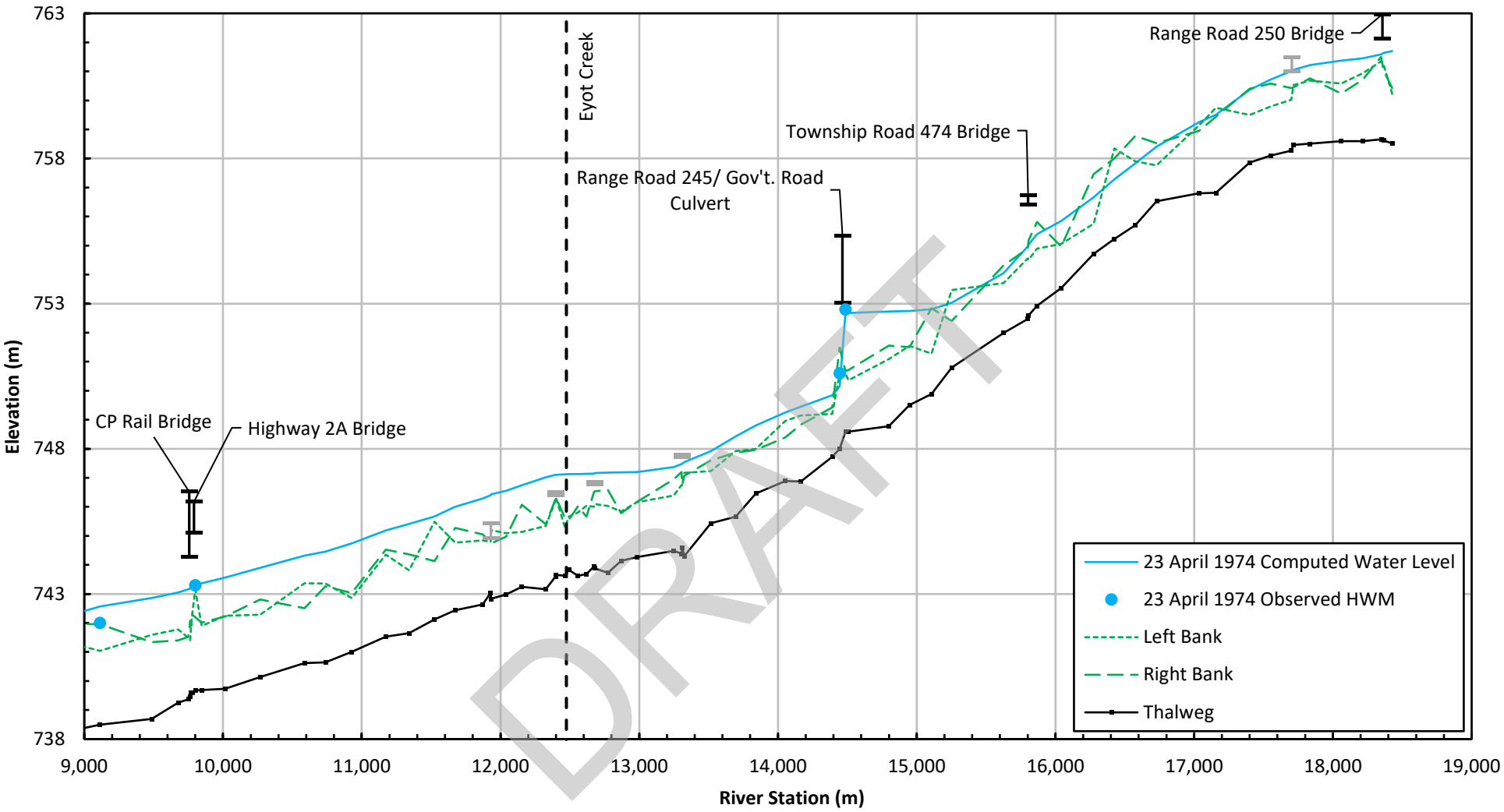
NHC selected the April 1974 flood as the calibration event because it is the only recorded flood within the study area with available HWMs and discharge estimates. High flow calibration was conducted only for Pipestone Creek, as no HWM data is available for Eyot Creek or Snake Drain.

The April 1974 HWM event is the largest recorded, with an estimated instantaneous peak discharge of 32.1 m^3/s in Pipestone Creek above Eyot Creek and 46.2 m^3/s below Eyot Creek. These estimates exceed the 100-year discharge but remain below the 200-year discharge. They were determined based on NHC's open water hydrology assessment (**Appendix D**).

The calibration results are illustrated by comparing the computed WSEs with the observed HWM elevations. Figure 4.3 shows a comparison between the computed water surface profile and the observed HWM elevations for the calibration event (April 1974 flood), Table 4.3 summarizes the comparison. For the April 1974 flood event, the average difference between computed and observed HWM elevations was zero, while the absolute difference was 0.30 m; the largest positive difference was 0.57 m, and largest negative difference was -0.45 m.

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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada / nhc	SCALE – AS SHOWN	MILLET FLOOD STUDY
	UNITS: AS SHOWN	**COMPUTED VS OBSERVED WATER LEVELS FOR PIPESTONE CREEK – 1974 FLOOD EVENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.3

Classification: Public

Table 4.3 High flow calibration results

River	Reach	River Station (m)	Location	Observed HWM Elevation (m)	Event	Discharge (m^3/s)	Computed WS Elevation (m)	Computed minus Observed (m)
Pipestone Creek	Above Eyot Creek	14,486	Range Road 245 (Upstream Side)	752.80	April 23, 1974	32.1	752.65	-0.15
		14,445	Range Road 245 (Downstream Side)	750.60			750.15	-0.45
	Below Eyot Creek	9,800	Highway 2A Bridge	743.30		46.2	743.31	0.01
		9,112	On a farmland (estimated from flood photographs)	742.00			742.57	0.57

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The high flow calibration for this study is based on four points along Pipestone Creek. Given the limited number of available calibration points, all four were included in the process. However, the previous study (NHC, 2003) raised concerns about the reliability of HWMs collected at the Range Road 245 crossing. These HWMs were measured upstream and downstream of a 4,300 mm CSP culvert, where NHC (2003) reported a 1.3 to 1.6 m difference between computed water levels and observed HWMs. The previous study also estimated a lower discharge for the 1974 flood compared to the current study and had modelled the culvert as an arch, whereas field observations from this study confirmed it to be circular. To improve accuracy, the current study also adjusted the culvert loss coefficients (within a plausible range) along with channel roughness parameters, resulting in a closer match between computed and observed water levels, reducing the difference between computed and observed water levels to 0.15 and 0.45 m.

Among the remaining two HWMs, the estimate derived from flood photographs taken on farmland carries higher uncertainty as it is believed to be a coarse estimation. As a result, this point was given less emphasis during calibration.

According to NHC (2003), the most reliable HWM among all four is the one measured at Highway 2A. The previous study relied solely on this point for calibration, thus it was prioritized in the current study as well. The computed and observed HWM elevations at Highway 2A during

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the 1974 flood differed by only 0.01 m, providing strong confidence in the high flow calibration process.

While high flow calibration impacts the selection of Manning's roughness values, the limited availability of calibration data makes it crucial to ensure that the chosen values align with those documented in the literature and fall within the range used in previous studies for similar streams. Additional details on channel roughness selection are provided in Section 4.3.4.

Low Flow Validation

Flow measurements and corresponding water levels from the May 2024 survey were used to validate the HEC-RAS model, with measurements taken for Pipestone Creek and Eyot Creek on May 7 and 8, 2024. The measured discharge on Pipestone Creek below Eyot Creek was 0.41 m^3/s on May 7, while Eyot Creek below Snake Drain had a discharge of 0.21 m^3/s on May 8. NHC also attempted to measure discharge on Pipestone Creek above Eyot Creek, but the flow was negligible (0.02 m^3/s), so the associated water level measurements with this discharge could not be used for low flow validation. At the time of survey, no flow was observed in Snake Drain, meaning the discharge measured in Eyot Creek is assumed to represent both the reaches above and below Snake Drain. Overall, the low flow validation is limited to the Pipestone Creek below Eyot Creek and Eyot Creek reaches.

The calibrated model was used to compute water levels along the reach for conditions observed on May 7 and 8, 2024. Notably, a flow roughness factor of 1.5 was applied to discharges at or below the 2-year flood level to account for increased roughness caused by tall vegetation in the grassed channel. This roughness is expected to decrease during higher magnitude floods as the vegetation flattens. Further details on the flow roughness factor are provided in Section 4.3.4.

The calibration results are shown by comparing the computed WSEs with the observed water levels in Figure 4.4 for Pipestone Creek below Eyot Creek and in Figure 4.5 for Eyot Creek. Table 4.4 provides a summary of the comparison. During the 2024 NHC survey period, computed water levels were on average 0.42 m below observed levels.

The results from low flow validation are reasonable and not unexpected. Low flow roughness values are typically higher than high flow roughness values due to the greater contribution of bed roughness and vegetation at low flow. A roughness factor even higher than 1.5 would be required to match the observed low flow water levels. However, the required roughness to match the computed and observed water levels are deemed unreasonable for flood modelling, suggesting that additional flow controls within the reach may be influencing low flow conditions. Furthermore, the presence of several beaver dams in the study area affects low flow calibration. While the model is not developed to simulate low flows, the results provide further confirmation of a trend of decreasing roughness with increasing discharge.

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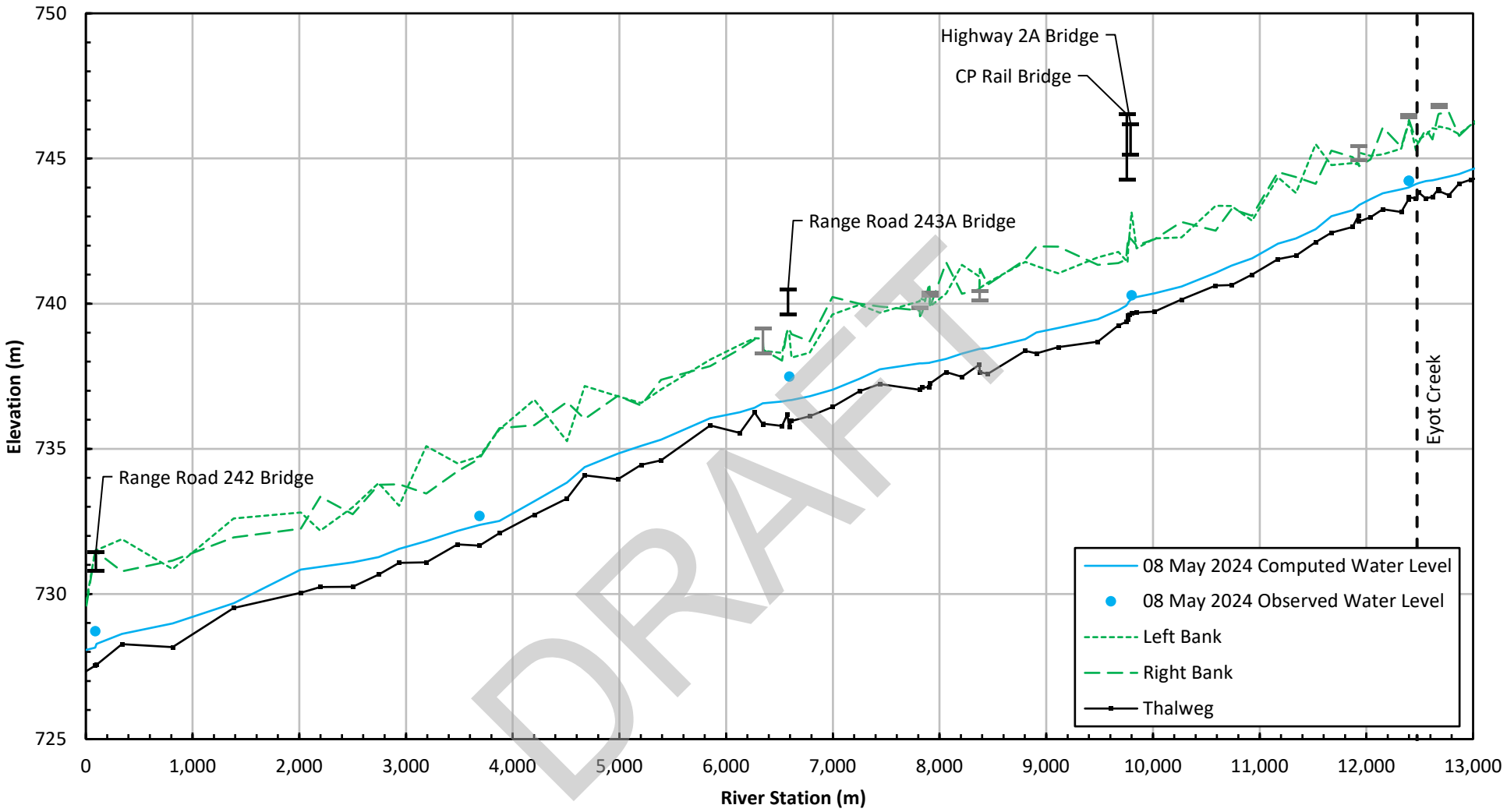
Classification: Public

Table 4.4 Low flow calibration results

River	River Station (m)	Observed WS Elevation (m)	Event	Discharge (m^3/s)	Computed WS Elevation (m)	Computed minus Observed (m)
Pipestone Creek	12,399	744.23	May 8, 2024	0.41	744.01	-0.22
	12,397	744.23			744.00	-0.23
	9,800	740.29			740.17	-0.12
	6,591	737.49			736.67	-0.82
	3,689	732.69			732.38	-0.31
	88	728.72			728.15	-0.57
Eyot Creek	4,195	748.38	May 7, 2024	0.21	747.59	-0.79
	3,569	748.41			747.37	-1.04
	1,394	746.56			746.06	-0.50
	901	745.72			745.47	-0.25
	396	744.98			744.83	-0.14
	209	744.42			744.35	-0.08

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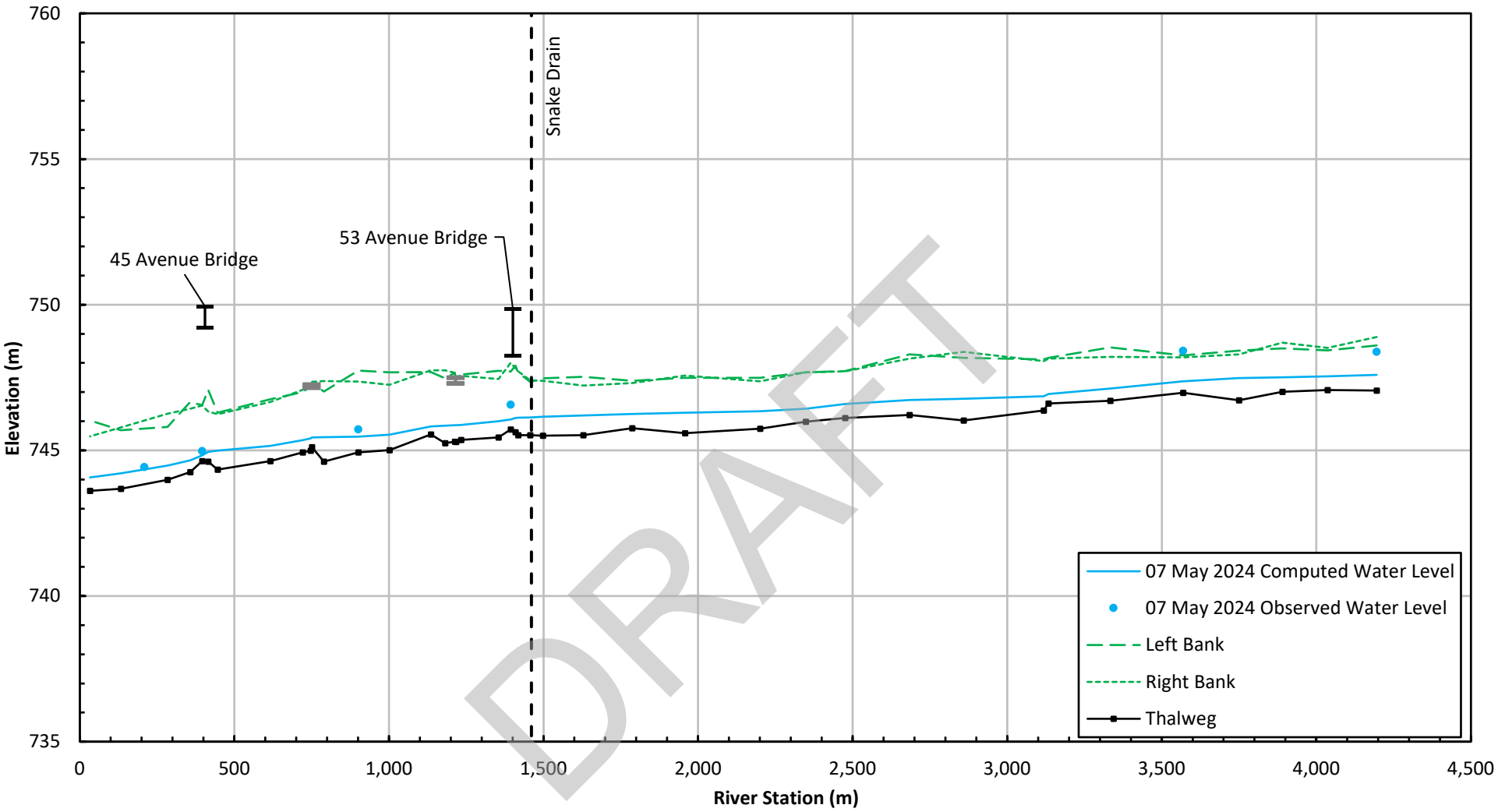


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**COMPUTED VS OBSERVED WATER LEVELS FOR PIPESTONE CREEK BELOW EYOT CREEK – 08 MAY 2024**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.4

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada / nhc	SCALE – AS SHOWN	MILLET FLOOD STUDY
	UNITS: AS SHOWN	**COMPUTED VS OBSERVED WATER LEVELS FOR EYOT CREEK – 07 MAY 2024**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.5

Classification: Public

4.3.4 Model Parameters and Options

The following sections describe the key model parameters and options adopted in the HEC-RAS model. These include Manning's roughness values for channel and overbank areas; contraction and expansion loss coefficients; ineffective areas; and roadway weir coefficient.

Manning's Roughness Coefficient

Manning's roughness is used to account for an array of energy losses that may vary with respect to discharge. A minimum of three (one channel and two overbank) roughness values were used within each cross section.

Channel Roughness

Manning's roughness values for the various channel characteristics were selected based on the literature (Chow 1959; Arcement and Schneider 1989) and high flow calibration based on 1974 flood event. NHC only calibrated channel roughness values along Pipestone Creek using April 1974 flood HWMs. Calibration was not possible for Eyot Creek and Snake Drain due to the absence of HWM data. Instead, the geomorphic characteristics of these channels—including type, material, and formation—were closely analyzed and aligned with literature and calibrated Pipestone Creek study reaches to assign Manning's roughness values.

Channel roughness values were selected as summarized in Table 4.5 with initial range of roughness values proposed based on literature (Chow, 1959), reach representative photos, survey, and site visit. The selected roughness values provided the best match between the computed water levels and the April 1974 HWM data for Pipestone Creek. Note that the selected roughness values are on the higher end of the plausible literature range to achieve better calibration.

The roughness values selected in this study (Table 4.5) are comparable to those used in NHC's previous study (2003), where Manning's roughness values ranged from 0.050 to 0.066 in Pipestone Creek, 0.033 to 0.066 in Eyot Creek, and 0.031 to 0.150 in Snake Drain.

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Table 4.5 Selected Manning's roughness values for main channel

River	Reach	River Station	Selected Manning's Roughness	Literature Manning's Roughness Range	Remarks
Pipestone Creek	Above Eyot Creek	18,427 to 12,491	0.055	0.040-0.055	Grassed channel with some weeds and stone and more ineffective slopes and sections
	Below Eyot Creek	12,464 to 0	0.065	0.050-0.070	Grassed channel with heavy weeds, sluggish reaction and deep pools
Eyot Creek	Above and Below Snake Drain	4,195 to 33	0.055	0.040-0.055	Grassed channel with some weeds and stones and more ineffective slopes and sections (Similar characteristics with Pipestone Creek above Eyot Creek)
Snake Drain	Above Range Road 245A	1,530 to 481	0.10	0.075–0.15	Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush
	Below Range Road 245A	463 to 40	0.040	0.030-0.045	Clean, winding, some pools, and shoals has Gabions

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Overbank Roughness

NHC selected Manning's roughness values for the various overbank characteristics based on values from available literature (Chow 1959; Arcement and Schneider 1989). Since overbank roughness varies based on land cover and vegetation type, values were assigned according to the dominant land cover within the study area, informed by aerial photographs, field observations, and drone video analysis. Table 4.6 summarizes the selected overbank roughness values for each land cover type. These values are consistent with NHC's recent experience conducting flood studies in the Alberta Prairie region, including the Stettler (NHC, 2025) and Camrose Flood Study (NHC, 2022).

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Table 4.6 Selected Manning's roughness values for overbank areas

Dominant Land Cover Type	Description	Selected Manning's Roughness	Literature Manning's Roughness Range
Cultivated Areas	Agricultural crops or pastureland within the overbank with grasses	0.060	0.040-0.080
Urban/Built Area	Development within the wetted width of the design flood with buildings, yards, parks, and transportation corridoes	0.085	0.060-0.14
Dense vegetation	Medium to dense brush	0.10	0.070-0.16
Trees	Dense, willows, straight tree covered area	0.15	0.11-0.20

Roughness Factor

The channel and overbank roughness values mentioned in the above tables (Table 4.5 and Table 4.6 were directly applied to floods of 10-year magnitude and larger. For floods with a recurrence interval of less than 10 years, adjustments were made using a flow roughness factor. Specifically, a factor of 1.5 was assigned to the 2-year flood, while a factor of 1.0 (no adjustment) was used for the 10-year flood. The flow roughness factor for the 5-year flood was interpolated between these values. These adjustments were implemented to improve accuracy and minimize unrealistic dry areas in the channel during 2-year and 5-year floods. These adjustments were followed by Henderson's (1996) recommendations for grassed channels.

Henderson (1966) described that vegetation growth in the channel may elevate roughness during lower flows, this effect tends to diminish with higher flows as the vegetation flattens. According to Henderson (1966), this behavior of roughness is observed mostly in grassed channels, and the transition from higher to normal roughness occurs usually between the 2-year and 5-year flood discharges. Consequently, variable roughness factors were incorporated into the HEC-RAS model to facilitate this transition. This methodology aligned with the approach utilized in the Stettler (NHC, 2025) and Camrose Flood Study (NHC, 2022).

Expansion and Contraction Coefficients

To account for the effect of flow contraction and expansion losses on the energy balance between successive cross sections, HEC-RAS multiplies the absolute difference in velocity head by a coefficient. The default values of 0.1 and 0.3 (for expansion and contraction coefficients) were utilized throughout the model domain, except for cross sections located at bridge and culvert crossings. At these locations, expansion and contraction coefficients were increased to the recommended values of 0.3 and 0.5, respectively.

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Weir Coefficient

HEC-RAS uses a broad crested weir formulation to simulate flow overtopping the hydraulic structures. Typical discharge coefficients range between 1.45 and 1.80, with larger values generating less backwater. Flow overtopping a bridge deck is not ideally represented by a broad crested weir overtopping scenario, and it is generally recommended that lower values be used when an increased resistance to flow from obstructions such as bridge railings, curbs, and debris (FHA, 2012) is anticipated. The bridges and road embankments within the study area could cause moderate resistance to flow, thus a weir coefficient of 1.6 was deemed appropriate for all hydraulic structure embankments in this study.

Upstream Boundary Condition

A specified discharge is required at the upstream end of each modelled reach. This study includes five modelled reaches within the study area, with flow input locations summarized in Table 4.7. The estimated flood frequencies from Table 3.1 as referenced in the table below, were used as the upstream boundary condition.

Table 4.7 Summary of flow input locations

River	Reach	River Station (m)	Flood Frequency Site	Flood Frequency Site Name
Pipestone Creek	Above Eyot Creek	18,427	Site 1	Pipestone Creek above Eyot Creek
	Below Eyot Creek	12,464	Site 2	Pipestone Creek at downstream study boundary
Eyot Creek	Above Snake Drain	4,195	Site 3	Eyot Creek above Snake Drain
	Below Snake Drain	1,457	Site 4	Eyot Creek at the mouth
Snake Drain	Main	1,530	Site 5	Snake Drain at the mouth

Downstream Boundary Condition

At the downstream boundary of Pipestone Creek, a normal depth water level approximation was applied as the boundary condition. The slope used for calculating normal depth was set to 0.0013 m/m representing the estimated energy grade line slope near the downstream boundary. This slope was determined using the measured water surface slope derived from the DTM data. This value was later verified against the surveyed thalweg and water level slope from NHC's May 2024 survey program and found to be acceptable. The adopted normal depth slope is similar to that used in the previous study (NHC, 2003), which was 0.0014 m/m. However, it is important to note that the downstream boundary for the current study is located further downstream than in the previous study.

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Ineffective Flow Areas

Ineffective flow areas were specified at cross sections in the HEC-RAS model based on a review of the local terrain and floodplain features both at and between cross sections. A preliminary 2D model was also used to define the ineffective flow areas. Ineffective flow areas can be specified within portions of cross sections where water is expected to pond, and where the velocity of that water, in the downstream direction, is expected to be close to or equal to zero (Brunner, 2016). The downstream direction is taken relative to the cross section lines defined in the model, so the orientation of cross sections was considered when specifying ineffective flow areas.

Ineffective flow areas in the model may be specified as either permanent or non-permanent. Permanent ineffective flow areas apply regardless of the water surface elevation, whereas non-permanent ineffective flow areas become effective above a defined elevation. The configuration of permanent and non-permanent ineffective flow areas was specified depending on site-specific circumstances and engineering judgement.

The general principles for determining ineffective flow areas were as follows:

- Non-permanent ineffective flow areas were used to "fill" local depressions on the floodplain that are obstructed by higher ground upstream or downstream. These areas were assumed to become engaged in the active flow area (or effective) once the water level exceeded the elevation of the adjacent ground.
- Permanent ineffective flow areas were used to permanently "fill" relic channels, tributary channels or excavated holes that would otherwise have incorrectly added flow area to the cross section.
- Permanent ineffective flow areas were defined where flow patterns were likely to be influenced by nearby bridge abutments and roadway embankments crossing the floodplain. These types of obstructions tend to direct flows towards the bridge opening. Several site-specific factors were taken into account when configuring ineffective flow areas at bridges and culverts in the study area, including: distance from the cross section to the bridge, terrain features, bridge geometry, and skew of the bridge opening relative to the river.
- Ineffective flow areas behind railroad and highway embankments were assessed on an individual basis. Aerial imagery, LiDAR, and historic information were used to determine if there were indications of flow behind and/or above embankments. Areas behind and below the height of the embankment were modelled as effective flow only if there was no downstream obstruction or if there was an indication of flow moving in the downstream direction. Otherwise, permanent ineffective flow areas were set to the top of embankment elevation, allowing areas behind embankments (assumed permeable) to be shown as wet and isolated but not conveying flow. Areas above embankments generally conveyed flow once the embankment was overtopped, unless an upstream or

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downstream obstruction was present causing local ponding or dead zones with limited flow.

Inline Structure

At Eyot Creek above Snake Drain, a narrow dirt access road constructed over the creek bed was identified during the survey program. This road, which crosses the creek, was modelled as an inline structure (RS 3,125) using survey data and an estimated width derived from aerial imagery (5 m).

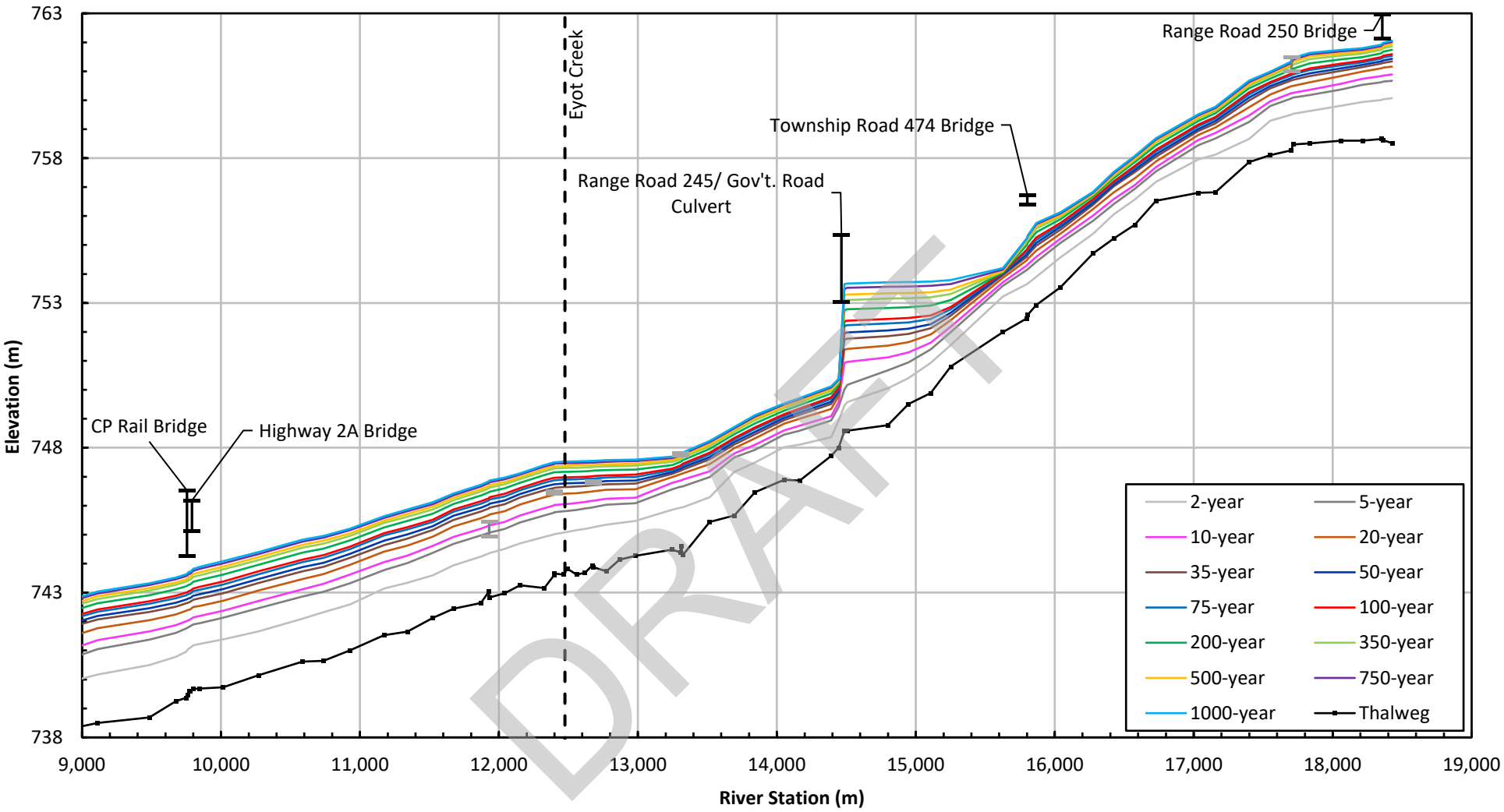
4.3.5 Flood Frequency Profiles

The hydraulic model was used to generate flood frequency profiles for the thirteen open water floods of varying magnitude ranging from 2-year to 1000-year return periods. The computed flood frequency water levels at each surveyed cross section on Pipestone Creek, Eyot Creek and Snake Drain are provided in **Appendix E**. These results are plotted graphically in Figure 4.6 for Pipestone Creek, Figure 4.7 for Eyot Creek and Figure 4.8 for Snake Drain.

It should be noted that water levels along Snake Drain were adjusted at XS-178 for the 10-year and 20-year floods and at XS-166 for the 750-year flood to prevent crossing water surface profiles (i.e., a water level from a smaller flood event being higher than a water level from a larger flood event). This adjustment was made by reviewing the flood frequency profiles above and below each location, as well as the cross sections upstream and downstream, to determine an appropriate water level substitution. A footnote reference marked with an asterisk is included in **Appendix E** at every instance of this adjustment in the tables.

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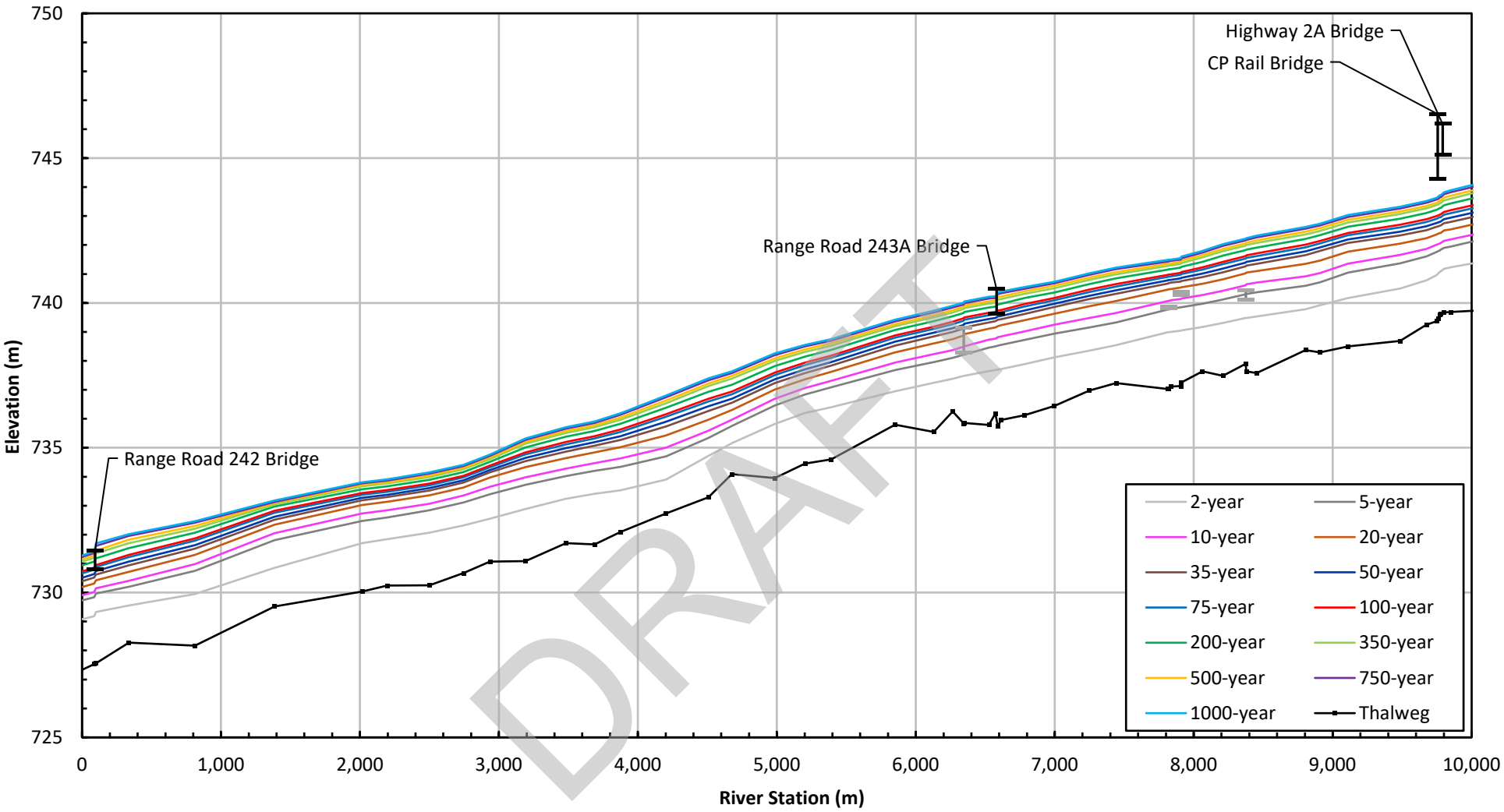


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
	UNITS: AS SHOWN	**PIPESTONE CREEK FLOOD FREQUENCY PROFILES (1/2)**
nhc	*Job: 1008862*	*Date: 02-APR-2025*
		FIGURE 4.6

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

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Job: 1008862

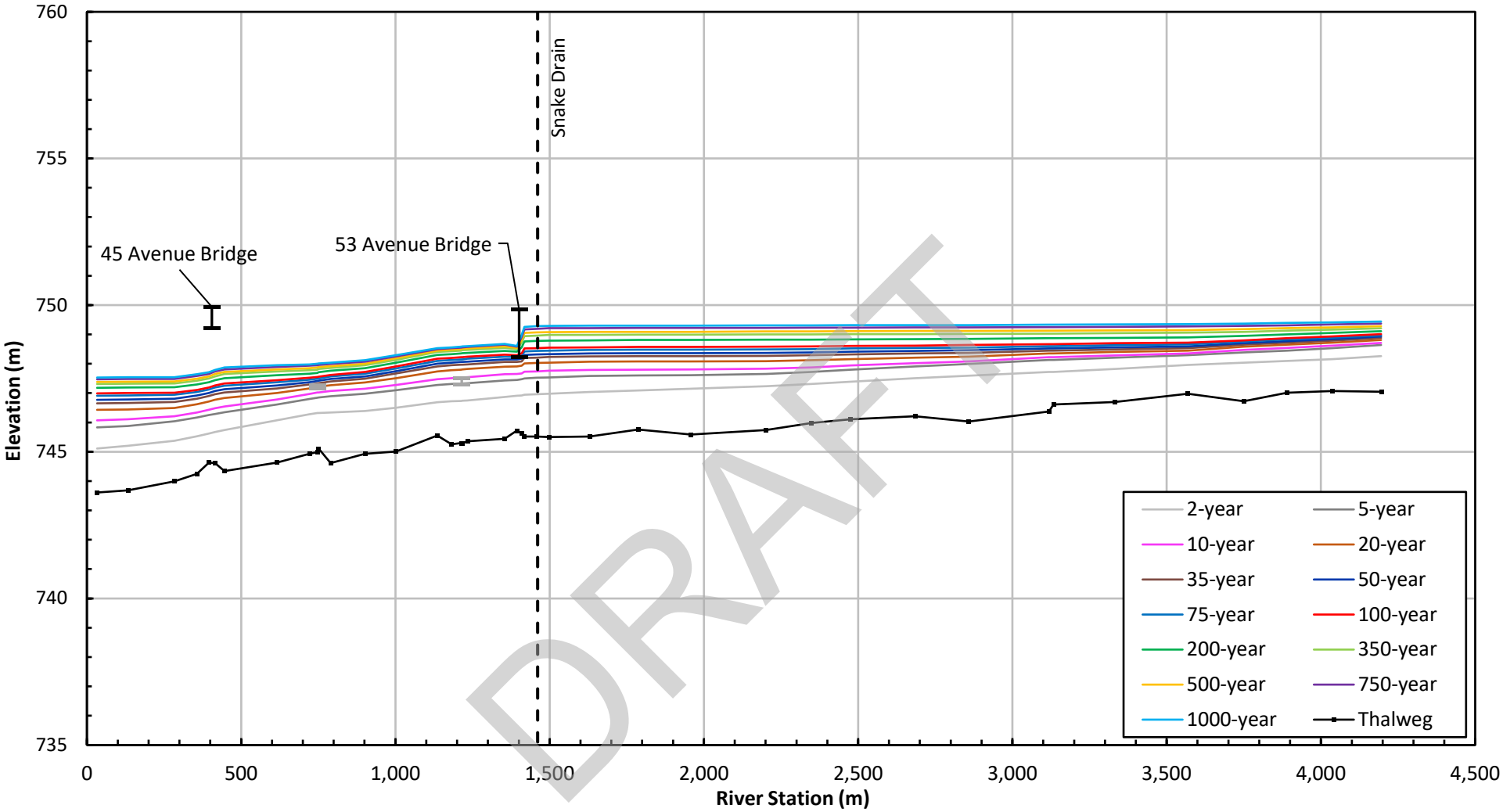
Date: 02-APR-2025

MILLET FLOOD STUDY

PIPESTONE CREEK FLOOD FREQUENCY PROFILES (2/2)

FIGURE 4.6

Classification: Public

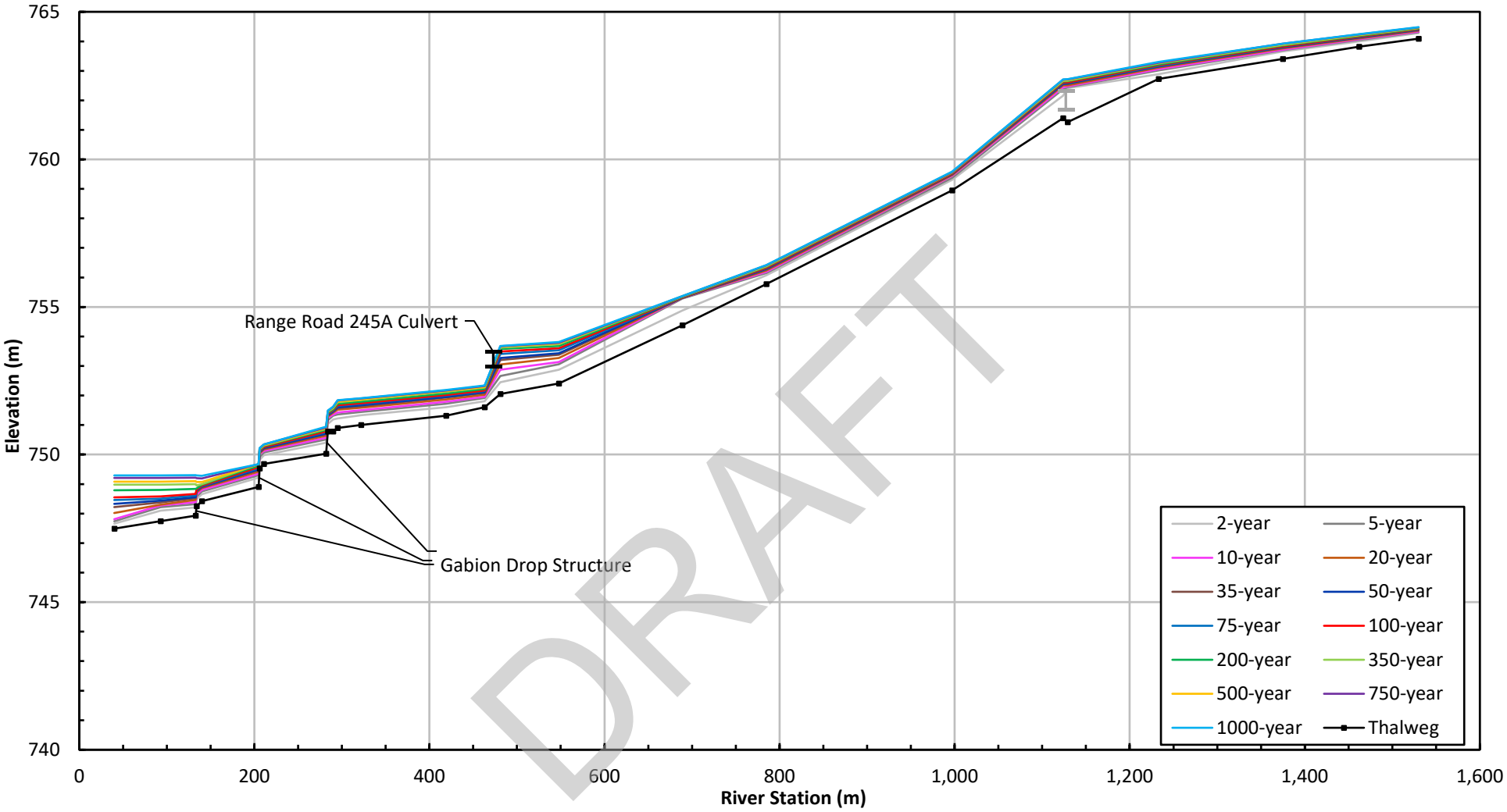


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Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**EYOT CREEK FLOOD FREQUENCY PROFILES**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.7

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Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**SNAKE DRAIN FLOOD FREQUENCY PROFILES**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.8

Classification: Public

4.3.6 Model Sensitivity

Uncertainties in boundary conditions, the Manning's roughness coefficient, and roadway weir coefficient in the hydraulic model could affect computed water levels and consequently flood depths and inundation extents. The sensitivity of computed water levels to these parameters was evaluated to gain an indication of the plausible range of modelling errors and to identify the relative sensitivity to each parameter. The 100-year flood was used as the baseline. A summary of the sensitivity analysis results is provided in the following sections.

Boundary Conditions

The boundary conditions for the HEC-RAS model for this study include a discharge specified at the upstream boundary and a specified normal depth slope at the downstream boundary used by the model to compute the water level corresponding to the discharge. Sensitivity analysis was conducted on both boundary conditions.

The discharges selected for the sensitivity analysis correspond to the lower and upper 95% confidence limits of the 100-year flood peak (Table 3.1). The computed water levels for these discharges are compared with the baseline model results in Figure 4.9, Figure 4.10 and Figure 4.11. A summary of comparison is provided in Table 4.8. The comparison indicates that the lower 95% confidence limit of 100-year discharges resulted in the computed 100-year flood levels being 0.14 m lower on average along Pipestone Creek, 0.12 m lower on average along Eyot Creek, and 0.05 m lower on average along Snake Drain; the upper 95% confidence limit of 100-year discharges resulted in the flood levels being 0.18 m higher on average along Pipestone Creek, 0.17 m higher on average along Eyot Creek, and 0.06 m higher on average along Snake Drain.

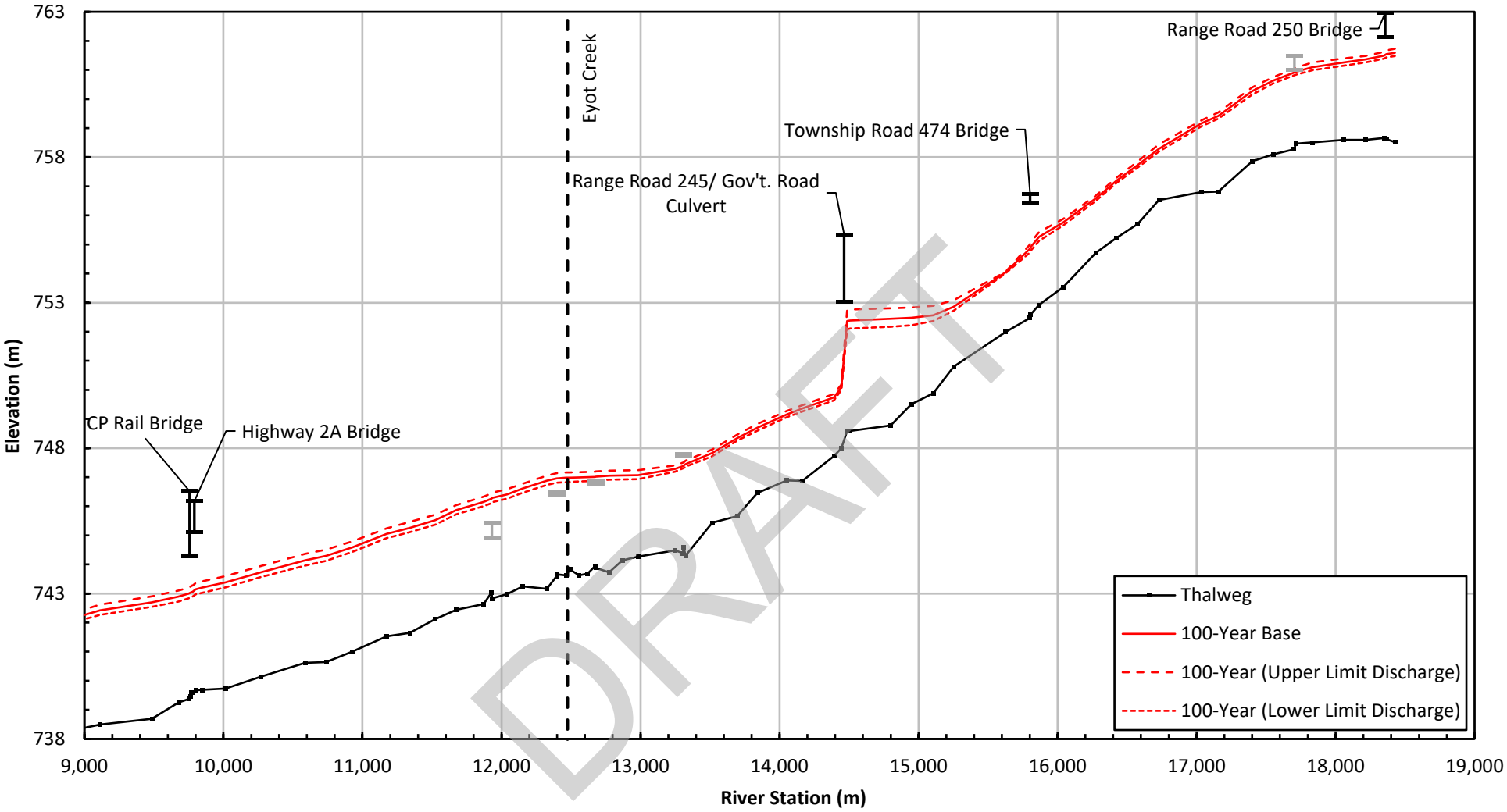
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Table 4.8 Sensitivity analysis results for variation in 100-year flood frequency estimates

River	Difference from Baseline Profile (m)			
	Lower Flood Frequency Estimates		Higher Flood Frequency Estimates	
	Maximum	Average	Maximum	Average
Pipestone Creek	-0.29	-0.14	0.37	0.18
Eyot Creek	-0.16	-0.12	0.24	0.17
Snake Drain	-0.16	-0.05	0.23	0.06

A downstream slope was specified to compute the water level at the downstream boundary. The 100-year flood level specified by the rating curve at the downstream boundary was El. 730.73 m. The sensitivity analysis was performed for this parameter by adopting ±0.30 m as a plausible range of uncertainty. The results are shown for the Pipestone Creek only in Figure 4.12, as the other two creeks were not affected.

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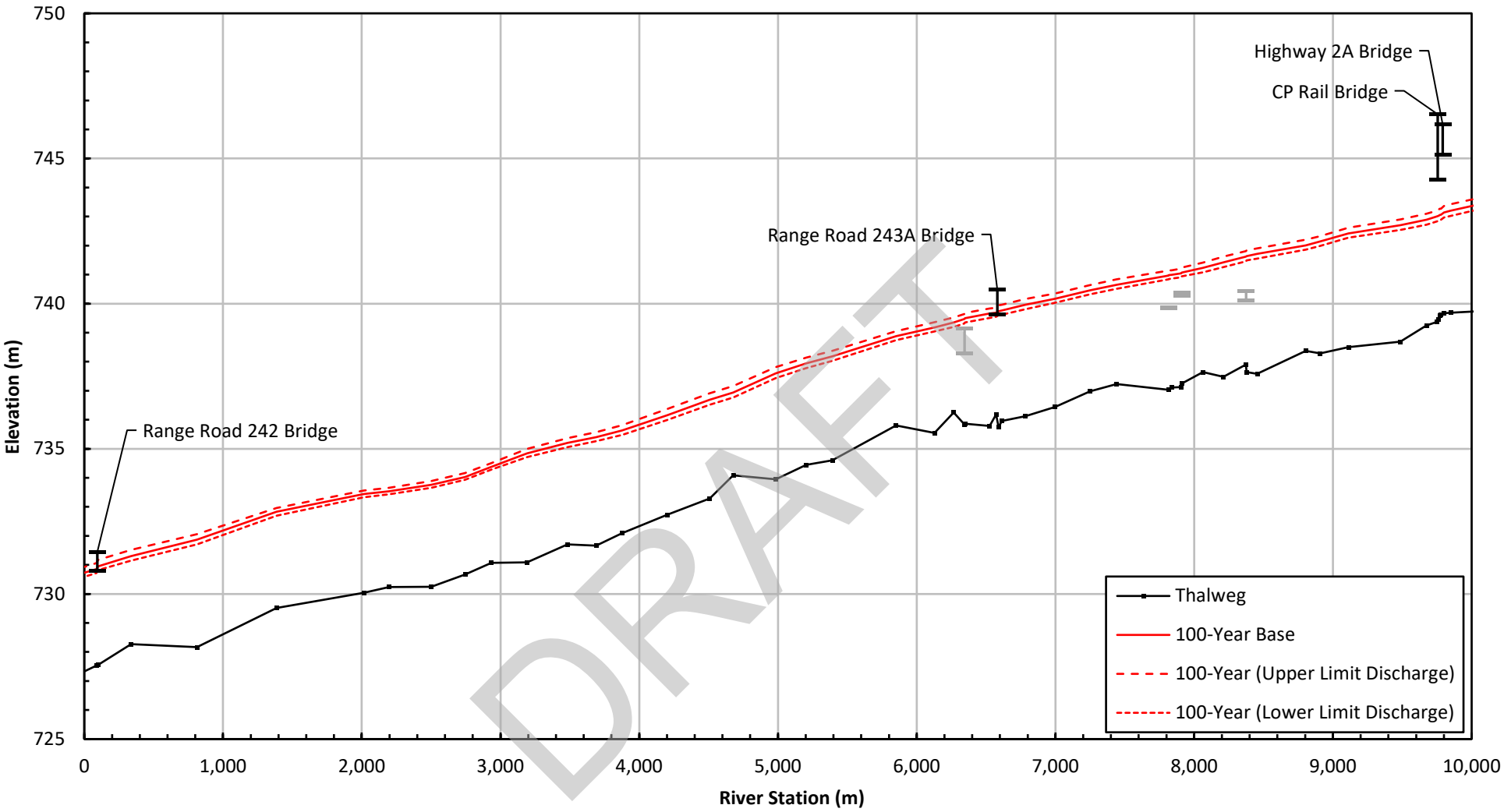


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
	UNITS: AS SHOWN	**PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – UPSTREAM BOUNDARY DISCHARGE (1/2)**
nhc	*Job: 1008862* / *Date: 02-APR-2025*	FIGURE 4.9

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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

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SCALE – AS SHOWN

UNITS: AS SHOWN

Job: 1008862

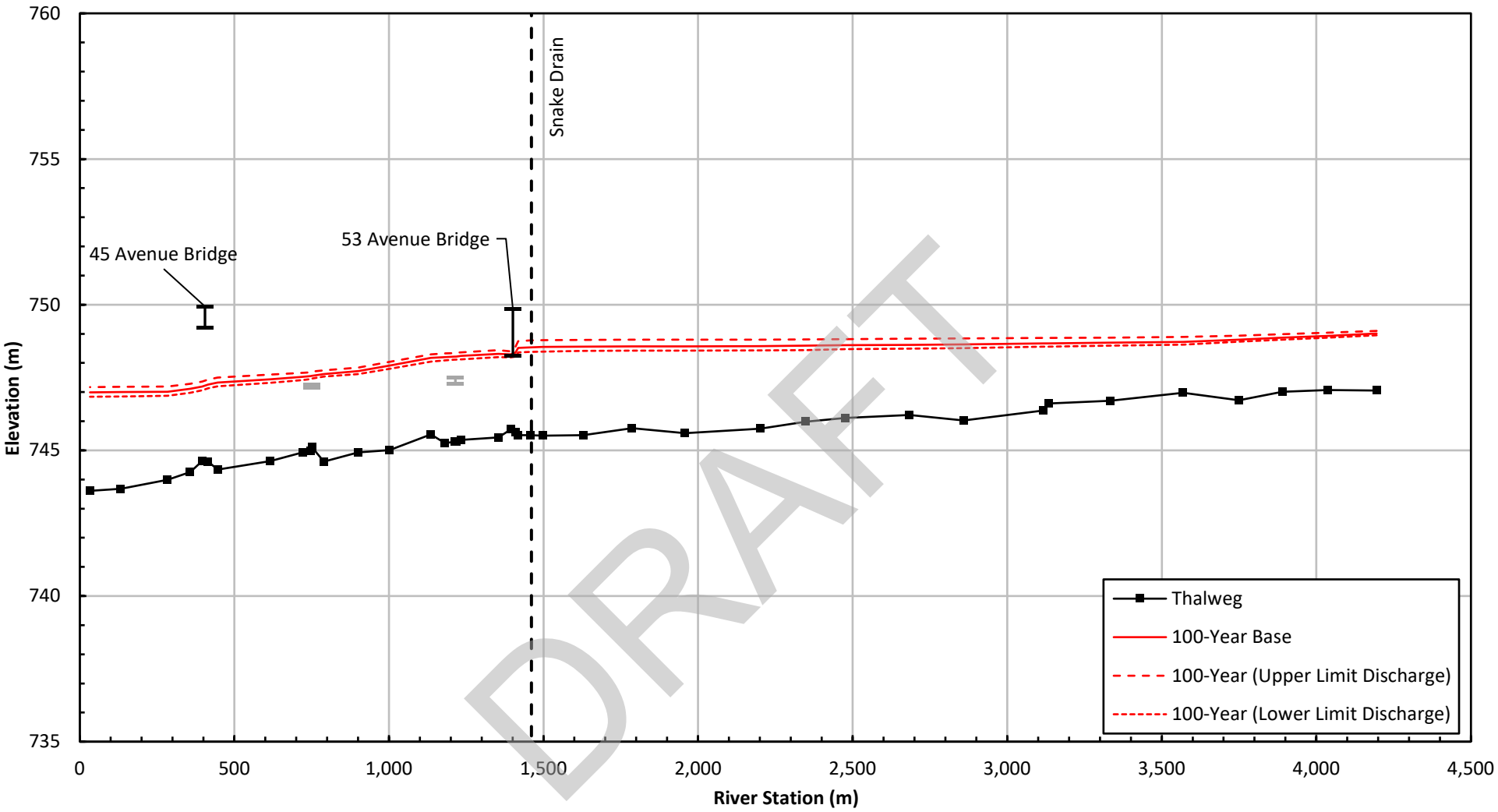
Date: 02-APR-2025

MILLET FLOOD STUDY

PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – UPSTREAM BOUNDARY DISCHARGE (2/2)

FIGURE 4.9

Classification: Public

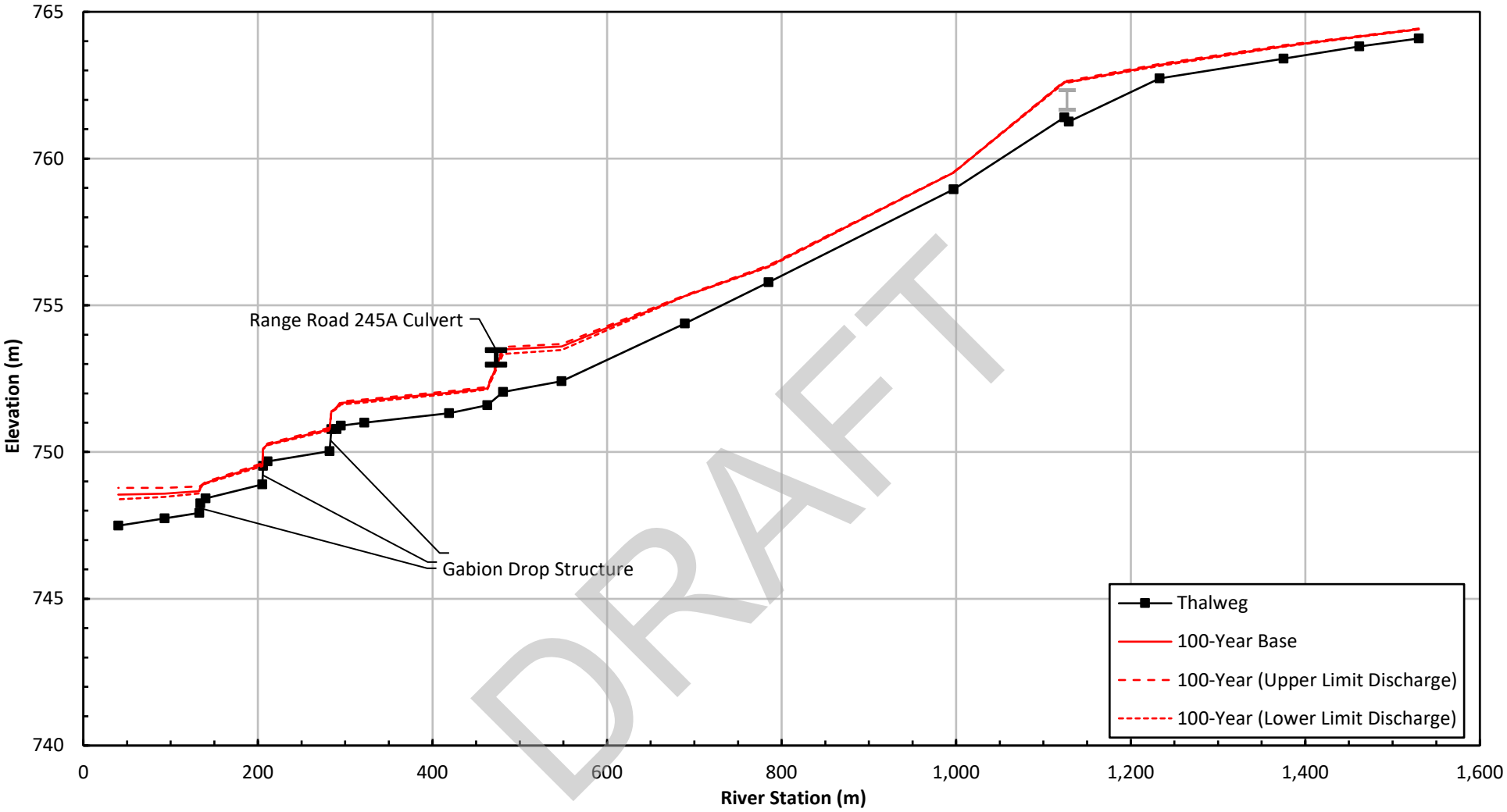


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Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**EYOT CREEK SENSITIVITY ANALYSIS PROFILE – UPSTREAM BOUNDARY DISCHARGE**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.10

Classification: Public

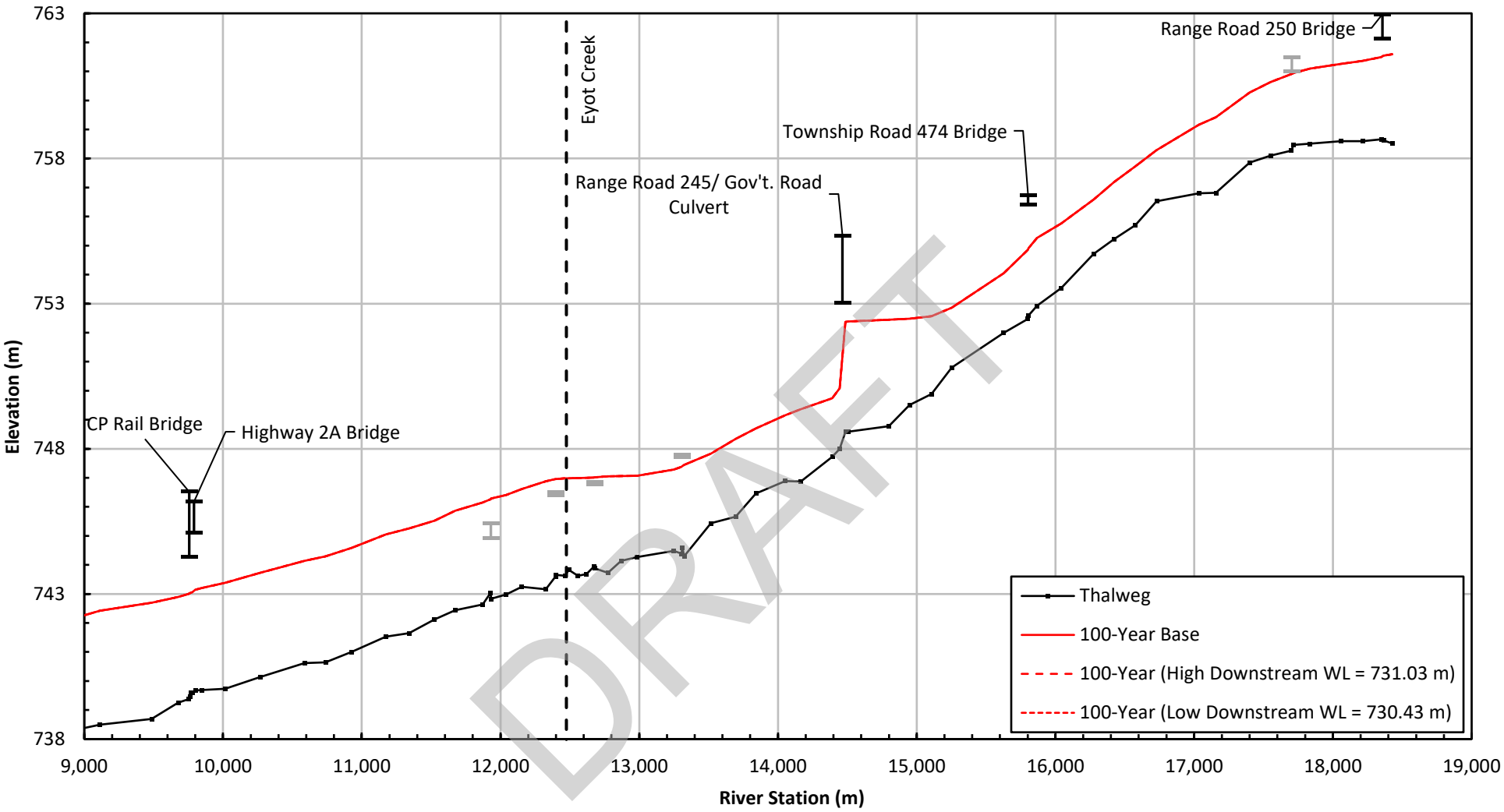


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**SNAKE DRAIN SENSITIVITY ANALYSIS PROFILE – UPSTREAM BOUNDARY DISCHARGE**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.11

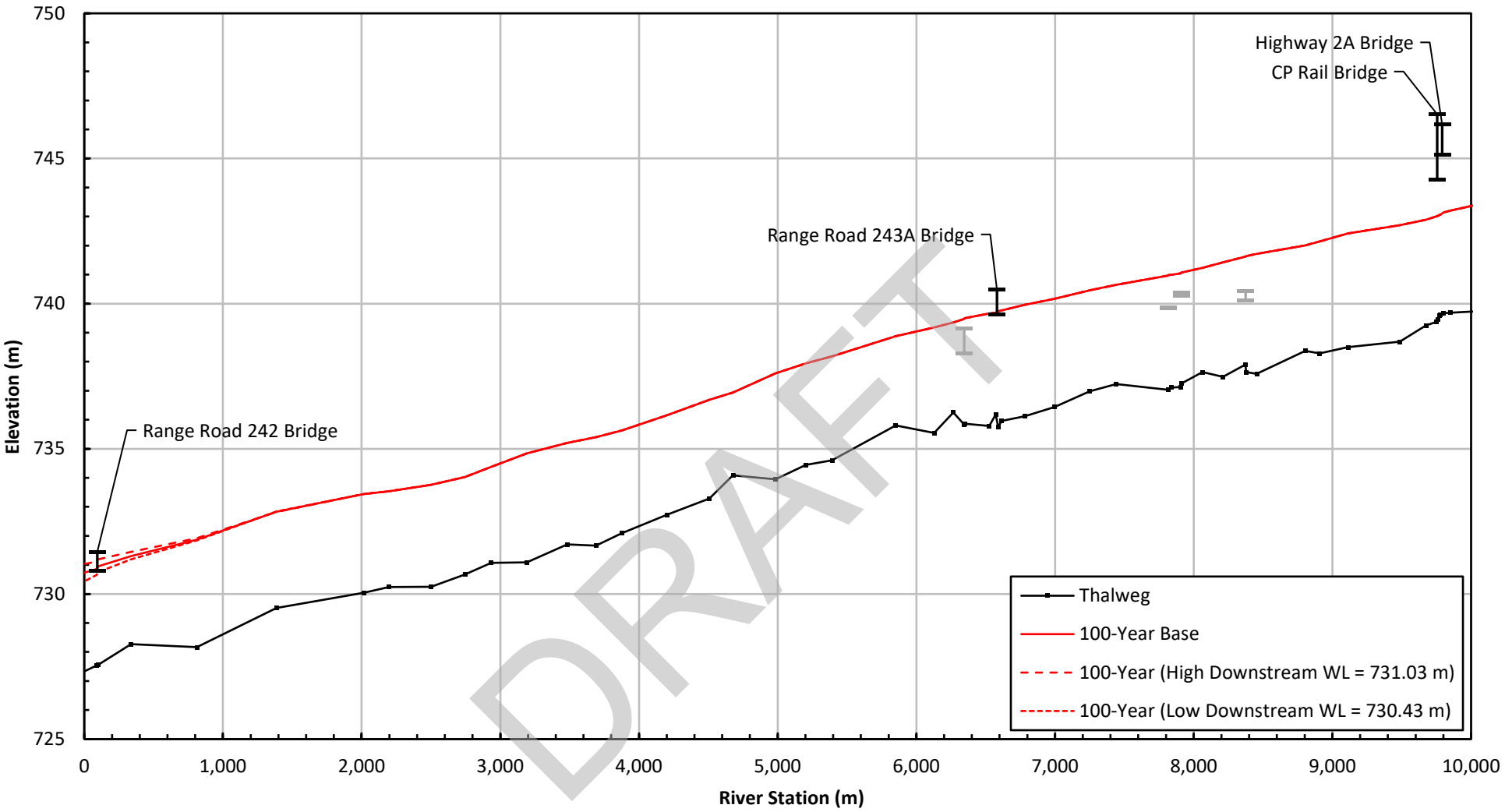
Classification: Public



Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – DOWNSTREAM BOUNDARY WATER LEVEL (1/2)**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.12

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada

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SCALE – AS SHOWN

UNITS: AS SHOWN

Job: 1008862

Date: 02-APR-2025

MILLET FLOOD STUDY

PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – DOWNSTREAM BOUNDARY WATER LEVEL (2/2)

FIGURE 4.12

Classification: Public

The deviation from the baseline profile drops below 0.01 m at RS 1,386 m, which lies beyond the downstream study limit of Pipestone Creek. Therefore, the downstream boundary condition has a negligible effect on water levels within the Pipestone Creek study reach. Additionally, Eyot Creek and Snake Drain were not affected by changes to the downstream boundary condition.

Detailed results of boundary condition sensitivity analyses are provided in **Appendix F**.

Manning's Roughness

The sensitivity of the model to Manning's roughness was evaluated, with channel roughness examined independently of overbank roughness. The sensitivity analysis was performed for all the modelled reaches and the results are discussed below.

The sensitivity of computed 100-year flood levels to channel roughness was assessed using low and high roughness values for each of the modelled river reaches. The channel roughness on Pipestone Creek above Eyot Creek was 0.055, and on Pipestone Creek below Eyot Creek was 0.065. For Eyot Creek, a channel roughness of 0.055 was selected. For Snake Drain, a channel roughness of 0.10 was selected for the channel above Range Road 245A, and 0.040 was for the channel below Range Road 245A. These channel roughness values were varied by ±20% in the sensitivity analysis, which was run concurrently for Pipestone Creek, Eyot Creek and Snake Drain using the values summarized in Table 4.9.

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Table 4.9 Channel roughness values used in sensitivity analysis

Reach Description	River Station (m)	Channel Roughness		
		Baseline	Low (-20%)	High (+20%)
Pipestone Creek above Eyot Creek	18,427 to 12,491	0.055	0.044	0.066
Pipestone Creek below Eyot Creek	12,464 to 0	0.065	0.052	0.078
Eyot Creek	4,195 to 33	0.055	0.044	0.066
Snake Drain above Range Road 245A	1,530 to 481	0.10	0.080	0.12
Snake Drain below Range Road 245A	463 to 40	0.040	0.032	0.048

The sensitivity results are illustrated in Figure 4.13, Figure 4.14 and Figure 4.15, and summarized in Table 4.10. Pipestone Creek, Eyot Creek and Snake Drain have an average deviation from the baseline 100-year profile reaching 0.18 m, 0.14 m, and 0.04 m respectively; and maximum deviations reaching 0.28 m, 0.20 m, and 0.18 m respectively.

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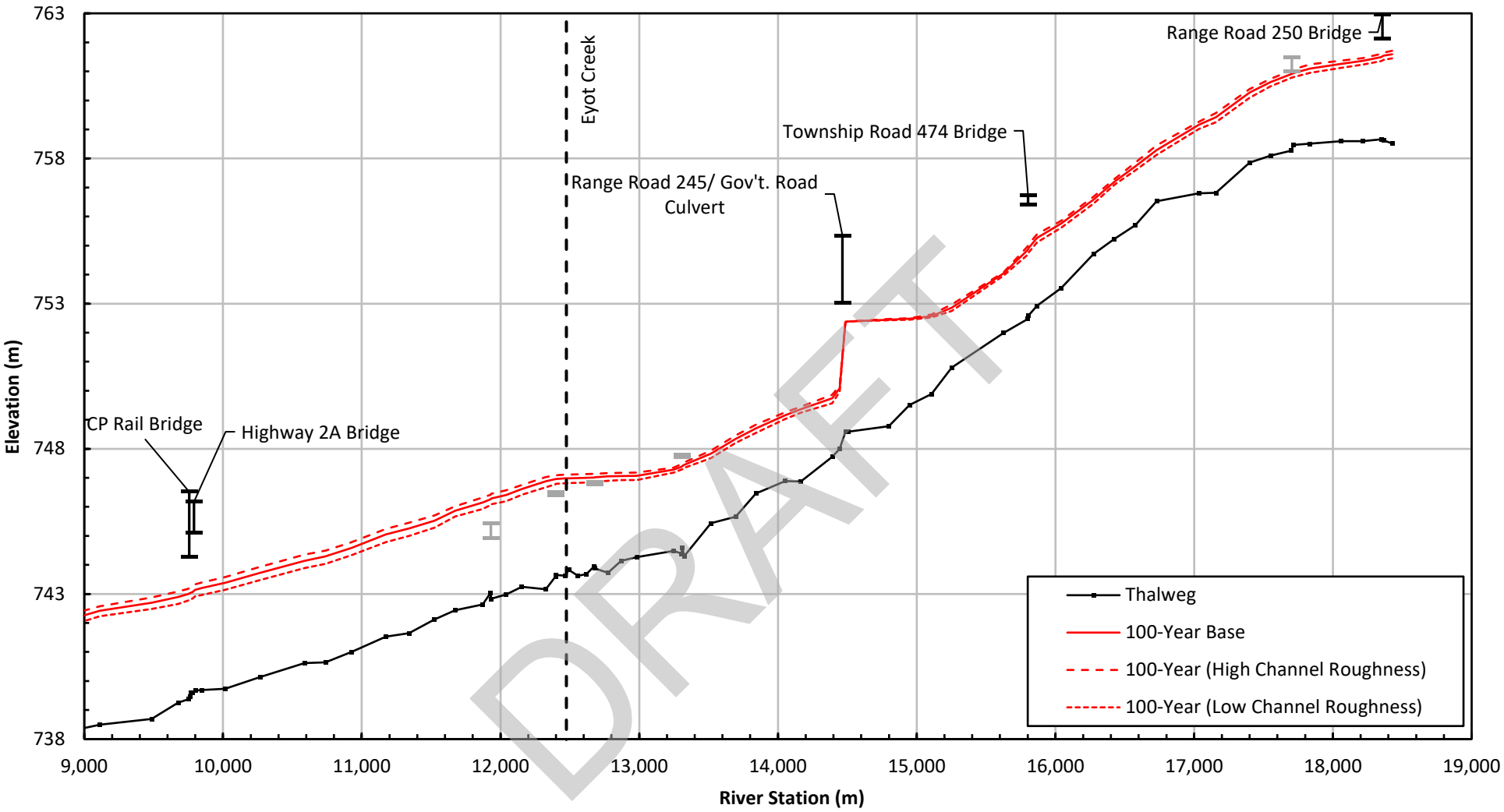
Table 4.10 Sensitivity analysis results for variation in main channel roughness

River	Difference from Baseline Profile (m)			
	Low Roughness (-20%)		High Roughness (+20%)	
	Maximum	Average	Maximum	Average
Pipestone Creek	-0.28	-0.18	0.22	0.14
Eyot Creek	-0.20	-0.14	0.20	0.13
Snake Drain	-0.17	-0.04	0.18	0.04

Detailed results of main channel roughness sensitivity analysis are provided in **Appendix F.**

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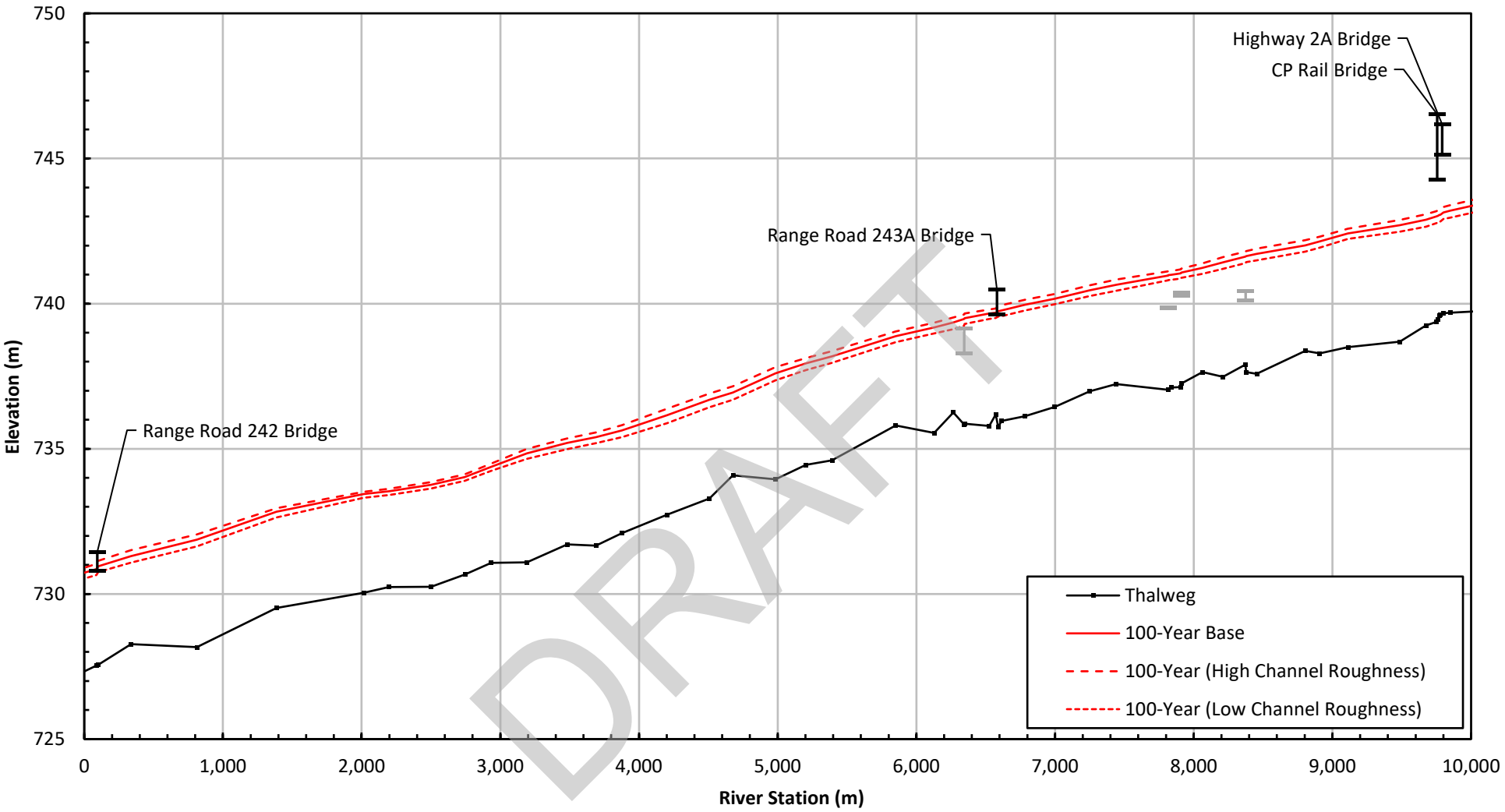
Classification: Public



Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
	UNITS: AS SHOWN	**PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – CHANNEL ROUGHNESS COEFFICIENT (1/2)**
nhc	*Job: 1008862* / *Date: 02-APR-2025*	FIGURE 4.13

Classification: Public

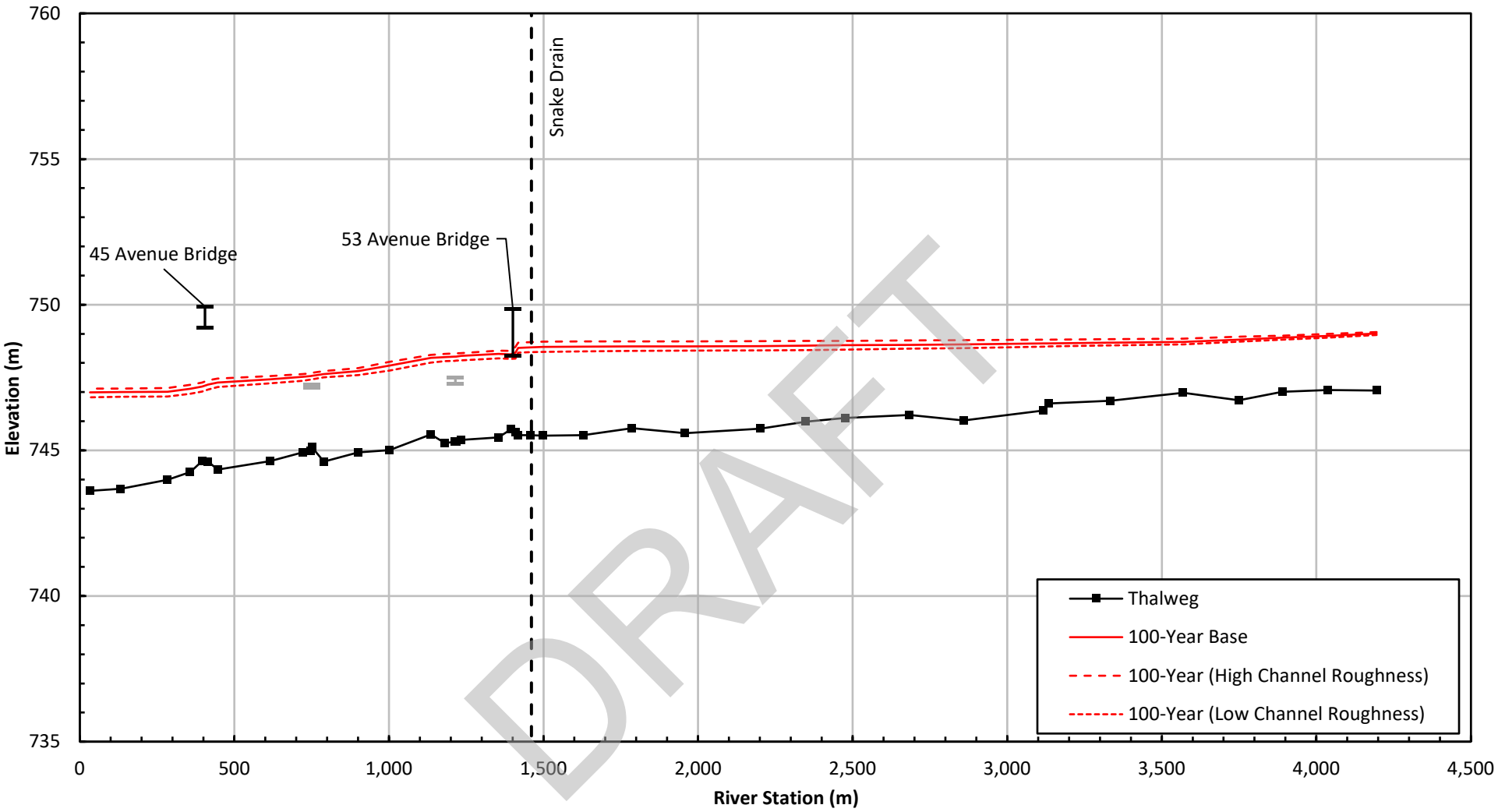


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY **PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – CHANNEL ROUGHNESS COEFFICIENT (2/2)**
nhc	UNITS: AS SHOWN	
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.13

Classification: Public

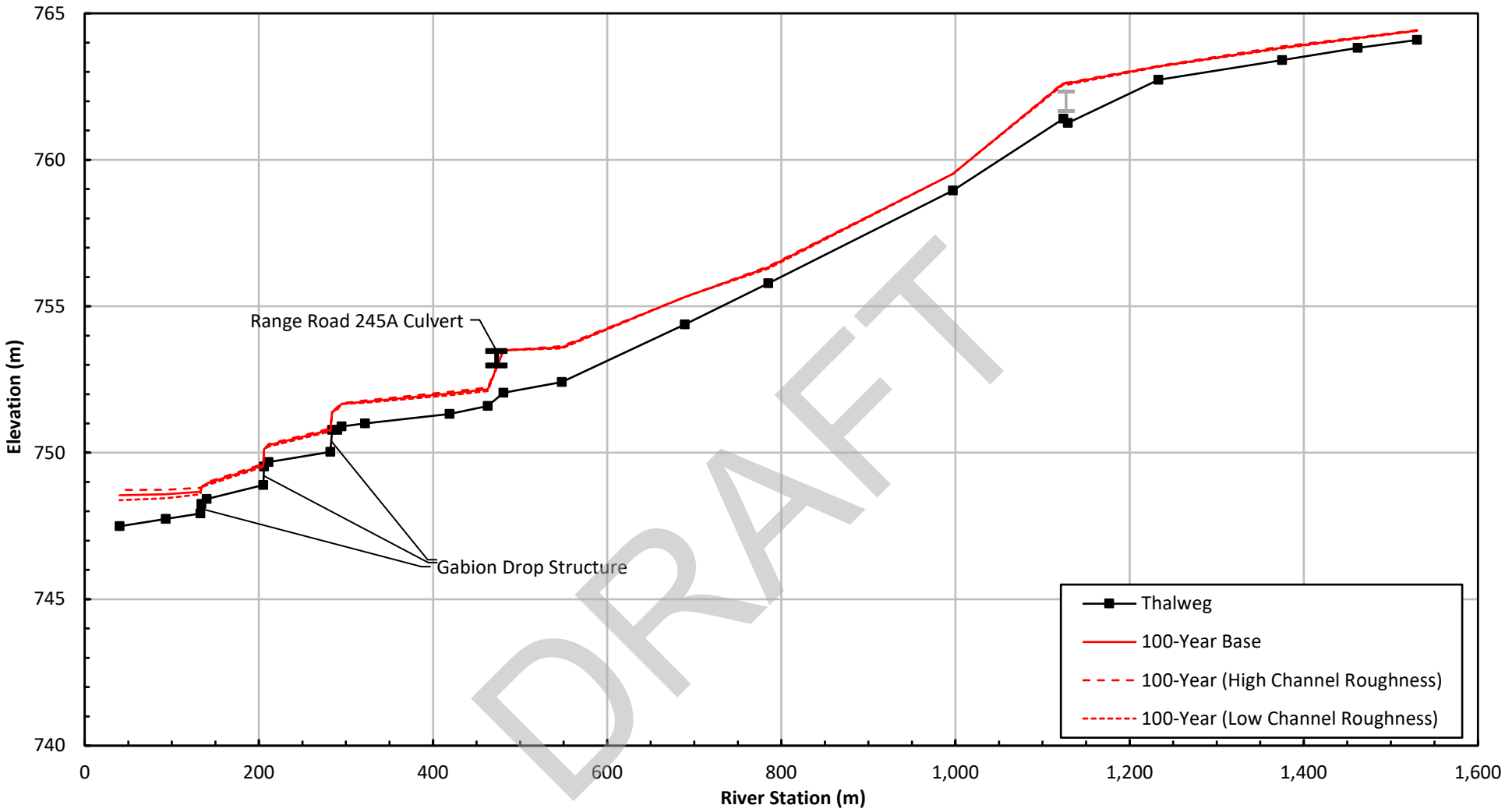


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**EYOT CREEK SENSITIVITY ANALYSIS PROFILE – CHANNEL ROUGHNESS COEFFICIENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.14

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**SNAKE DRAIN SENSITIVITY ANALYSIS PROFILE – CHANNEL ROUGHNESS COEFFICIENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.15

Classification: Public

The sensitivity of computed 100-year flood levels to overbank roughness variations was evaluated by selecting low and high roughness values for each of the modelled river reaches. These plausible values were generally within 20% of the overbank roughness values adopted for the base model considering seasonal variations in vegetation growth and density. For the low and high roughness sensitivity runs, the overbank roughness values were adjusted by ± 20% to reflect this range (Table 4.11). The sensitivity analysis was run concurrently for Pipestone Creek, Eyot Creek and Snake Drain.

Table 4.11 Overbank roughness values used in sensitivity analysis

River and Overbank	River Station (m)	Overbank Roughness		
		Baseline	Low (-20%)	High (+20%)
Pipestone Creek (Left and Right Overbanks)	18,427 to 13,516	0.10	0.080	0.12
	13,325 to 12,397	0.085	0.068	0.102
	12326 to 3,689	0.15	0.12	0.18
	3,483 to 2,197	0.10	0.080	0.12
	2,015 to 0	0.060	0.048	0.072
Eyot Creek (Left Overbank)	4,195 to 1,498	0.060	0.048	0.072
Eyot Creek (Right Overbank)	4,195 to 1,498	0.10	0.080	0.12
Eyot Creek (Left and Right Overbanks)	1,457 to 33	0.085	0.068	0.102
Snake Drain (Left and Right Overbanks)	1,530 to 40	0.10	0.080	0.12

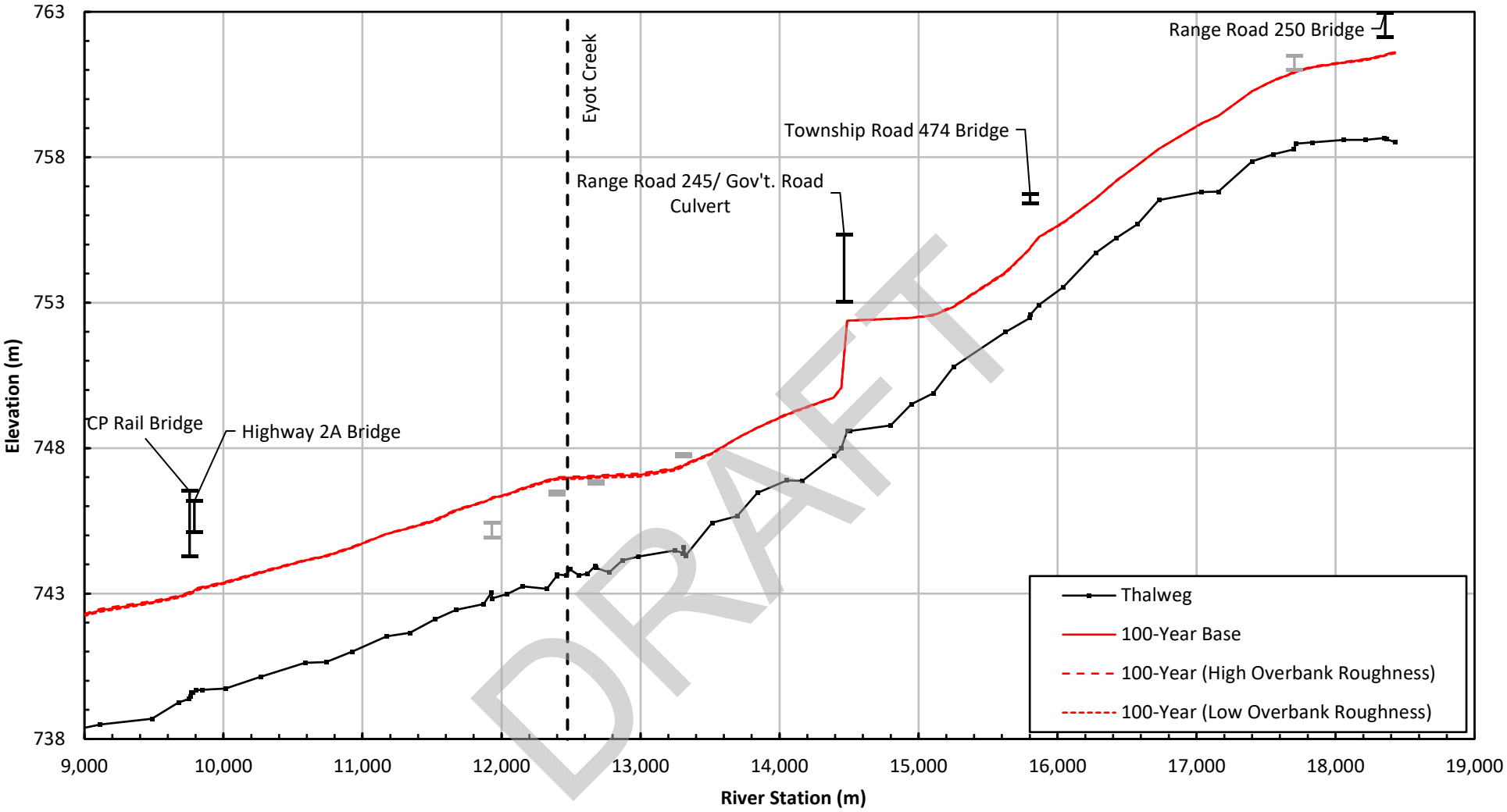
The sensitivity results are illustrated in Figure 4.16, Figure 4.17, and Figure 4.18, and summarized in Table 4.12. The changes in the simulated 100-year water levels resulting from variations in the overbank roughness values are negligible across the study reaches. The maximum deviation from the 100-year baseline profile is 0.06 m. This is primarily because most of the overbank flooded areas are situated within the low velocity zone. Detailed results of overbank roughness sensitivity analysis are provided in **Appendix F.**

Table 4.12 Sensitivity analysis results for variation in overbank roughness

River	Difference from Baseline Profile (m)			
	Low Roughness (-20%)		High Roughness (+20%)	
	Maximum	Average	Maximum	Average
Pipestone Creek	-0.06	-0.03	0.05	0.02
Eyot Creek	-0.05	-0.03	0.05	0.03
Snake Drain	-0.02	0.00	0.03	0.00

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Classification: Public

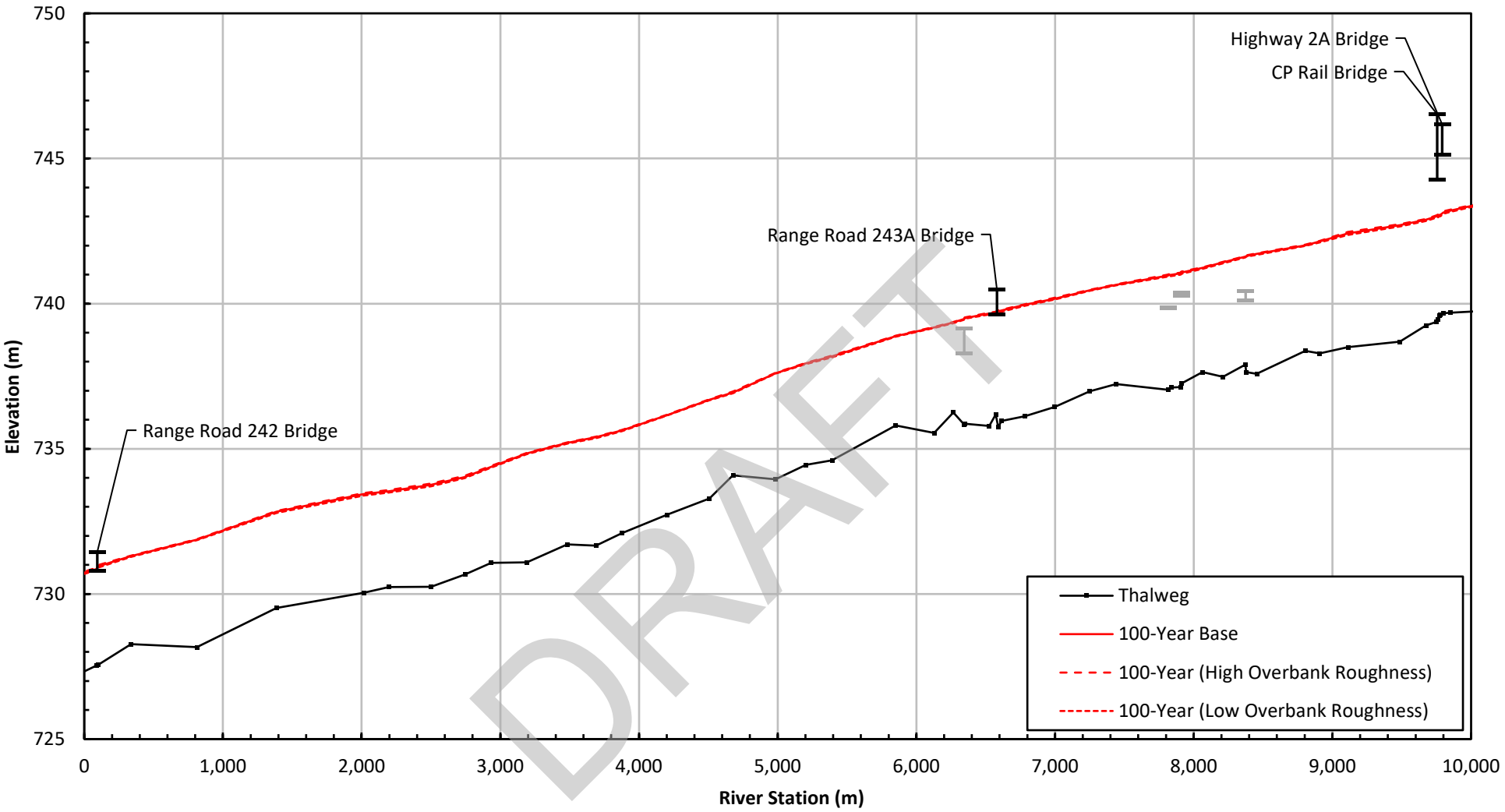


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY **PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – OVERBANK ROUGHNESS COEFFICIENT (1/2)**
nhc	UNITS: AS SHOWN	
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.16

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada

nhc

SCALE – AS SHOWN

UNITS: AS SHOWN

Job: 1008862

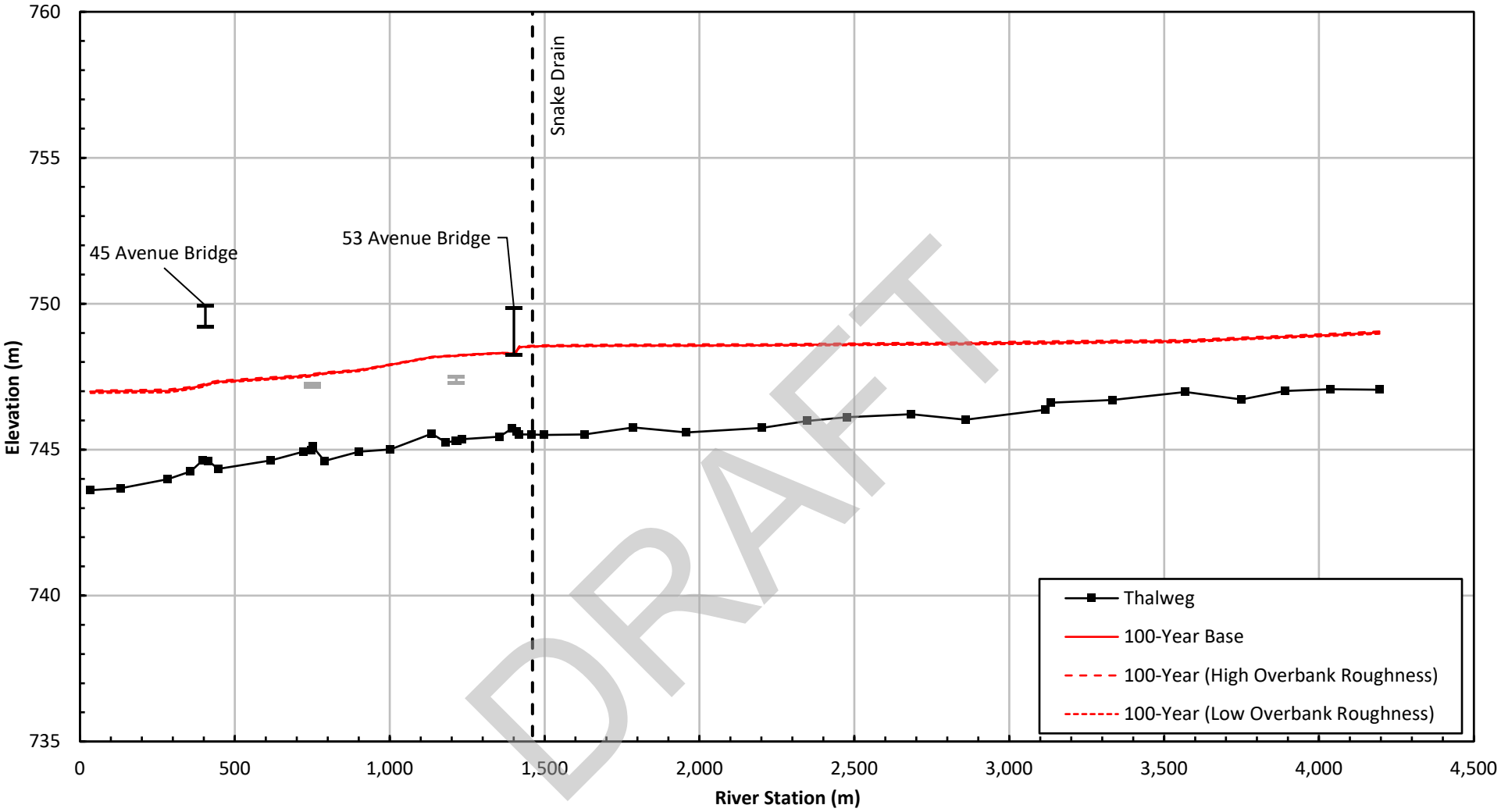
Date: 02-APR-2025

MILLET FLOOD STUDY

PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – OVERBANK ROUGHNESS COEFFICIENT (2/2)

FIGURE 4.16

Classification: Public

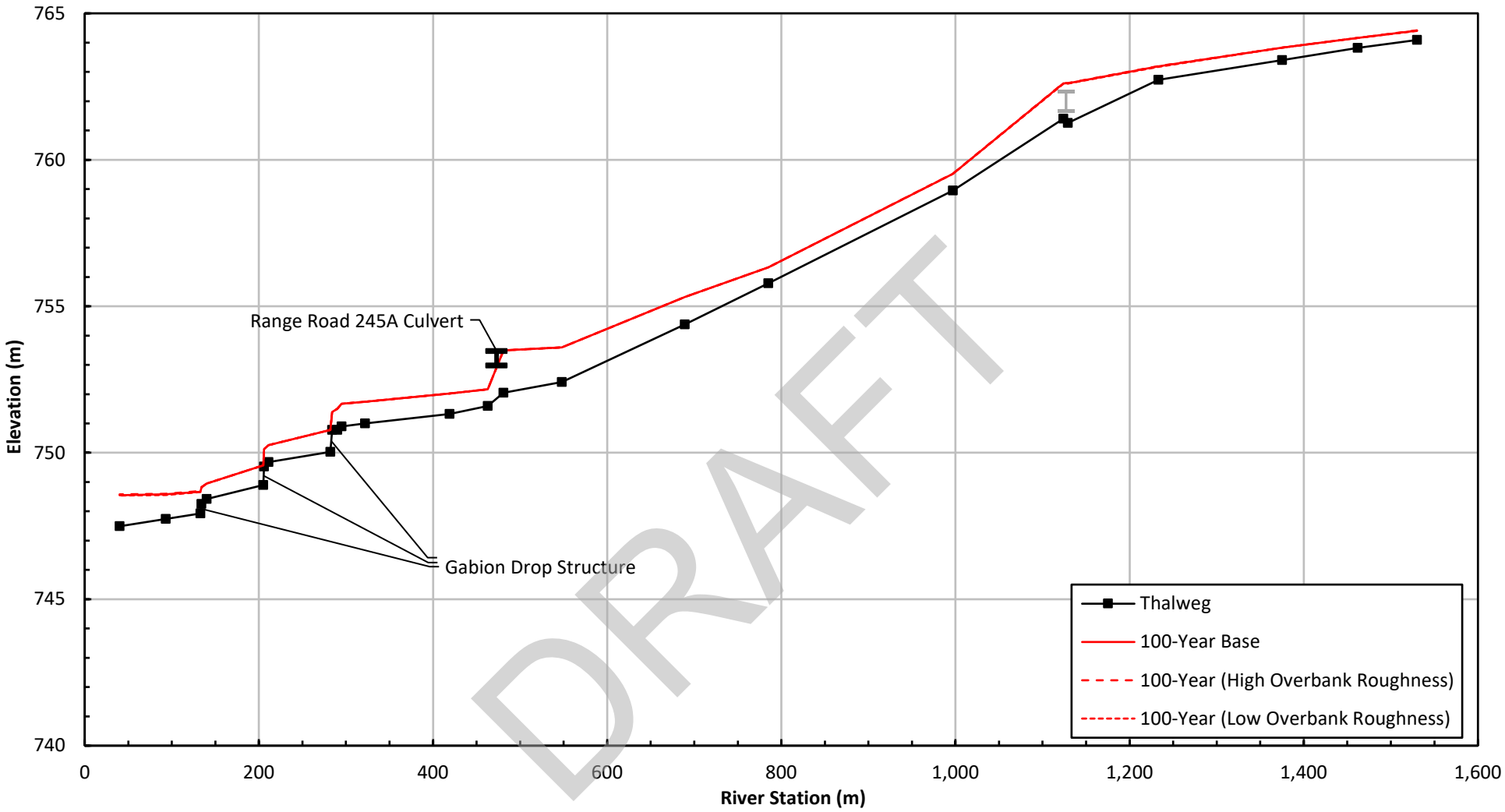


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**EYOT CREEK SENSITIVITY ANALYSIS PROFILE – OVERBANK ROUGHNESS COEFFICIENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.17

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**SNAKE DRAIN SENSITIVITY ANALYSIS PROFILE – OVERBANK ROUGHNESS COEFFICIENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.18

Classification: Public

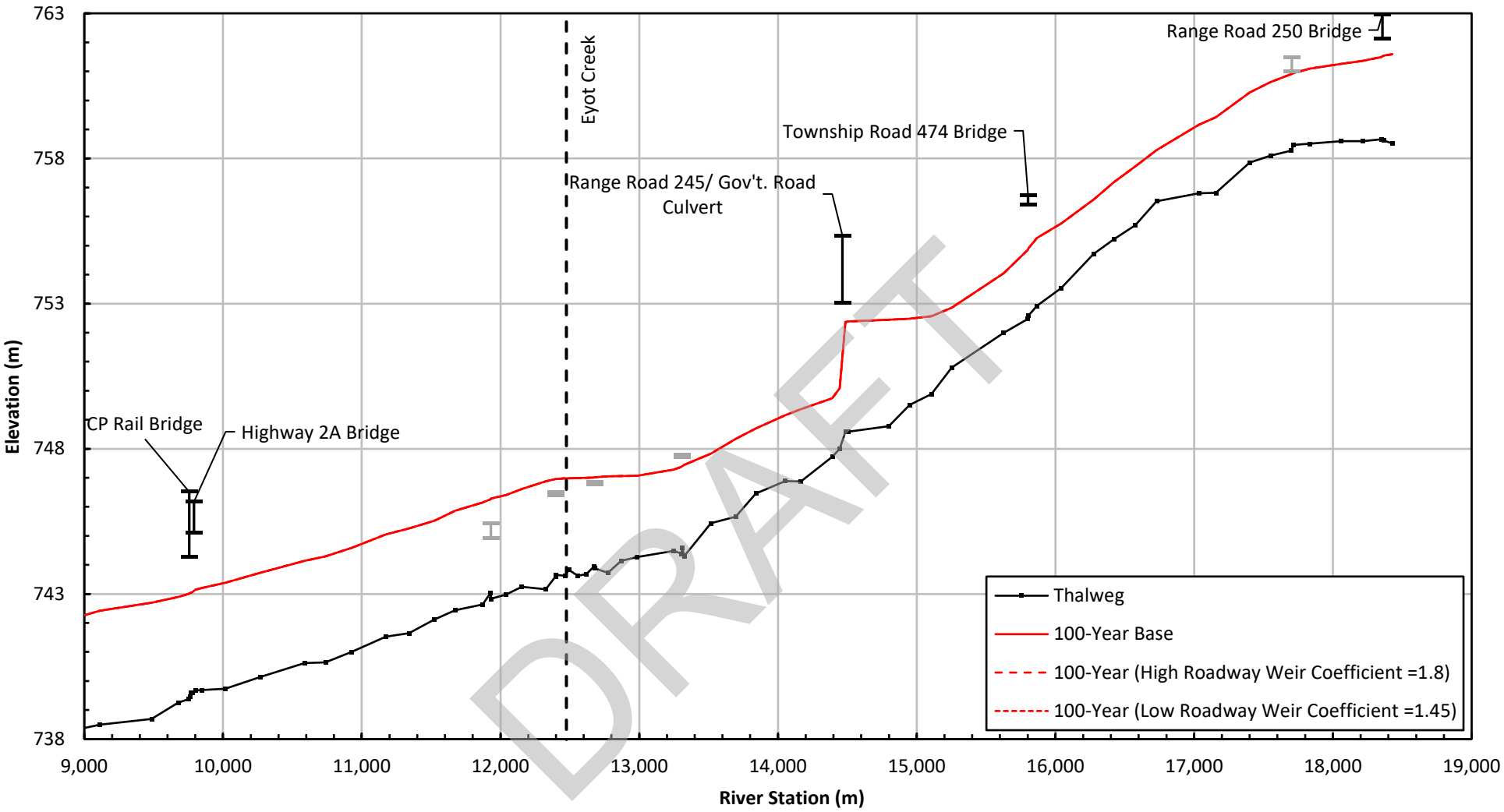
Roadway Weir Coefficient

The sensitivity of the model to the weir coefficient for roadway overtopping was evaluated. The weir coefficient used for the baseline model was 1.6. A sensitivity analysis was carried out with a lower weir coefficient of 1.45 and a higher weir coefficient of 1.8. Sensitivity analysis profiles are plotted on Figure 4.19, Figure 4.20 and Figure 4.21. There is no change in 100-year baseline water level profile due to changes in roadway weir coefficient, suggesting that the computation of 100-year flood levels is not sensitive to the selection of roadway weir coefficient. This is because most of the roadway are either not affected or fully submerged.

Detailed results of roadway weir coefficient sensitivity analysis are provided in **Appendix F.**

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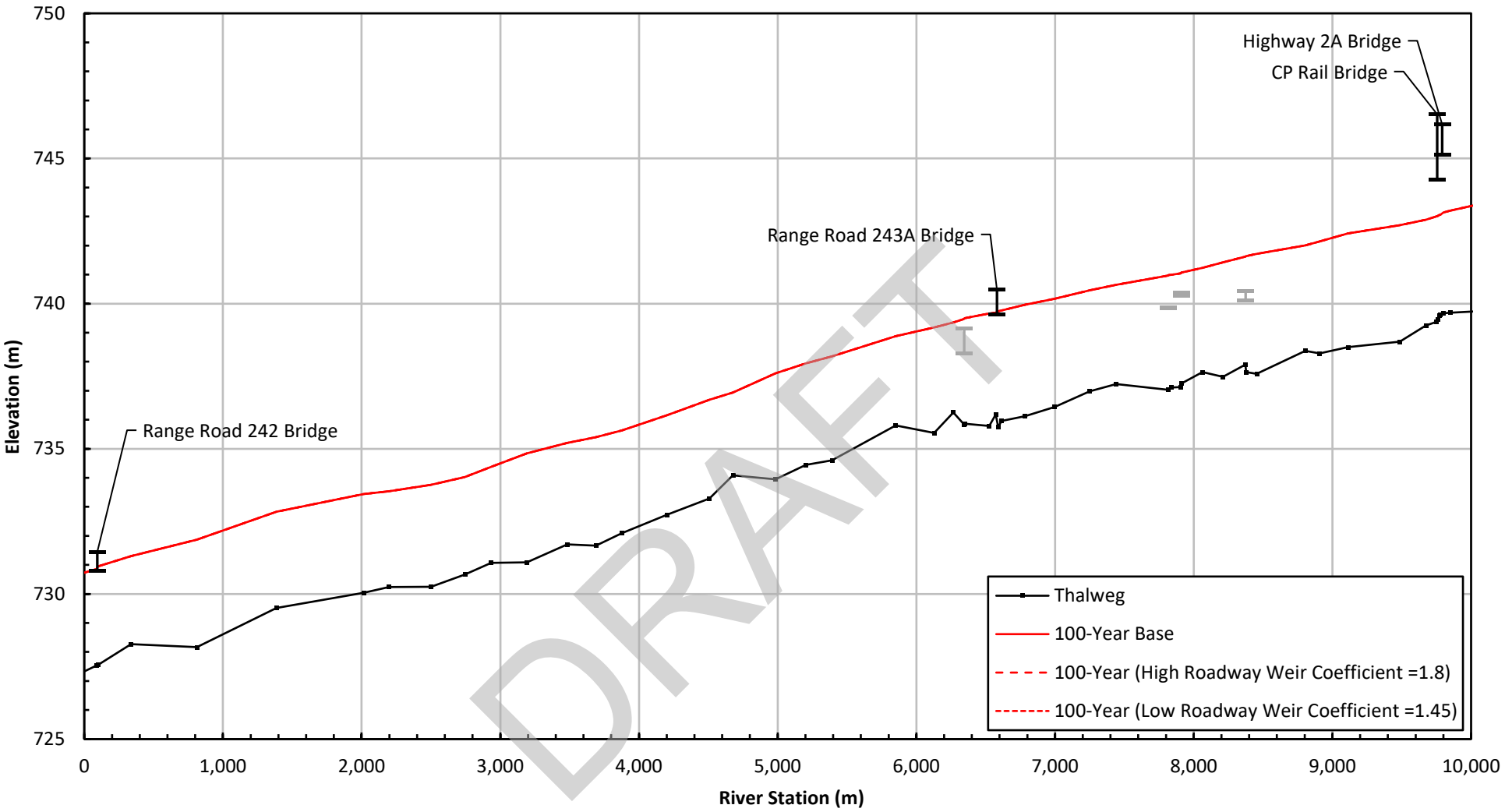
Classification: Public



Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – ROADWAY WEIR COEFFICIENT (1/2)**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.19

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

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SCALE – AS SHOWN

UNITS: AS SHOWN

Job: 1008862

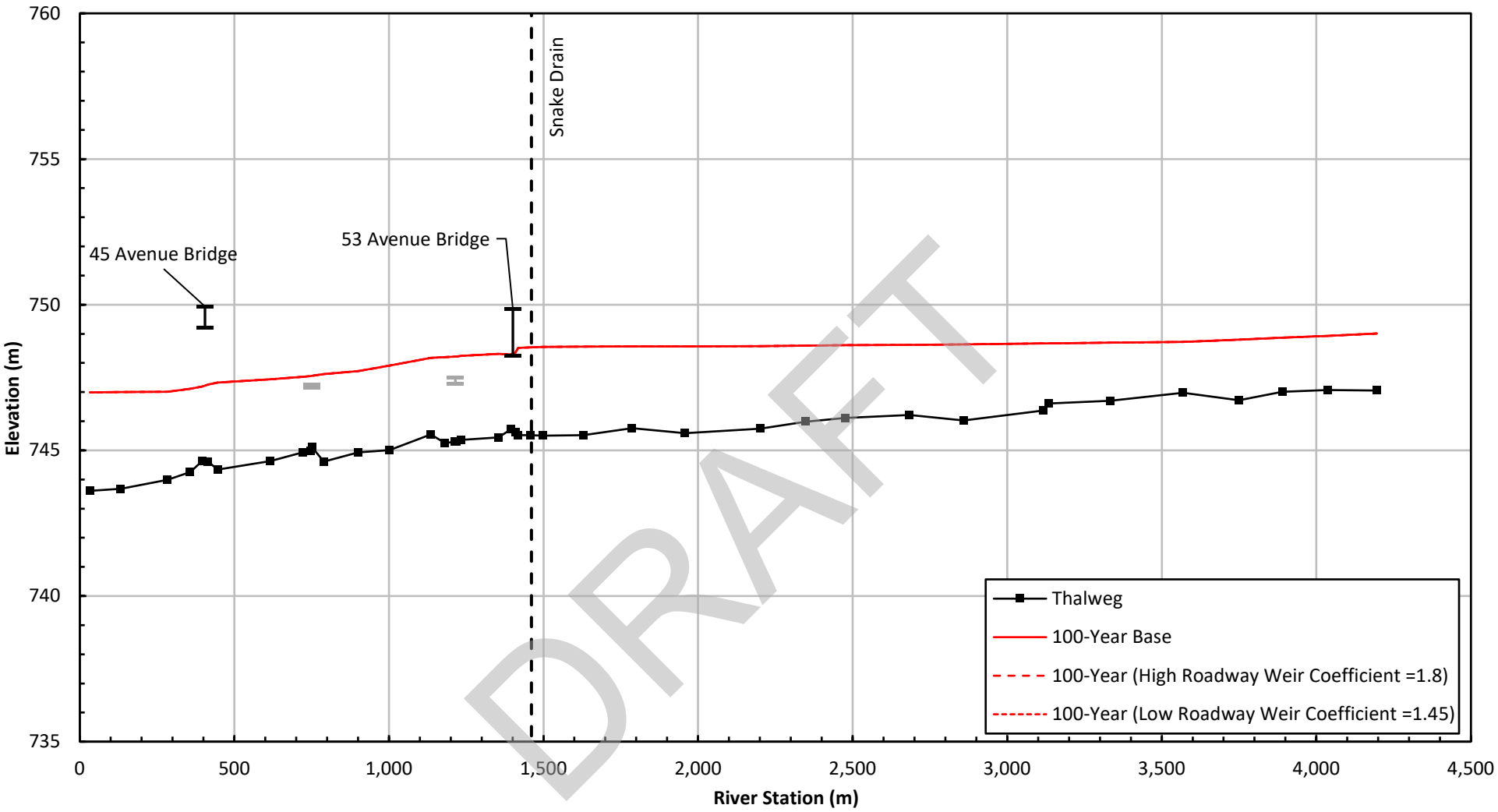
Date: 02-APR-2025

MILLET FLOOD STUDY

PIPESTONE CREEK SENSITIVITY ANALYSIS PROFILE – ROADWAY WEIR COEFFICIENT (2/2)

FIGURE 4.19

Classification: Public

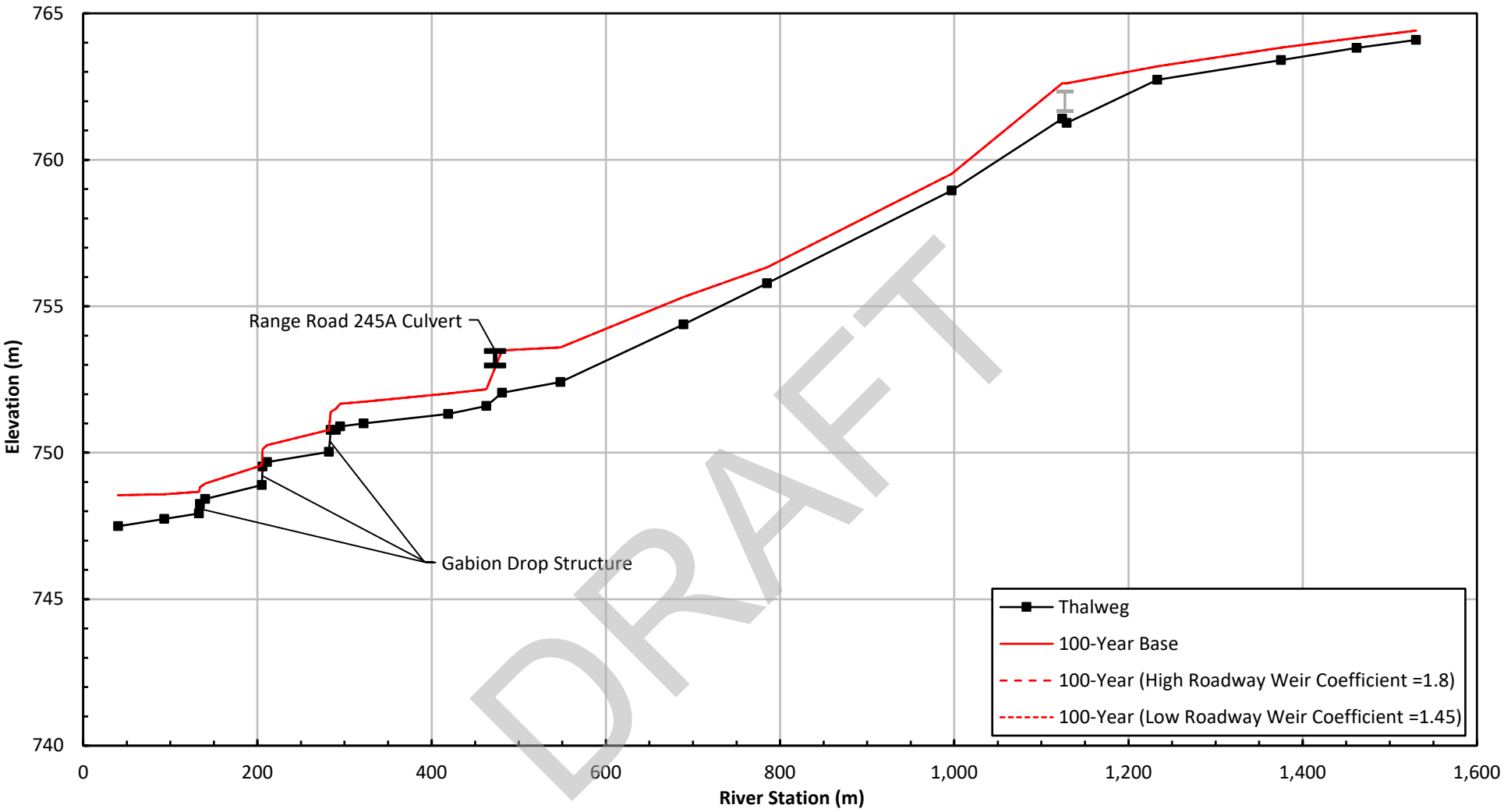


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**EYOT CREEK SENSITIVITY ANALYSIS PROFILE – ROADWAY WEIR COEFFICIENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.20

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**SNAKE DRAIN SENSITIVITY ANALYSIS PROFILE – ROADWAY WEIR COEFFICIENT**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 4.21

Classification: Public

5 FLOOD INUNDATION MAPS

Flood inundation mapping shows areas of ground that could be covered by water under one or more flood scenarios for existing conditions. For this study, one flood inundation map series was created for each of the 13 flood frequency return periods from the 2-year through 1000-year scenarios. The methodology used to generate the flood inundation maps are summarized below. The open water inundation maps are provided in **Appendix G.**

5.1 Methodology

The methodology used to create flood inundation maps is as follows.

- Create a water surface elevation (WSE) triangular irregular network (TIN) representing a contiguous flood level profile along the modelled river reaches.
- Generate a WSE grid with the same grid geometry as the underlying DTM. Assign elevation values to each grid cell based on the corresponding value taken from the WSE TIN.
- Generate a depth grid (with the same grid geometry as the WSE grid) by subtracting hydro-flattened DTM elevations from the corresponding WSE grid values. Negative depth values represent dry cells and were assigned a value of *NoData*.
- Generate inundation polygons based on the depth grids by converting depths greater than 0 m into inundation polygons.
- Minimum flood/inundation extents were delineated for several reach segments where the DTM (derived from LiDAR data) showed higher elevations than simulated water levels, likely due to deep pools caused by beaver dams, vegetation affecting the DTM, or marshland conditions. To prevent gaps, these extents were manually drawn using topographic features from the DTM, hillshade and aerial imagery, ensuring a smooth transition with adjacent inundation areas. The delineation process was guided by elevation changes in the DTM, variations in bank slope seen in the hillshade, and vegetation or wet areas identified in aerial imagery. In some cases, these extents were further validated using field survey data, including ground and aerial photos collected by NHC.
- The minimum inundation extents described above were primarily needed for low return period floods. However, some reaches, such as Snake Drain upstream of the Range Road 245A culvert, were affected up to the 1000-year flood due to the presence of multiple beaver dams, marshland characteristics, and dense vegetation. The contributing basin to Snake Drain was relatively small at approximately 4.84 km^2 compared to the extent of the marshy, wetted areas. Additionally, the 1000-year discharge from the basin is just 4.7 m^3/s, which is quite low. As a result, this area appeared dry in simulations and had to be merged with the minimum inundation extents. These extents remain consistent across

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all flood frequency events. While they may overestimate flood extent for lower return periods, the affected areas are generally wet under normal conditions, making their depiction as inundated across all flood scenarios reasonable.

- The inundation polygons were further processed by smoothing, filtering out wetted areas that were not directly inundated (or "isolated"), and removing very small dry areas (or "holes"). A PAEK smoothing algorithm was applied with a 20 m threshold, which was determined to be appropriate for this project area. Additionally, a 100 m^2 filtering threshold was used to eliminate islands and holes smaller than this size.
- The bigger isolated areas were reviewed manually and removed if there are no hydraulic connections. Some wetted areas not directly connected by overland flow were mapped as inundated if there was evidence of subsurface hydraulic connectivity through structures such as culverts or storm sewers. This assessment was based on a review of field-collected culvert and ditch data, aerial imagery, DTM, and other available information. An example of this hydraulic connection can be seen at Eyot Creek near XS-147, where a ditch flows into Eyot Creek through a subsurface connection.
- The final inundation polygons were then used to clip the WSE grids and depth grids to the full inundation extent. The WSE TINs, WSE grids, depth grids, and inundation extent polygons were produced in standard Esri file formats using ArcGIS tool sets.

5.2 Water Surface Elevation TIN Modifications

Necessary modifications were made to the water surface elevation TIN for areas that need manual edits (for example overbank flooding area or backwater area) so that inundation polygons could be re-generated from the data using the procedure described in Section 5.1 above.

Areas showing extensive overbank/backwater flooding directly connected to the channel at one distinct location (overtopping point) were adjusted such that the water surface elevation across that area was set equal to the water surface elevation at the overtopping point. This generally reduced the size of the inundated area upstream of an overtopping point and increased the size of the inundated area downstream of the overtopping point. When the size of the inundated area expanded downstream, NHC verified whether the extended area could potentially reconnect to the channel, ensuring a realistic connection in such instances.

Roadway crossings that were overtopped at a single distinct location (but were not fully submerged) were adjusted by setting the water surface elevation on top of the roadway crossing equal to the water surface elevation at the overtopped location. NHC followed the following steps for this adjustment.

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- The weir flows reported by the HEC-RAS model were examined to determine if each road with a culvert crossing was overtopped (but not fully submerged) during a specific frequency flood event.
- If the road was found to overtop, a water surface elevation breakline was inserted at approximately the downstream shoulder of the road.
- The water level from the upstream model cross section was applied to the breakline.
- The updated breaklines were used to generate the water surface TINs.

No flood control structures were affected by any of the frequency floods. Thus, no manual modification to the TIN was required due to partial flood control structure failure.

The adjusted TIN surfaces were then used to generate the adjusted flood depth grids and flood inundation polygons so that each product incorporates the adjustments made.

5.3 Flood Inundation Area

The impacts of flooding on developed areas and infrastructure are evident in the flood inundation maps (**Appendix G**).

5.3.1 Direct Flood Inundation Areas

A list of notable areas that would potentially be impacted by floods is presented in Table 5.1. It provides a range of flood return periods (or frequencies) that could impact residential, commercial, industrial, and other notable facilities. The table lists areas from upstream to downstream, with reference cross section number and river stations to assist in cross-referencing with the inundation mapping libraries. The shaded boxes provide a graphical display of the approximate range of flood frequency magnitudes impacting each area. For all flood inundation areas please refer to **Appendix G**.

5.3.2 Hydraulic Structures

There are twenty-two (22) crossings along the modelled reaches of Pipestone Creek, Eyot Creek and Snake Drain. Among these some are small private crossings (bridge/culverts). These crossings could be affected as early as during a 2- to 5-year floods. During the 100-year flood fourteen crossings (14) were affected. Few of the crossings like Range Road 250 bridge, Township Road 474 bridge, Highway 2A bridge, CP Rail bridge, and 45 Avenue bridge were not affected even during the 1000-year flood.

The summary of hydraulic structures impacted by different frequency floods is presented in Table 5.2. It provides a range of flood return periods (or frequencies) that could impact the hydraulic structures.

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For detailed road crossing inundation mapping, please refer to **Appendix G**.

5.3.3 Flood Control Structures

No flood control structures, including the North and South Wastewater Lagoon dikes, would be impacted by any of the modelled frequency flood events.

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Table 5.1 List of notable areas impacted by the range of flood magnitudes

River	Cross Section Reference	River Station	Impacted Areas Along Floodplain for different Flood Frequency Events											
			2-yr	5-yr	10-yr	20-yr	35-yr	50-yr	75-yr	100-yr	200-yr	350-yr	500-yr	750-yr	1000-yr
Pipestone Creek	XS-81	12,982	Moonen Heights Soccer Field												
						20	35	50	75	100	200	350	500	750	1000
	XS-60	10,928	Pipestone Motel, RV Park & Storage												
									75	100	200	350	500	750	1000
	XS-47	9,112	Buildings on East Side of Highway 2A												
						20	35	50	75	100	200	350	500	750	1000
	XS-9	2,500	Pipestone Links Golf Course												
				5	10	20	35	50	75	100	200	350	500	750	1000
Eyot Creek	XS-133	1,002	Building on West Side of 52 Street												
											200	350	500	750	1000
	XS-127	616	Pipestone Soccer Field												
						20	35	50	75	100	200	350	500	750	1000
	XS-127	616	Agriplex Baseball Fields												
									75	100	200	350	500	750	1000

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Table 5.2 Summary of hydraulic structures impacted by the range of flood magnitudes

Cross Section Number	Description	Structure Type	River Station (m)	ETC Bridge File	Flood Return Period												
					2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
Pipestone Creek	Range Road 250	Bridge	18,357	BF496	-	-	-	-	-	-	-	-	-	-	-	-	-
	Private Crossing	Bridge	17,704	N/A	-	-	-	-	-	-	-	-	Affected	Affected	Affected	Affected	Affected
	Township Road 474	Bridge	15,803	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pedestrian	Bridge	13,308	N/A	-	-	-	-	-	-	-	-	-	-	-	Affected	Affected
	Pedestrian	Bridge	12,677	N/A	-	-	-	-	-	Affected	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Pedestrian	Bridge	12,398	N/A	-	-	-	-	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Overhead Pipeline Crossing	Bridge	11,930	N/A	-	Affected	Affected	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Highway 2A	Bridge	9,791	BF72548	-	-	-	-	-	-	-	-	-	-	-	-	-
	CP Rail	Bridge	9,756	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
	Private Crossing	Bridge	8,375	N/A	-	Affected	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Private Crossing	Bridge	7,908	N/A	-	-	-	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Private Crossing	Bridge	7,816	N/A	-	-	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Range Road 243A	Bridge	6,581	BF359	-	-	-	-	-	-	Affected	Affected	Affected	Affected	Affected	Affected	Affected
	Private Crossing	Bridge	6,345	N/A	-	-	Affected	Affected	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Range Road 242	Bridge	94	BF727	-	-	-	-	-	-	Affected	Affected	Affected	Affected	Affected	Overtopped	Overtopped
Eyot Creek	53 Avenue	Bridge	1,401	BF70461	-	-	-	-	-	-	Affected	Affected	Affected	Affected	Affected	Affected	Affected
	Private Crossing	Bridge	1,215	N/A	-	Affected	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Pedestrian	Bridge	749	N/A	-	-	-	Affected	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	45 Avenue	Bridge	405	BF910	-	-	-	-	-	-	-	-	-	-	-	-	-
Pipestone Creek	Range Road 245/Gov't. Road	Culvert	14,465	BF9139	-	-	-	-	-	-	-	-	-	Submerged	Submerged	Submerged	Submerged
Snake Drain	Private Crossing	Culvert	1,127	N/A	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
	Range Road 245A	Culvert	473	N/A	-	-	-	Submerged	Submerged	Submerged	Submerged	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped

Notes: -

- "Affected" – Flood water between bridge low and high chord (bridges).
- "Submerged" – Flood water above culvert obvert, but below road elevation (culverts).
- "Overtopped" – Flood water above the bridge high chord (bridges) or roadway crossing (culverts).
- "-" – Flood water below the bridge low chord (bridges) or culvert obvert (culverts).

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6 FLOODWAY DETERMINATION

Flood hazard identification involves the delineation of floodway and flood fringe zones for a specified design flood. A description of key terms from the FHIP Flood Study Technical Guidelines (AEP, 2022), incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta, is provided below.

6.1 Design Flood Selection

As defined in the guidelines, the design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of occurring in any given year. The design flood can be based on either open water or ice jam flooding scenarios, depending on which scenario results in more severe flooding. The 1:100 flood has a statistical 100-year return period and is also referred to as the 100-year flood.

The 100-year open water flood was selected as the design flood for the study area. The discharge values for the 100-year open water flood are listed in Table 3.1.

6.2 Floodway and Flood Fringe Terminology

Flood Hazard Map

A flood hazard map is a specific type of flood map that identifies the area flooded or at risk of flooding for the 100-year design flood and divides that flood hazard area into floodway and flood fringe zones, and flood fringe sub-zones like the high hazard flood fringe and protected flood fringe. Flood hazard maps can also illustrate additional flood hazard information, including incremental areas at risk for more severe floods than the design flood, including the 200- and 500-year floods.

Floodway

When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard for the 100-year design flood, where flows are deepest, fastest, and most destructive. When a flood hazard map is updated, the floodway may reflect updated areas of highest hazard based on new information.

Flood Fringe

The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 100-year design flood. The flood fringe typically represents areas with shallower, slower, and

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less destructive flooding, but it may also include high hazard flood fringe areas. Areas at risk of flooding behind flood berms may also be mapped as protected flood fringe areas.

High Hazard Flood Fringe

The high hazard flood fringe identifies areas within the flood fringe with deeper or faster moving water than the rest of the flood fringe. High hazard flood fringe areas are likely to be more significant in flood maps that are being updated, but they may also be included in new flood maps.

Protected Flood Fringe

The protected flood fringe identifies areas that could be flooded if dedicated flood berms fail or do not work as designed during the 100-year design flood, even if they are not overtopped. Protected flood fringe areas illustrate residual flood risk and do not differentiate between areas with deeper and faster moving water and shallower or slower moving water.

6.3 Flood Hazard Identification

6.3.1 Floodway Determination Criteria

In areas being mapped for the first time, the floodway typically represents the area of highest hazard where flows are deepest, fastest, and most destructive during the design flood. The following criteria, based on those described in current FHIP guidelines (AEP, 2022), were used to delineate the floodway in such cases:

- Areas in which the depth of water exceeds 1 m, or the flow velocities are greater than 1 m/s shall be part of the floodway.
- Exceptions may be made for small backwater areas, ineffective flow areas, and to support creation of a hydraulically smooth floodway.
- The floodway must always include the main channel of a stream.
- For reaches of supercritical flow, the floodway boundary should typically correspond to the edge of inundation or the main channel, whichever is larger.

When a flood hazard map is updated, an existing floodway will not change in most circumstances. Exceptions to this include but are not limited to: (1) a floodway could get larger if a main channel shifts outside of a previously-defined floodway or (2) a floodway could get smaller if an area of previously-defined floodway is no longer flooded by the design flood.

Areas of deeper or faster moving water outside of the floodway were identified as high hazard flood fringe. These high hazard flood fringe zones were identified in all areas, whether they are newly-mapped or have an existing floodway.

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The final floodway limits were determined in consultation with the EPA project team. The floodway limit stations and limiting criteria for each cross section are tabulated in **Appendix H**. The limits of the floodway (also denoted as the floodway boundary) intersect cross sections at the floodway limit stations. For previously mapped reaches, the floodway largely follows the existing floodway, while for newly mapped reaches, it primarily aligns with the 1 m depth contour and main channel. In cases where no viable flood fringe exists or the previous floodway extended beyond the current inundation limit, the floodway coincides with the inundation limits. Additionally, in a few instances, the floodway follows the 1 m/s velocity contour and incorporates hydraulic smoothing criteria.

6.3.2 Design Flood Profile

The open water design flood levels presented in **Appendix H** were extracted from the HEC-RAS model for the 100-year flood. Figure 4.6 to Figure 4.8 earlier in the document depict the 100-year flood profile, which is the design flood.

6.3.3 Floodway Criteria Maps

A floodway criteria map documents the technical information that helps define the floodway (AEP, 2022). The information on the maps include:

- Inundation extents for the design flood.
- Areas where the depth of water is 1 m or greater and the corresponding 1 m depth contour.
- Areas where the computed velocity is 1 m/s or faster.
- The proposed floodway limits and, where applicable, the previous floodway boundary.
- Stranded areas of dry ground within the flood hazard area.
- The location and extent of all cross sections used in the HEC-RAS model.
- The extent of main channel at each cross section.

The floodway criteria maps for this study are provided in **Appendix I**.

The mapping exercise began with the computed water surface elevations and flow velocities for the open water design flood. The extent of inundation was then mapped using the general procedure described in Section 5. This procedure included generation of the corresponding water surface elevation (WSE) triangular irregular network (TIN), WSE grid, and flood depth grid.

Polygons representing 1 m or more than 1 m deep areas, and 1 m depth contour lines were derived from the flood depth grid. The depth contours were then filtered and smoothed using the same parameters and procedures as those applied to determine the inundation extents.

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Since a one-dimensional computational modelling approach was used for this study, flow velocities were only available at the cross section locations. HEC-RAS can apportion channel and overbank discharge into a maximum of 45 sub-sections at any cross section location. Discharge is apportioned based on the computed water level and a weighted flow area approach. This provides a convenient means to estimate the lateral variation in velocity across a section. For this study, the maximum number of velocity subsections were specified in the overbanks. The velocity values were assigned to the corresponding segments along each cross section. Those segments with velocities of 1 m/s or greater were emphasized on the maps to help visualize where local flow velocities were greater than or equal to 1 m/s.

6.3.4 Flood Hazard Maps

The flood hazard maps depict the floodway and flood fringe, including the high hazard flood fringe areas, for the design flood. The map also shows incremental areas at risk for more severe floods: the 200- and 500-year floods. The flood hazard maps are provided as **Appendix J**.

The limits of the floodway were delineated by the floodway boundary developed for the open water floodway criteria map. The floodway was represented as a contiguous polygon by including areas of high ground or areas of depth less than 1 m inside the floodway.

The design flood extent developed for the floodway criteria maps was adjusted to create the flood fringe. The limits of the flood fringe followed the extent of direct inundation of the design flood. Areas of high ground within the direct inundation extent (and outside of the floodway) were preserved and not indicated as flood fringe in the flood hazard map. High hazard flood fringe areas were differentiated in the flood hazard map.

Areas in the Floodway

The floodway primarily includes the main channel and parts of the overbank areas, which are mostly forested or farmland, with no significant areas of interest.

Areas in the High Hazard Flood Fringe

The high hazard flood fringe includes all inundated areas outside the floodway with deeper or faster moving water. The only notable area within this zone is the Pipestone Links Golf Course.

Areas in the Flood Fringe

The flood fringe includes all inundated areas outside the limits of the floodway and high hazard flood fringe. Notable inundated areas within the flood fringe include:

- Moonen Heights Soccer Field.
- Pipestone Motel, RV Park & Storage.

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- Buildings on East Side of Highway 2A.
- Pipestone Links Golf Course.
- Pipestone Soccer Field.
- Agriplex Baseball Fields.

7 POTENTIAL CLIMATE CHANGE IMPACTS

To address the potential impacts of climate change on flood levels, more severe open water flood scenarios were compared to the current design flood estimates to obtain a measure of "freeboard" that may be generally appropriate for long-term planning purposes. To obtain information appropriate for other applications, the simplified approach taken herein could be supplemented in the future by a more rigorous regional climate analysis and site-specific impact assessment.

7.1 Comparative Scenarios

For the open water flood hazard, the current 100-year design flood water levels were compared to those associated with discharges that are 10 and 20 percent greater than the current 100-year flood estimates. This approach is consistent with guidelines prepared by Engineers and Geoscientists British Columbia (EGBC, 2018). EGBC recommends that for basins where no historical trend is detectable in local or regional streamflow magnitude frequency relations, a 10 percent increase in design discharge be applied to account for likely future changes in water input from precipitation. On the other hand, if a statistically significant trend is detected, a 20 percent increase may be appropriate, particularly for smaller basins.

7.2 Results

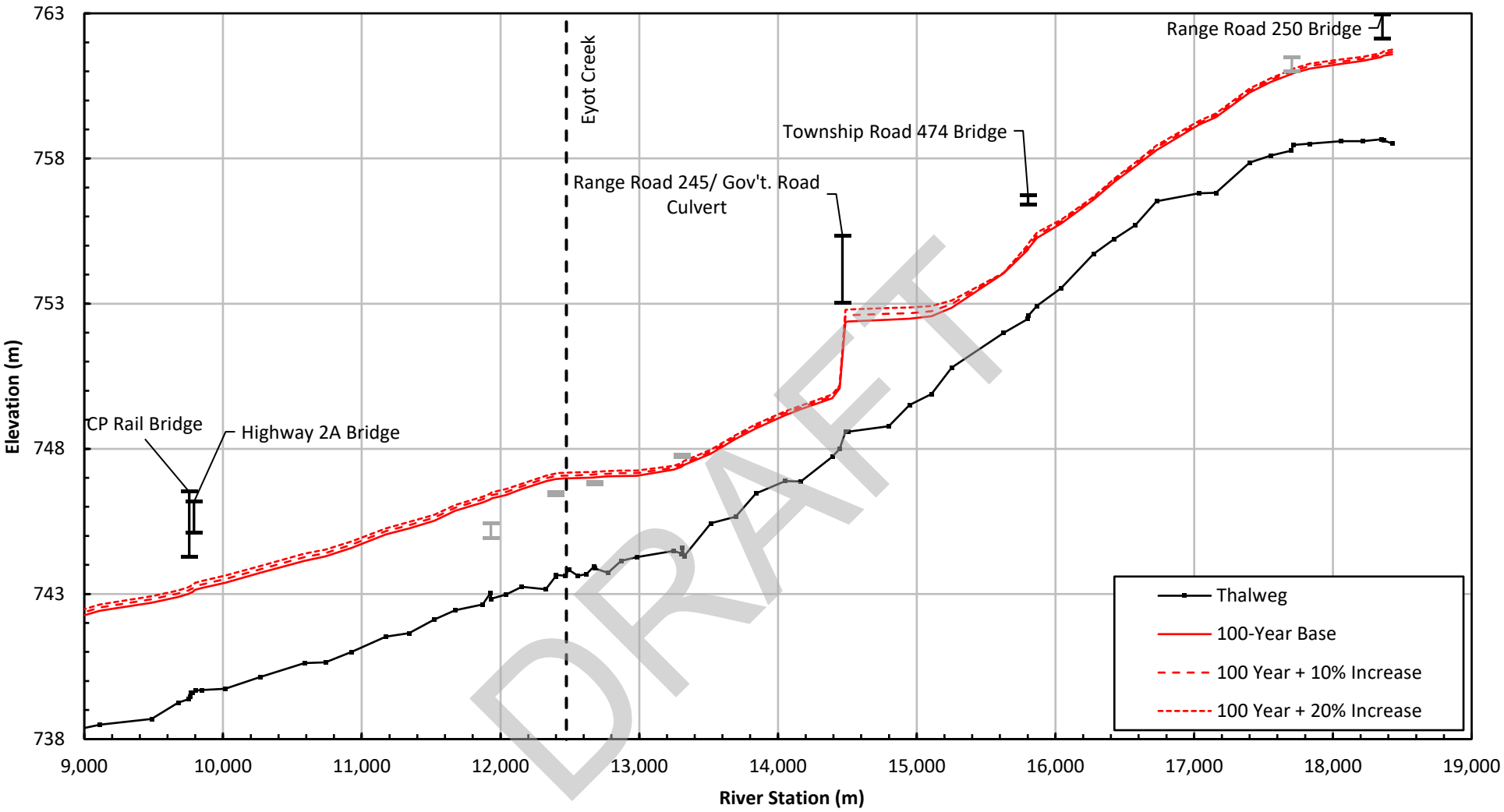
The magnitude of the increases was found to be fairly uniform along the study reach. The average increase in water levels due to a 10 and 20 percent increase in the 100-year flood discharge were 0.09 m and 0.17 m, respectively within all the creeks (Pipestone Creek, Eyot Creek, and Snake Drain). Figure 7.1, Figure 7.2 and Figure 7.3 plots a comparison between the computed 100-year flood level profile and profiles computed with discharges that are 10, and 20 percent greater than the 100-year flood discharge.

7.3 Supplementary Information

Climate change has the potential to affect many factors related to flood severity. For open water floods, more frequent and greater intensity summer rain storms are commonly attributed to future climate flood risks. A comprehensive analysis would consider meteorological and

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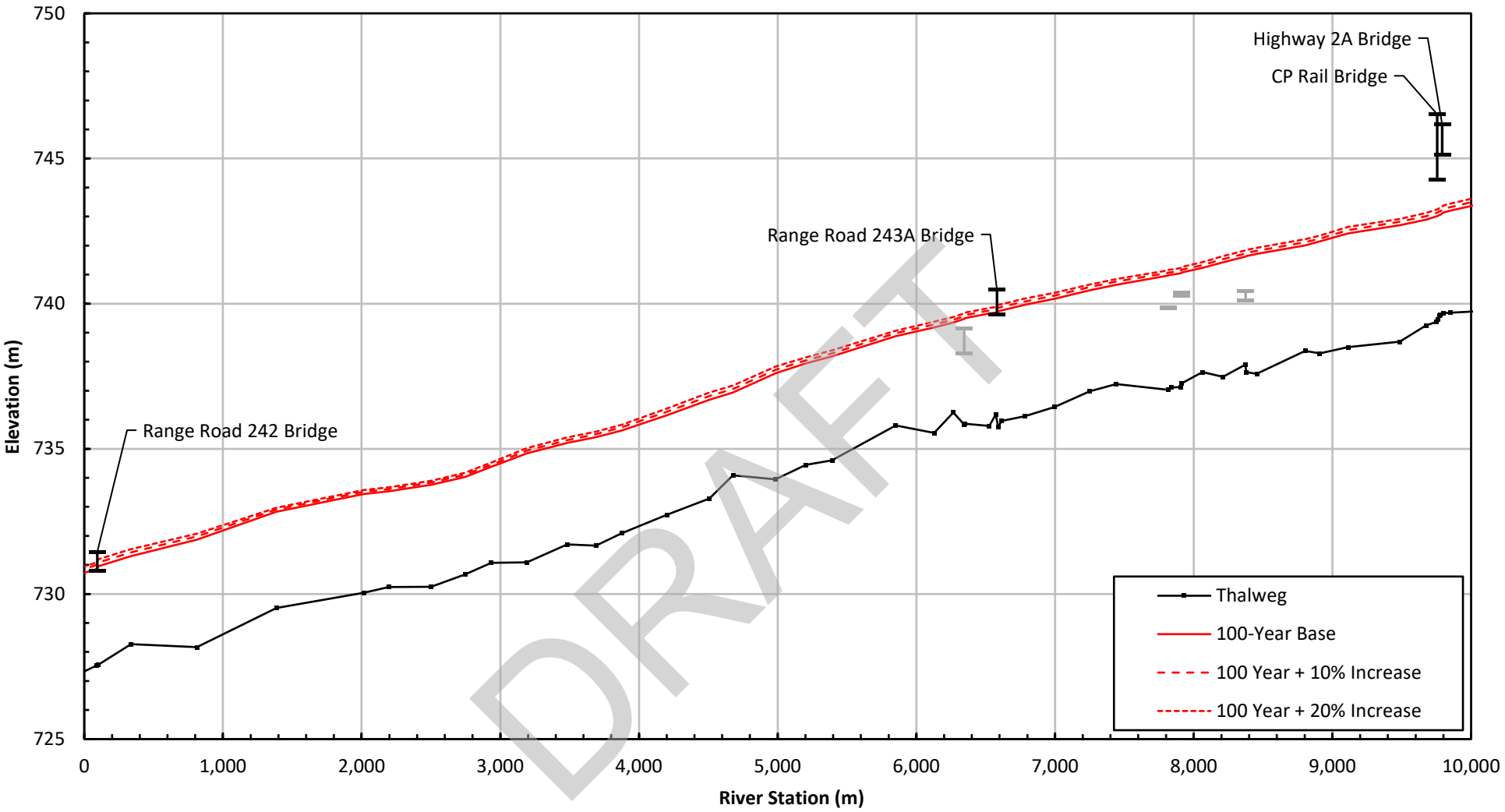


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**PIPESTONE CREEK POTENTIAL CLIMATE CHANGE IMPACT ON DESIGN FLOOD PROFILE (1/2)**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 7.1

Classification: Public

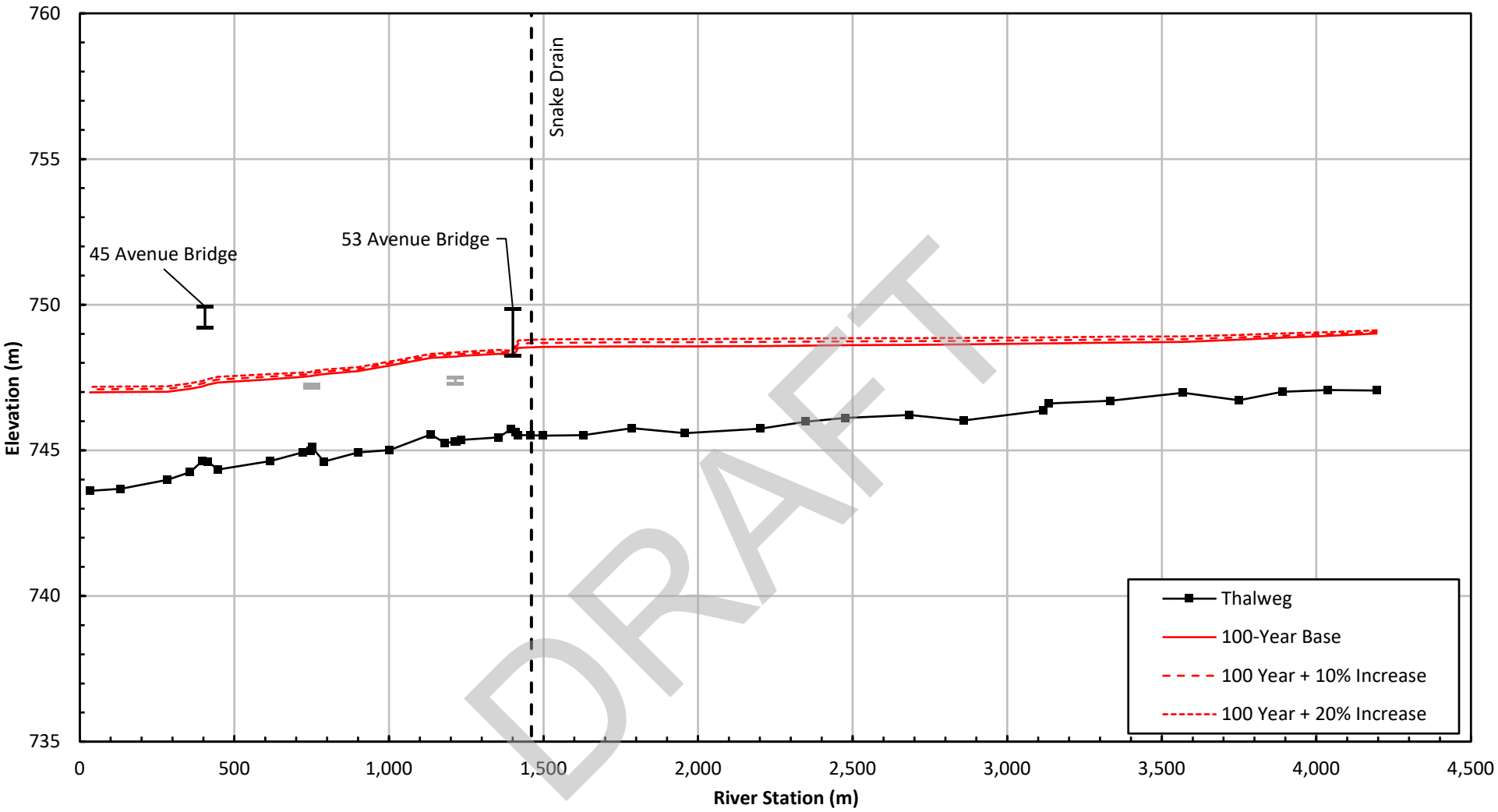


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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY **PIPESTONE CREEK POTENTIAL CLIMATE CHANGE IMPACT ON DESIGN FLOOD PROFILE (2/2)**
nhc	UNITS: AS SHOWN	
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 7.1

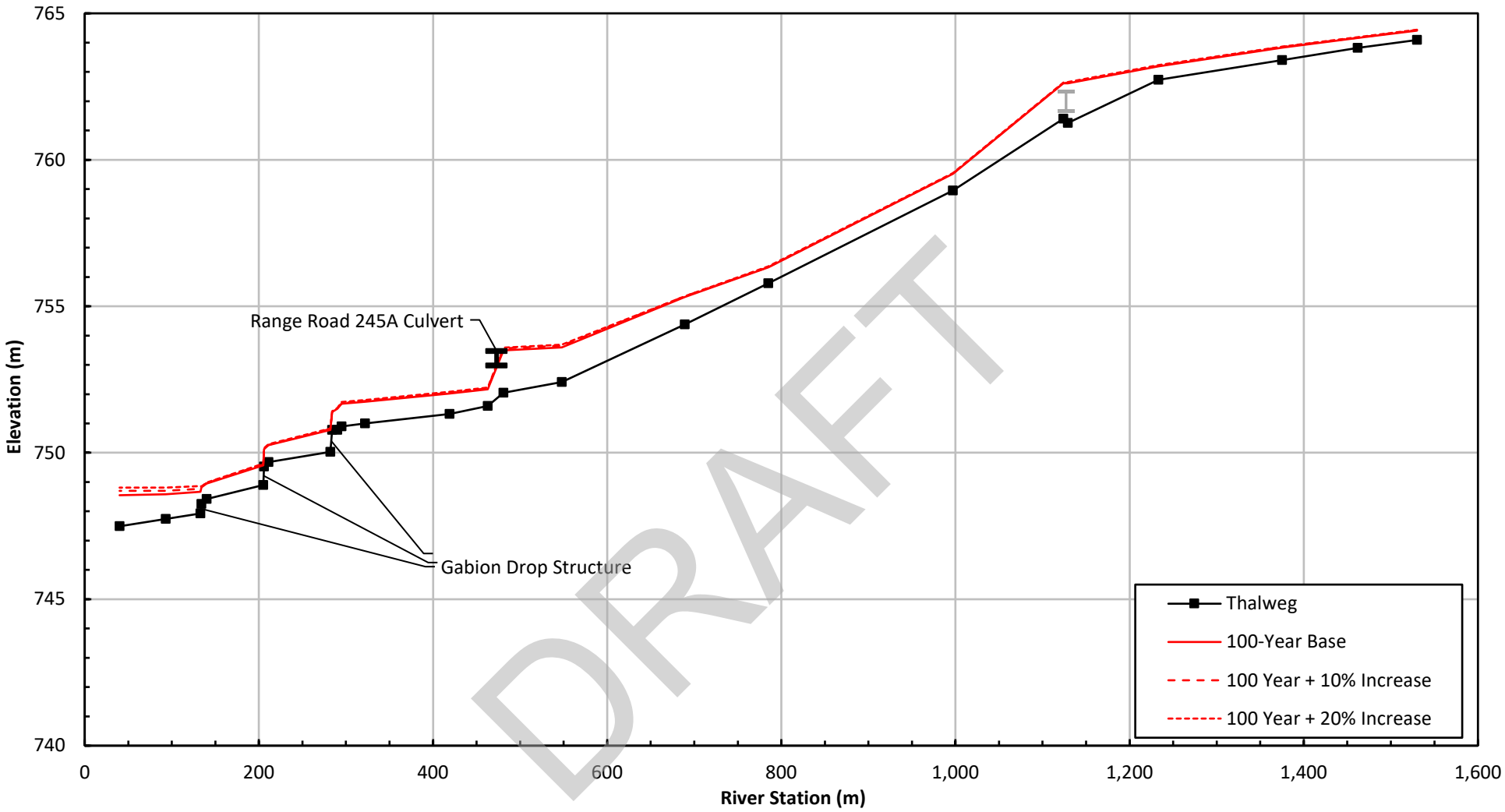
Classification: Public



Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**EYOT CREEK POTENTIAL CLIMATE CHANGE IMPACT ON DESIGN FLOOD PROFILE**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 7.2

Classification: Public



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Notes: 1. Pedestrian bridges and private crossings are depicted by grey bars and remain unlabeled due to absence of specified names.

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY
nhc	UNITS: AS SHOWN	**SNAKE DRAIN POTENTIAL CLIMATE CHANGE IMPACT ON DESIGN FLOOD PROFILE**
	Job: 1008862 / *Date: 02-APR-2025*	FIGURE 7.3

Classification: Public

8 CONCLUSIONS

The objectives of this study were to assess river flood-related hazards along 15 km of Pipestone Creek, 4 km of Eyot Creek, and 2 km of Snake Drain through the town of Millet and Wetaskiwin County No. 10. A provincial flood hazard mapping study was previously completed for Millet in 2003; however, the present study covers an expanded study reach and represents an update to the prior work.

The Millet Flood Study is comprised of five major components: 1) survey and base data collection; 2) open water hydrology assessment; 3) open water hydraulic modelling; 4) open water flood inundation mapping; and 5) design flood hazard mapping. This report summarizes the work of all five components.

The collection of survey and base data primarily supports the hydraulic modelling and flood mapping. A total of 186 cross sections were surveyed along the study reaches using ground surveys to complement the LiDAR-derived DTM of the overbank area. In addition, geometric details were collected for 18 bridges, 3 culvert crossings, and one overhead pipeline crossing within the study reaches. There are no specifically designated flood control structures within the study area. Nevertheless, the town has containment dikes in place for their wastewater lagoons. These containment dikes are located alongside Pipestone Creek within the study area and adjacent to the west town boundary.

The primary purpose of the open water hydrology assessment was to develop flood frequency estimates for Pipestone Creek, Eyot Creek and Snake Drain, in support of the hydraulic modelling and flood mapping tasks. Five sites were identified for flood frequency estimates to capture the changes in creek discharge that would occur within the study area. The study reaches are not gauged, and the flood frequency flows were estimated based on the regional analysis. The current flood frequency estimates are higher than those from AENV (2003), primarily due to differences in the selection of gauging stations for regional analysis. Additionally, this study incorporates longer flow records, including more recent data, and utilizes advanced topographic datasets such as LiDAR DTM for basin delineation. As a result, the flood frequency estimates in this study have lower uncertainties compared to previous studies.

A hydraulic model of the study reach was developed using the HEC-RAS program from the U.S. Army Corps of Engineers, with channel bathymetry and non-hydro-flattened DTM data used to establish the model geometry. Inflow discharges were assigned at the upstream boundaries of Pipestone Creek, Eyot Creek, and Snake Drain, while a normal depth slope of 0.0013 m/m was applied at the downstream boundary of Pipestone Creek, positioned well beyond the study limit to minimize its impact on the results. Channel roughness values were initially estimated based on geomorphic characteristics, literature, and roughness values from previous studies, followed by high flow calibration limited to Pipestone Creek. The final roughness values were selected through a combination of calibration and literature review. Overbank roughness coefficients were defined based on land cover composition, professional judgment, and literature guidance.

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The selected roughness values for both channel and overbank areas align with those used in prior studies (NHC, 2003). Water surface profiles were generated for various return period discharges, including the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year flood events. A sensitivity analysis was conducted on model parameters, including boundary conditions, Manning's roughness coefficients, and the roadway weir coefficient, revealing that the model is most sensitive to discharge and channel roughness, with minimal to no sensitivity to other parameters.

Flood inundation maps were created for various open water flood frequency return periods, ranging from 2- to 1000-year floods, using water surface profiles derived from hydraulic modelling. No residential buildings are expected to be inundated, even during the 1000-year flood event. However, some out buildings on residential lots, parks, golf courses, and playgrounds may experience inundation starting from the 5 to 20-year flood event. Of the 22 hydraulic structures within the study reach, 14 are projected to be affected by the 100-year flood, and 17 by the 1000-year flood. No flood control structures are expected to be overtopped during any of the modelled flood events.

Floodway criteria maps were developed for the 100-year design flood, showing the criteria used to define the floodway and flood fringes. The floodway boundary largely follows the previous floodway, 1 m depth, main channel, and inundation extent criteria. Flood hazard maps were later created to illustrate the floodway, flood fringe, and high hazard flood fringe areas for the design flood, along with incremental risk areas for the 200- and 500-year floods. No significant overbank areas are located within the floodway.

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Classification: Public

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April 2025

APPENDIX A

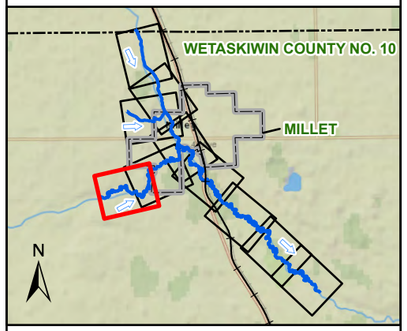
SURVEY OVERVIEW MAP

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- CONTROL POINT
- SURVEY POINT
- RIVER STATION MARKER
- STUDY REACH
- SURVEY CROSS SECTION
- PREVIOUS FLOOD STUDY CROSS SECTION (NHC, 2003)
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- LOCAL ROAD
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- TOWN OF MILLET
- COUNTY
- STUDY LIMIT

SCALE - 1:5,000

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Coordinate System: NAD 1983 CSRS 3TM 114;
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MILLET FLOOD STUDY

SURVEY OVERVIEW

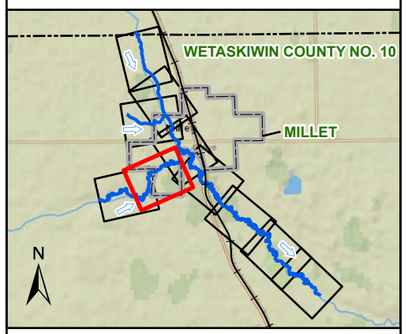
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SURVEY OVERVIEW

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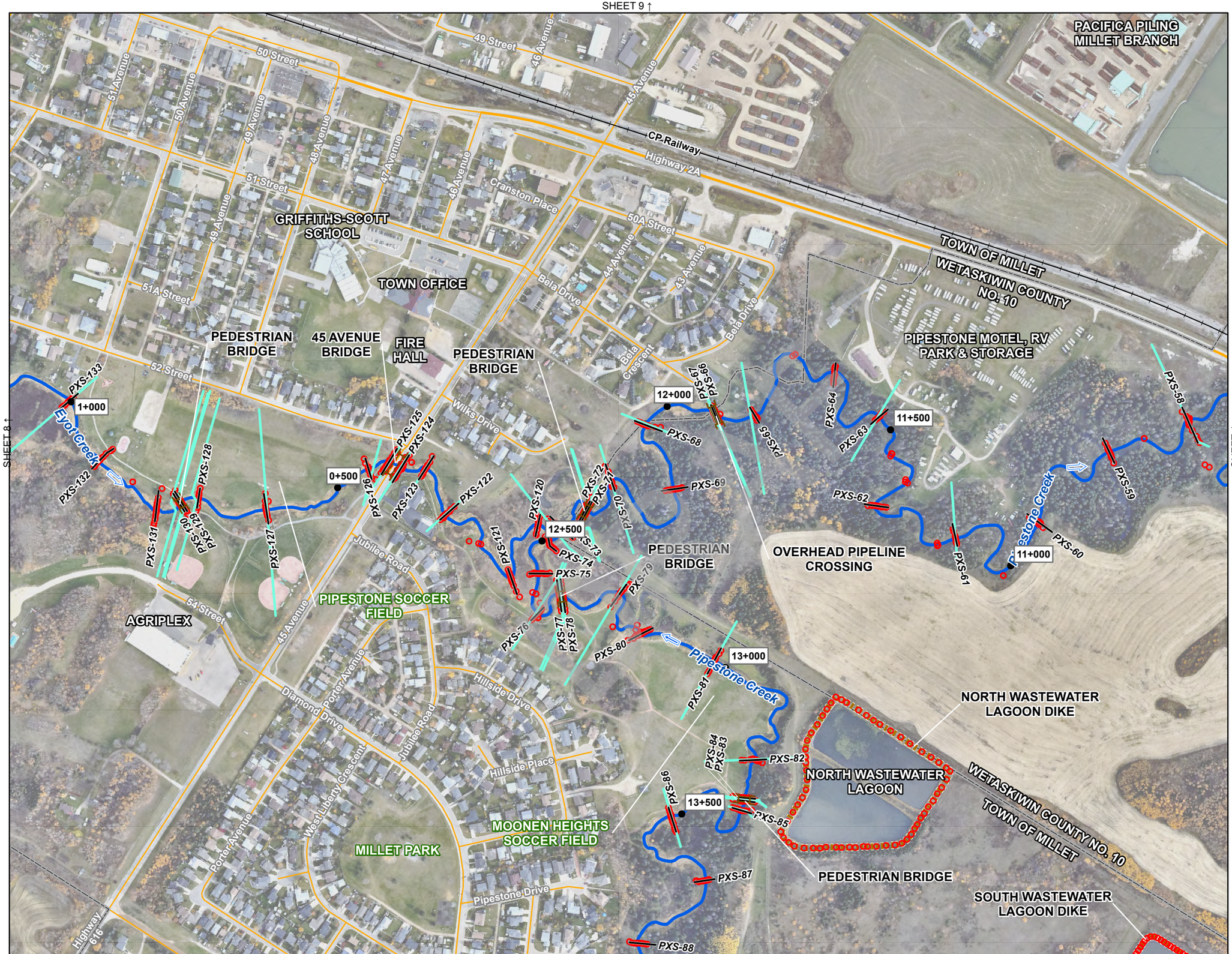
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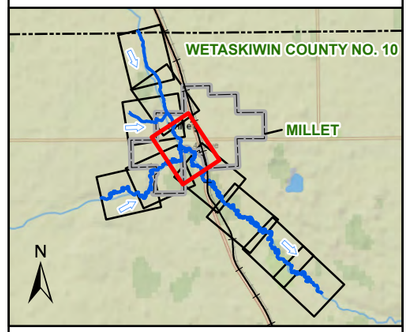
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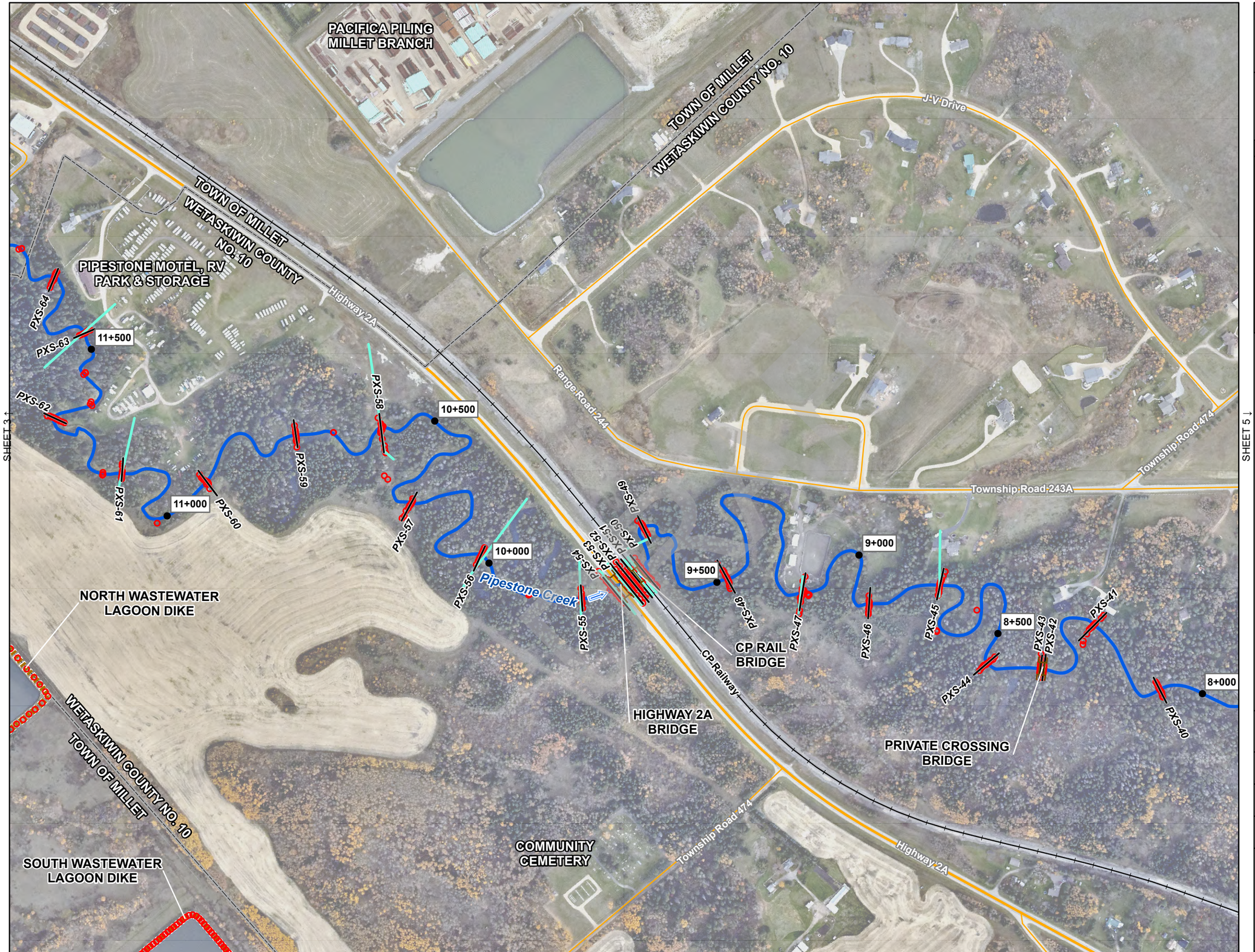
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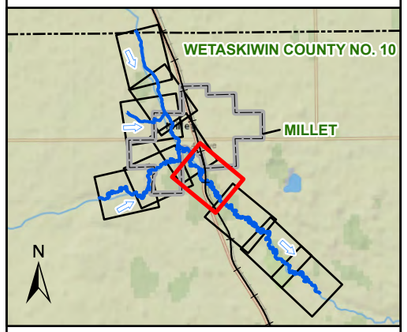
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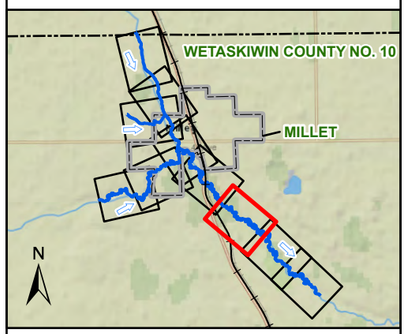
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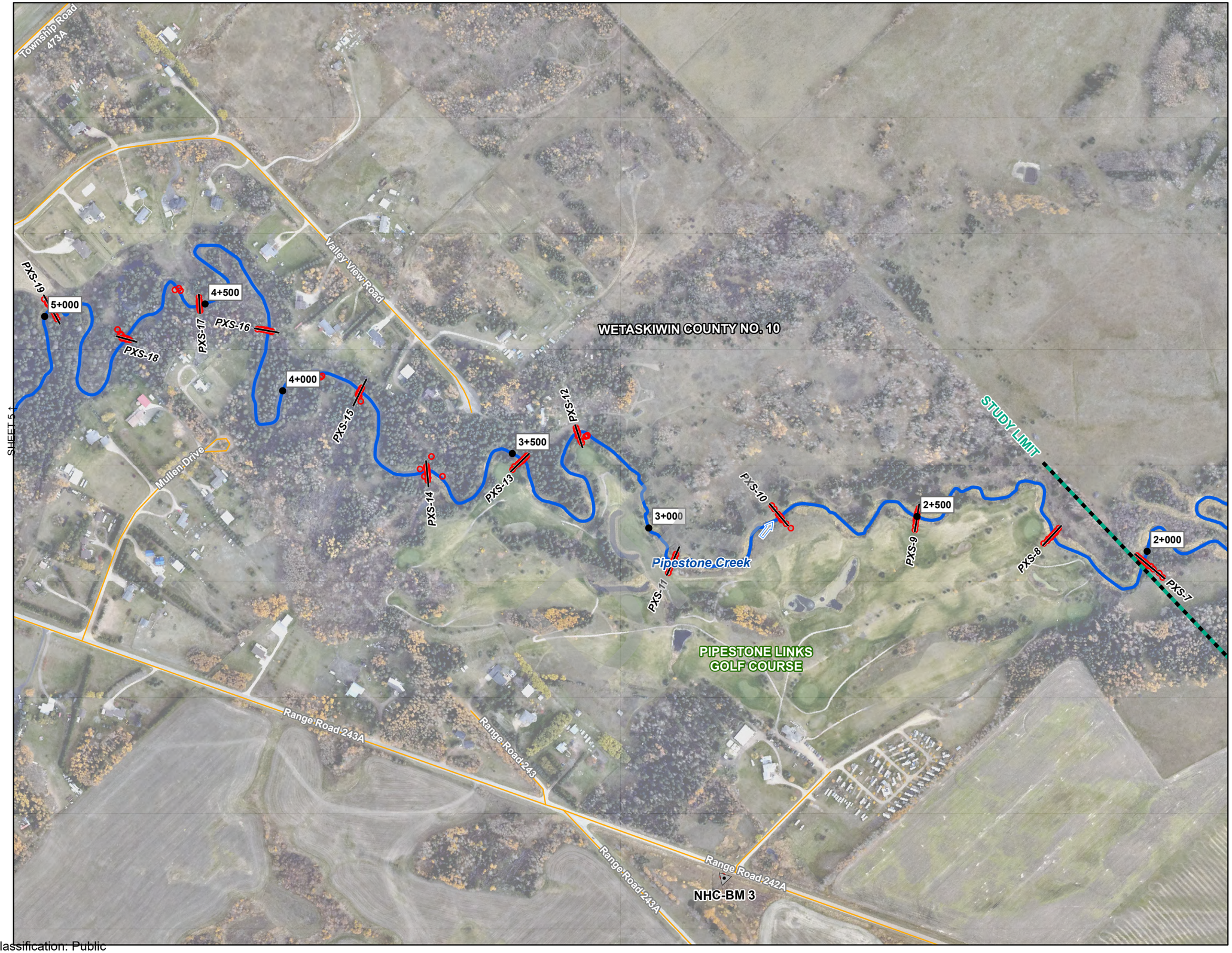
MILLET FLOOD STUDY

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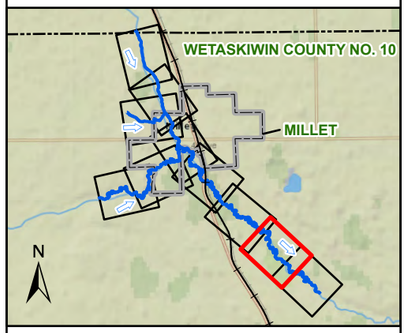
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MILLET FLOOD STUDY

SURVEY OVERVIEW

SHEET 6 OF 10

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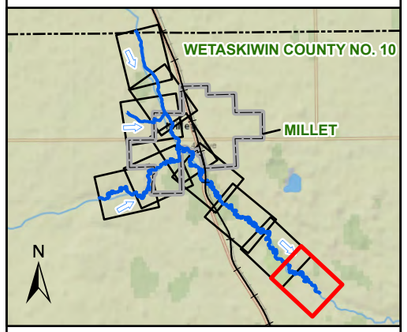
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MILLET FLOOD STUDY

SURVEY OVERVIEW

SHEET 7 OF 10

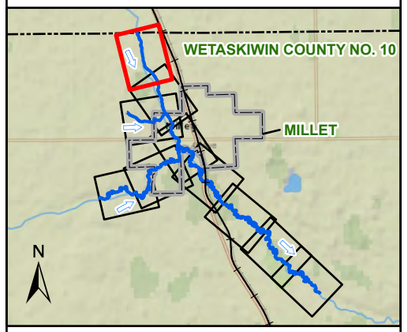
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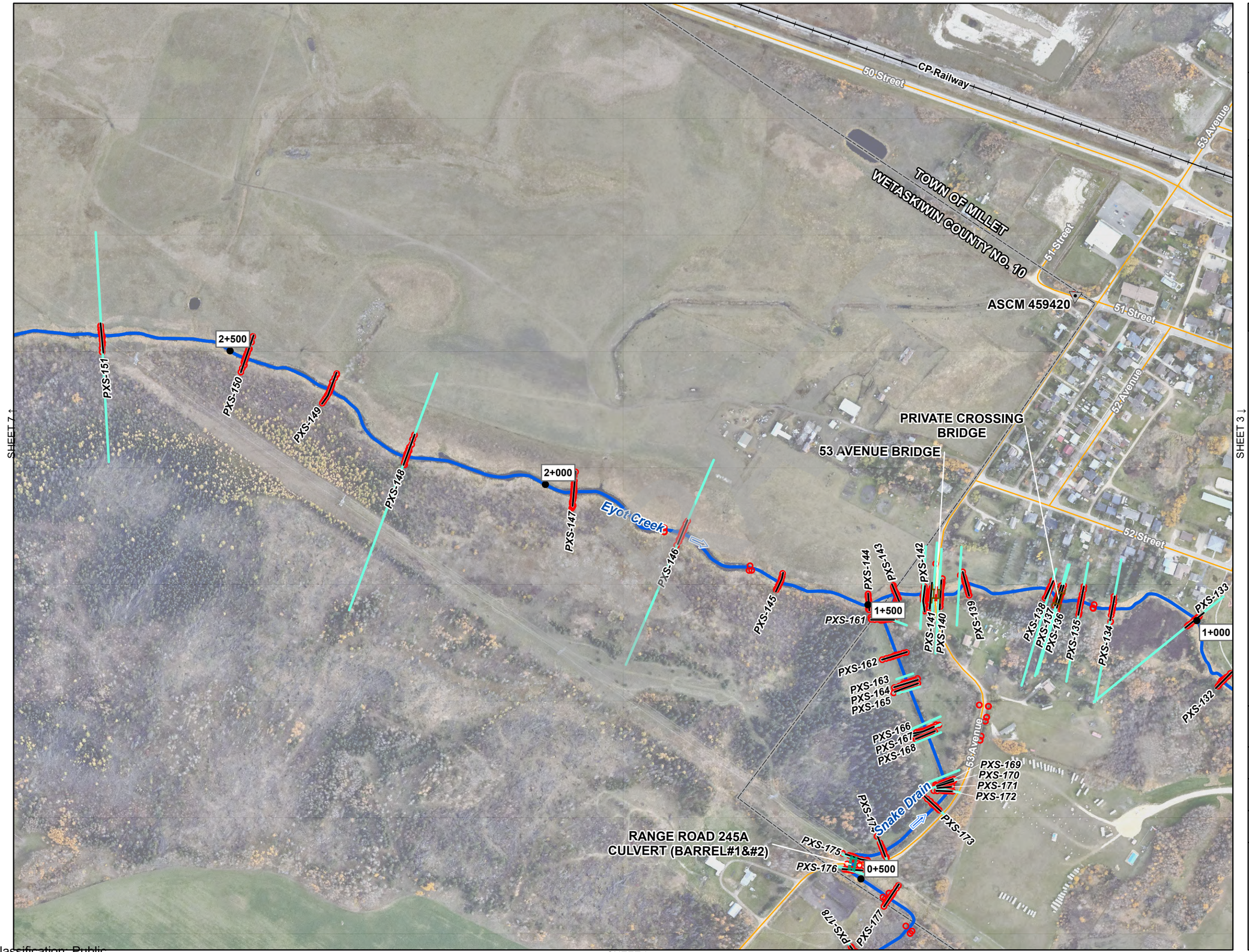
MILLET FLOOD STUDY

SURVEY OVERVIEW

SHEET 8 OF 10

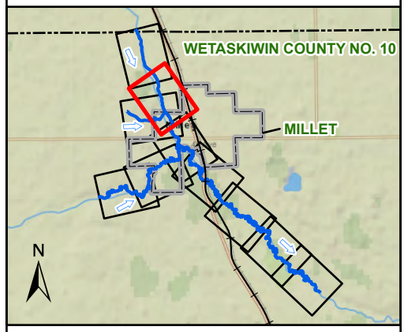
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Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	02-APR-2025

MILLET FLOOD STUDY

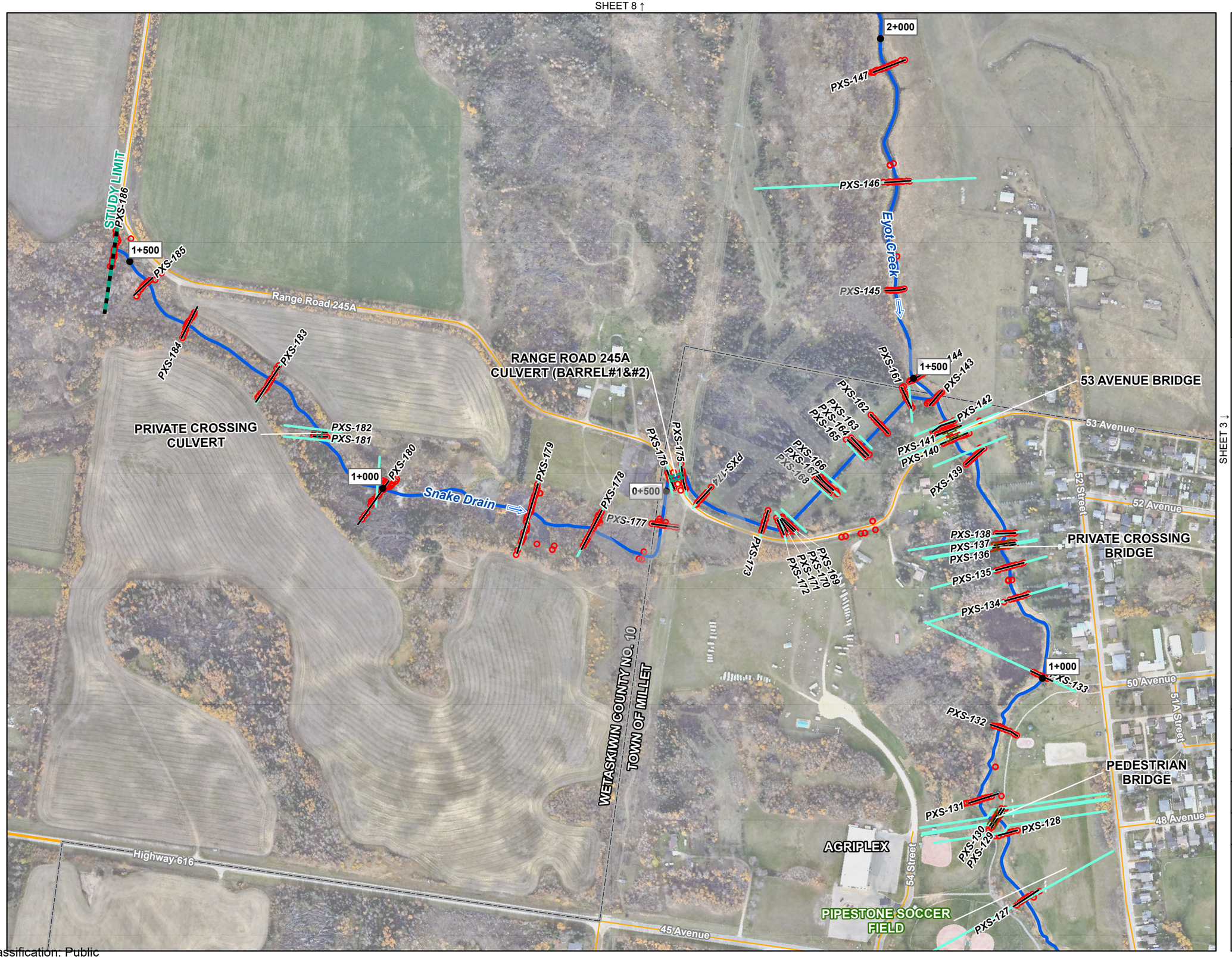
SURVEY OVERVIEW

SHEET 9 OF 10

JY: P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\SURVEY\MILLET FS SURVEY MAPPING.aprx

Classification: Public

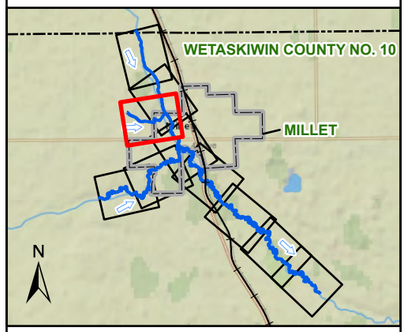
SHEET 8 ↑



SHEET 3 ↓

Alberta Canada

nhc



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- RIVER STATION MARKER
- STUDY REACH
- SURVEY CROSS SECTION
- PREVIOUS FLOOD STUDY CROSS SECTION (NHC, 2003)
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- TOWN OF MILLET
- COUNTY
- STUDY LIMIT

SCALE - 1:5,000

0 50 100 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	02-APR-2025

MILLET FLOOD STUDY

SURVEY OVERVIEW

SHEET 10 OF 10

JY: P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\SURVEY\MILLET FS SURVEY MAPPING.aprx

Classification: Public

April 2025

APPENDIX B

HYDRAULIC STRUCTURE DETAILS

DRAFT

Classification: Public

Bridge Description

Name:	Range Road 250 Bridge	**Bridge File No.:**	BF496
River:	Pipestone Creek	**River Station (m):**	18,357

Geometry

Span (m):	20	**Minimum High Chord (m):**	762.97
Width (m):	9	**Minimum Low Chord (m):**	762.12
Pier Type:	Wood	**No. of Piers:**	2
Pier Shape:	Square	**Pier Width (m):**	0.3

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Private Crossing Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	17,704

Geometry

Span (m):	13.5	**Minimum High Chord (m):**	761.47
Width (m):	3.2	**Minimum Low Chord (m):**	761.00
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Township Road 474 Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	15,803

Geometry

Span (m):	12.6	**Minimum High Chord (m):**	756.72
Width (m):	4.7	**Minimum Low Chord (m):**	756.40
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	13,308

Geometry

Span (m):	15.4	**Minimum High Chord (m):**	747.80
Width (m):	1.7	**Minimum Low Chord (m):**	747.72
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Pipestone	**River Station (m):**	12,677

Geometry

Span (m):	13.9	**Minimum High Chord (m):**	746.85
Width (m):	2.5	**Minimum Low Chord (m):**	746.77
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	12,398

Geometry

Span (m):	17	**Minimum High Chord (m):**	746.50
Width (m):	1.3	**Minimum Low Chord (m):**	746.40
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of bridge



Looking upstream at the downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	Overhead Pipeline Crossing	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	11,930

Geometry

Span (m):	25	**Minimum High Chord (m):**	745.43
Width (m):	0.5	**Minimum Low Chord (m):**	744.93
Pier Type:	Steel	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.2

Photo(s)

Looking downstream at the upstream side of pipeline crossing



DRAFT

Classification: Public

Bridge Description

Name:	Highway 2A Bridge	**Bridge File No.:**	BF72548
River:	Pipestone Creek	**River Station (m):**	9,791

Geometry

Span (m):	34	**Minimum High Chord (m):**	746.18
Width (m):	14.8	**Minimum Low Chord (m):**	745.12
Pier Type:	N/A	**No. of Piers:**	2
Pier Shape:	N/A	**Pier Width (m):**	0.51

Photo(s)

Looking downstream at the upstream side of bridge



Looking upstream at the downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	CP Rail Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	9,756

Geometry

Span (m):	20	**Minimum High Chord (m):**	746.52
Width (m):	5	**Minimum Low Chord (m):**	744.27
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of bridge



Looking upstream at the downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	Private Crossing Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	8,375

Geometry

Span (m):	16.8	**Minimum High Chord (m):**	740.43
Width (m):	3.4	**Minimum Low Chord (m):**	740.10
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Private Crossing Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	7,908

Geometry

Span (m):	20	**Minimum High Chord (m):**	740.38
Width (m):	1.7	**Minimum Low Chord (m):**	740.28
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at upstream side of bridge



Looking upstream and downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	Private Crossing Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	7,816

Geometry

Span (m):	18.5	**Minimum High Chord (m):**	739.86
Width (m):	0.8	**Minimum Low Chord (m):**	739.83
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at upstream side of bridge



Looking upstream at downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	Range Road 243A Bridge	**Bridge File No.:**	BF359
River:	Pipestone Creek	**River Station (m):**	6,581

Geometry

Span (m):	29	**Minimum High Chord (m):**	740.48
Width (m):	9	**Minimum Low Chord (m):**	739.63
Pier Type:	Steel	**No. of Piers:**	2
Pier Shape:	Box	**Pier Width (m):**	0.3

Photo(s)

Looking downstream at upstream side of bridge



Looking upstream at downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	Private Crossing Bridge	**Bridge File No.:**	N/A
River:	Pipestone Creek	**River Station (m):**	6,345

Geometry

Span (m):	15	**Minimum High Chord (m):**	739.13
Width (m):	2	**Minimum Low Chord (m):**	738.29
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at upstream side of bridge



Looking upstream at downstream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	Range Road 242 Bridge	**Bridge File No.:**	BF727
River:	Pipestone Creek	**River Station (m):**	94

Geometry

Span (m):	21	**Minimum High Chord (m):**	731.45
Width (m):	7	**Minimum Low Chord (m):**	730.80
Pier Type:	Wood	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.3

Photo(s)

Aerial view of the bridge



Looking upstream on dowsntream side of bridge



DRAFT

Classification: Public

Bridge Description

Name:	53 Avenue Bridge	**Bridge File No.:**	BF70461
River:	Eyot Creek	**River Station (m):**	1,401

Geometry

Span (m):	11.5	**Minimum High Chord (m):**	749.85
Width (m):	7	**Minimum Low Chord (m):**	748.23
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Private Crossing Bridge	**Bridge File No.:**	N/A
River:	Eyot Creek	**River Station (m):**	1,215

Geometry

Span (m):	16	**Minimum High Chord (m):**	747.49
Width (m):	1.6	**Minimum Low Chord (m):**	747.29
Pier Type:	Wood	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.25

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Eyot Creek	**River Station (m):**	749

Geometry

Span (m):	12.6	**Minimum High Chord (m):**	747.25
Width (m):	1.7	**Minimum Low Chord (m):**	747.15
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of the bridge



DRAFT

Classification: Public

Bridge Description

Name:	45 Avenue Bridge	**Bridge File No.:**	BF910
River:	Eyot Creek	**River Station (m):**	405

Geometry

Span (m):	31	**Minimum High Chord (m):**	749.94
Width (m):	16.1	**Minimum Low Chord (m):**	749.21
Pier Type:	Steel	**No. of Piers:**	2
Pier Shape:	Square	**Pier Width (m):**	0.31

Photo(s)

Looking downstream at the upstream side of the bridge



Looking upstream at the downstream side of bridge



DRAFT

Classification: Public

Culvert Description

Name:	Range Road 245/ Government Road Culvert	**Bridge File No.:**	BF9139
River:	Pipestone Creek	**River Station (m):**	14,465

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	748.74
Diameter (m):	4.3	**Downstream Invert Elev (m):**	747.97
Culvert Type:	CSP	**Barrel Length (m):**	36.3
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	755.34
Entrance Con:	Headwall		

Photo(s)

Looking downstream on upstream side of the culvert



Looking upstream on the downstream side of the culvert



Culvert Description

DRAFT

Classification: Public

Name:	Private Crossing Culvert	**Bridge File No.:**	N/A
River:	Snake Drain	**River Station (m):**	1,127

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	761.37
Diameter (m):	0.3	**Downstream Invert Elev (m):**	761.42
Culvert Type:	CSP	**Barrel Length (m):**	4.9
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	762.32
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on upstream side of the culvert



DRAFT

Classification: Public

Culvert Description

Name:	Range Road 245A Culvert (Barrel #1)	**Bridge File No.:**	N/A
River:	Snake Drain	**River Station (m):**	473

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	752.08
Diameter (m):	0.9	**Downstream Invert Elev (m):**	751.68
Culvert Type:	CSP	**Barrel Length (m):**	16.2
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	753.48
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on the upstream side of the culvert



Looking upstream on the downstream side of the culvert



DRAFT

Classification: Public

Culvert Description

Name:	Range Road 245A Culvert (Barrel #2)	**Bridge File No.:**	N/A
River:	Snake Drain	**River Station (m):**	473

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	752.08
Diameter (m):	0.9	**Downstream Invert Elev (m):**	751.61
Culvert Type:	CSP	**Barrel Length (m):**	16.5
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	753.35
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on the upstream side of the culvert



Looking upstream on the downstream side of the culvert



DRAFT

Classification: Public

April 2025

APPENDIX C

REACH REPRESENTATIVE PHOTOS

DRAFT

Classification: Public



1) Looking upstream on Pipestone Creek from Range Road 250 Bridge.



2) Looking downstream on Pipestone Creek from Private Crossing Bridge between PXS-112 & PXS-113.



3) Looking upstream on Pipestone Creek at PXS-103.



4) Looking downstream on Pipestone Creek from Range Road 245/Government Road Culvert.



5) Looking downstream on Pipestone Creek from Pedestrian Bridge between PXS-83 & PXS-84. .



6) Aerial view of Pipestone Creek near PXS-80.

DRAFT

Note:

Photos taken by NHC during site visit on April 29, 2024, and as part of their survey program May 8-14, 2024.

Alberta Canada

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MILLET FLOOD STUDY

REACH REPRESENTATIVE PHOTOS – PIPESTONE CREEK

1008862 | **C-1**

Classification: Public



7) Looking downstream on Pipestone Creek & Pedestrian Bridge from PXS-78.



8) Aerial view at confluence between Eyot Creek and Pipestone Creek.



9) Looking upstream on Pipestone Creek from PXS-62



10) Looking upstream on Pipestone Creek from PXS-44.



11) Looking downstream on Pipestone Creek from Private Crossing Bridge between PXS-38 & PXS-39.



12) Looking upstream on Pipestone Creek from Private Crossing Bridge between PXS-35 & PXS-36

Note:

Photos taken by NHC during site visit on April 29, 2024, and as part of their survey program May 8-14, 2024.

MILLET FLOOD STUDY

REACH REPRESENTATIVE PHOTOS – PIPESTONE CREEK

1008862 | **C-2**

Classification: Public



13) Looking downstream on Pipestone Creek from Private Crossing Bridge between PXS-35 & PXS-36



14) Looking upstream on Pipestone Creek from PXS-32



15) Looking downstream on Pipestone Creek between PXS-21 and PXS-22.



16) Looking downstream on Pipestone Creek from PXS-16.



17) Looking downstream on Pipestone Creek from PXS-8.



18) Looking downstream on Pipestone Creek from Range Road 242 Bridge.

DRAFT

Note:

Photos taken by NHC during site visit on April 29, 2024, and as part of their survey program May 8-14, 2024.

Alberta Canada

nhc

MILLET FLOOD STUDY

REACH REPRESENTATIVE PHOTOS – PIPESTONE CREEK

1008862 | **C-3**

Classification: Public



1) Looking downstream on Eyot Creek at PXS-160.



2) Looking upstream on Eyot Creek at PXS-155.



3) Looking upstream on Eyot Creek from 53 Avenue Bridge.



4) Aerial view of Eyot Creek near PXS-133.



5) Aerial view of Eyot Creek near PXS-123.



6) Aerial view at confluence of Eyot Creek and Pipestone Creek.

DRAFT

Note:

Photos taken by NHC during site visit on April 29, 2024, and as part of their survey program May 8-14, 2024.

Alberta Canada

nhc

MILLET FLOOD STUDY

REACH REPRESENTATIVE PHOTOS – EYOT CREEK

1008862 | **C-4**

Classification: Public



1) Looking downstream on Snake Drain Creek at PXS-184.



2) Looking downstream on Snake Drain Creek at PXS-182.



3) Looking downstream on Snake Drain Creek at PXS-178.



4) Looking downstream on Snake Drain Creek from PXS 176.



5) Looking downstream on Snake Drain Creek at PXS-168.



6) Looking downstream at the confluence of Snake Drain Creek and Eyot Creek.

Note:

Photos taken by NHC during site visit on April 29, 2024, and as part of their survey program May 8-14, 2024.

Alberta Canada

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MILLET FLOOD STUDY

REACH REPRESENTATIVE PHOTOS – SNAKE DRAIN

1008862 | **C-5**

Classification: Public

April 2025

APPENDIX D

OPEN WATER HYDROLOGY ASSESSMENT

DRAFT

Classification: Public

Northwest Hydraulic Consultants Ltd.
9819 – 12 Avenue SW
Edmonton, AB T6X 0E3
Tel: 780.436.5868
www.nhcwater.com

NHC Reference No. 1008862.01

October 9, 2024

Alberta Environment and Protected Areas
11th floor, Oxbridge Place
9820-106th Street NW
Edmonton, AB T5K 2J6

Attention: Tachara Larocque, P.Geo., River Hazard Specialist
Via email: Tachara.Larocque@gov.ab.ca

Re: Millet Flood Study
Open Water Hydrology Assessment Final Report

Dear Tachara:

This letter report presents the open water hydrology assessment conducted as part of the Millet Flood Study.

DRAFT

1 INTRODUCTION

In March 2024, Alberta Environment and Protected Areas (EPA) retained Northwest Hydraulic Consultants Ltd. (NHC) to complete a flood study for areas along approximately 15 km of Pipestone Creek, 4 km of Eyot Creek, and 2 km of Snake Drain through the town of Millet and the Wetaskiwin County No. 10. This study is part of Alberta's Flood Hazard Identification Program, which is intended to enhance public safety and reduce future flood damages in the province. Results from this study are also intended to inform local land use planning decisions, flood mitigation projects, and emergency response planning.

The scope of work for this study includes the following major components:

- survey and base data collection
- open water hydrology assessment
- open water hydraulic modelling
- open water flood inundation mapping
- design flood hazard mapping

- reporting and documentation

This letter report presents the results of the open water hydrology assessment, the primary objective of which is to develop flood frequency estimates for Pipestone Creek, and its tributaries including Eyot Creek, and Snake Drain within the study area, in support of the hydraulic modelling and flood mapping tasks for the Millet Flood Study.

2 STUDY AREA

Figure 1 shows the location and boundaries of the study area, which includes:

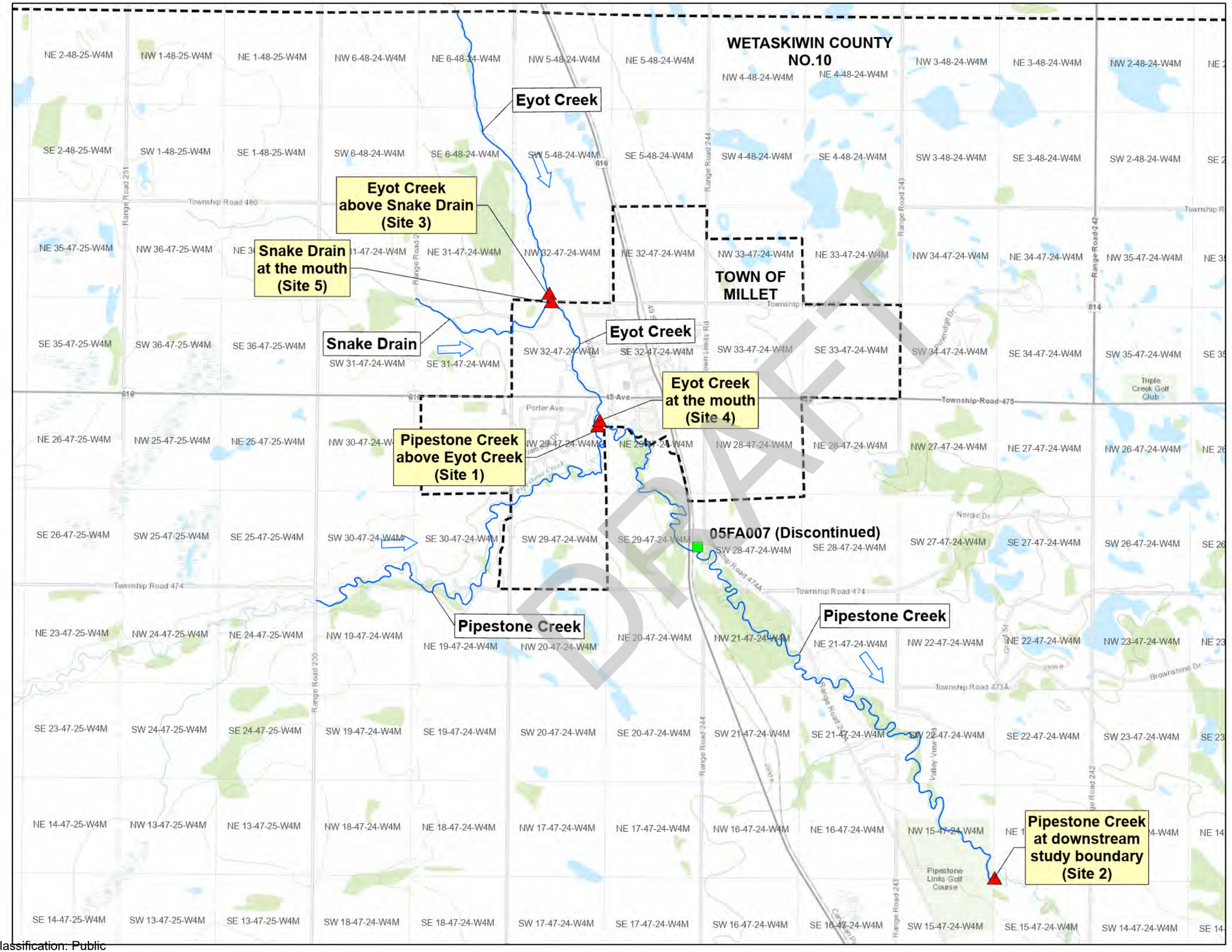
- 15 km of Pipestone Creek extending from Range Road 250 to the eastern boundary of NW 15-47-24-W4M.
- 4 km of Eyot Creek extending from the north boundary of Wetaskiwin County No.10 to its confluence with Pipestone Creek.
- 2 km of Snake Drain extending from the western boundary of NE/SE 31-47-24-W4M to its confluence with Eyot Creek

The terms of reference for this study does not specify sites where flood frequency estimates are required. In expectation that noticeable changes in the creek discharge would occur within the study area, five sites are identified in Figure 1 as the key locations where flood frequency estimates would be required for this flood study, including:

- Pipestone Creek above Eyot Creek (Site 1)
- Pipestone Creek at downstream study boundary (Site 2)
- Eyot Creek above Snake Drain (Site 3)
- Eyot Creek at the mouth (Site 4)
- Snake Drain at the mouth (Site 5)

DRAFT

Classification: Public



DRAFT

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- FLOW DIRECTION
- STUDY REACH
- FLOOD FREQUENCY ESTIMATE LOCATION
- WSC GAUGE STATION
- MUNICIPAL & COUNTY BOUNDARIES
- ALBERTA TOWNSHIP QUARTER SECTION BOUNDARY

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:30,000

0 1 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY/MMM	RBA

Job Number	Date
1008862	26-JUN-2024

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

FLOOD STUDY REACH AND FLOOD FREQUENCY ESTIMATE LOCATIONS

FIGURE 1

J:\Y_P_Projects (Active)\1008862 Millet Flood Study\50_GIS\HYDROLOGY\MILLET FS HYDROLOGY.aprx

Classification: Public

3 HYDROLOGIC CHARACTERISTICS

This section of the report describes hydrologic characteristics of the study area, including basin settings, sizes, and flood characteristics.

3.1 Basin Settings

Pipestone Creek is a major tributary of the Battle River, which is a tributary of the North Saskatchewan River. The creek is a prairie stream flowing through central Alberta. It originates east of Pigeon Lake and flows generally east for approximately 35 km to the town of Millet. From there, it flows southeast for approximately 20 km to Coal Lake, which discharges to the Batter River south of Gwynne, Alberta.

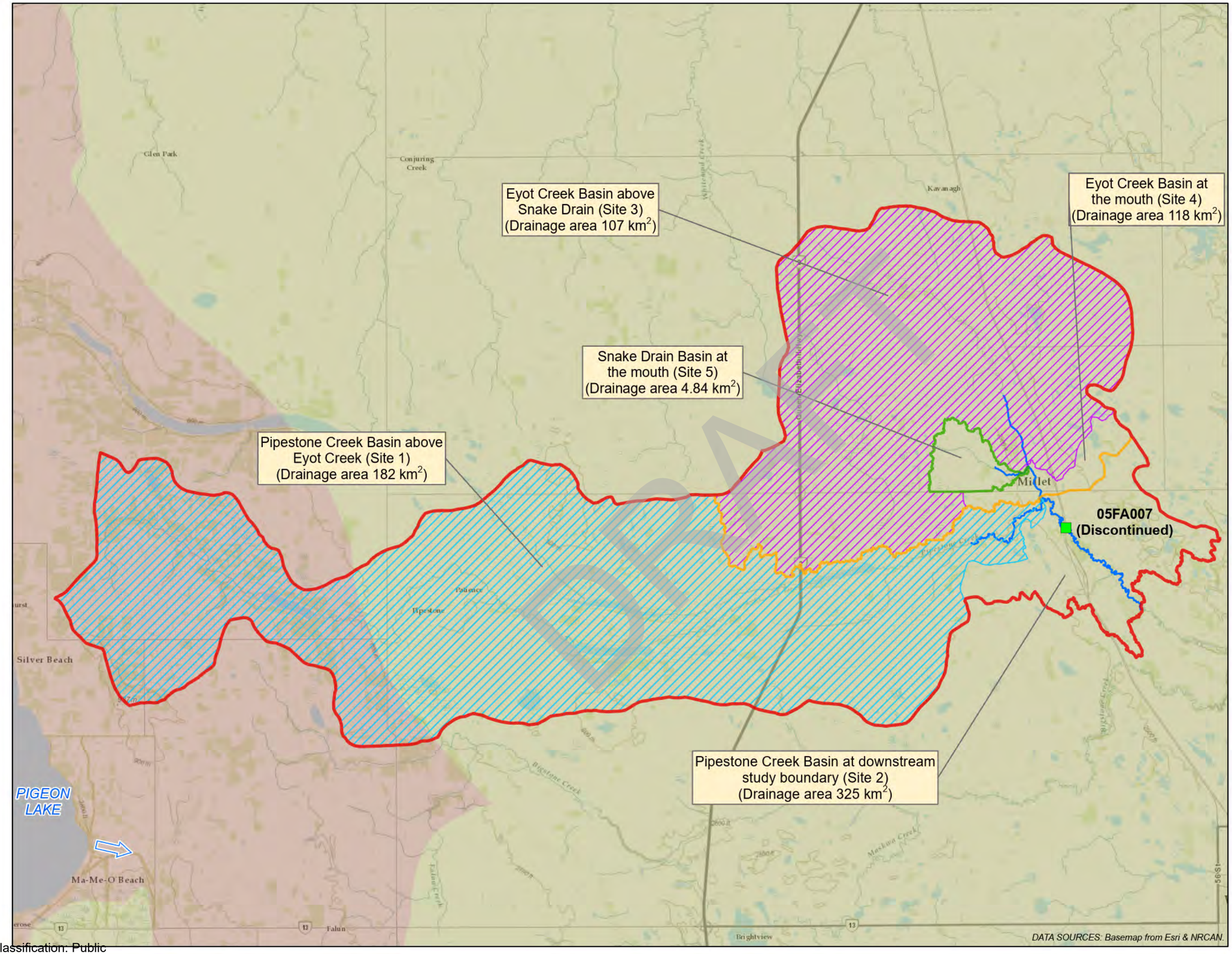
Eyot Creek is a tributary of Pipestone Creek. It flows in a southern direction through the town of Millet before joining Pipestone Creek.

Snake Drain conveys runoff from land immediately west of the town of Millet and joins Eyot Creek at the north boundary of the town. Realigned and excavated in the mid-1970s, Snake Drain's present-day alignment within the town's limits differs from its characterization in the base map shown in Figure 1.

Figure 2 presents the study basin areas overlaying Alberta's natural subregions. Alberta's land classification system divides the province into six natural regions and 21 subregions, which are defined geographically based on landscape patterns, notably the vegetation, soils, and physiographic features reflecting the combined influence of climate, hydrology, topography, and geology. Most of the study basin areas are located within the Central Parkland natural subregion. Only the upper portion of the Pipestone Creek basin lies in the Dry Mixed-Wood natural subregion. Generally, the Central Parkland subregion is slightly warmer and receives slightly less precipitation than the Dry Mixed-Wood subregion. Additionally, the Central Parkland subregion is more cultivated than the Dry Mixed-Wood subregion. The study basin areas also feature relatively flat terrain with many undrained or intermittently draining wetlands and sloughs, which are typical physiographic features for prairie stream basins. Land use in these basin areas is dominated by agriculture.

DRAFT

Classification: Public



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nhc



- WSC GAUGE STATION
- STUDY REACH
- PIPESTONE CREEK BASIN ABOVE EYOT CREEK (SITE 1)
- PIPESTONE CREEK BASIN AT THE DOWNSTREAM STUDY BOUNDAY (SITE 2)
- EYOT CREEK BASIN ABOVE SNAKE DRAIN (SITE 3)
- EYOT CREEK BASIN AT THE MOUTH (SITE 4)
- SNAKE DRAIN BASIN AT THE MOUTH (SITE 5)
- CENTRAL PARKLAND NATURAL SUBREGION
- DRY MIXEDWOOD NATURAL SUBREGION

SCALE - 1:120,000

0 2 4 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY/MMM	RBA

Job Number	Date
1008862	04-JUL-2024

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

STUDY BASIN OVERVIEW

FIGURE 2

JY: P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\HYDROLOGY\MILLET FS HYDROLOGY.aprx

Classification: Public

3.2 Basin Sizes

Figure 2 shows drainage areas upstream of the selected flood frequency estimate locations mentioned above. The sizes of these drainage areas are tabulated in Table 1. These drainage areas were determined based on the Water Survey of Canada (WSC) station information, Prairie Farm Rehabilitation Administration (PFRA) Watersheds project data (Version 8), LiDAR 7.5 m digital elevation model (DEM) data, and Alberta Flow Estimation Tool for Ungauged Watershed (AFETUW).

Table 1 Summary of drainage areas for flood frequency estimate sites.

Flood Frequency Estimate Location	Gross Drainage Area (km^2)
Pipestone Creek above Eyot Creek (Site 1)	182
Pipestone Creek at downstream study boundary (Site 2)	325
Eyot Creek above Snake Drain (Site 3)	107
Eyot Creek at the mouth (Site 4)	118
Snake Drain at the mouth (Site 5)	4.84

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3.3 Flood Characteristics

Long-term flow data are not available within the study reaches. The only WSC gauge station within the study reach, 05FA007 (Pipestone Creek near Millet), was discontinued and provides only daily flows measured in April and early May of 1925. However, long-term Pipestone Creek flow monitoring data are available downstream of the study area. Currently, WSC operates a gauging station on Pipestone Creek about 10 km downstream of the study area, which has been in operation from 1972-1979, and from 1990 to the present (WSC Station 05FA012 – Pipestone Creek near Wetaskiwin, drainage area = 1,030 km^2). Additionally, a now-discontinued gauging station was operated 3 km upstream of the current gauge from 1979 to 1990 (Station 05FA022 - Pipestone Creek below Bigstone Creek, drainage area = 1,020 km^2). The data from these two gauges are transferable due to the similarity of the drainage areas. In this study, the data gap (1980-1990) of Station 05FA012 was filled with the data from 05FA022.

Both WSC Station 05FA012 and 05FA022 are located close to the study area, but their drainage areas are about three times as large as the Pipestone Creek study basin area, due to a major tributary, Bigstone Creek, joining Pipestone Creek just downstream of the study area. Despite the difference in the drainage area size, data from WSC Stations 05FA012 and 05FA022 can be used to describe the flood characteristics for the current study area due to their similar climate and physiographic conditions.

Most annual peak flows from Pipestone Creek occur between March and May due to snowmelt or rain on snow, with some peak flows resulting from summer rainfall in certain years. The

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largest flood on record was observed in the spring of 1974, with an instantaneous peak of 98 m^3/s at WSC Station 05FA012 – Pipestone Creek near Wetaskiwin. The 1974 flood is the largest peak flood by a significant margin across many basins in central and northern Alberta, including the Pipestone Creek basin.

The 1925 spring flood is likely the second largest event on record for the Pipestone Creek basin. WSC Station 05FA007 – Pipestone Creek near Millet reported a maximum daily discharge of 37.7 m^3/s on April 13, 1925. On the same day, WSC Station 05FA008 – Bigstone Creek near Bigstone recorded the maximum daily discharge of the year: 19.3 m^3/s. Accordingly, the daily discharge of April 13, 1925, for Pipestone Creek near Wetaskiwin was estimated as 61.0 m^3/s, which is greater than all annual maximum daily discharges reported for this gauge except the 1974 value.

There were no flow measurements available for Pipestone Creek between 1926 and 1971. NHC reviewed historical precipitation data for the study area. The precipitation data suggest that the 1925 spring event was likely the largest event in the period from 1925 to 1971. Therefore, the 1925 spring event might be the second largest flood event in the Pipestone Creek basin within the period from 1925 to 2023, next to the 1974 spring flood.

No systematic flow records are available for Pipestone Creek prior to 1925 or between 1926 and 1971. According to Alberta Transportation bridge file #72548, which includes the history and observed flood levels at the Highway 2A bridge, a significant flood occurred in June 1954. This flood was likely a summer flood. No peak discharge estimation is available for this flood.

Ice jams have not typically been a problem along the study reaches for Millet Flood Study.

4 REGIONAL STREAMFLOW DATA SERIES PREPARATION

Flood frequency estimates for Pipestone Creek, Eyot Creek, and Snake Drain need to be determined from a regional analysis because these streams are not gauged within the study area.

For this study, nine WSC gauge stations were selected for the regional analysis. These gauge stations are summarized in Table 2, and their locations and drainage basins are shown in Figure 3. These gauge stations were selected in consideration of various factors including, their proximity to the study basin, basin size, length and period of record, basin landcover, topography, and climate condition. Another key factor is that each of the selected reference basins, except 05EB910, contains a significant portion of noneffective drainage area. WSC Station 05EB910 (Pointe-Aux-Pins Tributary No. 2 Near Ardrossan) has an effective area equal to its gross drainage area. This station is included in the analysis because of its relatively small drainage area (8.1 km^2), which is expected to make the regional flood frequency estimation better represent Snake Drain within the study area (Site 5, with a drainage area of approximately 4.84 km^2).

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Note that the record for WSC Station 05EE009 -Vermilion River at Vegreville (1987-2022, drainage area 1,620 km^2) were extended using the adjacent discontinued WSC Station 05EE003-Vermilion River near Vegreville (1971-1986, drainage area 1,590 km^2) given the proximity of the two stations. Also, as indicated earlier, the data gap for Station 05FA012 (Pipestone Creek near Wetaskiwin) was filled with the data from 05FA022 (Pipestone Creek below Bigstone Creek).

Table 2 List of candidate hydrometric stations initially selected for the regional analysis.

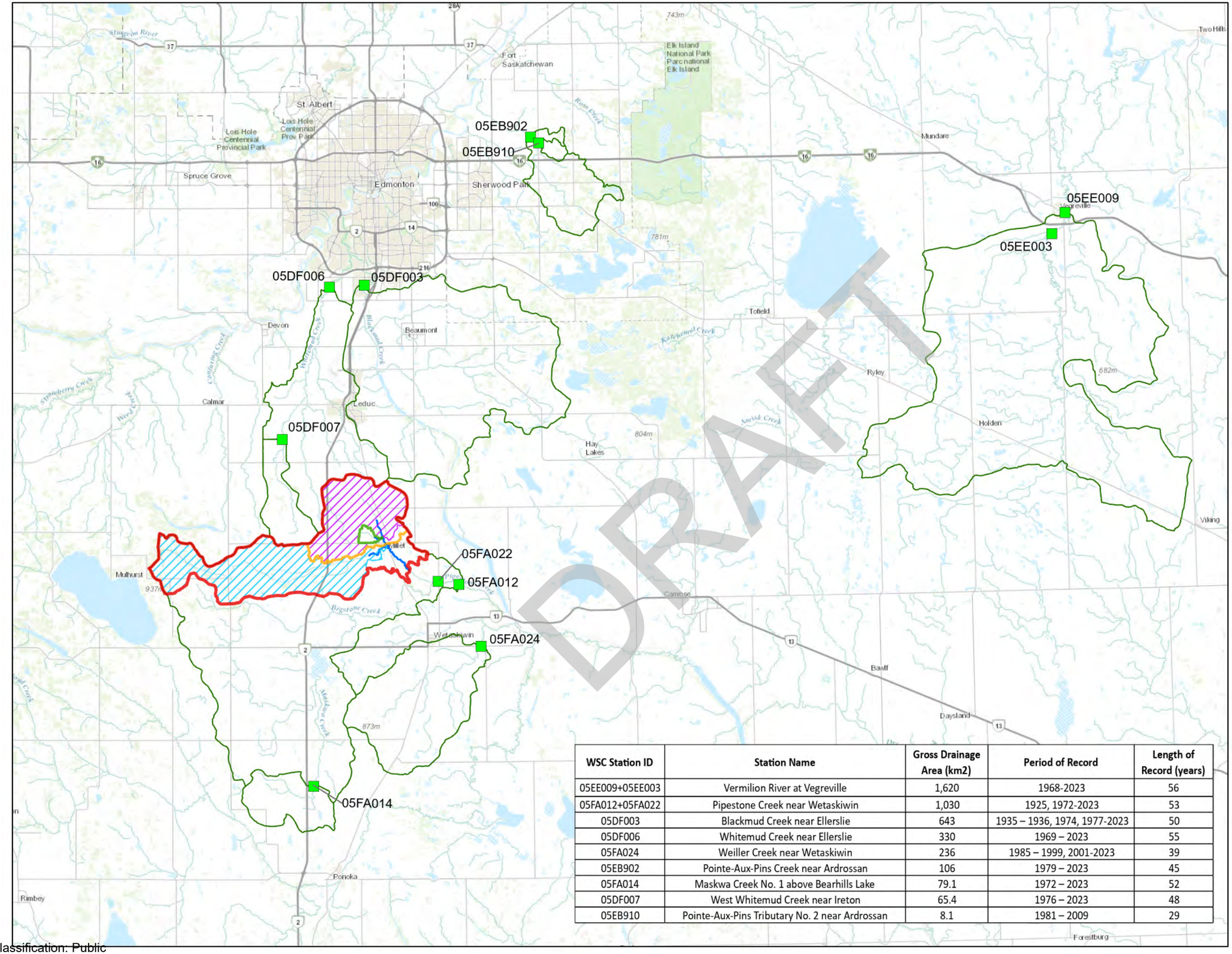
WSC Station ID	Station Name	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	Period of Record	Length of Record (years)
05EE009+05EE003	Vermilion River at Vegreville[1]	1,620	367	1968-2022, 2023[2]	56
05FA012+05FA022	Pipestone Creek near Wetaskiwin[3]	1,030	733	1925[4], 1972 – 2022, 2023[2]	53
05DF003	Blackmud Creek near Ellerslie	643	374	1935 – 1936, 1974[5] 1977 – 2022, 2023[2]	50
05DF006	Whitemud Creek near Ellerslie	330	301	1969 – 2022, 2023[2]	55
05FA024	Weiller Creek near Wetaskiwin	236	90.1	1985 – 1999, 2001 – 2022, 2023[2]	39
05EB902	Pointe-Aux-Pins Creek near Ardrossan	106	63.2	1979 – 2022, 2023[6]	45
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79.1	61.2	1972 – 2022, 2023[2]	52
05DF007	West Whitemud Creek near Ireton	65.4	53.2	1976 – 2022, 2023[2]	48
05EB910	Pointe-Aux-Pins Tributary No. 2 near Ardrossan	8.1	8.1	1981 – 2009	29

Notes:
1. The flood peak record for WSC Station 05EE009 -Vermilion River at Vegreville (1987-2022) was extended using available data from adjacent discontinued WSC Station 05EE003-Vermilion River near Vegreville (1971-1986).
2. Preliminary data obtained from WSC.
3. The flood peak record for WSC Station 05FA012 – Pipestone Creek near Wetaskiwin (1972 – 1979 and 1991 – 2023) was infilled using available data from adjacent discontinued WSC Station 05FA022 – Pipestone Creek below Bigstone Creek (1980 – 1990).
4. The 1925 flood peak was estimated based on available data from discontinued WSC Station 05FA007 – Pipestone Creek near Millet (1925) and WSC Station 05FA008 – Bigstone Creek near Bigstone (1925).
5. The 1974 data was estimated by AENV (1981).
6. Preliminary data obtained from EPA.

All data series used for the regional analysis are presented in Appendix A, including annual peak instantaneous discharges (Q_p) and maximum daily discharges (Q_d) for each of the selected regional stations. All reported annual peak instantaneous values were used in the analysis. For years when peak instantaneous values were missing, they were calculated for each station based on the correlation between the instantaneous and daily values for years when both were measured.

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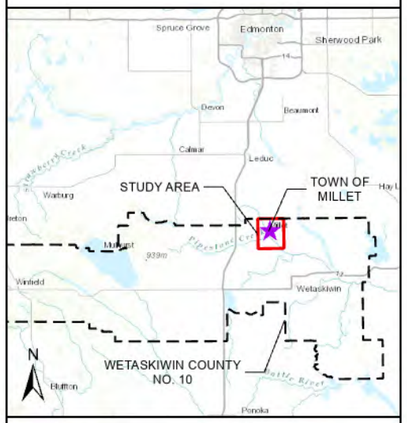


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WSC Station ID	Station Name	Gross Drainage Area (km2)	Period of Record	Length of Record (years)
05EE009+05EE003	Vermilion River at Vegreville	1,620	1968-2023	56
05FA012+05FA022	Pipestone Creek near Wetaskiwin	1,030	1925, 1972-2023	53
05DF003	Blackmud Creek near Ellerslie	643	1935 – 1936, 1974, 1977-2023	50
05DF006	Whitemud Creek near Ellerslie	330	1969 – 2023	55
05FA024	Weiller Creek near Wetaskiwin	236	1985 – 1999, 2001-2023	39
05EB902	Pointe-Aux-Pins Creek near Ardrossan	106	1979 – 2023	45
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79.1	1972 – 2023	52
05DF007	West Whitemud Creek near Ireton	65.4	1976 – 2023	48
05EB910	Pointe-Aux-Pins Tributary No. 2 near Ardrossan	8.1	1981 – 2009	29

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- WSC STATION SELECTED FOR REGIONAL ANALYSIS
- STUDY REACH
- PIPESTONE CREEK BASIN ABOVE EYOT CREEK (SITE 1)
- PIPESTONE CREEK BASIN AT THE DOWNSTREAM STUDY BOUNDAY (SITE 2)
- EYOT CREEK BASIN ABOVE SNAKE DRAIN (SITE 3)
- EYOT CREEK BASIN AT THE MOUTH (SITE 4)
- SNAKE DRAIN BASIN AT THE MOUTH (SITE 5)
- SELECTED BASIN FOR REGIONAL ANALYSIS

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:500,000
0 10 20 KM
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Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY/MMM	RBA

Job Number	Date
1008862	03-SEP-2024

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

REGIONAL ANALYSIS BASIN OVERVIEW

FIGURE 3

JY_P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\HYDROLOGY\MILLET FS HYDROLOGY.aprx

Classification: Public

5 REGIONAL FLOOD FREQUECY ANALYSIS

Regional analysis was performed to provide instantaneous peak discharge estimates for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1000-year open water floods, at the five flood frequency estimate locations along the study reaches.

The annual peak instantaneous discharges (Q_p) for each of the selected regional stations listed above were normalized by their mean value (Q_{pm}) and are plotted in Figure 4 against their empirical return periods (or plotting positions) based on the Cunnane formula (Cunnane, 1978). Different theoretical probability distributions including normal, log-normal (LN), three-parameter log-normal (3LN), Pearson type III (P3), log-Pearson type III (LP3), Gumbel, generalized extreme value (GEV), and Weibull were tested for each individual station. Appendix B contains plots of these tested flood frequency distributions for each of the selected regional stations. The P3 distribution is among the best in representing the historical flood data of the stations. As such, a normalized P3 curve was used to fit the normalized regional flow data. The normalized P3 curve shown in Figure 4 was computed by varying the standard deviation and coefficient of skewness within the respective ranges of the values for the selected gauge stations, until the sum of the SSE values (Equation 1) for the gauge stations that contain the 1974 event (05EE009, 05FA012, 05DF003, 05DF006, and 05FA014) reached the minimum. This resulted in a best-fit curve weighted towards the data sets containing the largest regional flood on record.

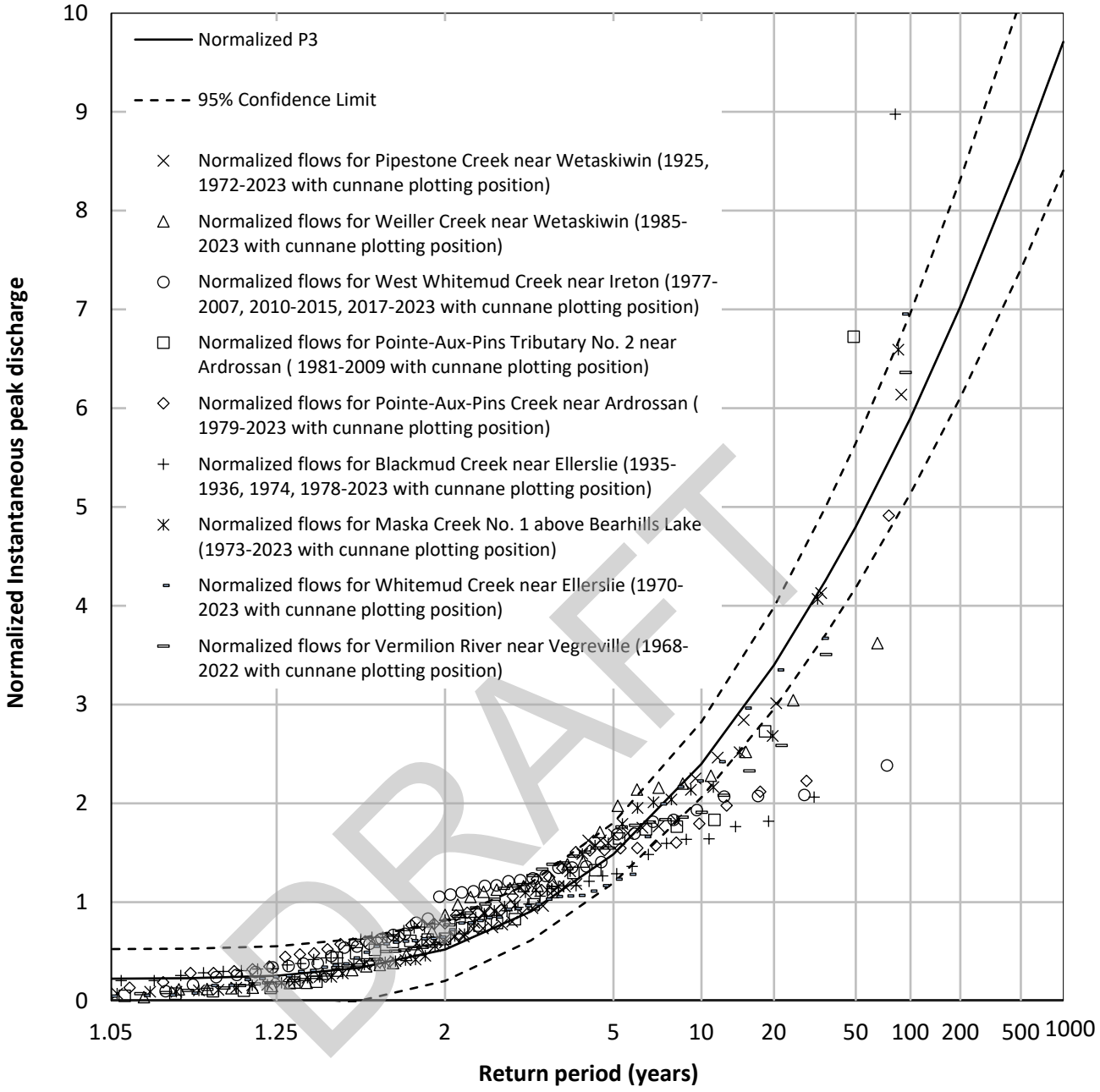
$$SSE = \sqrt{\frac{1}{n-m}\sum_{i=1}^{n}(x_i - y_i)^2} \qquad \textbf{(Equation 1)}$$

As shown in the figure, the curve fit most data points reasonably well, although it represents the best fit for the data sets that include the 1974 flood peaks. As mentioned, the 1974 flood is the largest event which impacted many central and northern Alberta basins. The flood data series are highly skewed by this event, as shown in Figure 4. The normalized 1974 flood peak for WSC Station 05DF003 (Blackmud Creek near Ellerslie) is the highest among all regional data points and deviates the most from the curve. As noted earlier, this data point is an estimate from AENV (1981) and not a measurement. Figure 4 also shows the 95% confidence limits for the normalized P3 curve, which are estimated based on the average length of the regional flood data series (47 years).

Figure 5 shows the relationship between the mean annual peak discharges (Q_{pm}) and gross drainage areas for the selected regional stations. The relationship indicates that the peak discharge is proportional to the gross drainage area to the power of 0.63. Using this relationship together with the normalized regional curve from Figure 4, flood frequency estimates can be developed for the ungauged sites in the study area with drainage area as the input.

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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008862

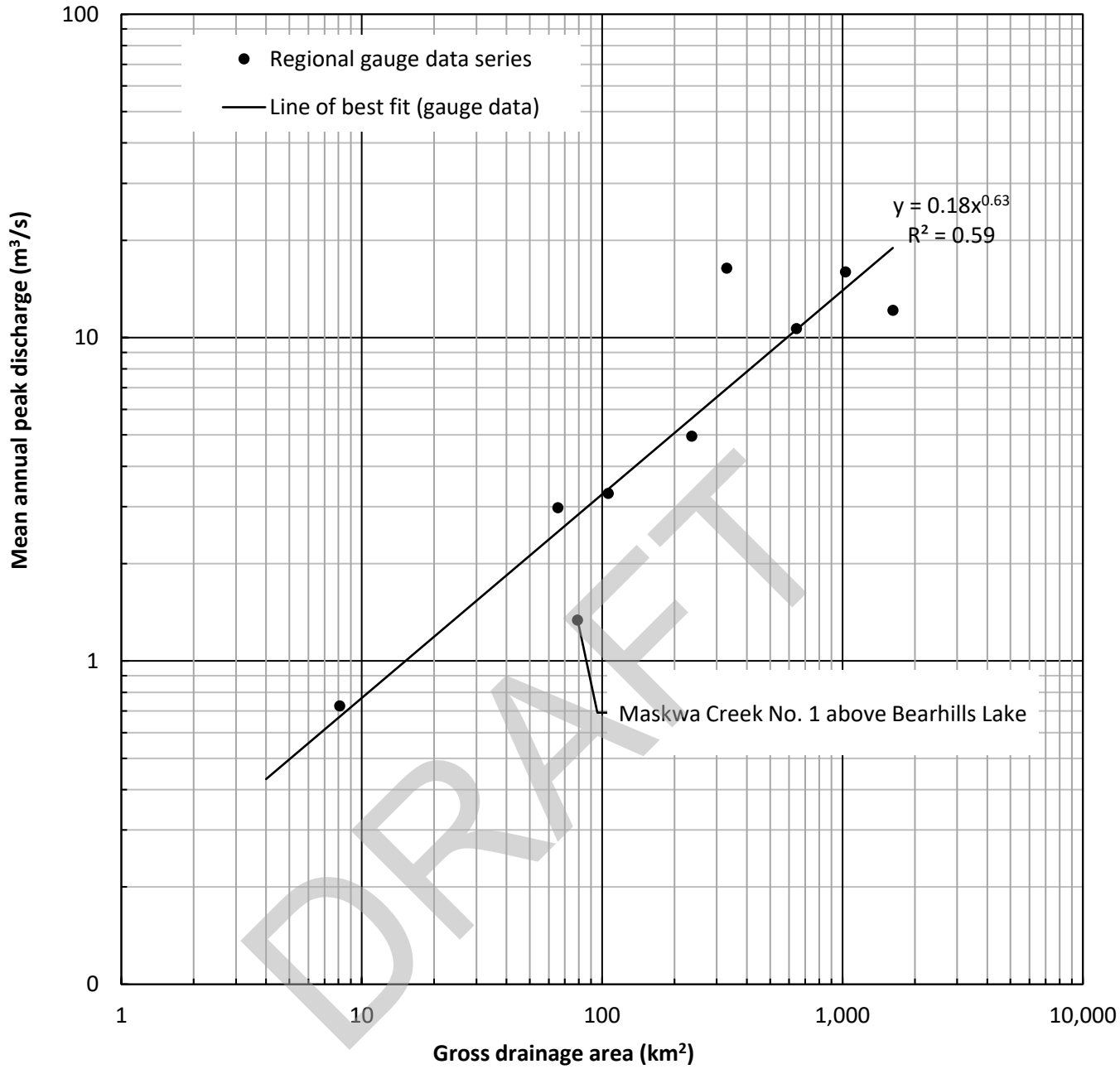
Date: 09-SEP-2024

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

ADOPTED NORMALIZED P3 FLOOD FREQUENCY CURVE

FIGURE 4

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Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT **RELATIONSHIP BETWEEN MEAN ANNUAL PEAK DISCHARGE AND DRAINAGE AREA**
nhc	Coordinate System: Units: As Shown	
	Job: 1008862 / *Date: 09-SEP-2024*	FIGURE 5

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Figure 6 presents a comparison of the flood frequency curves for WSC Station 05FA012+05FA022 – Pipestone Creek near Wetaskiwin, derived from both regional and single station analyses. The two curves are similar, indicating that the regional curve is reliable in predicting flood frequencies for ungauged sites within the Pipestone Creek basin. Note that neither of the curves fits the data point representing the 1974 flood peak, of which the plotting position was determined based on the total number of years (53) with available data. As discussed in section 3.3, the 1974 and 1925 spring flood peaks were likely the largest two events on Pipestone Creek over the 99-year period from 1925 to 2023. Figure 6 shows the adjusted plotting positions for these two events based on the 99-year span of the record (using the Cunnane formula). Based on the adjusted plotting position, the return period for the 1974 flood event would be approximately 165 years, which appears more reasonable. The regional curve fit this adjusted 1974 flood data point better, while the curve from the single station analysis tends to underpredict flood peaks for this and longer return periods. As such, it is recommended that the regional frequency curve be used in this study to develop flood frequency estimates for the study sites.

6 FLOOD FREQUENCY ESTIMATES

Flood frequency estimates were provided for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1000-year open water floods for the selected five locations along the study reach.

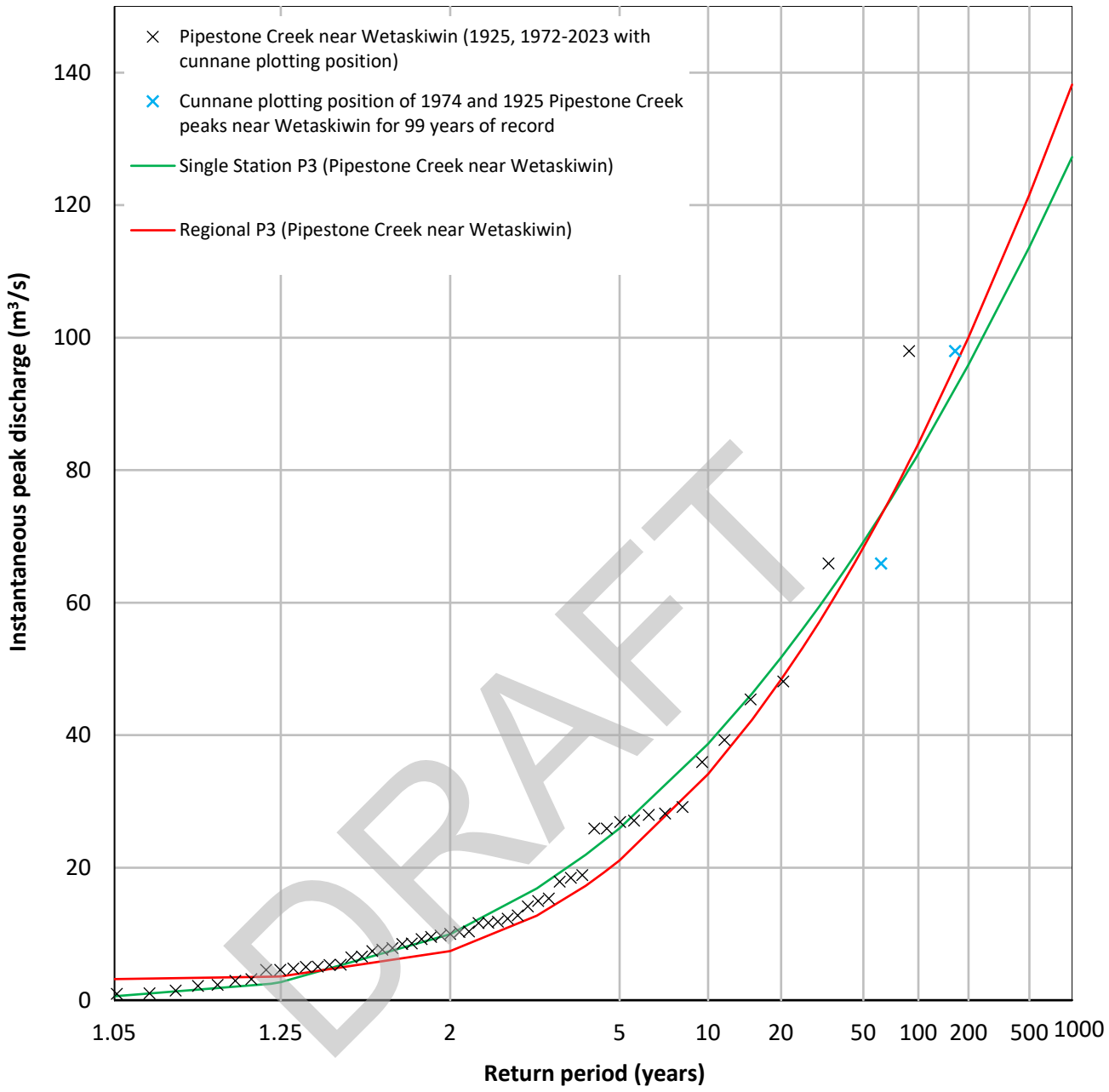
Table 3 shows the mean annual peak discharges for the flood frequency estimate sites computed with the relationship shown in Figure 5. Flood frequency estimates for each site were then developed from the normalized P3 regional curve in Figure 4. The results are summarized in Table 4.

Table 3 Computed mean annual peak discharges for flood frequency estimate sites

Flood Frequency Estimate Location	Gross Drainage Area (km^2)	Mean Annual Flood Peak (m^3/s)
Pipestone Creek above Eyot Creek (Site 1)	182	4.78
Pipestone Creek at downstream study boundary (Site 2)	325	6.88
Eyot Creek above Snake Drain (Site 3)	107	3.42
Eyot Creek at the mouth (Site 4)	118	3.64
Snake Drain at the mouth (Site 5)	4.84	0.49

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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008862

Date: 09-SEP-2024

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

COMPARISON OF FLOOD FREQUENCY CURVES FOR PIPESTONE CREEK NEAR WETASKIWIN

FIGURE 6

Classification: Public

Table 4 Flood frequency estimates from regional analysis

Return Period (years)	Peak Instantaneous Discharge (m^3/s)									
	Pipestone Creek above Eyot Creek (Site 1)		Pipestone Creek at downstream study boundary (Site 2)		Eyot Creek above Snake Drain (Site 3)		Eyot Creek at the mouth (Site 4)		Snake Drain at the mouth (Site 5)	
	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit	Value	Upper 95% Limit Lower 95% Limit
1000	46.4	55.1 40.2	66.8	79.4 57.9	33.2	39.4 28.7	35.3	41.9 30.6	4.7	5.6 4.1
750	44.1	52.4 38.2	63.6	75.5 55.1	31.6	37.5 27.3	33.6	39.9 29.1	4.5	5.3 3.9
500	40.8	48.4 35.4	58.8	69.8 51.0	29.2	34.7 25.3	31.1	36.9 26.9	4.2	4.9 3.6
350	38.1	45.1 33.0	54.9	65.0 47.6	27.2	32.3 23.6	29.0	34.3 25.1	3.9	4.6 3.4
200	33.6	39.7 29.2	48.4	57.2 42.0	24.0	28.4 20.9	25.5	30.2 22.2	3.4	4.0 3.0
100	28.2	33.3 24.5	40.6	47.9 35.3	20.2	23.8 17.6	21.5	25.3 18.7	2.9	3.4 2.5
75	26.1	30.7 22.7	37.6	44.3 32.7	18.7	22.0 16.2	19.8	23.4 17.3	2.7	3.1 2.3
50	22.9	27.0 20.0	33.0	38.9 28.8	16.4	19.3 14.3	17.5	20.5 15.2	2.3	2.7 2.0
35	20.3	23.9 17.7	29.3	34.4 25.5	14.5	17.1 12.7	15.5	18.2 13.5	2.1	2.4 1.8
20	16.2	19.0 14.1	23.4	27.4 20.4	11.6	13.6 10.1	12.4	14.5 10.8	1.7	1.9 1.4
10	11.5	13.5 9.8	16.5	19.4 14.2	8.2	9.7 7.0	8.7	10.3 7.5	1.2	1.4 1.0
5	7.1	8.6 5.7	10.2	12.4 8.2	5.1	6.2 4.1	5.4	6.6 4.3	0.7	0.9 0.6
2	2.5	3.9 1.0	3.6	5.6 1.4	1.8	2.8 0.7	1.9	2.9 0.7	0.3	0.4 0.1

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7 COMPARISON WITH PREVIOUS STUDIES

The flood frequency estimates for Pipestone Creek, Eyot Creek, and Snake Drain were compared against the estimates from two previous studies (EPEC, 1983 and AENV, 2003). The comparison is shown in Table 5 for four sites: Pipestone Creek above Eyot Creek (Site 1), Eyot Creek above Snake Drain (Site 3), Eyot Creek at the mouth (Site 4), and Snake Drain at the mouth (Site 5). No comparisons were made for Pipestone Creek at downstream study boundary (Site 2) as the previous studies did not include this location.

Table 5 Comparison with previous flood frequency estimates

Return Period (years)	Pipestone Creek above Eyot Creek (Site 1)			Eyot Creek above Snake Drain (Site 3)			Eyot Creek at the mouth (Site 4)			Snake Drain at the mouth (Site 5)		
	This Study	AENV (2003)	EPEC (1983)	This Study	AENV (2003)	EPEC (1983)	This Study	AENV (2003)	EPEC (1983)	This Study	AENV (2003)	EPEC (1983)
	Drainage Area (km^2)											
	182	**166**	**184**	**107**	**125**	**-**	**118**	**-**	**114**	**4.84**	**3.96**	**-**
100	28.2	21.59	26.5	20.2	16.51	-	21.5	-	18.5	2.9	0.55	-
50	22.9	16.25	-	16.4	12.34	-	17.5	-	-	2.3	0.40	-
20	16.2	10.53	-	11.6	7.96	-	12.4	-	-	1.7	0.26	-
10	11.5	7.36	-	8.2	5.55	-	8.7	-	-	1.2	0.18	-
5	7.1	4.88	-	5.1	3.67	-	5.4	-	-	0.7	0.12	-
2	2.5	2.35	-	1.8	1.78	-	1.9	-	-	0.3	0.06	-

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The current study provides higher estimates than both previous studies for all corresponding sites and return periods. For example, the 100-year flood peak estimates for Pipestone and Eyot creeks from the current study are 22% to 31% higher than those from AENV (2003), and 6% to 16% higher than those from EPEC (1983). For Snake Drain, the current 100-year flood estimate is 2.9 m^3/s, significantly higher than the value of 0.55 m^3/s from AENV (2003).

The primary difference between the current study and AENV (2003) is the selection of gauging stations for the regional analysis. The regional analysis of AENV (2003) relied on two stations: WSC Station 05FA012 (Pipestone Creek near Wetaskiwin, infilled with 05FA022) and WSC Station 05FA014 (Maskwa Creek No. 1 above Bearhills Lake). As illustrated in Figure 5, the Maskwa Creek basin appears to have a lower runoff potential than the other basins in the region. As such, AENV's method has the tendency to underestimate flood peaks at the study sites. The current study includes seven additional regional stations with a greater variety of drainage areas. The runoff potentials of these regional basins are slightly higher than Maskwa Creek while consistent with Pipestone Creek near Wetaskiwin. So, the regional analysis of the current study tends to produce higher estimates at the study sites with reduced uncertainties in comparison with AENV (2003).

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EPEC (1983) does not present the data that their analysis was based on. So, the reason for their lower estimates cannot be evaluated.

In addition, the current study used longer flow records that include data for more recent years and benefited from the latest topographic datasets including LiDAR DEM data for basin delineation. So, the flood frequency estimates from the current study would bear lower uncertainties than the previous studies.

Overall, the differences between the current and previous studies reflect the impact of updated data and improved methodologies on flood frequency estimates.

8 IMPACT OF URBAN DRAINAGE

The footprint of the current urban and industrial development in and around the Town of Millet is approximately 9 km^2, as visible in the 2023 aerial imagery. Most runoff from this developed urban area ultimately flows into Pipestone and Eyot creeks. The percentage of urban area within each basin used in the flood frequency estimate is summarized in Table 6 below.

Table 6 Summary of urban developments within each flood frequency estimate basin

Flood Frequency Estimate Location	Gross Drainage Area (km^2)	Approximate Percentage of Urban Development
Pipestone Creek above Eyot Creek (Site 1)	182	<1%
Pipestone Creek at downstream study boundary (Site 2)	325	3%
Eyot Creek above Snake Drain (Site 3)	107	3%
Eyot Creek at the mouth (Site 4)	118	4%
Snake Drain at the mouth (Site 5)	4.84	0%

As shown in the above table, the urban development areas within each flood frequency estimate drainage basin areas are small. Additionally, annual flood peaks in Pipestone and Eyot creeks are primarily governed by snowmelt with or without rain. In urban areas, snow tends to melt earlier, and surface water from snowmelt or summer rainfall generally runs off faster than in rural areas. While urban development increases both runoff volume and peak discharge, the timing of peak discharge from the urban area and from the overall basin may not coincide. Thus, NHC concludes that the effect of urbanization within the Millet Flood Study area is negligible and could be ignored when developing the flood frequency estimates.

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9 CLIMATE CHANGE COMMENTARY

This section provides a summary of a qualitative interpretation of climate and hydrologic projections obtained from the scientific literature that would be pertinent to evaluating future changes in flood hazards in the study area.

Current global climate models (GCMs) indicate that temperature will increase due to projected increases in CO_2 concentrations in the atmosphere. Increased temperatures in the winter months will likely result in smaller snowpacks, earlier snowmelt runoff, higher winter flows as more winter precipitation falls as rain instead of snow, and lower spring flows due to reduced snow storage. While there are no investigations on potential impacts of climate change on flood hydrology specifically for Pipestone Creek or the Battle River, some assessments of the North Saskatchewan River basin are pertinent, since Pipestone Creek is a tributary within the North Saskatchewan River basin. These pertinent observations are summarized in this section.

The effect of climate change over the North Saskatchewan River basin was presented in Sauchyn et al. (2022). This study focuses primarily on the Edmonton region. It indicates that the region has experienced temperature increases up to three times the global average and that average winter temperatures have increased significantly, with future projections indicating warmer and wetter winters and springs, and drier summers. Based on the Canadian Regional Climate Model Version 4 (CanRCM4) model under the Representative Concentration Pathway 8.5 (RCP8.5) scenario, the study indicates that average annual temperatures could rise by approximately 2°C in the near future and 4°C by 2080. The study suggests that higher temperatures would prompt earlier snowmelt in mountainous areas, leading to higher river flows in spring and early summer, consequently increasing the risk of more frequent and severe flooding. Hydrological modelling in this study also projected a future shift in annual peak flows occurring about one month earlier in the year, with higher winter flows and significantly lower summer flows.

Golder (2008) assessed potential changes in the water yield from the North Saskatchewan River basin in Alberta under forecasted future climatic conditions. Trend analyses across the basin suggested an increasing trend in air temperature, but the trends in monthly, seasonal, and annual precipitation data were not statistically significant. The study forecasted air temperature, precipitation, and water yield for the 2021 to 2050 period for 12 GCM combinations and future development scenarios, and the results were compared to the conditions for the 1961 to 1990 baseline period. The forecasted air temperature was higher than the baseline by 0.3 to 2.2 °C, while changes in mean annual precipitation ranged from an 8% decrease to an 19% increase, depending on the GCM combination scenario. The predicted changes in annual yield varied from a 23% decrease to 15% increase, and increases in monthly yield tended to occur during the spring months. Most of the GCM combination scenarios resulted in average increases in yield for May of 11% and variations from -3% to +28%; however, the changes in June varied from -26% to +31%, with an average of -1.3%. The study did not evaluate changes in daily flows or flood peaks.

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Poitras et al. (2011) investigated projected changes in average and extreme streamflows of 10 major river basins across western Canada. The streamflows were derived from climate simulations performed with the fourth generation of the CanRCM4 forced with and upper, mid-range, A2 emission scenario representing a very heterogeneous world where economic development is regionally oriented and economic growth and technological change are relatively slow. The comparisons were made for the 1961 to 1990 period and the 2041 to 2070 period. Mean annual flows were projected to increase in all basins, with a 17% increase in the North Saskatchewan River basin. Future snowmelt events in the basin were predicted to occur earlier and peak discharges were assessed as likely to increase by up to 20%.

According to DFO (2013), annual temperatures in the Prairies will increase for all seasons in the range of 0.8 – 5.4 °C, and winter temperatures will increase more than summer temperatures. Annual precipitation over large basins is projected to generally increase; however, projections are more uncertain for the Saskatchewan River basin as different climate models have predicted both an increase and a decrease in precipitation. Higher precipitation is expected in winter compared to summer, and the type of precipitation will change (e.g., more winter rain vs. snow). Fewer precipitation events were predicted in this study, but they are expected to occur at higher intensity or as more extreme weather events. During the summer months, streamflow volumes in the Saskatchewan River basin could decrease by up to 50%.

While increases in spring flows are expected, the forecast becomes more complicated and inconclusive in some recent studies that consider effects from the El Niño – Southern Oscillation, such as Islam and Gan (2015). Moreover, while temperature has been generally increasing over the last 100 years, the trend of changes in annual peak discharge of many Canadian rivers to be different than forecasted. Yue and Pilon (2003) performed trend analyses on annual minimum, mean, and maximum daily flows of streams with 30 to 50 years of gauge records in Canada, using the Mann-Kendall statistical test and a trend-free pre-whitening procedure. They noted that the annual maximum daily flow decreased across Canada south of latitude 60°N; however, a bootstrap test at the significance level of 0.05 showed this trend was insignificant.

As part of this assessment, a trend analysis was performed by NHC on available annual peak instantaneous flow data for WSC Station 05FA012 and 05FA022 – Pipestone Creek near Wetaskiwin using the Mann-Kendall (MK) test and Sen's slope. The MK test is a non-parametric statistic test that is commonly used to detect trends in hydrologic data. Sen's slope is a nonparametric estimate of the slope of a trend. Annual instantaneous peak discharges for the 1972-2023 period were used by NHC for the trend analysis. While the data series appears to have a slightly downward trend (with Sen's slope calculated as -0.08 m^3/s per year), the MK test indicates there is likely no trend (p-value = 0.23), which is consistent with the assessment of Yue and Pilon (2003).

Overall, there is insufficient information to be able to identify all the linkages between precipitation and runoff to make any forecasts about how climate change might affect flood peaks for the study reaches. Hydrologic modelling for the Pipestone Creek basin would be

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necessary to evaluate potential impacts of climate change on the flood risk in the study area, which is beyond the scope of this study.

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We trust this report meets your needs. If you have any questions or requests, please feel free to contact the undersigned at (780) 436-5868.

Sincerely,

Northwest Hydraulic Consultants Ltd.

Report prepared by:	**Report reviewed by:**
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APEGA Permit to Practice Number: P654

NHC File Path: "P:_Projects (Active)\1008862 Millet Flood Study\06 Report\02- OW Hydrology Memo\03_FINAL\1008862 Millet FS OW Hydrology Letter Report FINAL.docx"

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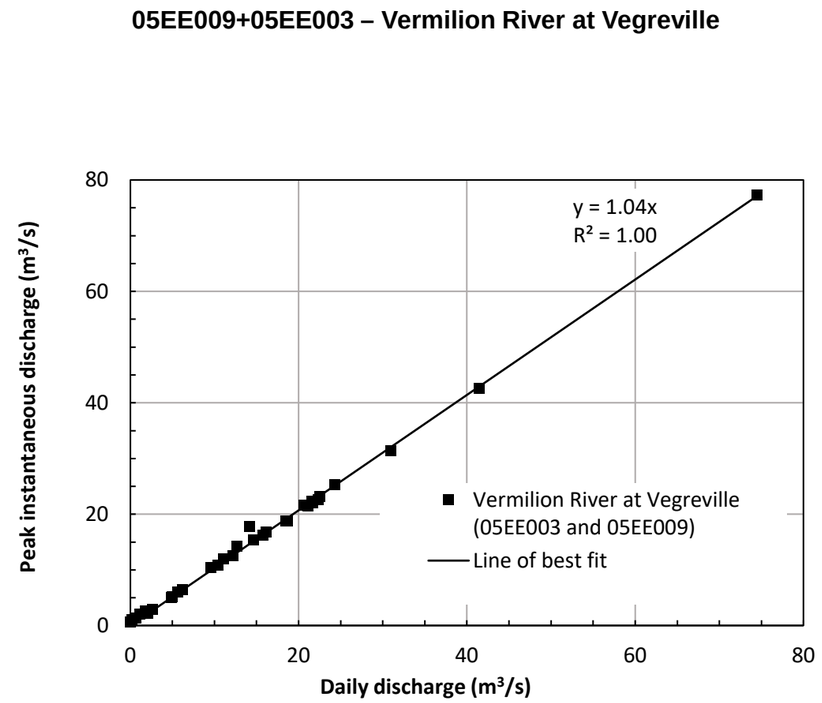
Appendix A

Flow Data Used for Regional Analysis

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Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1968	**6.56**		6.31	07-Mar	
1969	**13.83**		13.30	12-Apr	
1970	**6.74**		6.48	13-Apr	
1971	21.60	18-Apr	20.70	18-Apr	
1972	12.50	15-Apr	12.20	15-Apr	
1973	18.80	07-Jul	18.50	07-Jul	
1974	77.30	20-Apr	74.50	20-Apr	
1975	10.40	25-Apr	9.57	25-Apr	
1976	**2.23**		2.14	12-Apr	
1977	**1.57**		1.51	03-Jun	
1978	5.10	21-Sep	5.01	21-Sep	
1979	25.30	20-Apr	24.30	20-Apr	
1980	6.42	14-Apr	6.26	14-Apr	
1981	**7.04**		6.77	19-Mar	
1982	16.20	08-Jul	15.80	08-Jul	
1983	22.60	02-Jul	22.30	02-Jul	
1984	**4.07**		3.91	31-Mar	
1985	11.90	04-Apr	11.10	04-Apr	
1986	22.30	31-Mar	21.60	31-Mar	
1987	17.80	10-Apr	14.20	10-Apr	
1988	1.28	20-Aug	0.69	21-Aug	
1989	**1.87**		1.80	08-Apr	
1990	**14.14**		13.60	02-Apr	
1991	**0.88**		0.85	08-Apr	
1992	**4.33**		4.16	18-Mar	
1993	**3.19**		3.07	14-Apr	
1994	**11.44**		11.00	04-Apr	
1995	**9.33**		8.97	25-Mar	
1996	**6.26**		6.02	11-Apr	
1997	42.60	19-Apr	41.50	19-Apr	
1998	**1.40**		1.35	08-Apr	
1999	6.07	09-Apr	5.69	08-Apr	
2000	**0.20**		0.19	04-Apr	
2001	1.03	12-May	0.23	12-May	
2002	**0.08**		0.08	11-Apr	
2003	2.08	19-Apr	1.17	19-Apr	
2004	**4.42**		4.25	01-Apr	
2005	22.00	06-Apr	21.70	06-Apr	
2006	**18.30**		17.60	09-Apr	
2007	21.40	22-Apr	21.10	22-Apr	
2008	2.88	02-May	2.61	02-May	
2009	10.80	13-Apr	10.40	13-Apr	
2010	2.60	12-Jun	1.84	22-Jul	1.80
2011	18.80	22-Apr	18.70	22-Apr	
2012	0.54	08-Aug	0.05	24-May	0.04
2013	15.40	26-Apr	14.70	27-Apr	
2014	**6.13**		5.89	13-Apr	
2015	14.30	31-Mar	12.70	31-Mar	
2016	5.04	12-Jul	4.88	12-Jul	
2017	16.80	04-Apr	16.20	04-Apr	
2018	31.40	23-Apr	31.00	23-Apr	
2019	23.20	01-Apr	22.50	01-Apr	
2020	**28.29**		27.20	23-Apr	
2021	2.21	28-May	2.06	28-May	
2022	**16.95**		16.30	07-Apr	
2023	**2.47**		2.38	23-Apr	



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Notes:
1. The bolded and underlined values are based on Qi=1.04Qd.
2. Data for 2023 is preliminary from WSC.

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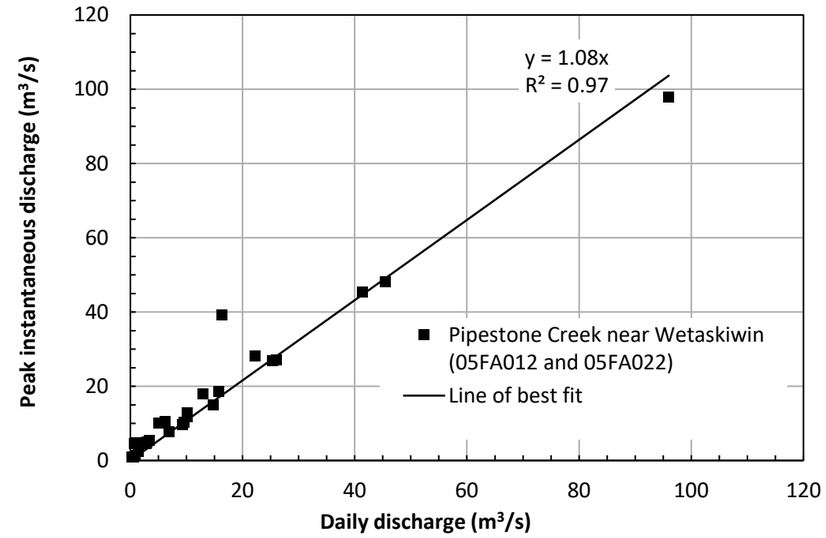
MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
VERMILION RIVER AT VEGREVILLE MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-1

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1925	***65.91***		*61.03*	*13-Apr*	
1972	**15.34**		14.20	07-Apr	
1973	18.50	02-Jul	15.80	02-Jul	
1974	98.00	23-Apr	96.00	23-Apr	
1975	**9.57**		8.86	23-Apr	
1976	**5.36**		4.96	06-Apr	
1977	4.59	09-Aug	2.80	10-Aug	
1978	5.32	29-Mar	3.37	29-Mar	
1979	12.80	20-Mar	10.10	20-Mar	
1980	11.70	05-Apr	10.20	06-Apr	
1981	10.40	19-Mar	6.60	17-Mar	6.23
1982	45.40	24-Apr	41.40	25-Apr	
1983	15.00	08-Jul	14.80	08-Jul	
1984	5.09	01-Apr	3.96	25-Mar	3.02
1985	28.20	03-Apr	23.20	07-Apr	22.20
1986	**8.48**		7.85	02-Mar	
1987	**7.87**		7.29	08-Apr	
1988	1.48	06-Jul	0.93	06-Jul	
1989	**6.59**		6.10	11-Apr	
1990	48.10	07-Jul	45.50	07-Jul	
1991	39.30	06-Jul	16.40	06-Jul	
1992	**11.66**		10.80	22-Mar	
1993	**9.23**		8.55	28-Mar	
1994	**5.05**		4.68	30-Mar	
1995	**3.21**		2.97	23-Mar	
1996	**14.15**		13.10	10-Apr	
1997	**25.92**		24.00	13-Apr	
1998	17.90	05-Jul	13.00	06-Jul	
1999	**25.92**		24.00	13-Apr	
2000	4.57	02-Jul	1.52	10-Jul	0.67
2001	1.06	29-Jul	0.69	01-Aug	0.58
2002	**6.48**		6.00	24-Apr	
2003	**11.88**		11.00	11-Apr	
2004	4.78	19-Jul	1.11	19-Jul	
2005	**18.90**		17.50	04-Apr	
2006	**8.59**		7.95	06-Apr	
2007	26.90	08-May	25.30	08-May	
2008	0.95	16-May	0.28	16-May	
2009	**0.23**		0.21	12-Apr	
2010	10.00	14-Jul	5.17	14-Jul	
2011	27.10	29-Jul	26.10	29-Jul	
2012	**2.17**		2.01	15-Apr	
2013	10.30	26-Apr	9.57	26-Apr	
2014	**29.16**		27.00	11-Apr	
2015	7.64	31-Mar	6.90	31-Mar	
2016	2.33	11-Jul	1.94	09-Oct	1.48
2017	**12.31**		11.40	30-Mar	
2018	**27.97**		25.90	21-Apr	
2019	**7.43**		6.88	29-Mar	
2020	**35.96**		33.30	19-Apr	
2021	**2.96**		2.74	18-Apr	
2022	9.77	10-Jul	9.30	11-Jul	
2023	**0.64**		0.60	06-May	

05FA012+05FA022 – Pipestone Creek near Wetaskiwin



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Notes:
1. The bolded and underlined values are based on Qi=1.08Qd.
2. The 1925 peak discharge is estimated by NHC.
3. Data for 2023 is preliminary from WSC.

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MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
PIPESTONE CREEK NEAR WETASKIWIN MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

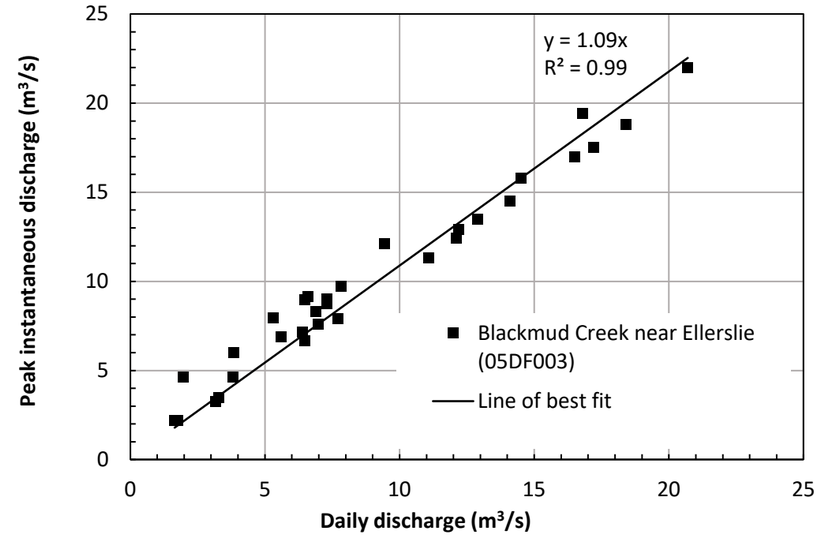
FIGURE A-2

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1935	**3.42**		3.14	21-Apr	
1936	**17.44**		16.00	16-Apr	
1974	***95.70***		*87.80*	*24-Apr*	
1978	2.17	09-Apr	1.78	18-Sep	1.50
1979	9.02	21-Mar	7.30	21-Mar	
1980	7.58	28-Aug	6.98	18-Apr	5.88
1981	**6.87**		6.30	26-Mar	
1982	14.50	27-Apr	14.10	27-Apr	
1983	19.40	07-Jul	16.80	07-Jul	
1984	4.03		3.70	27-Mar	
1985	17.50	04-Apr	17.20	04-Apr	
1986	8.29	20-Mar	6.89	20-Mar	
1987	5.98	05-Aug	3.84	09-Apr	3.78
1988	12.10	06-Jul	9.44	06-Jul	
1989	4.62	09-Jul	3.83	09-Jul	
1990	**12.43**		11.40	31-Mar	
1991	8.95	08-Jun	6.49	14-May	5.56
1992	**3.86**		3.54	23-Mar	
1993	**2.74**		2.51	25-Mar	
1994	**4.45**		4.08	02-Apr	
1995	**3.18**		2.92	22-Mar	
1996	**8.80**		8.07	08-Apr	
1997	15.80	22-Apr	14.50	22-Apr	
1998	9.72	30-Jun	7.83	01-Jul	
1999	6.65	11-Apr	6.49	11-Apr	
2000	3.46	21-Jul	3.29	22-Jul	
2001	9.13	29-Jul	6.61	30-Jul	
2002	**3.03**		2.78	21-Apr	
2003	**10.08**		9.25	09-Apr	
2004	**1.20**		1.10	13-Mar	
2005	**10.45**		9.59	12-Mar	
2006	3.27	09-Apr	3.18	09-Apr	
2007	12.90	05-May	12.20	05-May	
2008	2.18	01-May	1.65	01-May	
2009	**0.41**		0.37	02-Apr	
2010	4.63	13-Jul	1.96	13-Jul	
2011	18.80	27-Jul	18.40	27-Jul	
2012	7.15	16-Jul	6.41	16-Jul	
2013	12.40	29-Apr	12.10	29-Apr	
2014	11.30	10-Apr	11.10	10-Apr	
2015	**9.23**		8.47	19-Mar	
2016	7.95	22-May	5.31	23-May	
2017	7.88	09-Apr	7.71	09-Apr	
2018	17.00	26-Apr	16.50	26-Apr	
2019	13.50	31-Mar	12.90	31-Mar	
2020	22.00	22-Apr	20.70	22-Apr	
2021	8.73	19-May	7.32	19-May	
2022	6.86	15-Jun	5.61	15-Jun	
2023	**13.72**		12.59	19-Jun	

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05DF003 – Blackmud Creek near Ellerslie



Notes:
1. The bolded and underlined values are based on Qi=1.09Qd.
2. The 1974 data is from AENV (1981).
3. Data for 2023 is preliminary from WSC.

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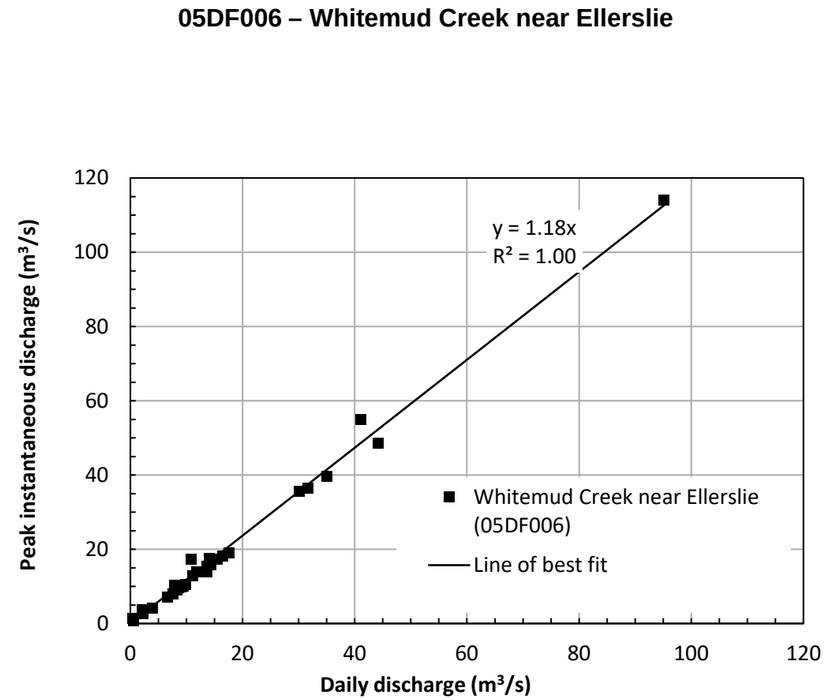
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MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
BLACKMUD CREEK NEAR ELLERSLIE
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-3

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1970	36.50	10-Apr	31.70	11-Apr	
1971	54.90	17-Apr	41.10	16-Apr	
1972	17.40	07-Apr	15.50	07-Apr	
1973	17.30	31-Mar	10.90	31-Mar	
1974	114.00	23-Apr	95.10	23-Apr	
1975	10.30	21-Apr	7.93	22-Apr	
1976	**10.36**		8.78	06-Apr	
1977	**0.92**		0.78	18-May	
1978	8.07	19-Sep	7.65	19-Sep	
1979	13.80	18-Mar	13.60	17-Mar	
1980	15.80	06-Apr	14.40	06-Apr	
1981	12.90	15-Mar	11.20	16-Mar	
1982	48.60	23-Apr	44.20	23-Apr	
1983	18.20	08-Jul	16.50	08-Jul	
1984	**5.04**		4.27	24-Mar	
1985	39.70	02-Apr	35.00	02-Apr	
1986	9.75	04-Mar	8.56	04-Mar	
1987	**4.89**		4.14	03-Apr	
1988	4.15	07-Jul	3.98	08-Jul	
1989	**12.98**		11.00	04-Apr	
1990	10.60	05-Jul	9.82	05-Jul	
1991	**13.33**		11.30	02-Apr	
1992	**5.90**		5.00	15-Mar	
1993	**6.15**		5.21	26-Mar	
1994	**15.22**		12.90	31-Mar	
1995	**5.61**		4.75	22-Mar	
1996	**16.87**		14.30	08-Apr	
1997	**16.05**		13.60	14-Apr	
1998	7.14	01-Jul	6.68	01-Jul	
1999	19.10	09-Apr	17.60	09-Apr	
2000	**2.58**		2.19	31-Mar	
2001	17.50	31-Jul	14.10	31-Jul	
2002	9.91	22-Apr	9.16	22-Apr	
2003	**9.44**		8.00	11-Apr	
2004	0.79	31-Mar	0.56	31-Mar	
2005	**32.69**		27.70	02-Apr	
2006	**3.52**		2.98	05-Apr	
2007	35.50	06-May	30.20	06-May	
2008	**0.35**		0.29	02-May	
2009	**0.20**		0.17	11-Apr	
2010	3.73	15-Jul	2.07	16-Jul	
2011	15.30	28-Jul	13.70	28-Jul	
2012	0.98	16-Apr	0.55	16-Apr	
2013	10.00	24-Apr	9.52	25-Apr	
2014	**27.26**		23.10	10-Apr	
2015	**11.80**		10.00	15-Mar	
2016	1.29	10-Aug	0.83	31-Aug	0.45
2017	9.06	29-Mar	8.37	29-Mar	
2018	**20.18**		17.10	21-Apr	
2019	**21.00**		17.80	29-Mar	
2020	**60.18**		51.00	19-Apr	
2021	2.56	19-May	2.26	19-May	
2022	13.90	24-Mar	11.90	25-Mar	
2023	**3.98**		3.37	19-Jun	



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Alberta Canada

nhc

Notes:
1. The bolded and underlined values are based on Qi=1.18Qd.
2. Data for 2023 is preliminary from WSC.

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MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
WHITEMUD CREEK NEAR ELLERSLIE MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

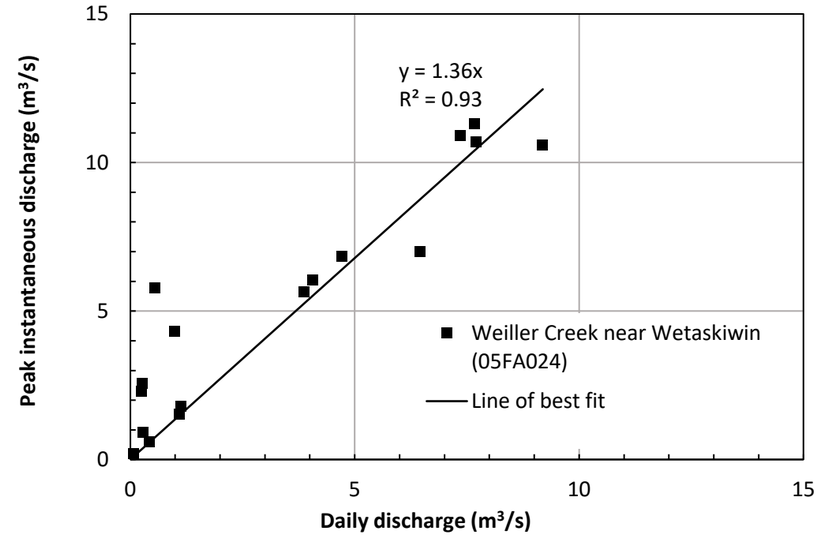
FIGURE A-4

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1985	6.99	20-Mar	6.46	19-Mar	
1986	**4.83**		3.55	02-Mar	
1987	**0.63**		0.47	31-Mar	
1988	2.31	24-Oct	0.89	13-Jul	0.25
1989	2.56	27-Oct	1.35	04-Apr	0.26
1990	4.32	04-Jul	2.30	29-Mar	0.98
1991	**1.73**		1.27	30-Mar	
1992	**3.48**		2.56	21-Mar	
1993	**0.89**		0.66	27-Mar	
1994	**0.74**		0.54	21-Mar	
1995	0.60	19-Aug	0.43	19-Aug	
1996	**1.89**		1.39	08-Apr	
1997	**5.21**		3.83	13-Apr	
1998	1.52	06-Jul	1.11	29-Jun	1.09
1999	**9.79**		7.20	11-Apr	
2000	**0.65**		0.48	31-Mar	
2001	0.19	29-Jul	0.08	29-Jul	
2002	**1.54**		1.13	19-Apr	
2003	**5.75**		4.23	10-Apr	
2004	5.77	05-Jul	0.55	05-Jul	
2005	10.90	11-Mar	8.13	02-Apr	7.36
2006	**8.47**		6.23	06-Apr	
2007	10.70	05-May	7.71	05-May	
2008	**0.15**		0.11	30-Apr	
2009	**0.10**		0.07	09-Apr	
2010	6.85	23-Jul	4.72	23-Jul	
2011	10.60	16-Apr	9.19	16-Apr	
2012	1.80	16-Jul	1.12	16-Jul	
2013	5.65	25-Apr	3.87	25-Apr	
2014	**5.58**		4.10	11-Apr	
2015	6.03	28-Mar	4.07	28-Mar	
2016	**0.58**		0.42	16-Mar	
2017	**12.50**		9.19	28-Mar	
2018	**15.10**		11.10	19-Apr	
2019	**5.47**		4.02	29-Mar	
2020	**17.95**		13.20	18-Apr	
2021	0.91	18-May	0.29	24-Aug	0.28
2022	11.30	24-Jun	7.67	24-Jun	
2023	**1.35**		0.99	19-Jun	

DRAFT

05FA024 – Weiller Creek near Wetaskiwin



Notes:
1. The bolded and underlined values are based on Qi=1.36Qd.
2. Data for 2023 is preliminary from WSC.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

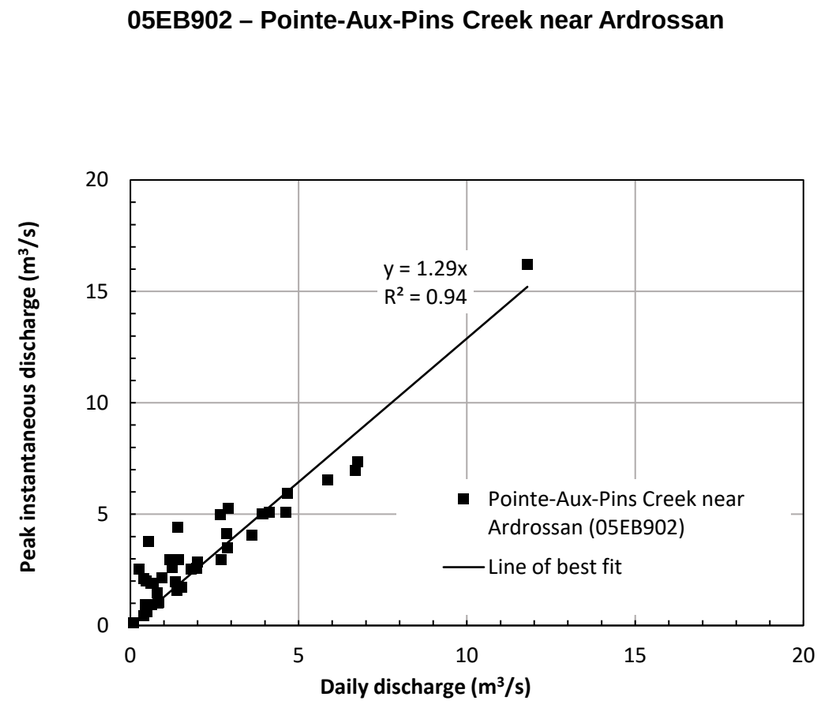
Job: 1008862 | *Date: 27-JUN-2024*

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
WEILLER CREEK NEAR WETASKIWIN MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-5

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1979	4.13	14-Jul	2.86	14-Jul	
1980	5.03	11-Apr	3.92	11-Apr	
1981	**3.03**		2.35	18-Mar	
1982	6.52	24-Apr	5.88	24-Apr	
1983	16.20	25-Jun	11.80	26-Jun	
1984	1.59	25-Mar	1.40	25-Mar	
1985	5.09	02-Apr	4.13	02-Apr	
1986	2.54	04-Mar	1.82	04-Mar	
1987	3.49	05-Apr	2.90	04-Apr	
1988	4.06	06-Jul	3.61	07-Jul	
1989	2.53	21-Apr	0.94	20-May	0.26
1990	4.43	06-Jul	1.72	04-Jul	1.41
1991	5.02	14-May	3.94	15-May	
1992	0.62	14-Mar	0.53	12-Mar	0.50
1993	**0.37**		0.28	24-Jun	
1994	2.57	31-Mar	1.98	31-Mar	
1995	1.98	19-Mar	1.35	20-Mar	
1996	2.85	06-Apr	2.01	07-Apr	
1997	7.34	23-Jun	6.76	23-Jun	
1998	5.28	02-Jul	2.91	02-Jul	
1999	4.97	27-Mar	2.69	27-Mar	
2000	0.93	27-Mar	0.55	10-Jul	0.46
2001	1.47	29-Jul	0.80	29-Jul	
2002	1.89	20-Apr	0.69	20-Apr	
2003	3.78	08-Aug	2.27	10-Apr	0.55
2004	2.14	30-Mar	0.93	31-Mar	
2005	2.95	10-Mar	1.44	10-Mar	
2006	2.10	25-May	1.01	06-Apr	0.41
2007	5.92	05-May	4.67	05-May	
2008	0.12	30-Apr	0.09	30-Apr	
2009	0.99	11-Apr	0.84	11-Apr	
2010	0.92	13-Jul	0.63	14-Jul	
2011	6.98	23-Jul	6.69	23-Jul	
2012	0.44	16-Jul	0.40	16-Jul	
2013	2.59	15-Jul	2.36	27-Apr	1.24
2014	2.94	25-Jul	1.19	25-Jul	
2015	2.01	09-Apr	0.88	30-Mar	0.49
2016	1.91	09-Aug	0.61	09-Aug	
2017	2.96	25-Apr	2.71	25-Apr	
2018	5.10	21-Apr	4.63	21-Apr	
2019	**1.55**		1.20	25-Mar	
2020	**5.19**		4.02	19-Apr	
2021	1.05	19-May	0.85	20-May	
2022	1.72	04-Apr	1.53	03-Apr	
2023	**1.14**		0.89	19-Jun	



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Notes: 1. The bolded and underlined values are based on Qi=1.29Qd.
2. Data for 2023 is preliminary from EPA.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008862 | Date: 27-JUN-2024

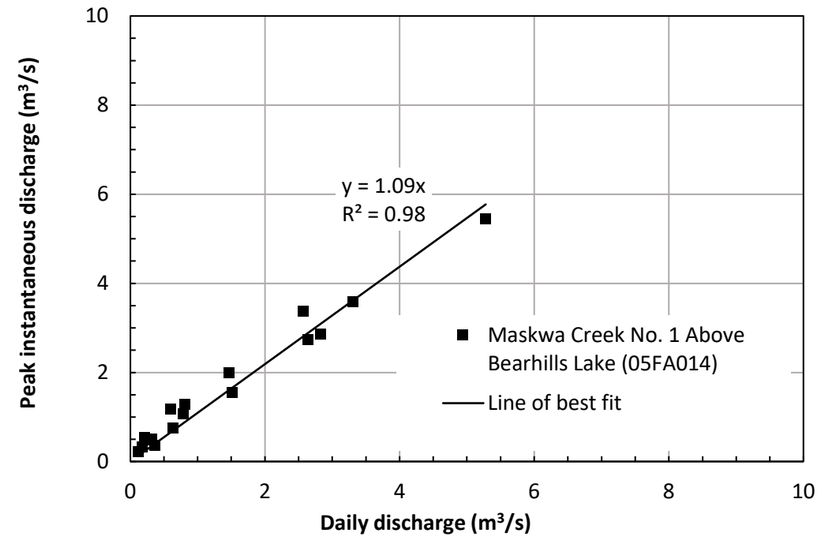
MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
POINTE-AUX-PINS CREEK NEAR ARDROSSAN MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-6

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1973	**2.90**		2.66	01-Jul	
1974	**8.83**		8.10	20-Apr	
1975	**1.75**		1.61	20-Apr	
1976	**0.55**		0.51	07-Apr	
1977	**0.14**		0.13	16-May	
1978	**0.32**		0.30	29-Mar	
1979	1.28	18-Apr	0.92	18-Mar	0.82
1980	1.06	28-Aug	0.79	28-Aug	
1981	**1.50**		1.38	15-Mar	
1982	5.45	21-Apr	5.28	22-Apr	
1983	1.99	02-Apr	1.47	02-Apr	
1984	**0.12**		0.11	30-Mar	
1985	2.73	04-Apr	2.64	04-Apr	
1986	0.51	26-Feb	0.33	27-Feb	
1987	**0.56**		0.51	12-Apr	
1988	**0.25**		0.23	09-Jun	
1989	**0.52**		0.48	12-Apr	
1990	**2.10**		1.93	31-Mar	
1991	**1.22**		1.12	04-Apr	
1992	**0.79**		0.73	18-Mar	
1993	**0.61**		0.56	21-Mar	
1994	**0.22**		0.20	17-Mar	
1995	**0.18**		0.16	19-Mar	
1996	**2.14**		1.96	11-Apr	
1997	**1.30**		1.19	18-Apr	
1998	**0.12**		0.11	29-Jun	
1999	**2.62**		2.40	10-Apr	
2000	0.48	29-Mar	0.27	29-Mar	
2001	0.49	29-Jul	0.28	29-Jul	
2002	1.18	25-Apr	0.60	25-Apr	
2003	**2.40**		2.20	10-Apr	
2004	**0.15**		0.14	29-Mar	
2005	2.86	05-Apr	2.83	05-Apr	
2006	**0.31**		0.29	07-Apr	
2007	0.74	05-May	0.64	05-May	
2008	**0.05**		0.04	29-Apr	
2009	**0.09**		0.08	13-Apr	
2010	0.54	13-Jul	0.22	14-Jul	
2011	**2.69**		2.47	14-Apr	
2012	0.33	20-Apr	0.18	06-May	0.17
2013	**0.91**		0.83	07-May	
2014	**1.47**		1.35	08-May	
2015	0.37	31-Mar	0.36	09-May	0.36
2016	**0.10**		0.09	10-May	
2017	1.55	03-Apr	1.52	11-May	
2018	3.37	20-Apr	2.57	12-May	
2019	**1.50**		1.38	13-May	
2020	3.59	20-Apr	3.31	14-May	
2021	0.21	19-May	0.12	15-May	
2022	**0.88**		0.81	16-May	
2023	**0.27**		0.25	02-May	

05FA014 – Maskwa Creek No. 1 Above Bearhills Lake



DRAFT

Notes: 1. The bolded and underlined values are based on Qi=1.09Qd.
2. Data for 2023 is preliminary from WSC.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

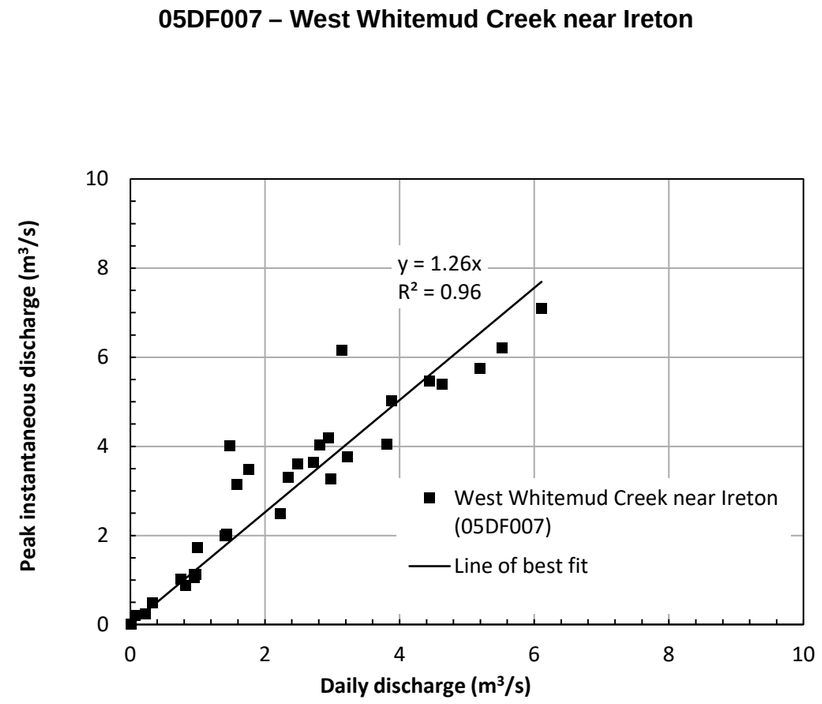
Job: 1008862 | *Date: 27-JUN-2024*

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
MASKWA CREEK NO. 1 ABOVE BEARHILLS LAKE MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-7

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1977	3.14	29-May	1.59	29-May	
1978	3.77	18-Sep	3.23	18-Sep	
1979	3.60	17-Mar	2.90	19-Apr	2.49
1980	3.30	05-Apr	2.35	05-Apr	
1981	1.72	13-Mar	1.00	14-Mar	
1982	6.21	23-Apr	5.52	23-Apr	
1983	3.64	03-Jul	2.72	03-Jul	
1984	0.87	09-Jun	0.82	09-Jun	
1985	5.75	02-Apr	5.20	02-Apr	
1986	1.13	15-May	1.10	02-Mar	0.95
1987	3.48	02-Apr	1.76	02-Apr	
1988	0.49	07-Jul	0.34	08-Jul	
1989	6.16	04-Apr	3.14	04-Apr	
1990	4.05	04-Jul	3.81	04-Jul	
1991	4.02	07-Jul	2.82	07-Jul	
1992	**0.78**		0.62	02-Mar	
1993	**1.60**		1.27	25-Mar	
1994	**1.64**		1.30	27-Mar	
1995	**0.71**		0.57	19-Mar	
1996	**3.47**		2.75	16-Mar	
1997	**5.04**		4.00	01-Apr	
1998	4.18	06-Jul	2.95	06-Jul	
1999	4.01	03-Apr	2.63	09-Apr	1.48
2000	**0.29**		0.23	13-Jun	
2001	1.99	30-Jul	1.41	30-Jul	
2002	1.12	20-Apr	0.97	21-Apr	
2003	**3.20**		2.54	09-Apr	
2004	0.01	03-Apr	0.01	03-Apr	
2005	**3.69**		2.93	10-Mar	
2006	1.05	04-Apr	0.96	05-Apr	
2007	7.10	05-May	6.11	05-May	
2010	2.02	14-Jul	1.44	14-Jul	
2011	5.40	27-Jul	4.63	27-Jul	
2012	0.21	20-Apr	0.08	20-Apr	
2013	1.01	23-Apr	0.80	25-Apr	0.76
2014	5.46	09-Apr	4.45	09-Apr	
2015	**1.35**		1.07	14-Mar	
2017	**1.86**		1.48	28-Mar	
2018	3.27	20-Apr	2.98	20-Apr	
2019	2.48	21-Jul	2.23	21-Jul	
2020	**6.17**		4.90	18-Apr	
2021	0.24	20-May	0.23	20-May	
2022	5.02	06-Jul	3.88	06-Jul	
2023	**2.36**		1.87	21-Jun	



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Notes:
1. The bolded and underlined values are based on Qi=1.26Qd.
2. Data for 2023 is preliminary from WSC.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008862 | *Date: 27-JUN-2024*

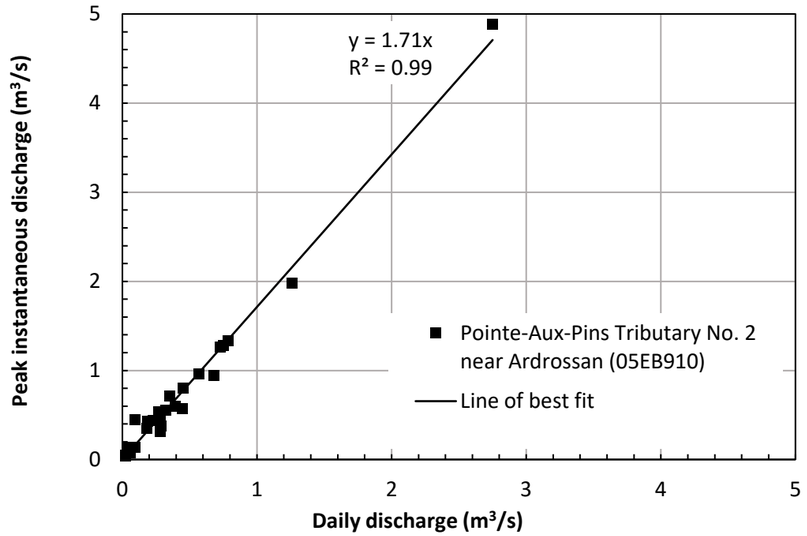
MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
WEST WHITEMUD CREEK NEAR IRETON MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-8

Classification: Public

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Same Event of Peak Instantaneous Discharge (m^3/s)
1981	**1.19**		0.70	14-Mar	
1982	1.98	21-Apr	1.26	22-Apr	
1983	4.88	25-Jun	2.75	25-Jun	
1984	0.32	22-Mar	0.28	23-Mar	
1985	0.94	01-Apr	0.68	01-Apr	
1986	1.33	04-Mar	0.79	04-Mar	
1987	1.28	03-Apr	0.75	04-Apr	
1988	0.96	06-Jul	0.57	06-Jul	
1989	0.43	04-Apr	0.19	04-Apr	
1990	0.45	11-May	0.30	19-Mar	0.10
1991	1.26	14-May	0.73	14-May	
1992	0.14	14-May	0.07	15-Mar	0.05
1993	**0.07**		0.04	08-May	
1994	0.44	31-Mar	0.23	31-Mar	
1995	0.55	17-Mar	0.33	18-Mar	
1996	0.60	06-Apr	0.45	08-Apr	0.39
1997	0.80	23-Jun	0.52	31-Mar	0.45
1998	0.54	02-Jul	0.27	02-Jul	
1999	0.57	26-Mar	0.45	26-Mar	
2000	0.10	10-Jul	0.05	27-Mar	0.04
2001	0.05	29-Jul	0.03	29-Jul	
2002	0.04	15-Apr	0.02	16-Apr	
2003	0.35	09-Apr	0.18	09-Apr	
2004	0.46	30-Mar	0.28	31-Mar	
2005	0.71	10-Mar	0.35	10-Mar	
2006	0.14	04-Apr	0.09	04-Apr	
2007	0.38	05-May	0.29	05-May	
2008	0.04	27-Apr	0.03	27-Apr	
2009	0.07	10-Apr	0.06	10-Apr	

05EB910 – Pointe-Aux-Pins Tributary No. 2 near Ardrossan



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Notes: 1. The bolded and underlined values are based on Qi=1.71Qd.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008862 | *Date: 27-JUN-2024*

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
POINTE-AUX-PINS TRIBUTARY NO. 2 NEAR ARDROSSAN MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE A-9

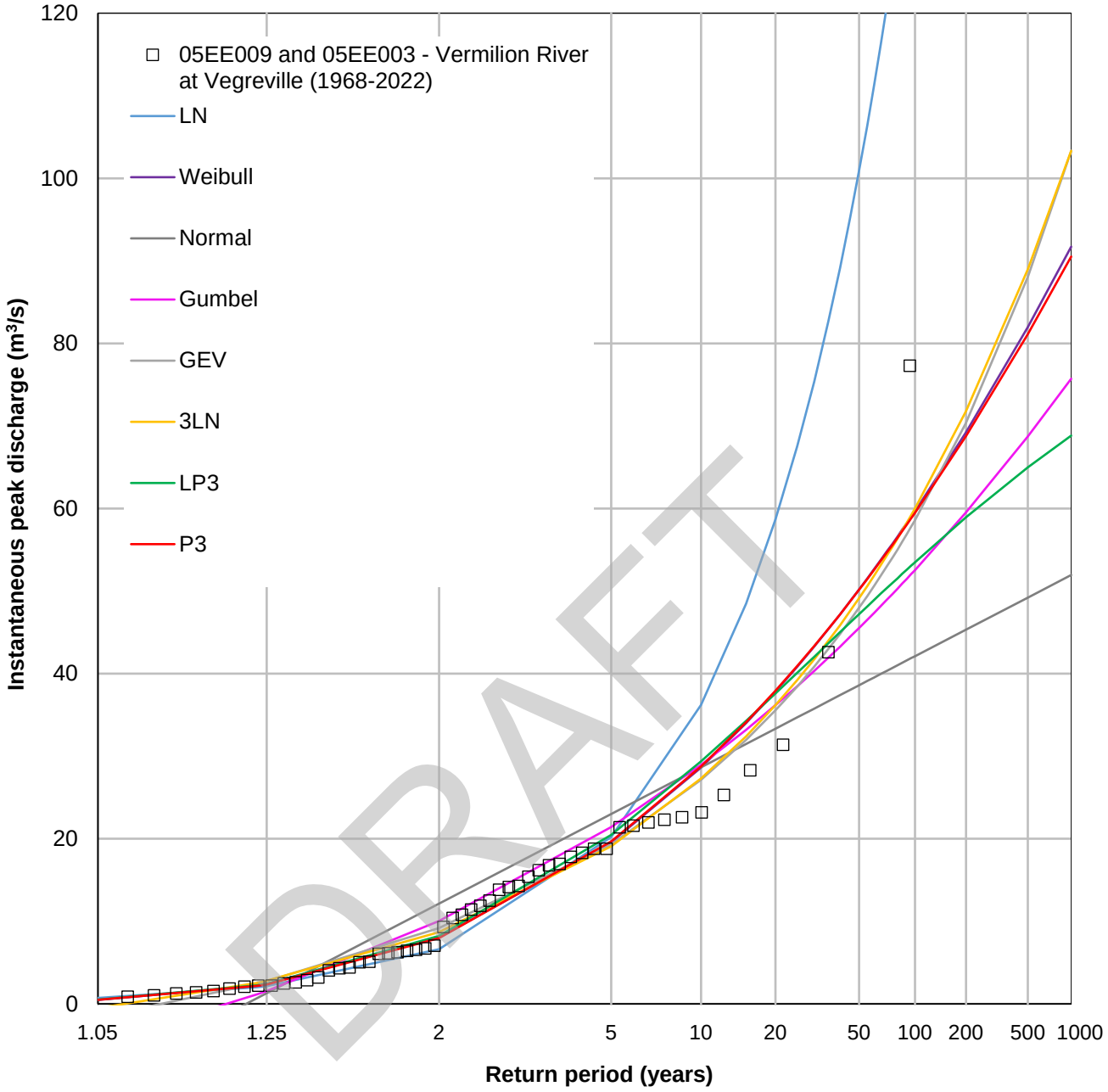
Classification: Public

Appendix B

Flood Frequency Analysis for Regional Stations

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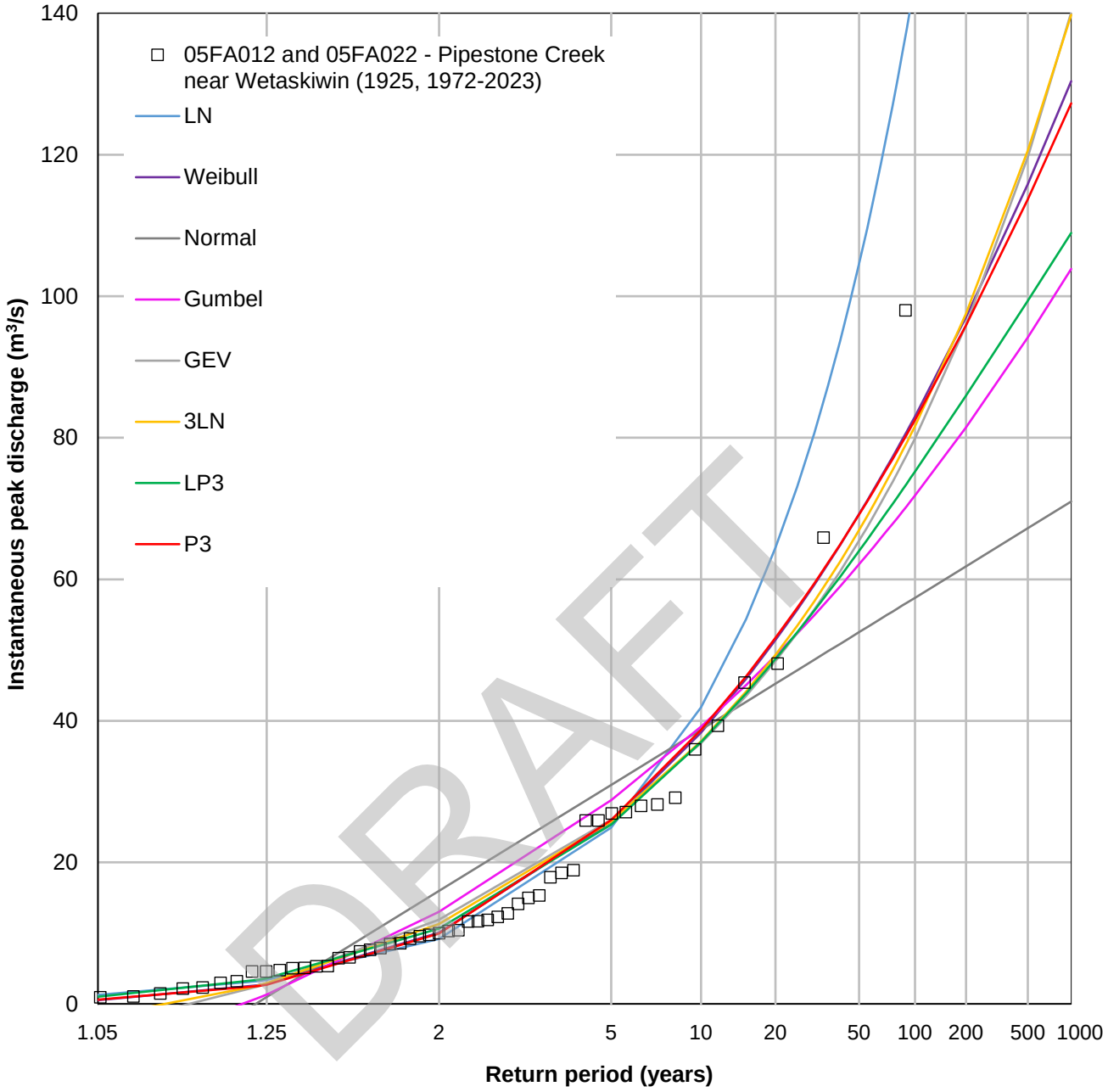
Classification: Public



DRAFT

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
nhc	Coordinate System: Units: As Shown	**FLOOD FREQUENCY CURVES FOR VERMILION RIVER AT VEGREVILLE**
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-1

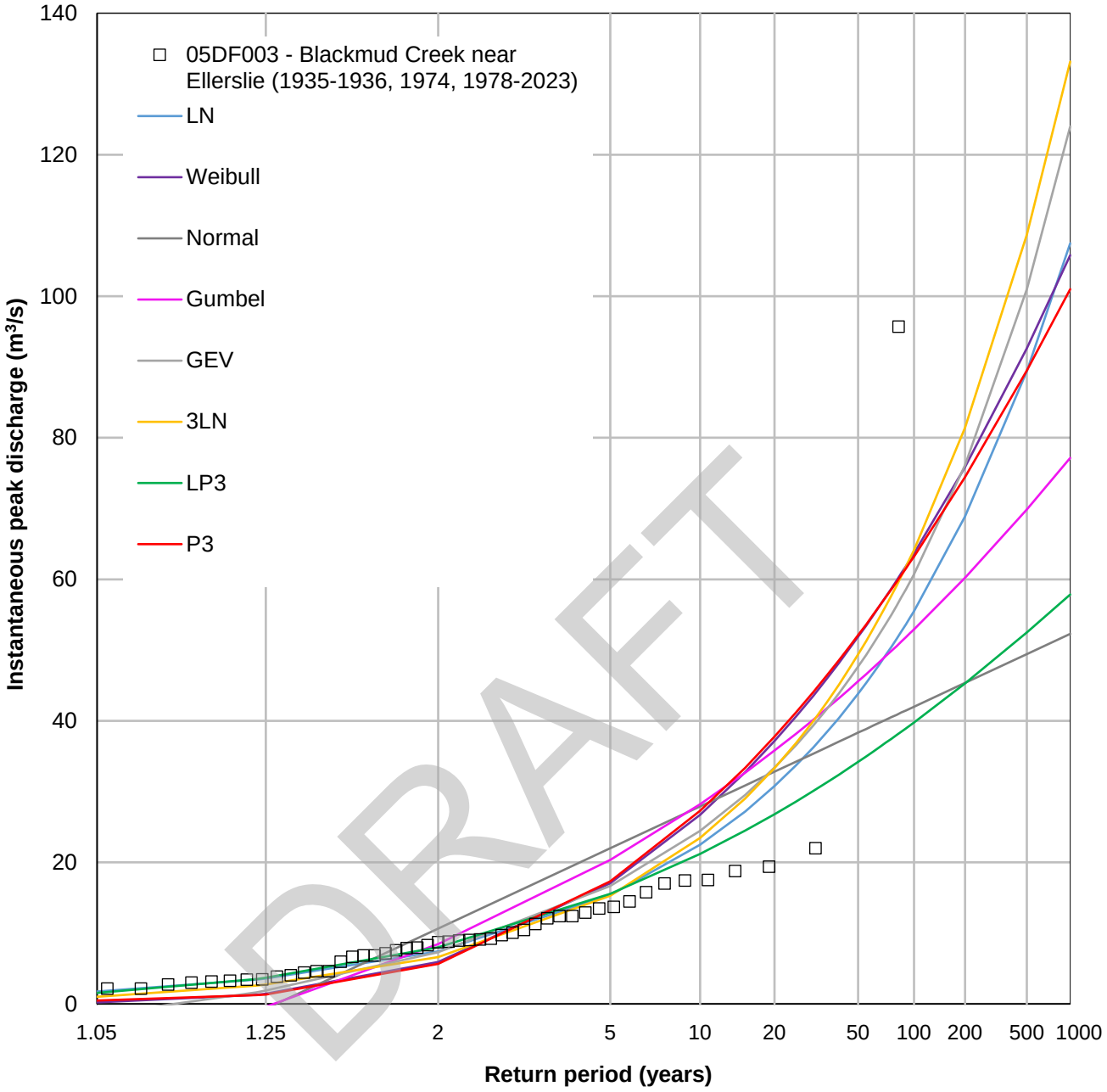
Classification: Public



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Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
nhc	Coordinate System: Units: As Shown	**FLOOD FREQUENCY CURVE FOR PIPESTONE CREEK NEAR WETASKIWIN**
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-2

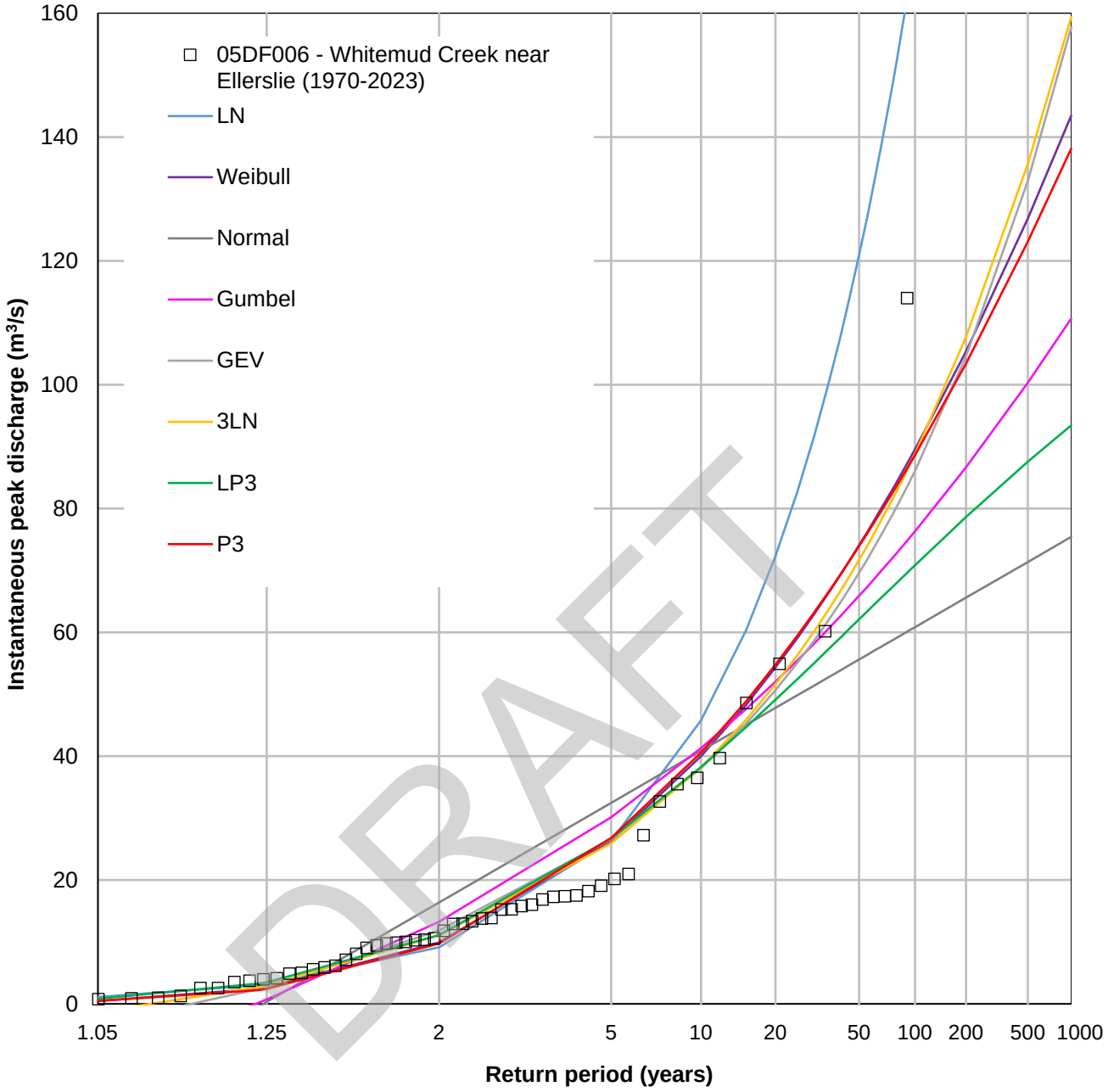
Classification: Public



DRAFT

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
nhc	Coordinate System: Units: As Shown	**FLOOD FREQUENCY CURVES FOR BLACKMUD CREEK NEAR ELLERSLIE**
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-3

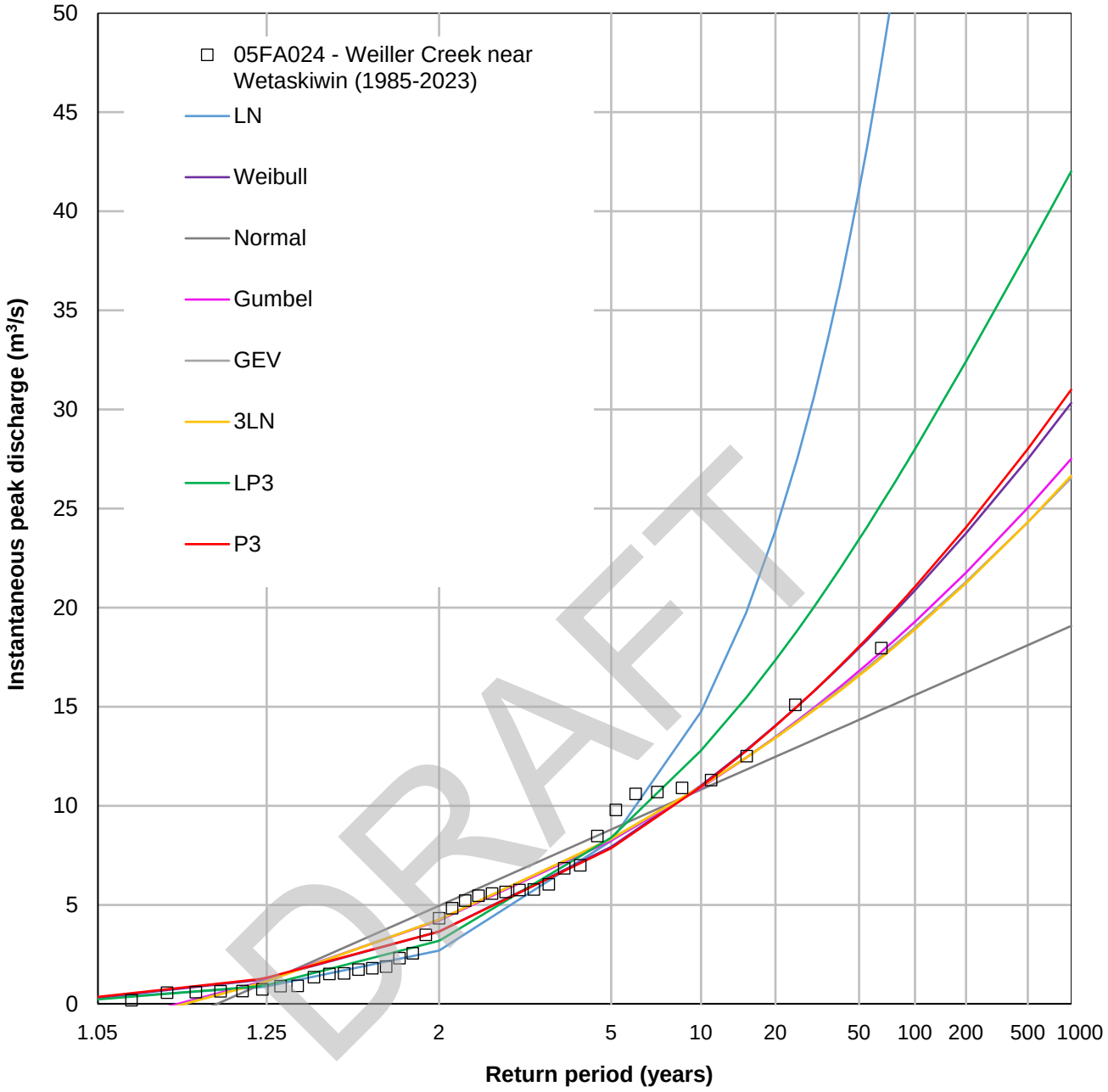
Classification: Public



DRAFT

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT **FLOOD FREQUENCY CURVES FOR WHITEMUD CREEK NEAR ELLERSLIE**
nhc	Coordinate System: Units: As Shown	
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-4

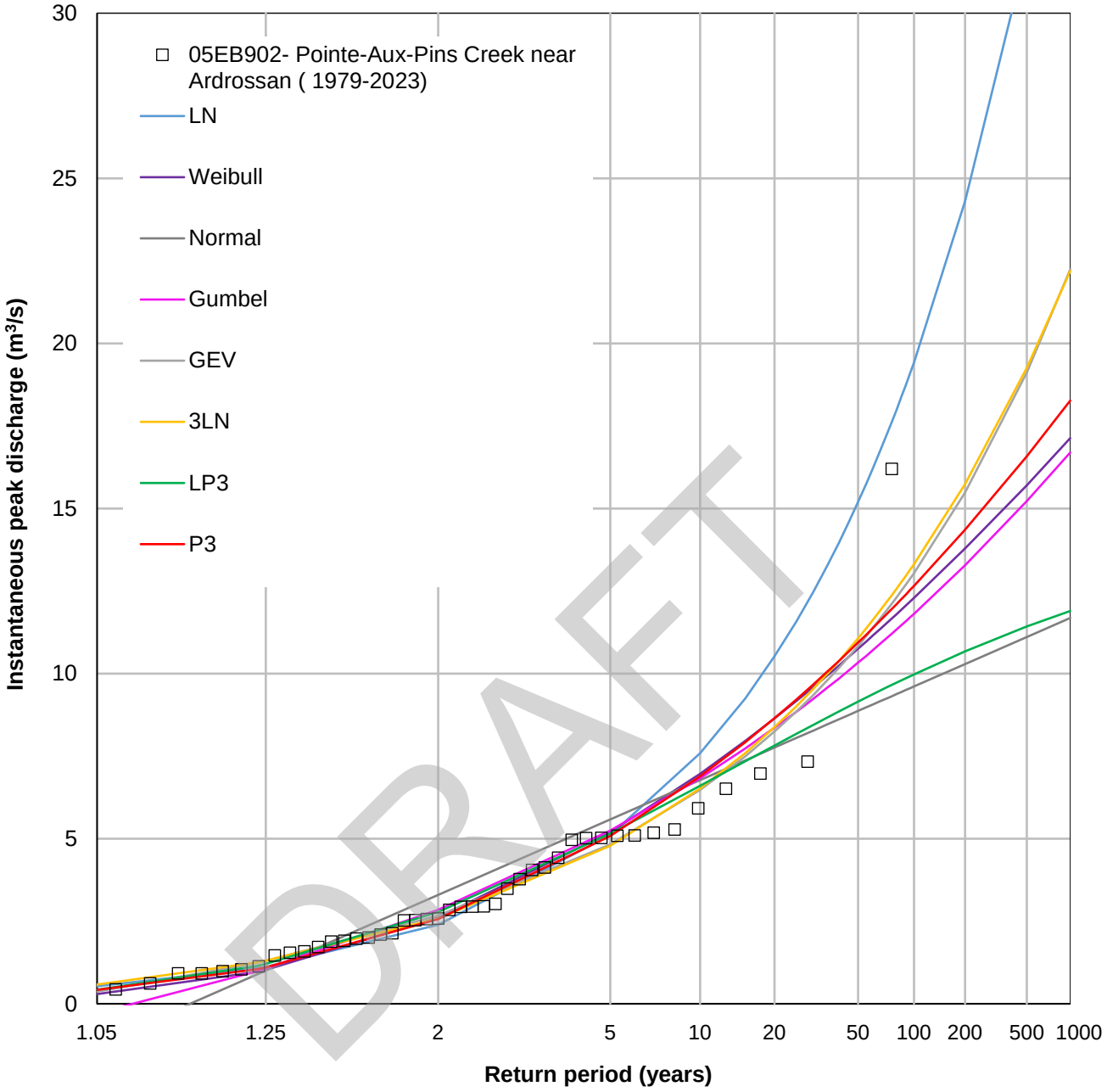
Classification: Public



DRAFT

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
nhc	Coordinate System: Units: As Shown	**FLOOD FREQUENCY CURVES FOR WEILLER CREEK NEAR WETASKIWIN**
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-5

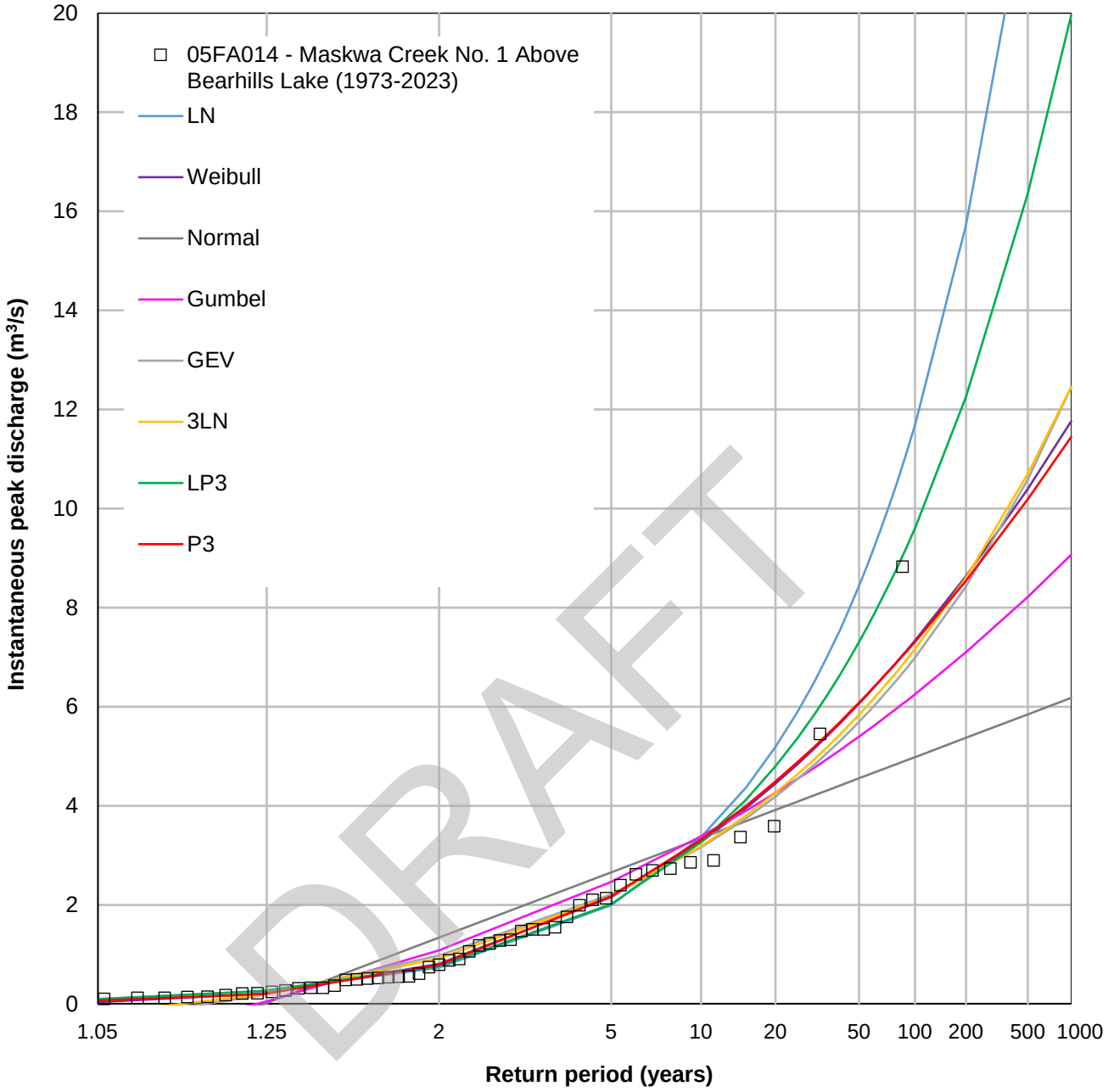
Classification: Public



DRAFT

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
nhc	Coordinate System: Units: As Shown	**FLOOD FREQUENCY CURVES FOR POINTE-AUX-PINS CREEK NEAR ARDROSSAN**
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-6

Classification: Public



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Alberta Canada

nhc

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008862

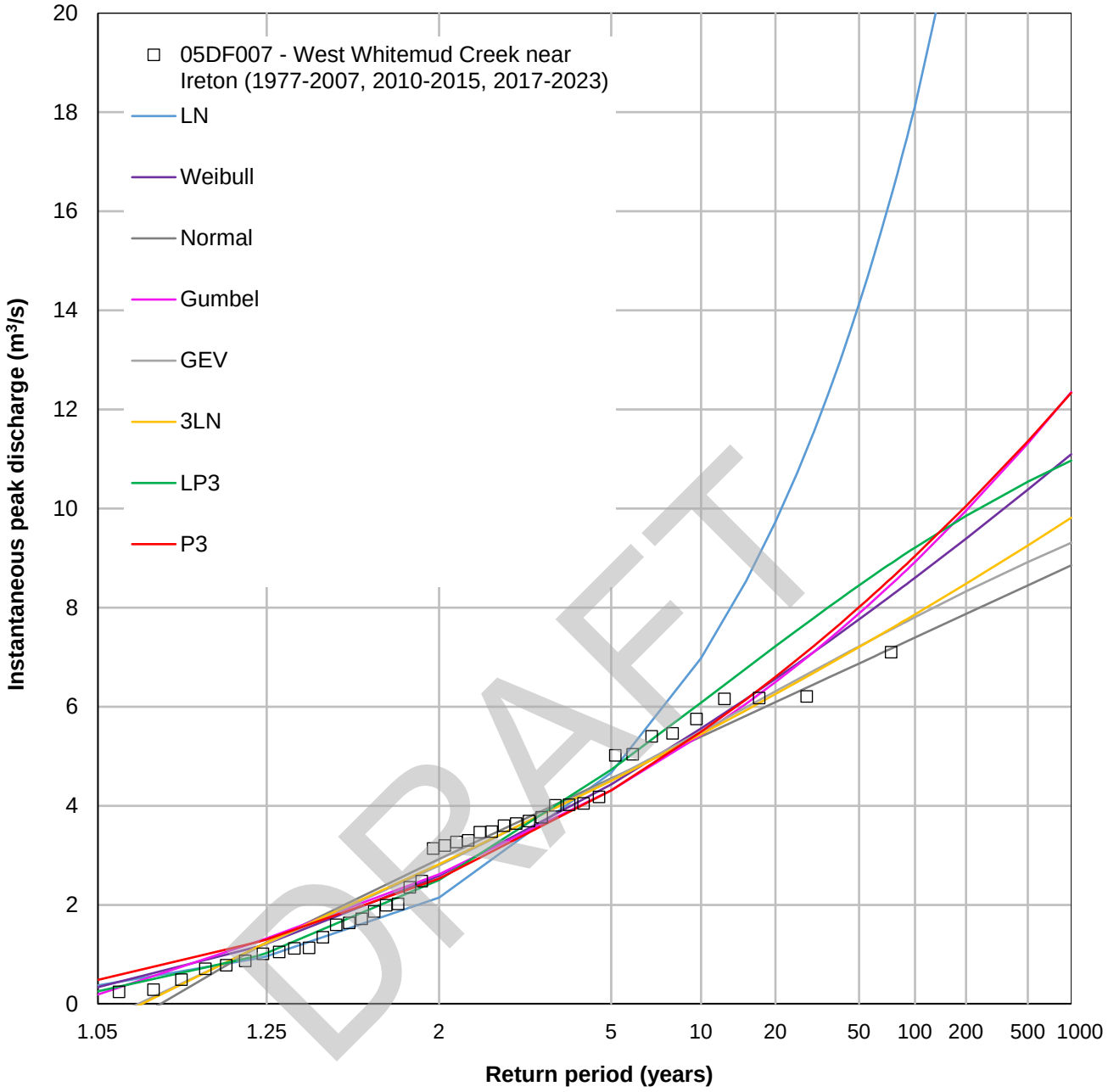
Date: 26-AUG-2024

MILLET FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

FLOOD FREQUENCY CURVES FOR MASKWA CREEK NO. 1 ABOVE BEARHILLS LAKE

FIGURE B-7

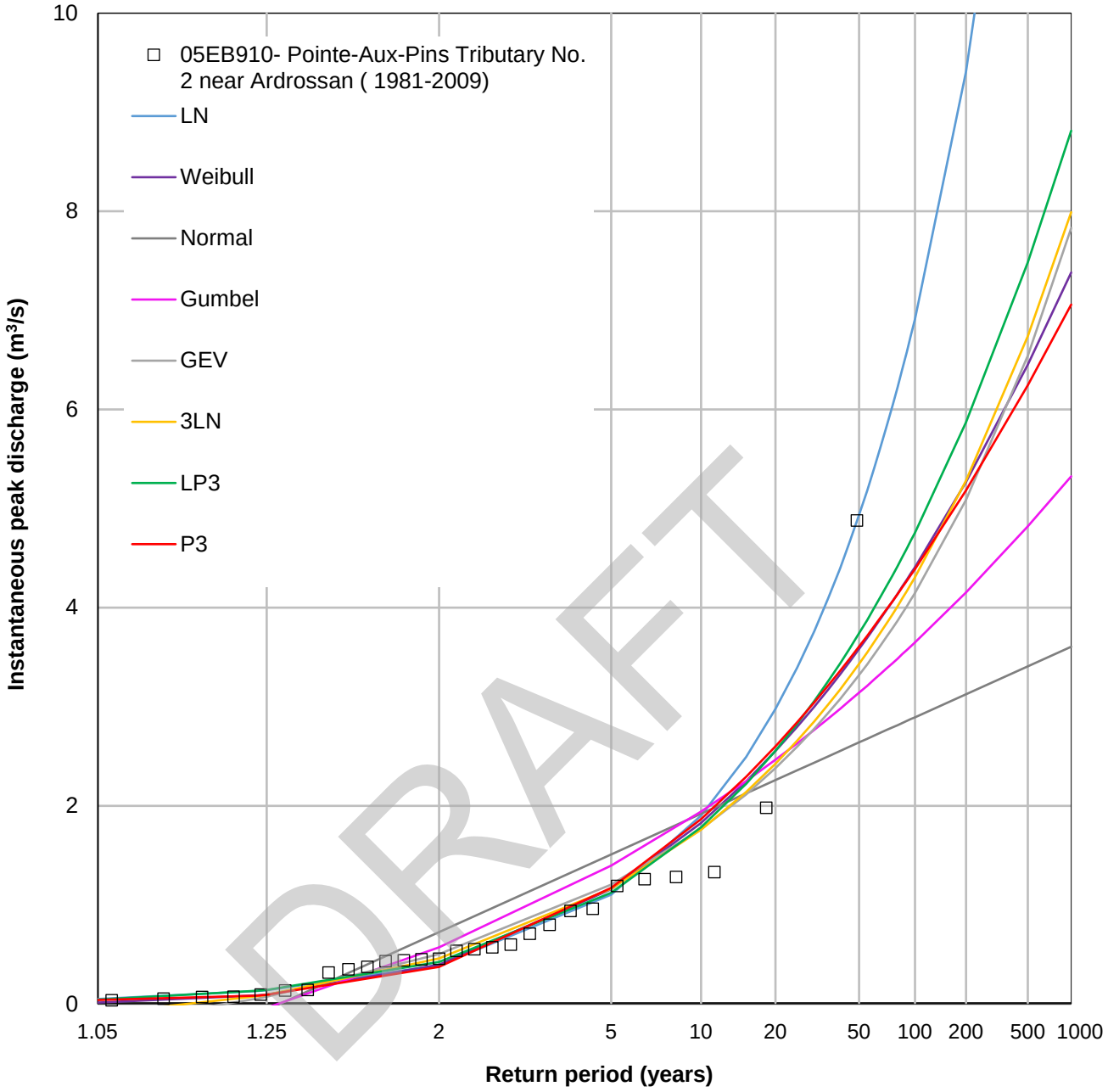
Classification: Public



DRAFT

Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT **FLOOD FREQUENCY CURVES FOR WEST WHITEMUD CREEK NEAR IRETON**
nhc	Coordinate System: Units: As Shown	
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-8

Classification: Public



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Alberta Canada	SCALE – AS SHOWN	MILLET FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT **FLOOD FREQUENCY CURVES FOR POINTE-AUX-PINS TRIBUTARY NO. 2 NEAR ARDROSSAN**
nhc	Coordinate System: Units: As Shown	
	Job: 1008862 / *Date: 26-AUG-2024*	FIGURE B-9

Classification: Public

April 2025

APPENDIX E

DETAILED MODEL DATA

DRAFT

Classification: Public

Table E-1 Cross section properties for Pipestone Creek

River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)	River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)
Pipestone Creek	XS-119	18427	758.52	18.91	Pipestone Creek	XS-89	14052	746.89	9.44
	XS-118	18365	758.62	12.67		XS-88	13841	746.46	11.84
	XS-117	18348	758.66	10.19		XS-87	13695	745.66	11.49
	XS-116	18214	758.60	12.29		XS-86	13516	745.44	5.47
	XS-115	18060	758.60	13.69		XS-85	13325	744.30	9.75
	XS-114	17834	758.51	13.71		XS-84	13310	744.60	7.96
	XS-113	17716	758.47	15.34		XS-83	13305	744.39	7.67
	XS-112	17700	758.27	10.36		XS-82	13248	744.48	6.19
	XS-111	17551	758.10	6.88		XS-81	12982	744.27	7.15
	XS-110	17399	757.86	7.12		XS-80	12869	744.14	33.54
	XS-109	17157	756.82	7.19		XS-79	12774	743.73	8.05
	XS-108	17034	756.80	11.17		XS-78	12679	743.88	8.34
	XS-107	16728	756.53	11.01		XS-77	12673	743.94	22.07
	XS-106	16576	755.70	11.06		XS-76	12619	743.68	20.67
	XS-105	16425	755.23	12.47		XS-75	12558	743.62	28.78
	XS-104	16276	754.71	8.93		XS-74	12491	743.83	26.26
	XS-103	16042	753.54	8.51		XS-73	12464	743.62	21.15
	XS-102	15867	752.93	6.74		XS-72	12399	743.66	12.25
	XS-101	15806	752.59	6.54		XS-71	12397	743.60	10.68
	XS-100	15800	752.47	6.13		XS-70	12326	743.16	8.25
	XS-99	15626	751.99	18.64		XS-69	12153	743.25	10.03
	XS-98	15252	750.80	8.22		XS-68	12040	742.98	7.99
	XS-97	15107	749.89	8.09		XS-67	11932	742.83	14.13
	XS-96	14948	749.51	8.86		XS-66	11928	743.04	12.70
	XS-95	14799	748.78	8.46		XS-65	11871	742.64	8.61
	XS-94	14507	748.59	7.62		XS-64	11673	742.44	11.56
	XS-93	14486	748.59	4.60		XS-63	11524	742.12	6.98
	XS-92	14445	748.00	6.89		XS-62	11341	741.65	8.69
	XS-91	14391	747.72	4.35		XS-61	11173	741.53	13.54
	XS-90	14165	746.87	17.16		XS-60	10928	741.00	9.58

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Table E-1 Cross section properties for Pipestone Creek (continued)

River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)	River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)
Pipestone Creek	XS-59	10738	740.64	10.84	Pipestone Creek	XS-29	6591	735.74	9.94
	XS-58	10587	740.62	11.52		XS-28	6573	736.18	11.75
	XS-57	10268	740.14	8.25		XS-27	6525	735.79	9.49
	XS-56	10016	739.73	10.23		XS-26	6348	735.86	8.37
	XS-55	9847	739.69	11.39		XS-25	6344	735.84	8.90
	XS-54	9800	739.67	13.96		XS-24	6266	736.25	10.51
	XS-53	9778	739.61	7.86		XS-23	6129	735.55	12.62
	XS-52	9770	739.60	6.51		XS-22	5851	735.80	17.82
	XS-51	9763	739.46	13.80		XS-21	5391	734.60	9.12
	XS-50	9749	739.37	9.74		XS-20	5203	734.45	14.05
	XS-49	9675	739.25	16.23		XS-19	4985	733.95	9.01
	XS-48	9485	738.69	11.41		XS-18	4676	734.09	10.52
	XS-47	9112	738.50	10.47		XS-17	4508	733.29	10.29
	XS-46	8909	738.29	7.39		XS-16	4203	732.73	9.01
	XS-45	8804	738.37	17.29		XS-15	3876	732.09	11.42
	XS-44	8453	737.58	10.76		XS-14	3689	731.66	10.69
	XS-43	8378	737.64	10.71		XS-13	3483	731.71	12.88
	XS-42	8373	737.90	10.18		XS-12	3191	731.09	9.11
	XS-41	8210	737.48	9.57		XS-11	2935	731.07	8.87
	XS-40	8063	737.64	10.98		XS-10	2744	730.67	8.66
	XS-39	7910	737.25	12.78		XS-9	2500	730.25	10.95
	XS-38	7906	737.13	10.02		XS-8	2197	730.24	24.33
	XS-37	7837	737.11	11.27		XS-7	2015	730.04	31.94
	XS-36	7817	737.04	11.94		XS-6	1386	729.52	7.74
	XS-35	7815	737.03	11.75		XS-5	813	728.17	8.53
	XS-34	7441	737.23	9.34		XS-4	337	728.27	15.25
	XS-33	7250	736.98	13.51		XS-3	100	727.56	13.91
	XS-32	6997	736.44	9.94		XS-2	88	727.53	12.70
	XS-31	6783	736.12	10.79		XS-1	0	727.33	11.19
	XS-30	6614	735.96	10.03					

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Table E-2 Cross section properties for Eyot Creek

River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)	River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)
	XS-160	4195	747.05	9.25		XS-139	1354	745.44	14.46
	XS-159	4036	747.07	14.00		XS-138	1233	745.36	8.49
	XS-158	3890	747.01	13.14		XS-137	1217	745.29	9.75
	XS-157	3750	746.72	19.40		XS-136	1213	745.30	9.21
	XS-156	3569	746.98	23.10		XS-135	1182	745.25	10.63
	XS-155	3333	746.70	11.12		XS-134	1136	745.55	9.08
	XS-154	3133	746.61	15.95		XS-133	1002	745.01	5.88
	XS-153	3118	746.37	19.33		XS-132	901	744.93	5.68
	XS-152	2859	746.03	9.28		XS-131	790	744.61	10.99
	XS-151	2684	746.21	14.14		XS-130	751	745.11	8.41
Eyot Creek	XS-150	2476	746.11	11.18	Eyot Creek	XS-129	747	744.99	9.32
	XS-149	2348	745.98	14.29		XS-128	721	744.93	6.33
	XS-148	2201	745.74	15.67		XS-127	616	744.63	9.63
	XS-147	1958	745.59	26.98		XS-126	446	744.34	5.57
	XS-146	1787	745.76	39.14		XS-125	415	744.61	6.54
	XS-145	1629	745.52	13.63		XS-124	396	744.63	5.73
	XS-144	1498	745.50	14.48		XS-123	357	744.25	5.17
	XS-143	1457	745.52	13.81		XS-122	284	743.99	5.35
	XS-142	1418	745.52	13.89		XS-121	133	743.68	6.31
	XS-141	1409	745.62	10.50		XS-120	33	743.61	9.06
	XS-140	1394	745.72	10.53					

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Table E-3 Cross section properties for Snake Drain

River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)	River	Cross Section Number	River Station (m)	Thalweg Elevation (m)	2-year Water Surface Width (m)
Snake Drain	XS-186	1530	764.09	57.51	Snake Drain	XS-173	322	751.00	4.27
	XS-185	1462	763.82	56.44		XS-172	295	750.90	5.02
	XS-184	1375	763.40	33.08		XS-171	290	750.78	2.31
	XS-183	1233	762.73	14.95		XS-170	284	750.78	1.79
	XS-182	1129	761.26	108.69		XS-169	282	750.03	4.17
	XS-181	1124	761.42	88.43		XS-168	211	749.68	4.33
	XS-180	997	758.95	2.78		XS-167	206	749.53	2.32
	XS-179	785	755.78	24.48		XS-166	205	748.90	4.66
	XS-178	689	754.38	1.22		XS-165	140	748.42	4.19
	XS-177	548	752.41	4.07		XS-164	134	748.25	2.75
	XS-176	481	752.05	4.47		XS-163	133	747.93	6.42
	XS-175	463	751.60	3.13		XS-162	93	747.74	4.12
	XS-174	419	751.32	5.55		XS-161	40	747.49	3.05

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Classification: Public

Table E-4 Modelled bridge properties

River	Description	River Station (m)	Municipality	TEC Bridge File	Design Drawing/ Info	Span (m)	Width (m)	Number of Piers	Pier Width (m)	Deck Skew (°)	Minimum Elevation (m)		Low Flow Modelling Approach	High Flow Modelling Approach
											Top Chord	Low Chord		
Pipestone Creek	Range Road 250	18357	Wetaskiwin County No. 10	BF496	No	20.0	9.0	2	0.30	N/A	762.97	762.12	Highest Energy Answer	Energy only (Standard step)
Pipestone Creek	Private Crossing	17704	Wetaskiwin County No. 10	N/A	No	13.5	3.2	0	N/A	N/A	761.47	761.00	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Township Road 474	15803	Wetaskiwin County No. 10	N/A	No	12.6	4.7	0	N/A	N/A	756.72	756.40	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Pedestrian	13308	Town of Millet	N/A	No	15.4	1.7	0	N/A	N/A	747.80	747.72	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Pedestrian	12677	Town of Millet	N/A	No	13.9	2.5	0	N/A	N/A	746.85	746.77	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Pedestrian	12398	Town of Millet	N/A	No	17.0	1.3	0	N/A	N/A	746.50	746.40	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Overhead Pipeline Crossing	11930	Town of Millet	N/A	No	25.0	0.5	2	0.20	N/A	745.43	744.93	Highest Energy Answer	Energy only (Standard step)
Pipestone Creek	Highway 2A	9791	Wetaskiwin County No. 10	BF72548	Yes	34.0	14.8	2	0.51	N/A	746.18	745.12	Highest Energy Answer	Energy only (Standard step)
Pipestone Creek	CP Rail	9756	Wetaskiwin County No. 10	N/A	No	20.0	5.0	0	N/A	N/A	746.52	744.27	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Private Crossing	8375	Wetaskiwin County No. 10	N/A	No	16.8	3.4	0	N/A	N/A	740.43	740.10	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Private Crossing	7908	Wetaskiwin County No. 10	N/A	No	20.0	1.7	0	N/A	N/A	740.38	740.28	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Private Crossing	7816	Wetaskiwin County No. 10	N/A	No	18.5	0.8	0	N/A	N/A	739.86	739.83	Energy (Standard Step)	Energy only (Standard step)

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Table E-4 Modelled bridge properties (continued)

River	Description	River Station (m)	Municipality	TEC Bridge File	Design Drawing/ Info	Span (m)	Width (m)	Number of Piers	Pier Width (m)	Deck Skew (°)	Minimum Elevation (m)		Low Flow Modelling Approach	High Flow Modelling Approach
											Top Chord	Low Chord		
Pipestone Creek	Range Road 243A	6581	Wetaskiwin County No. 10	BF359	No	29.0	9.0	2	0.30	N/A	740.48	739.63	Highest Energy Answer	Energy only (Standard step)
Pipestone Creek	Private Crossing	6345	Wetaskiwin County No. 10	N/A	No	15.0	2.0	0	N/A	N/A	739.13	738.29	Energy (Standard Step)	Energy only (Standard step)
Pipestone Creek	Range Road 242	94	Wetaskiwin County No. 10	BF727	No	21.0	7.0	2	0.30	N/A	731.45	730.80	Highest Energy Answer	Energy only (Standard step)
Eyot Creek	53 Avenue	1401	Town of Millet	BF70461	No	11.5	7.0	0	N/A	N/A	749.85	748.23	Energy (Standard Step)	Energy only (Standard step)
Eyot Creek	Private Crossing	1215	Town of Millet	N/A	No	16.0	1.6	2	0.25	N/A	747.49	747.29	Highest Energy Answer	Energy only (Standard step)
Eyot Creek	Pedestrian	749	Town of Millet	N/A	No	12.6	1.7	0	N/A	N/A	747.25	747.15	Energy (Standard Step)	Energy only (Standard step)
Eyot Creek	45 Avenue	405	Town of Millet	BF910	Yes	31.0	16.1	2	0.31	N/A	749.94	749.21	Highest Energy Answer	Energy only (Standard step)

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Table E-5 Modelled culvert properties

River	Description	River Station (m)	Municipality	AT Bridge File	Design Drawing/ Info	Culvert Shape	Culvert Type	Entrance Condition	# Barrels	Barrel Length (m)	Diameter, Rise, or Height (m)	Span or Width (m)	Upstream Invert Elevation (m)	Downstream Invert Elevation (m)	Loss Coefficient		Mannings's n	
															Entrance	Exit	Top	Bottom
Pipestone Creek	Range Road 245/Govt. Road	14465	Town of Millet	BF9139	Yes	Circular	CSP	Headwall	1	36.3	4.3	N/A	748.74	747.97	0.9	1	0.024	0.024
Snake Drain	Private Crossing	1127	Wetaskiwin County No. 10	N/A	No	Circular	CSP	Pipe Projecting from Fill	1	4.9	0.3	N/A	761.37	761.42	0.9	1	0.024	0.024
Snake Drain	Range Road 245A	473	Town of Millet	N/A	No	Circular	CSP	Pipe Projecting from Fill	2	16.2	0.9	N/A	752.08	751.68	0.9	1	0.024	0.024
										16.5	0.9	N/A	752.08	751.61	0.9	1	0.024	0.024

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Table E-6 Pipestone Creek flood frequency water surface elevation

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-119	18427	760.07	760.67	760.89	761.16	761.34	761.43	761.53	761.59	761.74	761.86	761.94	762.01	762.06
XS-118	18365	760.03	760.64	760.85	761.13	761.29	761.38	761.48	761.54	761.68	761.80	761.87	761.94	761.99
XS-117	18348	760.01	760.62	760.83	761.10	761.26	761.34	761.44	761.49	761.62	761.74	761.80	761.87	761.92
XS-116	18214	759.94	760.53	760.74	760.99	761.14	761.22	761.31	761.36	761.49	761.61	761.68	761.75	761.80
XS-115	18060	759.81	760.37	760.57	760.83	761.01	761.10	761.20	761.26	761.41	761.54	761.61	761.69	761.74
XS-114	17834	759.63	760.18	760.36	760.62	760.83	760.93	761.04	761.10	761.27	761.42	761.51	761.58	761.63
XS-113	17716	759.53	760.09	760.26	760.50	760.70	760.79	760.89	760.94	761.09	761.23	761.32	761.40	761.46
XS-112	17700	759.50	760.06	760.24	760.48	760.68	760.76	760.86	760.91	761.05	761.16	761.22	761.28	761.33
XS-111	17551	759.29	759.80	759.96	760.20	760.41	760.49	760.58	760.63	760.75	760.84	760.89	760.95	760.99
XS-110	17399	758.66	759.25	759.47	759.76	759.99	760.09	760.20	760.27	760.41	760.51	760.56	760.63	760.68
XS-109	17157	758.12	758.68	758.87	759.06	759.20	759.28	759.37	759.42	759.55	759.63	759.68	759.73	759.77
XS-108	17034	757.96	758.45	758.63	758.80	758.94	759.01	759.10	759.16	759.28	759.37	759.42	759.48	759.52
XS-107	16728	757.18	757.54	757.69	757.89	758.05	758.14	758.23	758.29	758.44	758.54	758.59	758.65	758.69
XS-106	16576	756.57	756.94	757.07	757.30	757.52	757.60	757.68	757.73	757.86	757.94	757.98	758.04	758.08
XS-105	16425	756.06	756.42	756.59	756.82	757.03	757.09	757.16	757.20	757.31	757.38	757.43	757.48	757.53
XS-104	16276	755.39	755.84	756.02	756.24	756.39	756.46	756.54	756.59	756.68	756.74	756.77	756.81	756.84
XS-103	16042	754.57	755.07	755.22	755.39	755.53	755.62	755.70	755.76	755.89	755.98	756.04	756.09	756.13
XS-102	15867	753.90	754.42	754.59	754.81	754.98	755.07	755.18	755.26	755.44	755.57	755.65	755.72	755.76
XS-101	15806	753.67	754.17	754.33	754.52	754.66	754.74	754.84	754.91	755.08	755.20	755.26	755.31	755.33
XS-100	15800	753.65	754.14	754.30	754.48	754.60	754.68	754.78	754.85	755.01	755.14	755.19	755.24	755.24
XS-99	15626	753.22	753.59	753.71	753.87	753.96	754.00	754.02	754.04	754.06	754.08	754.10	754.15	754.20
XS-98	15252	751.54	751.99	752.18	752.40	752.56	752.66	752.78	752.86	753.10	753.31	753.46	753.65	753.79
XS-97	15107	750.93	751.40	751.63	751.91	752.13	752.27	752.45	752.57	752.91	753.20	753.37	753.59	753.74
XS-96	14948	750.41	750.95	751.29	751.65	751.93	752.11	752.33	752.48	752.85	753.16	753.34	753.57	753.72

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Classification: Public

Table E-6 Pipestone Creek flood frequency water surface elevation (Continued)

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-95	14799	750.05	750.67	751.12	751.53	751.85	752.05	752.29	752.45	752.83	753.15	753.33	753.56	753.71
XS-94	14507	749.58	750.17	750.97	751.41	751.77	751.98	752.23	752.39	752.78	753.10	753.29	753.52	753.67
XS-93	14486	749.46	750.02	750.93	751.39	751.74	751.96	752.21	752.37	752.76	753.08	753.27	753.49	753.65
XS-92	14445	748.94	749.41	749.58	749.79	749.90	749.96	750.03	750.08	750.18	750.26	750.30	750.35	750.38
XS-91	14391	748.37	748.94	749.09	749.34	749.51	749.59	749.68	749.74	749.87	749.97	750.02	750.08	750.12
XS-90	14165	748.11	748.59	748.76	749.00	749.14	749.22	749.30	749.36	749.48	749.57	749.62	749.68	749.72
XS-89	14052	748.02	748.45	748.60	748.83	748.95	749.03	749.11	749.16	749.28	749.37	749.42	749.49	749.53
XS-88	13841	747.49	747.93	748.10	748.32	748.46	748.55	748.65	748.70	748.84	748.95	749.01	749.07	749.12
XS-87	13695	747.17	747.67	747.81	747.99	748.12	748.20	748.29	748.34	748.47	748.56	748.62	748.68	748.72
XS-86	13516	746.29	746.99	747.19	747.44	747.60	747.68	747.77	747.83	747.96	748.06	748.12	748.19	748.24
XS-85	13325	745.95	746.67	746.90	747.12	747.25	747.32	747.39	747.45	747.57	747.67	747.73	747.79	747.84
XS-84	13310	745.94	746.65	746.87	747.09	747.21	747.28	747.35	747.40	747.52	747.62	747.68	747.74	747.78
XS-83	13305	745.93	746.65	746.87	747.08	747.20	747.27	747.34	747.38	747.51	747.60	747.66	747.73	747.77
XS-82	13248	745.86	746.57	746.79	746.99	747.10	747.16	747.23	747.28	747.40	747.51	747.57	747.64	747.69
XS-81	12982	745.47	746.08	746.27	746.57	746.76	746.87	746.99	747.07	747.25	747.38	747.45	747.54	747.59
XS-80	12869	745.40	746.06	746.26	746.56	746.75	746.86	746.99	747.06	747.24	747.37	747.44	747.53	747.58
XS-79	12774	745.34	746.03	746.24	746.55	746.74	746.85	746.97	747.05	747.23	747.36	747.43	747.51	747.57
XS-78	12679	745.26	745.95	746.17	746.50	746.70	746.81	746.94	747.02	747.21	747.34	747.41	747.49	747.55
XS-77	12673	745.25	745.94	746.17	746.49	746.70	746.81	746.94	747.01	747.20	747.33	747.40	747.49	747.55
XS-76	12619	745.20	745.90	746.13	746.46	746.68	746.79	746.93	747.00	747.19	747.32	747.40	747.48	747.54
XS-75	12558	745.15	745.85	746.09	746.43	746.66	746.78	746.91	746.99	747.18	747.31	747.39	747.47	747.53
XS-74	12491	745.09	745.82	746.06	746.42	746.64	746.77	746.90	746.98	747.17	747.31	747.38	747.47	747.52
XS-73	12464	745.07	745.81	746.05	746.41	746.64	746.76	746.90	746.98	747.17	747.30	747.37	747.46	747.52
XS-72	12399	745.02	745.77	746.02	746.38	746.62	746.74	746.88	746.96	747.15	747.29	747.36	747.45	747.50

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Classification: Public

Table E-6 Pipestone Creek flood frequency water surface elevation (Continued)

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-71	12397	745.01	745.76	746.01	746.38	746.61	746.74	746.88	746.96	747.15	747.28	747.36	747.44	747.50
XS-70	12326	744.92	745.66	745.91	746.29	746.53	746.66	746.79	746.88	747.06	747.19	747.26	747.35	747.40
XS-69	12153	744.70	745.42	745.66	746.04	746.28	746.40	746.53	746.61	746.79	746.92	746.99	747.07	747.12
XS-68	12040	744.51	745.20	745.44	745.81	746.05	746.18	746.32	746.41	746.60	746.74	746.82	746.91	746.97
XS-67	11932	744.36	745.07	745.32	745.70	745.93	746.07	746.21	746.29	746.48	746.63	746.71	746.81	746.87
XS-66	11928	744.35	745.06	745.31	745.67	745.90	746.04	746.18	746.26	746.46	746.60	746.68	746.78	746.84
XS-65	11871	744.24	744.97	745.21	745.57	745.80	745.93	746.07	746.15	746.35	746.49	746.57	746.66	746.72
XS-64	11673	743.94	744.68	744.92	745.28	745.51	745.65	745.79	745.87	746.06	746.19	746.27	746.36	746.42
XS-63	11524	743.60	744.37	744.61	744.93	745.16	745.29	745.44	745.52	745.72	745.87	745.96	746.05	746.12
XS-62	11341	743.34	744.02	744.28	744.62	744.86	745.01	745.18	745.26	745.47	745.62	745.71	745.81	745.87
XS-61	11173	743.14	743.78	744.05	744.41	744.64	744.79	744.97	745.05	745.25	745.40	745.48	745.58	745.64
XS-60	10928	742.59	743.32	743.62	743.96	744.20	744.34	744.50	744.59	744.80	744.96	745.04	745.15	745.21
XS-59	10738	742.32	743.03	743.30	743.64	743.89	744.03	744.20	744.29	744.52	744.69	744.79	744.90	744.96
XS-58	10587	742.10	742.86	743.11	743.47	743.73	743.88	744.05	744.14	744.38	744.55	744.65	744.76	744.83
XS-57	10268	741.66	742.46	742.71	743.07	743.33	743.47	743.63	743.73	743.96	744.12	744.22	744.33	744.40
XS-56	10016	741.38	742.13	742.37	742.72	742.98	743.12	743.28	743.38	743.62	743.80	743.90	744.01	744.09
XS-55	9847	741.23	741.94	742.19	742.54	742.80	742.94	743.10	743.20	743.43	743.60	743.70	743.82	743.89
XS-54	9800	741.18	741.90	742.14	742.50	742.75	742.89	743.05	743.14	743.37	743.54	743.64	743.75	743.82
XS-53	9778	741.09	741.84	742.07	742.42	742.68	742.81	742.96	743.06	743.28	743.45	743.54	743.65	743.72
XS-52	9770	741.07	741.81	742.05	742.41	742.67	742.80	742.96	743.05	743.28	743.45	743.54	743.65	743.72
XS-51	9763	741.04	741.80	742.04	742.40	742.65	742.79	742.94	743.03	743.25	743.41	743.50	743.61	743.68
XS-50	9749	740.96	741.76	742.01	742.37	742.63	742.76	742.91	743.00	743.22	743.38	743.46	743.57	743.63
XS-49	9675	740.78	741.61	741.87	742.24	742.51	742.65	742.80	742.89	743.11	743.27	743.35	743.46	743.52
XS-48	9485	740.50	741.37	741.66	742.05	742.33	742.46	742.61	742.70	742.91	743.07	743.16	743.26	743.32

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Classification: Public

Table E-6 Pipestone Creek flood frequency water surface elevation (Continued)

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-47	9112	740.17	741.05	741.36	741.77	742.07	742.19	742.34	742.42	742.63	742.78	742.87	742.97	743.04
XS-46	8909	739.92	740.71	741.03	741.46	741.80	741.92	742.06	742.14	742.34	742.49	742.58	742.68	742.74
XS-45	8804	739.78	740.59	740.92	741.35	741.65	741.78	741.92	742.01	742.21	742.37	742.46	742.56	742.62
XS-44	8453	739.53	740.37	740.70	741.10	741.35	741.48	741.62	741.71	741.91	742.07	742.16	742.26	742.32
XS-43	8378	739.48	740.31	740.64	741.05	741.29	741.42	741.56	741.64	741.84	742.00	742.08	742.18	742.24
XS-42	8373	739.48	740.30	740.61	741.02	741.26	741.39	741.53	741.62	741.82	741.98	742.06	742.16	742.22
XS-41	8210	739.31	740.12	740.42	740.82	741.06	741.19	741.34	741.42	741.63	741.79	741.87	741.97	742.03
XS-40	8063	739.17	739.97	740.27	740.66	740.89	741.01	741.15	741.23	741.42	741.57	741.65	741.74	741.80
XS-39	7910	739.05	739.85	740.15	740.54	740.76	740.87	741.00	741.07	741.25	741.38	741.46	741.54	741.60
XS-38	7906	739.04	739.85	740.14	740.53	740.74	740.85	740.97	741.04	741.22	741.35	741.42	741.50	741.55
XS-37	7837	739.00	739.79	740.09	740.48	740.70	740.80	740.92	740.99	741.17	741.30	741.37	741.45	741.50
XS-36	7817	738.99	739.77	740.07	740.47	740.68	740.79	740.90	740.98	741.16	741.29	741.36	741.44	741.50
XS-35	7815	738.99	739.77	740.07	740.46	740.67	740.78	740.90	740.97	741.15	741.28	741.35	741.43	741.49
XS-34	7441	738.54	739.33	739.65	740.07	740.32	740.44	740.57	740.65	740.85	740.99	741.07	741.17	741.22
XS-33	7250	738.35	739.15	739.48	739.89	740.14	740.25	740.38	740.46	740.65	740.80	740.88	740.97	741.02
XS-32	6997	738.12	738.94	739.25	739.63	739.86	739.97	740.09	740.17	740.36	740.51	740.59	740.68	740.73
XS-31	6783	737.89	738.72	739.02	739.40	739.62	739.74	739.88	739.96	740.17	740.32	740.40	740.49	740.55
XS-30	6614	737.72	738.55	738.84	739.23	739.44	739.55	739.68	739.76	739.97	740.14	740.22	740.33	740.39
XS-29	6591	737.70	738.53	738.82	739.20	739.42	739.53	739.66	739.74	739.95	740.12	740.21	740.31	740.37
XS-28	6573	737.68	738.50	738.77	739.15	739.37	739.48	739.61	739.69	739.87	740.01	740.08	740.17	740.23
XS-27	6525	737.65	738.46	738.73	739.11	739.33	739.45	739.58	739.66	739.84	739.98	740.06	740.15	740.21
XS-26	6348	737.48	738.22	738.50	738.92	739.15	739.28	739.42	739.50	739.69	739.83	739.90	739.99	740.05
XS-25	6344	737.48	738.22	738.49	738.88	739.12	739.24	739.39	739.47	739.65	739.79	739.87	739.95	740.01
XS-24	6266	737.38	738.10	738.37	738.75	739.00	739.13	739.27	739.35	739.54	739.67	739.75	739.84	739.90

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Classification: Public

Table E-6 Pipestone Creek flood frequency water surface elevation (Continued)

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-23	6129	737.24	737.96	738.23	738.60	738.84	738.97	739.10	739.18	739.37	739.51	739.58	739.67	739.73
XS-22	5851	736.95	737.68	737.94	738.29	738.53	738.66	738.80	738.88	739.07	739.20	739.27	739.36	739.42
XS-21	5391	736.40	737.09	737.31	737.62	737.84	737.96	738.10	738.18	738.38	738.53	738.61	738.70	738.75
XS-20	5203	736.20	736.84	737.06	737.36	737.58	737.71	737.85	737.94	738.15	738.31	738.40	738.50	738.55
XS-19	4985	735.82	736.46	736.69	737.01	737.23	737.36	737.51	737.60	737.82	738.00	738.09	738.20	738.26
XS-18	4676	735.16	735.75	735.97	736.30	736.55	736.69	736.85	736.94	737.17	737.39	737.48	737.58	737.64
XS-17	4508	734.72	735.34	735.59	735.97	736.27	736.43	736.60	736.69	736.93	737.13	737.22	737.33	737.40
XS-16	4203	733.90	734.70	735.00	735.43	735.74	735.90	736.07	736.16	736.38	736.54	736.63	736.74	736.80
XS-15	3876	733.53	734.34	734.63	735.02	735.27	735.40	735.55	735.63	735.83	735.97	736.05	736.14	736.19
XS-14	3689	733.41	734.20	734.47	734.84	735.07	735.19	735.32	735.40	735.58	735.71	735.78	735.86	735.91
XS-13	3483	733.24	734.02	734.28	734.64	734.87	734.99	735.12	735.20	735.38	735.51	735.58	735.66	735.71
XS-12	3191	732.89	733.72	733.98	734.33	734.54	734.65	734.77	734.84	735.01	735.14	735.20	735.27	735.32
XS-11	2935	732.55	733.39	733.65	733.97	734.15	734.23	734.32	734.38	734.51	734.61	734.66	734.72	734.76
XS-10	2744	732.32	733.11	733.35	733.63	733.80	733.88	733.98	734.03	734.16	734.26	734.31	734.37	734.41
XS-9	2500	732.07	732.84	733.07	733.36	733.52	733.61	733.70	733.76	733.89	733.99	734.04	734.11	734.15
XS-8	2197	731.84	732.59	732.84	733.14	733.30	733.38	733.48	733.54	733.67	733.77	733.81	733.87	733.91
XS-7	2015	731.71	732.47	732.73	733.02	733.19	733.27	733.38	733.44	733.57	733.67	733.72	733.77	733.81
XS-6	1386	730.85	731.81	732.05	732.34	732.52	732.62	732.76	732.83	732.97	733.05	733.09	733.13	733.18
XS-5	813	729.95	730.75	730.98	731.30	731.52	731.64	731.79	731.87	732.07	732.21	732.30	732.41	732.46
XS-4	337	729.55	730.20	730.41	730.72	730.94	731.07	731.22	731.30	731.53	731.71	731.83	731.96	732.02
XS-3	100	729.33	729.97	730.15	730.42	730.62	730.74	730.88	730.95	731.18	731.35	731.45	731.61	731.70
XS-2	88	729.18	729.84	730.02	730.31	730.52	730.64	730.79	730.86	731.07	731.20	731.28	731.36	731.42
XS-1	0	729.08	729.73	729.91	730.19	730.39	730.51	730.66	730.73	730.94	731.07	731.15	731.23	731.28

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Classification: Public

Table E-7 Eyot Creek flood frequency water surface elevation

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-160	4195	748.26	748.64	748.71	748.81	748.88	748.93	748.97	749.01	749.11	749.21	749.28	749.37	749.44
XS-159	4036	748.16	748.53	748.62	748.72	748.79	748.84	748.89	748.93	749.05	749.16	749.24	749.34	749.41
XS-158	3890	748.10	748.45	748.54	748.65	748.72	748.77	748.83	748.87	749.00	749.13	749.21	749.31	749.39
XS-157	3750	748.04	748.39	748.47	748.58	748.65	748.70	748.76	748.80	748.95	749.09	749.18	749.29	749.37
XS-156	3569	747.96	748.29	748.35	748.45	748.53	748.59	748.66	748.72	748.90	749.06	749.15	749.27	749.35
XS-155	3333	747.82	748.21	748.28	748.40	748.49	748.56	748.63	748.70	748.88	749.04	749.14	749.26	749.34
XS-154	3133	747.72	748.13	748.22	748.35	748.45	748.52	748.60	748.67	748.87	749.03	749.13	749.25	749.33
XS-153	3118	747.72	748.13	748.22	748.35	748.45	748.52	748.60	748.67	748.87	749.03	749.13	749.25	749.33
XS-152	2859	747.59	747.99	748.08	748.24	748.37	748.46	748.55	748.64	748.85	749.02	749.12	749.24	749.32
XS-151	2684	747.51	747.91	748.02	748.21	748.35	748.44	748.54	748.62	748.84	749.01	749.12	749.24	749.32
XS-150	2476	747.39	747.80	747.94	748.16	748.32	748.41	748.52	748.61	748.83	749.01	749.11	749.23	749.32
XS-149	2348	747.31	747.72	747.87	748.12	748.29	748.39	748.50	748.59	748.82	749.00	749.10	749.23	749.31
XS-148	2201	747.23	747.65	747.83	748.09	748.27	748.37	748.49	748.58	748.82	749.00	749.10	749.22	749.31
XS-147	1958	747.15	747.61	747.81	748.08	748.26	748.36	748.48	748.57	748.81	748.99	749.09	749.22	749.30
XS-146	1787	747.09	747.60	747.80	748.08	748.26	748.36	748.48	748.57	748.81	748.99	749.09	749.22	749.30
XS-145	1629	747.04	747.58	747.79	748.07	748.25	748.35	748.47	748.56	748.80	748.98	749.09	749.21	749.30
XS-144	1498	746.98	747.53	747.76	748.04	748.23	748.33	748.45	748.55	748.79	748.98	749.08	749.21	749.29
XS-143	1457	746.96	747.52	747.74	748.03	748.21	748.32	748.44	748.53	748.78	748.96	749.07	749.19	749.28
XS-142	1418	746.94	747.50	747.73	748.01	748.20	748.30	748.42	748.52	748.76	748.94	749.05	749.17	749.26
XS-141	1409	746.92	747.47	747.67	747.93	748.08	748.17	748.27	748.35	748.56	748.72	748.81	748.91	748.98
XS-140	1394	746.91	747.45	747.65	747.91	748.06	748.15	748.23	748.29	748.41	748.50	748.54	748.58	748.61
XS-139	1354	746.87	747.43	747.64	747.90	748.06	748.15	748.24	748.31	748.44	748.54	748.59	748.65	748.68
XS-138	1233	746.75	747.34	747.54	747.82	747.98	748.07	748.17	748.24	748.37	748.47	748.52	748.57	748.60
XS-137	1217	746.74	747.33	747.53	747.81	747.97	748.06	748.15	748.22	748.36	748.46	748.51	748.56	748.59

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Classification: Public

Table E-7 Eyot Creek flood frequency water surface elevation (Continued)

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-136	1213	746.73	747.32	747.53	747.80	747.97	748.06	748.15	748.22	748.35	748.45	748.50	748.55	748.58
XS-135	1182	746.72	747.31	747.51	747.78	747.95	748.04	748.13	748.20	748.33	748.43	748.48	748.53	748.56
XS-134	1136	746.69	747.28	747.47	747.74	747.91	748.00	748.10	748.17	748.30	748.40	748.45	748.50	748.53
XS-133	1002	746.50	747.10	747.28	747.51	747.67	747.75	747.84	747.91	748.04	748.13	748.19	748.25	748.29
XS-132	901	746.39	746.98	747.15	747.36	747.49	747.57	747.66	747.72	747.85	747.95	748.00	748.07	748.12
XS-131	790	746.34	746.89	747.07	747.27	747.40	747.48	747.57	747.62	747.76	747.86	747.92	747.99	748.04
XS-130	751	746.32	746.85	747.02	747.22	747.34	747.42	747.50	747.56	747.71	747.82	747.89	747.96	748.01
XS-129	747	746.32	746.84	747.02	747.21	747.33	747.41	747.49	747.55	747.69	747.80	747.87	747.95	748.00
XS-128	721	746.28	746.80	746.97	747.16	747.29	747.37	747.46	747.52	747.66	747.78	747.85	747.93	747.98
XS-127	616	746.07	746.61	746.78	747.00	747.16	747.26	747.37	747.44	747.61	747.74	747.81	747.89	747.95
XS-126	446	745.74	746.35	746.54	746.83	747.02	747.13	747.25	747.33	747.51	747.65	747.72	747.81	747.87
XS-125	415	745.67	746.29	746.48	746.77	746.96	747.07	747.19	747.26	747.44	747.57	747.65	747.74	747.79
XS-124	396	745.62	746.25	746.43	746.71	746.90	747.00	747.12	747.19	747.37	747.50	747.57	747.65	747.71
XS-123	357	745.53	746.17	746.34	746.62	746.81	746.92	747.04	747.11	747.29	747.42	747.49	747.58	747.64
XS-122	284	745.37	746.04	746.21	746.49	746.70	746.81	746.94	747.01	747.20	747.33	747.40	747.48	747.54
XS-121	133	745.20	745.88	746.11	746.44	746.66	746.78	746.92	747.00	747.19	747.32	747.39	747.48	747.54
XS-120	33	745.11	745.83	746.07	746.43	746.65	746.77	746.91	746.99	747.18	747.31	747.38	747.47	747.53

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Table E-8 Snake Drain flood frequency water surface elevation

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-186	1530	764.28	764.31	764.33	764.36	764.38	764.39	764.40	764.41	764.43	764.45	764.46	764.47	764.48
XS-185	1462	764.00	764.05	764.07	764.10	764.12	764.13	764.15	764.16	764.18	764.21	764.22	764.23	764.24
XS-184	1375	763.66	763.70	763.72	763.76	763.78	763.80	763.82	763.83	763.86	763.88	763.90	763.92	763.92
XS-183	1233	762.89	763.01	763.06	763.11	763.14	763.15	763.17	763.19	763.22	763.25	763.27	763.28	763.30
XS-182	1129	762.41	762.45	762.47	762.51	762.55	762.57	762.60	762.61	762.65	762.67	762.69	762.71	762.72
XS-181	1124	762.16	762.38	762.44	762.51	762.55	762.56	762.59	762.61	762.64	762.66	762.68	762.70	762.71
XS-180	997	759.31	759.37	759.44	759.47	759.49	759.50	759.52	759.52	759.54	759.56	759.56	759.57	759.59
XS-179	785	756.07	756.15	756.19	756.23	756.27	756.29	756.32	756.33	756.36	756.38	756.40	756.41	756.42
XS-178	689	754.88	755.29	755.31*	755.31*	755.31	755.31	755.32	755.32	755.34	755.35	755.36	755.36	755.37
XS-177	548	752.87	753.06	753.14	753.27	753.38	753.43	753.53	753.60	753.68	753.74	753.77	753.79	753.81
XS-176	481	752.45	752.66	752.87	753.05	753.20	753.27	753.41	753.49	753.58	753.63	753.65	753.67	753.68
XS-175	463	751.81	751.92	751.96	752.03	752.09	752.11	752.15	752.17	752.22	752.27	752.29	752.32	752.34
XS-174	419	751.60	751.72	751.79	751.87	751.93	751.95	752.00	752.02	752.07	752.13	752.15	752.17	752.19
XS-173	322	751.33	751.44	751.50	751.59	751.64	751.67	751.72	751.74	751.79	751.85	751.87	751.90	751.91
XS-172	295	751.22	751.36	751.43	751.52	751.57	751.60	751.65	751.67	751.72	751.77	751.80	751.83	751.84
XS-171	290	751.19	751.32	751.35	751.42	751.45	751.46	751.49	751.50	751.53	751.57	751.59	751.61	751.62
XS-170	284	751.04	751.16	751.25	751.29	751.32	751.34	751.37	751.39	751.42	751.45	751.46	751.48	751.49
XS-169	282	750.40	750.51	750.57	750.64	750.69	750.71	750.76	750.78	750.83	750.87	750.90	750.92	750.94
XS-168	211	749.98	750.07	750.12	750.17	750.20	750.22	750.25	750.26	750.29	750.31	750.32	750.34	750.34
XS-167	206	749.82	749.92	750.01	750.04	750.07	750.09	750.11	750.12	750.15	750.18	750.20	750.21	750.22
XS-166	205	749.22	749.30	749.35	749.42	749.47	749.50	749.54	749.57	749.62	749.67	749.67	749.67*	749.67
XS-165	140	748.66	748.75	748.80	748.86	748.89	748.91	748.93	748.95	748.98	749.00	749.07	749.19	749.28
XS-164	134	748.49	748.57	748.65	748.72	748.77	748.78	748.81	748.82	748.85	748.95	749.07	749.20	749.29
XS-163	133	748.21	748.32	748.39	748.46	748.52	748.56	748.62	748.67	748.84	749.00	749.10	749.22	749.30

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Classification: Public

Table E-8 Snake Drain flood frequency water surface elevation (Continued)

Cross Section Number	River Station (m)	Flood Return Period												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		Water Surface Elevation (m)												
XS-162	93	748.10	748.22	748.28	748.30	748.38	748.44	748.51	748.58	748.80	748.98	749.08	749.21	749.29
XS-161	40	747.66	747.74	747.81	748.02	748.22	748.33	748.46	748.55	748.79	748.98	749.08	749.21	749.29

Note: * indicates values that have been manually adjusted to eliminate the crossing profiles.

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APPENDIX F

SENSITIVITY ANALYSIS RESULTS

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Classification: Public

Table F-1 Sensitivity analysis results for flood frequency estimates

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
		Eyot Creek		
XS-160	4,195	748.95	749.01	749.10
XS-159	4,036	748.87	748.93	749.04
XS-158	3,890	748.80	748.87	748.99
XS-157	3,750	748.73	748.80	748.94
XS-156	3,569	748.63	748.72	748.89
XS-155	3,333	748.59	748.70	748.87
XS-154	3,133	748.56	748.67	748.86
XS-153	3,118	748.56	748.67	748.86
XS-152	2,859	748.51	748.64	748.84
XS-151	2,684	748.49	748.62	748.83
XS-150	2,476	748.47	748.61	748.82
XS-149	2,348	748.44	748.59	748.81
XS-148	2,201	748.43	748.58	748.80
XS-147	1,958	748.42	748.57	748.80
XS-146	1,787	748.42	748.57	748.80
XS-145	1,629	748.41	748.56	748.79
XS-144	1,498	748.39	748.55	748.78
XS-143	1,457	748.38	748.53	748.77
XS-142	1,418	748.36	748.52	748.75
XS-141	1,409	748.22	748.35	748.55
XS-140	1,394	748.19	748.29	748.40
XS-139	1,354	748.20	748.31	748.44
XS-138	1,233	748.12	748.24	748.36
XS-137	1,217	748.11	748.22	748.35
XS-136	1,213	748.11	748.22	748.34
XS-135	1,182	748.09	748.20	748.33
XS-134	1,136	748.05	748.17	748.29
XS-133	1,002	747.80	747.91	748.04

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Table F-1 Sensitivity analysis results for flood frequency estimates (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
		Eyot Creek		
XS-132	901	747.62	747.72	747.84
XS-131	790	747.53	747.62	747.75
XS-130	751	747.46	747.56	747.70
XS-129	747	747.45	747.55	747.68
XS-128	721	747.41	747.52	747.66
XS-127	616	747.32	747.44	747.60
XS-126	446	747.20	747.33	747.50
XS-125	415	747.13	747.26	747.43
XS-124	396	747.06	747.19	747.36
XS-123	357	746.98	747.11	747.28
XS-122	284	746.87	747.01	747.19
XS-121	133	746.85	747.00	747.18
XS-120	33	746.84	746.99	747.17
Average Difference		-0.12	0.00	0.17
Maximum Difference		-0.16	0.00	0.24
		Pipestone Creek		
XS-119	18,427	761.48	761.59	761.73
XS-118	18,365	761.43	761.54	761.67
XS-117	18,348	761.39	761.49	761.62
XS-116	18,214	761.26	761.36	761.48
XS-115	18,060	761.15	761.26	761.40
XS-114	17,834	760.99	761.10	761.26
XS-113	17,716	760.84	760.94	761.08
XS-112	17,700	760.81	760.91	761.04
XS-111	17,551	760.54	760.63	760.75
XS-110	17,399	760.15	760.27	760.40
XS-109	17,157	759.33	759.42	759.54
XS-108	17,034	759.06	759.16	759.27

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Table F-1 Sensitivity analysis results for flood frequency estimates (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Pipestone Creek				
XS-107	16,728	758.19	758.29	758.44
XS-106	16,576	757.64	757.73	757.85
XS-105	16,425	757.12	757.20	757.30
XS-104	16,276	756.50	756.59	756.68
XS-103	16,042	755.66	755.76	755.88
XS-102	15,867	755.13	755.26	755.43
XS-101	15,806	754.78	754.91	755.07
XS-100	15,800	754.72	754.85	755.00
XS-99	15,626	754.01	754.04	754.06
XS-98	15,252	752.72	752.86	753.08
XS-97	15,107	752.37	752.57	752.89
XS-96	14,948	752.22	752.48	752.83
XS-95	14,799	752.17	752.45	752.81
XS-94	14,507	752.11	752.39	752.76
XS-93	14,486	752.08	752.37	752.74
XS-92	14,445	750.00	750.08	750.18
XS-91	14,391	749.64	749.74	749.86
XS-90	14,165	749.26	749.36	749.47
XS-89	14,052	749.06	749.16	749.28
XS-88	13,841	748.60	748.70	748.83
XS-87	13,695	748.25	748.34	748.46
XS-86	13,516	747.72	747.83	747.95
XS-85	13,325	747.36	747.45	747.57
XS-84	13,310	747.31	747.40	747.51
XS-83	13,305	747.30	747.38	747.50
XS-82	13,248	747.19	747.28	747.40
XS-81	12,982	746.93	747.07	747.24
XS-80	12,869	746.92	747.06	747.23

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Table F-1 Sensitivity analysis results for flood frequency estimates (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
		Pipestone Creek		
XS-79	12,774	746.91	747.05	747.22
XS-78	12,679	746.88	747.02	747.20
XS-77	12,673	746.88	747.01	747.19
XS-76	12,619	746.86	747.00	747.18
XS-75	12,558	746.85	746.99	747.17
XS-74	12,491	746.84	746.98	747.16
XS-73	12,464	746.83	746.98	747.16
XS-72	12,399	746.81	746.96	747.14
XS-71	12,397	746.81	746.96	747.14
XS-70	12,326	746.73	746.88	747.05
XS-69	12,153	746.47	746.61	746.78
XS-68	12,040	746.26	746.41	746.59
XS-67	11,932	746.14	746.29	746.47
XS-66	11,928	746.11	746.26	746.44
XS-65	11,871	746.00	746.15	746.33
XS-64	11,673	745.72	745.87	746.04
XS-63	11,524	745.37	745.52	745.71
XS-62	11,341	745.11	745.26	745.46
XS-61	11,173	744.90	745.05	745.24
XS-60	10,928	744.43	744.59	744.79
XS-59	10,738	744.12	744.29	744.51
XS-58	10,587	743.96	744.14	744.36
XS-57	10,268	743.56	743.73	743.94
XS-56	10,016	743.21	743.38	743.60
XS-55	9,847	743.02	743.20	743.42
XS-54	9,800	742.97	743.14	743.36
XS-53	9,778	742.89	743.06	743.27
XS-52	9,770	742.88	743.05	743.27

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Table F-1 Sensitivity analysis results for flood frequency estimates (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Pipestone Creek				
XS-51	9,763	742.86	743.03	743.24
XS-50	9,749	742.83	743.00	743.20
XS-49	9,675	742.72	742.89	743.10
XS-48	9,485	742.54	742.70	742.90
XS-47	9,112	742.27	742.42	742.62
XS-46	8,909	741.99	742.14	742.32
XS-45	8,804	741.86	742.01	742.20
XS-44	8,453	741.55	741.71	741.90
XS-43	8,378	741.49	741.64	741.83
XS-42	8,373	741.46	741.62	741.81
XS-41	8,210	741.26	741.42	741.62
XS-40	8,063	741.08	741.23	741.41
XS-39	7,910	740.94	741.07	741.24
XS-38	7,906	740.91	741.04	741.21
XS-37	7,837	740.86	740.99	741.15
XS-36	7,817	740.85	740.98	741.15
XS-35	7,815	740.84	740.97	741.14
XS-34	7,441	740.51	740.65	740.84
XS-33	7,250	740.32	740.46	740.64
XS-32	6,997	740.03	740.17	740.35
XS-31	6,783	739.81	739.96	740.16
XS-30	6,614	739.62	739.76	739.96
XS-29	6,591	739.60	739.74	739.94
XS-28	6,573	739.55	739.69	739.86
XS-27	6,525	739.51	739.66	739.83
XS-26	6,348	739.35	739.50	739.68
XS-25	6,344	739.32	739.47	739.64
XS-24	6,266	739.20	739.35	739.52

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Table F-1 Sensitivity analysis results for flood frequency estimates (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Pipestone Creek				
XS-23	6,129	739.04	739.18	739.36
XS-22	5,851	738.74	738.88	739.05
XS-21	5,391	738.03	738.18	738.37
XS-20	5,203	737.78	737.94	738.14
XS-19	4,985	737.44	737.60	737.81
XS-18	4,676	736.77	736.94	737.16
XS-17	4,508	736.52	736.69	736.91
XS-16	4,203	735.99	736.16	736.37
XS-15	3,876	735.48	735.63	735.81
XS-14	3,689	735.26	735.40	735.57
XS-13	3,483	735.06	735.20	735.37
XS-12	3,191	734.71	734.84	735.00
XS-11	2,935	734.28	734.38	734.51
XS-10	2,744	733.93	734.03	734.16
XS-9	2,500	733.66	733.76	733.89
XS-8	2,197	733.43	733.54	733.66
XS-7	2,015	733.33	733.44	733.56
XS-6	1,386	732.69	732.83	732.96
XS-5	813	731.71	731.87	732.06
XS-4	337	731.15	731.30	731.52
XS-3	100	730.82	730.95	731.17
XS-2	88	730.72	730.86	731.06
XS-1	0	730.59	730.73	730.93
Average Difference		-0.14	0.00	0.18
Maximum Difference		-0.29	0.00	0.37
Snake Drain				
XS-186	1,530	764.40	764.41	764.43
XS-185	1,462	764.14	764.16	764.18

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Table F-1 Sensitivity analysis results for flood frequency estimates (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
		95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
		Snake Drain		
XS-184	1,375	763.81	763.83	763.86
XS-183	1,233	763.16	763.19	763.22
XS-182	1,129	762.59	762.61	762.65
XS-181	1,124	762.58	762.61	762.64
XS-180	997	759.52	759.52	759.54
XS-179	785	756.30	756.33	756.36
XS-178	689	755.31	755.32	755.34
XS-177	548	753.48	753.60	753.68
XS-176	481	753.34	753.49	753.58
XS-175	463	752.13	752.17	752.22
XS-174	419	751.98	752.02	752.07
XS-173	322	751.69	751.74	751.79
XS-172	295	751.62	751.67	751.72
XS-171	290	751.48	751.50	751.53
XS-170	284	751.36	751.39	751.42
XS-169	282	750.74	750.78	750.83
XS-168	211	750.23	750.26	750.29
XS-167	206	750.10	750.12	750.15
XS-166	205	749.52	749.57	749.62
XS-165	140	748.92	748.95	748.98
XS-164	134	748.79	748.82	748.85
XS-163	133	748.59	748.67	748.83
XS-162	93	748.47	748.58	748.78
XS-161	40	748.39	748.55	748.78
Average Difference		-0.05	0.00	0.06
Maximum Difference		-0.16	0.00	0.23

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Classification: Public

Table F-2 Sensitivity analysis results for downstream boundary conditions

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
		Eyot Creek		
XS-160	4,195	749.01	749.01	749.01
XS-159	4,036	748.93	748.93	748.93
XS-158	3,890	748.87	748.87	748.87
XS-157	3,750	748.80	748.80	748.80
XS-156	3,569	748.72	748.72	748.72
XS-155	3,333	748.70	748.70	748.70
XS-154	3,133	748.67	748.67	748.67
XS-153	3,118	748.67	748.67	748.67
XS-152	2,859	748.64	748.64	748.64
XS-151	2,684	748.62	748.62	748.62
XS-150	2,476	748.61	748.61	748.61
XS-149	2,348	748.59	748.59	748.59
XS-148	2,201	748.58	748.58	748.58
XS-147	1,958	748.57	748.57	748.57
XS-146	1,787	748.57	748.57	748.57
XS-145	1,629	748.56	748.56	748.56
XS-144	1,498	748.55	748.55	748.55
XS-143	1,457	748.53	748.53	748.53
XS-142	1,418	748.52	748.52	748.52
XS-141	1,409	748.35	748.35	748.35
XS-140	1,394	748.29	748.29	748.29
XS-139	1,354	748.31	748.31	748.31
XS-138	1,233	748.24	748.24	748.24
XS-137	1,217	748.22	748.22	748.22
XS-136	1,213	748.22	748.22	748.22
XS-135	1,182	748.20	748.20	748.20
XS-134	1,136	748.17	748.17	748.17
XS-133	1,002	747.91	747.91	747.91

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Table F-2 Sensitivity analysis results for downstream boundary conditions (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
		Eyot Creek		
XS-132	901	747.72	747.72	747.72
XS-131	790	747.62	747.62	747.62
XS-130	751	747.56	747.56	747.56
XS-129	747	747.55	747.55	747.55
XS-128	721	747.52	747.52	747.52
XS-127	616	747.44	747.44	747.44
XS-126	446	747.33	747.33	747.33
XS-125	415	747.26	747.26	747.26
XS-124	396	747.19	747.19	747.19
XS-123	357	747.11	747.11	747.11
XS-122	284	747.01	747.01	747.01
XS-121	133	747.00	747.00	747.00
XS-120	33	746.99	746.99	746.99
Average Difference		0.00	0.00	0.00
Maximum Difference		0.00	0.00	0.00
		Pipestone Creek		
XS-119	18,427	761.59	761.59	761.59
XS-118	18,365	761.54	761.54	761.54
XS-117	18,348	761.49	761.49	761.49
XS-116	18,214	761.36	761.36	761.36
XS-115	18,060	761.26	761.26	761.26
XS-114	17,834	761.10	761.10	761.10
XS-113	17,716	760.94	760.94	760.94
XS-112	17,700	760.91	760.91	760.91
XS-111	17,551	760.63	760.63	760.63
XS-110	17,399	760.27	760.27	760.27
XS-109	17,157	759.42	759.42	759.42
XS-108	17,034	759.16	759.16	759.16

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Classification: Public

Table F-2 Sensitivity analysis results for downstream boundary conditions (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
		Pipestone Creek		
XS-107	16,728	758.29	758.29	758.29
XS-106	16,576	757.73	757.73	757.73
XS-105	16,425	757.20	757.20	757.20
XS-104	16,276	756.59	756.59	756.59
XS-103	16,042	755.76	755.76	755.76
XS-102	15,867	755.26	755.26	755.26
XS-101	15,806	754.91	754.91	754.91
XS-100	15,800	754.85	754.85	754.85
XS-99	15,626	754.04	754.04	754.04
XS-98	15,252	752.86	752.86	752.86
XS-97	15,107	752.57	752.57	752.57
XS-96	14,948	752.48	752.48	752.48
XS-95	14,799	752.45	752.45	752.45
XS-94	14,507	752.39	752.39	752.39
XS-93	14,486	752.37	752.37	752.37
XS-92	14,445	750.08	750.08	750.08
XS-91	14,391	749.74	749.74	749.74
XS-90	14,165	749.36	749.36	749.36
XS-89	14,052	749.16	749.16	749.16
XS-88	13,841	748.70	748.70	748.70
XS-87	13,695	748.34	748.34	748.34
XS-86	13,516	747.83	747.83	747.83
XS-85	13,325	747.45	747.45	747.45
XS-84	13,310	747.40	747.40	747.40
XS-83	13,305	747.38	747.38	747.38
XS-82	13,248	747.28	747.28	747.28
XS-81	12,982	747.07	747.07	747.07
XS-80	12,869	747.06	747.06	747.06

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Classification: Public

Table F-2 Sensitivity analysis results for downstream boundary conditions (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
Pipestone Creek				
XS-79	12,774	747.05	747.05	747.05
XS-78	12,679	747.02	747.02	747.02
XS-77	12,673	747.01	747.01	747.01
XS-76	12,619	747.00	747.00	747.00
XS-75	12,558	746.99	746.99	746.99
XS-74	12,491	746.98	746.98	746.98
XS-73	12,464	746.98	746.98	746.98
XS-72	12,399	746.96	746.96	746.96
XS-71	12,397	746.96	746.96	746.96
XS-70	12,326	746.88	746.88	746.88
XS-69	12,153	746.61	746.61	746.61
XS-68	12,040	746.41	746.41	746.41
XS-67	11,932	746.29	746.29	746.29
XS-66	11,928	746.26	746.26	746.26
XS-65	11,871	746.15	746.15	746.15
XS-64	11,673	745.87	745.87	745.87
XS-63	11,524	745.52	745.52	745.52
XS-62	11,341	745.26	745.26	745.26
XS-61	11,173	745.05	745.05	745.05
XS-60	10,928	744.59	744.59	744.59
XS-59	10,738	744.29	744.29	744.29
XS-58	10,587	744.14	744.14	744.14
XS-57	10,268	743.73	743.73	743.73
XS-56	10,016	743.38	743.38	743.38
XS-55	9,847	743.20	743.20	743.20
XS-54	9,800	743.14	743.14	743.14
XS-53	9,778	743.06	743.06	743.06
XS-52	9,770	743.05	743.05	743.05

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Classification: Public

Table F-2 Sensitivity analysis results for downstream boundary conditions (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
		Pipestone Creek		
XS-51	9,763	743.03	743.03	743.03
XS-50	9,749	743.00	743.00	743.00
XS-49	9,675	742.89	742.89	742.89
XS-48	9,485	742.70	742.70	742.70
XS-47	9,112	742.42	742.42	742.42
XS-46	8,909	742.14	742.14	742.14
XS-45	8,804	742.01	742.01	742.01
XS-44	8,453	741.71	741.71	741.71
XS-43	8,378	741.64	741.64	741.64
XS-42	8,373	741.62	741.62	741.62
XS-41	8,210	741.42	741.42	741.42
XS-40	8,063	741.23	741.23	741.23
XS-39	7,910	741.07	741.07	741.07
XS-38	7,906	741.04	741.04	741.04
XS-37	7,837	740.99	740.99	740.99
XS-36	7,817	740.98	740.98	740.98
XS-35	7,815	740.97	740.97	740.97
XS-34	7,441	740.65	740.65	740.65
XS-33	7,250	740.46	740.46	740.46
XS-32	6,997	740.17	740.17	740.17
XS-31	6,783	739.96	739.96	739.96
XS-30	6,614	739.76	739.76	739.76
XS-29	6,591	739.74	739.74	739.74
XS-28	6,573	739.69	739.69	739.69
XS-27	6,525	739.66	739.66	739.66
XS-26	6,348	739.50	739.50	739.50
XS-25	6,344	739.47	739.47	739.47
XS-24	6,266	739.35	739.35	739.35

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Table F-2 Sensitivity analysis results for downstream boundary conditions (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
Pipestone Creek				
XS-23	6,129	739.18	739.18	739.18
XS-22	5,851	738.88	738.88	738.88
XS-21	5,391	738.18	738.18	738.18
XS-20	5,203	737.94	737.94	737.94
XS-19	4,985	737.60	737.60	737.60
XS-18	4,676	736.94	736.94	736.94
XS-17	4,508	736.69	736.69	736.69
XS-16	4,203	736.16	736.16	736.16
XS-15	3,876	735.63	735.63	735.63
XS-14	3,689	735.40	735.40	735.40
XS-13	3,483	735.20	735.20	735.20
XS-12	3,191	734.84	734.84	734.84
XS-11	2,935	734.38	734.38	734.38
XS-10	2,744	734.03	734.03	734.03
XS-9	2,500	733.76	733.76	733.76
XS-8	2,197	733.54	733.54	733.54
XS-7	2,015	733.44	733.44	733.44
XS-6	1,386	732.84	732.83	732.82
XS-5	813	731.84	731.87	731.92
XS-4	337	731.19	731.30	731.45
XS-3	100	730.75	730.95	731.19
XS-2	88	730.65	730.86	731.11
XS-1	0	730.43	730.73	731.03
Average Difference		-0.01	0.00	0.01
Maximum Difference		-0.30	0.00	0.30
Snake Drain				
XS-186	1,530	764.41	764.41	764.41
XS-185	1,462	764.16	764.16	764.16

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Table F-2 Sensitivity analysis results for downstream boundary conditions (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Downstream Conditions		
		0.3 m below Adopted W.S. (W. S. = 730.43 m)	Adopted W.S.=730.73 m	0.3 m above Adopted W.S. (W. S. = 731.03 m)
Snake Drain				
XS-184	1,375	763.83	763.83	763.83
XS-183	1,233	763.19	763.19	763.19
XS-182	1,129	762.61	762.61	762.61
XS-181	1,124	762.61	762.61	762.61
XS-180	997	759.52	759.52	759.52
XS-179	785	756.33	756.33	756.33
XS-178	689	755.32	755.32	755.32
XS-177	548	753.60	753.60	753.60
XS-176	481	753.49	753.49	753.49
XS-175	463	752.17	752.17	752.17
XS-174	419	752.02	752.02	752.02
XS-173	322	751.74	751.74	751.74
XS-172	295	751.67	751.67	751.67
XS-171	290	751.50	751.50	751.50
XS-170	284	751.39	751.39	751.39
XS-169	282	750.78	750.78	750.78
XS-168	211	750.26	750.26	750.26
XS-167	206	750.12	750.12	750.12
XS-166	205	749.57	749.57	749.57
XS-165	140	748.95	748.95	748.95
XS-164	134	748.82	748.82	748.82
XS-163	133	748.67	748.67	748.67
XS-162	93	748.58	748.58	748.58
XS-161	40	748.55	748.55	748.55
Average Difference		0.00	0.00	0.00
Maximum Difference		0.00	0.00	0.00

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Table F-3 Sensitivity analysis results for channel roughness values

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
		Eyot Creek		
XS-160	4,195	748.96	749.01	749.06
XS-159	4,036	748.87	748.93	749.00
XS-158	3,890	748.80	748.87	748.94
XS-157	3,750	748.73	748.80	748.90
XS-156	3,569	748.64	748.72	748.83
XS-155	3,333	748.60	748.70	748.82
XS-154	3,133	748.57	748.67	748.80
XS-153	3,118	748.56	748.67	748.80
XS-152	2,859	748.51	748.64	748.78
XS-151	2,684	748.49	748.62	748.77
XS-150	2,476	748.46	748.61	748.76
XS-149	2,348	748.44	748.59	748.76
XS-148	2,201	748.43	748.58	748.75
XS-147	1,958	748.42	748.57	748.74
XS-146	1,787	748.41	748.57	748.74
XS-145	1,629	748.40	748.56	748.74
XS-144	1,498	748.38	748.55	748.73
XS-143	1,457	748.37	748.53	748.71
XS-142	1,418	748.35	748.52	748.70
XS-141	1,409	748.15	748.35	748.55
XS-140	1,394	748.14	748.29	748.41
XS-139	1,354	748.16	748.31	748.42
XS-138	1,233	748.09	748.24	748.34
XS-137	1,217	748.08	748.22	748.33
XS-136	1,213	748.07	748.22	748.33
XS-135	1,182	748.06	748.20	748.31
XS-134	1,136	748.01	748.17	748.28
XS-133	1,002	747.74	747.91	748.04
XS-132	901	747.58	747.72	747.82

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Classification: Public

Table F-3 Sensitivity analysis results for channel roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Eyot Creek				
XS-131	790	747.51	747.62	747.72
XS-130	751	747.44	747.56	747.66
XS-129	747	747.43	747.55	747.64
XS-128	721	747.39	747.52	747.62
XS-127	616	747.30	747.44	747.55
XS-126	446	747.17	747.33	747.46
XS-125	415	747.09	747.26	747.40
XS-124	396	747.02	747.19	747.33
XS-123	357	746.94	747.11	747.25
XS-122	284	746.85	747.01	747.14
XS-121	133	746.84	747.00	747.12
XS-120	33	746.82	746.99	747.12
Average Difference		-0.14	0.00	0.13
Maximum Difference		-0.20	0.00	0.20
Pipestone Creek				
XS-119	18,427	761.45	761.59	761.71
XS-118	18,365	761.40	761.54	761.65
XS-117	18,348	761.35	761.49	761.60
XS-116	18,214	761.23	761.36	761.46
XS-115	18,060	761.12	761.26	761.37
XS-114	17,834	760.95	761.10	761.24
XS-113	17,716	760.80	760.94	761.07
XS-112	17,700	760.78	760.91	761.03
XS-111	17,551	760.49	760.63	760.74
XS-110	17,399	760.09	760.27	760.39
XS-109	17,157	759.25	759.42	759.57
XS-108	17,034	759.02	759.16	759.27
XS-107	16,728	758.12	758.29	758.45
XS-106	16,576	757.59	757.73	757.86

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Classification: Public

Table F-3 Sensitivity analysis results for channel roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
		Pipestone Creek		
XS-105	16,425	757.09	757.20	757.29
XS-104	16,276	756.45	756.59	756.69
XS-103	16,042	755.62	755.76	755.86
XS-102	15,867	755.11	755.26	755.39
XS-101	15,806	754.76	754.91	755.04
XS-100	15,800	754.69	754.85	754.98
XS-99	15,626	753.97	754.04	754.08
XS-98	15,252	752.75	752.86	752.97
XS-97	15,107	752.52	752.57	752.63
XS-96	14,948	752.45	752.48	752.50
XS-95	14,799	752.43	752.45	752.47
XS-94	14,507	752.39	752.39	752.39
XS-93	14,486	752.37	752.37	752.37
XS-92	14,445	749.96	750.08	750.18
XS-91	14,391	749.57	749.74	749.86
XS-90	14,165	749.24	749.36	749.45
XS-89	14,052	749.03	749.16	749.26
XS-88	13,841	748.55	748.70	748.83
XS-87	13,695	748.20	748.34	748.46
XS-86	13,516	747.68	747.83	747.94
XS-85	13,325	747.34	747.45	747.53
XS-84	13,310	747.29	747.40	747.48
XS-83	13,305	747.28	747.38	747.47
XS-82	13,248	747.18	747.28	747.35
XS-81	12,982	746.92	747.07	747.18
XS-80	12,869	746.92	747.06	747.17
XS-79	12,774	746.90	747.05	747.16
XS-78	12,679	746.86	747.02	747.14
XS-77	12,673	746.86	747.01	747.14

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Classification: Public

Table F-3 Sensitivity analysis results for channel roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Pipestone Creek				
XS-76	12,619	746.84	747.00	747.13
XS-75	12,558	746.83	746.99	747.12
XS-74	12,491	746.82	746.98	747.11
XS-73	12,464	746.81	746.98	747.11
XS-72	12,399	746.79	746.96	747.09
XS-71	12,397	746.78	746.96	747.09
XS-70	12,326	746.67	746.88	747.03
XS-69	12,153	746.42	746.61	746.75
XS-68	12,040	746.19	746.41	746.57
XS-67	11,932	746.09	746.29	746.45
XS-66	11,928	746.06	746.26	746.42
XS-65	11,871	745.93	746.15	746.32
XS-64	11,673	745.67	745.87	746.02
XS-63	11,524	745.28	745.52	745.70
XS-62	11,341	745.00	745.26	745.45
XS-61	11,173	744.78	745.05	745.24
XS-60	10,928	744.34	744.59	744.78
XS-59	10,738	744.04	744.29	744.49
XS-58	10,587	743.89	744.14	744.35
XS-57	10,268	743.48	743.73	743.93
XS-56	10,016	743.14	743.38	743.58
XS-55	9,847	742.96	743.20	743.39
XS-54	9,800	742.92	743.14	743.33
XS-53	9,778	742.83	743.06	743.25
XS-52	9,770	742.83	743.05	743.24
XS-51	9,763	742.80	743.03	743.22
XS-50	9,749	742.77	743.00	743.18
XS-49	9,675	742.65	742.89	743.08
XS-48	9,485	742.48	742.70	742.88

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Classification: Public

Table F-3 Sensitivity analysis results for channel roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
		Pipestone Creek		
XS-47	9,112	742.23	742.42	742.58
XS-46	8,909	741.93	742.14	742.31
XS-45	8,804	741.79	742.01	742.19
XS-44	8,453	741.49	741.71	741.89
XS-43	8,378	741.43	741.64	741.81
XS-42	8,373	741.40	741.62	741.79
XS-41	8,210	741.20	741.42	741.60
XS-40	8,063	741.03	741.23	741.39
XS-39	7,910	740.89	741.07	741.21
XS-38	7,906	740.86	741.04	741.18
XS-37	7,837	740.82	740.99	741.12
XS-36	7,817	740.81	740.98	741.11
XS-35	7,815	740.80	740.97	741.11
XS-34	7,441	740.44	740.65	740.83
XS-33	7,250	740.26	740.46	740.63
XS-32	6,997	739.98	740.17	740.33
XS-31	6,783	739.76	739.96	740.13
XS-30	6,614	739.57	739.76	739.94
XS-29	6,591	739.56	739.74	739.91
XS-28	6,573	739.51	739.69	739.83
XS-27	6,525	739.47	739.66	739.80
XS-26	6,348	739.30	739.50	739.66
XS-25	6,344	739.24	739.47	739.63
XS-24	6,266	739.12	739.35	739.52
XS-23	6,129	738.97	739.18	739.34
XS-22	5,851	738.67	738.88	739.04
XS-21	5,391	737.96	738.18	738.36
XS-20	5,203	737.71	737.94	738.12
XS-19	4,985	737.36	737.60	737.81

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Table F-3 Sensitivity analysis results for channel roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Pipestone Creek				
XS-18	4,676	736.69	736.94	737.15
XS-17	4,508	736.43	736.69	736.90
XS-16	4,203	735.88	736.16	736.38
XS-15	3,876	735.40	735.63	735.81
XS-14	3,689	735.19	735.40	735.56
XS-13	3,483	734.99	735.20	735.36
XS-12	3,191	734.65	734.84	735.00
XS-11	2,935	734.24	734.38	734.49
XS-10	2,744	733.90	734.03	734.12
XS-9	2,500	733.63	733.76	733.85
XS-8	2,197	733.41	733.54	733.62
XS-7	2,015	733.31	733.44	733.52
XS-6	1,386	732.63	732.83	732.95
XS-5	813	731.64	731.87	732.05
XS-4	337	731.08	731.30	731.51
XS-3	100	730.75	730.95	731.14
XS-2	88	730.65	730.86	731.04
XS-1	0	730.53	730.73	730.90
Average Difference		-0.18	0.00	0.14
Maximum Difference		-0.28	0.00	0.22
Snake Drain				
XS-186	1,530	764.40	764.41	764.43
XS-185	1,462	764.14	764.16	764.18
XS-184	1,375	763.80	763.83	763.87
XS-183	1,233	763.17	763.19	763.21
XS-182	1,129	762.57	762.61	762.64
XS-181	1,124	762.57	762.61	762.64
XS-180	997	759.52	759.52	759.52
XS-179	785	756.29	756.33	756.36

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Classification: Public

Table F-3 Sensitivity analysis results for channel roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness Values		
		Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Snake Drain				
XS-178	689	755.32	755.32	755.32
XS-177	548	753.56	753.60	753.64
XS-176	481	753.49	753.49	753.49
XS-175	463	752.11	752.17	752.23
XS-174	419	751.96	752.02	752.08
XS-173	322	751.71	751.74	751.78
XS-172	295	751.66	751.67	751.69
XS-171	290	751.48	751.50	751.56
XS-170	284	751.39	751.39	751.39
XS-169	282	750.73	750.78	750.83
XS-168	211	750.21	750.26	750.29
XS-167	206	750.12	750.12	750.12
XS-166	205	749.52	749.57	749.62
XS-165	140	748.89	748.95	748.99
XS-164	134	748.82	748.82	748.82
XS-163	133	748.58	748.67	748.80
XS-162	93	748.45	748.58	748.74
XS-161	40	748.38	748.55	748.73
Average Difference		-0.04	0.00	0.04
Maximum Difference		-0.17	0.00	0.18

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Classification: Public

Table F-4 Sensitivity analysis results for overbank roughness values

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
		Eyot Creek		
XS-160	4,195	748.97	749.01	749.05
XS-159	4,036	748.89	748.93	748.97
XS-158	3,890	748.83	748.87	748.90
XS-157	3,750	748.77	748.80	748.84
XS-156	3,569	748.68	748.72	748.76
XS-155	3,333	748.66	748.70	748.74
XS-154	3,133	748.63	748.67	748.71
XS-153	3,118	748.63	748.67	748.71
XS-152	2,859	748.60	748.64	748.67
XS-151	2,684	748.59	748.62	748.66
XS-150	2,476	748.58	748.61	748.64
XS-149	2,348	748.57	748.59	748.63
XS-148	2,201	748.56	748.58	748.61
XS-147	1,958	748.55	748.57	748.61
XS-146	1,787	748.55	748.57	748.60
XS-145	1,629	748.54	748.56	748.59
XS-144	1,498	748.53	748.55	748.58
XS-143	1,457	748.52	748.53	748.56
XS-142	1,418	748.50	748.52	748.54
XS-141	1,409	748.33	748.35	748.38
XS-140	1,394	748.27	748.29	748.31
XS-139	1,354	748.29	748.31	748.32
XS-138	1,233	748.22	748.24	748.25
XS-137	1,217	748.21	748.22	748.24
XS-136	1,213	748.20	748.22	748.23
XS-135	1,182	748.19	748.20	748.22
XS-134	1,136	748.15	748.17	748.18
XS-133	1,002	747.89	747.91	747.93
XS-132	901	747.69	747.72	747.74

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Classification: Public

Table F-4 Sensitivity analysis results for overbank roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
		Eyot Creek		
XS-131	790	747.59	747.62	747.65
XS-130	751	747.52	747.56	747.59
XS-129	747	747.51	747.55	747.58
XS-128	721	747.48	747.52	747.55
XS-127	616	747.40	747.44	747.48
XS-126	446	747.29	747.33	747.36
XS-125	415	747.22	747.26	747.30
XS-124	396	747.15	747.19	747.23
XS-123	357	747.07	747.11	747.15
XS-122	284	746.96	747.01	747.06
XS-121	133	746.95	747.00	747.04
XS-120	33	746.94	746.99	747.03
Average Difference		-0.03	0.00	0.03
Maximum Difference		-0.05	0.00	0.05
		Pipestone Creek		
XS-119	18,427	761.57	761.59	761.61
XS-118	18,365	761.51	761.54	761.56
XS-117	18,348	761.47	761.49	761.51
XS-116	18,214	761.33	761.36	761.38
XS-115	18,060	761.24	761.26	761.28
XS-114	17,834	761.09	761.10	761.12
XS-113	17,716	760.93	760.94	760.96
XS-112	17,700	760.89	760.91	760.93
XS-111	17,551	760.62	760.63	760.64
XS-110	17,399	760.26	760.27	760.27
XS-109	17,157	759.42	759.42	759.42
XS-108	17,034	759.15	759.16	759.16
XS-107	16,728	758.29	758.29	758.29
XS-106	16,576	757.73	757.73	757.73

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Classification: Public

Table F-4 Sensitivity analysis results for overbank roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
		Pipestone Creek		
XS-105	16,425	757.19	757.20	757.21
XS-104	16,276	756.59	756.59	756.59
XS-103	16,042	755.74	755.76	755.77
XS-102	15,867	755.25	755.26	755.26
XS-101	15,806	754.91	754.91	754.91
XS-100	15,800	754.84	754.85	754.85
XS-99	15,626	754.01	754.04	754.06
XS-98	15,252	752.85	752.86	752.88
XS-97	15,107	752.56	752.57	752.59
XS-96	14,948	752.47	752.48	752.48
XS-95	14,799	752.44	752.45	752.45
XS-94	14,507	752.39	752.39	752.39
XS-93	14,486	752.37	752.37	752.37
XS-92	14,445	750.06	750.08	750.10
XS-91	14,391	749.73	749.74	749.75
XS-90	14,165	749.34	749.36	749.37
XS-89	14,052	749.14	749.16	749.18
XS-88	13,841	748.69	748.70	748.71
XS-87	13,695	748.33	748.34	748.35
XS-86	13,516	747.80	747.83	747.84
XS-85	13,325	747.41	747.45	747.47
XS-84	13,310	747.35	747.40	747.43
XS-83	13,305	747.34	747.38	747.42
XS-82	13,248	747.23	747.28	747.32
XS-81	12,982	747.01	747.07	747.12
XS-80	12,869	747.00	747.06	747.11
XS-79	12,774	746.99	747.05	747.09
XS-78	12,679	746.97	747.02	747.06
XS-77	12,673	746.96	747.01	747.05

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Table F-4 Sensitivity analysis results for overbank roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
		Pipestone Creek		
XS-76	12,619	746.96	747.00	747.04
XS-75	12,558	746.94	746.99	747.03
XS-74	12,491	746.94	746.98	747.02
XS-73	12,464	746.93	746.98	747.01
XS-72	12,399	746.91	746.96	747.00
XS-71	12,397	746.91	746.96	746.99
XS-70	12,326	746.84	746.88	746.90
XS-69	12,153	746.58	746.61	746.64
XS-68	12,040	746.38	746.41	746.42
XS-67	11,932	746.27	746.29	746.31
XS-66	11,928	746.24	746.26	746.28
XS-65	11,871	746.13	746.15	746.17
XS-64	11,673	745.84	745.87	745.89
XS-63	11,524	745.49	745.52	745.55
XS-62	11,341	745.25	745.26	745.28
XS-61	11,173	745.04	745.05	745.06
XS-60	10,928	744.57	744.59	744.61
XS-59	10,738	744.27	744.29	744.31
XS-58	10,587	744.12	744.14	744.16
XS-57	10,268	743.70	743.73	743.75
XS-56	10,016	743.35	743.38	743.41
XS-55	9,847	743.16	743.20	743.23
XS-54	9,800	743.10	743.14	743.18
XS-53	9,778	743.01	743.06	743.10
XS-52	9,770	743.01	743.05	743.09
XS-51	9,763	742.98	743.03	743.07
XS-50	9,749	742.96	743.00	743.04
XS-49	9,675	742.85	742.89	742.92
XS-48	9,485	742.66	742.70	742.74

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Table F-4 Sensitivity analysis results for overbank roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
		Pipestone Creek		
XS-47	9,112	742.37	742.42	742.47
XS-46	8,909	742.11	742.14	742.16
XS-45	8,804	741.99	742.01	742.03
XS-44	8,453	741.68	741.71	741.73
XS-43	8,378	741.62	741.64	741.66
XS-42	8,373	741.59	741.62	741.64
XS-41	8,210	741.39	741.42	741.44
XS-40	8,063	741.20	741.23	741.25
XS-39	7,910	741.03	741.07	741.10
XS-38	7,906	741.00	741.04	741.07
XS-37	7,837	740.95	740.99	741.02
XS-36	7,817	740.94	740.98	741.01
XS-35	7,815	740.93	740.97	741.00
XS-34	7,441	740.63	740.65	740.67
XS-33	7,250	740.44	740.46	740.48
XS-32	6,997	740.14	740.17	740.20
XS-31	6,783	739.93	739.96	739.98
XS-30	6,614	739.72	739.76	739.79
XS-29	6,591	739.70	739.74	739.77
XS-28	6,573	739.66	739.69	739.72
XS-27	6,525	739.63	739.66	739.69
XS-26	6,348	739.48	739.50	739.52
XS-25	6,344	739.45	739.47	739.48
XS-24	6,266	739.33	739.35	739.37
XS-23	6,129	739.16	739.18	739.20
XS-22	5,851	738.86	738.88	738.90
XS-21	5,391	738.15	738.18	738.21
XS-20	5,203	737.92	737.94	737.96
XS-19	4,985	737.59	737.60	737.62

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Classification: Public

Table F-4 Sensitivity analysis results for overbank roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Pipestone Creek				
XS-18	4,676	736.91	736.94	736.97
XS-17	4,508	736.67	736.69	736.71
XS-16	4,203	736.15	736.16	736.17
XS-15	3,876	735.61	735.63	735.65
XS-14	3,689	735.37	735.40	735.42
XS-13	3,483	735.18	735.20	735.22
XS-12	3,191	734.82	734.84	734.86
XS-11	2,935	734.35	734.38	734.41
XS-10	2,744	733.99	734.03	734.07
XS-9	2,500	733.71	733.76	733.80
XS-8	2,197	733.49	733.54	733.58
XS-7	2,015	733.39	733.44	733.48
XS-6	1,386	732.79	732.83	732.86
XS-5	813	731.85	731.87	731.89
XS-4	337	731.28	731.30	731.32
XS-3	100	730.91	730.95	730.99
XS-2	88	730.82	730.86	730.90
XS-1	0	730.69	730.73	730.77
Average Difference		-0.03	0.00	0.02
Maximum Difference		-0.06	0.00	0.05
Snake Drain				
XS-186	1,530	764.40	764.41	764.42
XS-185	1,462	764.16	764.16	764.16
XS-184	1,375	763.83	763.83	763.83
XS-183	1,233	763.17	763.19	763.20
XS-182	1,129	762.60	762.61	762.62
XS-181	1,124	762.59	762.61	762.62
XS-180	997	759.52	759.52	759.53
XS-179	785	756.33	756.33	756.33

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Classification: Public

Table F-4 Sensitivity analysis results for overbank roughness values (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness Values		
		Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
		Snake Drain		
XS-178	689	755.32	755.32	755.32
XS-177	548	753.60	753.60	753.60
XS-176	481	753.49	753.49	753.49
XS-175	463	752.17	752.17	752.17
XS-174	419	752.02	752.02	752.02
XS-173	322	751.74	751.74	751.74
XS-172	295	751.67	751.67	751.67
XS-171	290	751.50	751.50	751.50
XS-170	284	751.39	751.39	751.39
XS-169	282	750.78	750.78	750.78
XS-168	211	750.26	750.26	750.26
XS-167	206	750.12	750.12	750.12
XS-166	205	749.57	749.57	749.57
XS-165	140	748.95	748.95	748.95
XS-164	134	748.82	748.82	748.82
XS-163	133	748.66	748.67	748.69
XS-162	93	748.56	748.58	748.60
XS-161	40	748.54	748.55	748.58
Average Difference		0.00	0.00	0.00
Maximum Difference		-0.02	0.00	0.03

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Table F-5 Sensitivity analysis results for roadway weir coefficient

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Eyot Creek		
XS-160	4,195	749.01	749.01	749.01
XS-159	4,036	748.93	748.93	748.93
XS-158	3,890	748.87	748.87	748.87
XS-157	3,750	748.80	748.80	748.80
XS-156	3,569	748.72	748.72	748.72
XS-155	3,333	748.70	748.70	748.70
XS-154	3,133	748.67	748.67	748.67
XS-153	3,118	748.67	748.67	748.67
XS-152	2,859	748.64	748.64	748.64
XS-151	2,684	748.62	748.62	748.62
XS-150	2,476	748.61	748.61	748.61
XS-149	2,348	748.59	748.59	748.59
XS-148	2,201	748.58	748.58	748.58
XS-147	1,958	748.57	748.57	748.57
XS-146	1,787	748.57	748.57	748.57
XS-145	1,629	748.56	748.56	748.56
XS-144	1,498	748.55	748.55	748.55
XS-143	1,457	748.53	748.53	748.53
XS-142	1,418	748.52	748.52	748.52
XS-141	1,409	748.35	748.35	748.35
XS-140	1,394	748.29	748.29	748.29
XS-139	1,354	748.31	748.31	748.31
XS-138	1,233	748.24	748.24	748.24
XS-137	1,217	748.22	748.22	748.22
XS-136	1,213	748.22	748.22	748.22
XS-135	1,182	748.20	748.20	748.20
XS-134	1,136	748.17	748.17	748.17
XS-133	1,002	747.91	747.91	747.91
XS-132	901	747.72	747.72	747.72

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Classification: Public

Table F-5 Sensitivity analysis results for roadway weir coefficient (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Eyot Creek		
XS-131	790	747.62	747.62	747.62
XS-130	751	747.56	747.56	747.56
XS-129	747	747.55	747.55	747.55
XS-128	721	747.52	747.52	747.52
XS-127	616	747.44	747.44	747.44
XS-126	446	747.33	747.33	747.33
XS-125	415	747.26	747.26	747.26
XS-124	396	747.19	747.19	747.19
XS-123	357	747.11	747.11	747.11
XS-122	284	747.01	747.01	747.01
XS-121	133	747.00	747.00	747.00
XS-120	33	746.99	746.99	746.99
Average Difference		0.00	0.00	0.00
Maximum Difference		0.00	0.00	0.00
		Pipestone Creek		
XS-119	18,427	761.59	761.59	761.59
XS-118	18,365	761.54	761.54	761.54
XS-117	18,348	761.49	761.49	761.49
XS-116	18,214	761.36	761.36	761.36
XS-115	18,060	761.26	761.26	761.26
XS-114	17,834	761.10	761.10	761.10
XS-113	17,716	760.94	760.94	760.94
XS-112	17,700	760.91	760.91	760.91
XS-111	17,551	760.63	760.63	760.63
XS-110	17,399	760.27	760.27	760.27
XS-109	17,157	759.42	759.42	759.42
XS-108	17,034	759.16	759.16	759.16
XS-107	16,728	758.29	758.29	758.29
XS-106	16,576	757.73	757.73	757.73

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Table F-5 Sensitivity analysis results for roadway weir coefficient (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Pipestone Creek		
XS-105	16,425	757.20	757.20	757.20
XS-104	16,276	756.59	756.59	756.59
XS-103	16,042	755.76	755.76	755.76
XS-102	15,867	755.26	755.26	755.26
XS-101	15,806	754.91	754.91	754.91
XS-100	15,800	754.85	754.85	754.85
XS-99	15,626	754.04	754.04	754.04
XS-98	15,252	752.86	752.86	752.86
XS-97	15,107	752.57	752.57	752.57
XS-96	14,948	752.48	752.48	752.48
XS-95	14,799	752.45	752.45	752.45
XS-94	14,507	752.39	752.39	752.39
XS-93	14,486	752.37	752.37	752.37
XS-92	14,445	750.08	750.08	750.08
XS-91	14,391	749.74	749.74	749.74
XS-90	14,165	749.36	749.36	749.36
XS-89	14,052	749.16	749.16	749.16
XS-88	13,841	748.70	748.70	748.70
XS-87	13,695	748.34	748.34	748.34
XS-86	13,516	747.83	747.83	747.83
XS-85	13,325	747.45	747.45	747.45
XS-84	13,310	747.40	747.40	747.40
XS-83	13,305	747.38	747.38	747.38
XS-82	13,248	747.28	747.28	747.28
XS-81	12,982	747.07	747.07	747.07
XS-80	12,869	747.06	747.06	747.06
XS-79	12,774	747.05	747.05	747.05
XS-78	12,679	747.02	747.02	747.02
XS-77	12,673	747.01	747.01	747.01

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Table F-5 Sensitivity analysis results for roadway weir coefficient (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Pipestone Creek		
XS-76	12,619	747.00	747.00	747.00
XS-75	12,558	746.99	746.99	746.99
XS-74	12,491	746.98	746.98	746.98
XS-73	12,464	746.98	746.98	746.98
XS-72	12,399	746.96	746.96	746.96
XS-71	12,397	746.96	746.96	746.96
XS-70	12,326	746.88	746.88	746.88
XS-69	12,153	746.61	746.61	746.61
XS-68	12,040	746.41	746.41	746.41
XS-67	11,932	746.29	746.29	746.29
XS-66	11,928	746.26	746.26	746.26
XS-65	11,871	746.15	746.15	746.15
XS-64	11,673	745.87	745.87	745.87
XS-63	11,524	745.52	745.52	745.52
XS-62	11,341	745.26	745.26	745.26
XS-61	11,173	745.05	745.05	745.05
XS-60	10,928	744.59	744.59	744.59
XS-59	10,738	744.29	744.29	744.29
XS-58	10,587	744.14	744.14	744.14
XS-57	10,268	743.73	743.73	743.73
XS-56	10,016	743.38	743.38	743.38
XS-55	9,847	743.20	743.20	743.20
XS-54	9,800	743.14	743.14	743.14
XS-53	9,778	743.06	743.06	743.06
XS-52	9,770	743.05	743.05	743.05
XS-51	9,763	743.03	743.03	743.03
XS-50	9,749	743.00	743.00	743.00
XS-49	9,675	742.89	742.89	742.89
XS-48	9,485	742.70	742.70	742.70

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Table F-5 Sensitivity analysis results for roadway weir coefficient (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Pipestone Creek		
XS-47	9,112	742.42	742.42	742.42
XS-46	8,909	742.14	742.14	742.14
XS-45	8,804	742.01	742.01	742.01
XS-44	8,453	741.71	741.71	741.71
XS-43	8,378	741.64	741.64	741.64
XS-42	8,373	741.62	741.62	741.62
XS-41	8,210	741.42	741.42	741.42
XS-40	8,063	741.23	741.23	741.23
XS-39	7,910	741.07	741.07	741.07
XS-38	7,906	741.04	741.04	741.04
XS-37	7,837	740.99	740.99	740.99
XS-36	7,817	740.98	740.98	740.98
XS-35	7,815	740.97	740.97	740.97
XS-34	7,441	740.65	740.65	740.65
XS-33	7,250	740.46	740.46	740.46
XS-32	6,997	740.17	740.17	740.17
XS-31	6,783	739.96	739.96	739.96
XS-30	6,614	739.76	739.76	739.76
XS-29	6,591	739.74	739.74	739.74
XS-28	6,573	739.69	739.69	739.69
XS-27	6,525	739.66	739.66	739.66
XS-26	6,348	739.50	739.50	739.50
XS-25	6,344	739.47	739.47	739.47
XS-24	6,266	739.35	739.35	739.35
XS-23	6,129	739.18	739.18	739.18
XS-22	5,851	738.88	738.88	738.88
XS-21	5,391	738.18	738.18	738.18
XS-20	5,203	737.94	737.94	737.94
XS-19	4,985	737.60	737.60	737.60

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Table F-5 Sensitivity analysis results for roadway weir coefficient (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Pipestone Creek		
XS-18	4,676	736.94	736.94	736.94
XS-17	4,508	736.69	736.69	736.69
XS-16	4,203	736.16	736.16	736.16
XS-15	3,876	735.63	735.63	735.63
XS-14	3,689	735.40	735.40	735.40
XS-13	3,483	735.20	735.20	735.20
XS-12	3,191	734.84	734.84	734.84
XS-11	2,935	734.38	734.38	734.38
XS-10	2,744	734.03	734.03	734.03
XS-9	2,500	733.76	733.76	733.76
XS-8	2,197	733.54	733.54	733.54
XS-7	2,015	733.44	733.44	733.44
XS-6	1,386	732.83	732.83	732.83
XS-5	813	731.87	731.87	731.87
XS-4	337	731.30	731.30	731.30
XS-3	100	730.95	730.95	730.95
XS-2	88	730.86	730.86	730.86
XS-1	0	730.73	730.73	730.73
Average Difference		0.00	0.00	0.00
Maximum Difference		0.00	0.00	0.00
		Snake Drain		
XS-186	1,530	764.41	764.41	764.41
XS-185	1,462	764.16	764.16	764.16
XS-184	1,375	763.83	763.83	763.83
XS-183	1,233	763.19	763.19	763.19
XS-182	1,129	762.61	762.61	762.61
XS-181	1,124	762.61	762.61	762.61
XS-180	997	759.52	759.52	759.52
XS-179	785	756.33	756.33	756.33

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Table F-5 Sensitivity analysis results for roadway weir coefficient (Continued)

Cross Section Number	River Station (m)	100-Year Flood Levels (m) for Roadway Weir CoefficientValues		
		Low Weir Coefficient (C=1.45)	Adopted Weir Coefficient (C=1.6)	High Weir Coefficient (C=1.8)
		Snake Drain		
XS-178	689	755.32	755.32	755.32
XS-177	548	753.60	753.60	753.60
XS-176	481	753.49	753.49	753.49
XS-175	463	752.17	752.17	752.17
XS-174	419	752.02	752.02	752.02
XS-173	322	751.74	751.74	751.74
XS-172	295	751.67	751.67	751.67
XS-171	290	751.50	751.50	751.50
XS-170	284	751.39	751.39	751.39
XS-169	282	750.78	750.78	750.78
XS-168	211	750.26	750.26	750.26
XS-167	206	750.12	750.12	750.12
XS-166	205	749.57	749.57	749.57
XS-165	140	748.95	748.95	748.95
XS-164	134	748.82	748.82	748.82
XS-163	133	748.67	748.67	748.67
XS-162	93	748.58	748.58	748.58
XS-161	40	748.55	748.55	748.55
Average Difference		0.00	0.00	0.00
Maximum Difference		0.00	0.00	0.00

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APPENDIX G

OPEN WATER FLOOD INUNDATION MAP LIBRARY

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APPENDIX H

FLOODWAY DETERMINATION CRITERIA AND DESIGN FLOOD LEVELS

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Table H-1 Floodway Limits and Determination Criteria

River	Cross Section Number	River Station (m)	Left		Right	
			Floodway Limit	Determining Criteria	Floodway Limit	Determining Criteria
Pipestone Creek	XS-118	18365	59.2	1m Depth	78.4	1m Depth
	XS-117	18348	70.6	1m Depth	81.0	1m Depth
	XS-116	18214	169.2	1m Depth	184.6	1m Depth
	XS-115	18060	160.1	1m Depth	170.3	1m Depth
	XS-114	17834	37.4	1m Depth	53.9	1m Depth
	XS-113	17716	83.2	1m Depth	101.6	1m Depth
	XS-112	17700	62.4	1m Depth	73.6	1m Depth
	XS-111	17551	76.2	1m Depth	84.8	1m Depth
	XS-110	17399	61.8	1m Depth	74.1	1m Depth
	XS-109	17157	33.7	Inundation Extent[1]	45.5	Main Channel
	XS-108	17034	134.2	Main Channel	171.9	Main Channel
	XS-107	16728	160.8	Main Channel	177.9	Inundation Extent[1]
	XS-106	16576	247.7	Inundation Extent[1]	268.9	Inundation Extent[1]
	XS-105	16425	66.4	Inundation Extent[1]	94.7	Inundation Extent[1]
	XS-104	16276	65.2	Previous Floodway	80.5	Inundation Extent[2]
	XS-103	16042	141.2	Previous Floodway	162.0	Inundation Extent[1]
	XS-102	15867	150.2	1m Depth	163.1	Inundation Extent[1]
	XS-101	15806	105.8	Previous Floodway	116.3	Inundation Extent[2]
	XS-100	15800	107.0	Inundation Extent[2]	116.1	Inundation Extent[2]
	XS-99	15626	164.8	Previous Floodway	175.8	1m/s Velocity
	XS-98	15252	90.9	Previous Floodway	103.6	Previous Floodway
	XS-97	15107	132.0	Previous Floodway	160.4	1m Depth
	XS-96	14948	38.0	Previous Floodway	55.0	1m Depth
	XS-95	14799	92.9	Previous Floodway	104.9	Previous Floodway
	XS-94	14507	52.3	Previous Floodway	77.9	Previous Floodway
	XS-93	14486	107.2	Previous Floodway	166.2	Previous Floodway
	XS-92	14445	112.2	1m/s Velocity	123.3	Inundation Extent[1]
	XS-91	14391	89.9	Inundation Extent[1]	116.4	Previous Floodway
	XS-90	14165	54.9	Previous Floodway	86.2	Previous Floodway
	XS-89	14052	51.7	Previous Floodway	62.1	Previous Floodway

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Table H-1 Floodway Limits and Determination Criteria (Continued)

River	Cross Section Number	River Station (m)	Left		Right	
			Floodway Limit	Determining Criteria	Floodway Limit	Determining Criteria
Pipestone Creek	XS-88	13841	53.6	1m Depth	65.0	1m Depth
	XS-87	13695	135.9	1m Depth	148.7	Inundation Extent[2]
	XS-86	13516	103.4	Previous Floodway	123.4	Previous Floodway
	XS-85	13325	186.6	Previous Floodway	199.3	Previous Floodway
	XS-84	13310	182.0	Previous Floodway	194.9	Previous Floodway
	XS-83	13305	182.2	Previous Floodway	195.2	Previous Floodway
	XS-82	13248	182.5	Previous Floodway	198.1	Previous Floodway
	XS-81	12982	182.3	Previous Floodway	196.9	Previous Floodway
	XS-80	12869	38.0	1m Depth	204.9	Previous Floodway
	XS-79	12774	123.3	Inundation Extent[2]	197.6	1m Depth
	XS-78	12679	84.0	Inundation Extent[2]	135.1	Previous Floodway
	XS-77	12673	81.9	Inundation Extent[2]	143.9	Previous Floodway
	XS-76	12619	58.1	Inundation Extent[2]	142.9	Previous Floodway
	XS-75	12558	59.7	Inundation Extent[2]	180.9	1m Depth
	XS-74	12491	62.5	Inundation Extent[2]	245.6	1m Depth
	XS-73	12464	60.8	1m Depth	153.2	Previous Floodway
	XS-72	12399	49.9	Previous Floodway	138.3	1m Depth
	XS-71	12397	51.6	Previous Floodway	134.9	1m Depth
	XS-70	12326	70.2	Inundation Extent[2]	118.5	Previous Floodway
	XS-69	12153	54.5	Previous Floodway	146.1	Inundation Extent[1]
	XS-68	12040	54.5	Inundation Extent[1]	98.9	Previous Floodway
	XS-67	11932	40.3	Inundation Extent[1]	67.2	1m Depth
	XS-66	11928	42.6	Previous Floodway	68.5	1m Depth
	XS-65	11871	76.3	Previous Floodway	99.5	Previous Floodway
	XS-64	11673	32.6	Inundation Extent[2]	84.2	Inundation Extent[2]
	XS-63	11524	52.5	Inundation Extent[1]	105.8	Previous Floodway
	XS-62	11341	44.3	Inundation Extent[1]	108.1	Inundation Extent[2]
	XS-61	11173	63.1	Previous Floodway	124.1	Inundation Extent[2]
	XS-60	10928	111.5	Previous Floodway	140.7	Inundation Extent[2]
	XS-59	10738	97.7	Inundation Extent[2]	157.2	Inundation Extent[1]

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Table H-1 Floodway Limits and Determination Criteria (Continued)

River	Cross Section Number	River Station (m)	Left		Right	
			Floodway Limit	Determining Criteria	Floodway Limit	Determining Criteria
Pipestone Creek	XS-58	10587	98.4	Previous Floodway	149.8	Previous Floodway
	XS-57	10268	124.9	Inundation Extent[2]	156.6	Inundation Extent[1]
	XS-56	10016	116.6	Inundation Extent[2]	146.6	Previous Floodway
	XS-55	9847	146.6	Inundation Extent[2]	210.3	Inundation Extent[2]
	XS-54	9800	75.3	Inundation Extent[2]	97.9	Inundation Extent[2]
	XS-53	9778	78.6	Inundation Extent[2]	100.8	Inundation Extent[2]
	XS-52	9770	78.4	Inundation Extent[2]	109.4	Inundation Extent[1]
	XS-51	9763	78.7	Inundation Extent[2]	102.5	Inundation Extent[1]
	XS-50	9749	78.6	1m Depth	103.5	Inundation Extent[1]
	XS-49	9675	78.5	Previous Floodway	183.0	Inundation Extent[1]
	XS-48	9485	103.0	Inundation Extent[2]	167.4	Previous Floodway
	XS-47	9112	129.7	Previous Floodway	146.1	Previous Floodway
	XS-46	8909	150.9	Previous Floodway	171.3	Inundation Extent[2]
	XS-45	8804	118.6	1m Depth	139.3	1m Depth
	XS-44	8453	81.0	Inundation Extent[2]	144.2	Inundation Extent[2]
	XS-43	8378	73.1	Inundation Extent[2]	114.7	Inundation Extent[2]
	XS-42	8373	62.5	Inundation Extent[2]	111.6	Inundation Extent[2]
	XS-41	8210	47.4	Inundation Extent[2]	110.7	Inundation Extent[2]
	XS-40	8063	106.3	Previous Floodway	141.0	Inundation Extent[2]
	XS-39	7910	65.7	Inundation Extent[2]	104.1	Inundation Extent[2]
	XS-38	7906	66.1	Inundation Extent[2]	102.4	Inundation Extent[2]
	XS-37	7837	19.0	Inundation Extent[2]	112.6	Inundation Extent[2]
	XS-36	7817	38.8	Inundation Extent[2]	191.5	Inundation Extent[1]
	XS-35	7815	37.6	Inundation Extent[2]	190.4	Inundation Extent[1]
	XS-34	7441	28.0	Inundation Extent[1]	167.9	Inundation Extent[2]
	XS-33	7250	54.3	Inundation Extent[2]	104.6	Inundation Extent[2]
	XS-32	6997	38.7	Inundation Extent[2]	142.1	Inundation Extent[2]
	XS-31	6783	49.2	Previous Floodway	156.6	Inundation Extent[2]
	XS-30	6614	112.0	Previous Floodway	179.2	Previous Floodway
	XS-29	6591	136.4	Previous Floodway	180.3	Previous Floodway

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Table H-1 Floodway Limits and Determination Criteria (Continued)

River	Cross Section Number	River Station (m)	Left		Right	
			Floodway Limit	Determining Criteria	Floodway Limit	Determining Criteria
Pipestone Creek	XS-28	6573	128.9	Previous Floodway	167.8	Previous Floodway
	XS-27	6525	59.3	Hydraulic Smoothing	103.7	1m Depth
	XS-26	6348	126.7	1m Depth	140.9	1m Depth
	XS-25	6344	122.5	1m Depth	133.9	1m Depth
	XS-24	6266	81.1	Inundation Extent[1]	99.0	1m Depth
	XS-23	6129	116.4	Main Channel	133.7	1m Depth
	XS-22	5851	166.2	1m Depth	181.7	1m Depth
	XS-21	5391	137.9	1m Depth	149.8	1m Depth
	XS-20	5203	182.9	1m Depth	202.4	1m Depth
	XS-19	4985	30.9	Inundation Extent[1]	49.2	1m Depth
	XS-18	4676	106.1	Inundation Extent[1]	121.7	1m Depth
	XS-17	4508	152.7	1m Depth	190.0	Inundation Extent[1]
	XS-16	4203	45.1	Inundation Extent[1]	57.8	1m Depth
	XS-15	3876	37.8	Inundation Extent[1]	54.8	1m Depth
	XS-14	3689	137.5	1m Depth	153.6	1m Depth
	XS-13	3483	53.3	1m Depth	69.3	1m Depth
	XS-12	3191	41.2	Inundation Extent[1]	59.4	1m Depth
	XS-11	2935	145.5	1m Depth	160.5	1m Depth
	XS-10	2744	64.1	1m Depth	76.8	1m Depth
	XS-9	2500	64.0	1m Depth	84.5	1m Depth
	XS-8	2197	132.8	1m Depth	159.2	1m Depth
	XS-7	2015	139.3	1m Depth	156.0	1m Depth
Eyot Creek	XS-160	4195	111.0	Main Channel	125.4	Main Channel
	XS-159	4036	163.0	Main Channel	189.0	Main Channel
	XS-158	3890	74.9	Main Channel	93.4	Main Channel
	XS-157	3750	138.1	Main Channel	161.4	Main Channel
	XS-156	3569	192.2	Main Channel	223.6	Main Channel
	XS-155	3333	420.6	Main Channel	439.6	Main Channel
	XS-154	3133	537.4	Main Channel	571.5	Main Channel
	XS-153	3118	542.6	Main Channel	569.9	Main Channel

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Table H-1 Floodway Limits and Determination Criteria (Continued)

River	Cross Section Number	River Station (m)	Left		Right	
			Floodway Limit	Determining Criteria	Floodway Limit	Determining Criteria
Eyot Creek	XS-152	2859	420.1	Previous Floodway	491.5	Previous Floodway
	XS-151	2684	350.0	Previous Floodway	372.3	Previous Floodway
	XS-150	2476	238.4	Previous Floodway	280.2	Previous Floodway
	XS-149	2348	219.7	Previous Floodway	265.8	Previous Floodway
	XS-148	2201	323.6	Previous Floodway	349.5	Previous Floodway
	XS-147	1958	90.7	Previous Floodway	158.1	Previous Floodway
	XS-146	1787	113.2	Previous Floodway	183.4	Previous Floodway
	XS-145	1629	133.1	Previous Floodway	188.3	Previous Floodway
	XS-144	1498	116.1	Previous Floodway	151.1	Previous Floodway
	XS-143	1457	81.7	Previous Floodway	112.0	Previous Floodway
	XS-142	1418	85.2	Previous Floodway	99.5	1m Depth
	XS-141	1409	57.9	Main Channel[3]	71.5	Main Channel[3]
	XS-140	1394	58.4	Previous Floodway	73.2	Main Channel[3]
	XS-139	1354	34.3	Previous Floodway	52.0	Previous Floodway
	XS-138	1233	32.2	Previous Floodway	51.8	Previous Floodway
	XS-137	1217	30.0	Previous Floodway	47.6	Previous Floodway
	XS-136	1213	30.1	Previous Floodway	49.5	Previous Floodway
	XS-135	1182	45.8	Previous Floodway	64.8	Previous Floodway
	XS-134	1136	62.8	1m Depth	74.9	1m Depth
	XS-133	1002	41.1	Inundation Extent[1]	58.2	Previous Floodway
	XS-132	901	87.5	Previous Floodway	125.8	Previous Floodway
	XS-131	790	137.5	Previous Floodway	168.3	Previous Floodway
	XS-130	751	177.5	Previous Floodway	189.9	Previous Floodway
	XS-129	747	177.2	Previous Floodway	189.9	Previous Floodway
	XS-128	721	143.2	Previous Floodway	154.8	1m Depth
	XS-127	616	126.5	Previous Floodway	140.1	Previous Floodway
	XS-126	446	46.1	Previous Floodway	55.9	1m Depth
	XS-125	415	10.0	Inundation Extent[1]	29.1	Previous Floodway
	XS-124	396	14.3	Inundation Extent[2]	29.9	Previous Floodway
	XS-123	357	31.4	Previous Floodway	44.1	Previous Floodway

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Table H-1 Floodway Limits and Determination Criteria (Continued)

River	Cross Section Number	River Station (m)	Left		Right	
			Floodway Limit	Determining Criteria	Floodway Limit	Determining Criteria
Eyot Creek	XS-122	284	37.7	Previous Floodway	55.1	1m Depth
	XS-121	133	23.5	Previous Floodway	155.2	Inundation Extent[2]
	XS-120	33	65.6	1m Depth	207.3	Inundation Extent[2]
Snake Drain	XS-186	1530	17.8	Inundation Extent[1]	32.0	Main Channel
	XS-185	1462	25.0	Main Channel	48.1	Main Channel
	XS-184	1375	31.4	Main Channel	50.5	Main Channel
	XS-183	1233	21.2	Main Channel[3]	35.9	Previous Floodway
	XS-182	1129	184.9	Main Channel	187.8	Main Channel
	XS-181	1124	188.1	Main Channel	193.9	Main Channel
	XS-180	997	95.9	Main Channel[3]	121.8	Previous Floodway
	XS-179	785	47.3	Main Channel[3]	120.15	Main Channel[3]
	XS-178	689	35.3	Previous Floodway	47.4	Previous Floodway
	XS-177	548	48.7	Main Channel[3]	63.0	Main Channel[3]
	XS-176	481	43.5	Main Channel[3]	55.9	Main Channel[3]
	XS-175	463	31.5	Inundation Extent[1]	41.3	Inundation Extent[2]
	XS-174	419	15.3	Inundation Extent[1]	23.7	Inundation Extent[1]
	XS-173	322	6.8	Inundation Extent[1]	15.1	Inundation Extent[1]
	XS-172	295	21.1	Inundation Extent[1]	27.5	Inundation Extent[1]
	XS-171	290	21.1	Inundation Extent[1]	25.3	Inundation Extent[1]
	XS-170	284	13.7	Inundation Extent[1]	21.3	Inundation Extent[1]
	XS-169	282	12.4	Inundation Extent[1]	20.4	Inundation Extent[1]
	XS-168	211	19.3	Inundation Extent[1]	25.3	Inundation Extent[1]
	XS-167	206	19.0	Inundation Extent[1]	26.4	Inundation Extent[1]
	XS-166	205	17.5	Inundation Extent[1]	24.3	Inundation Extent[1]
	XS-165	140	14.5	Inundation Extent[1]	19.9	Inundation Extent[1]
	XS-164	134	16.9	Inundation Extent[1]	26.9	Inundation Extent[1]
	XS-163	133	17.1	Inundation Extent[1]	26.4	Inundation Extent[1]
	XS-162	93	17.7	Inundation Extent[1]	24.3	Inundation Extent[2]
	XS-161	40	214.3	Inundation Extent[1]	231.1	Inundation Extent[1]

Notes: 1. No viable flood fringe. 2. The previous floodway is outside the inundation extent. 3. The previous floodway is inside the main channel.

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Classification: Public

Table H-2 Computed Design Flood Levels

River	Cross Section Number	River Station (m)	Design Flood Level (m)	River	Cross Section Number	River Station (m)	Design Flood Level (m)
Pipestone Creek	XS-118	18365	761.54	Pipestone Creek	XS-88	13841	748.7
	XS-117	18348	761.49		XS-87	13695	748.34
	XS-116	18214	761.36		XS-86	13516	747.83
	XS-115	18060	761.26		XS-85	13325	747.45
	XS-114	17834	761.1		XS-84	13310	747.4
	XS-113	17716	760.94		XS-83	13305	747.38
	XS-112	17700	760.91		XS-82	13248	747.28
	XS-111	17551	760.63		XS-81	12982	747.07
	XS-110	17399	760.27		XS-80	12869	747.06
	XS-109	17157	759.42		XS-79	12774	747.05
	XS-108	17034	759.16		XS-78	12679	747.02
	XS-107	16728	758.29		XS-77	12673	747.01
	XS-106	16576	757.73		XS-76	12619	747
	XS-105	16425	757.2		XS-75	12558	746.99
	XS-104	16276	756.59		XS-74	12491	746.98
	XS-103	16042	755.76		XS-73	12464	746.98
	XS-102	15867	755.26		XS-72	12399	746.96
	XS-101	15806	754.91		XS-71	12397	746.96
	XS-100	15800	754.85		XS-70	12326	746.88
	XS-99	15626	754.04		XS-69	12153	746.61
	XS-98	15252	752.86		XS-68	12040	746.41
	XS-97	15107	752.57		XS-67	11932	746.29
	XS-96	14948	752.48		XS-66	11928	746.26
	XS-95	14799	752.45		XS-65	11871	746.15
	XS-94	14507	752.39		XS-64	11673	745.87
	XS-93	14486	752.37		XS-63	11524	745.52
	XS-92	14445	750.08		XS-62	11341	745.26
	XS-91	14391	749.74		XS-61	11173	745.05
	XS-90	14165	749.36		XS-60	10928	744.59
	XS-89	14052	749.16		XS-59	10738	744.29

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Classification: Public

Table H-2 Computed Design Flood Levels (Continued)

River	Cross Section Number	River Station (m)	Design Flood Level (m)	River	Cross Section Number	River Station (m)	Design Flood Level (m)
	XS-58	10587	744.14		XS-32	6997	740.17
	XS-57	10268	743.73		XS-31	6783	739.96
	XS-56	10016	743.38		XS-30	6614	739.76
	XS-55	9847	743.2		XS-29	6591	739.74
	XS-54	9800	743.14		XS-28	6573	739.69
	XS-53	9778	743.06		XS-27	6525	739.66
	XS-52	9770	743.05		XS-26	6348	739.5
	XS-51	9763	743.03		XS-25	6344	739.47
	XS-50	9749	743		XS-24	6266	739.35
	XS-49	9675	742.89		XS-23	6129	739.18
	XS-48	9485	742.7		XS-22	5851	738.88
	XS-47	9112	742.42		XS-21	5391	738.18
Pipestone Creek	XS-46	8909	742.14	Pipestone Creek	XS-20	5203	737.94
	XS-45	8804	742.01		XS-19	4985	737.6
	XS-44	8453	741.71		XS-18	4676	736.94
	XS-43	8378	741.64		XS-17	4508	736.69
	XS-42	8373	741.62		XS-16	4203	736.16
	XS-41	8210	741.42		XS-15	3876	735.63
	XS-40	8063	741.23		XS-14	3689	735.4
	XS-39	7910	741.07		XS-13	3483	735.2
	XS-38	7906	741.04		XS-12	3191	734.84
	XS-37	7837	740.99		XS-11	2935	734.38
	XS-36	7817	740.98		XS-10	2744	734.03
	XS-35	7815	740.97		XS-9	2500	733.76
	XS-34	7441	740.65		XS-8	2197	733.54
	XS-33	7250	740.46		XS-7	2015	733.44
	XS-160	4195	749.01		XS-156	3569	748.72
Eyot Creek	XS-159	4036	748.93	Eyot Creek	XS-155	3333	748.7
	XS-158	3890	748.87		XS-154	3133	748.67
	XS-157	3750	748.8		XS-153	3118	748.67

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Classification: Public

Table H-2 Computed Design Flood Levels (Continued)

River	Cross Section Number	River Station (m)	Design Flood Level (m)	River	Cross Section Number	River Station (m)	Design Flood Level (m)
Eyot Creek	XS-152	2859	748.64	Eyot Creek	XS-135	1182	748.2
	XS-151	2684	748.62		XS-134	1136	748.17
	XS-150	2476	748.61		XS-133	1002	747.91
	XS-149	2348	748.59		XS-132	901	747.72
	XS-148	2201	748.58		XS-131	790	747.62
	XS-147	1958	748.57		XS-130	751	747.56
	XS-146	1787	748.57		XS-129	747	747.55
	XS-145	1629	748.56		XS-128	721	747.52
	XS-144	1498	748.55		XS-127	616	747.44
	XS-143	1457	748.53		XS-126	446	747.33
	XS-142	1418	748.52		XS-125	415	747.26
	XS-141	1409	748.35		XS-124	396	747.19
	XS-140	1394	748.29		XS-123	357	747.11
	XS-139	1354	748.31		XS-122	284	747.01
	XS-138	1233	748.24		XS-121	133	747
	XS-137	1217	748.22		XS-120	33	746.99
	XS-136	1213	748.22				
Snake Drain	XS-186	1530	764.41	Snake Drain	XS-173	322	751.74
	XS-185	1462	764.16		XS-172	295	751.67
	XS-184	1375	763.83		XS-171	290	751.5
	XS-183	1233	763.19		XS-170	284	751.39
	XS-182	1129	762.61		XS-169	282	750.78
	XS-181	1124	762.61		XS-168	211	750.26
	XS-180	997	759.52		XS-167	206	750.12
	XS-179	785	756.33		XS-166	205	749.57
	XS-178	689	755.32		XS-165	140	748.95
	XS-177	548	753.6		XS-164	134	748.82
	XS-176	481	753.49		XS-163	133	748.67
	XS-175	463	752.17		XS-162	93	748.58
	XS-174	419	752.02		XS-161	40	748.55

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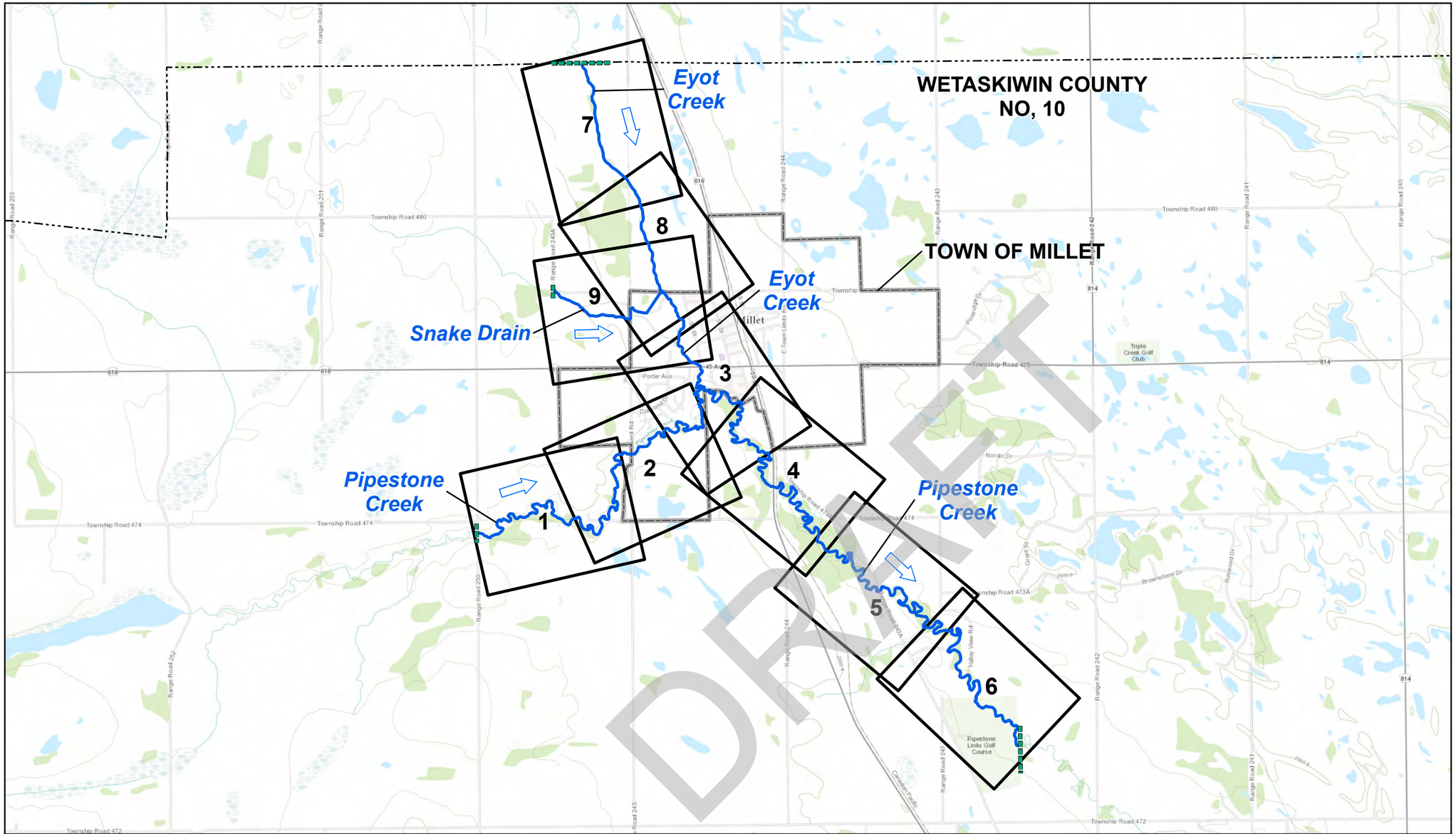
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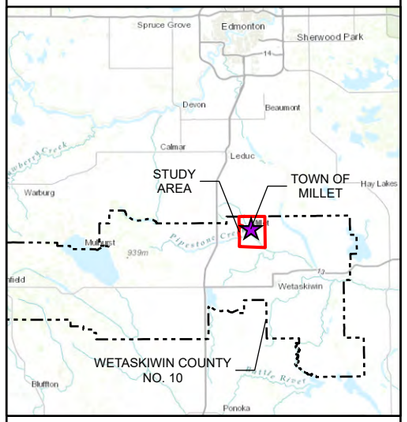
APPENDIX I

FLOODWAY CRITERIA MAPS

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Classification: Public





FLOW DIRECTION
STUDY LIMIT
MAP SHEET
TOWN OF MILLET
WETASKIWIN COUNTY NO. 10

SCALE - 1:45,000

0 500 1,000 1,500 m

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	21-APR-2025

MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

INDEX MAP

Notes to Users:

1. Please refer to the accompanying **Millet Study Report** for important information concerning these maps.
2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.
3. Non-riverine and local sources of water have not been considered, and structures such roads, railways or barriers such as levees can restrict water flow and affect local flood levels. Channel obstruction, local stormwater inflow, groundwater seepage or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a flooded area may be subject to flooding from tributary streams not indicated on the maps.
4. The flood inundation area is shown above the line work for bridges and flood control structures that are below flood levels.

Definitions:

Flood Hazard Map - A flood hazard map is a specific type of flood map that identifies the area flooded for the 1:100 design flood, and divides that flood hazard area into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including the incremental areas at risk for more severe floods like the 1:200 and 1:500 floods. Flood hazard maps are typically used for long-term flood hazard area management and land-use planning.

Design Flood - The design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of being equaled or exceeded in any given year. The design flood is typically based on the 1:100 open water flood, but it can also reflect 1:100 ice jam flood levels or be based on a historical flood event. Different sized floods have different chances of occurring – for example, a 1:200 flood has a 0.5% chance of occurring in any given year and a 1:500 flood has a 0.2% chance of occurring in any given year – but only the 1:100 design flood is used to define the floodway and flood fringe zones on flood hazard maps.

Floodway - When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 1:100 design flood. When a flood hazard map is updated, the floodway will not get larger in most circumstances to maintain long-term regulatory certainty, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe - The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 1:100 design flood. The flood fringe typically represents areas with shallower, slower, and less destructive flooding, but it may also include "high hazard flood fringe" areas. Areas at risk of flooding behind flood berms may also be mapped as "protected flood fringe" areas.

High Hazard Flood Fringe - The high hazard flood fringe identifies areas within the flood fringe with deeper or faster moving water than the rest of the flood fringe. High hazard flood fringe areas are likely to be most significant for flood maps that are being updated, but they may also be included in new flood maps.

Protected Flood Fringe - The protected flood fringe identifies areas that could be flooded if dedicated flood berms fail or do not work as designed during the 1:100 design flood, even if they are not overtopped. Protected flood fringe areas are part of the flood fringe and do not differentiate between areas with deeper or faster moving water and shallower or slower moving water.

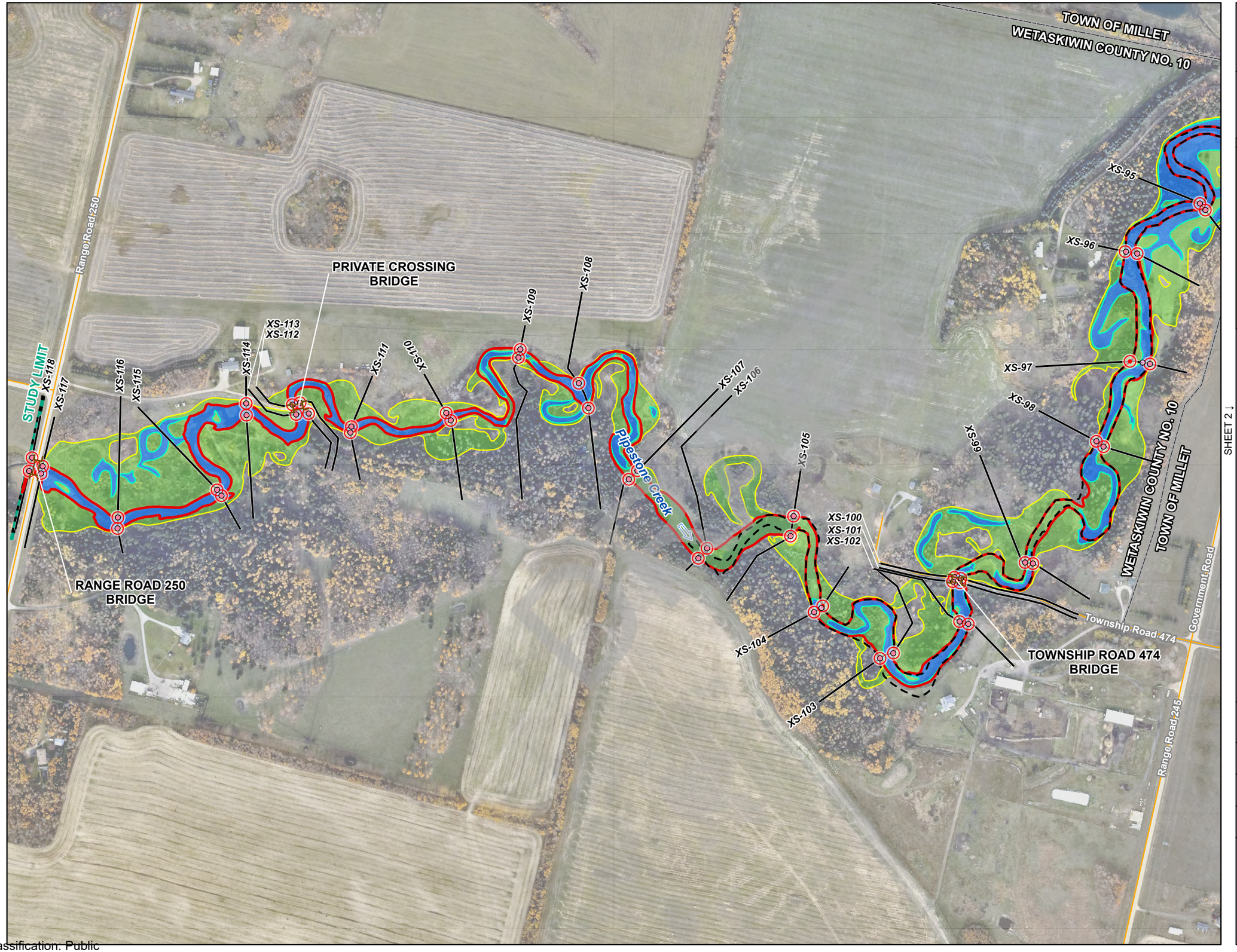
Data Sources and References:

1. Orthophoto imagery was acquired by OGL Engineering for Alberta Environment and Protected Areas on 10 October 2023. Fully processed orthophoto mosaics were provided to Northwest Hydraulic Consultants by Alberta Environment and Protected Areas in October 2024.
2. Flood extent mapping is based on a digital terrain model derived from 2023 LiDAR data collected by others and 2024 bathymetric and topographic survey data collected by Northwest Hydraulic Consultants Ltd.
3. Base data from the Town of Millet, Natural Resources Canada, Alberta Environment and Protected Areas, and Altalis.

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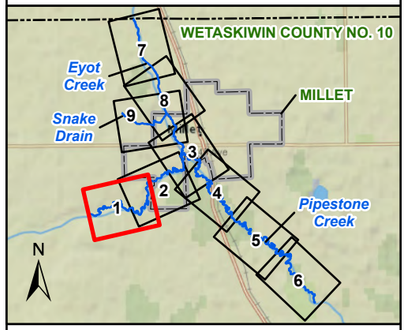
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SHEET 2 ↓

Alberta Canada

nhc



- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- TOWN OF MILLET
- COUNTY
- BANK STATION
- PROPOSED FLOODWAY LIMIT
- PROPOSED FLOODWAY BOUNDARY
- PREVIOUS FLOODWAY
- VELOCITY ≥ 1 m/s
- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK ABOVE EYOT CREEK = 28.2 m^3/s

SCALE - 1:5,000
0 50 100 M
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

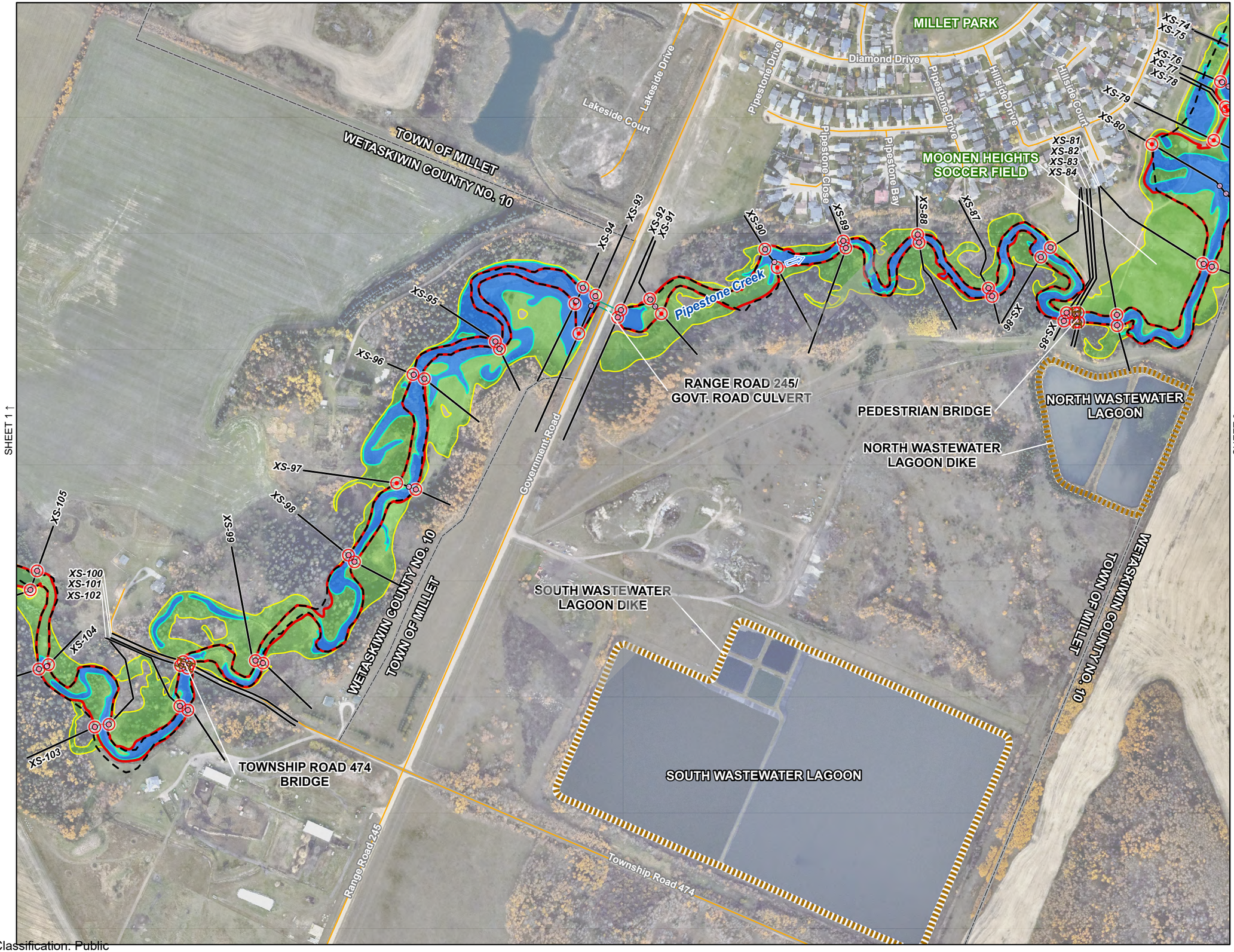
MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 1 OF 9

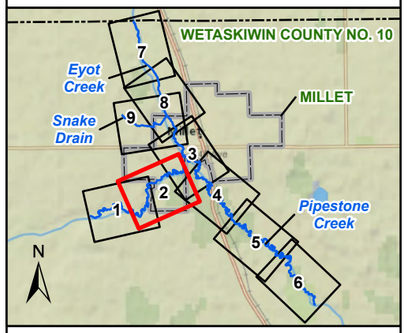
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- STUDY LIMIT
- MODEL CROSS SECTION
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- CULVERT
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- PREVIOUS FLOODWAY
- VELOCITY ≥ 1 m/s
- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK ABOVE EYOT CREEK = 28.2 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
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Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 2 OF 9

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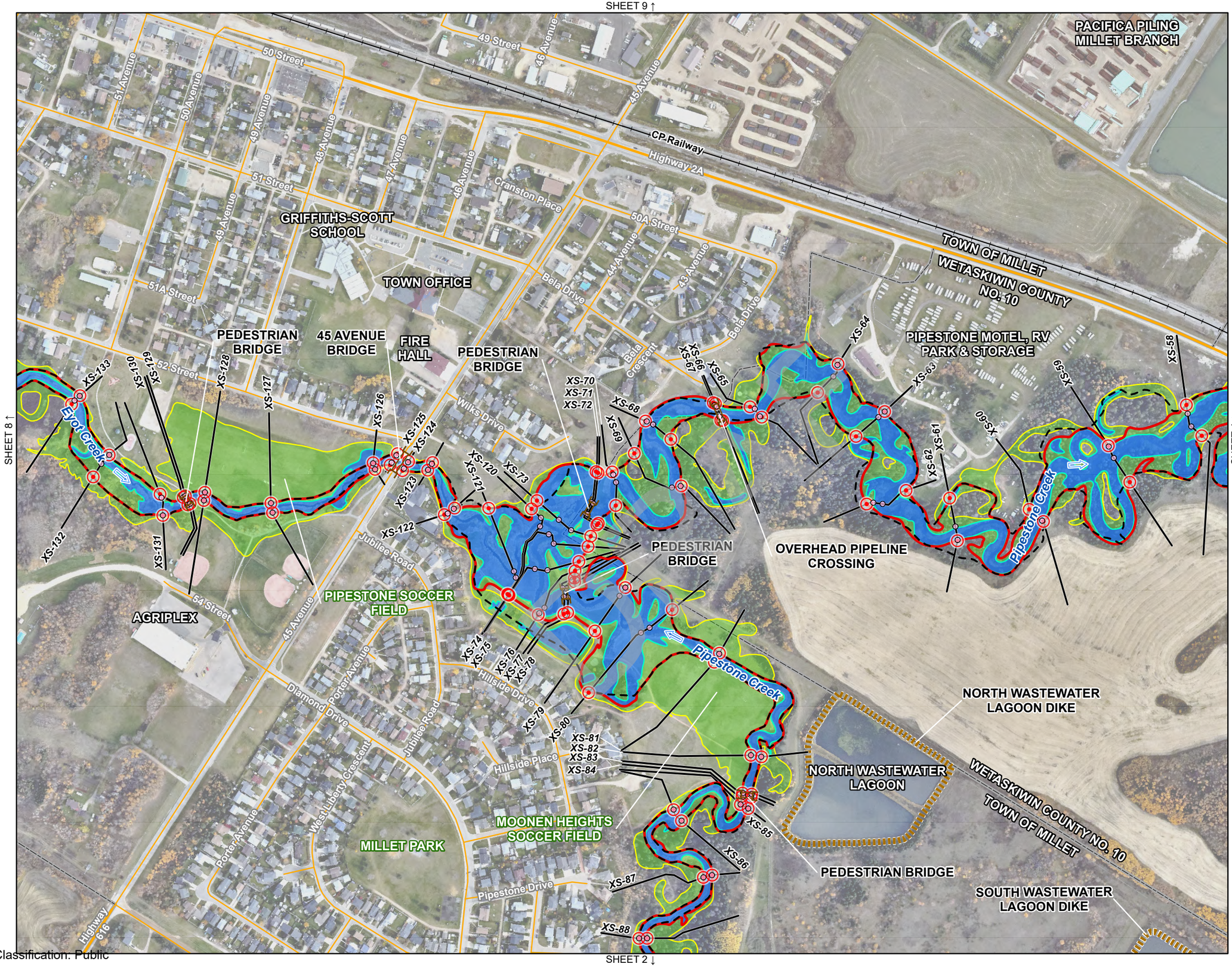
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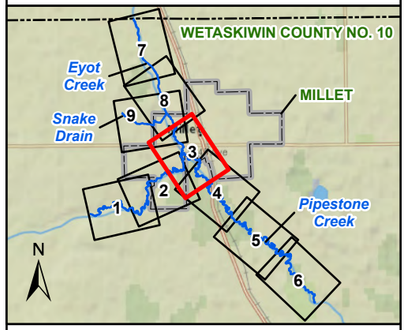
SHEET 9 ↑

SHEET 8 ↑

SHEET 4 ↓

SHEET 2 ↓





- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
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- CULVERT
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- PROPOSED FLOODWAY BOUNDARY
- PREVIOUS FLOODWAY
- VELOCITY ≥ 1 m/s
- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK ABOVE EYOT CREEK = 28.2 m^3/s
EYOT CREEK BELOW SNAKE DRAIN = 21.5 m^3/s
PIPESTONE CREEK BELOW EYOT CREEK = 40.6 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

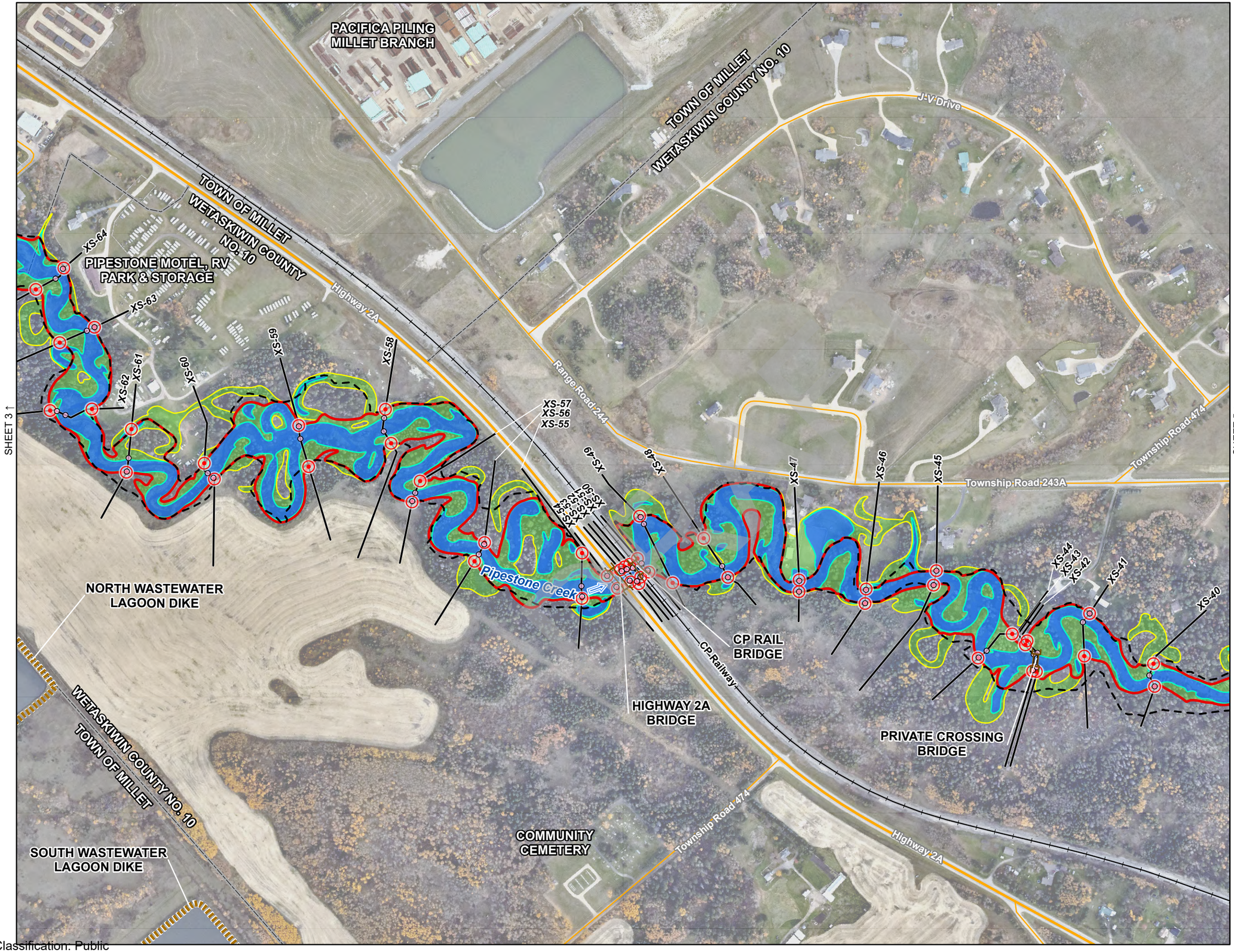
MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 3 OF 9

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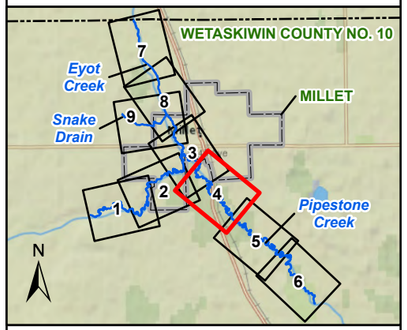


SHEET 3 ↑

SHEET 5 ↓

Alberta Canada

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- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
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- PREVIOUS FLOODWAY
- VELOCITY ≥ 1 m/s
- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK BELOW EYOT CREEK = 40.6 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
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Job Number	Date
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MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 4 OF 9

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Classification: Public

WETASKIWIN COUNTY NO. 10

Township Road 474

J-V Drive

Range Road 243

Township Road 473A

Valley View Road

PRIVATE CROSSING BRIDGE

PRIVATE CROSSING BRIDGE

Range Road 243A

XS-40 XS-39 XS-38 XS-37 XS-36 XS-35 XS-34 XS-33 XS-31 XS-32 XS-28 XS-29 XS-30 XS-25 XS-26 XS-27 XS-24 XS-23 XS-22 XS-21 XS-20 XS-19 XS-18

Pipestone Creek

PRIVATE CROSSING BRIDGE

RANGE ROAD 243A BRIDGE

Highway Street

Range Road 243A

Mullen Drive

CP Railway

Highway 2A

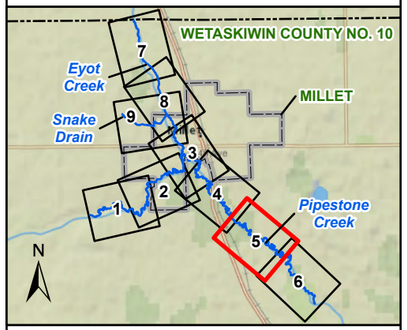
Range Road 244

SHEET 4 ↑

SHEET 6 ↓

Alberta Canada

nhc



- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- TOWN OF MILLET
- COUNTY
- BANK STATION
- PROPOSED FLOODWAY LIMIT
- PROPOSED FLOODWAY BOUNDARY
- PREVIOUS FLOODWAY
- VELOCITY ≥ 1 m/s
- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK BELOW EYOT CREEK = 40.6 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

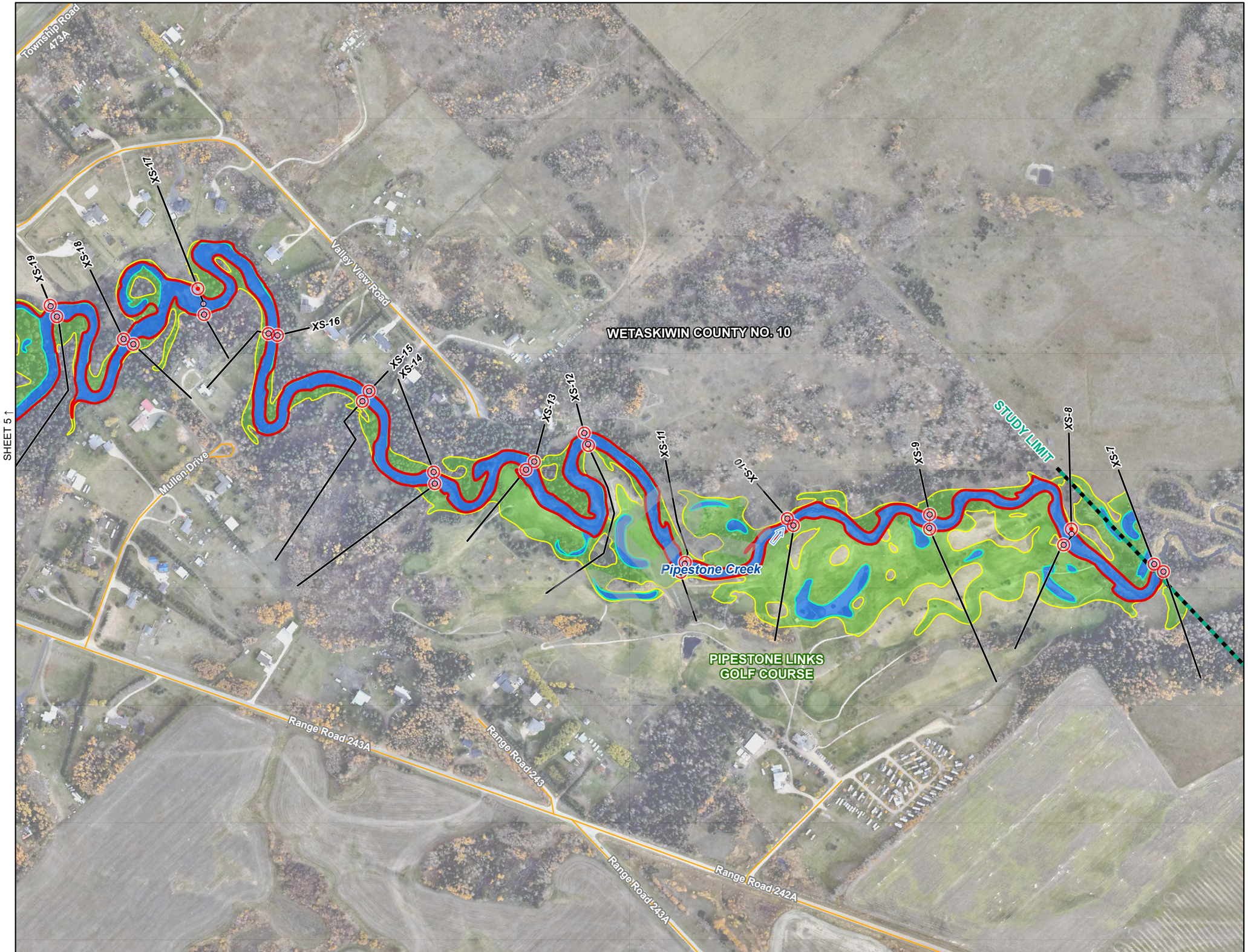
MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 5 OF 9

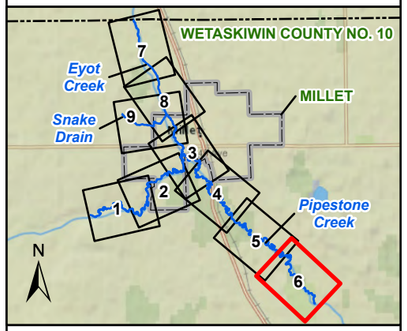
JY, P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOODWAY CRITERIA.aprx

Classification: Public



Alberta Canada

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- FLOW DIRECTION
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- MODEL CROSS SECTION
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DISCHARGE
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SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 6 OF 9

JY, P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOODWAY CRITERIA.aprx

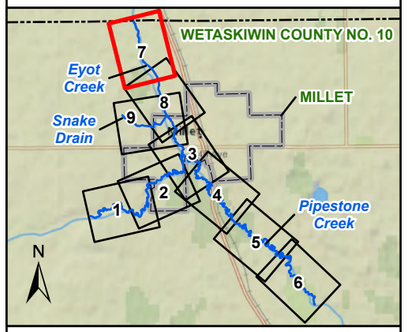
Classification: Public



SHEET 8 ↓

Alberta Canada

nhc



- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- PROVINCIAL HIGHWAY
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- VELOCITY ≥ 1 m/s
- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
EYOT CREEK ABOVE SNAKE DRAIN = 20.2 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 7 OF 9

JY; P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOODWAY CRITERIA.aprx

Classification: Public

SHEET 7 ↑

SHEET 3 ↓

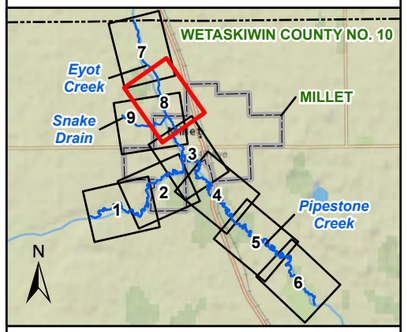
SHEET 9 ↓

XS-151
XS-150
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XS-168
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XS-170
XS-171
XS-172
XS-173
XS-176
XS-174
XS-175
XS-177
XS-178

50 Street
CP Railway
53 Avenue
TOWN OF MILLET
WETASKIWIN COUNTY NO. 10
51 Street
52 Avenue
PRIVATE CROSSING
BRIDGE
53 AVENUE BRIDGE
Eyot Creek
55 Avenue
Snake Drain
RANGE ROAD 245A
CULVERT (BARREL#1&#2)

Alberta Canada

nhc



FLOW DIRECTION
STUDY LIMIT
MODEL CROSS SECTION
FLOOD CONTROL STRUCTURE
BRIDGE
CULVERT
RAILWAY
PROVINCIAL HIGHWAY
LOCAL ROAD
TOWN OF MILLET
COUNTY
BANK STATION
PROPOSED FLOODWAY LIMIT
PROPOSED FLOODWAY BOUNDARY
PREVIOUS FLOODWAY
VELOCITY ≥ 1 m/s
1 m DEPTH CONTOUR
DEPTH ≥ 1 m
100-YEAR OPEN WATER DESIGN FLOOD EXTENT

DISCHARGE
EYOT CREEK ABOVE SNAKE DRAIN = 20.2 m^3/s
SNAKE DRAIN = 2.9 m^3/s
EYOT CREEK BELOW SNAKE DRAIN = 21.5 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
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Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

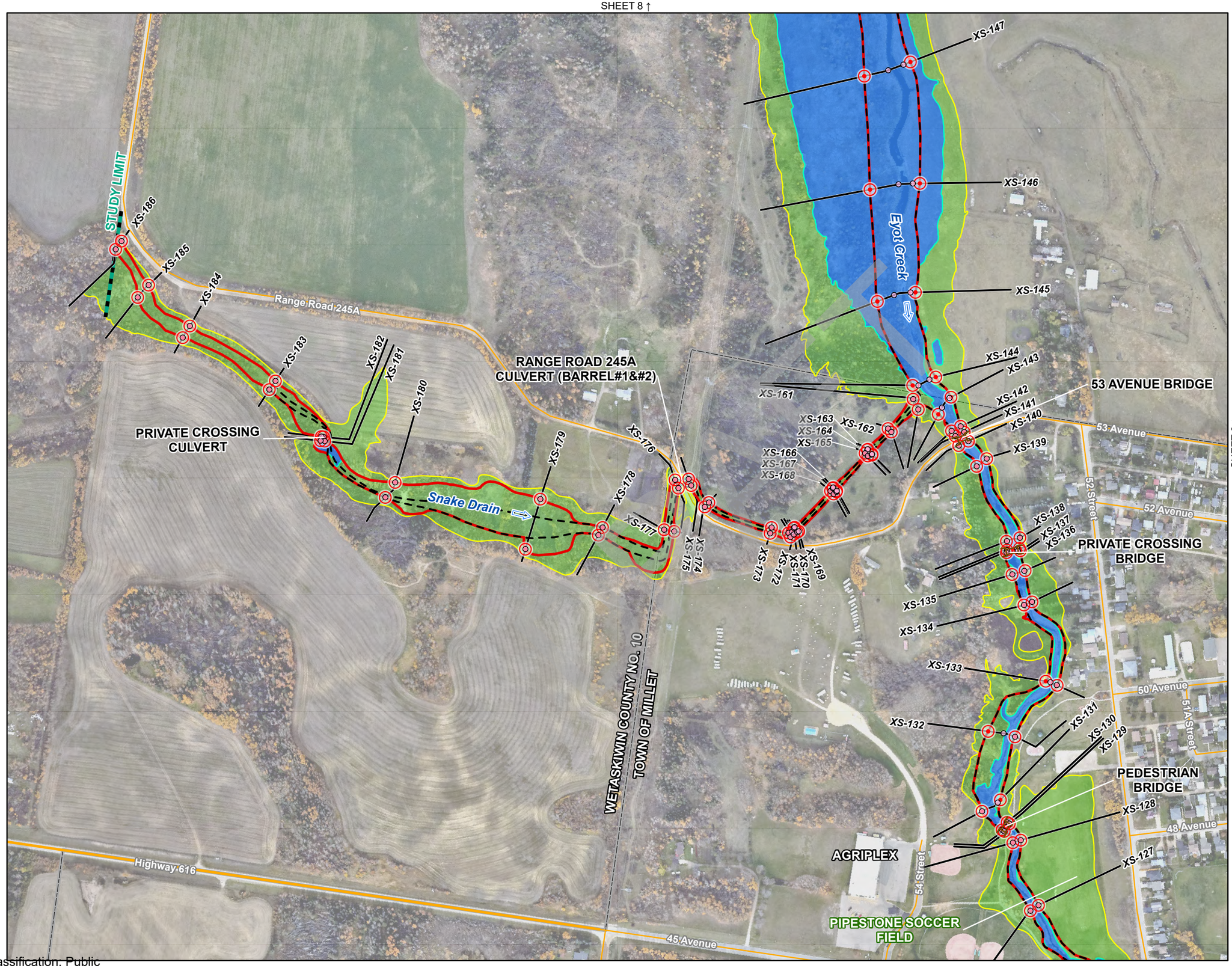
FLOODWAY CRITERIA MAP

SHEET 8 OF 9

JY, P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOODWAY CRITERIA.aprx

Classification: Public

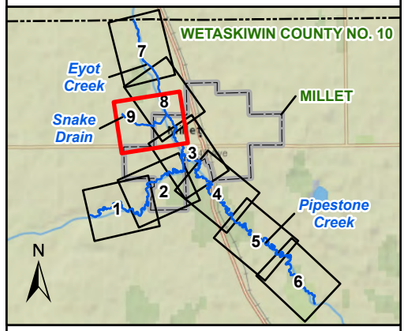
SHEET 8 ↑



SHEET 3 ↓

Alberta Canada

nhc



- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
- BRIDGE
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- 1 m DEPTH CONTOUR
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT

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EYOT CREEK ABOVE SNAKE DRAIN = 20.2 m^3/s
EYOT CREEK BELOW SNAKE DRAIN = 21.5 m^3/s

SCALE - 1:5,000
0 50 100 M
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 9 OF 9

JY; P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOODWAY CRITERIA.aprx

Classification: Public

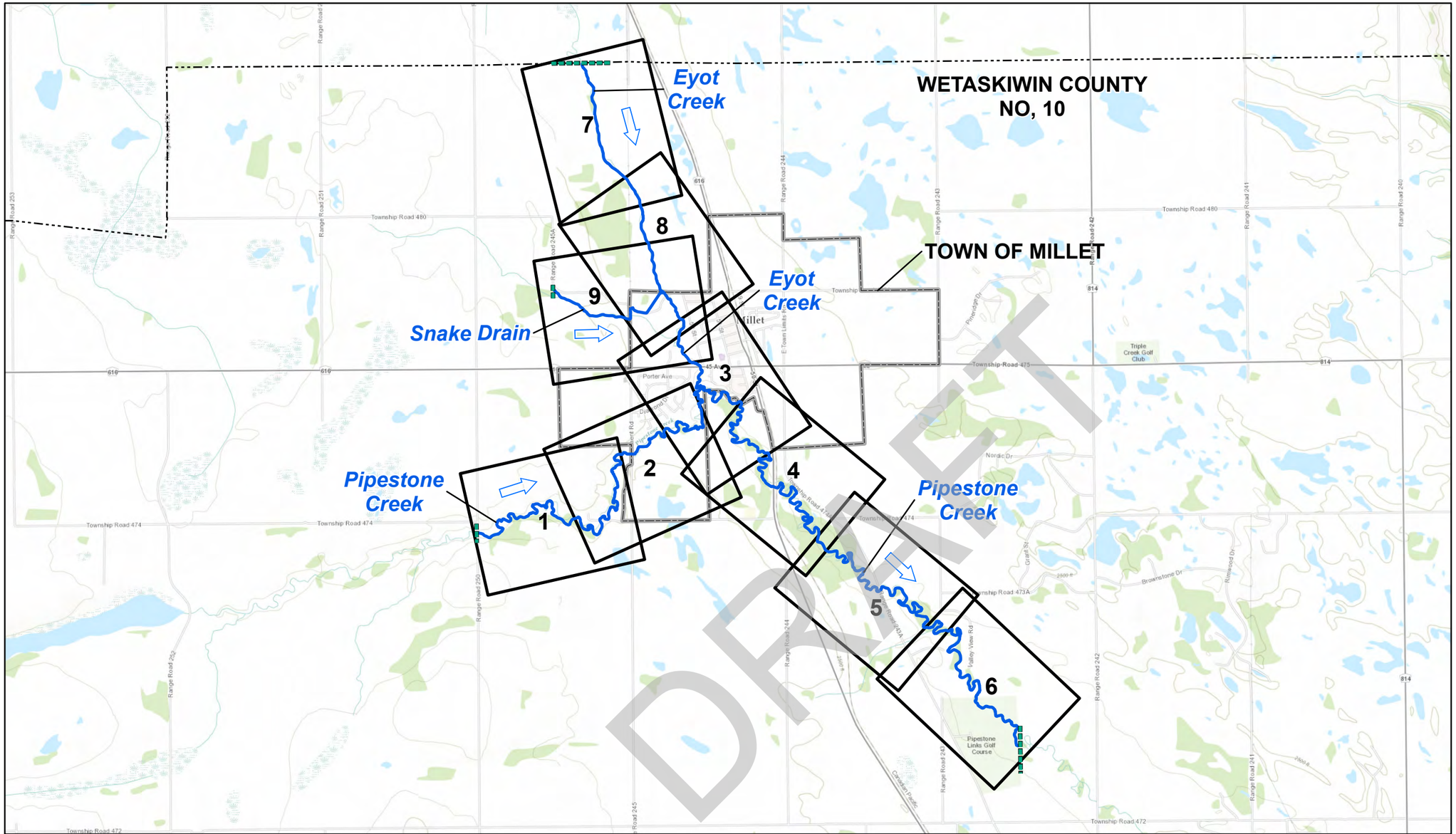
April 2025

APPENDIX J

FLOOD HAZARD MAPS

DRAFT

Classification: Public



Notes to Users:

1. Please refer to the accompanying **Millet Study Report** for important information concerning these maps.
2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.
3. Non-riverine and local sources of water have not been considered, and structures such roads, railways or barriers such as levees can restrict water flow and affect local flood levels. Channel obstruction, local stormwater inflow, groundwater seepage or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a flooded area may be subject to flooding from tributary streams not indicated on the maps.
4. The flood inundation area is shown above the line work for bridges and flood control structures that are below flood levels.

Definitions:

Flood Hazard Map - A flood hazard map is a specific type of flood map that identifies the area flooded for the 1:100 design flood, and divides that flood hazard area into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including the incremental areas at risk for more severe floods like the 1:200 and 1:500 floods. Flood hazard maps are typically used for long-term flood hazard area management and land-use planning.

Design Flood - The design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of being equaled or exceeded in any given year. The design flood is typically based on the 1:100 open water flood, but it can also reflect 1:100 ice jam flood levels or be based on a historical flood event. Different sized floods have different chances of occurring – for example, a 1:200 flood has a 0.5% chance of occurring in any given year and a 1:500 flood has a 0.2% chance of occurring in any given year – but only the 1:100 design flood is used to define the floodway and flood fringe zones on flood hazard maps.

Floodway - When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 1:100 design flood. When a flood hazard map is updated, the floodway will not get larger in most circumstances to maintain long-term regulatory certainty, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe - The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 1:100 design flood. The flood fringe typically represents areas with shallower, slower, and less destructive flooding, but it may also include "high hazard flood fringe" areas. Areas at risk of flooding behind flood berms may also be mapped as "protected flood fringe" areas.

High Hazard Flood Fringe - The high hazard flood fringe identifies areas within the flood fringe with deeper or faster moving water than the rest of the flood fringe. High hazard flood fringe areas are likely to be most significant for flood maps that are being updated, but they may also be included in new flood maps.

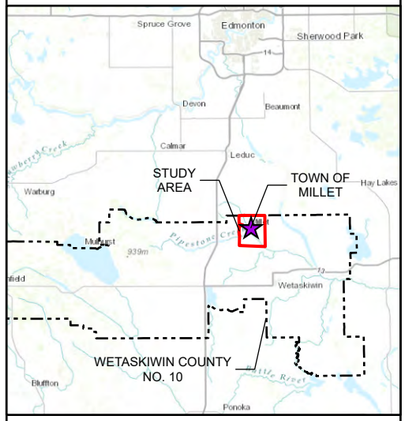
Protected Flood Fringe - The protected flood fringe identifies areas that could be flooded if dedicated flood berms fail or do not work as designed during the 1:100 design flood, even if they are not overtopped. Protected flood fringe areas are part of the flood fringe and do not differentiate between areas with deeper or faster moving water and shallower or slower moving water.

Data Sources and References:

1. Orthophoto imagery was acquired by OGL Engineering for Alberta Environment and Protected Areas on 10 October 2023. Fully processed orthophoto mosaics were provided to Northwest Hydraulic Consultants by Alberta Environment and Protected Areas in October 2024.
2. Flood extent mapping is based on a digital terrain model derived from 2023 LiDAR data collected by others and 2024 bathymetric and topographic survey data collected by Northwest Hydraulic Consultants Ltd.
3. Base data from the Town of Millet, Natural Resources Canada, Alberta Environment and Protected Areas, and Altalis.

Alberta Canada

nhc



FLOW DIRECTION
STUDY LIMIT
MAP SHEET
TOWN OF MILLET
WETASKIWIN COUNTY NO. 10

SCALE - 1:45,000

0 500 1,000 1,500 m

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	21-APR-2025

MILLET FLOOD STUDY

FLOOD HAZARD MAP

INDEX MAP

J:\Y_P\1_Projects (Active)\1008862 Millet Flood Study\90_GIS\INDEX MAPS\1008862_MFS_INDEX_MAPS_INDEX_MAPS.aprx

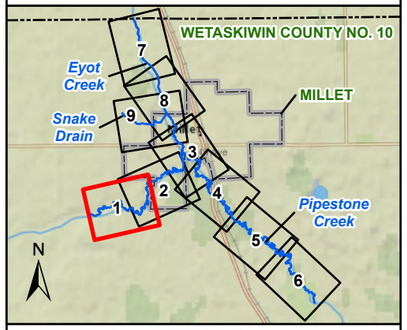
Classification: Public



SHEET 2 ↓

Alberta Canada

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- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- TOWN OF MILLET
- COUNTY
- FLOODWAY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK ABOVE EYOT CREEK = 28.2 m^3/s

SCALE - 1:5,000
0 50 100 M

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 1 OF 9

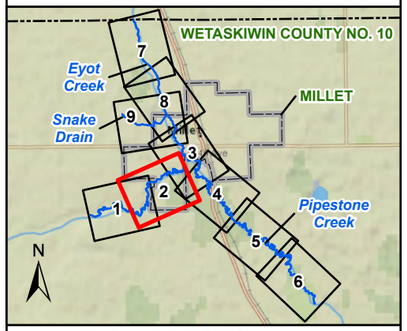
JY; P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOOD HAZARD.aprx

Classification: Public



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1008862	20-APR-2025

MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 2 OF 9

JY P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOOD HAZARD.aprx

Classification: Public

SHEET 9 ↑

SHEET 8 ↑

SHEET 4 ↓

SHEET 2 ↓

PACIFICA PILING MILLET BRANCH

CP Railway

Highway 2A

TOWN OF MILLET

WETASKIWIN COUNTY NO. 10

GRIFFITHS-SCOTT SCHOOL

TOWN OFFICE

PEDESTRIAN BRIDGE

45 AVENUE BRIDGE

FIRE HALL

PEDESTRIAN BRIDGE

PIPESTONE MOTEL, RV PARK & STORAGE

Eyot Creek

Pipestone Creek

PEDESTRIAN BRIDGE

OVERHEAD PIPELINE CROSSING

AGRIPLEX

PIPESTONE SOCCER FIELD

MOONEN HEIGHTS SOCCER FIELD

MILLET PARK

NORTH WASTEWATER LAGOON DIKE

NORTH WASTEWATER LAGOON

WETASKIWIN COUNTY NO. 10

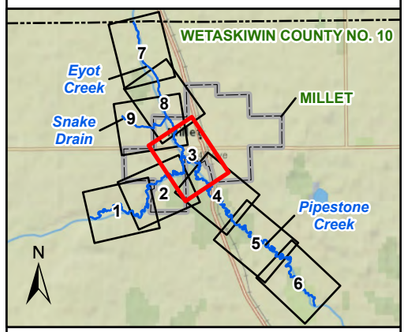
TOWN OF MILLET

PEDESTRIAN BRIDGE

SOUTH WASTEWATER LAGOON DIKE

49 Street, 50 Street, 51 Avenue, 50 Avenue, 49 Avenue, 48 Avenue, 47 Avenue, 46 Avenue, 45 Avenue, 51 Street, Cranston Place, 50A Street, 44 Avenue, 43 Avenue, Bela Drive, Bela Crescent, 51A Street, 52 Street, Wilks Drive, Jubilee Road, 54 Street, Diamond Drive, Porter Avenue, West Liberty Crescent, Hillside Drive, Hillside Place, Pipestone Drive, Highway 616

XS-58, XS-59, XS-60, XS-61, XS-62, XS-63, XS-64, XS-65, XS-66, XS-67, XS-68, XS-69, XS-70, XS-71, XS-72, XS-73, XS-74, XS-75, XS-76, XS-77, XS-78, XS-79, XS-80, XS-81, XS-82, XS-83, XS-84, XS-85, XS-86, XS-87, XS-88, XS-120, XS-121, XS-122, XS-123, XS-124, XS-125, XS-126, XS-127, XS-128, XS-129, XS-130, XS-131, XS-132, XS-133



- FLOW DIRECTION
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- FLOOD CONTROL STRUCTURE
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- HIGH HAZARD FLOOD FRINGE
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- 500-YEAR FLOOD EXTENT

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0 50 100 M

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Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 3 OF 9

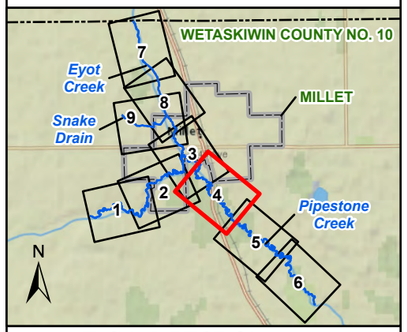
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Classification: Public



Alberta Canada

nhc



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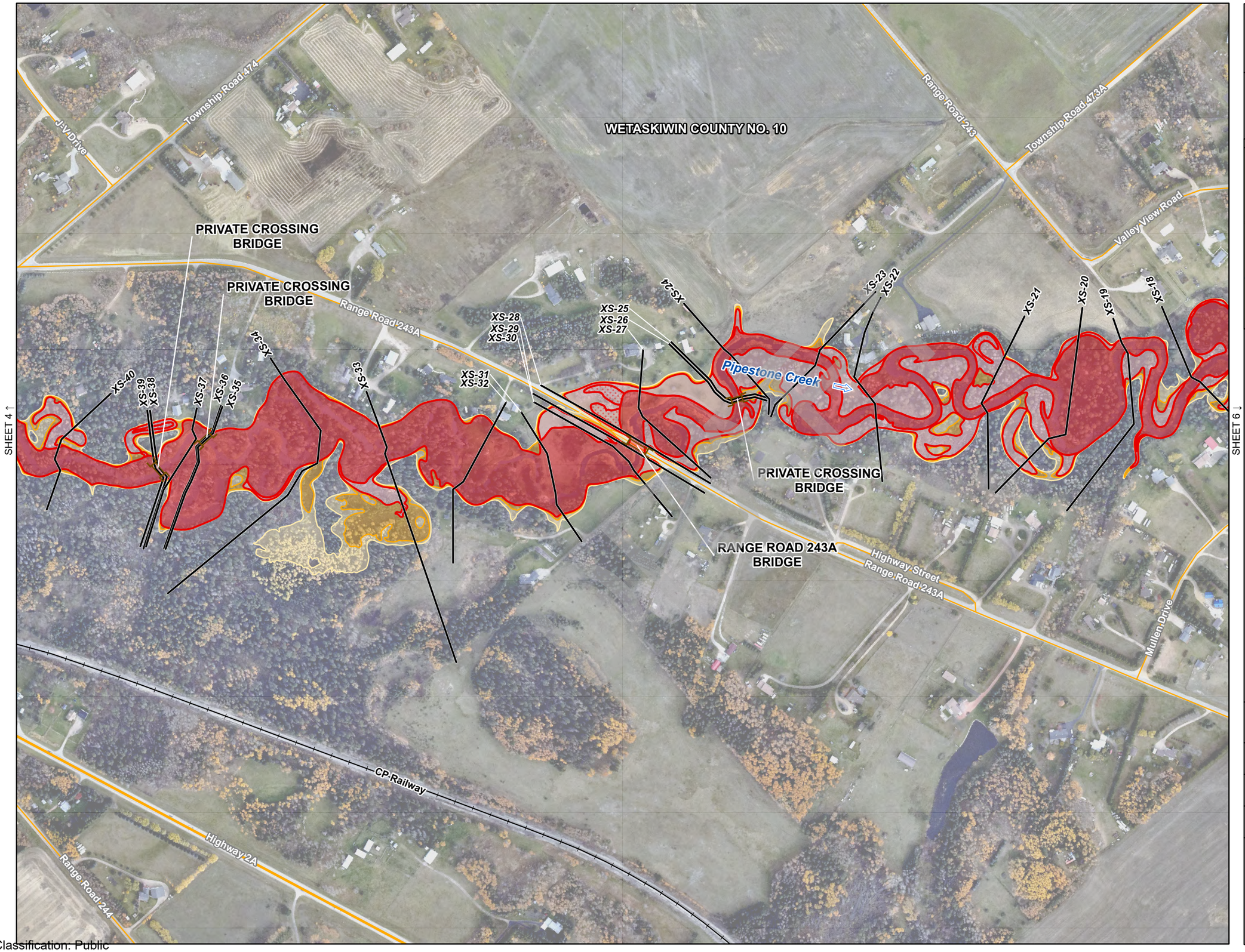
MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 4 OF 9

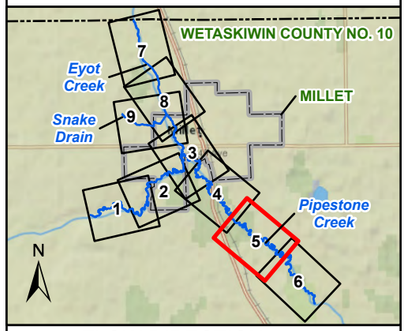
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MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 5 OF 9

JY, P:_Projects (Active)\1008862 Millet Flood Study\90_GIS\FLOOD HAZARD\MILLET FS FLOOD HAZARD.aprx

Classification: Public

SHEET 5 ↑

Township Road 473A

Valley View Road

Mullen Drive

Range Road 243A

Range Road 243

Range Road 243A

Range Road 242A

WETASKIWIN COUNTY NO. 10

PIPESTONE LINKS GOLF COURSE

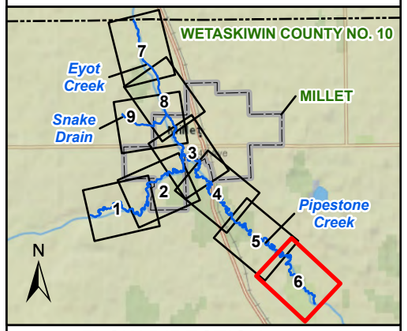
Pipestone Creek

STUDY LIMIT

XS-1
XS-2
XS-3
XS-4
XS-5
XS-6
XS-7
XS-8
XS-9
XS-10
XS-11
XS-12
XS-13
XS-14
XS-15
XS-16
XS-17
XS-18
XS-19

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- FLOW DIRECTION
- STUDY LIMIT
- MODEL CROSS SECTION
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- RAILWAY
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- TOWN OF MILLET
- COUNTY
- FLOODWAY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
PIPESTONE CREEK BELOW EYOT CREEK = 40.6 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
MMM	JY	RBA

Job Number	Date
1008862	20-APR-2025

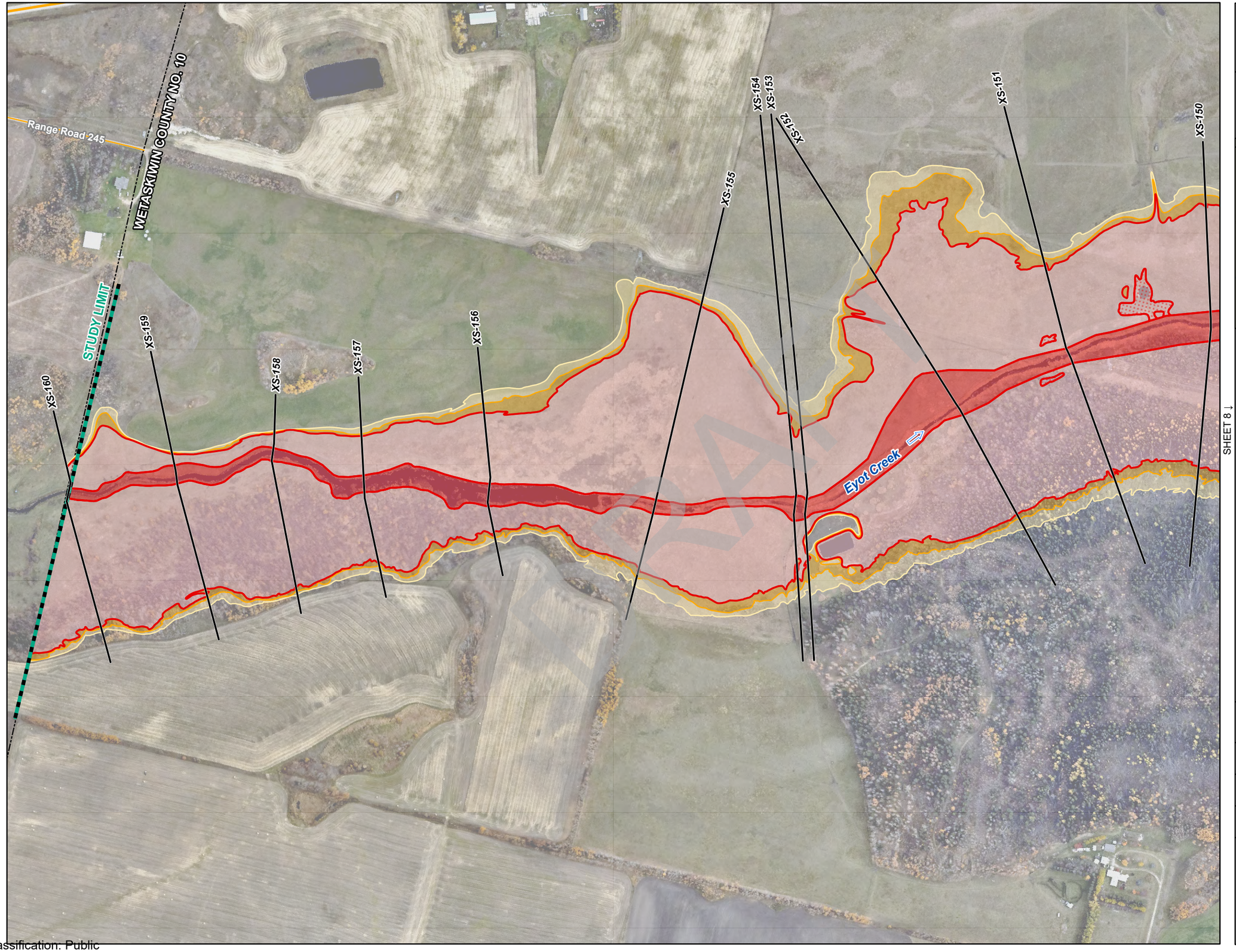
MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 6 OF 9

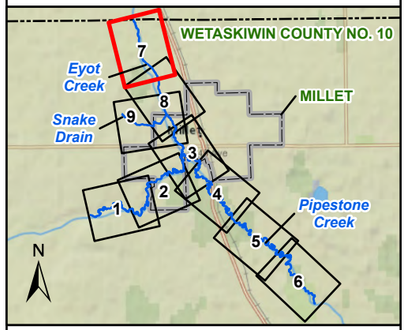
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- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
EYOT CREEK ABOVE SNAKE DRAIN = 20.2 m^3/s

SCALE - 1:5,000
0 50 100 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

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MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 7 OF 9

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SHEET 7 ↑

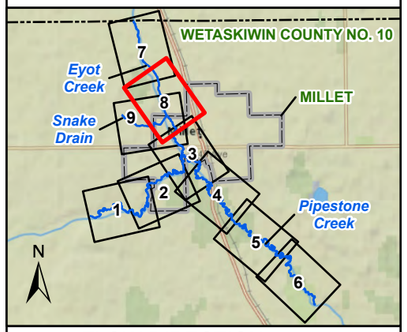
SHEET 3 ↓

CP Railway
50 Street
TOWN OF MILLET
WETASKIWIN COUNTY NO. 10
51 Street
53 Avenue
52 Avenue
52 Street
PRIVATE CROSSING
BRIDGE
53 AVENUE BRIDGE
Eyot Creek
Snake Drain
RANGE ROAD 245A
CULVERT (BARREL#1&#2)
XS-132
XS-133
XS-134
XS-135
XS-136
XS-137
XS-138
XS-139
XS-140
XS-141
XS-142
XS-143
XS-144
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XS-166
XS-167
XS-168
XS-169
XS-170
XS-171
XS-172
XS-173
XS-174
XS-175
XS-176
XS-177
XS-178

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

DISCHARGE
EYOT CREEK ABOVE SNAKE DRAIN = 20.2 m^3/s
SNAKE DRAIN = 2.9 m^3/s
EYOT CREEK BELOW SNAKE DRAIN = 21.5 m^3/s

SCALE - 1:5,000
0 50 100 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

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1008862	20-APR-2025

MILLET FLOOD STUDY

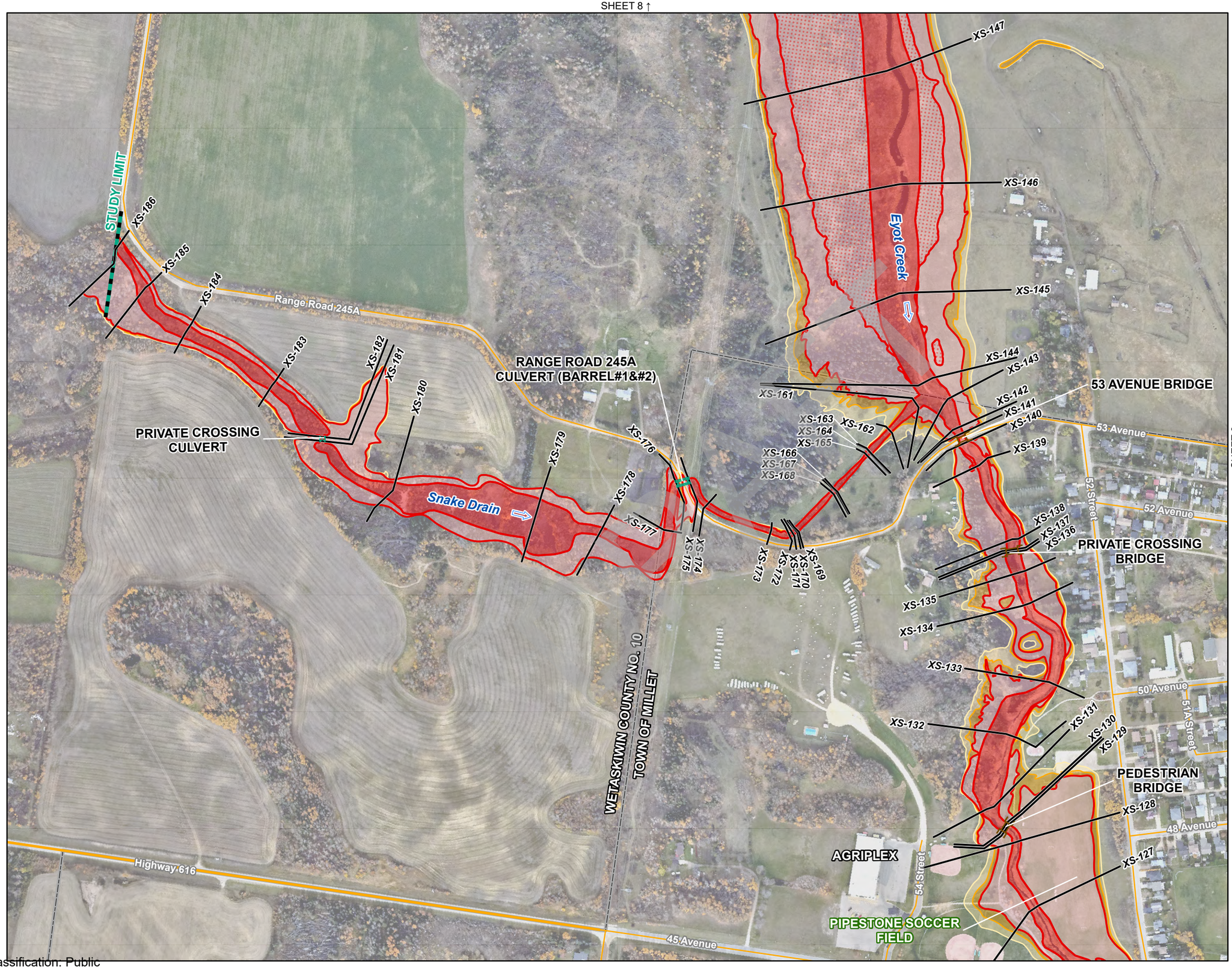
FLOOD HAZARD MAP

SHEET 8 OF 9

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Classification: Public

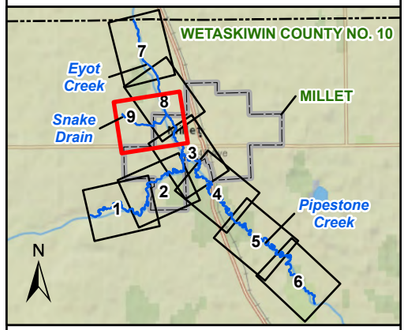
SHEET 8 ↑



SHEET 3 ↓

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- 500-YEAR FLOOD EXTENT

DISCHARGE
SNAKE DRAIN = 2.9 m^3/s
EYOT CREEK ABOVE SNAKE DRAIN = 20.2 m^3/s
EYOT CREEK BELOW SNAKE DRAIN = 21.5 m^3/s

SCALE - 1:5,000
0 50 100 M
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

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1008862	20-APR-2025

MILLET FLOOD STUDY

FLOOD HAZARD MAP

SHEET 9 OF 9

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