



MANNING FLOOD STUDY

Prepared for: **ALBERTA ENVIRONMENT AND PROTECTED AREAS**

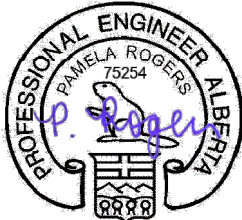
Prepared by: **MONTROSE ENVIRONMENTAL SOLUTIONS CANADA INC.**

Version 2.0
April 2025
Edmonton, Alberta

Suite 200, 5083 Windermere Blvd. SW
Edmonton, AB, Canada T6W 0J5
T 780.490.6830 F 780.465.2973
www.montrose-env.com

MANNING FLOOD STUDY

Prepared for Alberta Environment and Protected Areas, April 2025



9 April 2025

Pamela Rogers M.Eng., P.Eng.
Water Resources Engineer



09 April 2025

reviewed by
Manas Shome, Ph.D., P.Eng.
Principal Water Resources Engineer

CONTRIBUTORS

Name	Job Title	Role
Manas Shome, Ph.D., P.Eng.	Principal Water Resources Engineer	Senior technical review, project direction, co-author and authenticating professional
Brandyn Coates, M.Eng., P.Eng.	Water Resources Engineer	Project Manager and technical review
Sabrina Rashid Sheonty, E.I.T.	Water Resources Engineer	Hydraulic modelling
Pamela Rogers, M.Eng. P.Eng.	Water Resources Engineer	Hydraulic modelling; co-author of the report
Karen Hofbauer, M.Sc., P.Eng.	Senior Water Resources Engineer	Hydraulic modelling review
Matt Wilkinson, MGIS	GIS Specialist	Map and database creation and organization
Dylan Bosak, B.Sc.	GIS Specialist	Map and database creation and organization

PERMIT TO PRACTICE
MATRIX SOLUTIONS INC.

RM SIGNATURE:

RM APEGA ID #: 57054

DATE: 09 April 2025

PERMIT NUMBER: P005540
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

This document represents an electronic version of the original hard copy document, sealed, signed, and dated and retained on file by Matrix Solutions Inc. The content of the electronically transmitted document can be confirmed by referring to the original hard copy.

DISCLAIMER

Montrose Environmental Solutions Canada Inc. certifies that this report is accurate and complete and accords with the information available during the project. Information obtained during the project or provided by third parties is believed to be accurate but is not guaranteed. Montrose Environmental Solutions Canada Inc. has exercised reasonable skill, care, and diligence in assessing the information obtained during the preparation of this report.

This report was prepared for Alberta Environment and Protected Areas. The report may not be relied upon by any other person or entity without the written consent of Montrose Environmental Solutions Canada Inc. and of Alberta Environment and Protected Areas. Any uses of this report by a third party, or any reliance on decisions made based on it, are the responsibility of that party. Neither Montrose Environmental Solutions Canada Inc. nor its affiliates are responsible for damages or injuries incurred by any third party as a result of decisions made or actions taken based on this report.

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V 0.1	23-Dec-2024	Draft	35915-531 Manning FS R 2024-12-23 draft V0.1.docx	Issued to client for review
V1.0	12-Feb-2025	Final	35917-531 Manning FS R 2025-02-12 final V1.0.docx	Issued to client as final
V2.0	09-Apr-2025	Final Revised	35917-531 Manning FS R 2025-04-09 final V2.0.docx	Revisions to Section 7, Issued to client as final

DRAFT

CREDITS AND ACKNOWLEDGEMENTS

Montrose Environmental Solutions Canada Inc. expresses thanks to Tachara Larocque, P.Geo. and Zahidul Islam, Ph.D., P.Eng., of Alberta Environment and Protected Areas (EPA) for providing overall study guidance and management throughout the project duration. The 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.

The field survey was conducted by Measurement Sciences Inc. (MSI). Hydraulic modelling was conducted by Pamela Rogers, M.Eng., P.Eng. with technical guidance provided by Karen Hofbauer, M.Sc., P.Eng., and contributions by Sabrina Rashid Sheonty, E.I.T. Map and database creation and organization was completed by Dylan Bosak, B.Sc., with technical guidance provided by Matthew Wilkinson, MGIS. Overall study management was completed by Brandyn Coates, M.Sc., P.Eng., and senior technical review and project direction was provided by Manas Shome, Ph.D., P.Eng.

DRAFT

EXECUTIVE SUMMARY

Montrose Environmental Solutions Canada Inc. (Montrose; formerly Matrix Solutions Inc.) was retained by the Government of Alberta (GoA) to conduct the Manning Flood Study. This flood study is one of several similar studies completed as part of a larger effort by GoA to identify flood hazard areas in communities throughout Alberta to increase public safety and reduce future flood related damages. Information required to complete this study was gathered collectively by Montrose, Measurement Sciences Inc. (MSI), key project stakeholders, and GoA (including LiDAR provider OGL Engineering).

The purpose of the Manning Flood Study is to assess and identify flood hazards along the Notikewin River through the Town of Manning and County of Northern Lights, located about 100 km north of Peace River, Alberta. The study reach extends from the western boundary of NW 13-091-24 W5M to just downstream of the railway bridge near Range Road 231 at the western boundary of SW 36-091-26 W5M and covers a distance of 24 km. The downstream model boundary on the Notikewin River has been extended by approximately 600 m downstream of the study reach boundary so that any uncertainty in the downstream boundary conditions does not impact simulated water levels within the study reach.

Flow estimates for the 2-year to 1,000-year flood events for the study were estimated by utilizing recorded flows at the Water Survey of Canada (WSC) hydrometric gauging station, Notikewin River at Manning (07HC001). This WSC station has a relatively long period of records (62 years of data), is located within the study reach and the recorded flow data are considered natural flows. The hydrologic analysis involved evaluation of recorded annual maximum instantaneous discharge and annual maximum daily discharge data, analysis of the extended data series for statistical outliers, and selection of the most suitable probability distribution. The goodness of fit of each distribution was compared through the Kolmogorov Smirnov (KS) test, Anderson Darling test, and Least Squares method. A visual inspection of various theoretical frequency distributions to the flow data and statistical goodness of fit test results indicated that the log Pearson Type III distribution has the most representative fit to the recorded data and was used to derive flood frequencies ranging from 2-year to 1,000-year return periods for hydraulic modelling.

The hydraulic model and resulting map products were constructed using LiDAR data provided by GoA and surveyed cross-sections, and hydraulic structure data collected by MSI under Montrose's supervision. All surveyed data was tied together using Alberta Survey Control Network (ASCN) benchmarks that were surveyed independently during the various data collection phases.

A total of 79 cross-sections were identified for surveying; cross-sections were extended into the floodplain based on the digital terrain model (DTM) provided to Montrose by EPA. The combined channel and floodplain data often amounted to more than 500 points per cross-section. The 'minimize area change' point routine in HEC-RAS was used to filter the cross-section data; final sections were examined to ensure that they retained surveyed channel data and appropriately represented the channel geometry.

Three hydraulic structures were included in the hydraulic model, including the following:

- Highway 35 bridge
- Rail bridge
- Weir structure

The HEC-RAS hydraulic modelling software (Version 6.5; USACE 2024) was used to simulate flood levels through the model reach for flood events associated with various return periods ranging from the 1:2-year to the 1:1,000-year flood. The hydraulic model was calibrated and validated against surveyed highwater marks (HWMs) and the corresponding peak discharge for major events that occurred on the Notikewin River. The source of data used for the assessment were HWMs obtained from EPA. HWMs observed during the 1990, 1991, and 2022 flood events were selected to calibrate the developed hydraulic model.

Survey and base data collection documentation is provided in Appendix A and the hydrologic assessment report is provided in Appendix B. Open water flood frequency maps for the 2-year to 1,000-year flood events are provided in Appendix C. The 1:100-year design flood profile was used in preparing design flood hazard maps for the study area. The governing floodway criterion for the flood hazard maps was the 1 m depth contour and no viable flood fringe in several areas where the inundated areas were considered undevelopable. Floodway criteria maps are provided in Appendix D and design flood hazard maps are provided in Appendix E.

DRAFT

TABLE OF CONTENTS

EXECUTIVE SUMMARY	iv
1 INTRODUCTION	1
1.1 Study Background	1
1.2 Study Objectives	1
1.3 Study Area and Reach	2
2 SURVEY AND BASE DATA COLLECTION	2
2.1 Procedures and Methodology	3
2.1.1 Benchmarks	3
2.2 Cross-sections	4
2.3 Hydraulic Structures	4
2.4 Flood Control Structures	5
3 FLOOD HYDROLOGY	5
3.1 Flooding History	5
3.1.1 Historical Floods	5
3.1.2 Recent Floods	5
3.1.3 Ice Jam Floods	5
3.2 Flood Frequency Analysis	5
3.2.1 Overview	5
3.2.2 Flood Frequency Flow Estimates	6
3.2.2.1 Previous Study	6
3.2.2.2 Current Study	6
3.2.3 Comparison to Previous Study	7
4 HYDRAULIC MODELLING	8
4.1 Available Data	8
4.1.1 Digital Terrain Model	8
4.1.2 Existing Models	8
4.1.3 Highwater Marks	8
4.1.4 Gauge Data and Rating Curves	9
4.2 River and Valley Features	9
4.2.1 General Description and River Characteristics	9
4.2.2 Floodplain Characteristics	10
4.2.3 Anthropogenic Features	10
4.3 Model Construction	10
4.3.1 Methodology	10
4.3.2 Geometric Base Data	11
4.3.2.1 Cross-section Data	11
4.3.2.2 Bridge Data	11
4.3.2.3 Flood Control Structures	11
4.3.3 Calibration	11
4.3.3.1 Methodology	11

	4.3.3.2	Calibration Results	12
	4.3.4	Flood Frequency Profiles	12
	4.3.5	Model Sensitivity	12
5		FLOOD INUNDATION MAPS	13
	5.1	Methodology.....	13
	5.2	Water Surface Elevation TIN Modifications.....	13
	5.3	Flood Inundation Areas.....	14
	5.3.1	Key Observations	14
	5.3.2	Flood Polygon Discontinuities.....	15
6		FLOODWAY DETERMINATION.....	15
	6.1	Design Flood Selection.....	15
	6.2	Floodway and Flood Fringe Terminology.....	15
	6.3	Flood Hazard Identification.....	16
	6.3.1	Floodway Determination Criteria	16
	6.3.2	Design Flood Profile	17
	6.3.3	Floodway Criteria Maps.....	17
	6.3.4	Flood Hazard Maps	17
	6.3.4.1	Areas Within The Floodway	17
	6.3.4.2	Areas Within The Flood Fringe.....	18
7		POTENTIAL CLIMATE CHANGE IMPACTS.....	18
8		CONCLUSIONS.....	19
9		REFERENCES.....	20

IN-TEXT TABLES

TABLE A	Alberta Survey Control Network Benchmarks for Survey Control.....	3
TABLE B	Government of Alberta Highwater Mark Benchmarks	4
TABLE C	Hydraulic Structure Details	5
TABLE D	Notikewin River at Manning (07HC001), Flood Frequency Estimates.....	7
TABLE E	Comparison of Flood Frequency Estimates	7
TABLE F	Highwater Mark Data and Flows	9
TABLE G	Computed Water Levels for Potential Climate Change Impacts	18

FIGURES

FIGURE 1	Location Plan
FIGURE 2	Study Area, Cross-Section, Hydraulic Structure and Highwater Mark Locations
FIGURE 3	Notikewin River at Manning (07HC001), Rating Curve
FIGURE 4	Calibration Profiles
FIGURE 5	Flood Frequency Profiles
FIGURE 6	Sensitivity Analysis Profiles, Variable Downstream Boundary Conditions
FIGURE 7	Sensitivity Analysis Profiles, Variable Channel Manning Roughness
FIGURE 8	Sensitivity Analysis Profiles, Variable Overbank Manning Roughness
FIGURE 9	Design Flood Profile

TABLES

TABLE 1	Hydraulic Structure Details
TABLE 2	Calibration Results
TABLE 3	Computed Flood Frequency Water Surface Elevations
TABLE 4	Sensitivity Analysis, Variable Downstream Boundary Conditions at 100-year Flood
TABLE 5	Sensitivity Analysis, Variable Channel Manning Roughness at 100-year Flood
TABLE 6	Sensitivity Analysis, Variable Overbank Manning Roughness at 100-year Flood
TABLE 7	Floodway Stations and Limiting Floodway Determination Criteria
TABLE 8	Design Flood Water Surface Elevations

APPENDICES

APPENDIX A	Survey and Base Data Collection Documentation
APPENDIX B	Hydrologic Assessment Memorandum
APPENDIX C	Flood Inundation Maps
APPENDIX D	Floodway Criteria Maps
APPENDIX E	Flood Hazard Maps

1 INTRODUCTION

Montrose Environmental Solutions Canada Inc. (Montrose, formerly Matrix Solutions Inc.) was retained by the Government of Alberta (GoA) to conduct the Manning Flood Study. Key stakeholders for this project include the GoA, the Town of Manning, and the County of Northern Lights. This flood study is one of several similar studies completed as part of a larger effort by GoA to identify flood hazard areas in communities throughout Alberta to increase public safety and reduce future flood related damages. Information required to complete this study was gathered collectively by Montrose, MSI (surveying subcontractor), key project stakeholders, and the GoA (including its providers of topography and aerial photography information).

1.1 Study Background

A flood frequency analysis of the Notikewin River at Manning using regional frequency analysis method was completed by EPA in 1991 (Alberta Environmental Protection 1991) and derived flood frequencies up to 100-year flood event. A flood risk study for an 8 km reach of the Notikewin River through the Town of Manning was completed by EPA in 2000 (AENV 2000). The current study updates the flood frequencies with return periods ranging from 2-year to 1,000-year using the available historical flood data collected to date and expands the hydraulic modelling extent and flood mapping coverage.

Since the previous flood risk study, GoA has updated flood hazard identification methodology and expanded the scope of its Flood Hazard Identification Program (FHIP). The current study is conducted under the FHIP, utilizing the following documents:

- Manning Flood Study – Specific Terms of Reference (TOR; EPA 2022)
- FHIP Guidelines (AEP 2022)

1.2 Study Objectives

The key study objectives included the following:

- Survey and base data collection:
 - surveying river cross-sections
 - surveying hydraulic structures
 - integrating survey and digital terrain model (DTM) data
- Open water hydraulic modelling:
 - documenting open water flood history
 - creating, calibrating, and validating a HEC-RAS hydraulic model for the Notikewin River
 - simulating 13 flood frequency estimates and creating associated water surface profiles
- Open water flood inundation mapping:
 - preparing flood inundation maps for the specified flood frequency events
 - preparing associated electronic GIS data

- Design flood hazard mapping:
 - preparing flood hazard and floodway criteria maps based on various floodway delineation criteria for the 1:100 year design open water flood
- Reporting and documentation:
 - preparing a study report and associated electronic GIS study file and digital deliverables database to document methods and results

1.3 Study Area and Reach

The study reach extends from the western boundary of NW 13-091-24 W5M to just downstream of the railway bridge near Range Road 231 at the western boundary of SW 36-091-26 W5M and covers a distance of 24 km (Figure 1).

The Notikewin River is a tributary of the Peace River; its headwater is in the Clear Hills, and it flows in an easterly direction toward its confluence with the Peace River approximately 85 km downstream. The upper reaches of the river basin are forested with White and Black Spruce and Aspen Poplar and the major land use surrounding the town and County of Northern Lights is agricultural. The Notikewin River flows through the Town of Manning; developed areas are located on both banks of the river.

A WSC gauging station 07HC001 (Notikewin River at Manning) is located within the study reach and has been operating since 1961. Based on a review of historical streamflow data, past flood events affecting the Notikewin River study reach have been primarily open water floods. Based on the gauge records, large flood events usually occur from April through July, although annual peak discharges have been recorded as late as September. The drainage area of the Notikewin River at the gauge location is 4,680 km².

2 SURVEY AND BASE DATA COLLECTION

Montrose conducted a site visit with GoA and MSI staff on June 5 and 6, 2023, to inform the survey work. This included confirming the proposed cross-section locations that were identified during the initial desktop review of the study reach imagery and topography, identifying hydraulic structures to be included in the project, identifying highwater marks to be surveyed and refining the survey scope. The information collected has suggested that there are no flood control structures present along any of these rivers within the study reach.

The survey work was completed in June 2023; MSI led the data collection and quality management process under Montrose's supervision and direction. Data collected along the study reach during the survey included the following:

- river cross-sections
- hydraulic structure (bridges and weir) geometry
- WSC hydrometric station benchmarks
- GoA highwater mark benchmarks

- ASCN benchmarks
- associated georeferenced photographs

The scope of work for survey and base data collection did not include the collection of LiDAR topography data. This information was provided to Montrose by the GoA to inform the Manning Flood Study.

2.1 Procedures and Methodology

A brief overview of the procedures and methodology of the various parts of the survey work is summarized below. All survey data collected for the study met the standards and accuracy described in the FHIP:

- Ground survey data have an absolute positional accuracy of ± 0.05 m, at 95% confidence. Bathymetric survey data have an absolute positional accuracy of ± 0.15 m.
- All survey data is reported using the appropriate local 3-Degree Transverse Mercator (3TM) zone referenced horizontally to the Canadian Spatial Reference System (Government of Canada 2018, North American Datum of 1983, Epoch 2002 [NAD83 [CSRS], Epoch 2002]). Vertically, the data is referenced to the Canadian Geodetic Vertical Datum of 1928 (CGVD28). Ellipsoidal heights will be transformed to CGVD28 orthometric heights using the HTv2.0 hybrid geoid model.
- The ASCN was used for the survey control for the project. ASCN benchmarks were surveyed using a static Global Navigation Satellite System (GNSS) measurement at a minimum of 4 hours in duration and 2 hours of redundancy.

Summarized quality assurance and accuracy quantification documentation related to the control survey and the daily survey activities is provided in Appendix A.

2.1.1 Benchmarks

The ASCN benchmarks used for the project's survey control are listed in Table A; each benchmark was ground-surveyed by MSI. A comparison of elevations confirmed consistency between the reported and surveyed values. The MSI benchmark elevations were adopted for this project.

TABLE A Alberta Survey Control Network Benchmarks for Survey Control

ASCN Benchmark ID	3TM Coordinates (m; NAD 83 (CSRS) 3TM 117)		ASCN Elevation (m)	MSI Surveyed Elevation (m)	Difference (m)
	Easting	Northing			
291369	-33143.559	6313238.648	462.054	461.973	0.081
742825	-38362.501	6311652.756	483.295	483.274	0.021
803734	-38406.694	6310518.430	469.487	469.456	0.031
918193	-38190.872	6309679.298	486.035	486.033	0.002

Benchmarks established by the GoA during the 2023 post-flood response were also surveyed by MSI (Table B).

TABLE B Government of Alberta Highwater Mark Benchmarks

GoA Benchmark Location	GoA Benchmark Name	Description	3TM Coordinates (m; NAD 83 (CSRS) 3TM 117)		MSI Surveyed Elevation (m)
			Easting	Northing	
Manning 1	Benchmark 1	northwest bolt on light post at southwest corner of bridge	-38,312.439	6,310,910.900	460.475
Manning 2	Benchmark 2	middle bracket on fence post	-38,975.171	6,310,710.467	457.840
Manning 3	Benchmark 1	middle of top bar of railing of gazebo on west side of octagon	-37,543.569	6,310,501.909	455.665
Manning 4	Benchmark 1	downstream of WSC shack	-37,648.021	6,310,537.700	455.985
	Benchmark 2	southwest corner of WSC shack	-37,662.368	6,310,547.183	455.430
	Benchmark 3	near power pole	-37,660.404	6,310,528.681	456.960
Manning 5	Benchmark 1	top of concrete on corrugated steel pipe culvert	-38,857.068	6,311,012.915	456.367
	Benchmark 2	top of concrete on sidewalk each of house	-38,857.380	6,310,992.540	457.852

2.2 Cross-sections

Channel and overbank cross-sectional geometry, including near overbank topography and channel bathymetry, were surveyed at locations identified in the approved survey plan using a combination of conventional and echo sounding survey methods.

A combination of the Leica® GS14s GNSS Real-Time Kinematic (RTK) GPS System, and Hemisphere S621 and S321 antennas were used for the collection of most survey data. An echosounder was not used to collect the bathymetry data due to low flow depths encountered at the time of survey. The combined accuracy of points collected meet the requirements listed in Section 2.1.

2.3 Hydraulic Structures

Hydraulic structure surveys were completed using standard RTK equipment. An inventory of surveyed hydraulic structures is provided in Table C, listed upstream to downstream; the structures are shown on Figure 2. The three hydraulic structures listed below are included in the model.

- Weir structure
- Highway 35 bridge
- Rail bridge near the downstream end of the study reach

TABLE C Hydraulic Structure Details

Hydraulic Structure Name	Bounding River Stations (m)	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 117)	
		Northing	Easting
Weir Structure	8714.77 and 8698.65	-38,818.278	6,310,595.710
Highway 35 Bridge	7326.89 and 7292.71	-35,126.688	6,311,718.097
Rail Bridge	928.96 and 898.20	-38,286.598	6,310,942.679

2.4 Flood Control Structures

No flood control structures are located within the study reach.

3 FLOOD HYDROLOGY

3.1 Flooding History

3.1.1 Historical Floods

Several historical floods have occurred on the Notikewin River during the period of record. Recent flooding was experienced in May 2022, as detailed in Section 3.1.2. The largest recorded historical flood prior to 2022 occurred in 1964 with a magnitude of 537 m³/s; the second largest flood occurred in 1972 with a magnitude of 487 m³/s. Several historical floods with magnitude greater than 400 m³/s occurred in 1963, 1964, 1972, 1977, and 1978. The study area has also been subject to severe floodings in the recent years including 2013 (225 m³/s), 2019 (225 m³/s), 2020 (314 m³/s), and 2021 (157 m³/s).

3.1.2 Recent Floods

Two significant flood events were experienced on the Notikewin River in May 2022; the magnitudes of these floods are 452 m³/s for the May 8, 2022 flood and 592 m³/s for the May 31, 2022 flood. No major flood events have occurred on the Notikewin River since 2022.

3.1.3 Ice Jam Floods

Based on a review of historical background information, there is no indication of significant ice jam flooding through the study reach. Ice jam flood analysis was not included within the project TOR.

3.2 Flood Frequency Analysis

3.2.1 Overview

Hydrologic analysis was undertaken to recommend 2- to 1,000-year return period instantaneous flood estimates for the Notikewin River to be used for subsequent hydraulic modelling and flood inundation mapping. Since the WSC station (07HC001) has a relatively long period of records (62 years of data) and is located within the study reach, the flood frequency estimates at this location were used for deriving flood frequencies for this flood hazard mapping study. Included as Appendix B in this report, Montrose (2025) provided detailed information on the hydrologic analysis undertaken for the Notikewin River.

3.2.2 Flood Frequency Flow Estimates

3.2.2.1 Previous Study

A flood frequency analysis was completed in 1991 based on a regional analysis of limited maximum instantaneous discharge data (Alberta Environmental Protection 1991); these flood frequency estimates were adopted in the 2000 flood risk study (AENV 2000). The flood frequency estimates were derived for various return periods ranging from 2-year to 100-year floods and considered several theoretical probability distributions including, normal, log normal, 3-parameter log normal, Pearson III, log-Pearson III and Gumbel distributions. The estimated flood frequencies varied from 215 m³/s (2-year flood) to 2,590 m³/s (100-year flood; EPA 1991).

3.2.2.2 Current Study

Standard statistical analysis of the generated annual maximum instantaneous discharges for the WSC station, Notikewin River at Manning (07HC001), were completed as a part of the flow frequency analysis. Different theoretical probability distributions to the observed datasets were tested for their suitability for the subject dataset, and the most suitable theoretical distribution was selected based on comparing visual goodness of fit curves against the observed data and comparing results of statistical goodness of fit tests. The goodness of fit of each distribution, as applied to a flood series, was compared through the Kolmogorov-Smirnov (K-S) test, Anderson-Darling test, and Least-Squares method.

Various 2-parameter and 3-parameter theoretical probability distributions were tested. These distributions included: Normal, log normal, 3-parameter log normal, Pearson Type III, log-Pearson Type III, Extreme Value 1 (EV1), Exponential, Weibull, Gamma, and Gumbel extreme value distributions. Hydrological Frequency Analysis (Hyfran) Plus Version 1.2 software and the Microsoft Excel® based tool created for City of Calgary Frequency Analysis (AMEC 2014) were used to compute flood frequency estimates and to perform goodness of fit testing. Best fitting curve methods considered included method of moments and method of maximum likelihood. The Cunnane positioning formula was used to plot data points for visualization purposes.

The log-Pearson Type III distribution was selected to represent the flood frequencies for the Notikewin River at Manning (07HC001). A summary of the flood frequency estimates adopted for this study with 95% confidence intervals is provided below in Table D.

TABLE D Notikewin River at Manning (07HC001), Flood Frequency Estimates

Return Period (years)	Instantaneous Peak Discharge ¹ (m ³ /s)	Lower 95% Confidence Limit (m ³ /s)	Upper 95% Confidence Limit (m ³ /s)
2	177	154	203
5	299	257	356
10	386	327	473
20	474	393	596
35	545	454	681
50	590	479	765
75	642	522	832
100	677	543	898
200	767	607	1037
350	839	668	1132
500	888	692	1227
750	938	724	1302
1,000	980	756	1376

3.2.3 Comparison to Previous Study

A comparison of the flood frequency estimates for the 1991 study (EPA 1991) and the current study is provided below in Table E.

TABLE E Comparison of Flood Frequency Estimates

Return Period (years)	Flood Frequency Estimates in Current Study (m ³ /s)	Flood Frequency Estimates in 1991 Study (m ³ /s)
2	177	215
5	299	635
10	386	996
20	474	1,395
50	590	2,100
100	677	2,590

1991 flood frequency estimates for all return periods except the 2-year return period are significantly higher than the current estimates. In the 1991 report, it was noted that due to lack of adequate data, there is a high degree of uncertainty with the regional analysis adopted in that study; it was recommended that the 100-year flood magnitude be updated once more data is available.

Given the relatively long period of streamflow data at the WSC station (07HC001) located within the study area, flood frequency estimates derived in this study using a Single Station Flood Frequency Analysis method is considered appropriate and representative of flood conditions within the study reach.

4 HYDRAULIC MODELLING

4.1 Available Data

4.1.1 Digital Terrain Model

A 0.5 m grid DTM was procured by EPA and provided to Montrose for use in flood inundation mapping. The horizontal coordinates were provided in Alberta 3TM referenced to NAD83; vertical coordinates are referenced to CGVD28.

Though the DTM has already undergone independent quality control to ensure compliance with the FHIP guidelines accuracy standards, the DTM was compared to surveyed overbank elevations to confirm that the DTM is suitable for use in cross-section extraction and flood mapping. Generally, good agreement was observed between the DTM and overbank surveyed elevations. For the majority of the comparison points (71%), the DTM derived elevations were up to 0.3 m higher than the ground survey, which indicates that the vegetation in these areas was not penetrated by the LiDAR. Larger differences in elevation (ranging from 0.3 m to 1.0 m) were observed in areas of steep surfaces such as along channel banks or roadway embankments. In our experience, these elevation differences are consistent with those encountered in similar conditions and the DTM was considered acceptable for use in flood mapping.

4.1.2 Existing Models

As mentioned in Section 1.1, a flood risk study was undertaken in 2000 and a HEC-RAS hydraulic model was developed to calculate water surface profiles and delineate the floodway and flood fringe boundary for the 100-year flood. The developed model and study report was provided to Montrose by EPA and was reviewed to compare and confirm hydraulic parameters selected for use in the current hydraulic model.

4.1.3 Highwater Marks

HWMs related to several flood events were collected by EPA. HWMs through the study reach are available for the 1990, 1991 and two 2022 flood events. Locations of the HWMs selected for model calibration are provided on Figure 2; Table F provides a summary of the HWM data and corresponding flows.

TABLE F Highwater Mark Data and Flows

Alberta Environment and Parks Highwater Mark	River Station (m)	Observed Water Surface Elevation (m)
1990 Flood Event (Q = 368 m³/s)¹		
90-Notik-17	8488.74	456.47
90-Notik-12-a	7326.89	454.79
90-Notik-12-b	7292.71	454.76
1991 Flood Event (Q = 145 m³/s)		
Notik-91-20	9360.12	456.51
Notik-91-17	8355.61	455.20
Notik-91-12	7428.27	453.61
Notik-91-8.1	6714.91	452.98
Notik-91-7	5992.49	452.43
Notik-91-1	3847.00	448.29
May 8, 2022 (Q = 452 m³/s)		
Manning 2	8488.74	456.95
Manning-5	8081.35	456.07
Manning-1	7326.89	455.68
Manning-4	6714.91	454.78
Manning-3	6540.25	454.65
May 31, 2022 (Q = 592 m³/s)²		
Manning-2	8355.61	457.46
Manning-5	8081.35	456.52
Manning-3	6540.25	455.24

1. Spatial location information provided by EPA for the 1990 and 1991 HWMs was found to be inaccurate. 1990 and 1991 HWM locations adopted for use in this study were determined based on georeferencing of historic figures and landmarking based on written descriptions.
2. HWM ID not available. Location provided relative to May 12, 2022 HWM survey.

4.1.4 Gauge Data and Rating Curves

As discussed in Section 1.3, WSC gauge 07HC001 (Notikewin River at Manning) is located within the study reach approximately 750 m downstream of the Highway 35 bridge. Field recorded stage and discharge data for the gauge was provided by the WSC office for a period spanning May 1978 to May 2024. The maximum discharge recorded at the gauge was 309 m³/s in May 1978, which represents a return period near the 5-year flood. The stage data was transformed to geodetic elevations based on a gauge datum elevation of 450.674 m. The rating curve based on recorded discharge-elevation data at the 07HC001 gauge is presented on Figure 3, along with the current (2019) and past rating curves (1995 and 2015) developed by the WSC.

4.2 River and Valley Features

4.2.1 General Description and River Characteristics

EPA (1991) provided a general overview of the river valley and channel characteristics. The river valley is about 30 m deep and up to 1.5 km wide. The valley walls are moderately forested with continuous terraces. The channel bed is comprised of gravel overlying soft cohesive shale; bank materials are comprised of silt, sand, and erodible rock.

The river channel is confined and exhibits irregular patterns with almost tortuous meanders with pool and riffle sequence in combination with diagonal and point bars (Kellerhals et al. 1972). The general elevation of the river in the project area is in the range of 450 m. The bankfull width and depth vary throughout the study reach. The longitudinal slope of the river averages about 0.0015 throughout the study reach. A review of Alberta Transportation bridge file (#70594-Highway 35 over Notikewin River) indicates that the channel capacity is 1,000 m³/s with a bank height of 4.5 m, bottom width of 40 m, and a top width of 70 m at the bridge crossing location. The planform of the river within the study reach is a mainly single channel within the study area.

4.2.2 Floodplain Characteristics

The floodplain area is mainly cultivated with forested areas. The floodplains are wide and open with occasional slumps. The study reach passes through the Town of Manning; urban development is present on both river banks though the majority of the infrastructure is situated along the right bank through the Manning townsite.

4.2.3 Anthropogenic Features

A total of three hydraulic structures are located within the study reach, including one rail bridge, one vehicle bridge, and one weir (refer to Table 1 for details). The bridge decks, embankments, and adjacent road segments at both bridge crossings are situated sufficiently high so as not to be overtopped during the simulated flood events.

4.3 Model Construction

4.3.1 Methodology

The HEC-RAS hydraulic modelling software (Version 6.5; USACE 2024) was used to simulate flood levels through the model reach for flood events associated with various return periods ranging from the 2-year to the 1,000-year flood. HEC-RAS is a hydraulic model that solves 1D or 2D flow equations of conservation of mass and conservation of momentum representing the physical laws governing open channel flows. Specific capabilities include 1) calculation of subcritical, super critical, and mixed flow conditions; 2) modelling of effect of obstructions and structures such as bridges, culverts, and flood control structures such as weirs; and 3) modelling of effect of changes in channel geometry due to encroachments, channelization, and flood control dikes or levees. For this project, a 1D HEC-RAS model was developed to simulate flow conditions through the study reach. HEC-GeoRas in ArcGIS Desktop was used to translate merged topographic survey and LiDAR datasets into geometry files to be imported to HEC-RAS.

The downstream model boundary on the Notikewin River was extended by approximately 600 m downstream of the study reach boundary so that any uncertainty in the downstream boundary conditions does not impact simulated water levels within the study reach.

4.3.2 Geometric Base Data

4.3.2.1 Cross-section Data

A total of 79 cross-sections were identified for surveying; cross-sections were extended into the floodplain based on the DTM provided to Montrose by EPA.

The combined channel and floodplain data often amounted to more than 500 points per cross-section. The *minimize area change* point routine in HEC-RAS was used to filter the cross-section data; final sections were examined to ensure that they retained surveyed channel data and appropriately represented the channel geometry.

Ineffective areas were applied at select cross sections to reflect offline ponding areas that do not actively convey flow. In addition, ineffective areas were placed around bridge crossings using the approach outlined in the HEC-RAS Hydraulic Reference Manual (USACE 2022). Levees were also applied to select cross-sections to prevent flooding from extending into overbank locations that cannot be inundated from upstream or downstream modelled cross sections.

4.3.2.2 Bridge Data

Two bridges were included in the hydraulic model (Table 1). Model input data for bridges was obtained from survey data collected by MSI in June 2023.

Contraction and expansion coefficients of 0.1 and 0.3, respectively, were adopted for gradual transitions through the study reach. These coefficients were increased to 0.3 and 0.5 around all bridge crossings, at which abrupt changes in the effective flow area are encountered.

4.3.2.3 Flood Control Structures

No flood control structures are located within the study area.

4.3.3 Calibration

4.3.3.1 Methodology

Model calibration is an iterative process conducted to ensure that the model is providing representative flow behaviour based on comparison of simulated and observed water surface elevations. Though Manning roughness is the primary calibration parameter, adjustments to the ineffective flow area and expansion/contraction coefficients may also be required. Ineffective flow areas were initially defined based on visual inspection of the DTM and were adjusted slightly during the calibration process. Though sufficient adjustment to these parameters may be feasible to match observed water levels very closely, it is important to maintain gradual variations in roughness throughout the study reach and prescribe reasonable values for the given conditions.

The hydraulic model was calibrated and validated against surveyed highwater marks (HWMs) and the corresponding peak discharges for major flood events that occurred on the Notikewin River. The source of data used for the assessment were high water marks obtained from EPA. HWMs observed during June 1990, June 1991, and May 8, 2022 and May 31, 2022 flood events were selected to calibrate the HEC-RAS

model, as detailed in Table A. Note that two separate flood peaks occurred in May 2022; HWMs corresponding to each peak were collected and were used for model calibration, as detailed in Table F.

In the absence of observed water level data at the downstream boundary, the normal depth boundary condition was adopted based on an assumed energy slope 0.0015 m/m, which is equivalent to the average lower channel reach bed slope. Channel roughness values of 0.03 provided the best fit to the observed HWMs for all discharges. Overbank roughness was selected based on aerial imagery and photographs collected during the survey based on guidance provided in Chow (1959).

4.3.3.2 Calibration Results

Figure 4 provides a comparison of the simulated water surface profiles and observed HWMs for the calibration model runs. The simulated and observed water surface elevations are summarized below and in Table 2.

A channel roughness of 0.03 provided the best overall fit to the observed HWMs for all discharges. Overbank roughness varied from 0.04 to 0.08 and was selected based on aerial imagery and photographs collected during the survey based on guidance provided in Chow (1959). Calibration of the overbank roughness was not undertaken due to the limited observed water level data.

For the 1990 event, the difference between simulated and observed water level ranged from 0.05 m at RS 8489 to 0.32 m at RS 7327 (immediately upstream of the Highway 35 bridge). For the 1991 event, the difference between simulated and observed water level ranged from -0.24 m at RS 5992 to 0.42 m at RS 3847. For the May 8, 2022 event, the difference in water level ranged from -0.14 m at RS 7327 to 0.24 m at RS 8081. For the May 31, 2022 event, the difference in water level ranged from -0.25 m at RS 8356 to 0.35 m at RS 8081.

4.3.4 Flood Frequency Profiles

Figure 5 provides the simulated water surface profiles for the 2-year to 1,000-year flood discharges on the Notikewin River. Table 3 provides the water surface elevations at each model cross-section for the range of flood events simulated on the Notikewin River. The 07HC001 gauging station rating curve, including hydraulic model outputs for the range of modelled discharges, is presented on Figure 3.

4.3.5 Model Sensitivity

Sensitivity analyses were conducted to evaluate the impact of estimated model parameters on simulated water levels for the 100-year design flood and included the following:

- Variation of the downstream energy slope ($\pm 30\%$)
- Variation of the Manning roughness values ($\pm 20\%$)

Figure 6 and Table 4 provides a comparison of the simulated water surface profiles for the variable downstream boundary conditions. The deviation in water surface elevation from the calibrated 1:100-year flood profile diminishes to less than 0.05 m by RS 1142 (NOT007; 580 m upstream of the downstream mapping boundary) and to less than 0.1 m by RS 564 (NOT003; at the downstream mapping boundary).

The channel roughness adopted for the calibrated profile is 0.03; the alternate channel roughness values investigated here are 0.024 and 0.036. Figure 7 and Table 5 provides a comparison of the simulated water surface profiles for the variable channel roughness values. The average and maximum difference in water surface elevations is -0.41 m and -0.51 m, respectively, for the lower value of $n = 0.024$; these differences are 0.34 m and 0.42 m for the higher value of $n = 0.036$.

Figure 8 and Table 6 provides a comparison of the simulated water surface profiles for the variable overbank roughness conditions ($\pm 20\%$). The maximum difference in water surface elevations as compared to the calibrated profile for the lowered and raised overbank roughness conditions are 0.01 m and 0.04 m, respectively. The variations reported herein are considered to be within the expected modelling accuracy. It is concluded that the hydraulic model based on the assigned overbank and channel roughness values and downstream boundary conditions can be confidently used for developing flood inundation and flood hazard maps for the study reach.

5 FLOOD INUNDATION MAPS

5.1 Methodology

The flood surface profiles for all open water inundation scenarios modelled along the Notikewin River were interpolated and translated to inundation boundaries through ArcGIS Desktop 10.8.2. For each of the 13 flood inundation scenarios, an initial water surface elevation was generated using the automated triangulated irregular network (TIN) interpolation tools based on results from the hydraulic model using the 3D Analyst extension. The resulting water surface elevation TINs were then translated into a grid format adhering to raster resolution and snapping environments in ArcGIS to ensure all grid outputs are correctly aligned with the input terrain data. The DTM was then subtracted from the interpolated water surface elevation grid to calculate the flood depth grid. The DTM product compared against the interpolated water surface does not have the bathymetry of the channel represented in the topographic surface. When LiDAR is acquired, it can only return the surface of water and not the elevation of the bottom of the channel. As such, the flood depth values calculated in the channel will not be representative of the full flood depth. From the flood depth grid, a first estimate of the inundation extent grid was defined by identifying cells greater than zero. Cells less than zero are indicative of the topography being higher than the modelled water surface elevation. By reclassifying the flood depth surface, the inundation extent grid for a given inundation scenario were delineated with the same resolution as the original DTM. The inundation grid extent was then converted into a polygon, where it was run through a smoothing algorithm (PAEK; 15 m) and a polygon/polygon hole filter (<100 sq. m holes or polygons are removed unless otherwise flagged [see Section 5.3]).

Manual adjustments to the flood profile to accommodate backwater flood and overtopping are described in Section 5.2.

5.2 Water Surface Elevation TIN Modifications

The initial inundation extent was inspected to identify areas of backwater flooding where manual TIN modifications are required to modify water surface elevation where level pooling is expected. To address

these areas, the TIN water surface elevation was manipulated through the addition of breaklines and areas of constant water level elevation. In areas where there is a single overtopping point that was otherwise hydraulically confined (e.g., inundation spills over a road at a single location and pools behind it), the TIN surface was adjusted to a level surface in the area behind the road based on the elevation of that overtopping point. Areas where there are multiple overtopping points (e.g., the inundation spills at one point, continues flowing downgrade, and spills again to reconnect with the main channel) were adjusted so that the gradient between the upstream and downstream overtopping points was equal to the gradient in the main channel. The elevation at the overtopping point was based on the interpolated water level surface at upstream and downstream overtopping points.

5.3 Flood Inundation Areas

Open water flood inundation maps for the 2-year to 1,000-year flood events are presented in Appendix C.

5.3.1 Key Observations

A summary of key observations from the open water inundation maps is presented below:

- Pedestrian trails, roads and parking areas are impacted on right riverbank through the townsite at the 5-year flood and higher (mapsheet 7).
- A residence situated on the left riverbank between RS 19632 and RS 19236 is impacted at the 10-year flood and higher (mapsheet 3).
- A residence located on the left riverbank between RS 13566 and RS 14042 is impacted at the 10-year flood and higher (mapsheet 4).
- Parking areas located on the left riverbank are impacted at the 10-year flood and higher (mapsheet 8).
- An access road to a residence and outbuildings located on the left riverbank near RS 12376 is overtopped at the 20-year flood and higher (mapsheet 5).
- Several residences, roads, and commercial buildings situated on the right riverbank through the townsite are impacted at the 50-year flood and higher (mapsheet 7).
- Residences situated on the left riverbank between RS 6962 and RS 6715 are impacted at the 50-year flood and higher (mapsheet 8).
- An access road to a residence located off Township Road 914A near RS 14245 is impacted at the 100-year flood and higher (mapsheet 4). This residence is impacted at the 200-year flood and higher.
- Outbuildings at a residence located near RS 24209 are impacted at the 500-year flood and higher (mapsheet 1).
- Access to a residence located near RS 21486 is impacted at the 500-year flood and higher (mapsheet 2). This residence is impacted at the 750-year flood and higher.

At both bridges, the bridge decks, embankments and adjacent road segments were situated sufficiently high so as not to be overtopped during the simulated flood events.

5.3.2 Flood Polygon Discontinuities

Flood polygon discontinuities refer to those areas that are topographically isolated from the directly inundated areas but hydraulically connected via a hydraulic structure such as a culvert.

A suspected culvert affecting an otherwise isolated areas was identified during flood inundation mapping (Mapsheet 5 near RS 12376). The presence of this culvert was subsequently field verified by Town of Manning personnel; as such, this culvert has been identified on the mapping and the associated isolated area was retained in the inundation mapping. There are potentially other culverts that were not identified during aerial imagery review that may result in inundation of isolated areas that are not shown on the maps.

6 FLOODWAY DETERMINATION

6.1 Design Flood Selection

Flood hazard identification involves delineation of floodway and flood fringe zones for a specified design flood. As per the FHIP guidelines (AEP 2022), the 100-year flood was adopted as the open water design flood and is defined based on flood statistics available at the time of the study. A description of key terms from the FHIP guidelines (AEP 2022), incorporating technical changes as indicated in the TOR (EPA 2022) regarding how floodways are mapped in Alberta is provided in sections below.

6.2 Floodway and Flood Fringe Terminology

Flood hazard mapping identifies the area flooded during the design flood event and is typically divided into floodway and fringe zones. Flood hazard maps can also show additional flood hazard information, including areas of relatively high hazard within the flood fringe and incremental areas at risk for more severe floods, like the 200-year and 500-year floods. Flood hazard mapping is typically used for long-term flood hazard area management and land use planning.

- **Floodway:** when a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazards where flows are deepest, fastest, and most destructive during the 100-year design flood. The floodway generally includes the main channel of a stream and a portion of the adjacent overbank area. Previously mapped floodways do not typically become larger when a flood hazard map is updated, even if the flood hazard area gets larger or design flood levels get higher.
- **Flood fringe:** the flood fringe is the portion of the flood hazard area outside of the floodway. The flood fringe typically represents areas with shallower, slower, and less destructive flooding during the 100-year design flood. However, areas with deep or fast-moving water may also be identified as high hazard flood fringe within the flood fringe. Areas at risk behind flood berms may also be mapped as protected flood fringe areas.

- Design flood levels: design flood levels are the computed water levels associated with the design flood.

6.3 Flood Hazard Identification

6.3.1 Floodway Determination Criteria

The computed water levels associated with the design flood are used as the design flood levels in flood hazard identification and mapping process. Some important factors considered in floodway determination criteria include the following:

- 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, are 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 can be made in, but are not limited to, cases such as:
 - A floodway could get larger if main channel shifts outside of a previously defined floodway.
 - 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 are identified as high hazard flood fringe. These high hazard flood fringe zones are identified in all areas, whether they are newly mapped or have an existing floodway. The depth and velocity criteria used to define high hazard flood fringe zones are aligned with the 1 m depth and 1 m/s velocity floodway determination criteria for newly-mapped areas.
- All areas protected by dedicated flood berms that are not overtopped during the design flood are excluded from the floodway. Areas behind flood berms will still be mapped as flooded if they are overtopped, but areas at risk of flooding behind dedicated flood berms that are not overtopped will be mapped as a protected flood fringe zone.

Previously developed flood hazard maps for the study area were based on a 100-year flood with a magnitude of 2,590 m³/s (as opposed to the 100-year flood magnitude of 679 m³/s adopted for this study). As a result, the flood inundation mapping and flood hazard mapping developed for this study differ

significantly from the previous version and are considered more representative of the current hydrologic and hydraulic conditions of the river. No flood control structures are located within the study reach. Floodway stations were selected using the above-mentioned factors and considering geomorphic and landscape features under design flood levels (Table 7).

6.3.2 Design Flood Profile

Table 8 lists the water surface elevations computed for the 100-year design flood; water surface profiles are plotted on Figure 9.

6.3.3 Floodway Criteria Maps

Floodway criteria maps are a tool for determining floodway and flood fringe extents for the design flood including boundaries of high hazard flood fringe and protected flood fringe areas. The Open Water Floodway Criteria Maps (Sheet 1 to Sheet 10, Appendix D) provided in the Maps and Drawings section of this report show:

- inundation extents of the 100-year open water design flood
- areas where the depth of water is 1 m or greater and the corresponding 1 m depth contour
- the portions of each cross-section where the computed velocity is 1 m/s or greater
- the proposed floodway boundary, as well as the floodway stations corresponding to the floodway determination criteria
- isolated areas of non-flooded, high ground (i.e., “dry” areas) within the design flood extent
- the location and extent of all cross-sections used in the HEC-RAS model
- additional information concerning flood criteria maps are provided in the section below

6.3.4 Flood Hazard Maps

Flood hazard maps for the 100-year design flood are provided in Appendix E. The floodway is primarily governed by the 1 m depth contour for the study reach. Manual adjustments to the floodway boundary were made in some locations in consultation with EPA to maintain a hydraulically smooth floodway between cross-sections; this resulted in some areas with flow depths greater than 1 m being classified as flood fringe. These areas are categorized as high hazard flood fringe zone.

6.3.4.1 Areas Within The Floodway

Throughout the study reach, the floodway varies in width from 48 m to 353 m with depth and no viable flood fringe as the governing criteria. Several flood fringe areas are observed in low-lying areas, through inside channel bends and a historic meander scar. Though a floodway has previously been developed for this reach, given the updates to the flood magnitudes, the floodway was redefined based on the current study. Floodplain impacted by the floodway generally consists of cultivated or forested land. Several residences, outbuildings, an access roach and pedestrian trails/parking areas are situated within the floodway, including:

- A residence situated on the left riverbank between RS 19632 and RS 19236 (mapsheet 3).

- A residence located off Township Road 914A near RS 14245 (mapsheet 4).
- An access road to a residence and outbuildings located on the left riverbank near RS 12376 (mapsheet 5).
- Pedestrian trails, roads and parking areas on the right riverbank through the townsite (mapsheet 7).

6.3.4.2 Areas Within The Flood Fringe

As noted above, several flood fringe areas are located through inside channel bends and at a low-lying historic meander scar. Areas of high hazard flood fringe (>1 m depth) are present along the Notikewin River at the following locations:

- Right bank near RS 23527 (mapsheet 1)
- Left bank near RS 22857 (mapsheet 1)
- Right bank near RS 20004 (mapsheet 2)
- Left bank near RS 19236 (mapsheet 3)
- Right bank near RS 3249 (mapsheet 9)
- Left bank near RS 318 (mapsheet 10)

7 POTENTIAL CLIMATE CHANGE IMPACTS

Climate change projections for Alberta generally predict an increase in annual temperatures and precipitation as well as increased intensity and frequency of extreme events (Alberta WaterPortal 2018). In an effort to quantify these impacts, the 100-year flood magnitude was increased by 10% and 20%, with resulting water levels compared to the baseline elevations. The climate change estimates undertaken herein rely on a simplified approach and do not include an assessment of comprehensive regional climate change impacts. Table G provides a summary of the average increase in water level (as compared to baseline water levels) for an increase of 10% and 20% to the 100-year flood discharge. Based on these results, it would be reasonable to apply a freeboard 0.5 m to simulated design water levels when attempting to account for climate change concerns. This freeboard has not been incorporated in the flood mapping presented herein.

TABLE G Computed Water Levels for Potential Climate Change Impacts

	Water Level Difference (m) ¹	
	10% Increase Q = 745 m ³ /s	20% Increase Q = 812 m ³ /s
Average	0.21	0.40
Maximum	0.27	0.51

1. As compared to baseline water levels.

8 CONCLUSIONS

Flow estimates for the 2-year to 1,000-year flood events for the study were estimated by utilizing recorded flows at the Water Survey of Canada (WSC) hydrometric gauging station, Notikewin River at Manning (07HC001).

The hydraulic model and resulting map products were constructed using LiDAR data provided by GoA and surveyed cross-sections, and hydraulic structure data collected by MSI under Montrose's supervision. All surveyed data was tied together using ASCN benchmarks that were surveyed independently during the various data collection phases. The hydraulic model was calibrated using surveyed HWMs collected during the 1990, 1991, and 2022 flood events.

A summary of major conclusions from the open water inundation maps (Appendix C) for the 2-year to 1,000-year flood events is presented below:

- Mapsheet 1: Outbuildings at a residence located near RS 24209 are impacted at the 500-year flood and higher.
- Mapsheet 2: Access to a residence located near RS 21486 is impacted at the 500-year flood and higher. This residence is impacted at the 750-year flood and higher.
- Mapsheet 3: A residence situated on the left riverbank between RS 19632 and RS 19236 is impacted at the 10-year flood and higher.
- Mapsheet 4: A residence located on the left riverbank between RS 13566 and RS 14042 is impacted at the 10-year flood and higher. An access road to a residence located off Township Road 914A near RS 14245 is impacted at the 100-year flood and higher. This residence is impacted at the 200-year flood and higher.
- Mapsheet 5: An access road to a residence and outbuildings located on the left riverbank near RS 12376 is overtopped at the 20-year flood and higher.
- Mapsheet 7: Pedestrian trails, roads and parking areas are impacted on right riverbank through the townsite at the 5-year flood and higher. Several residences, roads and commercial buildings situated on the right riverbank through the townsite are impacted at the 50-year flood and higher.
- Mapsheet 8: Parking areas located on the left riverbank are impacted at the 10-year flood and higher. Residences situated on the left riverbank between RS 6962 and RS 6715 are impacted at the 50-year flood and higher.

At both bridges, the bridge decks, embankments and adjacent road segments were situated sufficiently high so as not to be overtopped during the simulated flood events.

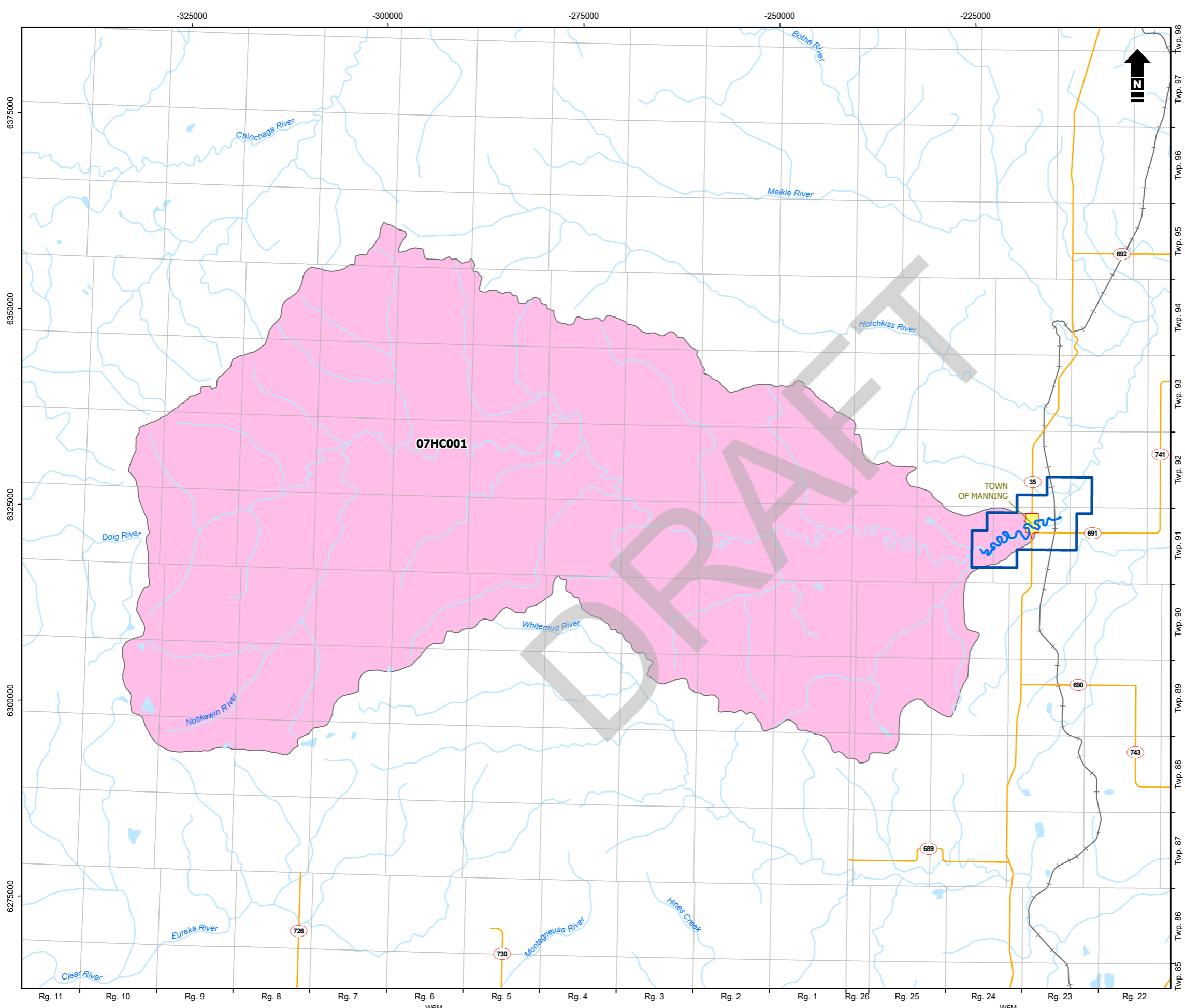
The 1:100-year design flood profile was used in preparing flood hazard maps for the study area. Floodway criteria maps are provided in Appendix D and design flood hazard maps are provided in Appendix E. The governing floodway criterion for the flood hazard maps was the 1 m depth contour, and included flood

fringe in several areas where the inundated area was considered to be inviable flood fringe. Though a floodway has previously been developed for this reach, given the updates to the flood magnitudes determined for the current study, the floodway was redefined based on the updated modelling results. Several flood fringe areas are located through inside channel bends and at a low-lying historic meander scar; areas of high hazard flood fringe (>1 m depth) are present at several locations.

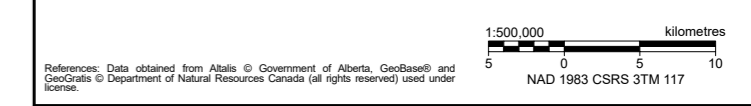
9 REFERENCES

- Alberta Environment and Parks (AEP). 2022. *Flood Hazard Identification Program Flood Study Technical Guidelines*. River Engineering and Technical Services. June 2022.
- Alberta Environment and Protected Areas (EPA). 2022. *Red Deer River County and Markerville Flood Study - Terms of Reference*. August 2022.
- Alberta Environmental Protection. 1991. *Flood Frequency Analyses Notikewin River at Manning Floodplain Study*. Water Resources Management Services, Technical Services Division, Hydrology Branch. Draft Prepared for the Town of Manning. March 1991.
- Alberta Environment (AENV). 2000. *Notikewin River at Manning*. Prepared as a Part of the Flood Damage Reduction Program. July 2000.
- Alberta WaterPortal Society (Alberta WaterPortal). 2018. *The history of climate in Alberta and effects of climate change on Alberta's watersheds*. Calgary, Alberta. 2018.
- AMEC Environment & Infrastructure (AMEC). 2014. *Frequency Analysis Procedure for Stormwater Design*. Prepared for The City of Calgary. Calgary, Alberta. April 2014.
- Chow V.T. 1959. *Open-channel Hydraulics*. McGraw Hill Inc. 1959.
- Government of Canada. 2018. *Canadian Spatial Reference System (CSRS)*. Natural Resources Canada. March 26, 2018. <https://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/9052>
- Kellerhals R. et al. 1972. *Hydraulic and Geomorphic Characteristics of Rivers in Alberta*. Research Council of Alberta. River Engineering and Surface Hydrology Report 72-1. 1972.
- United States Army Corps of Engineers (USACE). 2022. *HEC-RAS River Analysis System - User's Manual Version 6.3*. CPD-68, Prepared by US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center. Davis, California. 2022. <https://www.hec.usace.army.mil/confluence/rasdocs/rasum/6.3>
- USACE Hydrologic Engineering Center (USACE). 2024. *HEC-RAS Release Notes*. Version 6.5. <https://www.hec.usace.army.mil/confluence/rasdocs/rasrn/latest>

AlbantaEnvironmentalParks36918\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template\aprc - Template.aprx - Tabbed_L - 20-Jan-25, 02:27 PM - shanes - TTD005



- LiDAR and Aerial Image Acquisition
 - Community
 - Water Body
 - Watercourse
 - Study Reach
 - Railway
 - Highway
- WSC Subwatershed ID, WSC Subwatershed Name**
- 07HC001, Notikewin River at Manning



References: Data obtained from Altalis © Government of Alberta, GeoBase® and GeoGratis © Department of Natural Resources Canada (all rights reserved) used under license.
 NAD 1983 CSRS 3TM 117



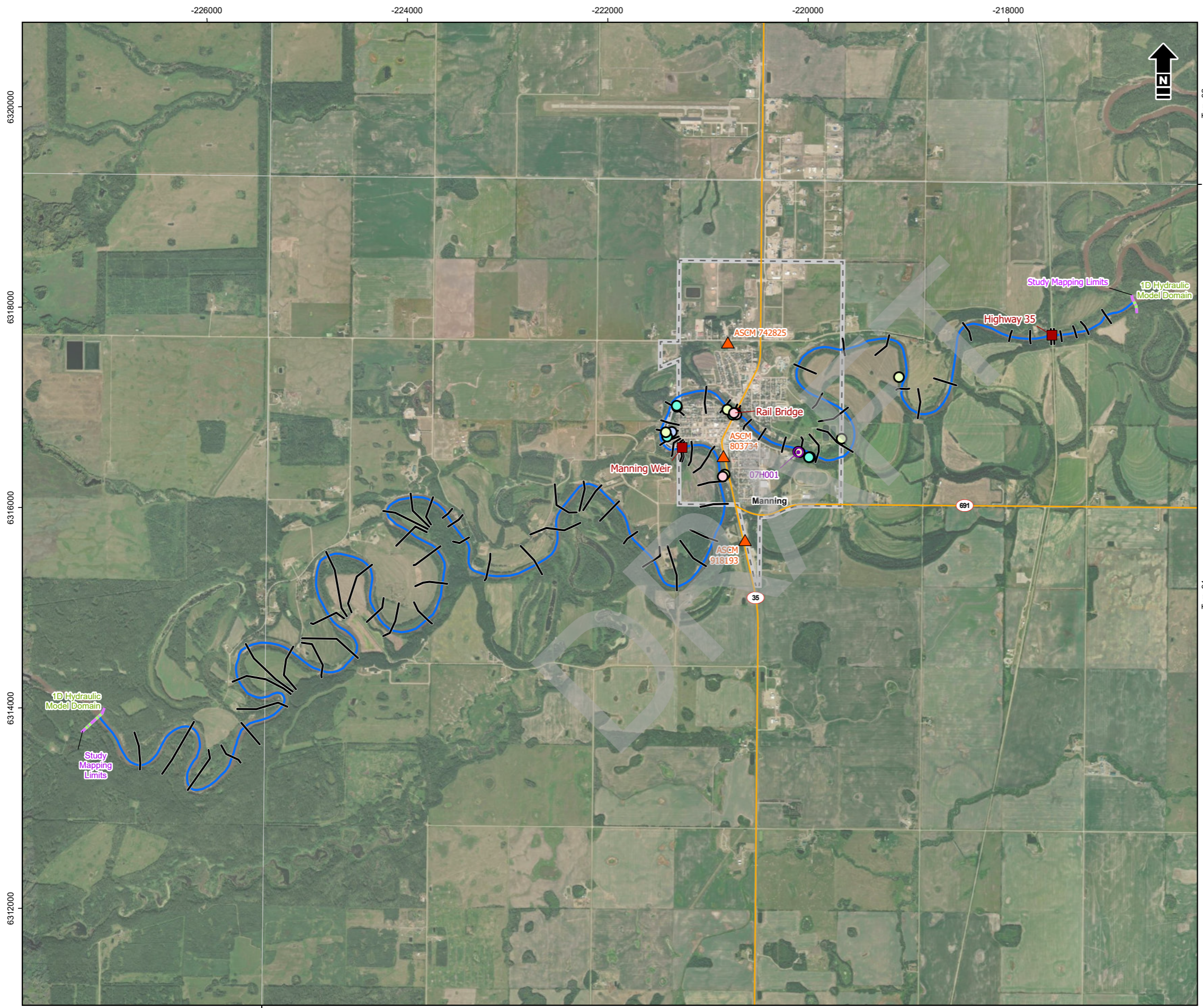
Alberta Environment and Protected Areas
 Manning Flood Study

Location Plan

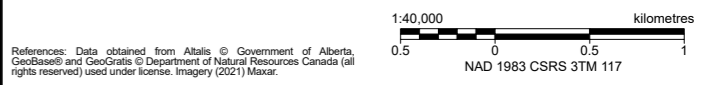
Date: January 2025	Project: 35915	Submitter: P. Rogers	Reviewer: M. Shome
--------------------	----------------	----------------------	--------------------

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

AlbionEnvironmental\Public\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 20-Jan-25, 02:29 PM - shanes - TID005



- Study Reach
- Cross Section
- Study Mapping Limit
- 1D Hydraulic Model Domain
- Municipal Boundary (Urban)
- Highway
- Road/Railroad Bridge
- Hydrometric Station
- ASCM Marker
- High Water Mark Location | 1990 Survey
- High Water Mark Location | 1991 Survey
- High Water Mark Location | May 8, 2022 Survey
- High Water Mark Location | May 31, 2022 Survey



Alberta Environment and Protected Areas
Manning Flood Study

Study Area, Cross-Sections, Hydraulic Structures, and High Water Mark Locations

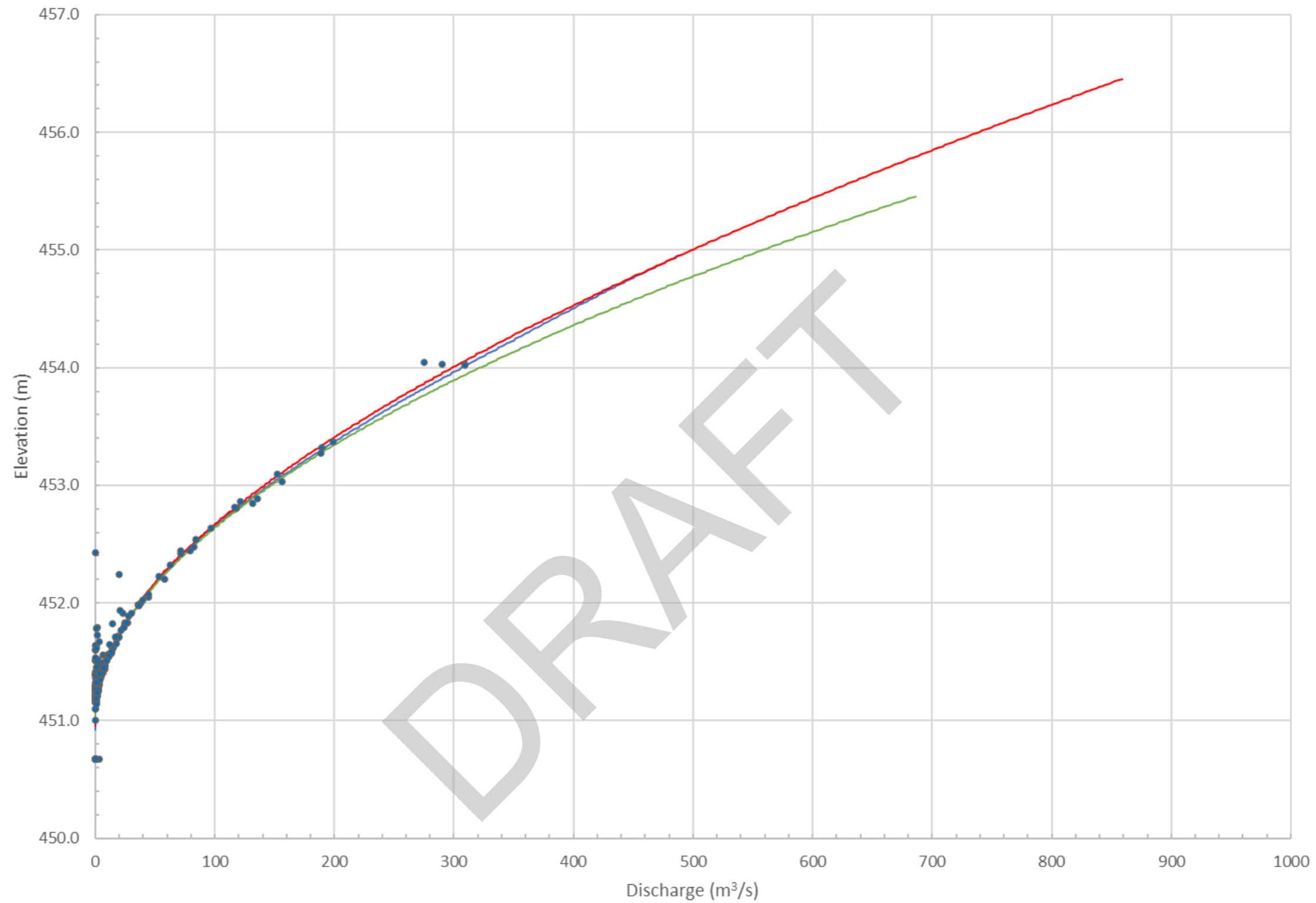
Date: January 2025	Project: 35915	Submitter: P. Rogers	Reviewer: M. Shome
--------------------	----------------	----------------------	--------------------

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Rg. 24

Rg. 23

W5M



— WSC (1995)
 — WSC (2015)
 — WSC (2019)
 — Simulated
 • Field Measured Data

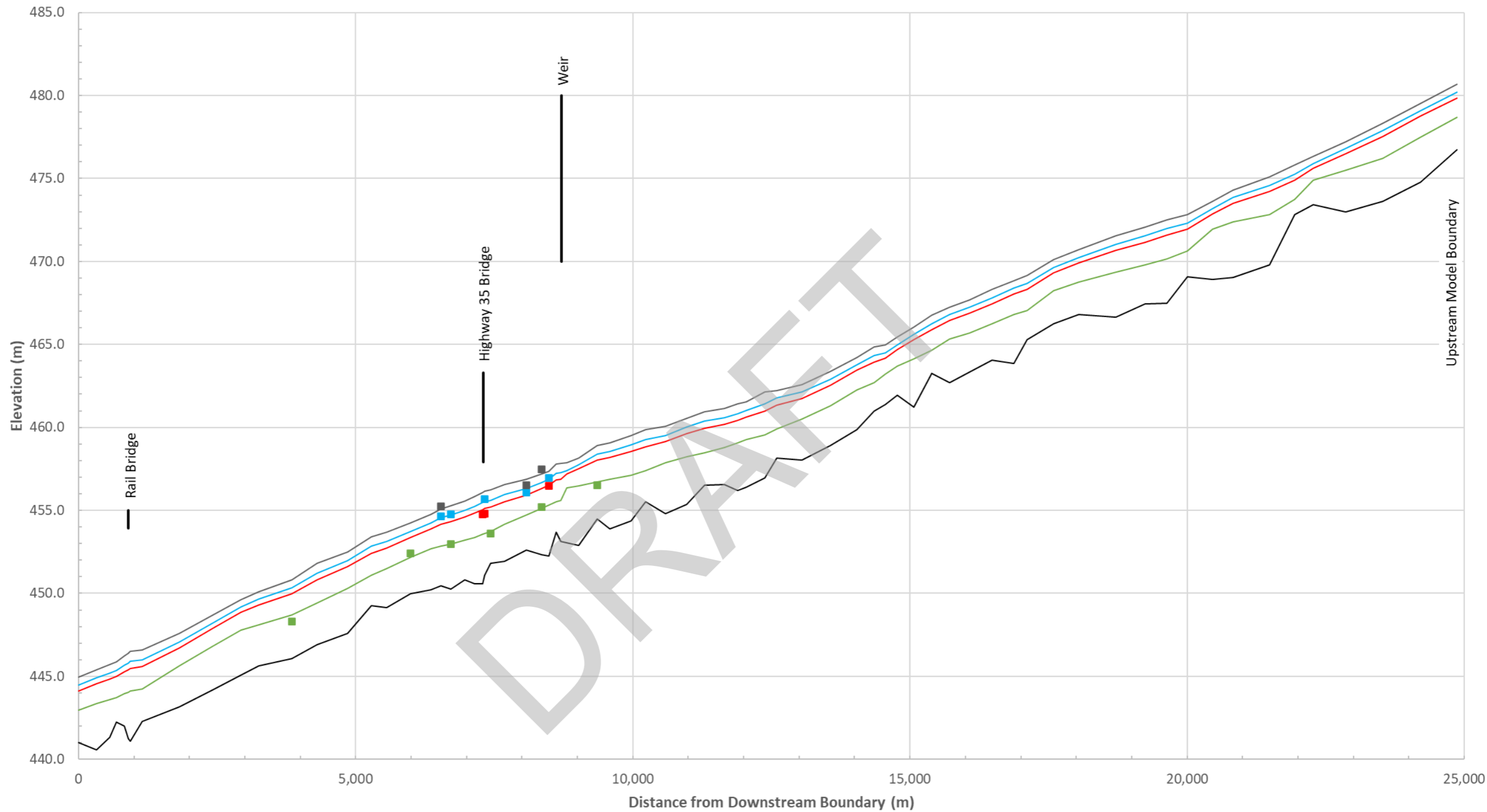


Alberta Environment and Protected Areas
Manning Flood Study

**Notikewin River at Manning (07HC001)
Rating Curve**

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.



- Thalweg
- 1990 Simulated WSE (m)
- 1990 Observed WSE (m)
- 1991 Simulated WSE (m)
- 1991 Observed WSE (m)
- May 8, 2022 Simulated WSE (m)
- May 8, 2022 Observed WSE (m)
- May 31, 2022 Simulated WSE (m)
- May 31, 2022 Observed WSE (m)

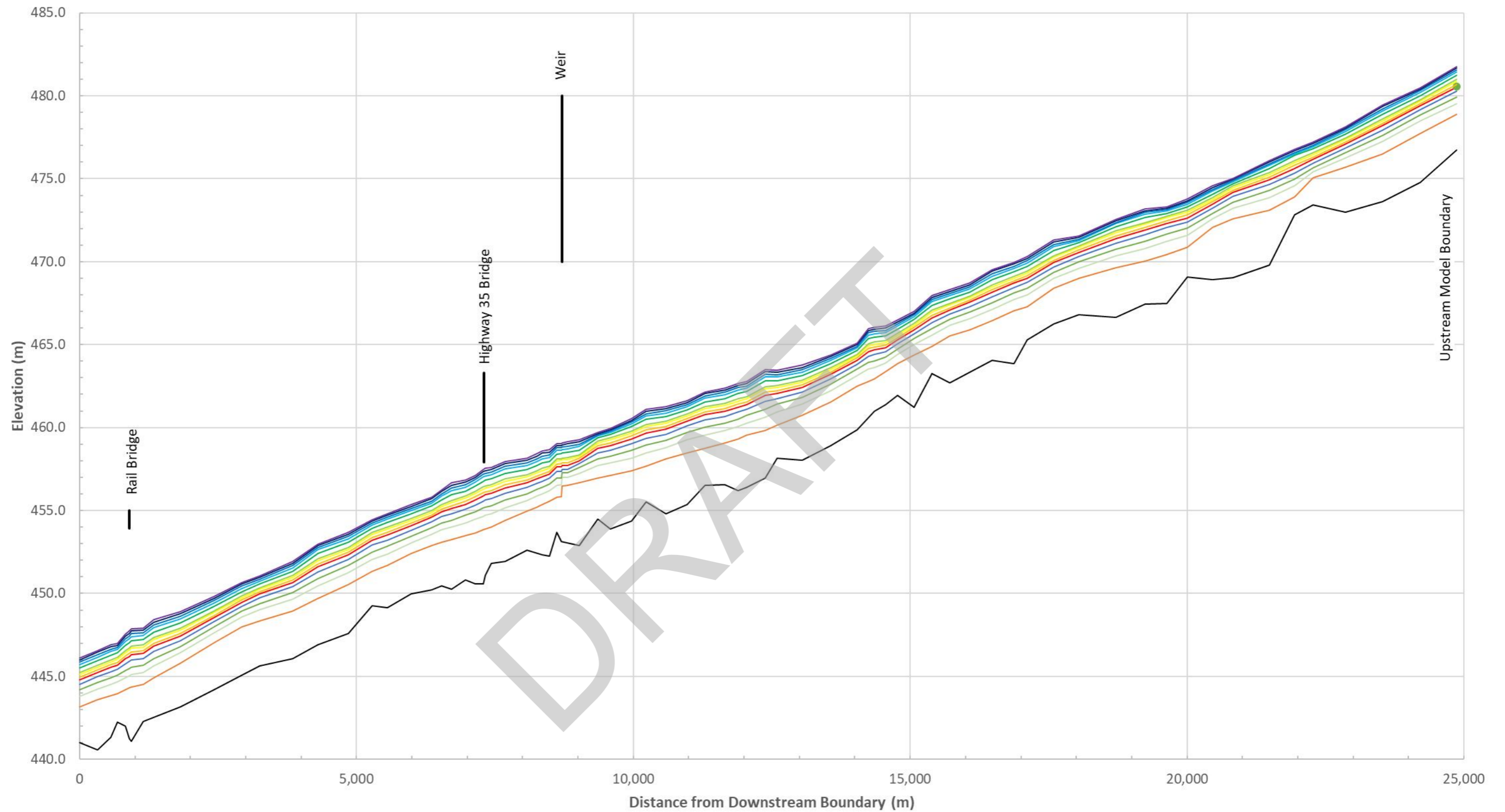


Alberta Environment and Protected Areas
Manning Flood Study

Calibration Profiles

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.



— Thalweg — 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

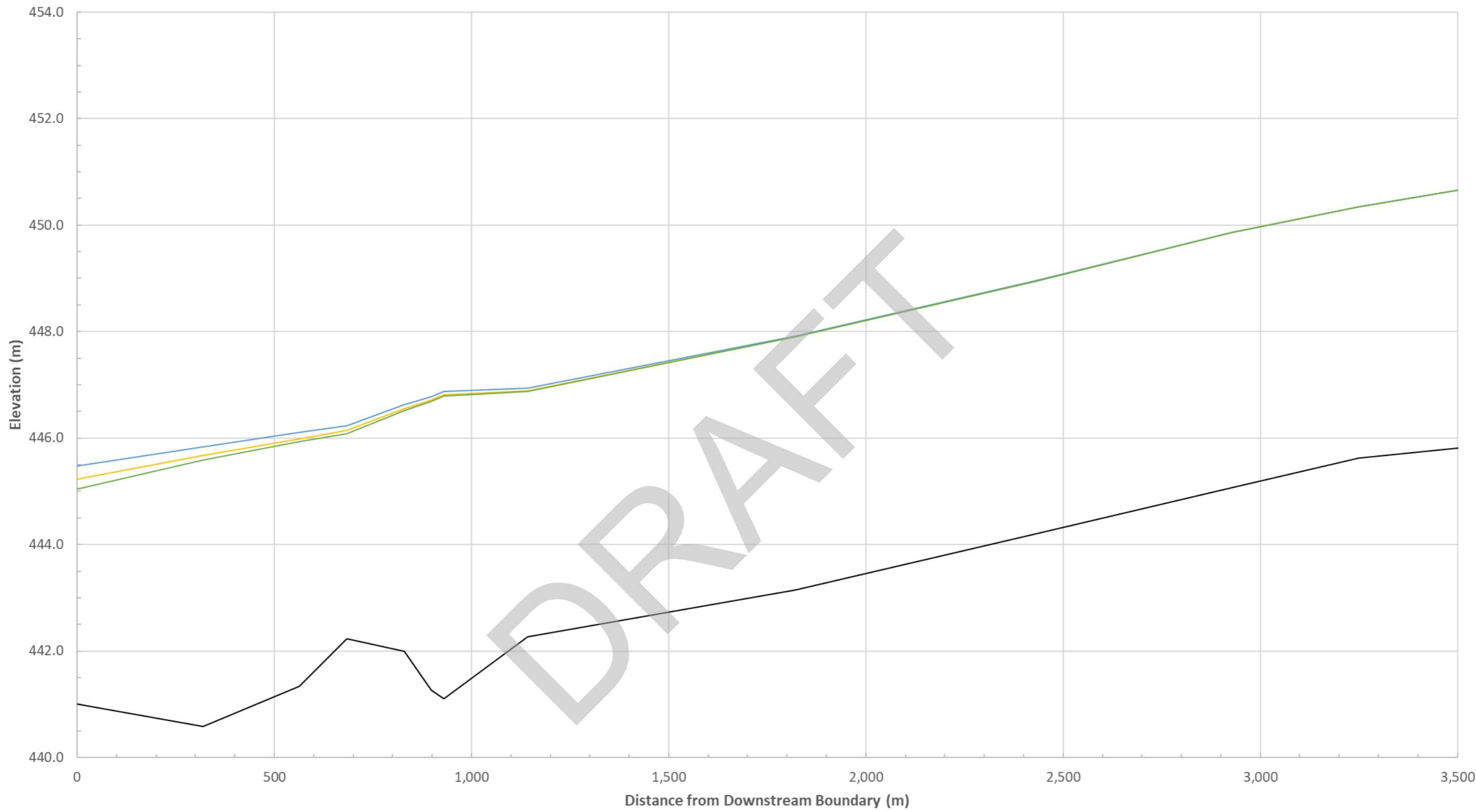


Alberta Environment and Protected Areas
Manning Flood Study

Flood Frequency Profiles

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.



— Thalweg
— Calibrated WSE (m)
— Downstream Slope -20%
— Downstream Slope +20%

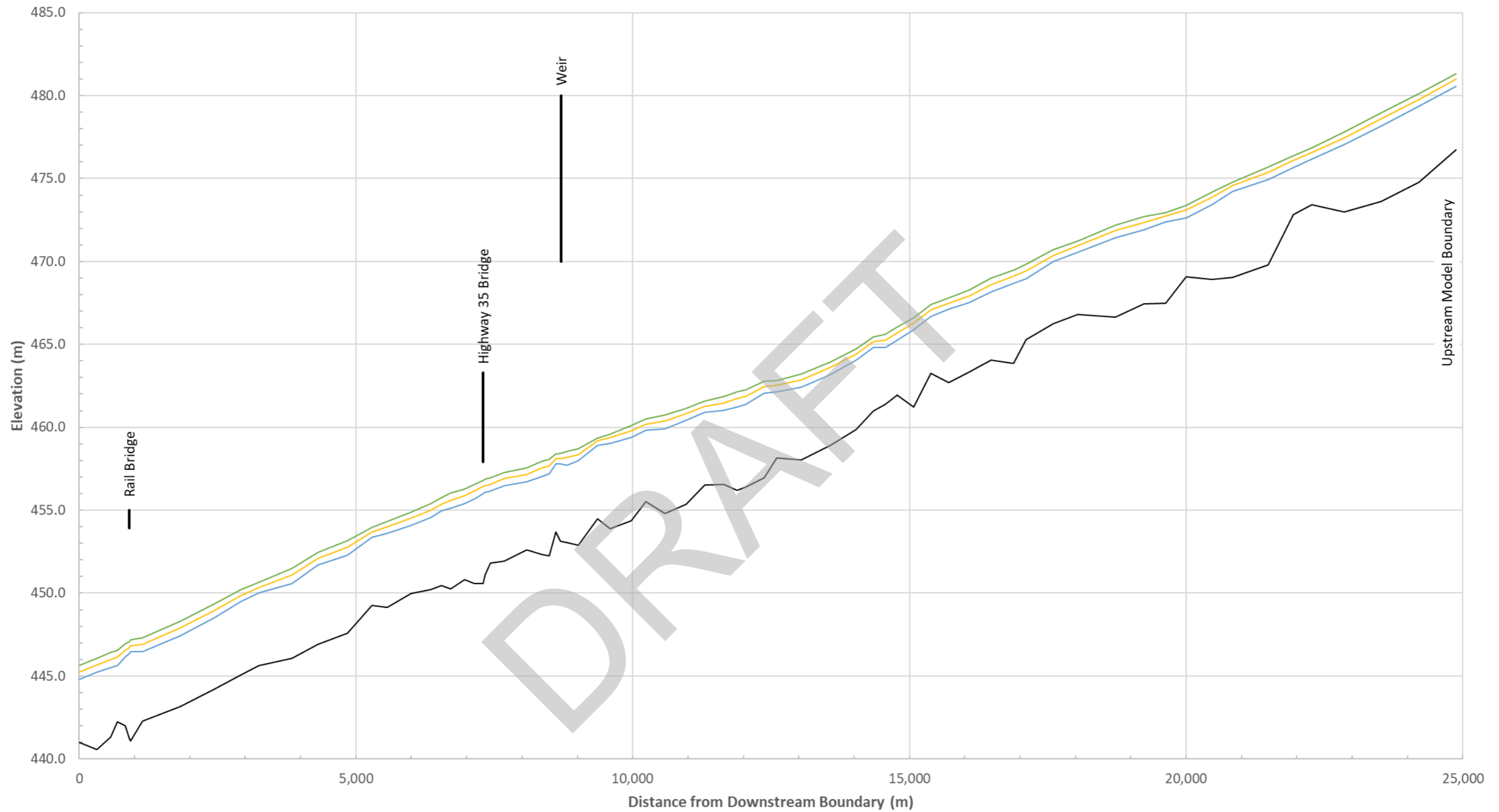


Alberta Environment and Protected Areas
Manning Flood Study

**Sensitivity Analysis Profiles
Variable Downstream Boundary Condition**

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.



— Thalweg

— Calibrated WSE (m)

— Channel Roughness -20%, WSE (m)

— Channel Roughness +20%, WSE (m)

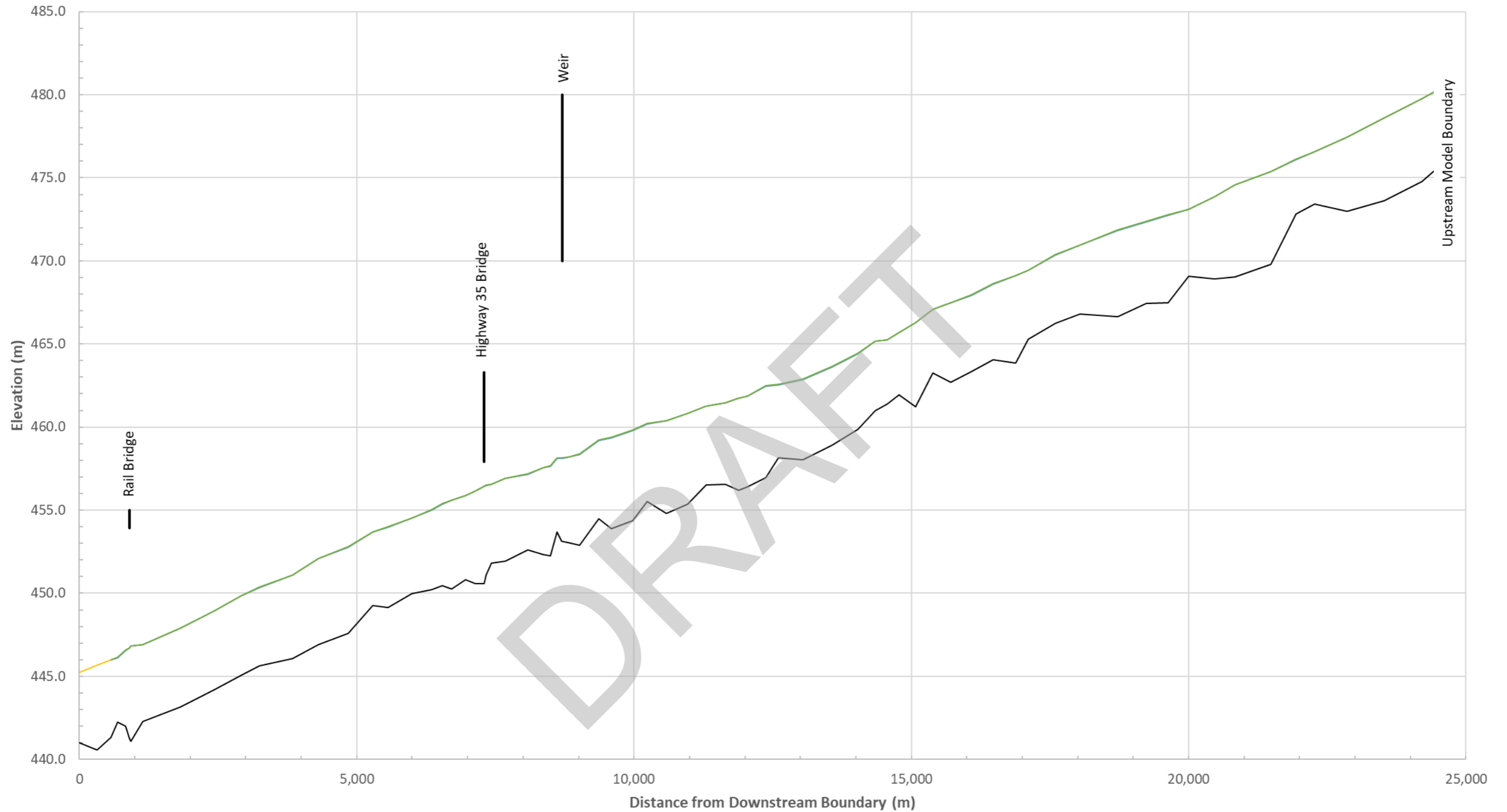


Alberta Environment and Protected Areas
Manning Flood Study

**Sensitivity Analysis Profiles
Variable Channel Manning Roughness**

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.



— Thalweg

— Calibrated WSE (m)

— Overbank Roughness -20%, WSE (m)

— Channel Roughness +20%, WSE (m)

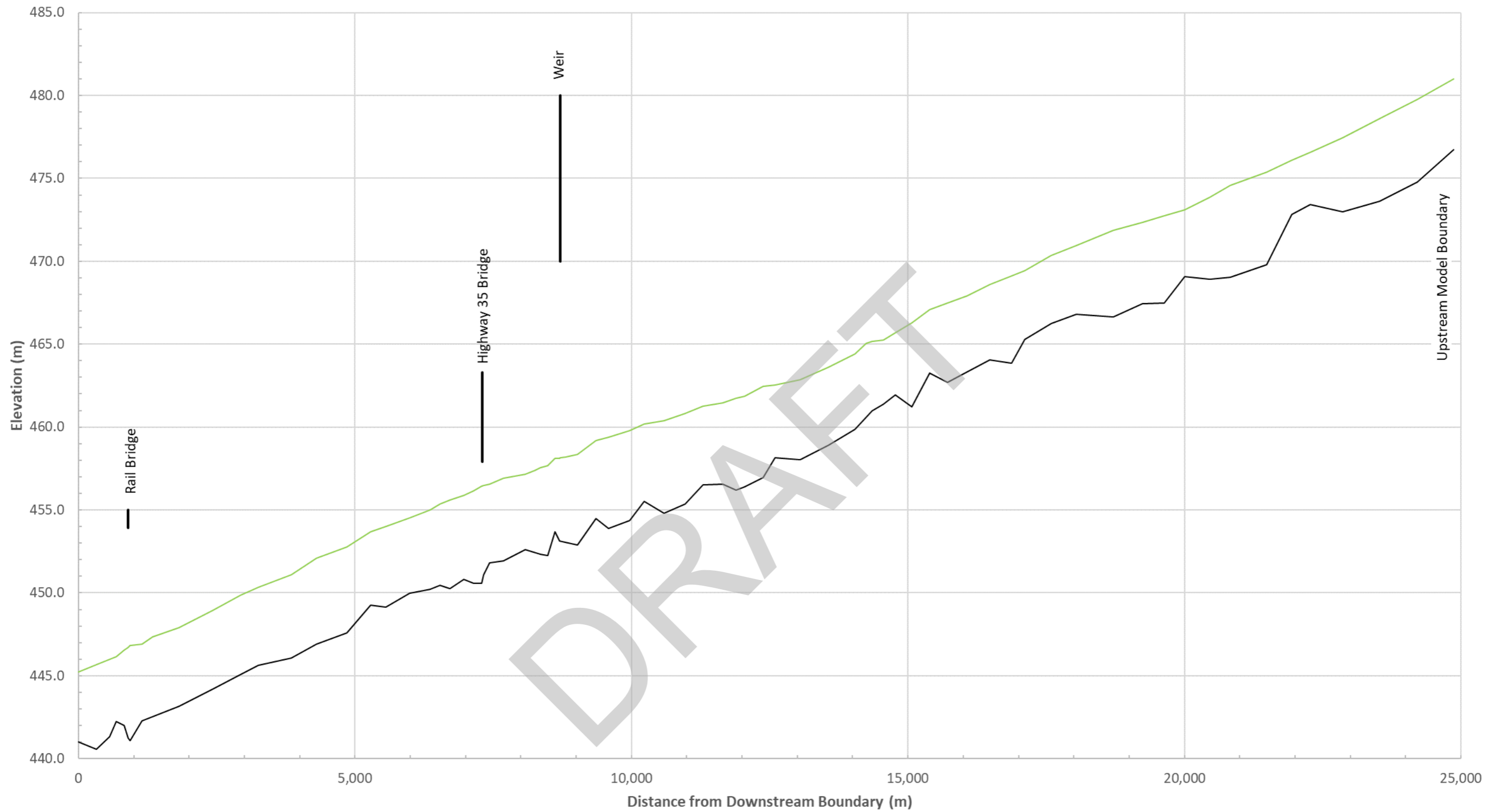


Alberta Environment and Protected Areas
Manning Flood Study

**Sensitivity Analysis Profiles
Variable Overbank Manning Roughness**

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.



— Thalweg — 100-yr



Alberta Environment and Protected Areas
Manning Flood Study

Design Flood Profile

Date:	January 2025	Project:	35915	Submitter:	P.Rogers	Reviewer:	M.Shome
-------	--------------	----------	-------	------------	----------	-----------	---------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.

TABLE 1: HYDRAULIC STRUCTURE DETAILS

Structure Name	Bounding Cross Sections	Details
Weir	8714.77 and 8698.65	<ul style="list-style-type: none">• 69 m long corrugated metal weir with rectangular notch• Average top elevation, El. 455.18 m• Average notch elevation, El. 453.9 m
Highway 35 Bridge	7326.89 and 7292.71	<ul style="list-style-type: none">• 108 m long concrete bridge with two concrete piers• Deck width of 15.3 m• Average low chord elevation, El. 458.68 m• Average high chord elevation, El. 461.10 m
Rail Bridge	928.96 and 898.20	<ul style="list-style-type: none">• 152 m long timber trestle bridge with three concrete piers• Deck width of 5.4 m• Average low chord elevation, El. 459.90 m• Average high chord elevation, El. 462.21 m

DRAFT

TABLE 2: CALIBRATION RESULTS

AEP Highwater Mark	River Station	Simulated WSE ¹ (m)	Observed WSE (m)	Difference (m)
1990 Flood Event (Q = 368 m³/s)				
90-Notik-17	8489	456.52	456.47	0.05
90-Notik-12	7327	455.11	454.79	0.32
90-Notik-12	7293	455.05	454.76	0.29
1991 Flood Event (Q = 143 m³/s)				
Notik-91-20	9360	456.72	456.51	0.21
Notik-91-17	8356	455.12	455.20	-0.08
Notik-91-12	7428	453.73	453.61	0.12
Notik-91-8.1	6715	452.98	452.98	0.00
Notik-91-7	5992	452.19	452.43	-0.24
Notik-91-1	3847	448.71	448.29	0.42
May 8, 2022 Flood Event (Q = 454 m³/s)				
Manning 2	8489	456.88	456.95	-0.07
Manning-5	8081	456.31	456.07	0.24
Manning-1	7327	455.54	455.68	-0.14
Manning-4	6715	454.74	454.78	-0.04
Manning-3	6540	454.57	454.65	-0.08
May 31, 2022 Flood Event (Q = 592 m³/s)				
Manning-2*	8355.61	457.21	457.46	-0.25
Manning-5*	8081.35	456.86	456.52	0.34
Manning-3*	6540.25	455.09	455.24	-0.15

1. WSE = water surface elevation

* HWM ID not available. Location provided relative to May 12, 2022 HWM survey.

TABLE 3: COMPUTED FLOOD FREQUENCY WATER SURFACE ELEVATIONS

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
NOT077	24872.66	478.90	479.53	479.91	480.27	480.54	480.70	480.88	480.99	481.25	481.43	481.55	481.66	481.75
NOT076	24209.30	477.74	478.47	478.83	479.15	479.39	479.53	479.68	479.77	480.01	480.19	480.31	480.41	480.49
NOT075	23526.76	476.49	477.24	477.61	477.94	478.19	478.33	478.50	478.60	478.87	479.07	479.22	479.35	479.45
NOT074	22857.27	475.69	476.25	476.58	476.87	477.09	477.22	477.36	477.46	477.69	477.85	477.95	478.03	478.11
NOT073	22269.38	475.04	475.41	475.67	475.95	476.17	476.31	476.47	476.57	476.81	476.92	477.02	477.12	477.20
NOT072	21940.13	473.90	474.56	474.97	475.34	475.62	475.80	475.98	476.11	476.40	476.49	476.59	476.69	476.77
NOT071	21485.65	473.10	473.85	474.29	474.66	474.93	475.09	475.27	475.38	475.61	475.80	475.91	476.02	476.11
NOT070	20834.49	472.59	473.22	473.60	473.93	474.17	474.31	474.47	474.57	474.71	474.83	474.91	474.98	475.03
NOT069	20460.81	472.08	472.59	472.92	473.24	473.47	473.61	473.76	473.86	474.08	474.26	474.36	474.47	474.57
NOT068	20004.02	470.87	471.58	472.01	472.38	472.64	472.81	472.98	473.09	473.29	473.46	473.57	473.68	473.77
NOT067	19631.53	470.43	471.22	471.68	472.05	472.32	472.48	472.65	472.76	472.92	473.06	473.14	473.22	473.29
NOT066	19235.64	470.05	470.81	471.24	471.62	471.91	472.08	472.25	472.36	472.67	472.87	472.97	473.08	473.17
NOT065	18719.93	469.62	470.35	470.77	471.13	471.39	471.55	471.73	471.85	472.10	472.30	472.36	472.46	472.53
NOT064	18041.73	468.98	469.61	469.99	470.31	470.55	470.70	470.86	470.96	471.14	471.26	471.36	471.45	471.54
NOT063	17591.98	468.41	469.00	469.37	469.69	469.94	470.09	470.26	470.37	470.67	470.90	471.05	471.20	471.33
NOT062	17107.57	467.30	467.99	468.40	468.75	469.01	469.16	469.33	469.44	469.72	469.93	470.06	470.20	470.31
NOT061	16879.66	467.03	467.71	468.12	468.45	468.70	468.84	469.01	469.12	469.39	469.59	469.73	469.86	469.97
NOT060	16479.80	466.46	467.13	467.54	467.89	468.16	468.31	468.49	468.61	468.90	469.13	469.27	469.42	469.53
NOT059	16074.89	465.90	466.56	466.96	467.30	467.55	467.67	467.83	467.93	468.18	468.37	468.49	468.61	468.71
NOT058	15709.88	465.53	466.15	466.53	466.83	467.07	467.22	467.39	467.49	467.76	467.95	468.08	468.21	468.31
NOT057	15392.72	464.88	465.56	465.96	466.33	466.61	466.78	466.96	467.08	467.37	467.59	467.73	467.86	467.97
NOT056	15073.83	464.37	465.00	465.35	465.66	465.89	466.03	466.18	466.28	466.51	466.68	466.79	466.90	466.99
NOT055	14774.27	463.86	464.41	464.75	465.05	465.28	465.42	465.58	465.68	465.93	466.13	466.25	466.37	466.47
NOT054	14560.40	463.36	463.89	464.24	464.57	464.82	464.97	465.13	465.24	465.52	465.73	465.86	466.00	466.11
NOT053	14352.44	462.92	463.61	464.03	464.40	464.68	464.85	465.03	465.15	465.44	465.65	465.79	465.92	466.03
NOT052	14245.42	462.79	463.52	463.94	464.31	464.59	464.76	464.94	465.06	465.35	465.57	465.71	465.84	465.95
NOT051	14041.57	462.49	463.15	463.52	463.83	464.06	464.20	464.34	464.43	464.64	464.80	464.91	465.01	465.10
NOT050	13566.26	461.53	462.23	462.62	462.95	463.20	463.35	463.51	463.61	463.85	464.04	464.17	464.28	464.38
NOT049	13044.59	460.74	461.44	461.84	462.15	462.40	462.56	462.73	462.84	463.13	463.35	463.49	463.63	463.76
NOT048	12601.00	460.16	460.95	461.43	461.75	462.04	462.21	462.40	462.52	462.82	463.05	463.19	463.33	463.45
NOT047	12375.72	459.83	460.62	461.09	461.59	461.93	462.12	462.33	462.47	462.80	463.05	463.20	463.36	463.48
NOT046	12045.97	459.53	460.28	460.73	461.11	461.39	461.55	461.74	461.87	462.16	462.37	462.50	462.64	462.76
NOT045	11889.97	459.32	460.07	460.52	460.93	461.23	461.41	461.60	461.73	462.04	462.26	462.40	462.54	462.67
NOT044	11652.27	459.05	459.81	460.27	460.68	460.98	461.15	461.34	461.46	461.76	461.98	462.13	462.27	462.38
NOT043	11298.68	458.76	459.56	460.04	460.47	460.77	460.94	461.14	461.26	461.55	461.77	461.91	462.04	462.15
NOT042	10969.19	458.48	459.25	459.70	460.09	460.37	460.53	460.70	460.81	461.08	461.28	461.39	461.51	461.61
NOT041	10586.35	458.10	458.80	459.23	459.60	459.89	460.06	460.25	460.38	460.67	460.87	461.01	461.16	461.28
NOT040	10234.54	457.66	458.46	458.94	459.35	459.67	459.85	460.06	460.20	460.49	460.71	460.84	460.98	461.10
NOT039	9969.19	457.38	458.17	458.63	459.02	459.32	459.49	459.68	459.80	460.05	460.22	460.33	460.44	460.54
NOT038	9589.83	457.12	457.86	458.29	458.64	458.92	459.08	459.26	459.37	459.57	459.70	459.78	459.86	459.94
NOT037	9360.12	456.97	457.70	458.12	458.48	458.75	458.91	459.08	459.19	459.38	459.49	459.56	459.62	459.69
NOT036	9020.47	456.67	457.25	457.58	457.82	458.01	458.14	458.27	458.36	458.62	458.85	458.99	459.14	459.26
NOT035	8810.35	456.52	457.00	457.27	457.46	457.70	457.87	458.07	458.19	458.50	458.73	458.88	459.03	459.15
NOT034	8714.77	456.49	456.99	457.28	457.48	457.71	457.87	458.06	458.17	458.46	458.68	458.82	458.95	459.06

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
WEIR														
NOT032	8698.65	455.84	456.55	456.97	457.36	457.65	457.82	458.02	458.13	458.42	458.64	458.78	458.92	459.03
NOT031	8616.07	455.78	456.51	456.94	457.34	457.63	457.80	458.00	458.12	458.41	458.64	458.78	458.92	459.03
NOT030	8488.74	455.55	456.21	456.60	456.95	457.21	457.37	457.55	457.66	457.96	458.20	458.37	458.53	458.66
NOT029	8355.61	455.35	456.01	456.41	456.77	457.04	457.21	457.39	457.54	457.88	458.12	458.29	458.46	458.60
NOT028	8258.80	455.22	455.87	456.27	456.63	456.90	457.07	457.26	457.39	457.71	457.95	458.12	458.29	458.42
NOT027	8081.35	454.95	455.61	456.01	456.39	456.68	456.85	457.04	457.17	457.49	457.73	457.89	458.05	458.17
NOT026	7683.41	454.40	455.16	455.63	456.05	456.36	456.55	456.76	456.90	457.24	457.50	457.67	457.83	457.97
NOT025	7428.27	454.00	454.81	455.29	455.71	456.03	456.21	456.42	456.56	456.90	457.15	457.31	457.48	457.61
NOT024B	7326.89	453.90	454.72	455.21	455.63	455.95	456.13	456.35	456.48	456.83	457.08	457.24	457.40	457.54
NOT024A	7292.71	453.84	454.66	455.15	455.57	455.89	456.08	456.29	456.43	456.77	457.02	457.19	457.36	457.49
NOT023	7145.37	453.66	454.47	454.94	455.34	455.64	455.82	456.02	456.15	456.47	456.71	456.86	457.01	457.13
NOT022	6961.70	453.47	454.25	454.71	455.10	455.38	455.55	455.74	455.86	456.16	456.40	456.55	456.71	456.83
NOT021	6714.91	453.24	453.99	454.42	454.82	455.11	455.29	455.49	455.62	455.94	456.19	456.36	456.53	456.66
NOT020	6540.25	453.10	453.83	454.26	454.65	454.92	455.09	455.26	455.38	455.66	455.87	456.01	456.14	456.25
NOT019	6357.28	452.90	453.58	453.98	454.33	454.59	454.74	454.90	455.01	455.27	455.46	455.58	455.71	455.80
NOT018	5992.49	452.40	453.05	453.45	453.80	454.07	454.23	454.40	454.52	454.80	455.00	455.13	455.25	455.36
NOT017	5560.63	451.70	452.39	452.83	453.22	453.51	453.68	453.87	453.99	454.27	454.47	454.60	454.72	454.82
NOT016	5288.34	451.33	452.06	452.51	452.91	453.21	453.38	453.56	453.67	453.94	454.13	454.24	454.35	454.44
NOT015	4851.14	450.53	451.25	451.68	452.05	452.32	452.48	452.66	452.78	453.07	453.29	453.43	453.56	453.67
NOT014	4308.42	449.70	450.46	450.90	451.31	451.61	451.79	451.99	452.11	452.42	452.63	452.76	452.87	452.97
NOT013	3847.00	448.95	449.67	450.07	450.42	450.67	450.82	450.98	451.09	451.34	451.54	451.68	451.81	451.92
NOT012	3249.36	448.35	449.01	449.39	449.72	449.96	450.10	450.25	450.34	450.57	450.75	450.87	450.99	451.06
NOT011	2926.33	447.98	448.58	448.93	449.24	449.46	449.60	449.75	449.86	450.11	450.31	450.45	450.58	450.66
NOT010	2429.59	447.02	447.62	447.97	448.29	448.53	448.68	448.85	448.95	449.23	449.43	449.58	449.71	449.82
NOT009	1821.26	445.81	446.41	446.79	447.15	447.43	447.59	447.78	447.90	448.21	448.45	448.61	448.78	448.91
NOT008	1344.26	444.92	445.64	446.08	446.50	446.81	447.00	447.21	447.34	447.68	447.94	448.11	448.28	448.42
NOT007	1142.44	444.51	445.24	445.68	446.08	446.38	446.56	446.76	446.89	447.21	447.46	447.61	447.77	447.90
NOT006B	928.96	444.36	445.12	445.57	445.99	446.30	446.48	446.69	446.82	447.15	447.40	447.57	447.73	447.86
NOT006A	898.20	444.30	445.05	445.49	445.90	446.20	446.39	446.59	446.72	447.04	447.28	447.44	447.60	447.73
NOT005	829.47	444.19	444.93	445.37	445.77	446.06	446.24	446.43	446.56	446.87	447.11	447.26	447.41	447.54
NOT004	684.30	443.97	444.66	445.06	445.43	445.69	445.85	446.02	446.14	446.41	446.61	446.74	446.87	446.98
NOT003	564.13	443.83	444.51	444.91	445.28	445.54	445.70	445.88	445.99	446.27	446.49	446.64	446.78	446.90
NOT002	318.44	443.58	444.24	444.63	444.98	445.24	445.39	445.57	445.68	445.96	446.17	446.31	446.45	446.56
NOT001	0	443.17	443.81	444.19	444.53	444.79	444.95	445.12	445.23	445.51	445.72	445.86	446.00	446.11

TABLE 4: SENSITIVITY ANALYSIS, VARIABLE DOWNSTREAM BOUNDARY CONDITION AT 1:100 YR FLOOD

Cross-Section	River Station (m)	Simulated WSE at 1:100-yr Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope +20%
NOT077	24872.66	480.99	480.99	480.99
NOT076	24209.30	479.77	479.77	479.77
NOT075	23526.76	478.60	478.60	478.60
NOT074	22857.27	477.46	477.46	477.46
NOT073	22269.38	476.57	476.57	476.57
NOT072	21940.13	476.11	476.11	476.11
NOT071	21485.65	475.38	475.38	475.38
NOT070	20834.49	474.57	474.57	474.57
NOT069	20460.81	473.86	473.86	473.86
NOT068	20004.02	473.09	473.09	473.09
NOT067	19631.53	472.76	472.76	472.76
NOT066	19235.64	472.36	472.36	472.36
NOT065	18719.93	471.85	471.85	471.85
NOT064	18041.73	470.96	470.96	470.96
NOT063	17591.98	470.37	470.37	470.37
NOT062	17107.57	469.44	469.44	469.44
NOT061	16879.66	469.12	469.12	469.12
NOT060	16479.80	468.61	468.61	468.61
NOT059	16074.89	467.93	467.93	467.93
NOT058	15709.88	467.49	467.49	467.49
NOT057	15392.72	467.08	467.08	467.08
NOT056	15073.83	466.28	466.28	466.28
NOT055	14774.27	465.68	465.68	465.68
NOT054	14560.40	465.24	465.24	465.24
NOT053	14352.44	465.15	465.15	465.15
NOT052	14245.42	465.06	465.06	465.06
NOT051	14041.57	464.43	464.43	464.43
NOT050	13566.26	463.61	463.61	463.61
NOT049	13044.59	462.84	462.84	462.84
NOT048	12601.00	462.52	462.52	462.52
NOT047	12375.72	462.47	462.47	462.47
NOT046	12045.97	461.87	461.87	461.87
NOT045	11889.97	461.73	461.73	461.73
NOT044	11652.27	461.46	461.46	461.46
NOT043	11298.68	461.26	461.26	461.26
NOT042	10969.19	460.81	460.81	460.81
NOT041	10586.35	460.38	460.38	460.38
NOT040	10234.54	460.20	460.20	460.20
NOT039	9969.19	459.80	459.80	459.80
NOT038	9589.83	459.37	459.37	459.37
NOT037	9360.12	459.19	459.19	459.19
NOT036	9020.47	458.36	458.36	458.36
NOT035	8810.35	458.19	458.19	458.19
NOT034	8714.77	458.17	458.17	458.17
WEIR				
NOT032	8698.65	458.13	458.13	458.13
NOT031	8616.07	458.12	458.12	458.12
NOT030	8488.74	457.66	457.66	457.66
NOT029	8355.61	457.54	457.54	457.54
NOT028	8258.80	457.39	457.39	457.39
NOT027	8081.35	457.17	457.17	457.17
NOT026	7683.41	456.90	456.90	456.90

Cross-Section	River Station (m)	Simulated WSE at 1:100-yr Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope +20%
NOT025	7428.27	456.56	456.56	456.56
NOT024B	7326.89	456.48	456.48	456.48
NOT024A	7292.71	456.43	456.43	456.43
NOT023	7145.37	456.15	456.15	456.15
NOT022	6961.70	455.86	455.86	455.86
NOT021	6714.91	455.62	455.62	455.62
NOT020	6540.25	455.38	455.38	455.38
NOT019	6357.28	455.01	455.01	455.01
NOT018	5992.49	454.52	454.52	454.52
NOT017	5560.63	453.99	453.99	453.99
NOT016	5288.34	453.67	453.67	453.67
NOT015	4851.14	452.78	452.78	452.78
NOT014	4308.42	452.11	452.11	452.11
NOT013	3847.00	451.09	451.09	451.09
NOT012	3249.36	450.34	450.34	450.34
NOT011	2926.33	449.86	449.86	449.86
NOT010	2429.59	448.96	448.95	448.95
NOT009	1821.26	447.92	447.90	447.90
NOT008	1344.26	447.38	447.34	447.33
NOT007	1142.44	446.94	446.89	446.87
NOT006B	928.96	446.88	446.82	446.79
NOT006A	898.20	446.78	446.72	446.69
NOT005	829.47	446.63	446.56	446.52
NOT004	684.30	446.23	446.14	446.08
NOT003	564.13	446.11	445.99	445.93
NOT002	318.44	445.84	445.68	445.93
NOT001	0	445.48	445.23	445.04

Indicates cross-sections located outside of the study reach.

TABLE 5: SENSITIVITY ANALYSIS, VARIABLE CHANNEL MANNING ROUGHNESS AT 1:100 YR FLOOD

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
		$n_{\text{channel}} = 0.024$	$n_{\text{channel}} = 0.03$	$n_{\text{channel}} = 0.036$
NOT077	24872.66	480.55	480.99	481.33
NOT076	24209.30	479.38	479.77	480.12
NOT075	23526.76	478.16	478.60	478.98
NOT074	22857.27	477.06	477.46	477.80
NOT073	22269.38	476.16	476.57	476.85
NOT072	21940.13	475.67	476.11	476.36
NOT071	21485.65	474.95	475.38	475.71
NOT070	20834.49	474.22	474.57	474.77
NOT069	20460.81	473.43	473.86	474.18
NOT068	20004.02	472.61	473.09	473.39
NOT067	19631.53	472.37	472.76	472.96
NOT066	19235.64	471.92	472.36	472.70
NOT065	18719.93	471.43	471.85	472.17
NOT064	18041.73	470.56	470.96	471.22
NOT063	17591.98	470.00	470.37	470.72
NOT062	17107.57	468.96	469.44	469.84
NOT061	16879.66	468.69	469.12	469.49
NOT060	16479.80	468.16	468.61	468.99
NOT059	16074.89	467.53	467.93	468.27
NOT058	15709.88	467.12	467.49	467.81
NOT057	15392.72	466.70	467.08	467.40
NOT056	15073.83	465.89	466.28	466.61
NOT055	14774.27	465.26	465.68	466.03
NOT054	14560.40	464.81	465.24	465.61
NOT053	14352.44	464.83	465.15	465.44
NOT052	14245.42	464.76	465.06	465.34
NOT051	14041.57	464.06	464.43	464.75
NOT050	13566.26	463.18	463.61	463.94
NOT049	13044.59	462.41	462.84	463.20
NOT048	12601.00	462.15	462.52	462.83
NOT047	12375.72	462.07	462.47	462.79
NOT046	12045.97	461.38	461.87	462.27
NOT045	11889.97	461.24	461.73	462.14
NOT044	11652.27	461.01	461.46	461.85
NOT043	11298.68	460.89	461.26	461.59
NOT042	10969.19	460.42	460.81	461.16
NOT041	10586.35	459.90	460.38	460.74
NOT040	10234.54	459.81	460.20	460.49
NOT039	9969.19	459.40	459.80	460.09
NOT038	9589.83	459.03	459.37	459.59
NOT037	9360.12	458.92	459.19	459.35
NOT036	9020.47	457.99	458.36	458.73
NOT035	8810.35	457.73	458.19	458.55
NOT034	8714.77	457.86	458.17	458.47
WEIR	0.00	0.00	0.00	0.00
NOT032	8698.65	457.80	458.13	458.43
NOT031	8616.07	457.81	458.12	458.40
NOT030	8488.74	457.20	457.66	458.06
NOT029	8355.61	457.05	457.54	457.96
NOT028	8258.80	456.92	457.39	457.80
NOT027	8081.35	456.71	457.17	457.57

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
NOT026	7683.41	456.49	456.90	457.27
NOT025	7428.27	456.14	456.56	456.95
NOT024B	7326.89	456.07	456.48	456.86
NOT024A	7292.71	456.00	456.43	456.81
NOT023	7145.37	455.69	456.15	456.55
NOT022	6961.70	455.40	455.86	456.27
NOT021	6714.91	455.14	455.62	456.03
NOT020	6540.25	454.98	455.38	455.74
NOT019	6357.28	454.57	455.01	455.39
NOT018	5992.49	454.08	454.52	454.88
NOT017	5560.63	453.60	453.99	454.33
NOT016	5288.34	453.35	453.67	453.96
NOT015	4851.14	452.28	452.78	453.18
NOT014	4308.42	451.70	452.11	452.46
NOT013	3847.00	450.58	451.09	451.51
NOT012	3249.36	450.01	450.34	450.65
NOT011	2926.33	449.48	449.86	450.21
NOT010	2429.59	448.52	448.95	449.34
NOT009	1821.26	447.44	447.90	448.31
NOT008	1344.26	446.95	447.34	447.71
NOT007	1142.44	446.46	446.89	447.29
NOT006B	928.96	446.47	446.82	447.17
NOT006A	898.20	446.35	446.72	447.08
NOT005	829.47	446.16	446.56	446.93
NOT004	684.30	445.65	446.14	446.55
NOT003	564.13	445.52	445.99	446.41
NOT002	318.44	445.23	445.68	446.09
NOT001	0	444.78	445.23	445.63
average difference		-0.41		0.34
maximum difference		-0.51		0.42


 Indicates cross-sections located outside of the study reach.

TABLE 6: SENSITIVITY ANALYSIS, VARIABLE OVERBANK MANNING ROUGHNESS AT 1:100 YR FLOOD

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
NOT077	24872.66	480.99	480.99	481.00
NOT076	24209.30	479.77	479.77	479.78
NOT075	23526.76	478.60	478.60	478.60
NOT074	22857.27	477.46	477.46	477.46
NOT073	22269.38	476.57	476.57	476.58
NOT072	21940.13	476.11	476.11	476.12
NOT071	21485.65	475.38	475.38	475.39
NOT070	20834.49	474.57	474.57	474.58
NOT069	20460.81	473.86	473.86	473.87
NOT068	20004.02	473.09	473.09	473.11
NOT067	19631.53	472.76	472.76	472.79
NOT066	19235.64	472.36	472.36	472.37
NOT065	18719.93	471.84	471.85	471.86
NOT064	18041.73	470.96	470.96	470.97
NOT063	17591.98	470.37	470.37	470.38
NOT062	17107.57	469.44	469.44	469.45
NOT061	16879.66	469.12	469.12	469.13
NOT060	16479.80	468.61	468.61	468.62
NOT059	16074.89	467.93	467.93	467.95
NOT058	15709.88	467.49	467.49	467.50
NOT057	15392.72	467.08	467.08	467.08
NOT056	15073.83	466.28	466.28	466.29
NOT055	14774.27	465.68	465.68	465.69
NOT054	14560.40	465.24	465.24	465.25
NOT053	14352.44	465.15	465.15	465.16
NOT052	14245.42	465.05	465.06	465.07
NOT051	14041.57	464.42	464.43	464.45
NOT050	13566.26	463.61	463.61	463.64
NOT049	13044.59	462.84	462.84	462.88
NOT048	12601.00	462.52	462.52	462.56
NOT047	12375.72	462.47	462.47	462.49
NOT046	12045.97	461.86	461.87	461.88
NOT045	11889.97	461.73	461.73	461.74
NOT044	11652.27	461.46	461.46	461.48
NOT043	11298.68	461.26	461.26	461.28
NOT042	10969.19	460.81	460.81	460.84
NOT041	10586.35	460.38	460.38	460.39
NOT040	10234.54	460.19	460.20	460.21
NOT039	9969.19	459.79	459.80	459.81
NOT038	9589.83	459.36	459.37	459.38
NOT037	9360.12	459.19	459.19	459.21
NOT036	9020.47	458.35	458.36	458.39
NOT035	8810.35	458.19	458.19	458.18
NOT034	8714.77	458.17	458.17	458.18
WEIR	0.00	0.00	0.00	0.00
NOT032	8698.65	458.13	458.13	458.15
NOT031	8616.07	458.11	458.12	458.14
NOT030	8488.74	457.65	457.66	457.67
NOT029	8355.61	457.54	457.54	457.55
NOT028	8258.80	457.39	457.39	457.41
NOT027	8081.35	457.17	457.17	457.18

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
NOT026	7683.41	456.90	456.90	456.91
NOT025	7428.27	456.56	456.56	456.57
NOT024B	7326.89	456.48	456.48	456.50
NOT024A	7292.71	456.42	456.43	456.44
NOT023	7145.37	456.14	456.15	456.16
NOT022	6961.70	455.86	455.86	455.87
NOT021	6714.91	455.62	455.62	455.61
NOT020	6540.25	455.38	455.38	455.39
NOT019	6357.28	455.01	455.01	455.03
NOT018	5992.49	454.51	454.52	454.53
NOT017	5560.63	453.98	453.99	454.00
NOT016	5288.34	453.67	453.67	453.70
NOT015	4851.14	452.78	452.78	452.80
NOT014	4308.42	452.11	452.11	452.11
NOT013	3847.00	451.08	451.09	451.10
NOT012	3249.36	450.34	450.34	450.36
NOT011	2926.33	449.85	449.86	449.86
NOT010	2429.59	448.95	448.95	448.96
NOT009	1821.26	447.90	447.90	447.91
NOT008	1344.26	447.34	447.34	447.35
NOT007	1142.44	446.89	446.89	446.89
NOT006B	928.96	446.82	446.82	446.83
NOT006A	898.20	446.72	446.72	446.72
NOT005	829.47	446.56	446.56	446.57
NOT004	684.30	446.13	446.14	446.14
NOT003	564.13	445.99	445.99	446.00
NOT002	318.44	445.68	445.68	445.69
NOT001	0	445.23	445.23	445.24
maximum difference		-0.01		0.04

Indicates cross-sections located outside of the study reach.

TABLE 7: FLOODWAY STATIONS AND LIMITING FLOODWAY DETERMINATION CRITERIA

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
NOT077	24872.66	263.6	17.4	77.1	15.9	78.7	17.4	98.5	depth	hydraulically smoothed
NOT076	24209.30	378.1	310.0	364.2	312.1	363.0	310.0	365.3	depth	no viable flood fringe
NOT075	23526.76	608.7	30.1	99.4	33.0	95.6	28.4	99.4	depth	no viable flood fringe
NOT074	22857.27	472.0	409.4	467.9	410.4	467.0	409.4	469.1	depth	no viable flood fringe
NOT073	22269.38	271.7	130.8	215.4	132.1	213.9	130.8	217.4	depth	no viable flood fringe
NOT072	21940.13	282.0	13.4	112.4	15.0	99.5	10.5	112.4	depth	no viable flood fringe
NOT071	21485.65	519.2	438.4	501.5	446.3	498.1	446.2	508.3	depth	no viable flood fringe
NOT070	20834.49	636.5	34.5	119.8	35.2	86.5	34.5	119.8	depth	depth
NOT069	20460.81	676.5	5.9	85.3	6.5	67.6	5.9	85.3	depth	depth
NOT068	20004.02	491.7	20.2	85.0	20.8	84.7	20.2	85.0	depth	depth
NOT067	19631.53	461.5	359.6	427.0	361.4	426.5	349.5	429.1	hydraulically smoothed	hydraulically smoothed
NOT066	19235.64	631.8	524.3	621.7	566.4	620.4	524.3	623.0	depth	no viable flood fringe
NOT065	18719.93	376.3	175.3	240.6	177.9	233.2	175.3	240.6	depth	depth
NOT064	18041.73	685.0	17.3	93.4	22.0	79.4	14.3	93.4	hydraulically smoothed	no viable flood fringe
NOT063	17591.98	571.9	7.0	109.8	8.6	73.6	6.3	109.8	depth	no viable flood fringe
NOT062	17107.57	306.2	136.0	212.4	145.0	204.7	136.0	212.4	depth	depth
NOT061	16879.66	384.8	237.3	302.9	248.1	301.4	237.3	304.8	depth	no viable flood fringe
NOT060	16479.80	282.5	144.9	254.0	192.3	253.0	144.9	254.7	depth	no viable flood fringe
NOT059	16074.89	327.6	248.9	305.9	249.0	304.8	248.9	305.9	depth	depth
NOT058	15709.88	330.7	205.5	311.4	253.5	310.3	205.5	312.2	depth	no viable flood fringe
NOT057	15392.72	398.8	107.1	224.3	158.0	223.2	107.1	225.6	depth	no viable flood fringe
NOT056	15073.83	482.8	16.2	73.3	16.7	64.6	14.5	73.3	depth	no viable flood fringe
NOT055	14774.27	405.1	11.0	89.9	11.2	69.5	10.3	89.9	depth	no viable flood fringe
NOT054	14560.40	301.1	8.4	92.0	8.9	69.8	7.6	92.0	depth	no viable flood fringe
NOT053	14352.44	133.9	23.0	113.7	24.2	108.6	22.1	113.7	depth	no viable flood fringe
NOT052	14245.42	188.5	93.2	171.6	95.3	170.6	93.2	171.6	depth	depth
NOT051	14041.57	177.4	17.9	70.7	18.1	67.8	15.4	70.7	depth	no viable flood fringe
NOT050	13566.26	275.7	146.7	245.0	188.3	243.9	146.7	247.1	depth	no viable flood fringe
NOT049	13044.59	357.4	196.0	271.2	218.4	269.6	196.0	272.6	depth	no viable flood fringe
NOT048	12601.00	529.9	205.0	477.6	222.5	315.2	200.7	318.9	no viable flood fringe	no viable flood fringe
NOT047	12375.72	428.5	73.4	391.5	246.4	296.0	38.5	391.5	depth	hydraulically smoothed
NOT046	12045.97	299.9	9.2	69.5	9.8	54.3	8.0	126.9	hydraulically smoothed	no viable flood fringe
NOT045	11889.97	310.1	11.4	139.3	13.3	64.4	10.1	139.3	depth	no viable flood fringe
NOT044	11652.27	275.1	21.3	118.4	23.1	74.4	19.9	118.4	depth	no viable flood fringe
NOT043	11298.68	181.1	33.6	106.7	36.0	103.0	32.5	106.7	depth	hydraulically smoothed
NOT042	10969.19	296.8	144.9	219.5	146.7	195.2	144.9	219.5	depth	hydraulically smoothed
NOT041	10586.35	459.6	328.5	441.1	391.2	440.0	320.2	443.1	hydraulically smoothed	no viable flood fringe
NOT040	10234.54	372.6	236.9	365.6	278.2	361.9	256.7	366.9	depth	no viable flood fringe
NOT039	9969.19	296.1	202.6	282.6	227.9	279.9	202.6	282.6	depth	depth
NOT038	9589.83	277.9	176.4	267.2	219.4	265.7	175.1	267.2	depth	hydraulically smoothed
NOT037	9360.12	275.0	185.3	256.2	189.5	247.6	185.3	256.2	depth	depth

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
NOT036	9020.47	339.1	259.6	322.0	278.6	322.0	255.2	322.0	depth	hydraulically smoothed
NOT035	8810.35	242.1	66.1	228.7	181.5	227.0	66.1	228.7	depth	depth
NOT034	8714.77	213.3	43.2	175.4	101.2	174.1	31.9	175.4	depth	hydraulically smoothed
WEIR	0.00									
NOT032	8698.65	227.5	28.6	168.0	94.6	166.0	27.2	168.0	depth	hydraulically smoothed
NOT031	8616.07	211.0	16.8	115.0	18.2	101.2	15.0	115.0	depth	hydraulically smoothed
NOT030	8488.74	206.0	7.9	72.8	8.8	59.5	6.9	72.8	depth	no viable flood fringe
NOT029	8355.61	215.7	20.9	94.4	22.1	89.2	19.5	94.4	depth	no viable flood fringe
NOT028	8258.80	184.0	12.0	94.6	13.3	67.2	10.5	94.6	depth	no viable flood fringe
NOT027	8081.35	224.8	35.2	112.5	36.2	105.9	33.8	112.5	depth	no viable flood fringe
NOT026	7683.41	265.0	16.5	110.2	18.3	87.0	14.9	110.2	depth	no viable flood fringe
NOT025	7428.27	159.0	22.7	96.9	34.3	94.8	22.7	96.9	depth	depth
NOT024B	7326.89	150.9	36.4	109.9	46.9	106.6	36.4	109.9	depth	depth
NOT024A	7292.71	150.8	41.6	116.6	57.7	114.9	41.6	116.6	depth	depth
NOT023	7145.37	125.0	19.6	80.5	21.5	76.6	19.6	80.5	depth	depth
NOT022	6961.70	129.8	54.0	111.5	57.2	110.4	54.0	111.5	depth	depth
NOT021	6714.91	151.7	34.2	115.5	43.3	113.6	34.2	115.5	depth	depth
NOT020	6540.25	205.6	102.3	159.1	104.8	154.6	102.3	163.3	depth	hydraulically smoothed
NOT019	6357.28	315.9	235.4	297.6	237.5	284.0	235.4	300.1	depth	hydraulically smoothed
NOT018	5992.49	430.1	336.3	425.4	368.4	424.0	335.9	426.2	hydraulically smoothed	no viable flood fringe
NOT017	5560.63	334.0	209.1	308.2	248.3	306.4	209.1	311.2	depth	no viable flood fringe
NOT016	5288.34	181.2	95.2	170.4	99.0	157.2	95.2	171.8	depth	no viable flood fringe
NOT015	4851.14	237.3	21.1	88.7	22.6	66.5	20.5	88.7	depth	no viable flood fringe
NOT014	4308.42	170.1	35.4	138.1	89.1	135.9	35.4	139.9	depth	no viable flood fringe
NOT013	3847.00	256.8	11.4	57.8	11.4	56.9	10.0	57.8	depth	no viable flood fringe
NOT012	3249.36	135.9	31.7	107.4	50.2	106.9	31.7	107.4	depth	depth
NOT011	2926.33	297.9	200.4	278.9	218.7	278.1	200.4	280.1	depth	no viable flood fringe
NOT010	2429.59	235.8	135.3	213.9	137.1	201.7	135.3	220.4	depth	hydraulically smoothed
NOT009	1821.26	195.5	10.2	71.6	11.4	69.2	8.9	78.4	hydraulically smoothed	no viable flood fringe
NOT008	1344.26	108.8	11.2	94.2	29.9	92.5	11.2	94.2	depth	depth
NOT007	1142.44	129.2	53.6	114.1	63.7	112.2	53.6	114.1	depth	depth
NOT006B	928.96	153.5	42.9	109.2	44.2	107.9	42.9	109.2	depth	depth
NOT006A	898.20	152.9	39.9	110.5	41.7	108.7	39.9	110.5	depth	depth
NOT005	829.47	103.2	16.3	80.8	17.3	78.1	16.3	80.8	depth	depth
NOT004	684.30	119.8	52.2	103.3	52.7	101.2	52.2	103.3	depth	depth
NOT003	564.13	148.6	79.6	132.7	81.9	131.4	79.6	133.8	depth	no viable flood fringe
NOT002	318.44	162.3	47.0	101.2	47.4	99.4	47.0	101.2	depth	depth
NOT001	0	150.2	28.5	80.6	23.5	84.2	28.5	80.6	depth	depth

TABLE 8: DESIGN FLOOD WATER SURFACE ELEVATIONS

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
NOT077	24872.66	480.99
NOT076	24209.30	479.77
NOT075	23526.76	478.60
NOT074	22857.27	477.46
NOT073	22269.38	476.57
NOT072	21940.13	476.11
NOT071	21485.65	475.38
NOT070	20834.49	474.57
NOT069	20460.81	473.86
NOT068	20004.02	473.09
NOT067	19631.53	472.76
NOT066	19235.64	472.36
NOT065	18719.93	471.85
NOT064	18041.73	470.96
NOT063	17591.98	470.37
NOT062	17107.57	469.44
NOT061	16879.66	469.12
NOT060	16479.80	468.61
NOT059	16074.89	467.93
NOT058	15709.88	467.49
NOT057	15392.72	467.08
NOT056	15073.83	466.28
NOT055	14774.27	465.68
NOT054	14560.40	465.24
NOT051	14041.57	464.43
NOT050	13566.26	463.61
NOT049	13044.59	462.84
NOT048	12601.00	462.52
NOT045	11889.97	461.73
NOT044	11652.27	461.46
NOT043	11298.68	461.26
NOT042	10969.19	460.81
NOT039	9969.19	459.80
NOT038	9589.83	459.37
NOT037	9360.12	459.19
NOT034	8714.77	458.17
WEIR	0.00	0.00
NOT032	8698.65	458.13
NOT029	8355.61	457.54
NOT028	8258.80	457.39
NOT027	8081.35	457.17

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
NOT026	7683.41	456.90
NOT025	7428.27	456.56
NOT024B	7326.89	456.48
NOT022	6961.70	455.86
NOT021	6714.91	455.62
NOT020	6540.25	455.38
NOT019	6357.28	455.01
NOT018	5992.49	454.52
NOT017	5560.63	453.99
NOT016	5288.34	453.67
NOT015	4851.14	452.78
NOT014	4308.42	452.11
NOT013	3847.00	451.09
NOT010	2429.59	448.95
NOT009	1821.26	447.90
NOT008	1344.26	447.34
NOT007	1142.44	446.89
NOT006B	928.96	446.82
NOT006A	898.20	446.72
NOT005	829.47	446.56
NOT004	684.30	446.14
NOT003	564.13	445.99
NOT002	318.44	445.68
NOT001	0	445.23

 Indicates cross-sections located outside of the study reach.

APPENDIX A
Survey and Base Data Collection Documentation

DRAFT



APPENDIX B
Hydrologic Assessment Memorandum

DRAFT



February 3, 2025

Version 3.0
Ref. 35915-531

Tachara Larocque
ALBERTA ENVIRONMENT AND PROTECTED AREAS
RIVER ENGINEERING AND TECHNICAL SERVICES
Floor 11, Oxbridge Place
9820 - 106 St.
Edmonton, AB T5K 2J6

Subject: Manning Flood Study, Hydrologic Assessment

Dear Tachara Larocque:

1 INTRODUCTION

Montrose Environmental Solutions Canada Inc. (Montrose, formerly Matrix Solutions Inc.) was retained by Alberta Environment and Protected Areas (EPA) to assess and identify flood hazards along Notikewin River through the Town of Manning and County of Northern Lights located about 100 km north of Peace River and 600 km northwest of Edmonton, Alberta. These assessments are part of the continuing flood hazard mapping efforts of the Government of Alberta to identify, map, and document flood hazard areas in communities throughout Alberta. A flood frequency analysis of the Notikewin River at Manning using regional frequency analysis method was completed by EPA in 1991 and derived flood frequencies up to 100-year flood event. A flood risk mapping study for an 8 km reach of the river through the town was completed by EPA in 2000. The mapping extents have increased compared to the previously completed flood hazard study in 2000 and now extend from the western boundary of NW 13-091-24 W5M to just downstream of the railway bridge near Range Road 231 at the western boundary of SW 36-091-26 W5M, covering a distance of 24 km, as shown on Figure B1. The key project stakeholders are the Government of Alberta, Town of Manning, and County of Northern Lights. The current study updated the flood frequencies with return periods ranging from 2-year to 1,000-year using the available historical flood data to date and expand the hydraulic modelling extent and flood mapping coverage. In 2023, a hydrology report was submitted to EPA with the preliminary estimates of the 2022 flood. Since then, the Water Survey of Canada (WSC) published the maximum instantaneous discharge of the 2022 flood. This updated report reflected the revised flood frequency estimated based on the finalized maximum instantaneous discharge of 2022 flood.

The flood frequency estimates for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year open water floods with confidence intervals are required at key locations along the Notikewin River within the study area. The key locations include:

- at the upstream study area boundary
- at the gauging station located on the Notikewin River near the Town of Manning (07HC001)
- at the downstream boundary of the study area boundary
- any other locations where significant peak inflows entered the Notikewin River

This hydrology report has been prepared to support the flood hazard study by providing 2- to 1,000-year flood estimates. Hydrologic analysis conducted herein has been guided by the *Flood Hazard Identification Program Flood Study Technical Guidelines* (AEP 2022), the *Study Terms of Reference* (TOR; EPA 2023), and the *Guidelines for Determining Flood Flow Frequency, Bulletins 17B and 17C* (USGS 1982, 2018, 2019). The estimated flood frequencies will be used as model input data for hydraulic modelling and flood inundation and hazard mapping. A detailed description of the flood frequency analysis methodology and the flood frequency estimates are provided herein.

2 PROJECT SETTING

The Notikewin River is a tributary of the Peace River; its headwater is in the Clear Hills, and it flows in an easterly direction toward its confluence with the Peace River. The upper reaches of the river basin are forested with White and Black Spruce and Aspen Poplar and the major land use surrounding the town and County of Northern Lights is agriculture. The river channel is entrenched and confined within the valley wall. The river exhibits irregular patterns with almost tortuous meanders with pool and riffle sequence in combination with diagonal and point bars. The Notikewin River runs through the town of Manning flowing from the west and developed areas within the town are located on both sides of the river.

A WSC hydrometric gauging station, the Notikewin River at Manning (07HC001), is located on the river within the study reach. The drainage area of the Notikewin River at the WSC station is 4,680 km². There are three hydraulic structures, one bridge on Highway 35, one railway bridge, and a weir structure located about 1.3 km upstream of Highway 35 bridge across the river within the study area. As indicated in the TOR, the presence of the existing weir across the river at Manning has no significant hydrologic impact or flood attenuation capacity. Recorded flows at the WSC station were considered as natural and no flow naturalization was required for this study.

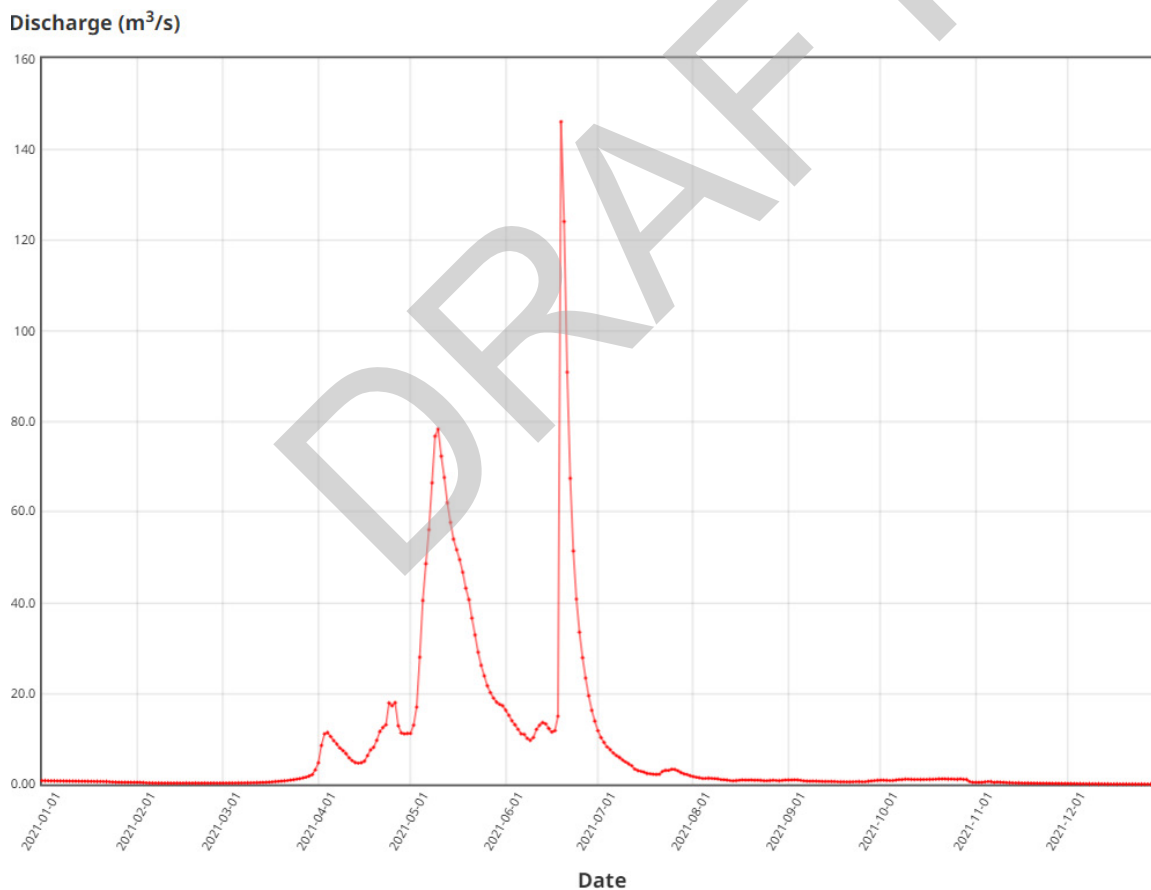
3 AVAILABLE STREAMFLOW RECORDS

Recorded historical streamflow data are required to derive flood frequency estimates associated with various return periods. The WSC maintains one hydrometric station within the reach. The period of available data for this station is presented in Table A.

TABLE A Key Hydrometric Stations

Station Name and ID	Gross Drainage Area (km ²)	Data Period
Notikewin River at Manning (07HC001)	4,680	1961-2022

Based on a review of the available historical flood data, the study area has been subject to severe historical floodings. Recently, the town also experienced two significant floods in May 2022. The magnitudes of these floods are 454 m³/s for the May 8, 2022 flood and 592 m³/s for the May 31, 2022 flood. The largest recorded historical flood prior to 2022 occurred in 1964 with a magnitude of 537 m³/s and the second largest flood with a magnitude of 487 m³/s occurred in 1972. Several historical large floods with magnitude more than 400 m³/s occurred in this area including floods in 1963, 1964, 1972, 1977, and 1978. The study area has also been subject to severe floodings in the recent years including floods in 2013 (225 m³/s), in 2019 (225 m³/s), in 2020 (314 m³/s), and in 2021 (157 m³/s). Based on a review of the historical flood data, it is also revealed that spring melt related runoff and flooding events occur generally in May and June as shown in the 2021 daily flow data below (Graph A).



GRAPH A 2021 Daily Time Series Flow Data at 07HC001

4 HYDROLOGIC ANALYSIS

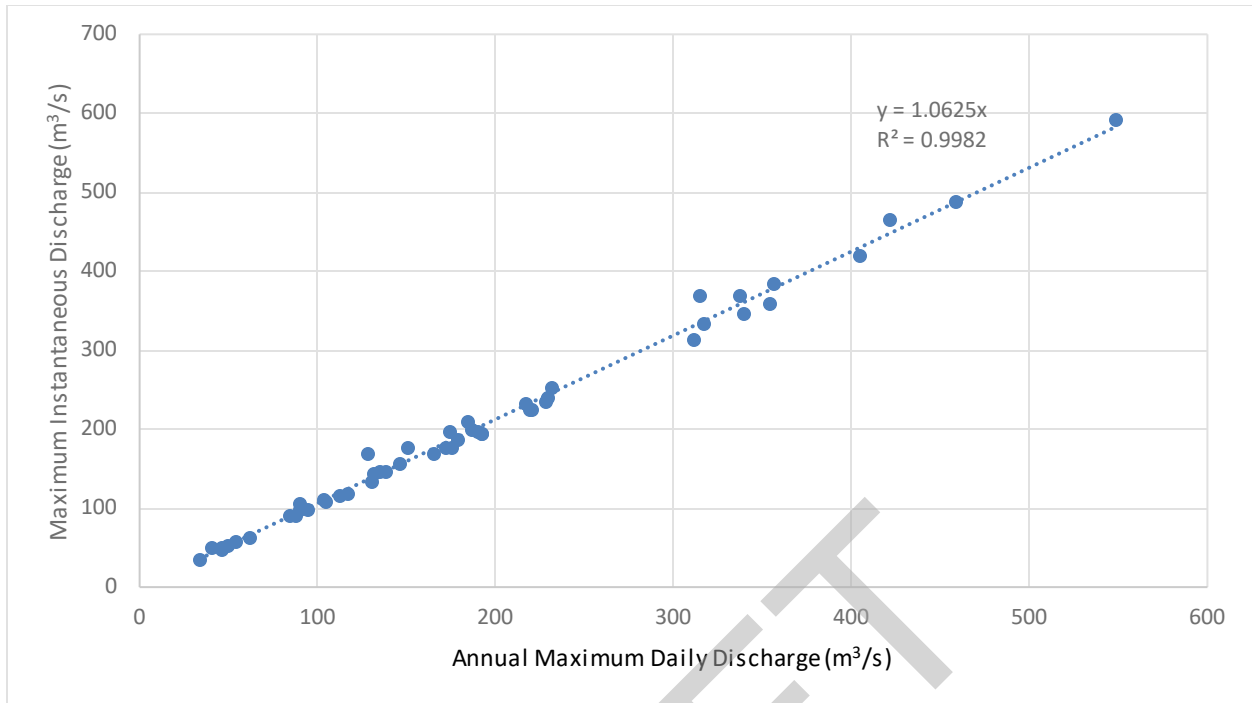
The hydrologic analysis was undertaken to recommend 2- to 1,000-year return period instantaneous flood estimates for the Notikewin River to be used for subsequent hydraulic modelling and flood inundation mapping. Since the WSC station (07HC001) has a relatively long period of records (62 years of data) and is located within the study reach, the flood frequency estimates at this location were used for deriving flood frequencies for this flood hazard mapping study. This analysis involves evaluation of recorded annual maximum instantaneous discharge and annual maximum daily discharge data, analysis of the extended data series for statistical outliers, and selection of the most suitable probability distribution.

4.1 Data Series Preparation

The Notikewin River at Manning station has 62 years of record; it has been recording flow data since 1961. Recorded annual maximum daily discharge and annual maximum instantaneous discharges data series for the WSC station (07HC001) is provided in Appendix B1 (Table B1).

Flood frequency estimates are based on the instantaneous peak discharge. For those years where instantaneous peak discharge data at the WSC station is missing, estimates were derived based on a linear regression between the available recorded coincident instantaneous peak discharges and the maximum daily discharges at the Manning gauging station. As shown on Graph B, the following relationship was derived to extend the instantaneous peak discharge data series for the Notikewin River at Manning:

where: $Q_{07HC001_I} = 1.0625 Q_{07HC001_M}$
 $Q_{07HC001_I}$ = instantaneous peak discharge at Notikewin River at Manning (m^3/s)
 $Q_{07HC001_M}$ = maximum daily discharge at Notikewin River at Manning (m^3/s)
 R^2 = coefficient of determination, 0.9982 for this relationship



GRAPH B Relationship between Annual Maximum Daily Discharge and Annual Maximum Instantaneous Discharge at Notikewin River at Manning (07HC001)

Table B2 (Appendix B1) presents the extended annual maximum instantaneous discharge data series containing 62 data points adopted for flood frequency analysis. The extended annual maximum instantaneous discharge data series contains flows ranging from 34 m³/s in 1980 to 621 m³/s in 2022. Figure B2 (Appendix B1) shows the historical annual maximum daily discharges and annual maximum instantaneous discharges. Table B summarizes the statistical parameters of the complete maximum instantaneous discharge dataset.

TABLE B Summaries of Statistical Parameters of Maximum Instantaneous Discharge of the Notikewin River at Manning (07HC001)

Parameters	Normal	Log-transformed
Years of	62	62
Mean	207.9	2.233
Maximum	592	2.793
Minimum	34	1.531
Standard	129.4	0.285
Coefficient	0.62	0.127
Coefficient	1.25,	0.25, 0.81, -0.30

Extreme high and low events were evaluated to determine whether they should be considered as outliers. Standard outlier analysis was conducted following the *Bulletin 17B* detection procedure (McCuen 2004). This analysis (summarized in Table C below) confirmed that the extreme low and high observations belong

to the same population as the remainder of the data series. The largest value of the maximum instantaneous discharge data series will be an outlier if Y_h is greater than Y_{oh} . On the other hand, the lowest discharge value of the maximum instantaneous discharge data series will be an outlier if Y_h is less than Y_{oh} . The analysis indicates that no outliers are present in the extended maximum instantaneous discharge data series and consequently all the data in the maximum instantaneous data series was used for flow frequency analysis (Table C).

TABLE C Outlier Analysis for Notikewin River at Manning (07HC001)

Peak Event	Record Length	Outlier Test Deviates (K_o) ¹	Logarithm of Flow (Y_h)	Mean of Logarithm Transformed Flow Data	Standard Deviation of Logarithm Transformed Flow Data	Detection Criteria (Y_{oh})	Outlier (Yes/No)
2022 (extreme high)	62	2.849	2.772	2.233	0.286	3.042	No
1980 (extreme low)			1.53			1.423	No

1 (McCuen 2004)

5 FLOOD FREQUENCY ESTIMATES

5.1 Previous Study

A flood frequency analysis was completed in 1991 based on a regional analysis of limited maximum instantaneous discharge data (EPA 1991) and the 1991 flood frequency estimates were used in the 2000 Flood Hazard Study (NHC 2000). A regional frequency analysis using the Index Flood method was used in deriving recommended flood frequencies in the 1991 study.

The flood frequency estimates were derived for various return periods ranging from 2-year to 100-year floods. The flood frequency analysis in the 1991 study considered several theoretical probability distributions including, normal, log normal, 3-parameter log normal, Pearson III, log-Pearson III and Gumbel distributions.

The estimated flood frequencies varied from a 2-year flood of 215 m³/s to a 100-year flood of 2,590 m³/s (EPA 1991). Further discussion on the flood frequency estimates in the 1991 analysis is provided in Section 6 of this report.

5.2 Current Study

Standard statistical analysis of the generated annual maximum instantaneous discharges for the WSC station, Notikewin River at Manning (07HC001), were completed as a part of the flow frequency analysis. Different theoretical probability distributions to the observed datasets were tested for their suitability for the subject dataset, and the most suitable theoretical distribution was selected based on comparing visual goodness of fit curves against the observed data and comparing results of statistical goodness of fit tests.

The goodness of fit of each distribution, as applied to a flood series, was compared through the Kolmogorov-Smirnov (K-S) test, Anderson-Darling test, and Least-Squares method.

Various 2-parameter and 3-parameter theoretical probability distributions were tested. These distributions included: Normal, log normal, 3-parameter log normal, Pearson Type III, log-Pearson Type III, Extreme Value 1 (EV1), Exponential, Weibull, Gamma, and Gumbel extreme value distributions. Hydrological Frequency Analysis (Hyfran) Plus Version 1.2 software and the Microsoft Excel® based tool created for City of Calgary Frequency Analysis (AMEC 2014) were used to compute flood frequency estimates and to perform goodness of fit testing. Best fitting curve methods considered included method of moments and method of maximum likelihood. The Cunnane positioning formula was used to plot data points for visualization purposes.

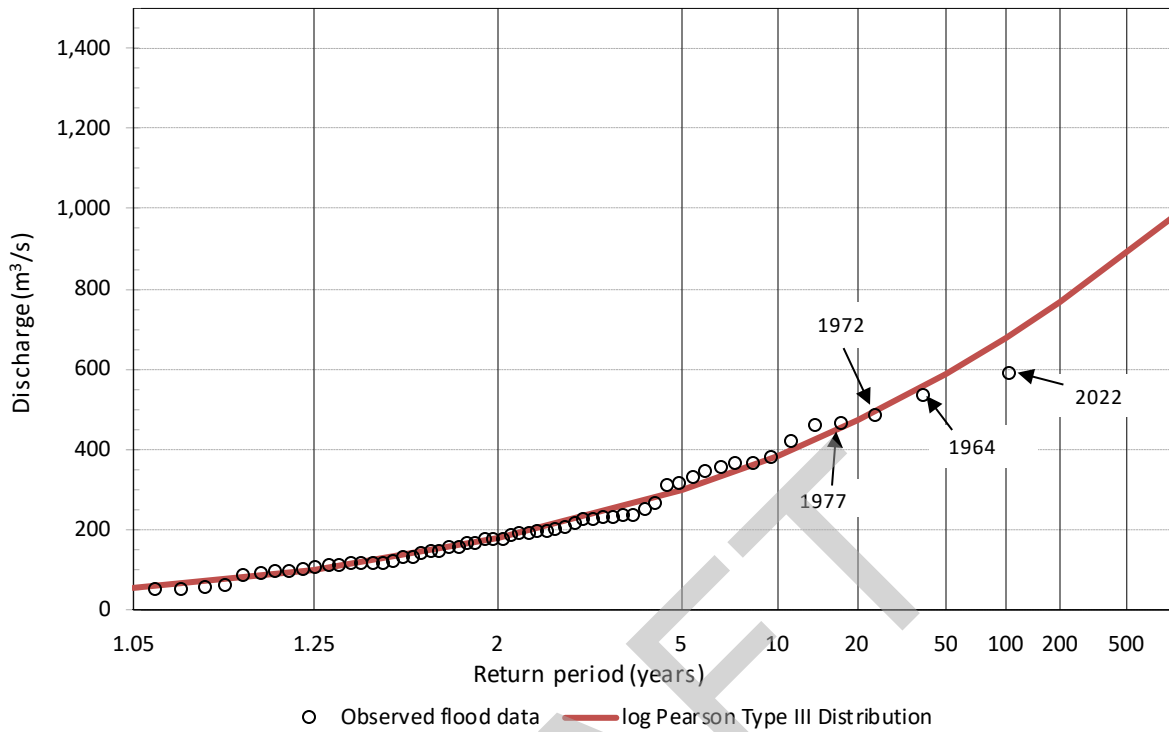
The flood frequency analysis completed as part of this study followed the *Guidelines for Determining Flood Frequency, Bulletin 17B* (USGS 1982) and *Bulletin 17C* (USGS 2018). The guidelines provide a procedure for computing flood flow frequency including accounting for historic flood information, zero flows, low and high outliers, and methods to estimate population parameters. Log-Pearson type III is recommended as the basic distribution for defining the annual floods series and recommended use of a weighted average of the station skew and a regional skew.

The guidelines in Bulletin 17C improve on Bulletin 17B by addressing major limitations. Bulletin 17C introduces a standardized Multiple Grubbs-Beck test to identify influential low flood outliers. A new recommended method for estimating regional skew is introduced in Bulletin 17C using the Bayesian Weighted Least-Squares/Bayesian Generalized Least-Squares method, which supersedes the regional skew coefficient map in Bulletin 17B. The new Expected Moments Algorithm (EMA) is used to extend the method of moments so that it can better handle lower outlier adjustments, regional skew information, and historical information. Regional skew estimates were developed to address the complexities of the EMA but are not available in Alberta. Therefore, only the station skewness and theoretical limits were used in this study.

In the absence of regional skew coefficients, flood frequency estimates following 17B guidelines are identical to those from the regular log-Pearson Type III distribution based on the method of moments.

5.3 Flood Frequency Estimates for Notikewin River

Figures B3.1 to B3.3 (Appendix B1) shows the comparison of theoretical probability distributions to the maximum instantaneous discharge data for ten distributions. Figure B4 (Appendix B1) show the summary of statistical goodness of fit test results. The overall rank of the log-Pearson Type III distribution is one out of ten distributions. A visual inspection of various frequency distributions to the flow data and goodness of fit also indicates that the log-Pearson Type III distribution has the most representative fit to the recorded data. Graph C presents the best fitted log-Pearson Type III distribution with observed data. The four largest flood events from historical record are also shown on Graph C.

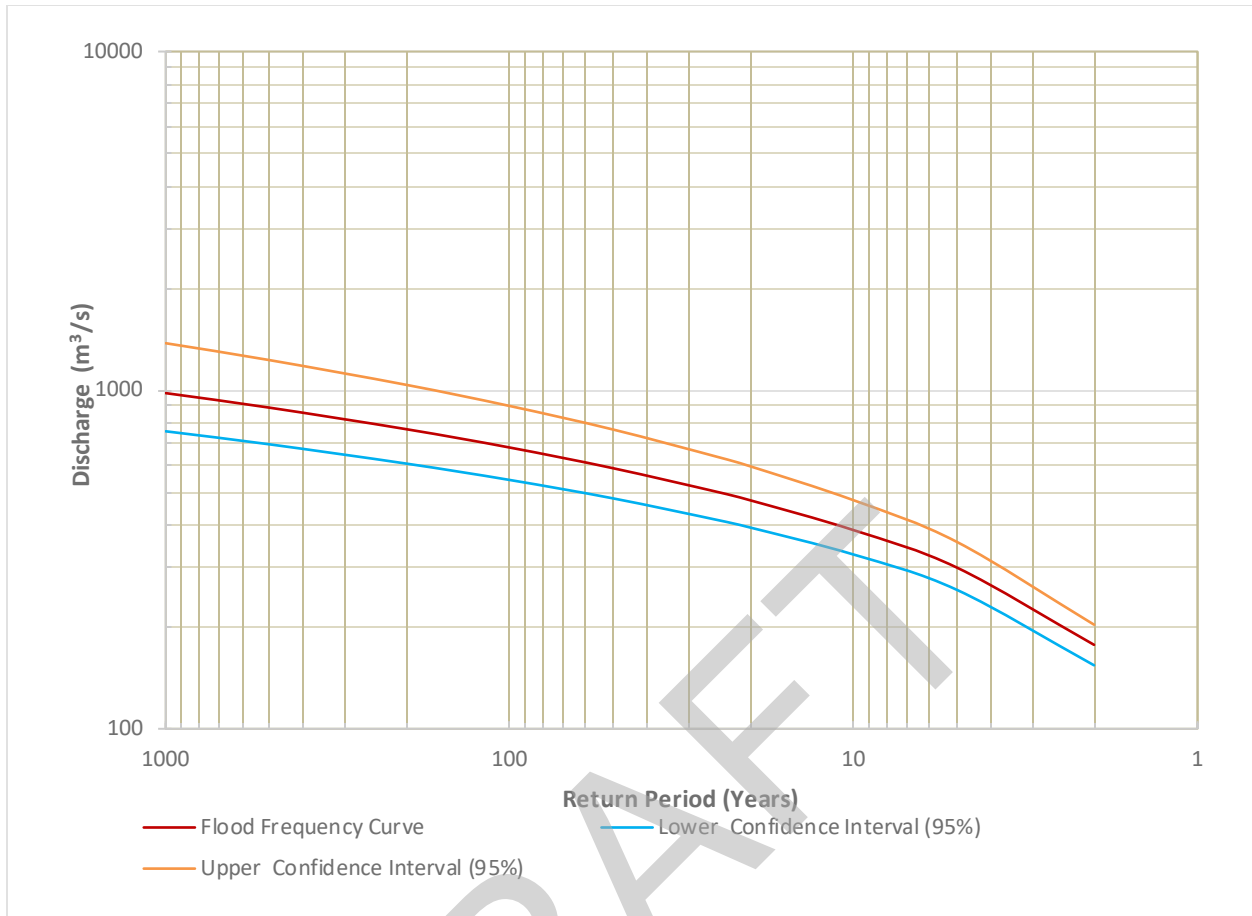


GRAPH C Best fitted log-Pearson Type III Distribution with Observed Flood Data at 07HC001

Therefore, the log-Pearson Type III distribution has been selected to represent the flood frequencies for the Notikewin River at Manning (07HC001). Table D presents the complete set of flood frequency estimates recommended for adoption for the flood risk mapping study within the Notikewin River study reach; Graph D presents the recommended flood frequency curve for the log-Pearson Type III distribution with 95% confidence intervals.

TABLE D Flood Frequency Estimates at Notikewin River at Manning (07HC001)

Return Period (years)	Flood Discharge ¹ (m ³ /s)	95% Confidence Limits
2	177	154-203
5	299	257-356
10	386	327-473
20	474	393-596
35	545	454-681
50	590	479-765
75	642	522-832
100	677	543-898
200	767	607-1,037
350	839	668-1,132
500	888	692-1,227
750	938	724-1,302
1,000	980	756-1,376



GRAPH D Flood Frequency Curve for Notikewin River at Manning (07HC001)

Based on a review of flood frequency estimates, it appears that the recorded and estimated floods on the Notikewin River at Manning have return periods ranging from 2 to more than 60 years. The historical peak floods are also plotted on Graph C. The magnitude of the estimated 100-year flood is 677 m³/s compared to the highest recorded flow of 592 m³/s on May 31, 2022, and the second highest recorded flow of 534 m³/s in 1964

6 DISCUSSION

A comparison of the flood frequency estimates of the 1991 study (EPA 1991) and the current study is provided in Table E below.

TABLE E Comparison of Flood Frequency Estimates

Return Period (years)	Flood Frequency Estimates in this Study (m ³ /s)	Flood Frequency Estimates in EPA (1991) Study
2	177	215
5	299	635
10	386	996
20	474	1,395
50	590	2,100
100	677	2,590

As seen in the above table, the 1991 flood frequency estimates for all return periods except the 2-year return period are significantly higher than the current estimates. In the 1991 report it was noted that due to lack of adequate data, there is a high degree of uncertainty with the regional analysis adopted in that study and the magnitude of the 100-year flood needs to be updated once more data is available.

Given the availability of relatively long period of streamflow data in the WSC station located within the study area, flood frequency estimates derived in this study using a Single Station Flood Frequency Analysis method of the recorded flow data at this WSC station are appropriate and reflect the flood conditions that can be expected in the study reach of the Notikewin River.

The flood frequency estimates based on the 62 years of data record reflect the most current data and methodologies available. Given the existence of uncertainty in estimating flood frequencies with greater return periods, the flood frequency estimates should be updated as more flood data becomes available.

7 RECOMMENDED FLOOD FREQUENCY ESTIMATES

The upstream boundary of the study area is located 18.4 km upstream of the WSC station Notikewin River at Manning (07HC001) and the downstream boundary is located 5.8 km from this WSC station.

Due to the short distance between the upstream and downstream boundaries from the WSC station on the Notikewin River and that there is no tributary or distributary channels within the study reach, the flood frequency estimates at the WSC station, Notikewin River at Manning (07HC001) can be used at the upstream boundary for hydraulic modelling purposes and can be used for the hydraulic modelling of the river within the study reach.

Table F presents the complete set of flood frequencies recommended for adoption for the flood risk mapping study and will be used in hydraulic modelling.

TABLE F Recommended Flood Frequency Estimates

Return Period (years)	Flood Discharge (m ³ /s)
2	177
5	299
10	386
20	474
35	545
50	590
75	642
100	677
200	767
350	839
500	888
750	938
1,000	980

7.1 Potential Effects of Climate Change

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.

Though occasional summer storms produce large summer flood peaks, flooding on the Notikewin River is largely dominated by spring snowmelt. From a climate change perspective, changes to winter and spring conditions are most likely to affect the hydrologic response of the Notikewin River watershed, which is a part of the Peace River basin. Significant uncertainty exists in quantifying the hydrologic response and any potential impact on flood magnitude and timing due to the complex nature and inherent uncertainty in projecting climate change.

Several studies have been conducted for assessing the climate change effects on river flows in western Canada and findings of some of the available documents are briefly discussed herein. Zaghoul et al. (2022) conducted a trend analysis for the water flow and climate data in the Athabasca River basin and in the Peace River basin using the Mann-Kendall test and Least-Squares method. The monthly, seasonal, and annual averaged trend analysis results for various historical periods were assessed. The findings of the study showed an increasing trend in temperature and a decline in annual precipitation across the basins. Winter water flow has been slowly and steadily increasing since 1956 because of the rising temperatures and the subsequent slow melting of snowpacks/glaciers.

Poitras et al. (2011) conducted a study on climate change effects and projected changes in average and extreme stream flows of ten major river basins (Nelson, Churchill, North Saskatchewan, South Saskatchewan, Peace, Athabasca, Mackenzie, Yukon, Fraser, and Columbia) in western Canada. They compared the results for the 2041-2070 period to the conditions that existed for the 1961-1990

baseline period. Mean annual flows were projected to increase in all basins with a 17% increase in the Peace River basin. Snowmelt events in the Peace River basin were predicted to occur earlier and peak discharges were likely to increase by up to 20%.

Using the Nonstationary flood frequency analysis (NFFA) technique in predicting future floods under climate change, Ammar et al. (2019) concluded that the majority of the studied catchments in the Peace River basin will likely experience considerable increases in the rate of occurrence of floods in the future period (2040–2064) relative to the historical period (1983–2007), with an average change of +41% and +57%, depending on the climate change scenarios considered in the study.

Rokaya et al. (2020) conducted a hydrological modelling study to investigate the streamflow conditions in the Smoky River, the largest unregulated tributary of the Peace River, in the 2071-2100 versus the 1981-2010 periods. The modelling results revealed significant changes in the hydrological regime of the Smoky River, such as increased discharge in winter (+190%) and spring (+130%), but reduced summer flows (–33%) in the 2071–2100 period compared with the baseline period. Similar response of the Notikewin River basin under climate change scenario is anticipated since the Notikewin River is located in a similar geographic location of the Smoky River basin and is a part of the Peace River basin.

Hydrological response to climate change varies at a local and regional scale, with each basin and subbasin responding differently to changes in climate parameters. Watershed-scale hydrological models in Alberta generally suggest that climate change will impact the hydrologic regime in the following ways (Alberta WaterPortal 2018):

- Increased average annual precipitation (whether as rain or snow or both)
- Changes in timing (spring, summer, fall, or winter) and magnitude (too much or too little) of streamflow
- More frequent and severe extreme events (droughts and floods)

Climate science is not well-developed yet, particularly for infrequent events that cause flooding. Global climate models, and even regional climate models, are designed to predict general trends, not event style data (NRCan 2019). As such, these models are not effective for quantifying future flooding characteristics. Given the uncertainty in quantifying the effect of climate change on estimated flood peaks for developing flood maps, Natural Resources Canada (2019) suggested several approaches that may be considered in climate change adaptation. These include: a) using a safety factor; b) carrying out sensitivity analysis; c) using a risk based approach; d) planning for adaptive designs; and e) managing residual risk during infrastructure operations (NRCan 2019).

Natural Resources Canada has developed the Federal Flood Mapping Guidelines Series and has recently published the document, *Case Studies on Climate Change in Floodplain Mapping* (Natural Resources Canada 2018a). While this document identifies different approaches (including a qualitative approach such as adding a freeboard to the design flood level and quantitative approach through the use of a hydrologic model) applied in different Canadian jurisdictions, there is currently no standard methodology

that has been adopted (NRCan 2019). Current practices in British Columbia are governed by the Association of Professional Engineers and Geoscientists of British Columbia's *Legislated Flood Assessments in a Changing Climate in BC* (Natural Resources Canada 2018b). This document recommends increasing the design flow by up to 20% to account for uncertainties on future conditions.

In order to gain insight to the flood levels during a design flood event (100-year flood) under a changing climate in the study area, the current study will undertake a sensitivity analysis by increasing the magnitude of the design flood by 10 and 20%.

8 SUMMARY AND CONCLUSIONS

Flood frequency estimates are required for the Manning flood study. A WSC hydrometric gauging station, the Notikewin River at Manning (07HC001) is located within the study area. Given the availability of relatively long period of streamflow data in the WSC station located within the study area, flood frequency estimates derived in this study using a Single Station Flood Frequency Analysis method of the recorded flow data at this WSC station are appropriate and reflect the flood conditions that can be expected in the study reach of the Notikewin River. Thus, the extended annual maximum instantaneous discharges covering a period of 1961 to 2022 consisting of 62 data points at the Notikewin River at Manning (07HC001) were used for flow frequency analysis.

Following standard flow frequency analysis procedures, different theoretical probability distributions to the observed datasets were tested for their suitability for the subject dataset. The most suitable theoretical distribution for each dataset was selected based on comparing visual goodness of fit curves against the observed data and comparing results of statistical goodness of fit tests. It was concluded that log-Pearson Type III distribution represents the annual maximum instantaneous discharges for this WSC station.

Due to the short distance (less than 25 km) between the upstream and downstream study boundaries, the absence of tributary or distributary channels within the study boundary, and the WSC station being located within these boundaries, the flood frequency estimates at the WSC station, Notikewin River at Manning (07HC001) can be used at the upstream boundary of the Notikewin River and can also be considered as representative of the flood frequencies for the whole study area.

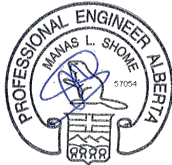
The flood frequency estimates based on the 62 years of data record reflect the most current data and methodologies available. Given the existence of uncertainty in estimating flood frequencies with greater return periods, the flood frequency estimates should be updated as more flood data becomes available.

9 CLOSURE

We trust that this letter report suits your present requirements. If you have any questions or comments, please call either of the undersigned at 780.490.6830.

Yours truly,

Montrose Environmental Solutions Canada Inc. Reviewed by



06 February 2025

Manas Shome, Ph.D., P.Eng.
Principal Water Resources Engineer



February 6 2025

Brandyn Coates, M.Eng., P.Eng.
General Manager

MS/eh
Attachments



CONTRIBUTORS

Name	Job Title	Role
Manas Shome, Ph.D., P.Eng.	Principal Water Resources Engineer	Author, engineer of record and Hydrology Specialist
Nadia Van Der Vinne, EIT	Water Resources Engineer-in-Training	Technical support
Brandyn Coates, M.Eng., P.Eng.	Water Resources Engineer	Reviewer

DISCLAIMER

Montrose Environmental Solutions Canada Inc. (Montrose) certifies to Alberta Environment and Protected Areas (the Client) that the conclusions in this report are the professional opinions of Montrose at the time of the report and concerning the scope described in the report. The opinions are based on the site conditions observed on the date set out in the report and information obtained during the performance of the scope and do not contemplate subsequent changes in site conditions or information or changes in applicable law or standards subsequent to the date of the report. Montrose has exercised a customary level of skill, care, and diligence in using information received from the Client and/or third parties in the preparation of the report, however assumes no responsibility or liability for the consequences of any error or omission contained in such information. This report was prepared solely for the use of the Client in relation to the specific scope, location, and purpose for which Montrose was retained and is not intended to be used for any variation or extension of the scope or any other project or purpose. Any other use or reliance on the report by the Client or any use or reliance by any third party without the prior express written consent of Montrose is at the sole risk and responsibility of the user and Montrose makes no representation or warranty with respect to any unauthorized use and expressly disclaims any legal duty of care to any such person. Neither Montrose nor its affiliates are responsible for damages, losses, fines, penalties, or other harm incurred by such unauthorized user as a result of decisions made or actions taken based on this report. This report may not be used or reproduced, except in its entirety.

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	16-May-20223	Draft	35915-531 LR 2023-05-16 draft V0.1.docx	Issued to client for review
V1.0	10-Nov-2023	Final	35915-531 LR 2023-11-10 final V1.0.docx	Issued as final
V2.0	23-Dec-2024	Final Revised	35915-531 LR 2024-12-23 final V2.0.docx	Revisions issued as final
V3.0	03-Feb-2025	Final Revised	35915-531 LR 2025-02-03 final V3.0.docx	Revisions issued as final

REFERENCES

- Alberta Environment and Parks (AEP). 2022. *Flood Hazard Identification Program Flood Study Technical Guidelines*. River Engineering and Technical Services. June 2022.
- Alberta Environment and Protected Areas (EPA). 2023. *Manning Flood Study, Specific Terms of Reference*. River Engineering and Technical Services. January 2023.
- Alberta WaterPortal Society (Alberta WaterPortal). 2018. *The history of climate in Alberta and effects of climate change on Alberta’s watersheds*. Calgary, Alberta. 2018.
- AMEC Environment & Infrastructure (AMEC). 2014. *Frequency Analysis Procedure for Stormwater Design*. Prepared for The City of Calgary. Calgary, Alberta. April 2014.
- Ammar M.E. et al. 2019. “Future floods using hydroclimatic simulations and peaks over threshold: An alternative to nonstationary analysis inferred from trend tests.” *Advances in Water Resources* 136 2019.
- McCuen R.H. 2004. *Hydrologic Analysis and Design*. Pearson College. April 15, 2004. 888 pp.
- Natural Resources Canada (NRCan). 2019. “Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation.” Version 1.0. Addendum to *Federal Flood Mapping Guidelines Series*. Ottawa, Ontario. 2019.
- Natural Resources Canada. 2018a. *Case Studies on Climate Change in Floodplain Mapping*. Volume 1. General Information Product 118e. 2018. <https://doi.org/10.4095/306436>
- Natural Resources Canada. 2018b. “Natural Hazards: Legislated Flood Assessments in a Changing Climate in BC.” Version 2.1. Addendum to *Professional Practice Guidelines*. British Columbia. August 28, 2018.
- Newton B.W. and Taube, N. 2023. *Regional variability and changing water distributions drive large-scale water resource availability in Alberta, Canada*. Canadian Water Resources Journal 2023, VOL. 48, NO. 3, 300–326.

Poitras V. et al. 2011. "Projected changes to streamflow characteristics over western Canada as simulated by the Canadian RCM." *Journal of Hydrometeorology* 12 (6): 1395–1413. December 2011.

Rokaya P. et al. 2020. "Impacts of future climate on the hydrology of a northern headwaters basin and its implications for a downstream deltaic ecosystem." *Hydrological Processes* 34 (7): 1630–1646. 2020.

United States Geological Survey (USGS). 2019. *Guidelines For Determining Flood Flow Frequency, Bulletin 17C: Techniques and Methods*. Chapter 5 of Section B, Surface Water. Book 4, Hydrologic Analysis and Interpretation. Techniques and Methods 4-B5. Version 1.1. Virginia. May 2019. <https://pubs.usgs.gov/tm/04/b05/tm4b5.pdf>

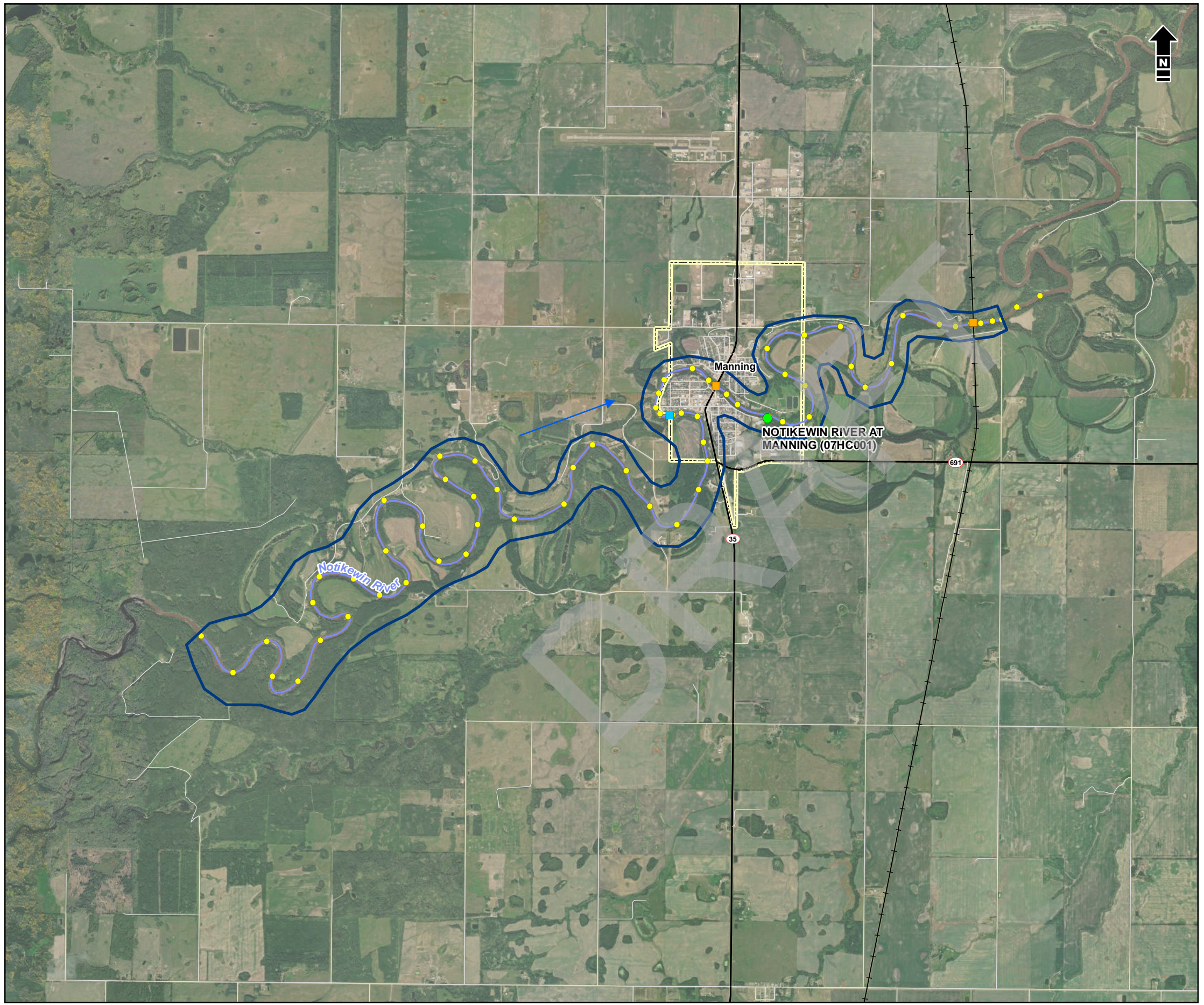
U.S. Department of the Interior Geological Survey (USGS). 1982. *Guidelines For Determining Flood Flow Frequency, Bulletin #17B of the Hydrology Subcommittee*. Virginia. March 1982.

U.S. Geological Survey (USGS). 2018. *Guidelines For Determining Flood Flow Frequency, Bulletin 17C: Techniques and Methods*. Chapter 5 of Section B, Surface Water. Book 4, Hydrologic Analysis and Interpretation. Virginia. 2018. <https://doi.org/10.3133/tm4B5>

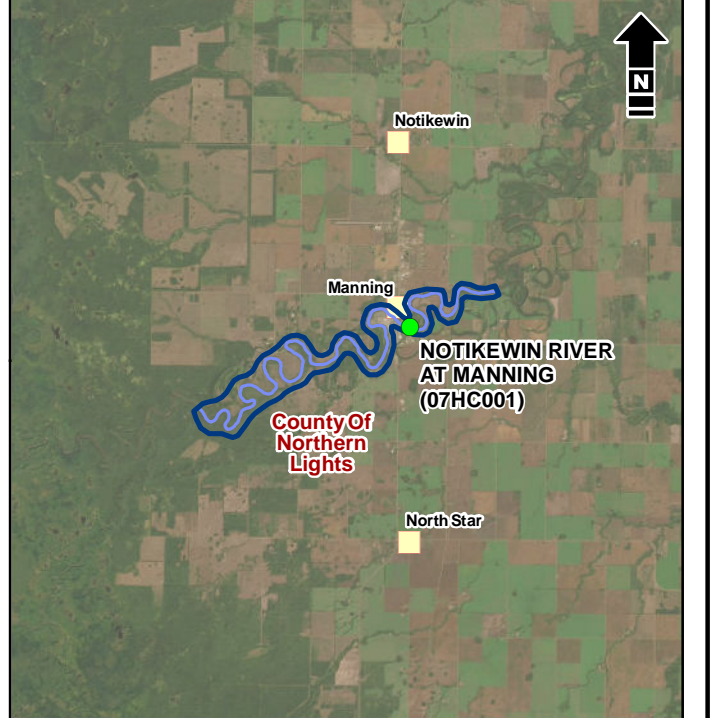
Zaghloul M.S. et al. 2022. "Long term trend analysis of River Flow and Climate in Northern Canada." *Hydrology* 9 (197) November 2022.

DRAFT

\\sands\environmental\parks\35915\FigureAndTables\Figure1_Study_Reach_and_Hydrometric_Station.mxd - Titled_L_07-Nov-23, 12:31 PM - jbosak - TDD05



- Study Area
- Urban Municipal Boundary
- Highway
- Road
- Railway
- Flow Direction
- Proposed Cross-Section Location
- Bridge
- Weir
- Hydrometric Station
- Study Reaches and Extents**
- Notikewin River



Reference: Data obtained from Altalis © Government of Alberta, GeoBase® and GeoGratis © Department of Natural Resources Canada (all rights reserved) used under license. GDM midstream and transportation infrastructure data and well data provided ©2023 by S&P Global Commodity Insights, a division of S&P Global Inc. All rights reserved. Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

1:50,000 kilometres
0.5 0 0.5 1
NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
Manning Flood Study

Study Reach and Hydrometric Station

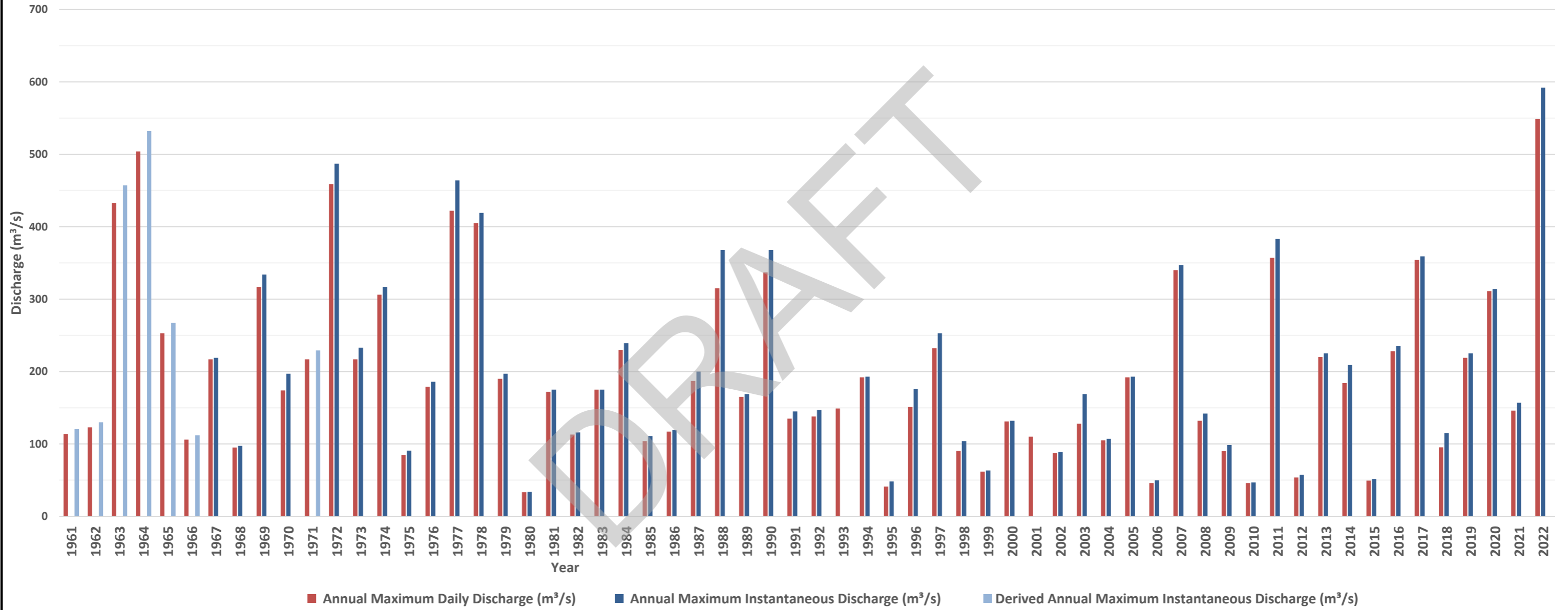
Date: November 2023	Project: 35915	Submitter: M. Wilkinson	Reviewer: M. Shome
Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to periodic change without prior notification. While every effort has been made by Matrix Solutions Inc. to ensure the accuracy of the information presented at the time of publication, Matrix Solutions Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.			Figure 1

APPENDIX B1
Notikewin River at Manning Station Figures and Tables




DRAFT

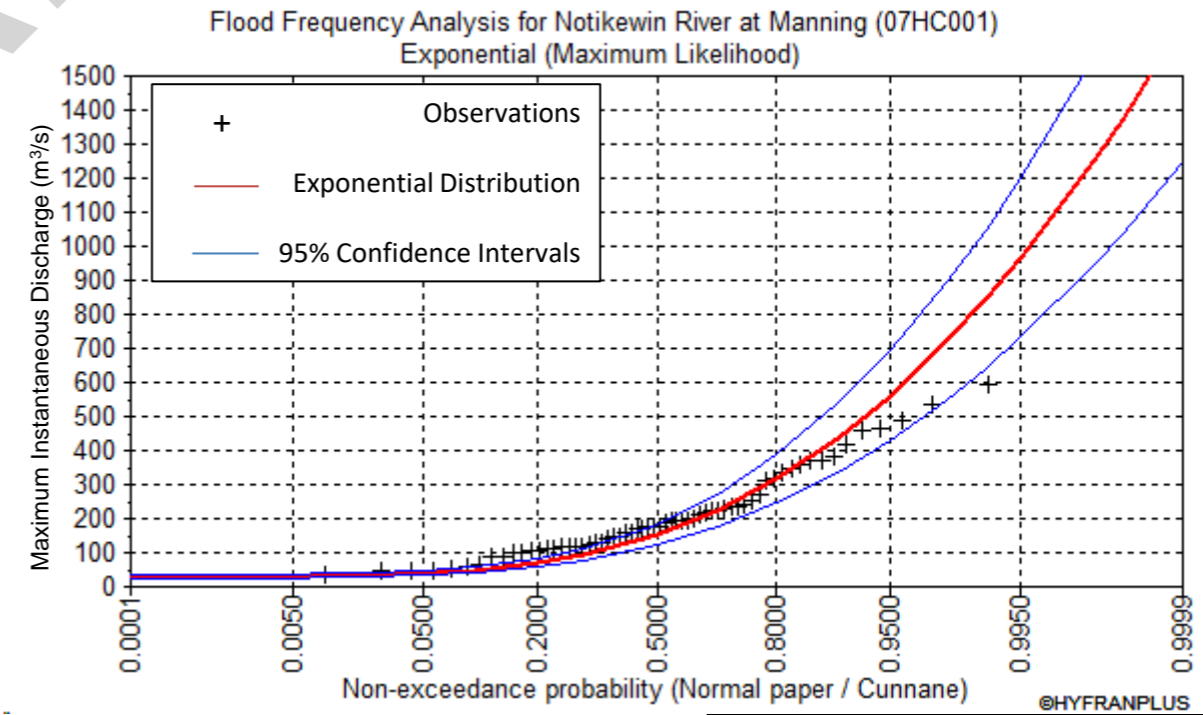
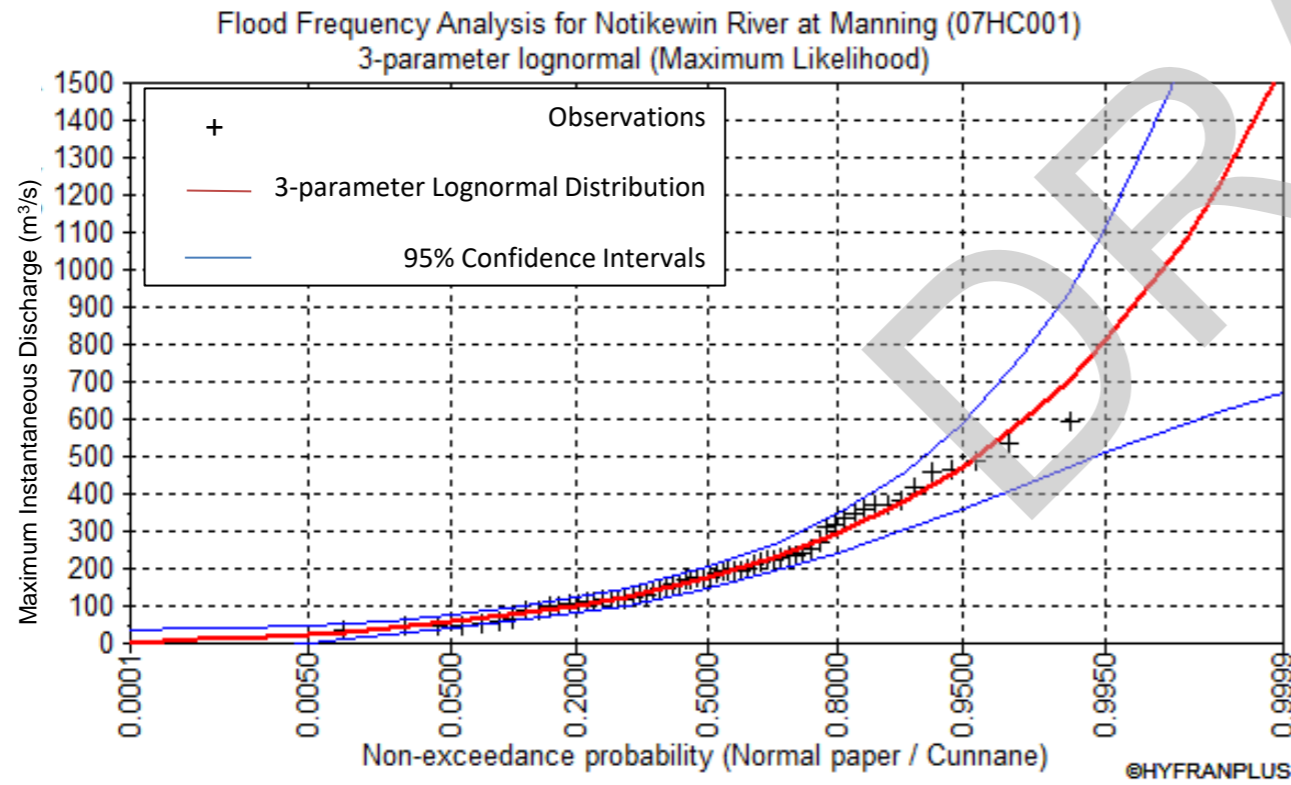
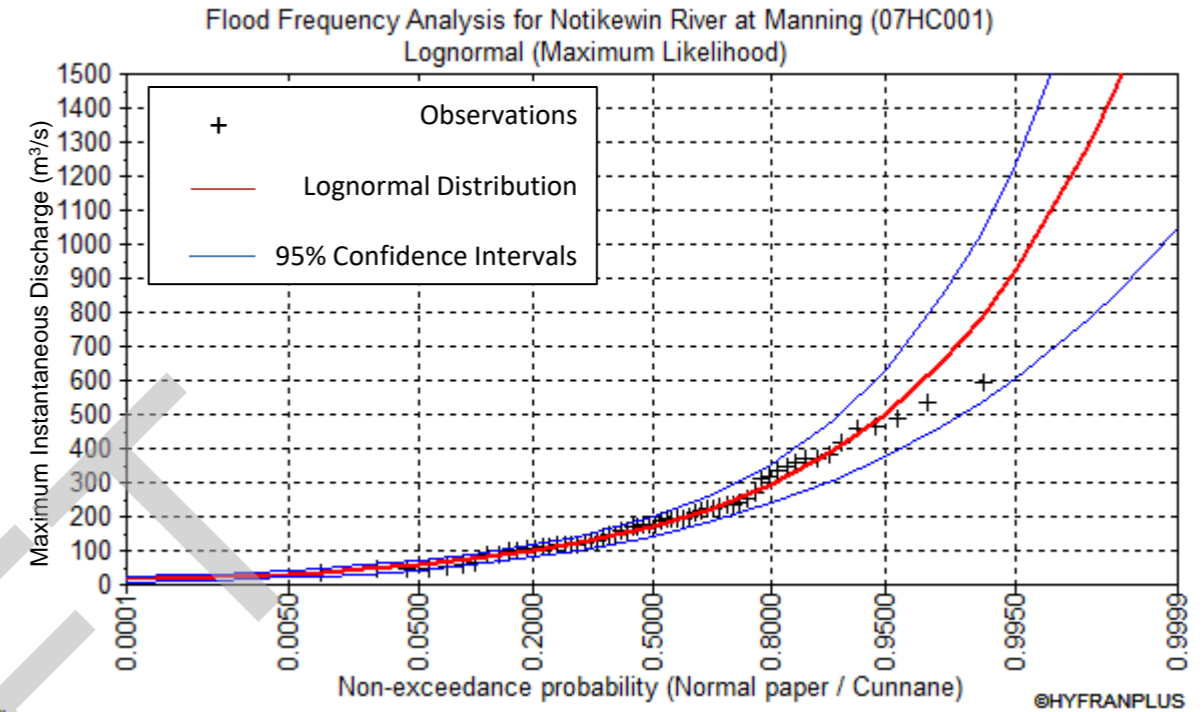
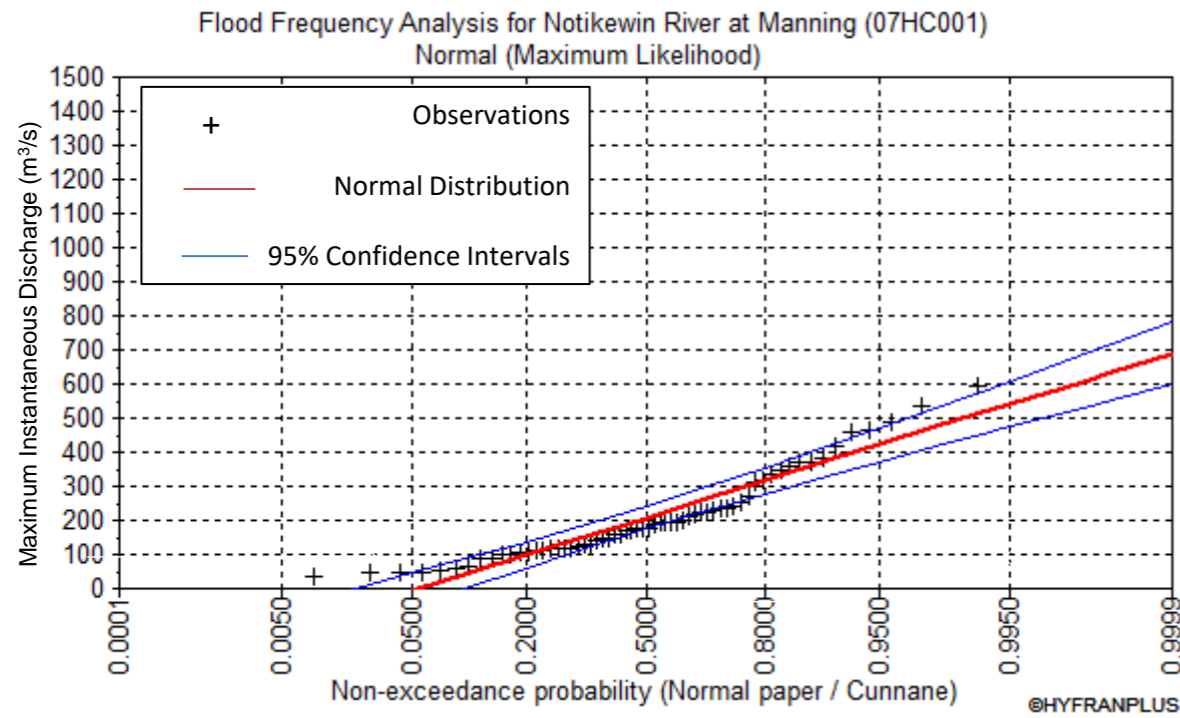


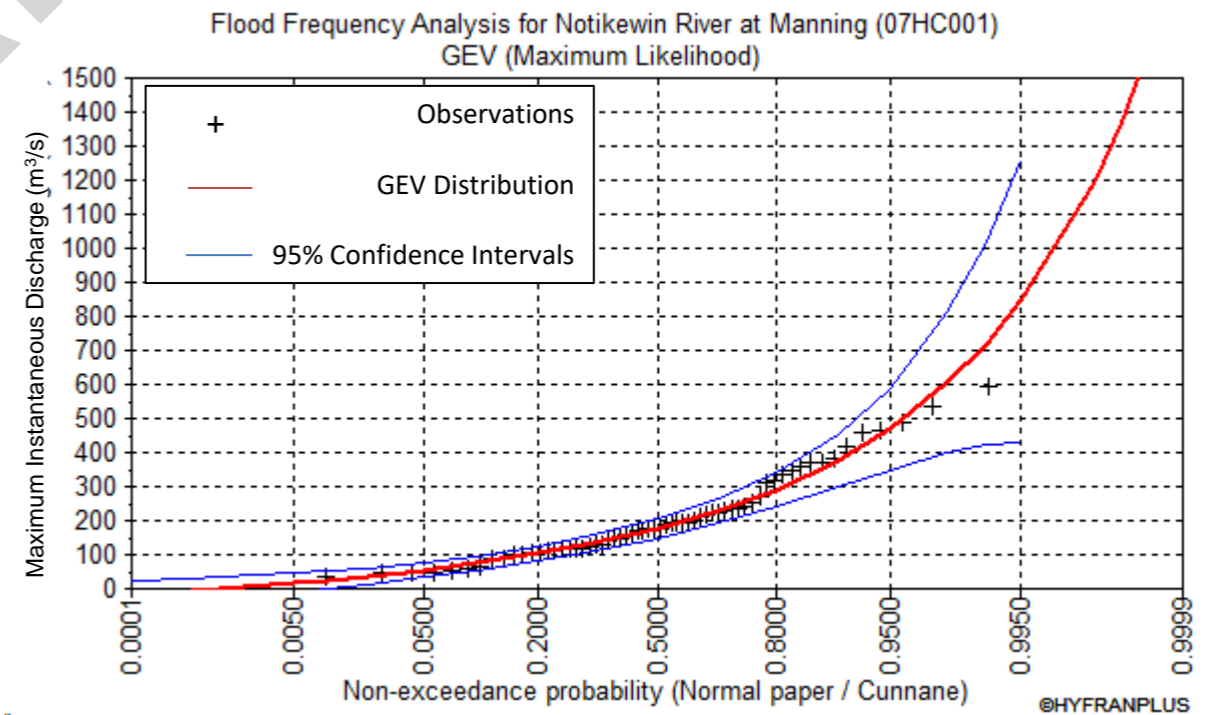
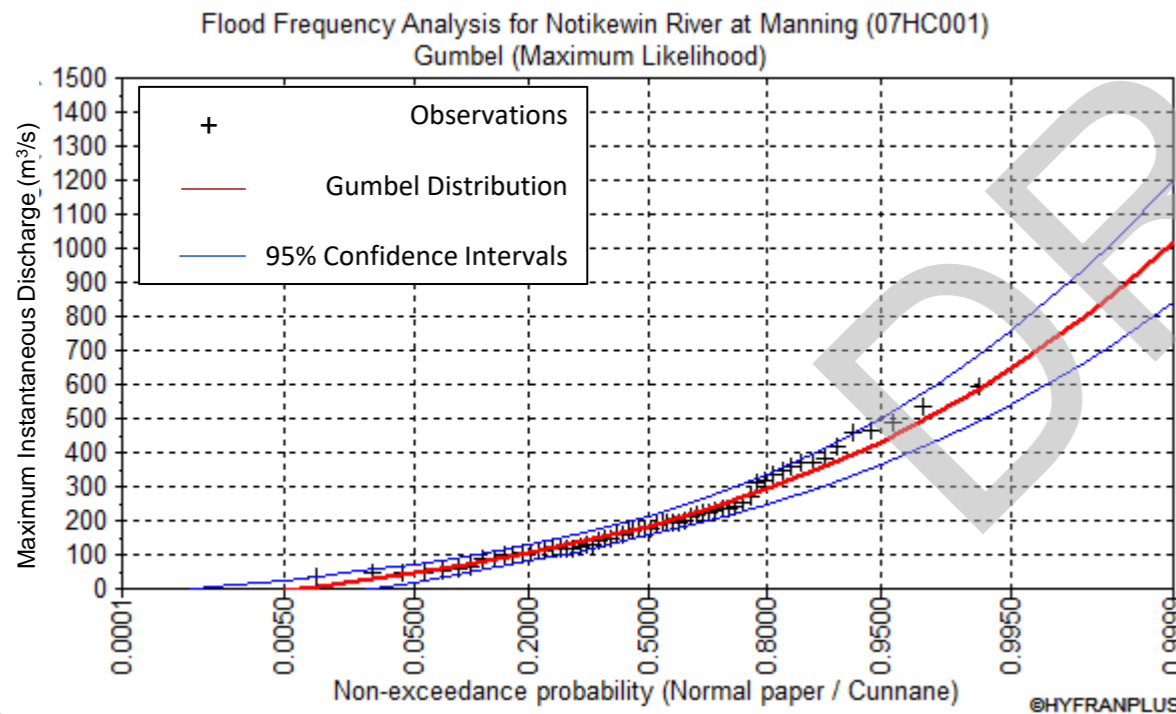
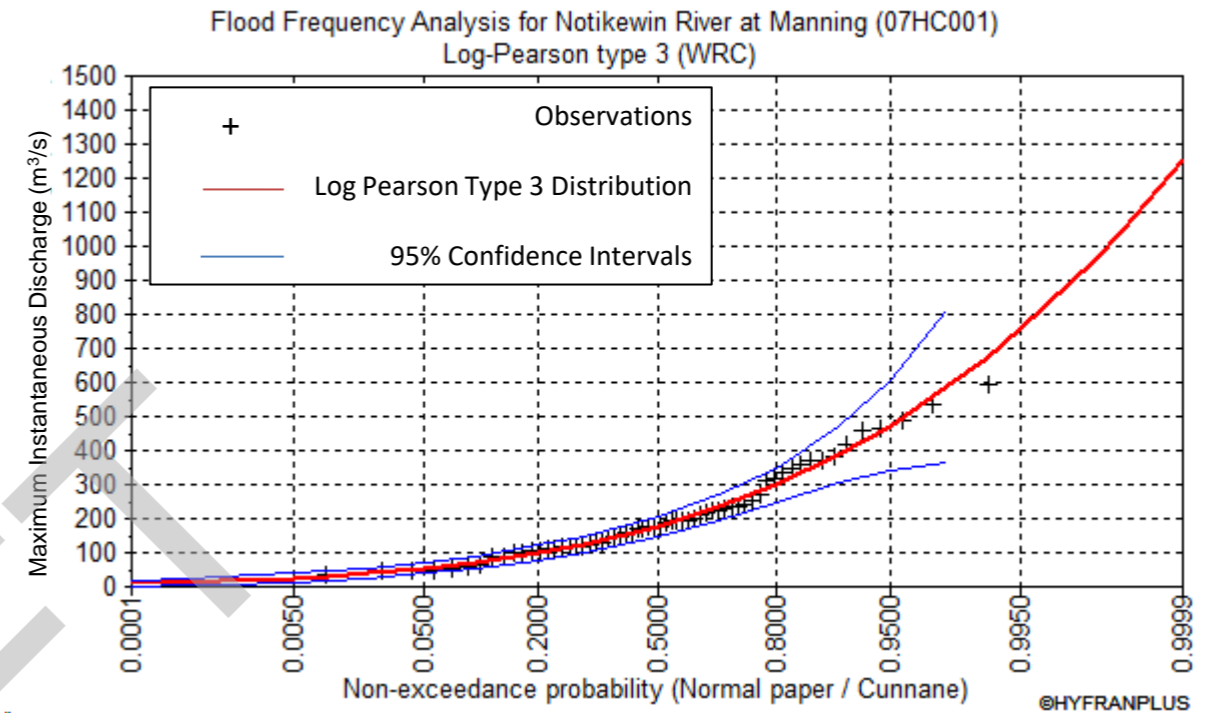
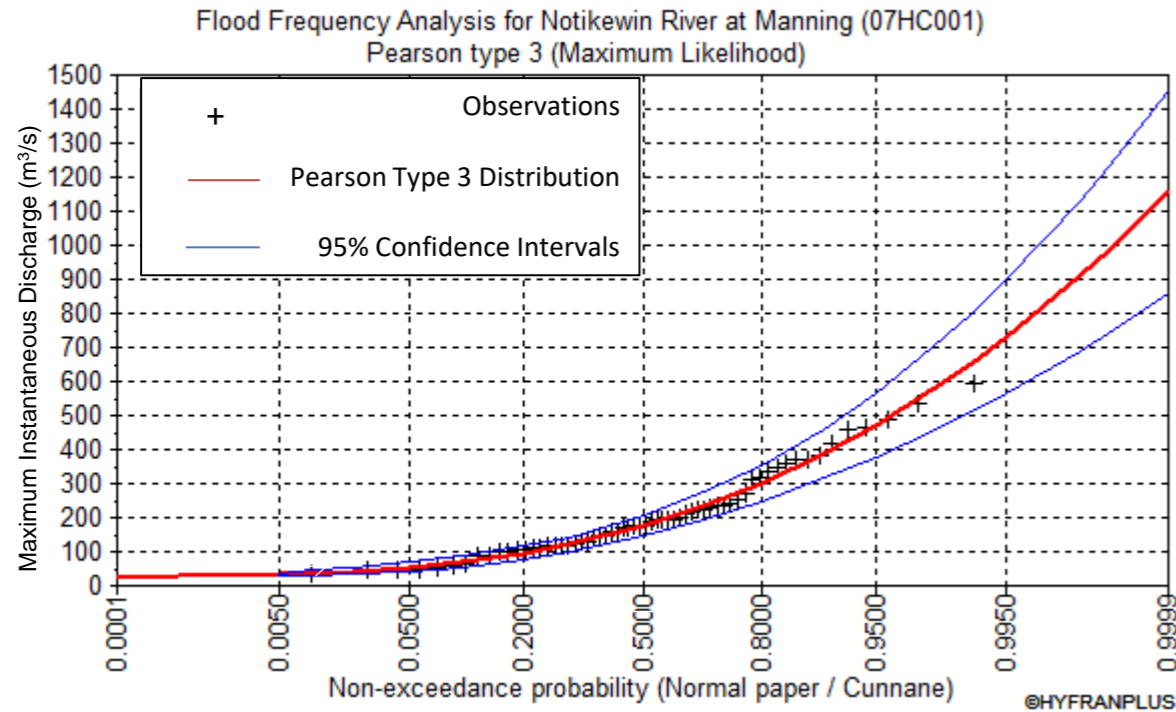
Comparison of Annual Maximum Daily and Annual Maximum Instantaneous Discharges

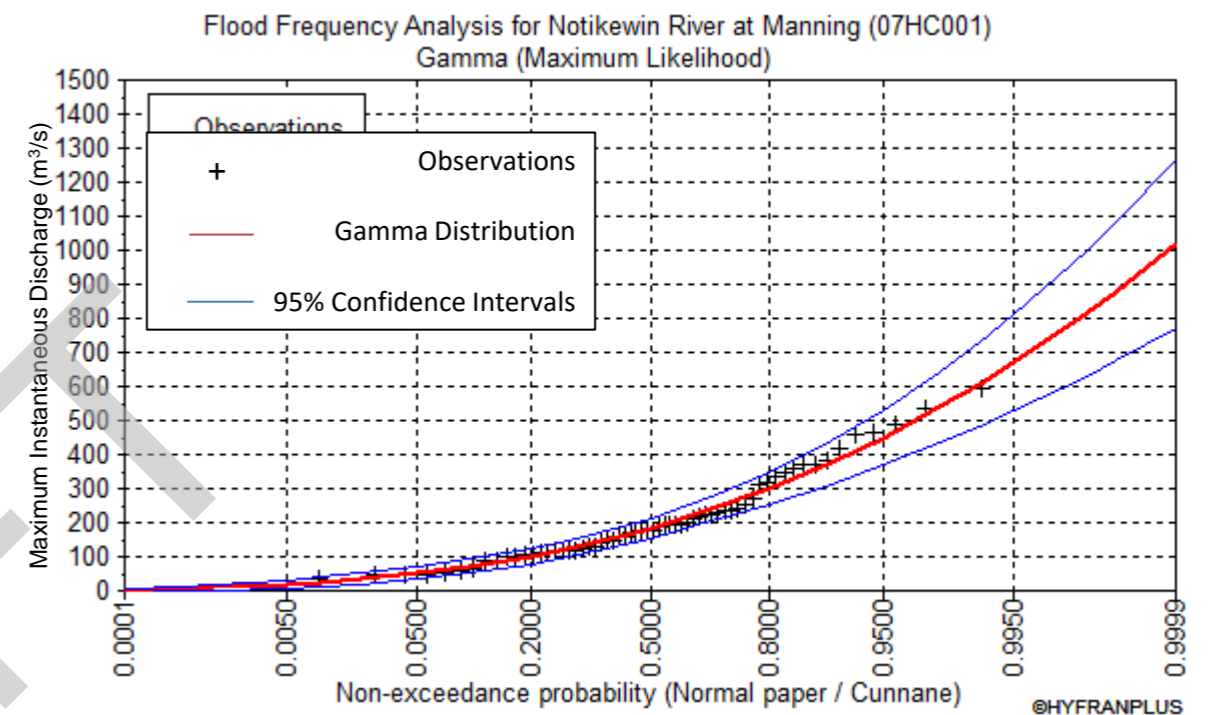
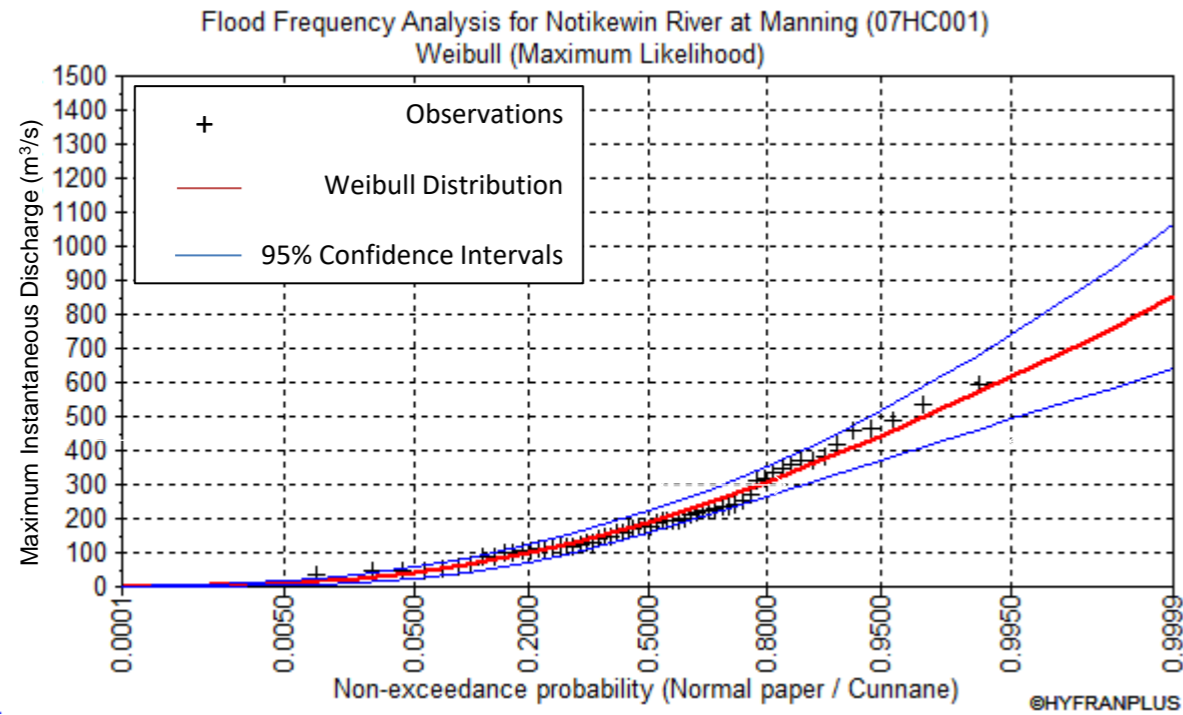


F:\35915\BST_195520 (35915-531)\2 - Open Water Hydrology Assessment\Hydrology\Report\Final\Appendix A

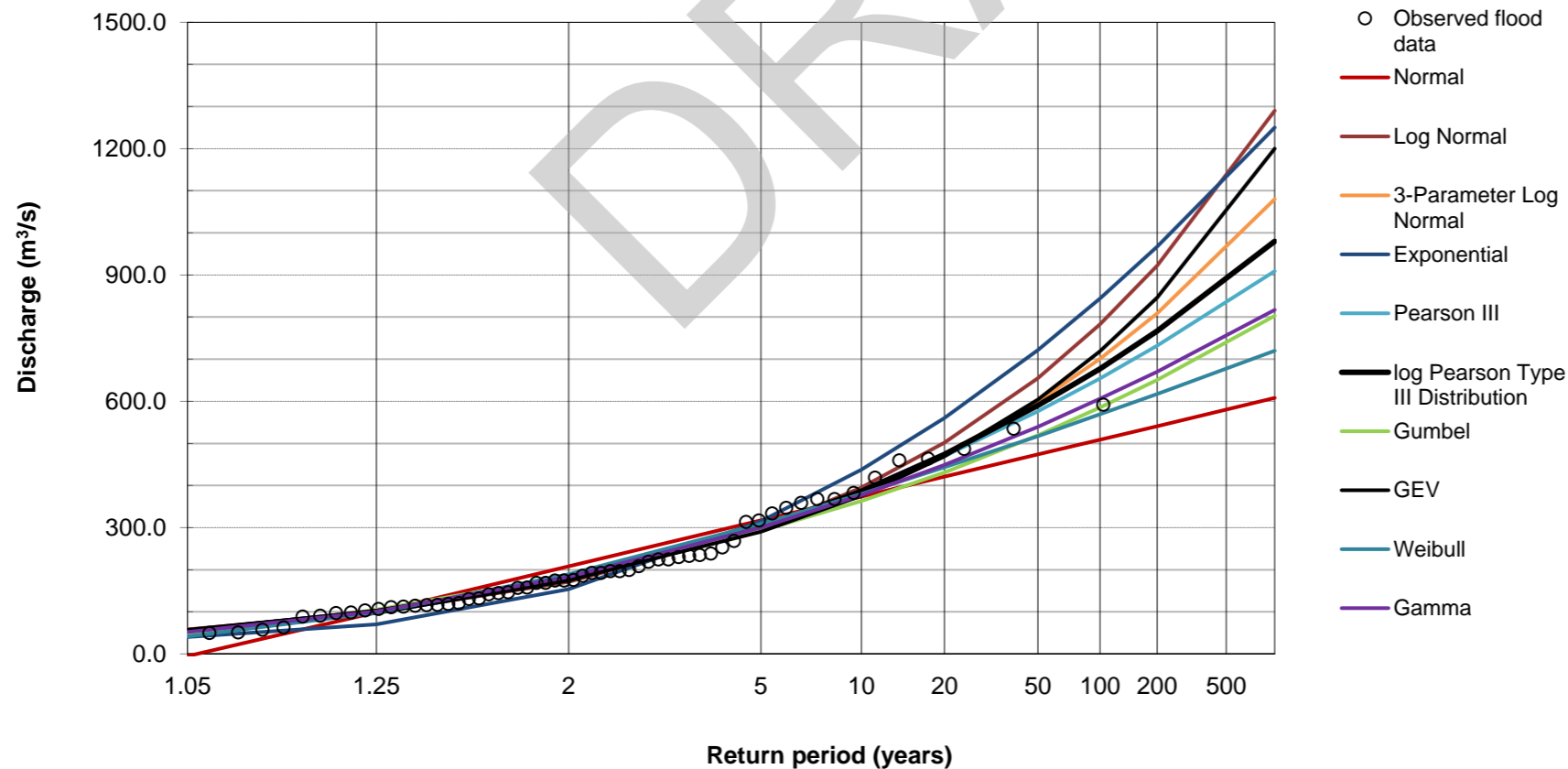
  			
Alberta Environment and Parks Manning Flood Hazard Study			
Notikewin River at Manning (07HC001) Hydrologic Analysis			
Date:	January 2025	Project:	35915
Submitter:	S.R. Sheonty	Reviewer:	M. Shome
<small>Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.</small>			Figure B2







Comparison of Different Flood Frequency Distributions at Notikewin River at Manning (07HC001)



Alberta ENVIRONMENTAL Canada

Alberta Environment and Parks
Manning Flood Hazard Study

**Notikewin River at Manning (07HC001)
Comparison of Frequency Distributions**

Date:	January 2025	Project:	35915	Submitter:	S.R. Sheonty	Reviewer:	M. Shome
-------	--------------	----------	-------	------------	--------------	-----------	----------

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.

Figure B3.3

1) Anderson-Darling Test (1952)

$$A^2 = -n - \frac{1}{n} \sum_{i=1}^n (2i-1) \cdot [\ln F(X_i) + \ln(1-F(X_{n-i+1}))]$$

H0= Data follows specified distribution
 HA= Data does not follow the specified distribution

Distribution Type:	Critical Value at 10%	Critical Value at 5%	Critical Value at 1%	A2	Hypothesis	Rank (1 = best fit)
Normal	1.929	2.502	3.907			
Lognormal	1.929	2.502	3.907	0.340	Accept H0	6
Lognormal III	1.929	2.502	3.907	0.266	Accept H0	2
Exponential	1.929	2.502	3.907	1.975	Accept H0	9
Pearson III	1.929	2.502	3.907	0.298	Accept H0	4
Log Pearson III	1.929	2.502	3.907	0.257	Accept H0	1
Gumbel	1.929	2.502	3.907	0.476	Accept H0	7
GEV	1.929	2.502	3.907	0.274	Accept H0	3
Weibull	1.929	2.502	3.907	0.550	Accept H0	8
Gamma	1.929	2.502	3.907	0.328	Accept H0	5

2) Kolmogorov-Smirnov Test (1933)

$$F_n(x) = \frac{1}{n} \cdot [\text{Number of observations} \leq x] \quad D_n = \sup_x |F_n(x) - F(x)|$$

H0= Data follows specified distribution
 HA= Data does not follow the specified distribution

Distribution Type:	Critical Value at 10%	Critical Value at 5%	Critical Value at 1%	Dn	Hypothesis	Rank (1 = best fit)
Normal	0.155	0.173	0.207	1.000	Reject H0	10
Lognormal	0.155	0.173	0.207	0.058	Accept H0	5
Lognormal III	0.155	0.173	0.207	0.055	Accept H0	2
Exponential	0.155	0.173	0.207	0.168	Accept H0	9
Pearson III	0.155	0.173	0.207	0.058	Accept H0	4
Log Pearson III	0.155	0.173	0.207	0.049	Accept H0	1
Gumbel	0.155	0.173	0.207	0.064	Accept H0	7
GEV	0.155	0.173	0.207	0.062	Accept H0	6
Weibull	0.155	0.173	0.207	0.081	Accept H0	8
Gamma	0.155	0.173	0.207	0.056	Accept H0	3

Distribution Type	Numerical Goodness-of-fit Tests from Spreadsheet			Average of Ranks	Ranking from Numerical Tests
	A-D Test	K-S Test	Least Squares Ranking		
Normal		10	10	6.67	7
Lognormal	6	5	8	6.33	6
Lognormal III	2	2	5	3.00	2
Exponential	9	9	9	9.00	10
Pearson III	4	4	2	3.33	4
Log Pearson III	1	1	3	1.67	1
Gumbel	7	7	6	6.67	7
GEV	3	6	7	5.33	5
Weibull	8	8	4	6.67	7
Gamma	5	3	1	3.00	2



Least Squares Ranking

Distribution Type:	Standard Error	Rank
Normal	243	10
Lognormal	30	8
Lognormal III	21	5
Exponential	48	9
Pearson III	16	2
Log Pearson III	17	3
Gumbel	21	6
GEV	23	7
Weibull	19	4
Gamma	16	1

$$SE_j = \sqrt{\frac{1}{n - m_j} \sum_{i=1}^n (x_i - y_i)^2}$$

NOTES

- For a detailed description of the Numerical Goodness of Fit Tests please refer to **Section 4.3 of the Frequency Analysis Procedure for Stormwater Design Manual**
 - For guidance on choosing the significance level value please refer to **Section 2.2.2.6 of the Frequency Analysis Procedure for Stormwater Design Manual**

Alberta Environment and Parks
 Manning Flood Hazard Study

**Notikewin River at Manning (07HC001)
 Statistical Test Summary**

Date: January 2025 | Project: 35915 | Submitter: S.R. Sheonty | Reviewer: M. Shome

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to period change without prior notification. While every effort has been made by Montrose Environmental Solutions Canada Inc. to ensure the accuracy of the information presented at the time of publication, Montrose Environmental Solutions Canada Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.

Figure **B4**

TABLE B1: Recorded Annual Maximum Daily and Maximum Instantaneous Discharges for WSC Gauging Station 07HC001

Notikewin River at Manning (07HC001)

Year	Annual Maximum Instantaneous Discharge (m ³ /s)	Date (mm--dd)	Annual Maximum Daily Discharge (m ³ /s)	Date (mm--dd)
1961	-	-	114	05--20
1962	-	-	123	05--22
1963	-	-	433	07--26
1964	-	-	504	05--23
1965	-	-	253	04--29
1966	-	-	106	05--12
1967	219	05--08	217	05--18
1968	97.4	07--31	95.1	07--31
1969	334	05--01	317	05--01
1970	197	07--02	174	07--02
1971	-	-	217	06--28
1972	487	07--12	459	07--12
1973	233	06--19	217	06--19
1974	317	04--27	306	05--09
1975	90.9	06--30	85	06--30
1976	186	08--19	179	08--19
1977	464	06--05	422	06--04
1978	419	05--24	405	05--24
1979	197	06--01	190	06--01
1980	34	09--28	33.4	09--28
1981	175	05--03	172	05--03
1982	116	05--14	113	05--15
1983	175	06--21	175	06--21
1984	239	05--23	230	05--23
1985	111	05--05	104	05--05
1986	119	05--13	117	05--13
1987	200	08--04	187	08--04
1988	368	07--03	315	07--02
1989	169	05--29	165	05--28
1990	368	06--14	337	06--14
1991	145	06--17	135	06--16
1992	147	05--02	138	05--02
1993	-	-	149	06--25
1994	193	05--05	192	05--05
1995	48.3	04--26	41.2	04--27
1996	176	09--03	151	09--03

TABLE B1: Recorded Annual Maximum Daily and Maximum Instantaneous Discharges for WSC Gauging Station 07HC001

Notikewin River at Manning (07HC001)

Year	Annual Maximum Instantaneous Discharge (m ³ /s)	Date (mm--dd)	Annual Maximum Daily Discharge (m ³ /s)	Date (mm--dd)
1997	253	06--22	232	06--22
1998	104	07--22	90.6	07--22
1999	63.4	06--11	61.9	06--11
2000	132	07--10	131	07--10
2001	-	-	110	07--26
2002	88.9	05--21	87.7	05--21
2003	169	04--25	128	04--25
2004	107	09--24	105	09--24
2005	193	04--24	192	04--24
2006	49.9	05--26	46	05--27
2007	347	05--07	340	05--07
2008	142	05--23	132	05--24
2009	98.5	05--29	90.2	05--30
2010	46.9	05--28	45.9	05--28
2011	383	07--12	357	07--11
2012	57.5	05--05	53.7	05--07
2013	225	05--15	220	05--15
2014	209	05--02	184	05--03
2015	51.6	05--01	49.4	05--01
2016	235	06--18	228	06--18
2017	359	05--15	354	05--15
2018	115	05--01	95.4	05--07
2019	225	07--27	219	07--27
2020	314	07--05	311	07--05
2021	157	06--19	146	06--19
2022	592	05--31	549	05--31

TABLE B2: Extended Annual Maximum Instantaneous and Recorded Annual Maximum Daily Discharges for WSC Gauging Station 07HC001

Notikewin River at Manning (07HC001)

Year	Annual Maximum Instantaneous Discharge (m ³ /s)	Date (mm--dd)	Annual Maximum Daily Discharge (m ³ /s)	Date (mm--dd)
1961	<u>121.1</u>	-	114	05--20
1962	<u>130.7</u>	-	123	05--22
1963	<u>460.1</u>	-	433	07--26
1964	<u>535.5</u>	-	504	05--23
1965	<u>268.8</u>	-	253	04--29
1966	<u>112.6</u>	-	106	05--12
1967	219	05--08	217	05--18
1968	97.4	07--31	95.1	07--31
1969	334	05--01	317	05--01
1970	197	07--02	174	07--02
1971	<u>230.6</u>	-	217	06--28
1972	487	07--12	459	07--12
1973	233	06--19	217	06--19
1974	317	04--27	306	05--09
1975	90.9	06--30	85	06--30
1976	186	08--19	179	08--19
1977	464	06--05	422	06--04
1978	419	05--24	405	05--24
1979	197	06--01	190	06--01
1980	34	09--28	33.4	09--28
1981	175	05--03	172	05--03
1982	116	05--14	113	05--15
1983	175	06--21	175	06--21
1984	239	05--23	230	05--23
1985	111	05--05	104	05--05
1986	119	05--13	117	05--13
1987	200	08--04	187	08--04
1988	368	07--03	315	07--02
1989	169	05--29	165	05--28
1990	368	06--14	337	06--14
1991	145	06--17	135	06--16
1992	147	05--02	138	05--02
1993	<u>158.3</u>	-	149	06--25
1994	193	05--05	192	05--05
1995	48.3	04--26	41.2	04--27
1996	176	09--03	151	09--03

TABLE B2: Extended Annual Maximum Instantaneous and Recorded Annual Maximum Daily Discharges for WSC Gauging Station 07HC001

Notikewin River at Manning (07HC001)

Year	Annual Maximum Instantaneous Discharge (m ³ /s)	Date (mm--dd)	Annual Maximum Daily Discharge (m ³ /s)	Date (mm--dd)
1997	253	06--22	232	06--22
1998	104	07--22	90.6	07--22
1999	63.4	06--11	61.9	06--11
2000	132	07--10	131	07--10
2001	<u>116.1</u>	-	110	07--26
2002	88.9	05--21	87.7	05--21
2003	169	04--25	128	04--25
2004	107	09--24	105	09--24
2005	193	04--24	192	04--24
2006	49.9	05--26	46	05--27
2007	347	05--07	340	05--07
2008	142	05--23	132	05--24
2009	98.5	05--29	90.2	05--30
2010	46.9	05--28	45.9	05--28
2011	383	07--12	357	07--11
2012	57.5	05--05	53.7	05--07
2013	225	05--15	220	05--15
2014	209	05--02	184	05--03
2015	51.6	05--01	49.4	05--01
2016	235	06--18	228	06--18
2017	359	05--15	354	05--15
2018	115	05--01	95.4	05--07
2019	225	07--27	219	07--27
2020	314	07--05	311	07--05
2021	157	06--19	146	06--19
2022	592	05--31	549	05--31

Note:

1. The underlined values are based on $Q_i = 1.0625Q_p$.

APPENDIX C
Flood Inundation Maps

DRAFT



[Appendix C - Placeholder]

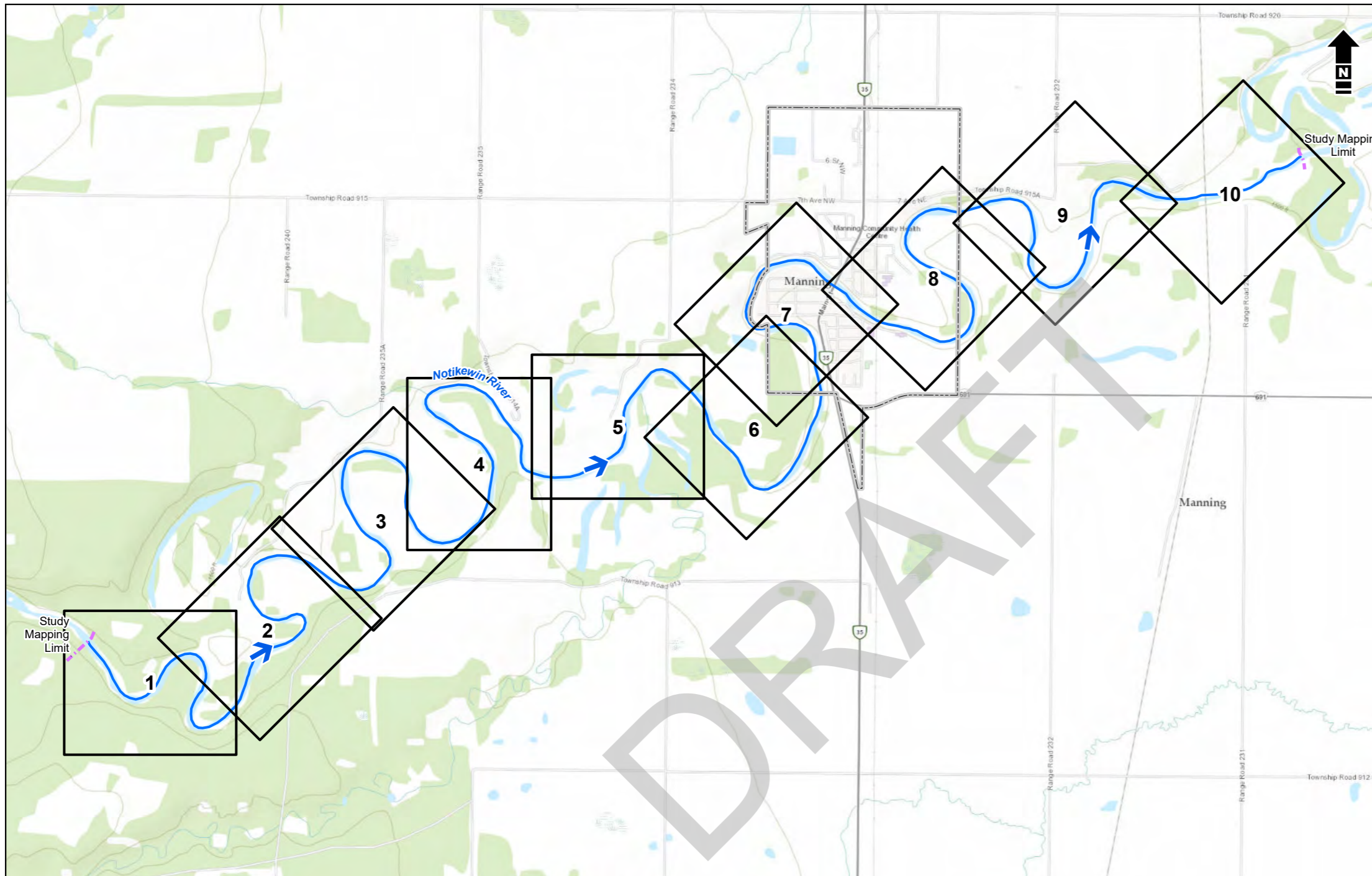
Inundation Library Issued Under Separate Cover

DRAFT

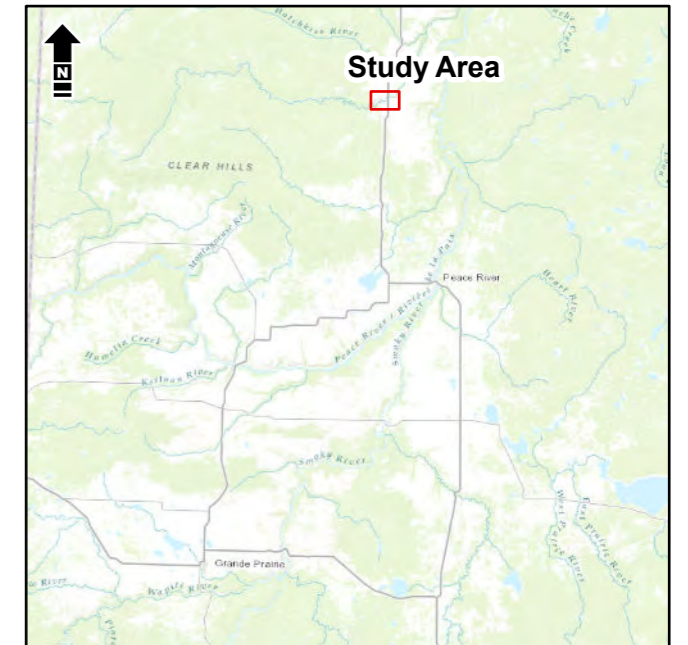
APPENDIX D
Floodway Criteria Maps

DRAFT





- Study Area
- Map Sheet
- Municipal Boundary (Urban)
- Study Mapping Limit
- Study Reach
- Flow Direction



Notes:

- Please refer to the accompanying Manning Flood Study for important information concerning these maps.
- 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.
- Non-riverine and local sources of water have not been considered, and structures such as roads or railways 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.

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.

References:

Data obtained from Altalis © Government of Alberta and GeoBase® used under license.

Base Mapping available ESRI Base Mapping and Imagery Services.

World Topographic Map: Esri Canada, Esri, HERE, Garmin, USGS, METI/NASA, EPA, USDA, AAFC, NRCan

World Topographic Map: Esri, © OpenStreetMap contributors, HERE, Garmin, FAO, USGS, EPA, NPS, AAFC, NRCan

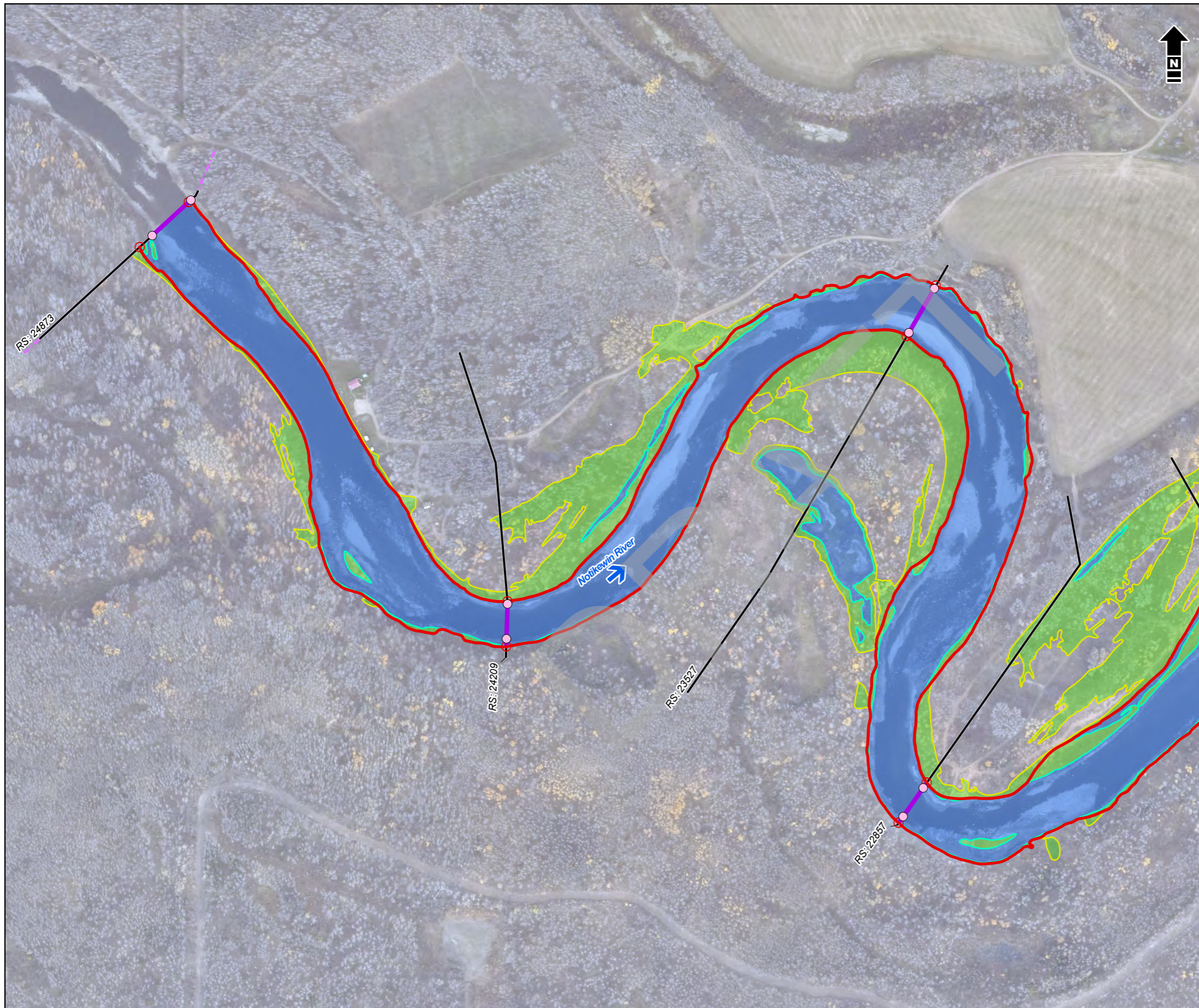


Alberta Environment and Protected Areas
Manning Flood Study

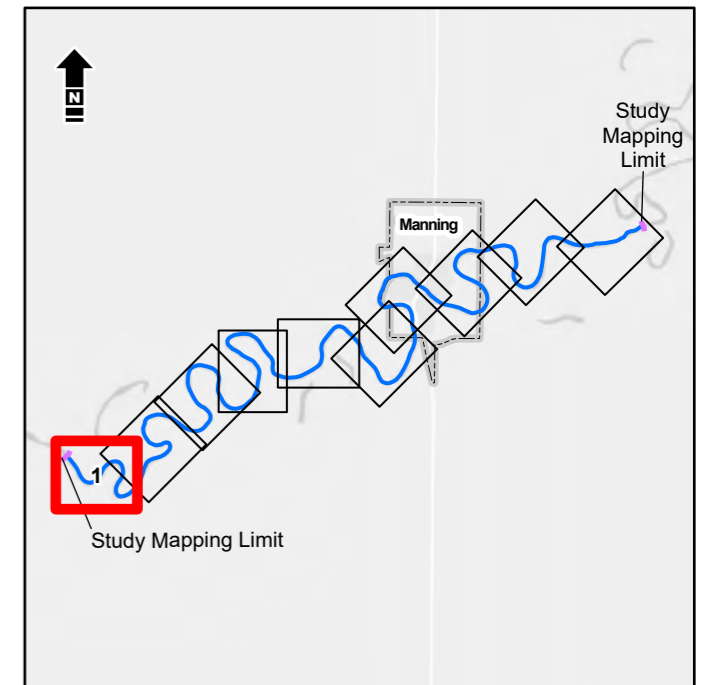
Floodway Criteria Index Map

Date: January 2025	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome
--------------------	----------------	----------------------	--------------------

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCan; Image: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



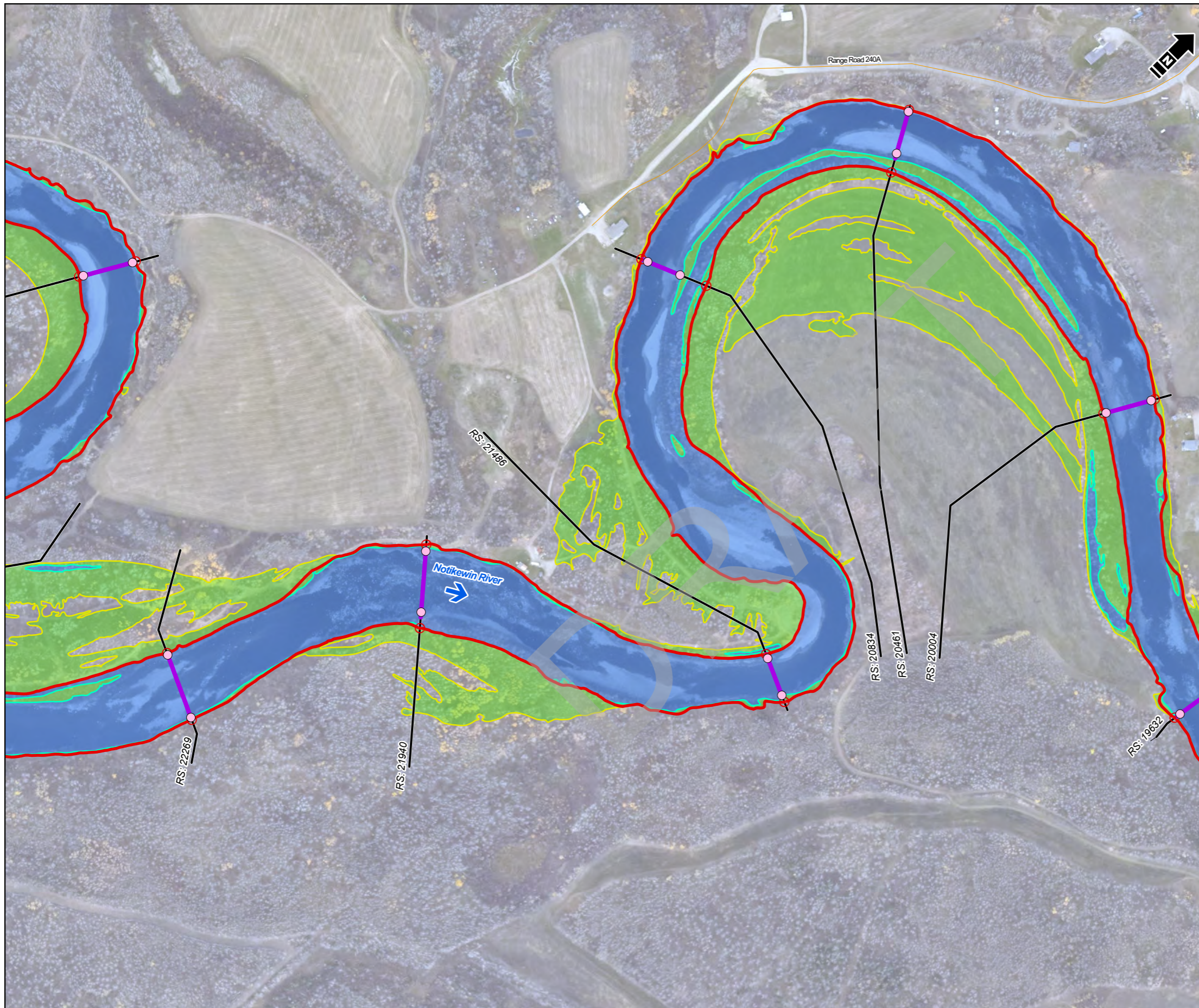
Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

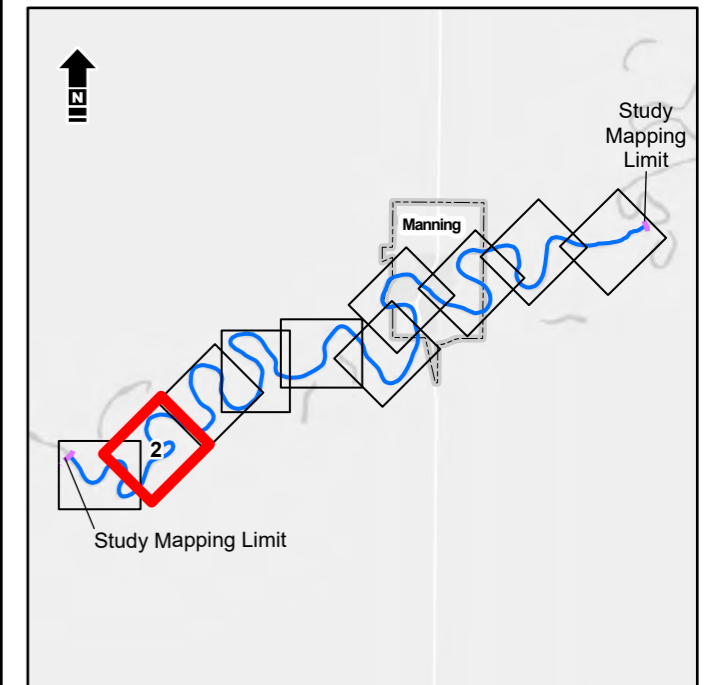
Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

AlbertaEnvironmentalandProtectedAreas\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template\aprx - Tabbed_L - 2b-Jan-25, 01:32 PM - crosak - T10005



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN, Image: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

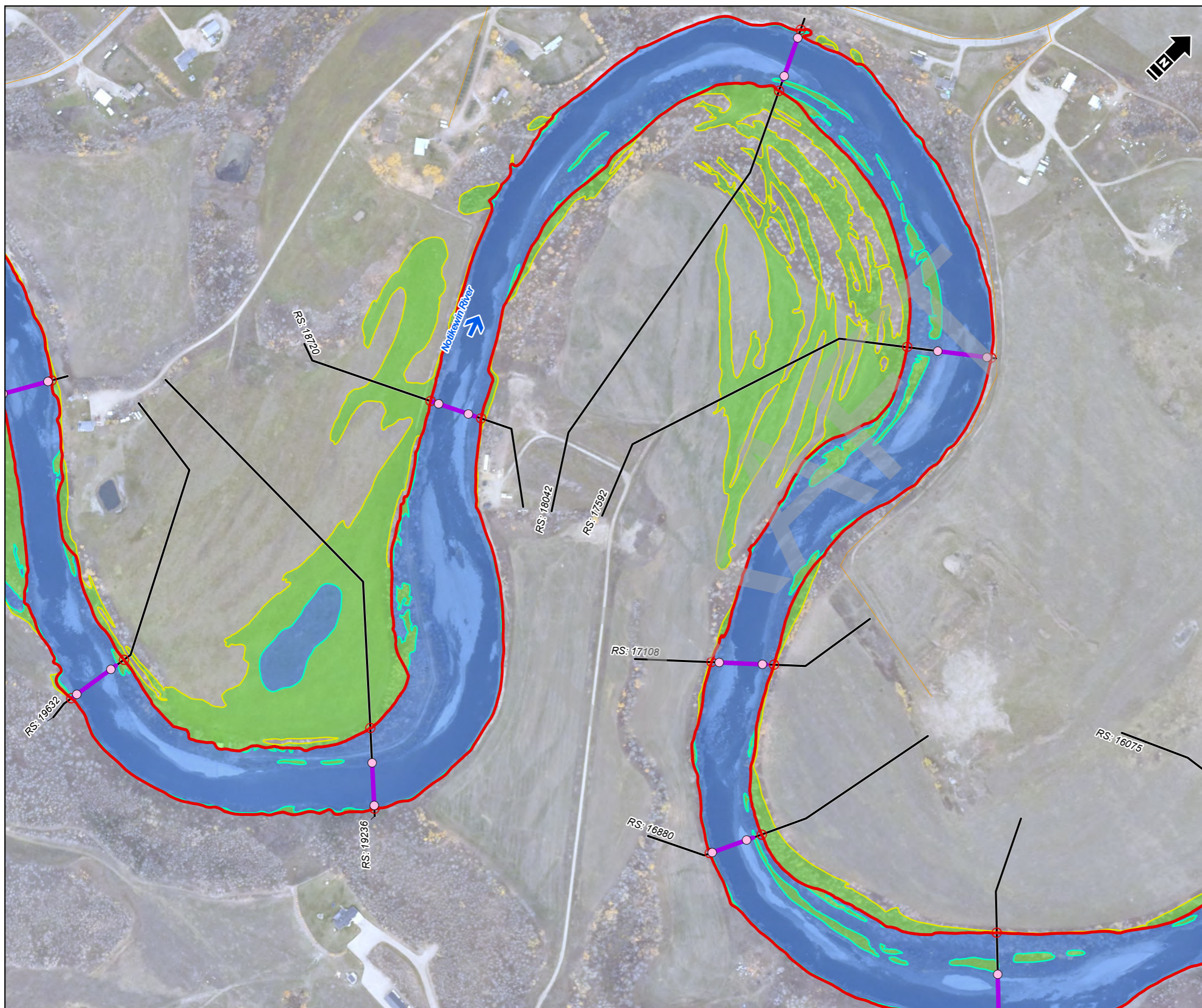
Floodway Criteria Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

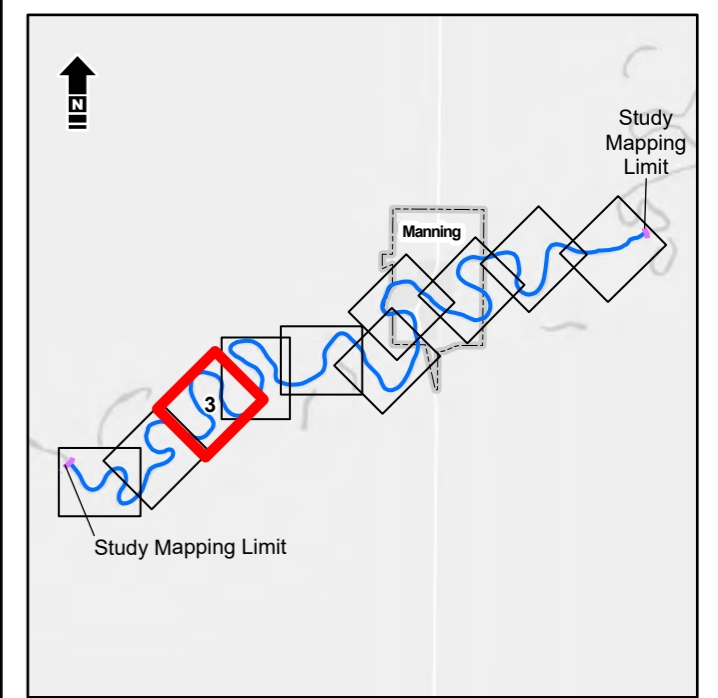
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Sheet 2 of 10

\\AlbertaEnvironmental\Public\36915\FigureAndTables\Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 28-Jan-25, 01:32 PM - crosak - T10005



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



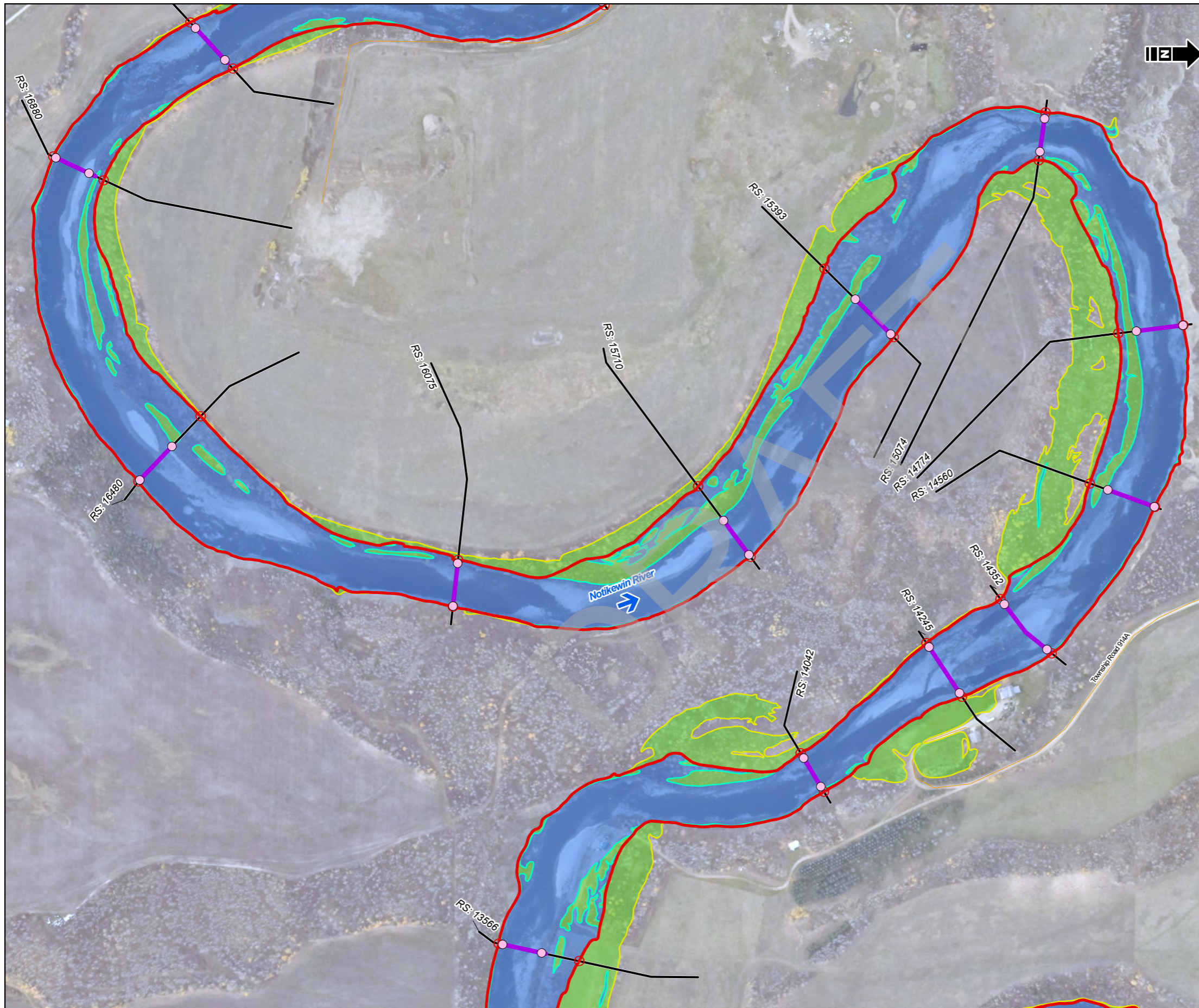
References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN; Image: ...
 Scale: 1:5,000 metres
 0 50 100
 NAD 1983 CSRS 3TM 117



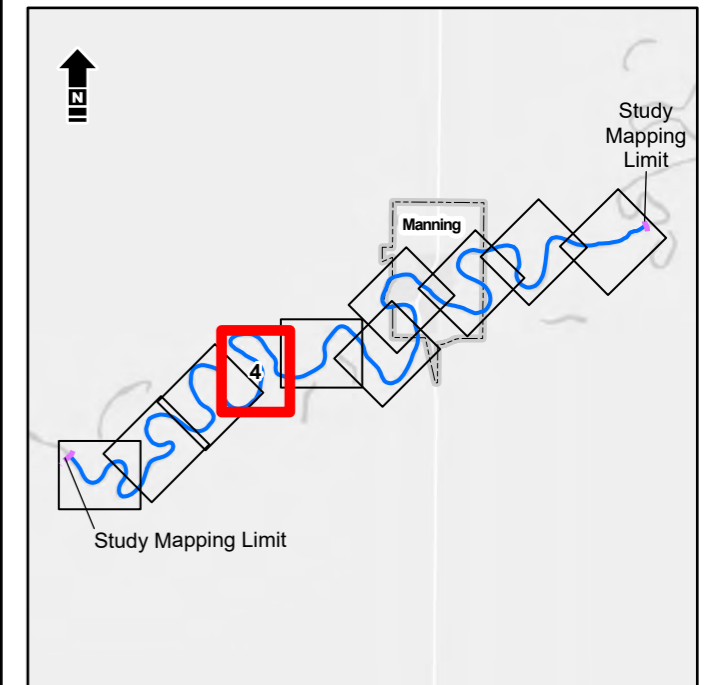
Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

Date: January 2025	Project: 35915	Submitter: P. Rogers	Reviewer: M. Shome
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.			Sheet 3 of 10



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN, Image: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

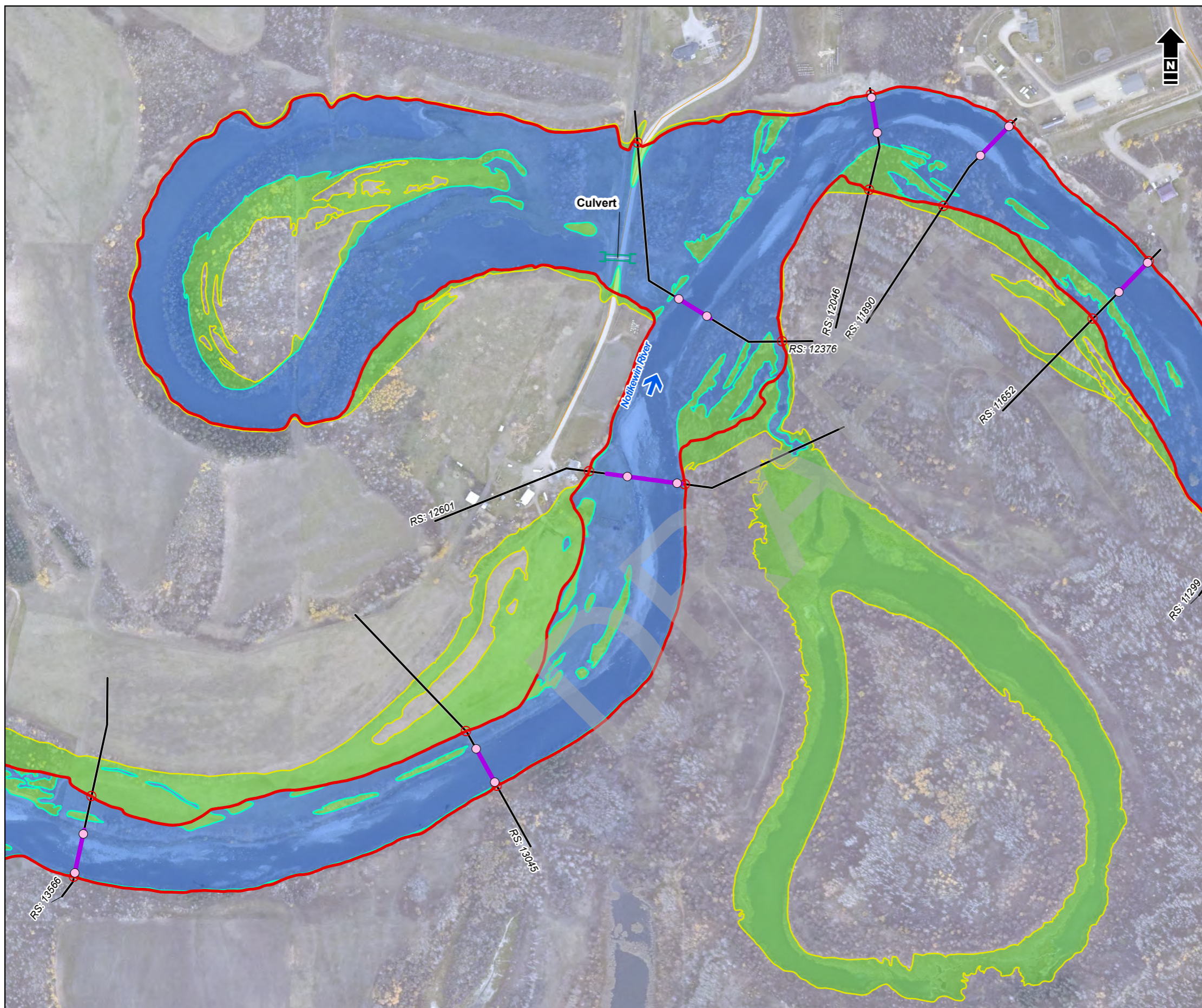
Floodway Criteria Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

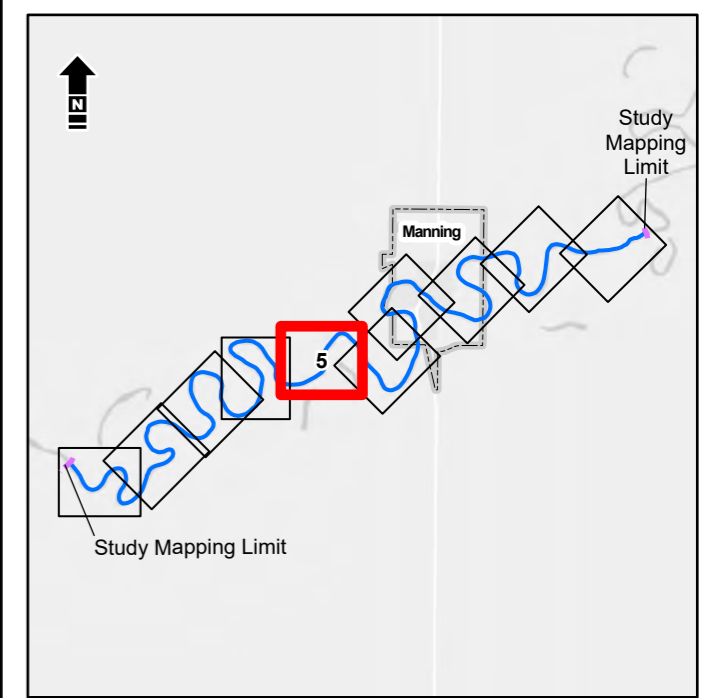
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

AlbertaEnvironmentalandProtectedAreas\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template\Mapbook_Template.aprx - Tabbed_L - 28-Jan-25, 01:33 PM - cbsaak - T10005

\\AlbertaEnvironmental\Public\35915\FigureAndTables\2023\Reporting\0_Figure\Flood_Mapbook_Template.aprx - Tabbed_L - 26-Jan-25, 01:33 PM - cborak - T10005



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlatlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN; Image: ...
 Scale: 1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



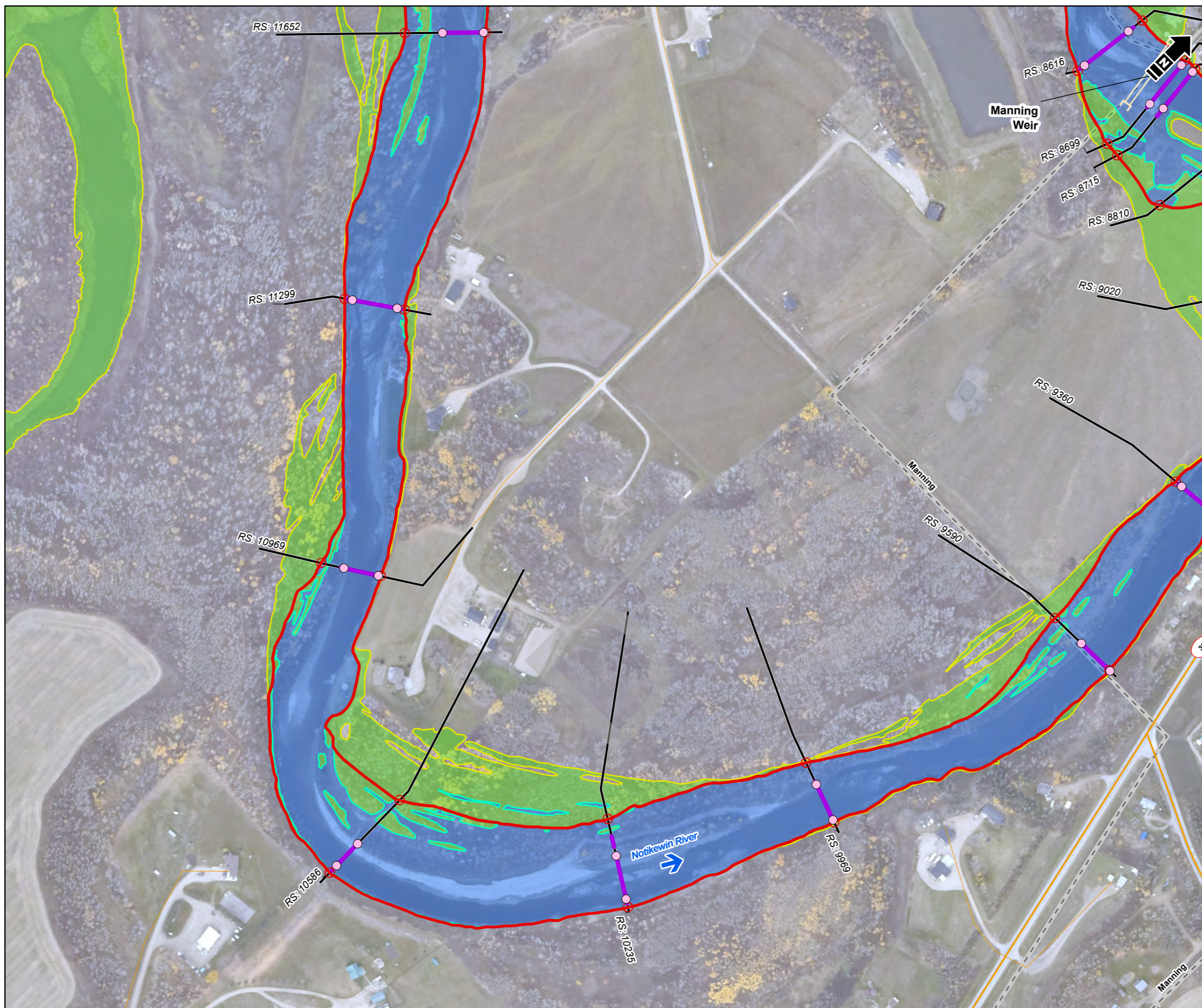
Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

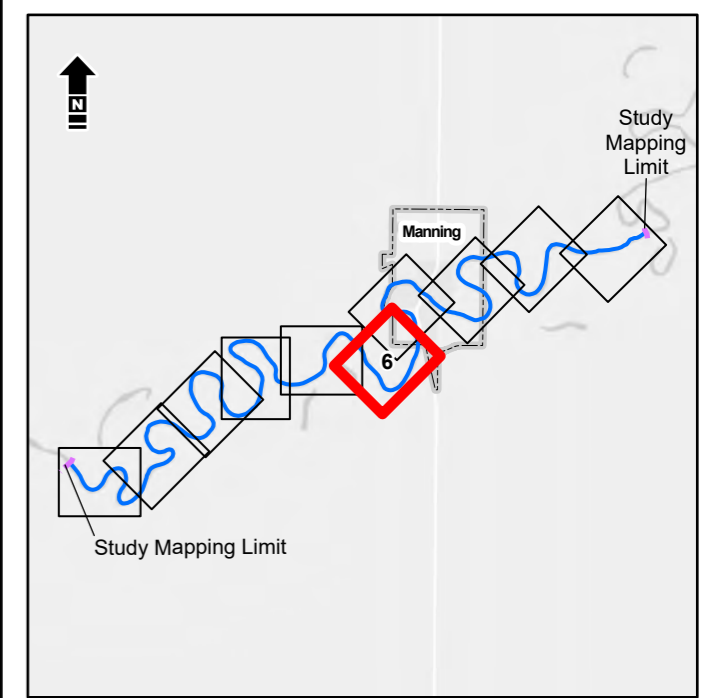
Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.
 Sheet 5 of 10

AlbertaEnvironmentalParks35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 26-Jan-25, 01:33 PM - chosak - T10005



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN; Image: ...
 Scale: 1:5,000 metres
 0 50 100
 NAD 1983 CSRS 3TM 117



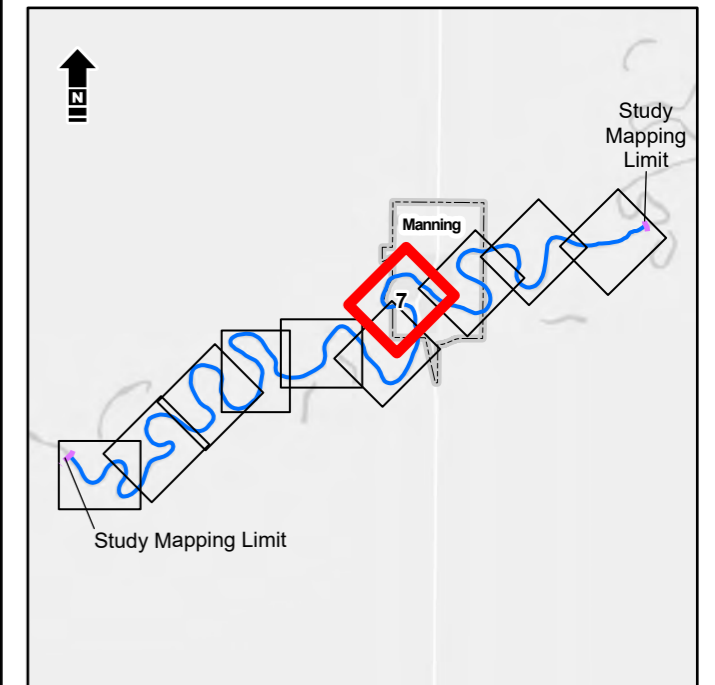
Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

Date: January 2025	Project: 35915	Submitter: P. Rogers	Reviewer: M. Shome
<small>Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.</small>			Sheet 6 of 10



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN, Image: ...
 Scale: 1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

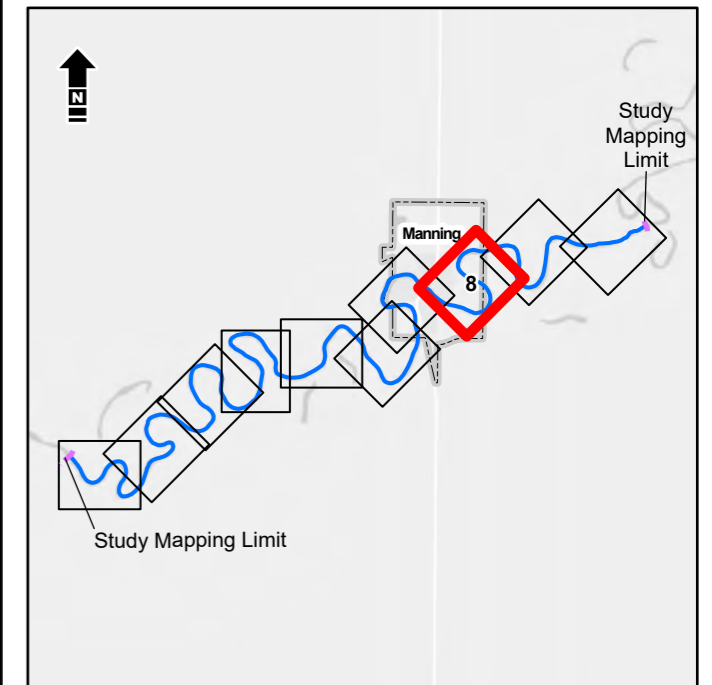
Floodway Criteria Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.
 Sheet 7 of 10



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN; Image: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

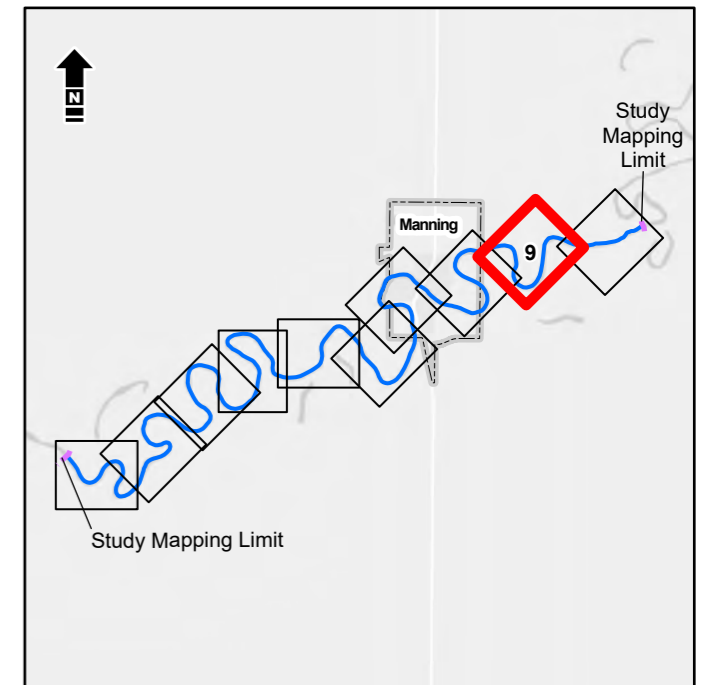
Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Sheet 8 of 10



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN; Imagery: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

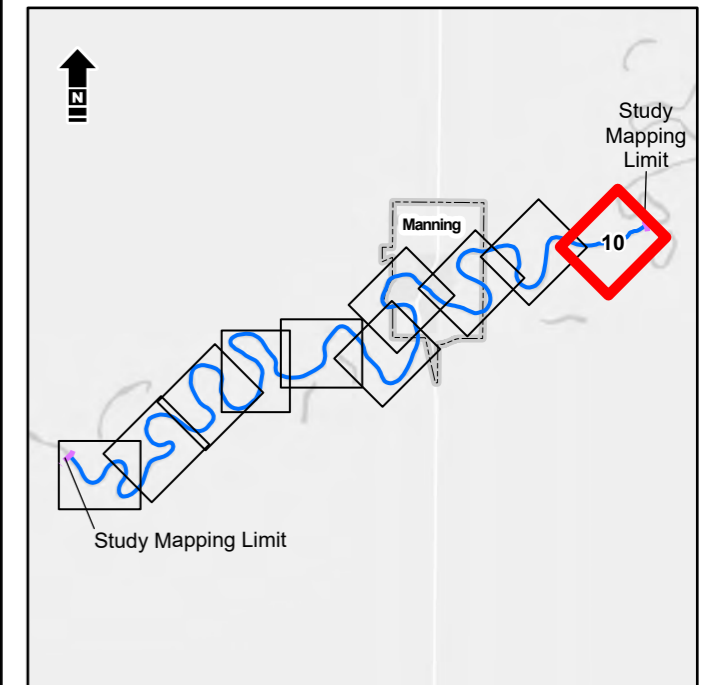
Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Sheet 9 of 10



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- Floodway Station
- 100 Year Inundation - ≥ 1 m/s Velocity
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥ 1 m Depth



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN; Image: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

Floodway Criteria Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

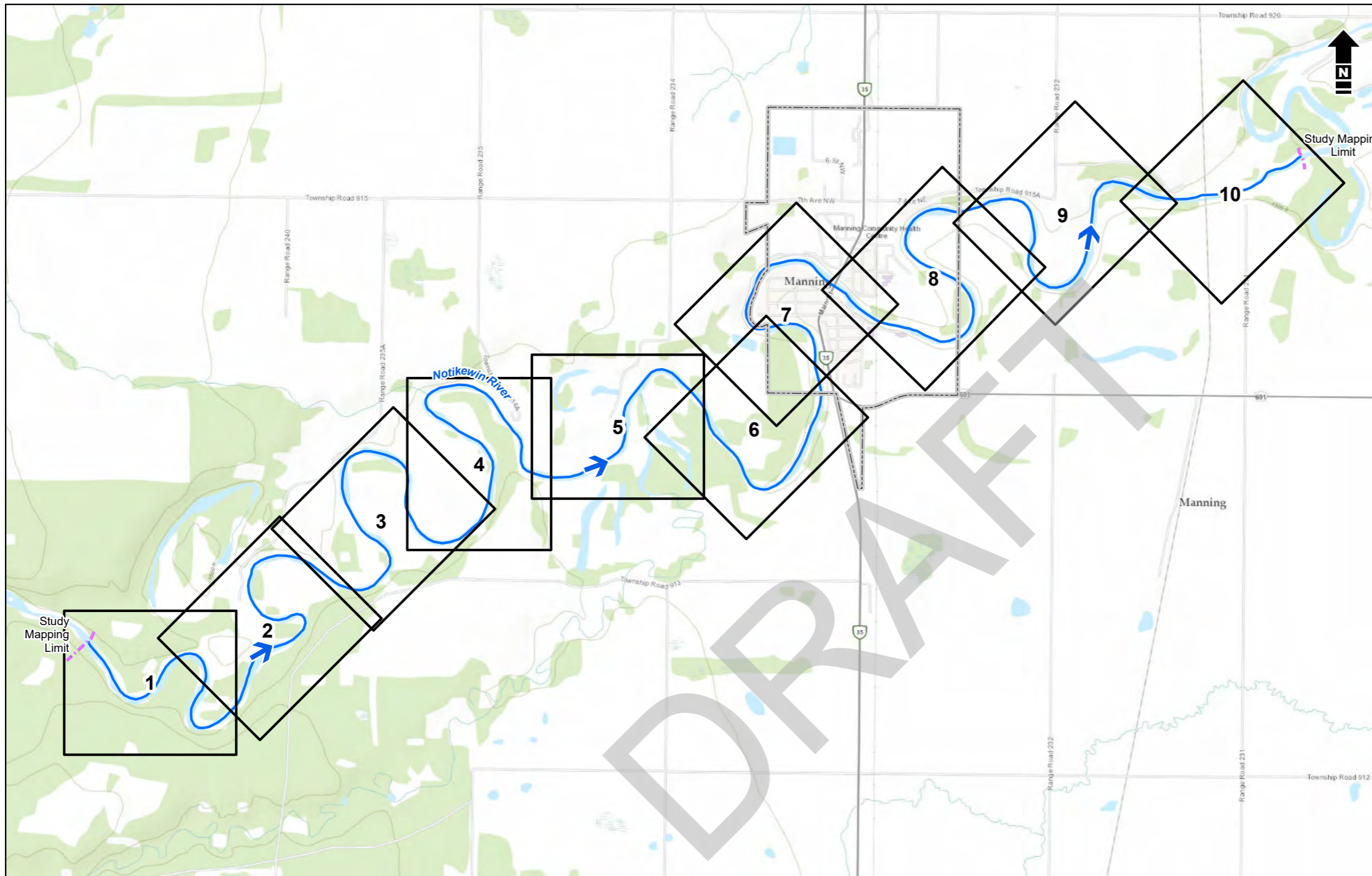
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

AlbertaEnvironmentalandProtectedAreas\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 28-Jan-25, 01:33 PM - cbsaak - T10005

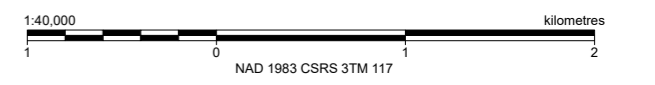
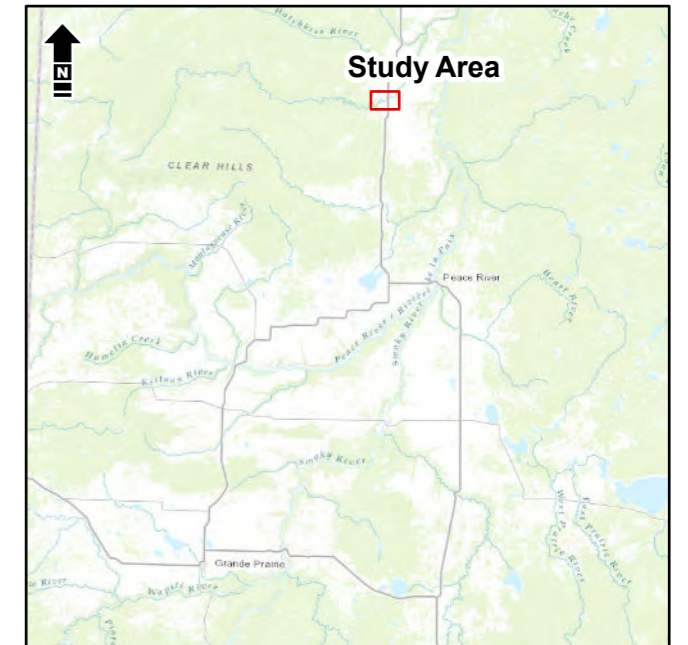
APPENDIX E
Flood Hazard Maps

DRAFT





- Study Area
- Map Sheet
- Municipal Boundary (Urban)
- Study Mapping Limit
- Study Reach
- Flow Direction



Notes:

- Please refer to the accompanying Manning Flood Study for important information concerning these maps.
- 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.
- Non-riverine and local sources of water have not been considered, and structures such as roads or railways 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.

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.

References:

Data obtained from Altalis© Government of Alberta and GeoBase© used under license.

Base Mapping available ESRI Base Mapping and Imagery Services.

World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, AAFC, NRCan
 World Topographic Map: Esri Canada, Esri, HERE, Garmin, USGS, METI/NASA, NGA, EPA, USDA, AAFC, NRCan



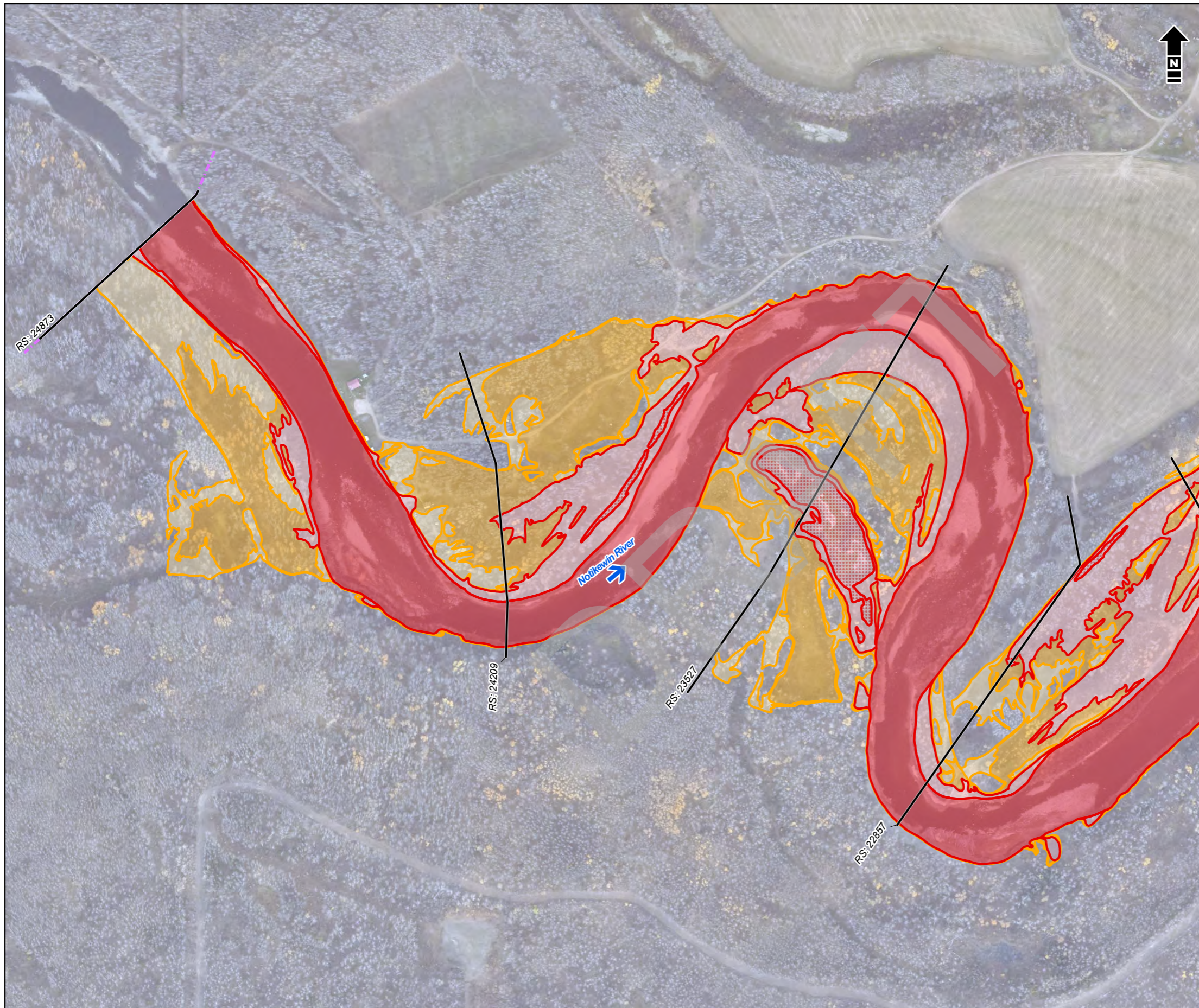
Alberta Environment and Protected Areas
Manning Flood Study

Governing Design Flood Hazard Index Map

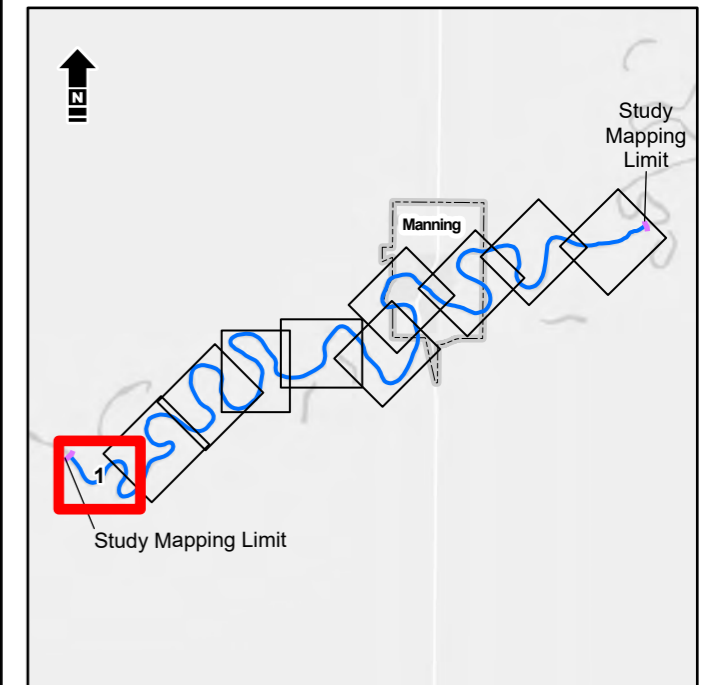
Date: January 2025	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome
--------------------	----------------	----------------------	--------------------

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Sheet
INDEX



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: .

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



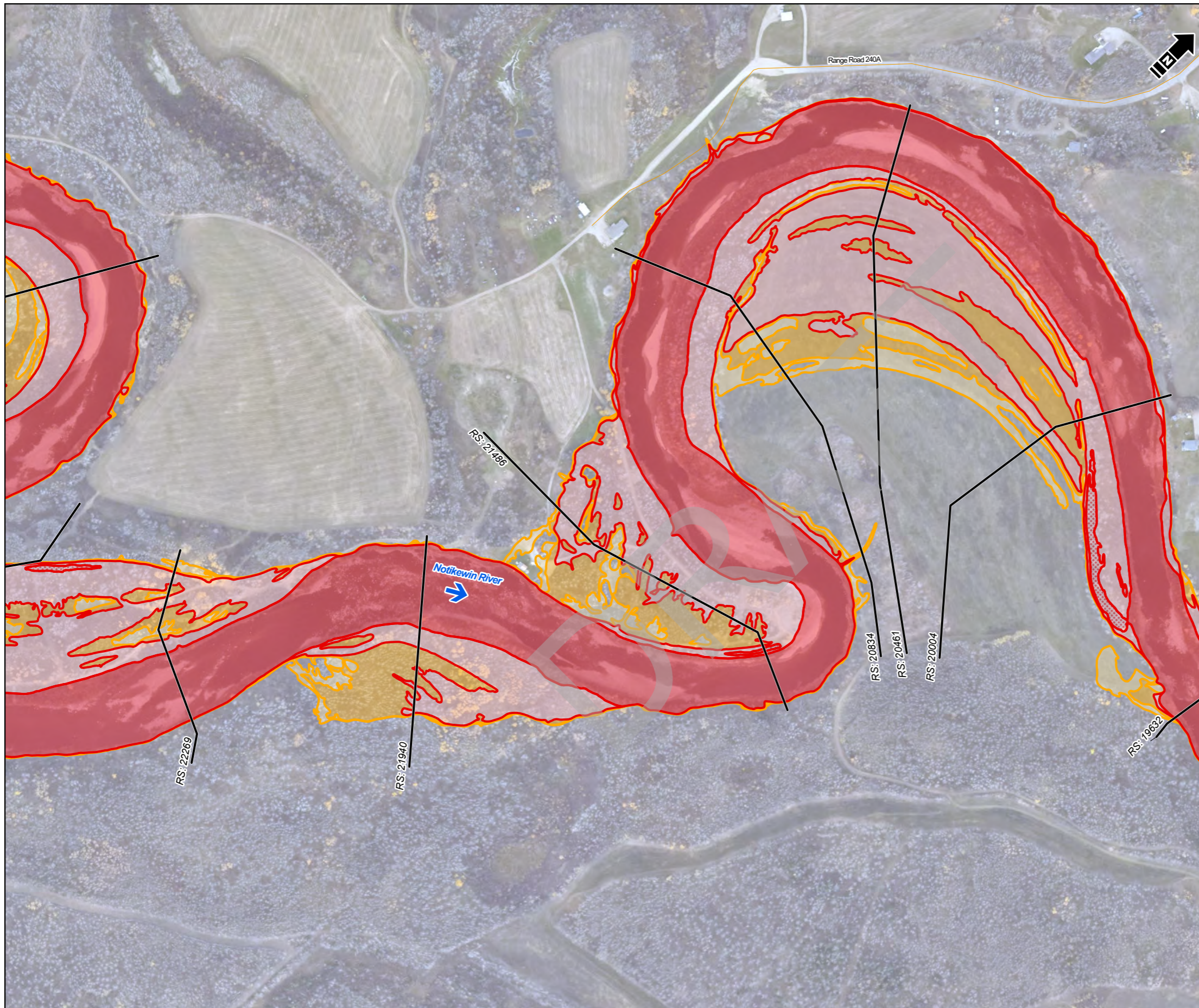
Alberta Environment and Protected Areas
 Manning Flood Study

Governing Design Flood Hazard Map

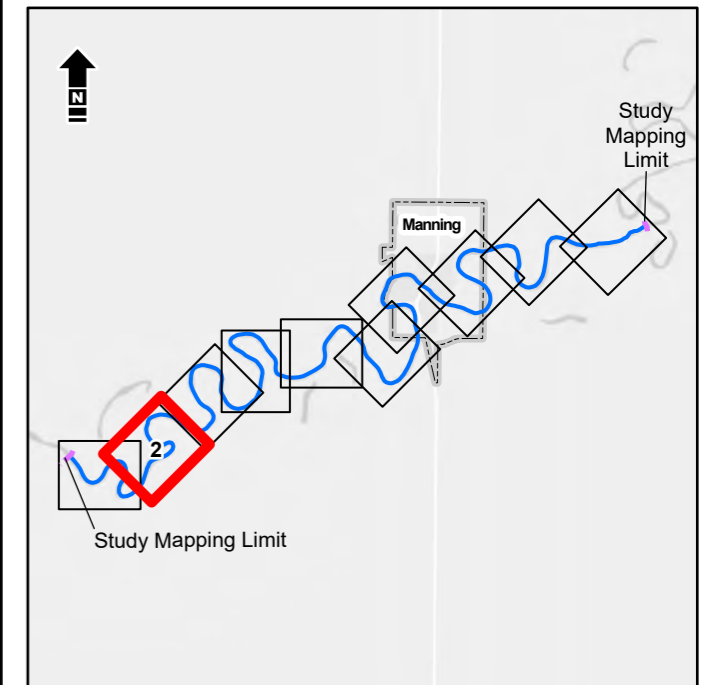
Date: January 2025 | Project: 35915 | Submitter: P. Rogers | Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Sheet
1 of 10



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

Governing Design Flood Hazard Map

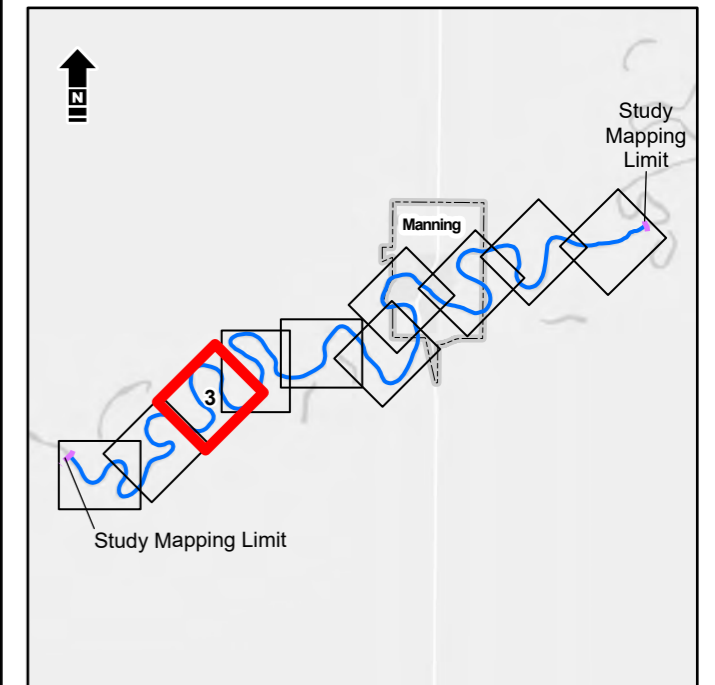
Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

AlbertaEnvironmentalParticipations\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 28-Jan-25, 01:38 PM - cbsaak - T10005



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Imagery: ..



Alberta Environment and Protected Areas
 Manning Flood Study

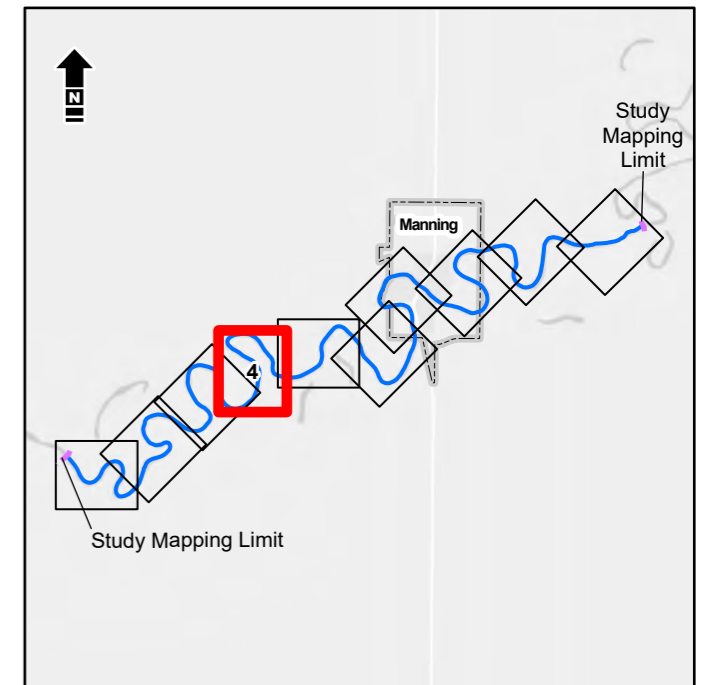
Governing Design Flood Hazard Map

Date: January 2025 | Project: 35915 | Submitter: P. Rogers | Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: .
 1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

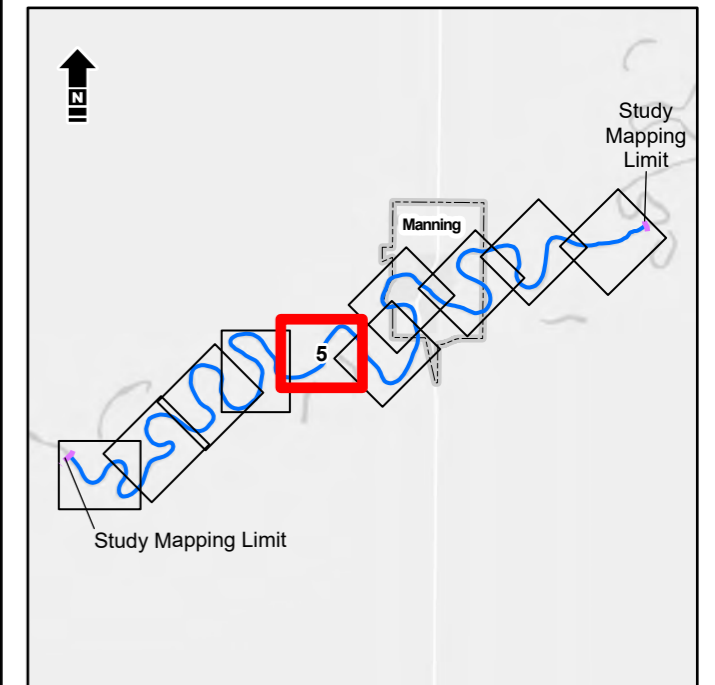
Governing Design Flood Hazard Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

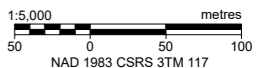
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.
 Sheet 4 of 10



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: ...



Alberta Environment and Protected Areas
 Manning Flood Study

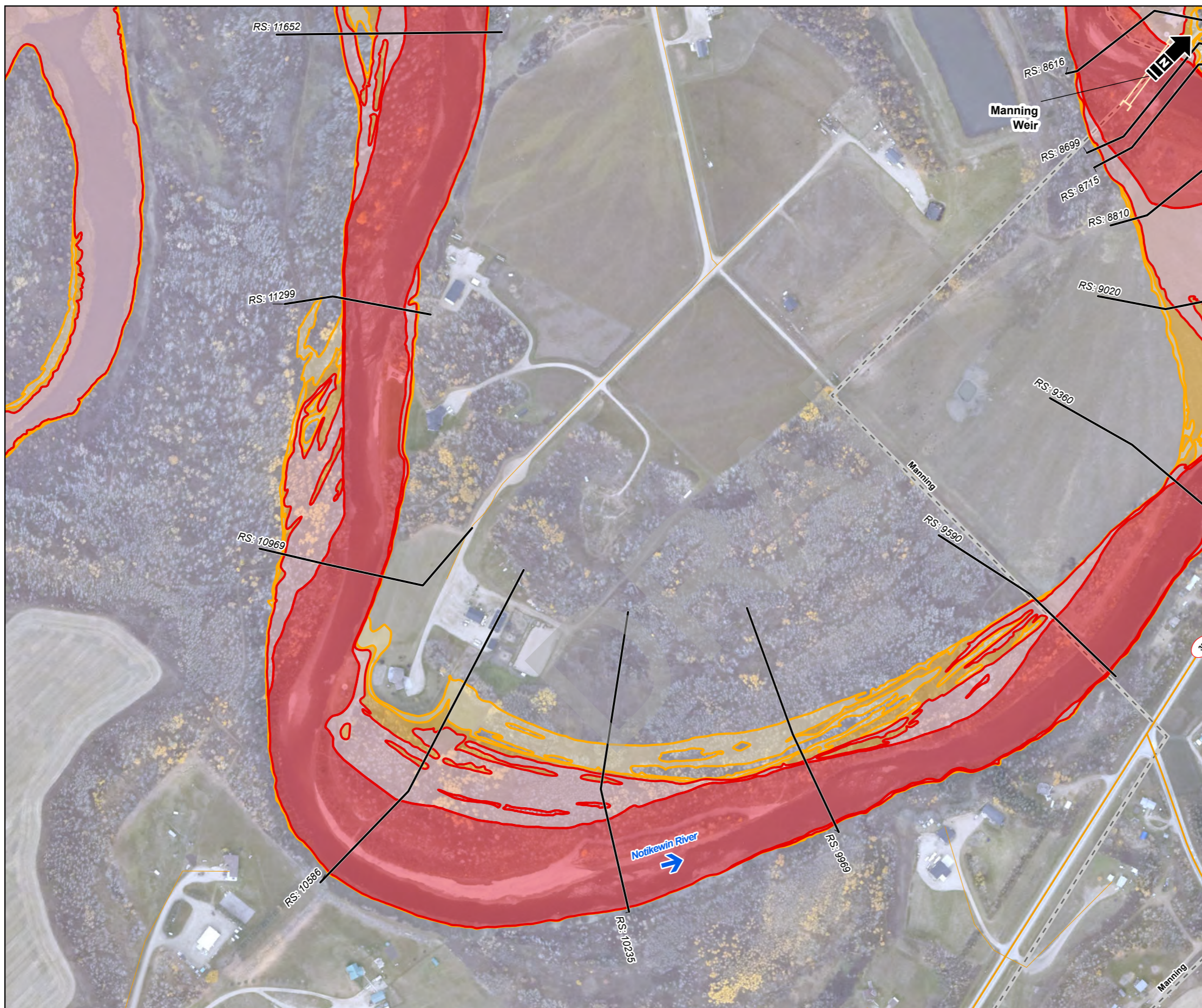
Governing Design Flood Hazard Map

Date: January 2025 | Project: 35915 | Submitter: P. Rogers | Reviewer: M. Shome

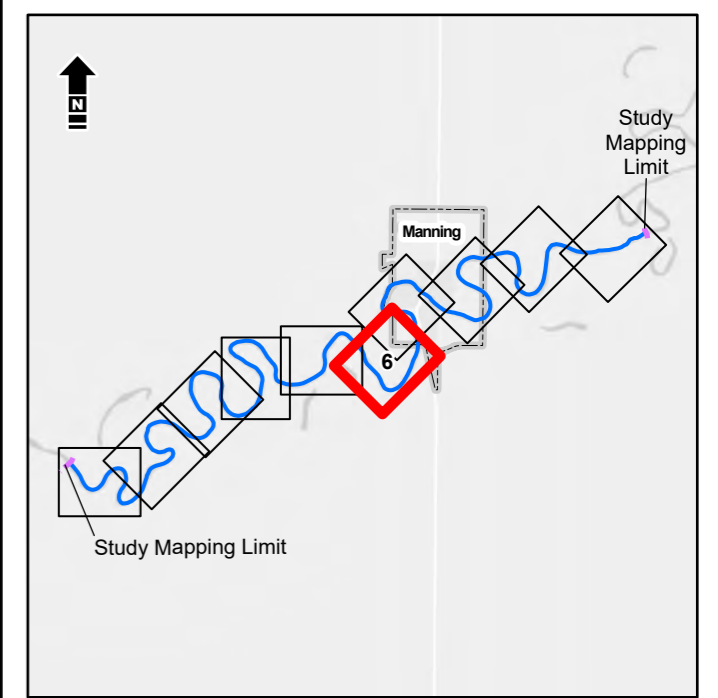
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

AlbertaEnvironmentalAndProtectedAreas\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 20-Jan-25, 01:38 PM - chosak - T10005

\\Alberta\Environmental\Participations\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 20-Jan-25, 01:38 PM - chosak - T10005



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: .
 1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



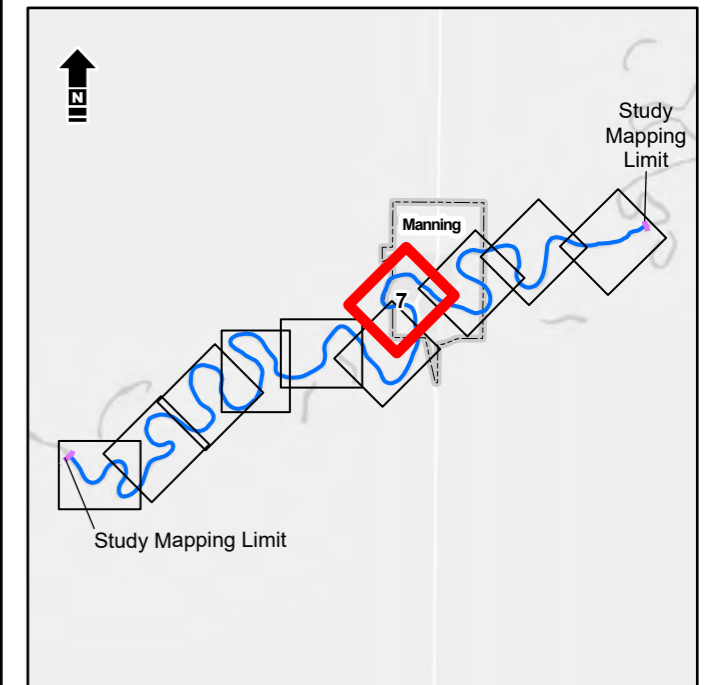
Alberta Environment and Protected Areas
 Manning Flood Study

Governing Design Flood Hazard Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Altiris © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Imagery: ...

1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



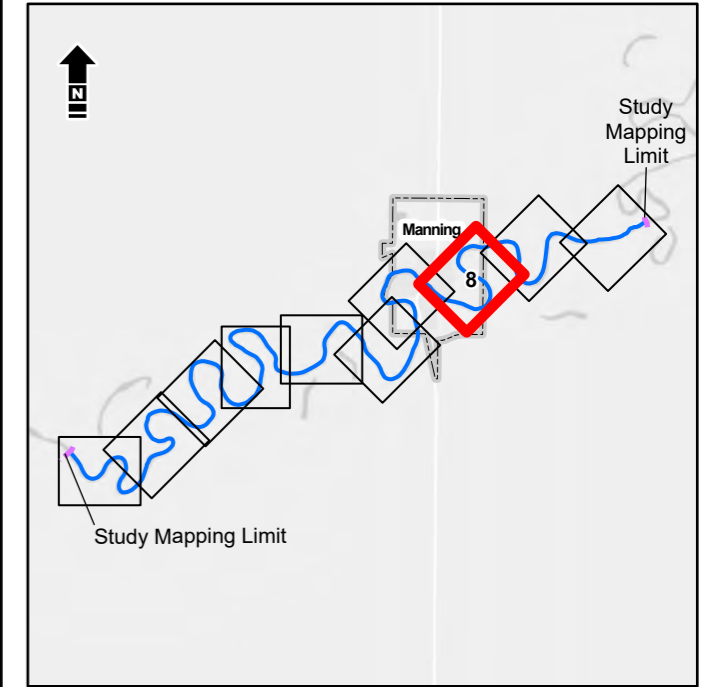
Alberta Environment and Protected Areas
 Manning Flood Study

Governing Design Flood Hazard Map

Date: January 2025	Project: 35915	Submitter: P. Rogers	Reviewer: M. Shome
--------------------	----------------	----------------------	--------------------



- RS: 24873 River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Altas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN, Image: ...
 1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117

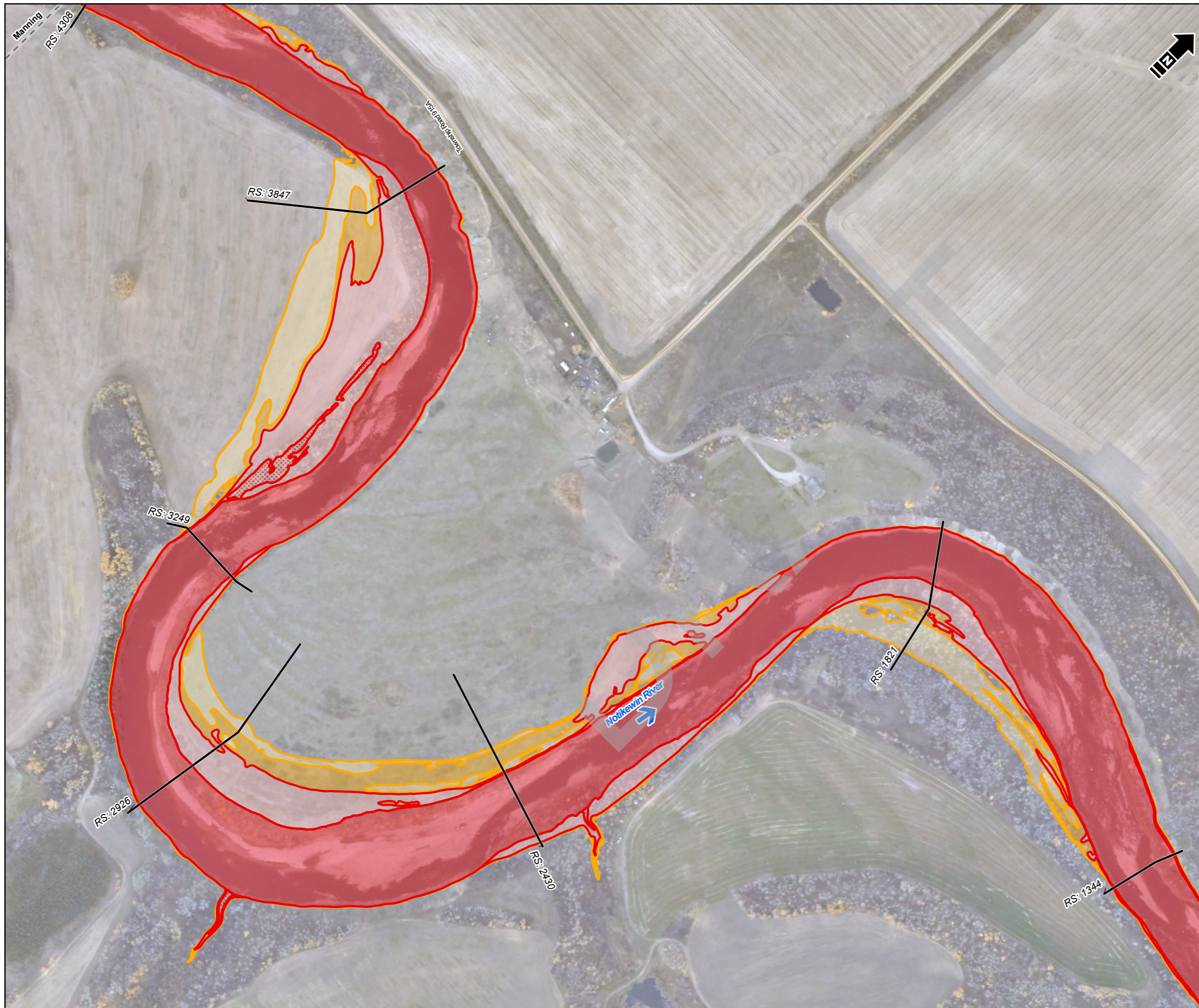


Alberta Environment and Protected Areas
 Manning Flood Study

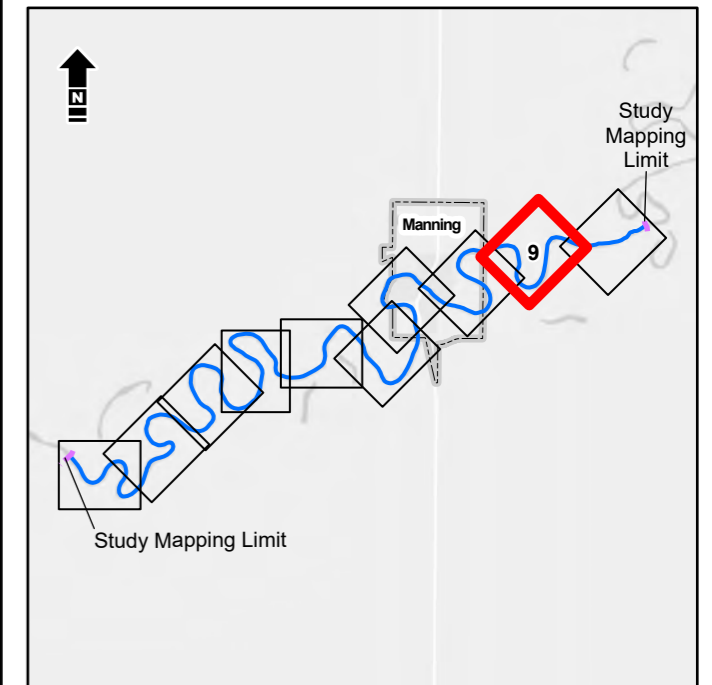
Governing Design Flood Hazard Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.
 Sheet 8 of 10



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: ...

1:5,000
 50 0 50 100 metres
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

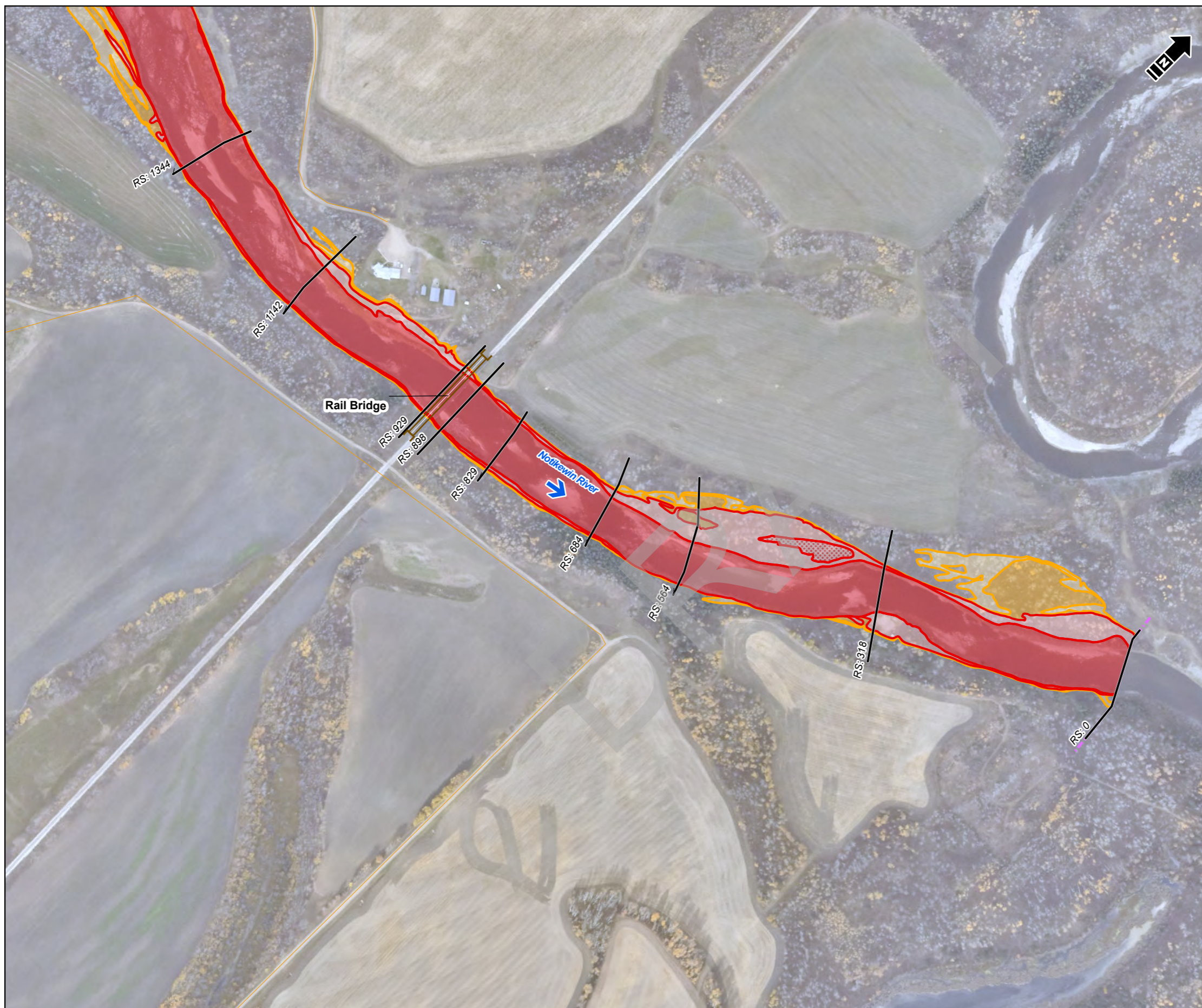
Governing Design Flood Hazard Map

Date: January 2025 | Project: 35915 | Submitter: P. Rogers | Reviewer: M. Shome

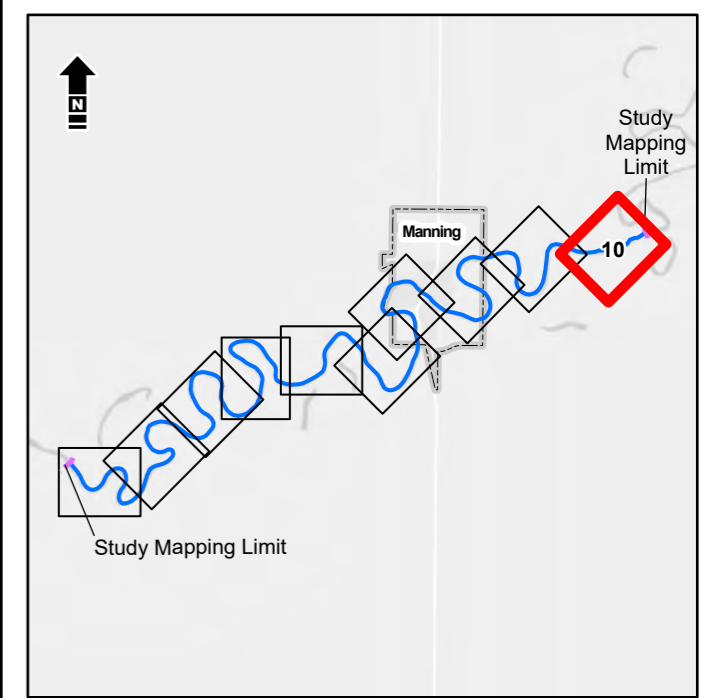
Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein.

Sheet **9 of 10**

\\alberta\environment\p\p\35915\FigureAndTables\FD2023\Reporting\0_Figure-Flood_Mapbook_Template.aprx - Tabbed_L - 20-Jan-25, 01:38 PM - cborak - T10005



- RS: 24873** River Station
- Bridge
- Culvert
- Weir
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation
- 500-Year Flood Inundation



References: Data obtained from Atlas © Government of Alberta and GeoBase® used under license. Imagery (October 2023) obtained from Alberta Environment and Protected Areas used under license.
 Service layer credits: World Light Gray Canvas Base: Esri, HERE, Garmin, USGS, EPA, NPS, NRCAN. Image: ...
 1:5,000 metres
 50 0 50 100
 NAD 1983 CSRS 3TM 117



Alberta Environment and Protected Areas
 Manning Flood Study

Governing Design Flood Hazard Map

Date: January 2025 Project: 35915 Submitter: P. Rogers Reviewer: M. Shome

Third party materials used in this report have not been independently verified and will not be updated for future changes. Montrose Environmental Solutions Canada Inc. has made customary efforts to ensure the accuracy of such materials at the time of publication, however we do not accept any liability for errors, omissions, or inaccuracies in same. Where attached to a report, this figure/drawing is subject to the limitations and conditions stated therein. **Sheet 10 of 10**