GRANDE PRAIRIE FLOOD STUDY

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

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Prepared for Alberta Environment and Protected Areas, June 2025

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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.

EXECUTIVE SUMMARY

Montrose Environmental Solutions Canada Inc. (Montrose; formerly Matrix Solutions Inc.) was retained by the Government of Alberta (GoA) to conduct the Grande Prairie 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 the GoA.

The purpose of the Grande Prairie Flood Study is to assess and identify flood hazards along the Bear River through the City of Grande Prairie and County of Grande Prairie. The study reach extends from the Bear Lake outlet in NE ¼ 24-072-07 W6M to just upstream of where an unnamed tributary joins the Bear River in SW ¼ 17-071-04 W6M and covers a distance of 58 km. The downstream model boundary on the Bear River has been extended to NW ¼ 08-071-04 W6M by approximately 1,500 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, Grande Prairie Creek near Sexsmith (07GE003). This WSC station has a relatively long period of records (1969 to 2023), is located outside of the study reach but within the Bear River watershed, 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 normal 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 at the WSC station.

The hydrologic analysis and assessment indicated that the peak flows along the Bear River below the confluence with Grande Prairie Creek can be estimated by using a 14% reduction of estimated peak flows in Grande Prairie Creek above its confluence with Bear River. A 14% reduction of estimated flood frequencies at Grande Prairie Creek above its confluence was used in determining flood frequencies at the Bear River below the confluence location. The flood frequency estimates in Grande Prairie Creek above its confluence with the Bear River and along the Bear River study reach at key locations downstream of the confluence were then determined using a linear drainage area method under the assumption that equal area contributes equal runoff. The estimated flood frequency estimates were used as input to the developed hydraulic model for flood hazard and flood inundation mapping.

The hydraulic model and resulting map products were constructed using LiDAR data provided by the 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 228 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.

Thirty-three hydraulic structures were included in the hydraulic model, including the following (Table 1):

- 1 culvert crossing
- 1 spillway with radial gates
    - For the purposes of this study, the gates were assumed to be fully open for all scenarios
- 1 rail bridge
- 15 pedestrian bridges
- 15 vehicle bridges

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 largest recorded historical flood at the Grande Prairie Creek gauging station (07GE003) occurred on June 14, 1990. Observed highwater marks were surveyed by EPA and provided to Montrose; however, a traditional hydraulic model calibration approach could not be undertaken since the peak discharge on Bear River corresponding to this flood event is unknown and the water level at the reservoir spillway is also not available. In the absence of the 1990 flood discharge through the study reach, a 'reverse' calibration process was undertaken to validate the model, which included: (i) selection of reasonable channel and overbank roughnesses based on best professional judgement; and (ii) simulation of water levels for variable discharges for comparison against the highwater marks.

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. Floodway criteria maps are provided in Appendix D and design flood hazard maps are provided in Appendix E.

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1 INTRODUCTION

Montrose Environmental Solutions Canada Inc. (Montrose, formerly Matrix Solutions Inc.) was retained by the Government of Alberta (GoA) to conduct the Grande Prairie Flood Study. Key stakeholders for this project include the GoA, the City of Grande Prairie, and the County of Grande Prairie. This flood study is one of several similar studies completed as part of a larger effort by the 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 previous flood study was completed by NHC; however, the mapping extents in the current study are larger than the previous completed flood risk mapping study. The NHC (2007) flood study used flood frequencies up to a 1,000-year flood event derived from the recorded flows at Grande Prairie Creek near Sexsmith (07GE003) covering a period from 1971 to 2003. The NHC (2007) flood study encompassed approximately 21 km of the Bear River, extending from 132 Avenue (Township Road 720) at the north end of the city and continued to approximately 48 Avenue at the south end of the city. The purpose of the current study is to update the flood frequencies with return periods ranging from 2-year to 1,000-year using the available historical flood data to date and to expand the hydraulic modelling extent and flood mapping coverage.

Since the previous flood risk study, the 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:

- Grande Prairie Flood Study – Specific Terms of Reference (TOR; EPA 2023)
- 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 Bear 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 Bear Lake outlet in NE ¼ 24-072-07 W6M to just upstream of where an unnamed tributary joins the Bear River in SW ¼ 17-071-04 W6M and covers a distance of 58 km (Figure 1). The Bear River basin is a part of the Wapiti, Smoky, and eventually the Peace River system. The Bear River, which is the mainstream of the Bear River basin, has several smaller tributaries and flows through two large lakes, La Glace Lake and Bear Lake (Figure 2). Most of the land use of the Bear River watershed comprises agricultural and forested areas. The drainage area of the Bear River at the downstream study boundary of the proposed flood study is approximately 1,958 km^2 and the drainage area of the Bear River at the outlet of Bear Lake is approximately 1,221 km^2. Approximately 63% of the drainage area of the Bear River at the downstream study boundary is located upstream of Bear Lake. This lake with a surface area of 33 km^2 is a key natural feature that plays a significant role in the attenuation of the peak flows in the Bear River downstream of the lake as discussed below.

Grande Prairie Creek, a major tributary of the Bear River drains into the Bear River approximately 3 km downstream of the Bear Lake outlet. The drainage area of the Grande Prairie Creek above its confluence with the Bear River is approximately 348 km^2. The peak inflows to Bear Lake (2,021 km^2 drainage area including Bear Lake) are significantly attenuated because of the large storage capacity of Bear Lake. Under flood conditions, the attenuated peak outflows from this lake combined with peak flows through Grande Prairie Creek and local runoff from the surrounding lands flow through the proposed Bear River study reach.

In addition to natural storage features such as Bear Lake and La Glace Lake, flows along the Bear River are regulated at the Grande Prairie Reservoir, located within the city. The reservoir was built in 1948 and reconstructed in 1975-76 (SNC 2021). Its original purpose was to supply water to the city but it is currently used for recreational purposes. The city and the county are located within the study reach and have several stormwater outfalls that discharge to the Bear River. As a result, summer storm events may result in temporarily relatively high contribution to total flow in the Bear River; however, since flooding in the Bear River is generally governed by snowmelt runoff events, the likelihood of these events occurring simultaneously is very low and thus the contribution of stormwater outfalls was not investigated further for this study.

2 SURVEY AND BASE DATA COLLECTION

Montrose conducted a site visit with the GoA and MSI staff on June 7 and 8, 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, and refining the survey scope. The information collected has suggested that there are no flood control structures present along the Bear River 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, culverts and spillway) geometry
- 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 Grande Prairie 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 120)		ASCN Elevation (m)	MSI Surveyed Elevation (m)	Difference (m)
	Easting	Northing			
38992	75,621.60	6,117,074.21	659.09	659.126	0.036
45039	76,867.67	6,112,391.17	654.736	654.699	-0.037
171355	76,867.55	6,112,390.88	648.546	648.523	-0.023
272823	75,157.79	6,116,667.09	659.549	659.616	0.067

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 B, listed upstream to downstream; the structures are shown on Figure 2.

TABLE B Hydraulic Structure Details

Hydraulic Structure Name	Bounding River Stations (m)	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 120)	
		Northing	Easting
Range Road 70 Bridge (BF 06922)	61671.05 and 61644.16	6,125,052.85	68,501.20
Range Road 65 Bridge (BF 71057)	58702.57 and 58686.2	6,125,265.58	70,101.89
Township Road 722 Bridge (BF 07301)	54227.29 and 54209.73	6,122,677.92	71,070.92
Highway 43X W Bridge	54096.79 and 54072.7	6,122,574.87	71,010.43
Highway 43X E Bridge	54053.88 and 54029.93	6,122,537.66	71,026.95
Unnamed Road Bridge	51674.15 and 51665.33	6,122,269.90	72,214.98
Range Road 63 Bridge (BF 71654)	48267.62 and 48237.6	6,120,392.28	73,446.83
Township Road 720 Bridge (BF 13766)	48267.62 and 48237.6	6,119,472.26	73,503.45
Pedestrian Bridge 3	41269.83 and 41263.54	6,117,485.77	75,079.11
Highway 43 Bridge (BF 13990)	41194.6 and 41165.23	6,117,462.93	75,163.39
Pedestrian Bridge 2	40970.09 and 40964.22	6,117,365.57	75,325.24
Spillway	39994.05 and 40061.16	6,116,837.45	75,905.09
Pedestrian Bridge 1	39698.45 and 39692.72	6,116,609.74	75,974.77
Pedestrian Bridge 0	39436.73 and 39430.16	6,116,372.33	76,037.09
Township Road 714 N Bridge (BF 01481W)	39311 and 39288.79	6,116,242.30	76,072.72
Township Road 714 S Bridge (BF77532E)	39271.28 and 39252.25	6,116,205.81	76,080.41
Pedestrian Bridge 6	39158.74 and 39150.5	6,116,099.44	76,085.89
Railway Bridge	39094.15 and 39085.34	6,116,035.37	76,087.41
Pedestrian Bridge 26	38700.32 and 38695.54	6,115,695.14	76,204.50
Pedestrian Bridge 24	37911.48 and 37904.65	6,115,159.06	76,316.24
84 Avenue Bridge (BF 77811)	37232.52 and 37204.43	6,114,657.60	76,238.51
Pedestrian Bridge 5	37197.68 and 37192.23	6,114,631.54	76,243.31
Pedestrian Bridge 13	37076.19 and 37070	6,114,513.40	76,264.77
Pedestrian Bridge 12	36298.75 and 36292.38	6,114,152.71	76,363.11
Pedestrian Bridge 11	35933.33 and 35925.88	6,114,034.49	76,478.57
Pedestrian Bridge 10	34497.99 and 34490.29	6,113,429.58	76,797.78
68 Avenue Bridge N (BF 86046)	33590.46 and 33354.07	6,113,055.99	76,659.83
68 Avenue Bridge S		6,113,039.85	76,656.92
Pedestrian Bridge 23	33385.56 and 33375.55	6,112,938.05	76,556.12
Pedestrian Bridge 22 (BF 71060)	29682.43 and 29674.83	6,111,910.20	76,848.81
Yellow Trail Bridge	28535.87 and 28530.05	6,111,849.59	77,513.93
Resources Road Culvert (BF 76732)	26041.09 and 25815.08	6,110,650.02	78,721.62
Township Road 713 Bridge (BF 79375)	6396.193 and 6383.527	6,114,818.40	87,943.52

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

The historical recorded streamflow data were assessed to establish hydrologic characteristics and to derive flood frequency estimates associated with various return periods. A Water Survey of Canada (WSC) hydrometric gauging station, Grande Prairie Creek near Sexsmith (07GE003), is located 18 km upstream of the confluence of Grande Prairie Creek with the Bear River has been in operation since 1969. There was a WSC station located on the Bear River near Grande Prairie (07GE005) but was only in operation from 1983 to 1987. There is no WSC station currently located on Bear River downstream of Bear Lake.

The historical recorded streamflow at the Grande Prairie Creek near Sexsmith (07GE003) covering a period from 1969 to 2022 was obtained to assess historical floods in the study reach. The largest recorded historical flood occurred in 1990 with a magnitude of 64 m^3/s; the second largest flood occurred in 2011 with a magnitude of 40.8 m^3/s; the third largest flood occurred in 2016 with a magnitude of 39 m^3/s; the fourth largest flood occurred in 1974 with a magnitude of 30.8 m^3/s; and the fifth largest flood occurred in 1997 with a magnitude of 22.9 m^3/s.

3.1.2 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 Bear River to be used for subsequent hydraulic modelling and flood inundation mapping. There is only one WSC station, Grande Prairie Creek near Sexsmith (07GE003) located in the Bear River watershed in the vicinity of the study area. The historical recorded streamflow at the Grande Prairie Creek near Sexsmith (07GE003) covering a period from 1969 to 2022 was obtained and analyzed to carry out a single station flood frequency analysis. Included as Appendix B in this report, Montrose (2025) provided detailed information on the hydrologic analysis undertaken for the Bear River.

3.2.2 Flood Frequency Flow Estimates

A detailed description of the hydrologic analysis and flood frequency estimates is provided in Appendix B of this report. The recommended flood frequencies at key locations along the Bear River within the study reach is provided below in Table C.

TABLE C Flood Frequency Estimates at Select Locations along Bear River

Return Period (years)	Discharge in Grande Prairie Creek Above its Confluence (m^3/s)[1]	Discharge Below The Confluence (m^3/s)	Discharge d/s of the Grande Prairie Reservoir (m^3/s)	Discharge at d/s Study Boundary (m^3/s)
2	24.4	21	21.8	26.2
5	47.7	41	42.6	51.2
10	67.9	58.4	60.7	72.9
20	90.7	78	81	97.3
35	111	95.8	99.5	120
50	126	108	112	135
75	143	123	128	153
100	156	134	139	167
200	190	164	170	204
350	221	190	198	237
500	242	208	216	260
750	269	231	240	288
1,000	286	246	256	307

The flood frequency estimates were used as input to the developed hydraulic model. In addition, peak outflows from Bear Lake under 13 modelling scenarios are also required to be used as upstream flow boundary conditions in the hydraulic model. Table D provides the recommended peak outflows from Bear Lake to be used as flow boundary conditions and to delineate flood hazard mapping for the Bear River reach between the Bear Lake outlet and above its confluence with Grande Prairie Creek.

TABLE D Computed Peak Outflows from Bear Lake

Return Period (years)	Peak Outflows (m^3/s)
2	3
5	7
10	10
20	25
35	35
50	40
75	50
100	55
200	80
350	95
500	100
750	120
1,000	140

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 (90%), the difference between DTM derived elevations and ground surveyed elevations were up to 0.3 m. 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 2007 and a HEC-RAS hydraulic model was developed to calculate water surface profiles and delineate the floodway and flood fringe boundary for up to the 1000-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

The largest recorded historical flood at the Grande Prairie Creek gauging station (07GE003) occurred on June 14, 1990. Observed highwater marks were surveyed by EPA and provided to Montrose; however, the peak discharge on Bear River corresponding to this event and the reservoir water level are unknown. Locations of the HWMs provided by EPA are provided on Figure 2; Table E provides a summary of the HWM data.

TABLE E Highwater Mark Data

Alberta Environment and Parks Highwater Mark	River Station (m)	Observed Water Surface Elevation (m)
1990 Flood Event[1]		
90-Bear-2b	54227.29	662.26
90-Bear-2a	54152.35	662.64
90-Bear-4a	41238.70	652.79
90-Bear-5.1a	39379.67	645.90
90-Bear-5.1b	39280.27	645.71
90-Bear-5.2b	39252.25	645.41
90-Bear-6a	37263.70	641.96
90-Bear-6b	37204.43	641.82
90-Bear-7	33375.55	634.18

1. Flood discharge in Bear River corresponding to HWMs not available.

4.2 River and Valley Features

4.2.1 General Description and River Characteristics

The Bear River basin is a part of the Wapiti, Smoky, and eventually the Peace River system. The Bear River, which is the mainstream of the Bear River basin, has several smaller tributaries and flows through two large lakes, La Glace Lake and Bear Lake. The peak inflows to Bear Lake are significantly attenuated because of the large storage capacity of Bear Lake. Grande Prairie Creek, a major tributary of the Bear River drains into the Bear River 2 km downstream of the Bear Lake outlet. Under flood conditions, the attenuated peak outflows from Bear Lake combined with peak flows through Grande Prairie Creek and local runoff from the surrounding lands flow through the Bear River study reach.

As discussed in various reports, it has been confirmed that high water levels at the confluence of Bear Lake and Grande Prairie Creek associated with peak flows in Grande Prairie Creek cause flow reversals in Bear River reach below Bear Lake and a companion reduction in the Grande Prairie Creek peak flow downstream of the confluence (Marshall, Macklin and Monaghan 1984; Samide Engineering Ltd. 1998). In addition to natural storage features such as Bear Lake and La Glace Lake, flows along the Bear River are regulated at the Grande Prairie Reservoir, located within the city.

The modelled reach can be divided into three generalized sub-reaches:

- The upstream sub-reach extending from the Bear Lake outlet (RS 61205) to the reservoir (RS 40819), which varies from winding to irregularly meandering and is frequently confined and incised with a channel bed slope of approximately 0.00052 m/m.
- The mid sub-reach extends from reservoir (RS 40819) to RS 8742, is irregularly meandering with a more neutral channel profile, and is frequently confined with a channel bed slope of approximately 0.00175 m/m.
- The lower sub-reach extends RS 8742 to the downstream boundary (RS 15), is irregularly meandering with a channel bed slope of approximately 0.00373 m/m.

4.2.2 Floodplain Characteristics

Most of the land use of the Bear River watershed comprises agricultural and forested areas. Upstream of the city, the banks and floodplains are generally cultivated and vegetated with grasses and crops. Through the City of Grande Prairie, urban development is present on both riverbanks throughout. In the lower sub-reach, the valley walls are densely vegetated with trees.

4.2.3 Anthropogenic Features

A total of 33 hydraulic structures are located within the study reach, including one culvert crossing, one spillway with radial gates, and 30 bridges (refer to Table B for details). The spillway and reservoir was built in 1948 and reconstructed in 1975-76 (SNC 2021). Its original purpose was to supply water to the City of Grande Prairie but it is currently used for recreational purposes. Releases from the reservoir are controlled by a spillway with two radial gates, each 5 m wide, and there are no separate low-level outlets. The gates are manually operated to manage spring floods and winter recreation. The reservoir normal operating level coincides with the spillway invert at the dam. In the spring, the gates are typically opened to pass flood flows. Later in the summer, the gates are often closed by mid-June to maintain higher reservoir levels for summer recreational use (i.e., near the full supply level).

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 Bear River was extended by approximately 1,500 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 228 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 Hydraulic Structure Data

Thirty-one bridges, one culvert crossing, and one spillway were included in the hydraulic model (Table B). 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 closely, it is important to maintain gradual variations in roughness throughout the study reach and prescribe reasonable values for the given conditions.

As discussed in Section 4.1.3., observed highwater marks corresponding to the June 14, 1990 flood event were surveyed by NHC (2007) and provided to Montrose. However, the peak discharge on Bear River corresponding to this flood event and the water at the reservoir is unknown. In addition, several of the bridges within the study reach included in the current model have been constructed or modified and the river has gone through natural morphological changes since the 1990 flood event. As a result, it is expected that the hydraulic responses obtained through the application of the model will not accurately represent the hydraulic conditions of the river as it existed during the 1990 flood. In the absence of the 1990 flood discharge through the study reach, and the above-mentioned rationale, a 'reverse' calibration process was undertaken to validate the model, which included the following:

- Selection of reasonable channel and overbank roughnesses based on best professional judgement
- Simulation of water levels for variable discharges for comparison against the highwater marks

A similar approach was utilized in the NHC (2007) flood study. HWMs observed during the June 1990 flood event are detailed on Table E. 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 0.0033 m/m, which is equivalent to the average lower channel reach bed slope.

4.3.3.2 Calibration Results

Figures 3a, 3b and 3c 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.

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.

As shown in Table 2, observed highwater marks compare to model simulations with flood discharges at the confluence ranging between 58.4 and 78 m^3/s, which corresponds to return periods of 10- and 20-years, respectively. Due to updated flood frequencies for the study area, the return periods of the flood events used in the current study are smaller than the return periods reported in the NHC (2007) study. The water levels simulated at the reservoir are also within the range of water levels anticipated based on the stage-discharge relationship reported by Golder (Golder Associates 2012). It is concluded that calibration results are reasonably consistent with the observed highwater marks, given the above rationale.

4.3.4 Flood Frequency Profiles

Figures 4a, 4b and 4c provides the simulated water surface profiles for the 2-year to 1,000-year flood discharges on the Bear River. Table 3 provides the water surface elevations at each model cross-section for the range of flood events simulated on the Bear River.

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 (± 20%)
- Variation of the Manning roughness values (± 20%)

Figure 5 and Table 4 provide 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 1183 (BR003).

The channel roughness adopted for the calibrated profile on the Bear River is 0.035; the alternate channel roughness values investigated here are 0.028 and 0.042. Figures 6a, 6b and 6c and Table 5 provide a comparison of the simulated water surface profiles for the variable channel roughness values. The average and maximum difference in water surface elevations as compared to the calibrated profile are -0.17 m and -0.48 m, respectively, for the lower value of n = 0.028; these differences are 0.16 m and 0.40 m for the higher value of n = 0.042.

Figures 7a, 7b, 7c, and Table 6 provide a comparison of the simulated water surface profiles for the variable overbank roughness conditions (±20%). The average and maximum difference in water surface elevations as compared to the calibrated profile are -0.04 m and -0.11 m, respectively, for the lowered overbank roughness values while these differences are 0.04 m and 0.20 m for the higher overbank roughness values.

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 Bear River were interpolated and translated to inundation boundaries through ArcGIS Desktop 10.7.1. 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:

- An RV Park on the north (left) bank is impacted at the 5-year flood and greater (mapsheet 5).
- Outbuildings on east (left) bank are impacted at 5-year flood and greater (mapsheets 4 and 8).
- Outbuildings on the north (left) bank are impacted at the 20-year flood and greater (mapsheet 2).
- Access to a residence on the south (right) bank is impacted at the 20-year flood and greater (mapsheet 5).
- Access to several residences and outbuildings on the north (left) bank are impacted at the 50-year flood and greater (mapsheet 2).
- A campground on the west (right) bank is impacted at the 50-year flood and greater (mapsheet 11).
- Outbuildings on the east (left) bank are impacted at the 75-year flood and greater (mapsheet 7).
- A commercial building and residences on the east (left) are impacted at the 75-year flood and greater (mapsheet 8).
- Access to a residence on the south (right) bank is impacted at the 75-year flood and greater (mapsheet 1).
- Commercial/institutional buildings and parking areas on both banks are impacted at the 100-year flood and greater (mapsheet 12).
- Several residences immediately downstream of Bear Lake are impacted at the 500-year flood and greater (mapsheet 1).
- Flood impacts to vehicle bridges are summarized below:
    - Range Road 70 Bridge (RS61670): road segment in right overbank overtopped at the 1,000-year flood and greater
    - Range Road 65 Bridge (RS 58690): road segments overtopped at the 35-year flood and greater
    - Township Road 722 Bridge (RS 54220): bridge/road not overtopped
    - Highway 43X West Bridge (RS 54080): bridge/road not overtopped
    - Highway 43X East Bridge (RS 54050): bridge/road not overtopped

- Unnamed Road Bridge (RS 51670): bridge/road overtopped at the 10-year flood and greater
- Range Road 63 Bridge (RS 48250): road segments overtopped at the 100-year flood and greater
- Township Road 720 Bridge (RS 46780): road segments overtopped at the 10-year flood and greater
- Highway 43 Bridge (RS 41180): bridge/road not overtopped
- Township Road 714 North (RS 39300): bridge/road not overtopped
- Township Road 714 South (RS 39260): bridge/road not overtopped
- Rail Bridge (RS 39090): bridge/rail not overtopped
- 84 Avenue Bridge (RS 37230): bridge/road not overtopped
- 68 Avenue Bridge (RS 33575): bridge/road not overtopped
- Township Road 713 Bridge (RS 6390): bridge/road not overtopped

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. The City of Grande Prairie maintains a database with spatial data for culverts located within city limits. These culverts have been incorporated into the flood inundation mapping and considered when selecting isolated polygons to retain. Outside of city limits, suspected culverts were reviewed in aerial imagery with associated polygons either retained or omitted pending the outcome. 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.

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 Figures 8a, 8b and 8c.

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 30, 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
- 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. In the upper (upstream of Township Road 720) and lower (downstream of 48 Avenue) Bear River, the floodway is primarily governed by the 1 m depth contour. A floodway was previously developed for a 21 km reach of the Bear River extending from Township Road 720 at the north end of the city and continued to 48 Avenue at the south end of the city. Through this sub-reach, the floodway generated herein generally follows the historic floodway. Manual adjustments to the floodway boundary were made in some locations in consultation with EPA to account for changes to channel morphology and 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

Through the study reach, the floodway varies in width from 15 m to 918 m. Floodplain impacted by the floodway generally consists of cultivated or forested land, though several buildings are situated within the floodway (mapsheets 4 and 8).

6.3.4.2 Areas Within The Flood Fringe

Several flood fringe areas are located in low-lying areas, through inside channel bends and at a historic meander scar. through inside channel bends and at a low-lying historic meander scar. There are no protected flood fringe areas within the study reach. Several areas of high hazard flood fringe (>1 m depth) are present throughout the study reach.

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 F 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 of 0.7 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 F Computed Water Levels for Potential Climate Change Impacts

	Water Level Difference (m)[1]	
	10% Increase	20% Increase
Average	0.15	0.29
Maximum	0.36	0.71

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, Grande Prairie Creek near Sexsmith (07GE003).

The hydraulic model and resulting map products were constructed using LiDAR data provided by the 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. Observed highwater marks corresponding to the June 14, 1990 flood event were surveyed by NHC (2007) and provided to Montrose. However, the peak discharge on Bear River corresponding to this flood event and the water at the reservoir is unknown and several of the bridges within the study reach were constructed or modified since the 1990 flood event. As such, a 'reverse' calibration process was undertaken to validate the model, which included (i) selection of reasonable channel and overbank roughness based on best professional judgement, and (ii) simulation of water levels for variable discharges for comparison against the highwater marks

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: Access to a residence on the south (right) bank is impacted at the 75-year flood and greater. Several residences immediately downstream of Bear Lake are impacted at the 500-year flood and greater.
- Mapsheet 2: Outbuildings on the north (left) bank are impacted at the 20-year flood and greater. Access to several residences and outbuildings on the north (left) bank are impacted at the 50-year flood and greater.
- Mapsheet 4: Outbuildings on east (left) bank are impacted at 5-year flood and greater.
- Mapsheet 5: An RV Park on the north (left) bank is impacted at the 5-year flood and greater. Access to a residence on the south (right) bank is impacted at the 20-year flood and greater.
- Mapsheet 7: Outbuildings on the east (left) bank are impacted at the 75-year flood and greater.
- Mapsheet 8: Outbuildings on east (left) bank are impacted at 5-year flood and greater. A commercial building and residences on the east (left) are impacted at the 75-year flood and greater.
- Mapsheet 11: A campground on the west (right) bank is impacted at the 50-year flood and greater. Commercial/institutional buildings and parking areas on both banks are impacted at the 100-year flood and greater.

Several bridges and roads are impacted by flooding through the study reach; a summary of impacted vehicle bridges is provided in Section 5.3.1 of this report.

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. In the upper (upstream of Township Road 720) and lower (downstream of 48 Avenue) Bear River, the floodway is primarily governed by the 1 m depth contour. Historic floodway is available for a 21 km reach of the Bear River extending from Township Road 720 at the north end of the city to 48 Avenue at the south end of the city. Through this sub-reach, the floodway generated herein generally follows the historic floodway. Several flood fringe areas are located through inside channel bends and at low-lying areas; areas of high hazard flood fringe (>1 m depth) are present at several locations.

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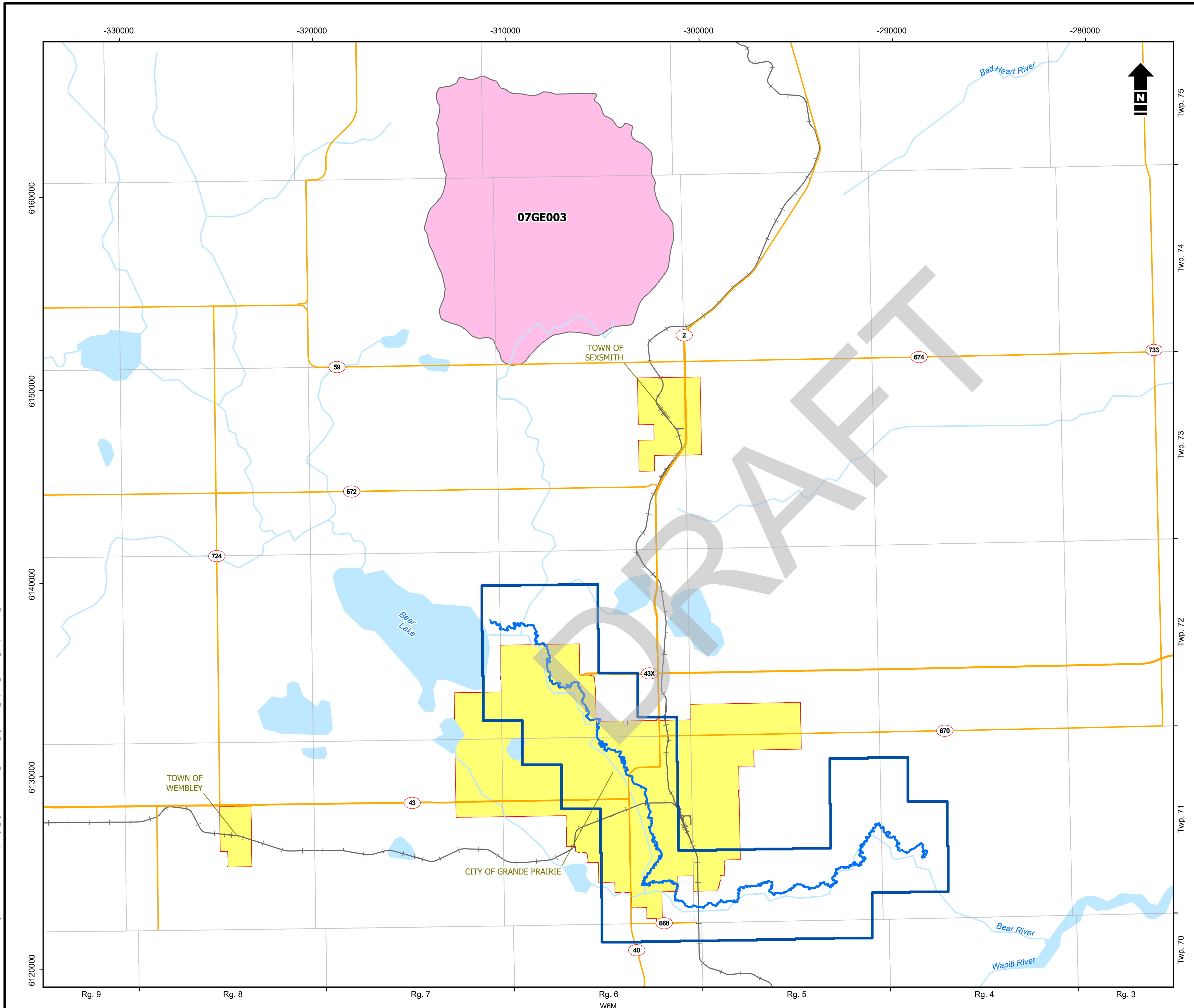


LiDAR and Aerial Image Acquisition
Community
Water Body
Watercourse
Study Reach
Railway
Highway

WSC Subwatershed ID, WSC Subwatershed Name

07GE003, Grande Prairie Creek near Sexsmith

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

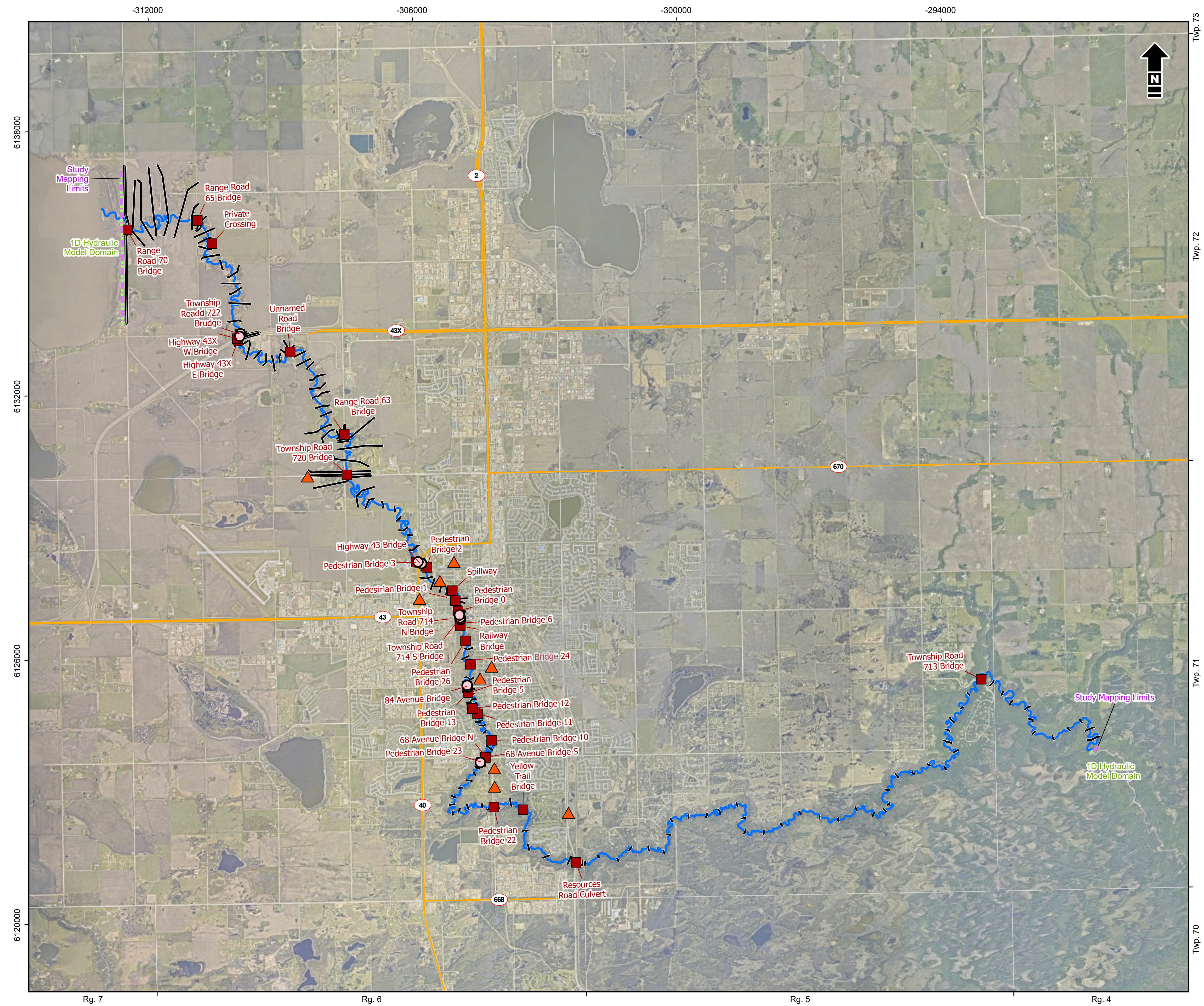
1:200,000 kilometres
2 0 2 4
NAD 1983 CSRS 3TM 120

Alberta Environment and Protected Areas
Grande Prairie Flood Study

Location Plan

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P. Rogers	M. Shome

Figure 1



Study Reach
Cross Section
Study Mapping Limit
1D Hydraulic Model Domain
Highway
Road/Railroad Bridge
Historic ASCM Benchmark
High Water Mark Location | 1990 Survey

1:90,000 kilometres
1 0 1 2
NAD 1983 CSRS 3TM 120

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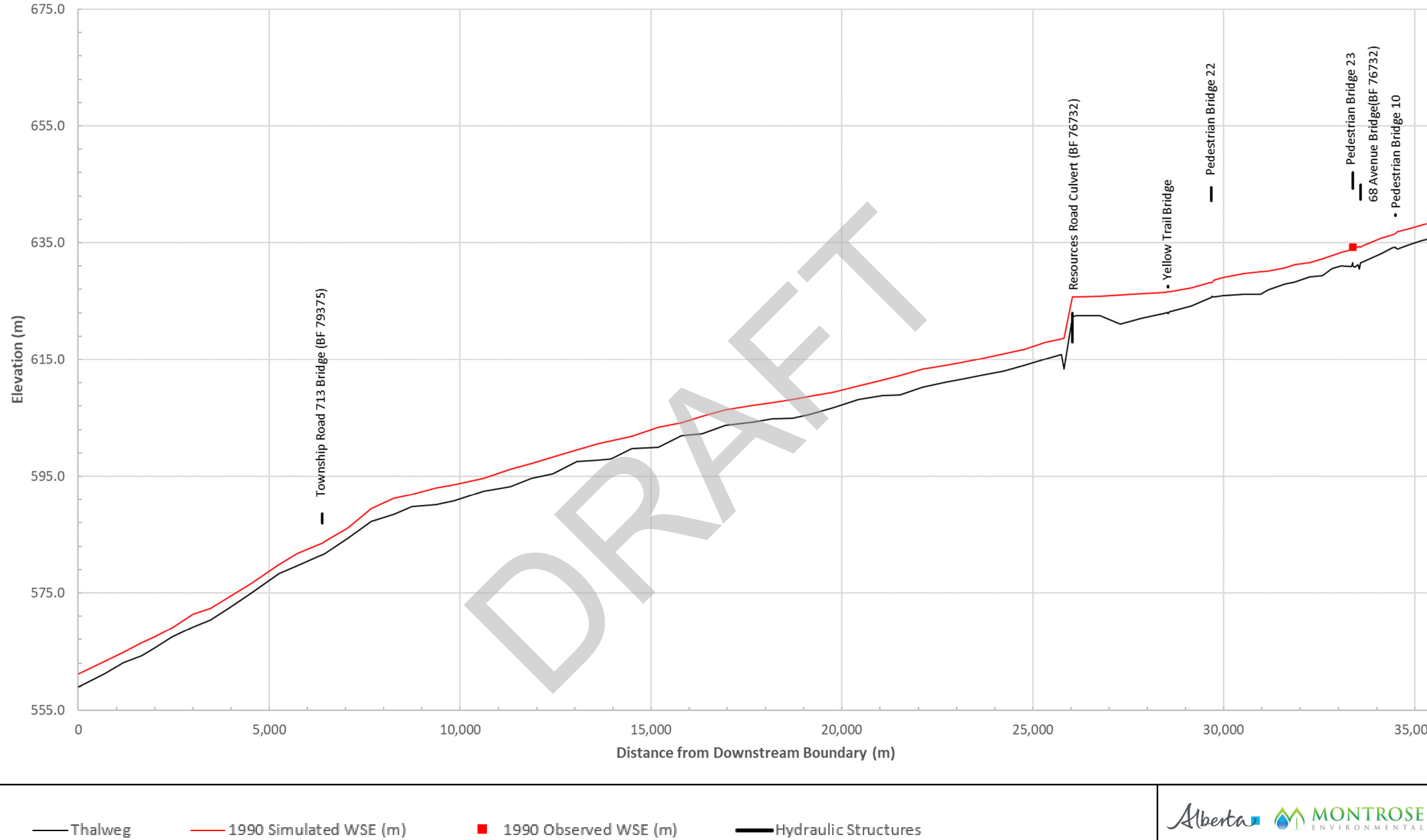
Alberta Environment and Protected Areas
Grande Prairie Flood Study

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

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P. Rogers	M. Shome

Figure 2

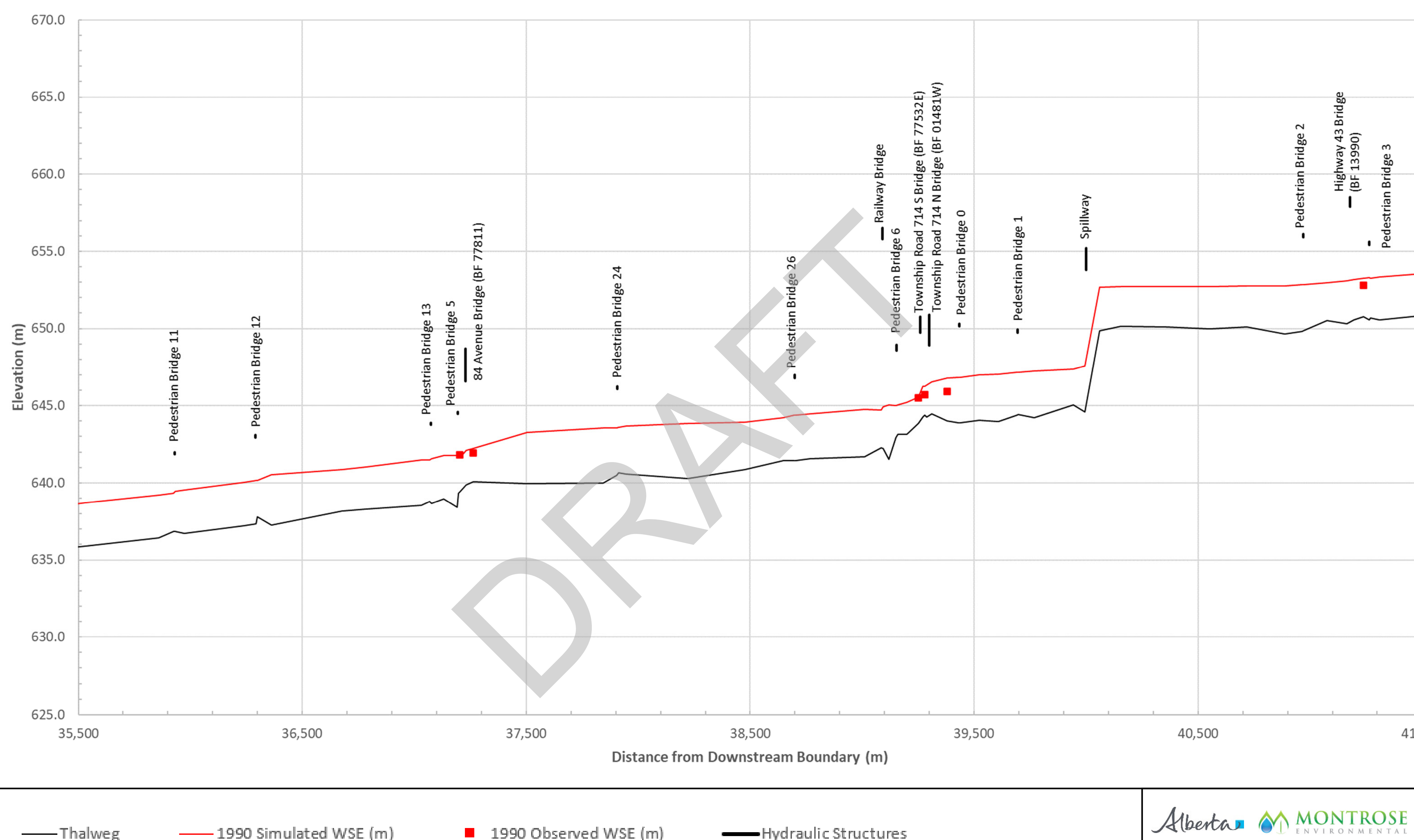


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Calibration Profile, Lower Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 3A



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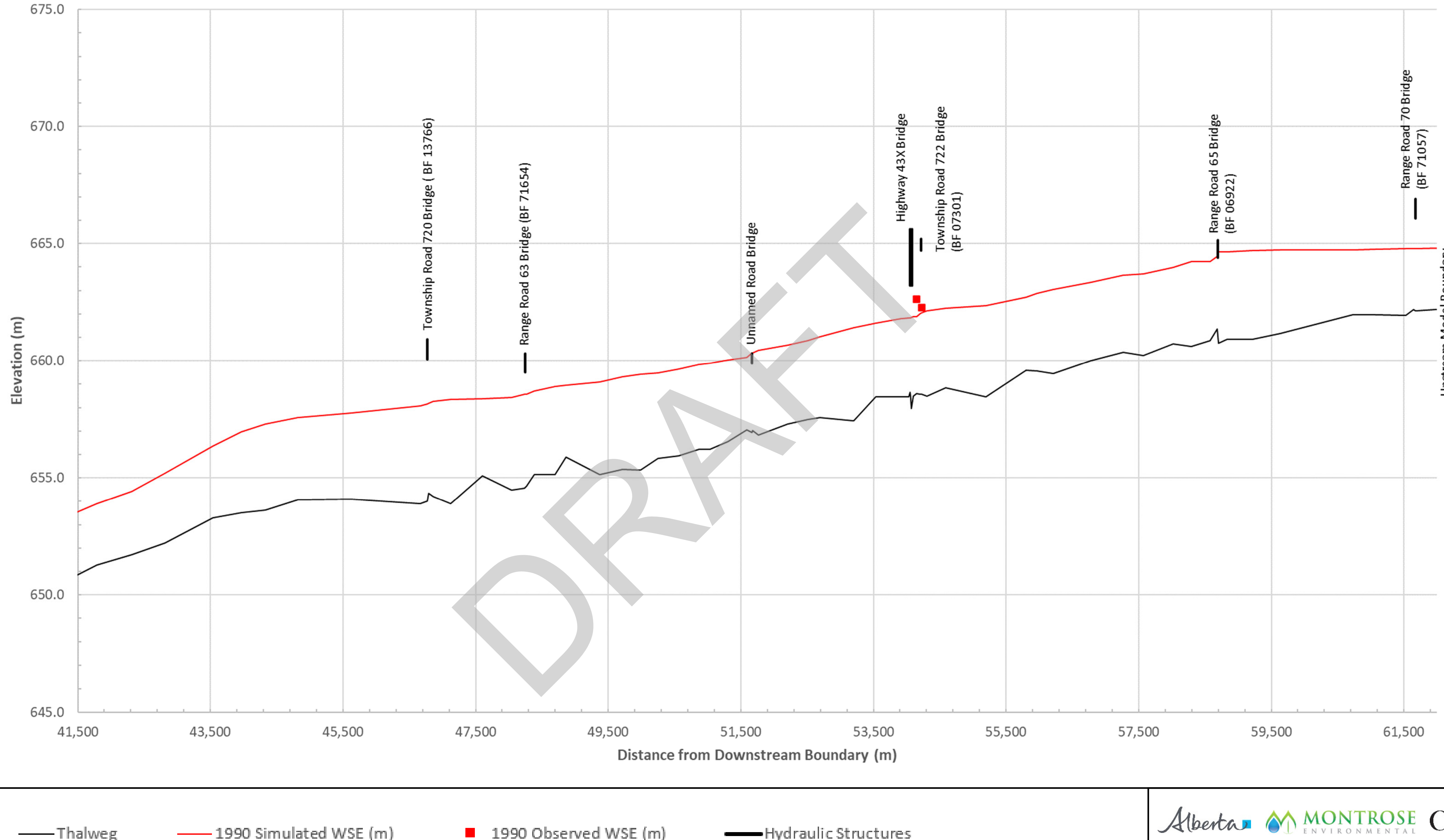
Alberta Environment and Protected Areas
Grande Prairie Flood Study

Calibration Profile, Mid Reach

Date: March 2025	Project: 35917	Submitter: P.Rogers	Reviewer: M.Shome

Figure 3B

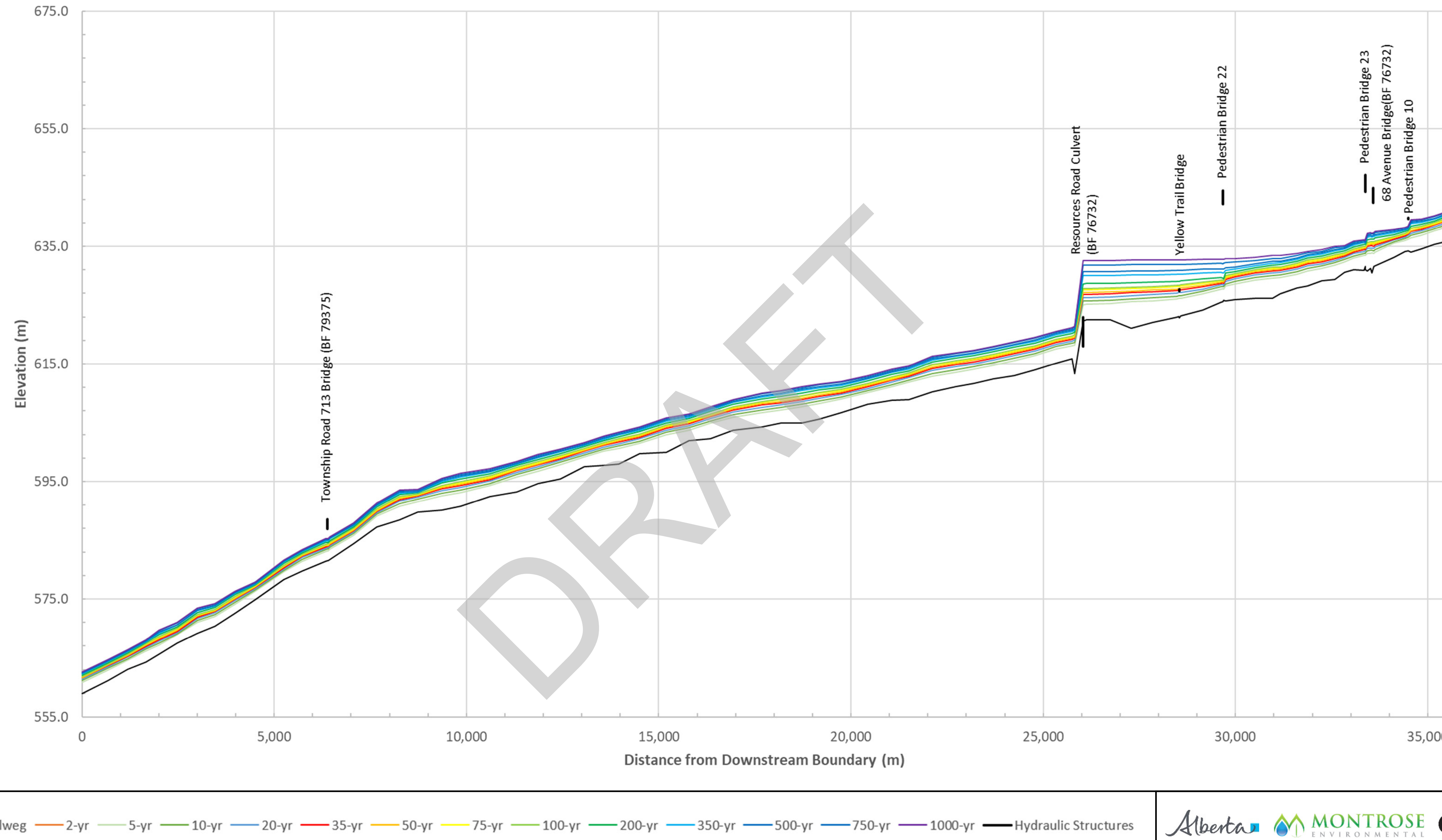


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Calibration Profiles, Upper Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 3C



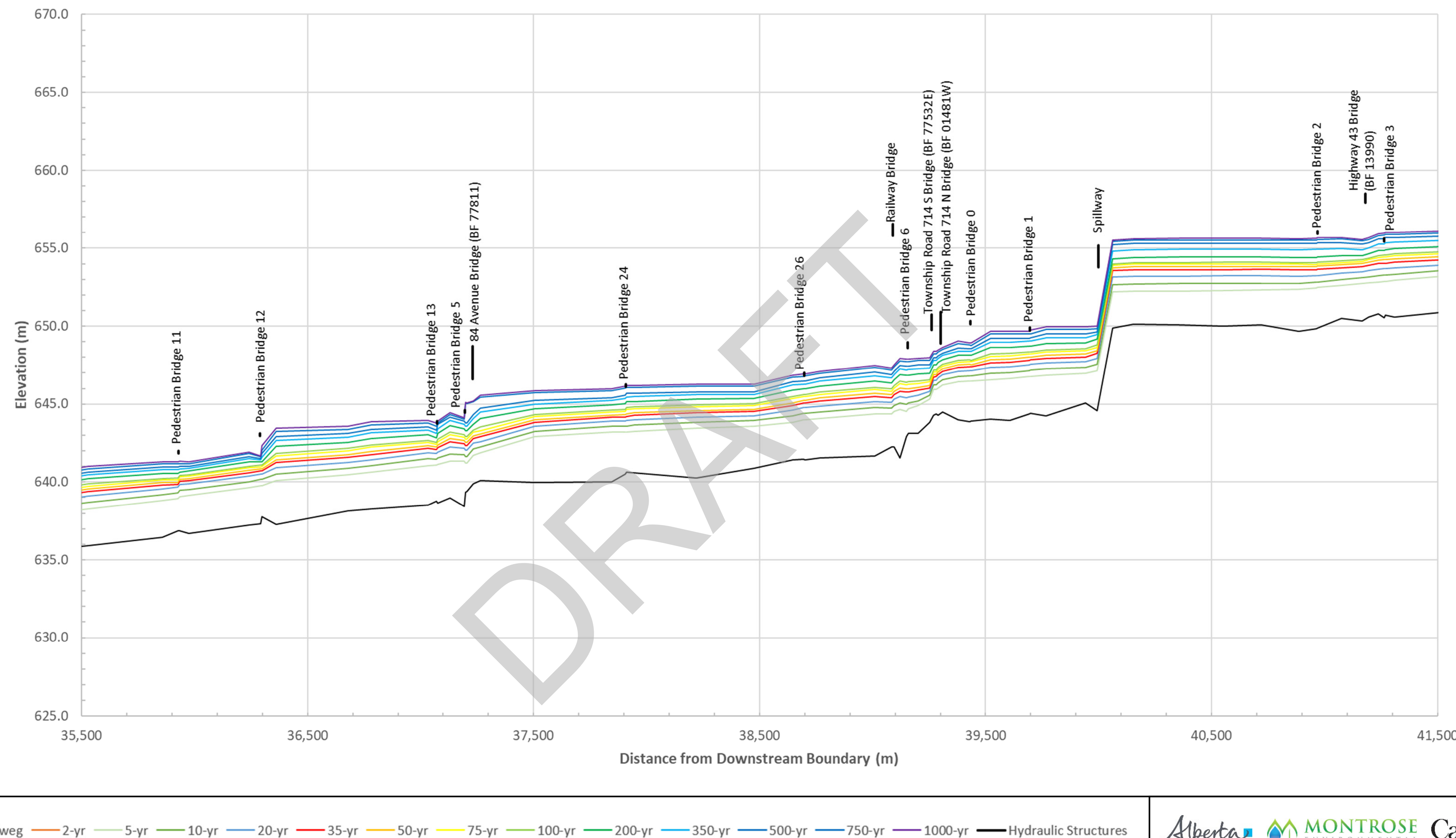
Alberta Environment and Protected Areas

Grande Prairie Flood Study

Flood Frequency Profiles. Lower Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 4A

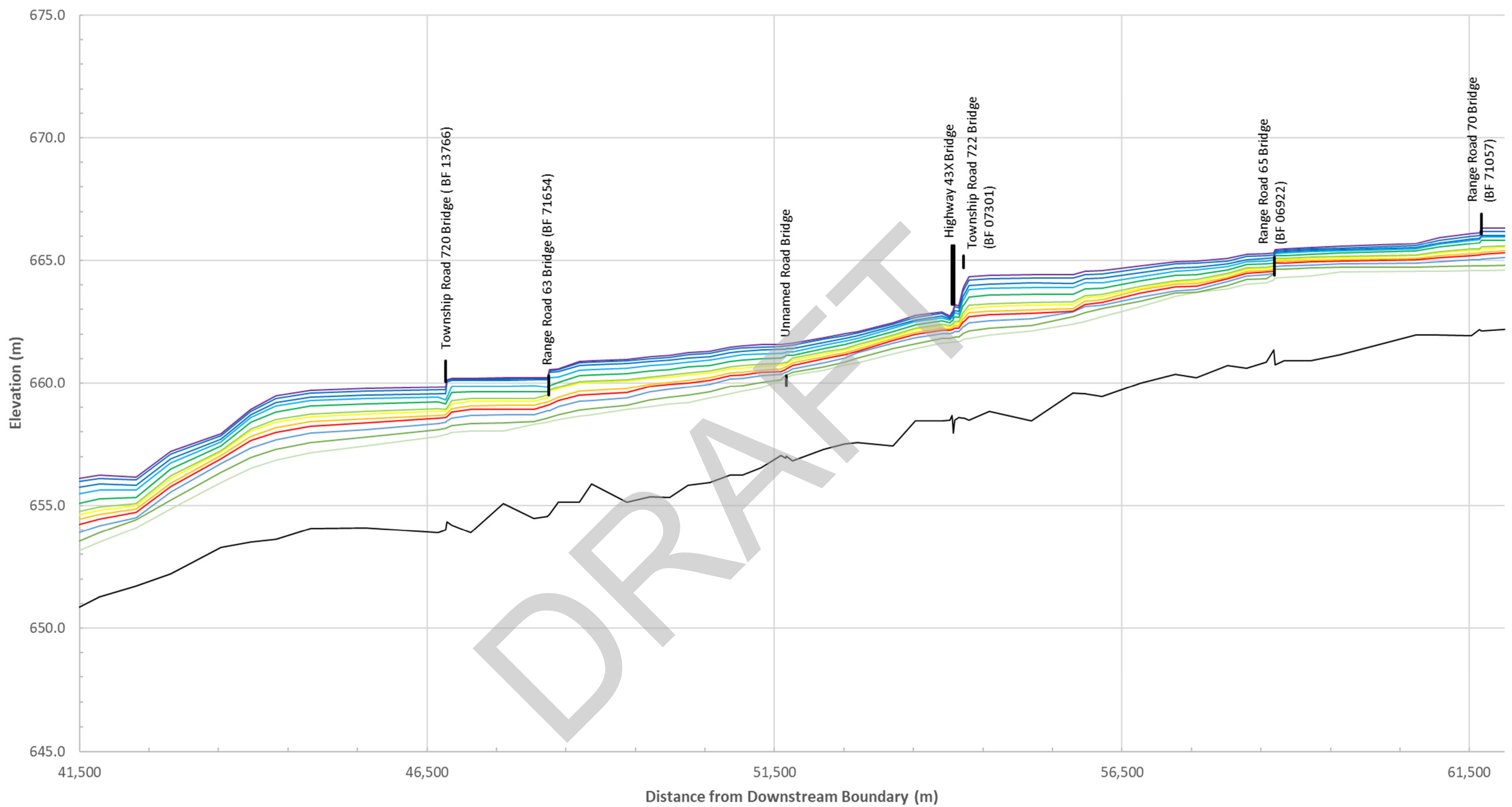


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Flood Frequency Profiles, Mid Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 4B



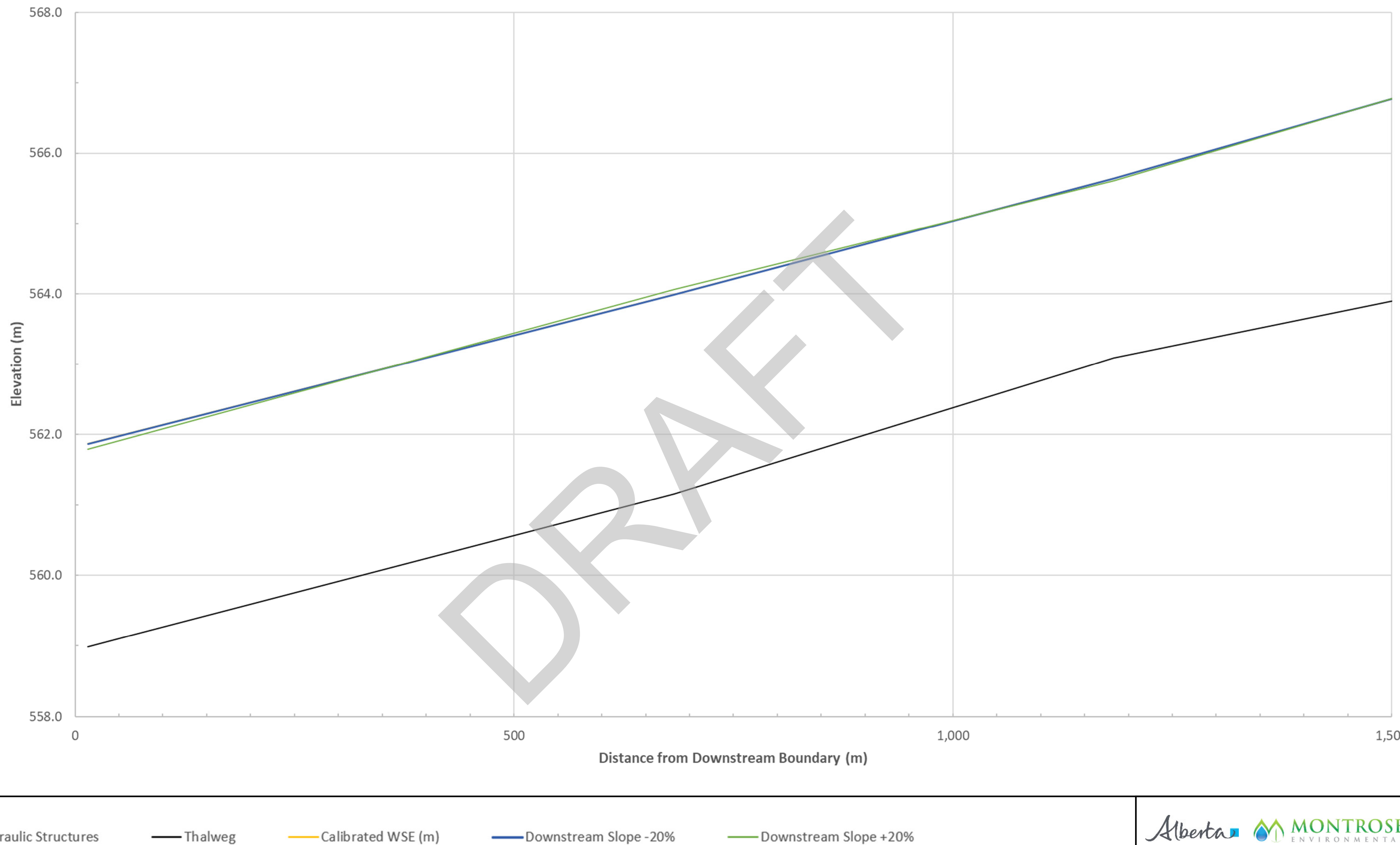
Alberta Environment and Protected Areas

Grande Prairie Flood Study

Flood Frequency Profiles, Upper Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 4C

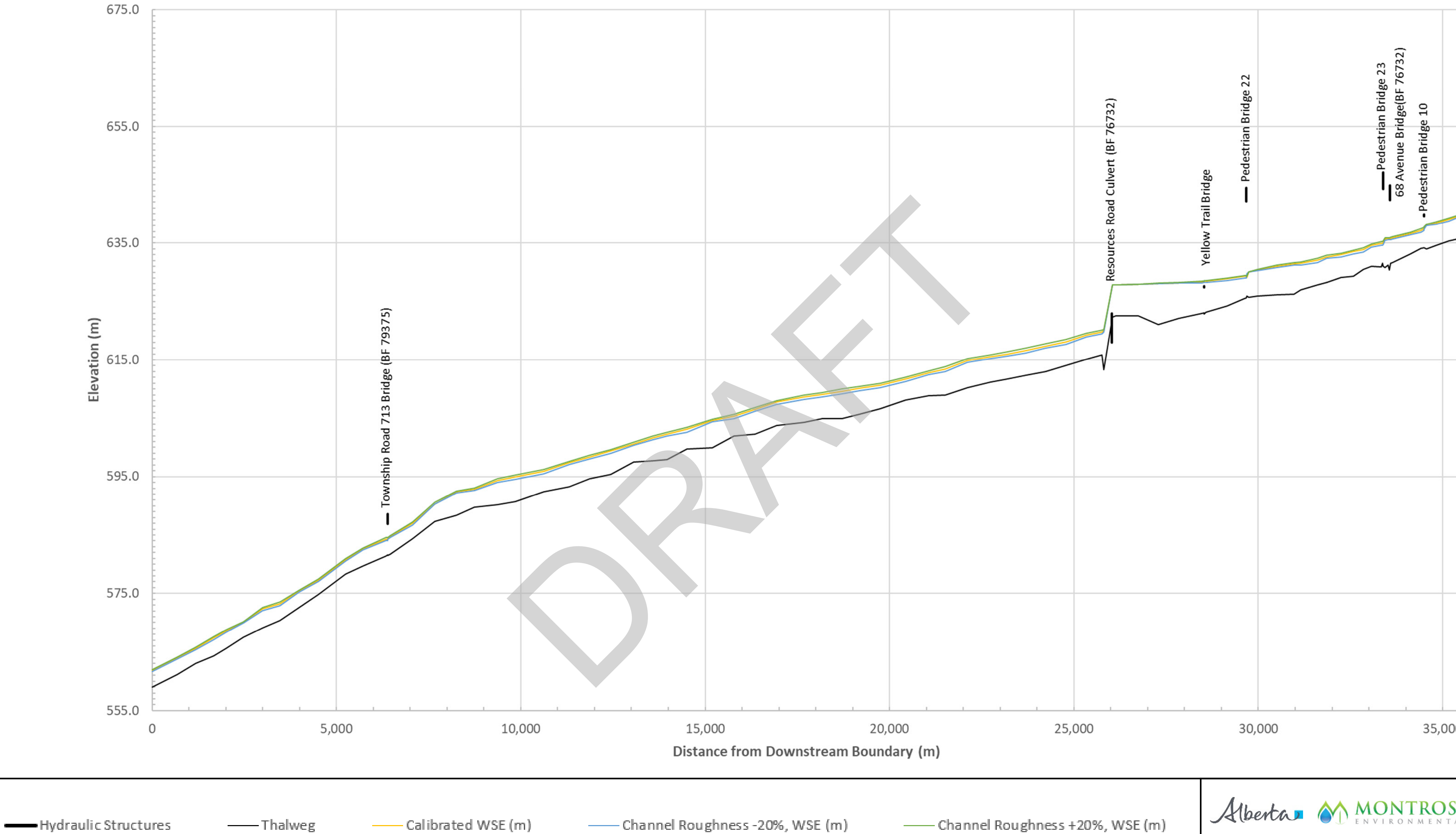


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Downstream Boundary Condition

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 5

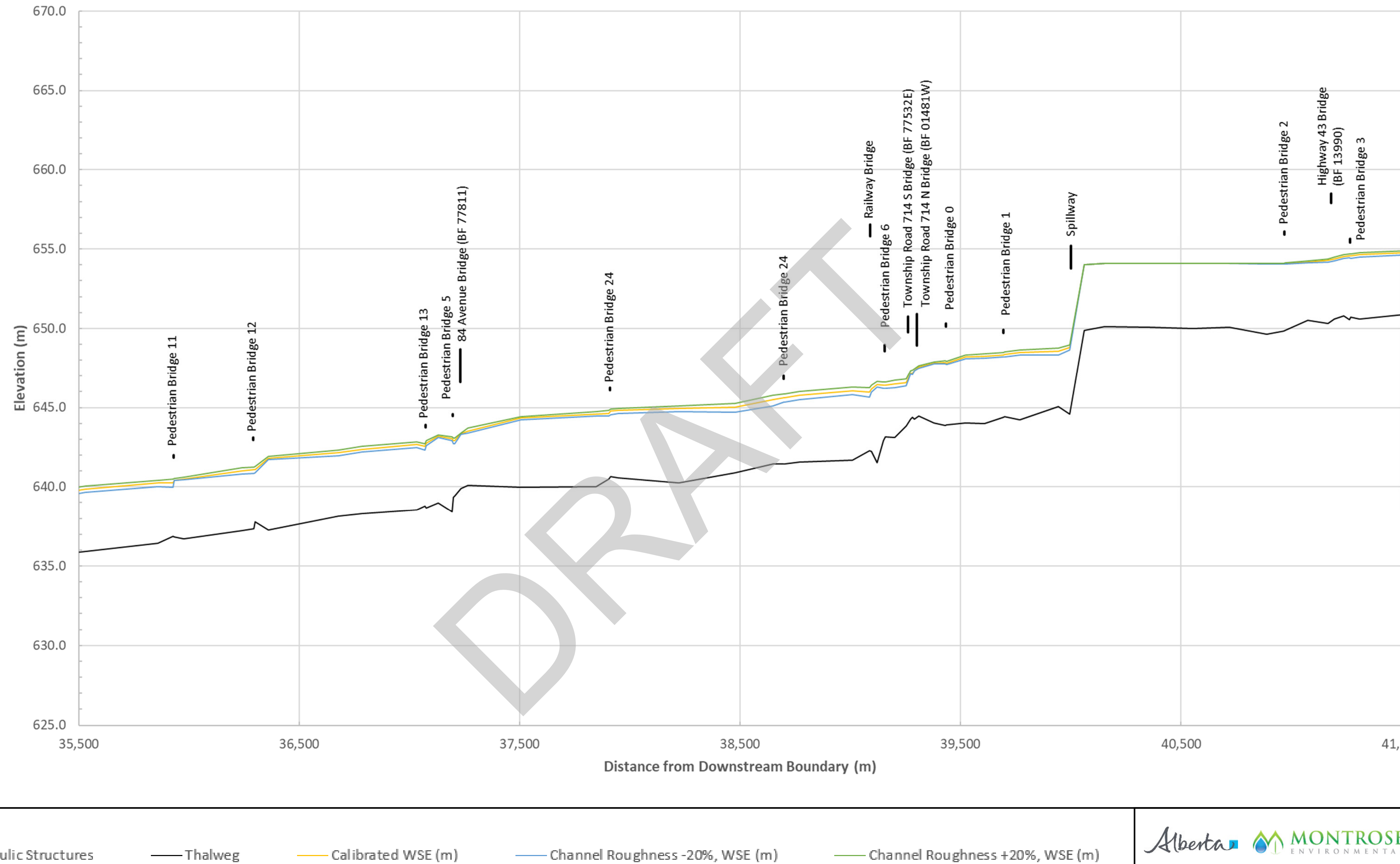


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Channel Manning Roughness
Lower Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 6A

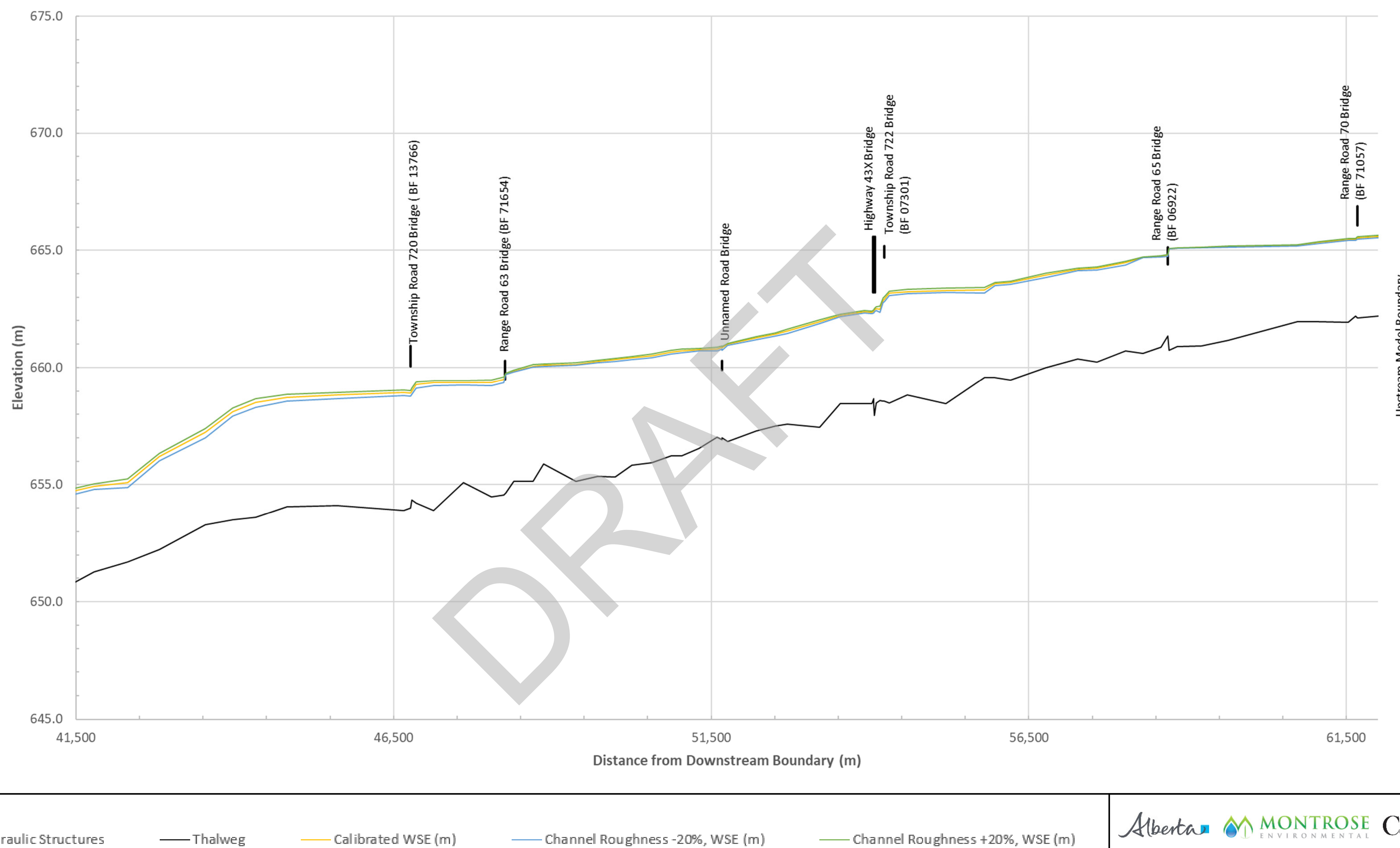


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Channel Manning Roughness
Mid Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 6B

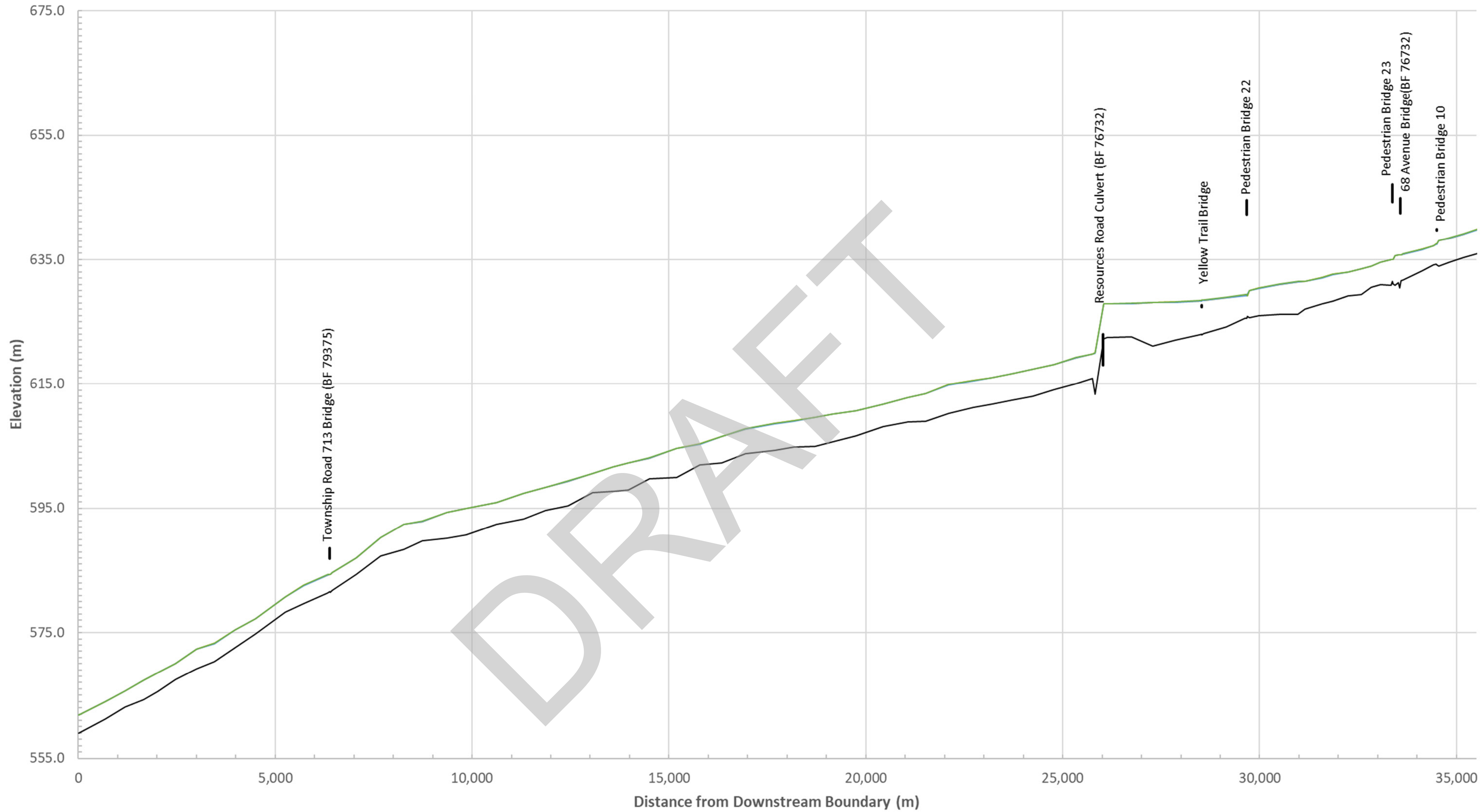


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Channel Manning Roughness
Upper Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 6C

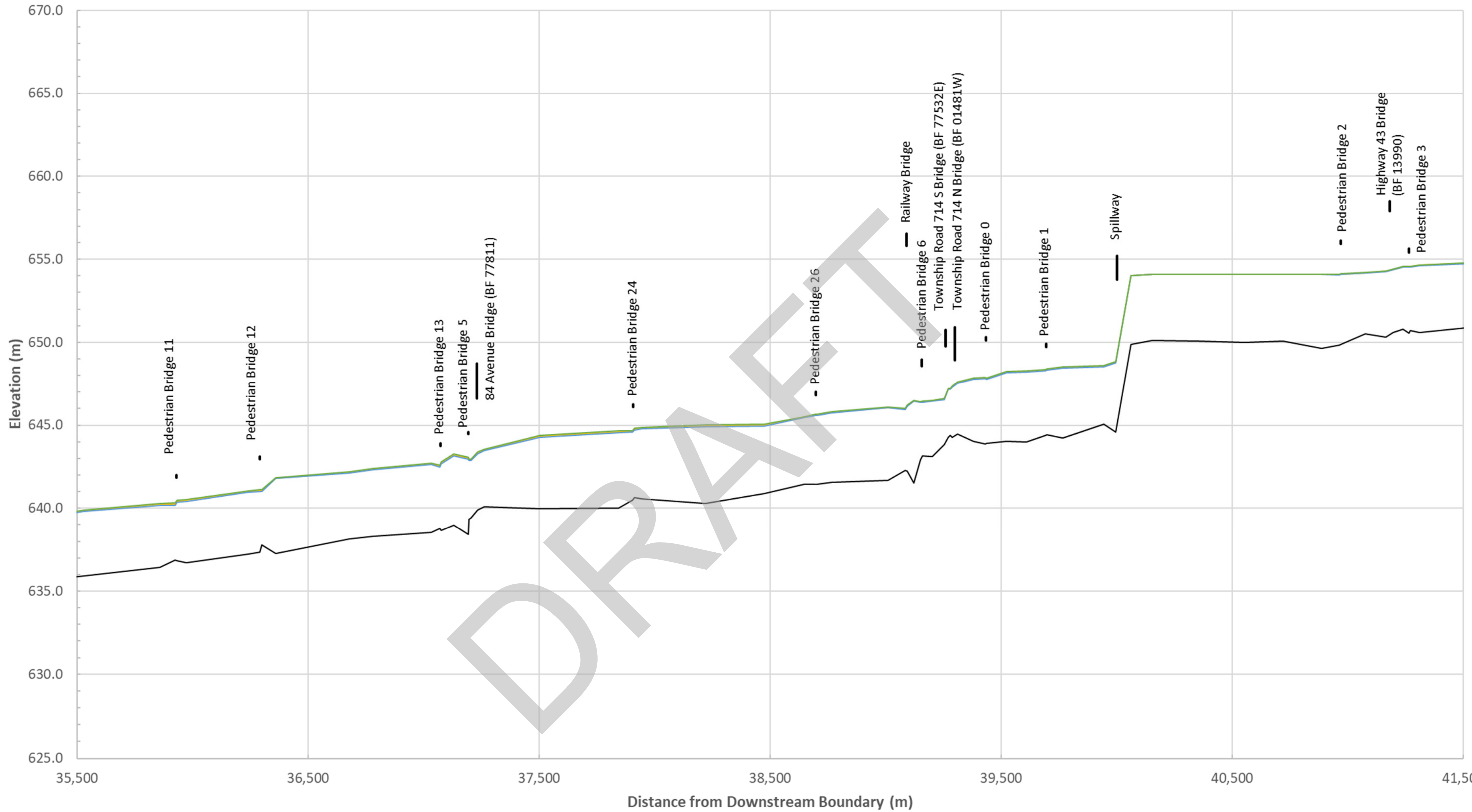


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Overbank Manning Roughness
Lower Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 7A

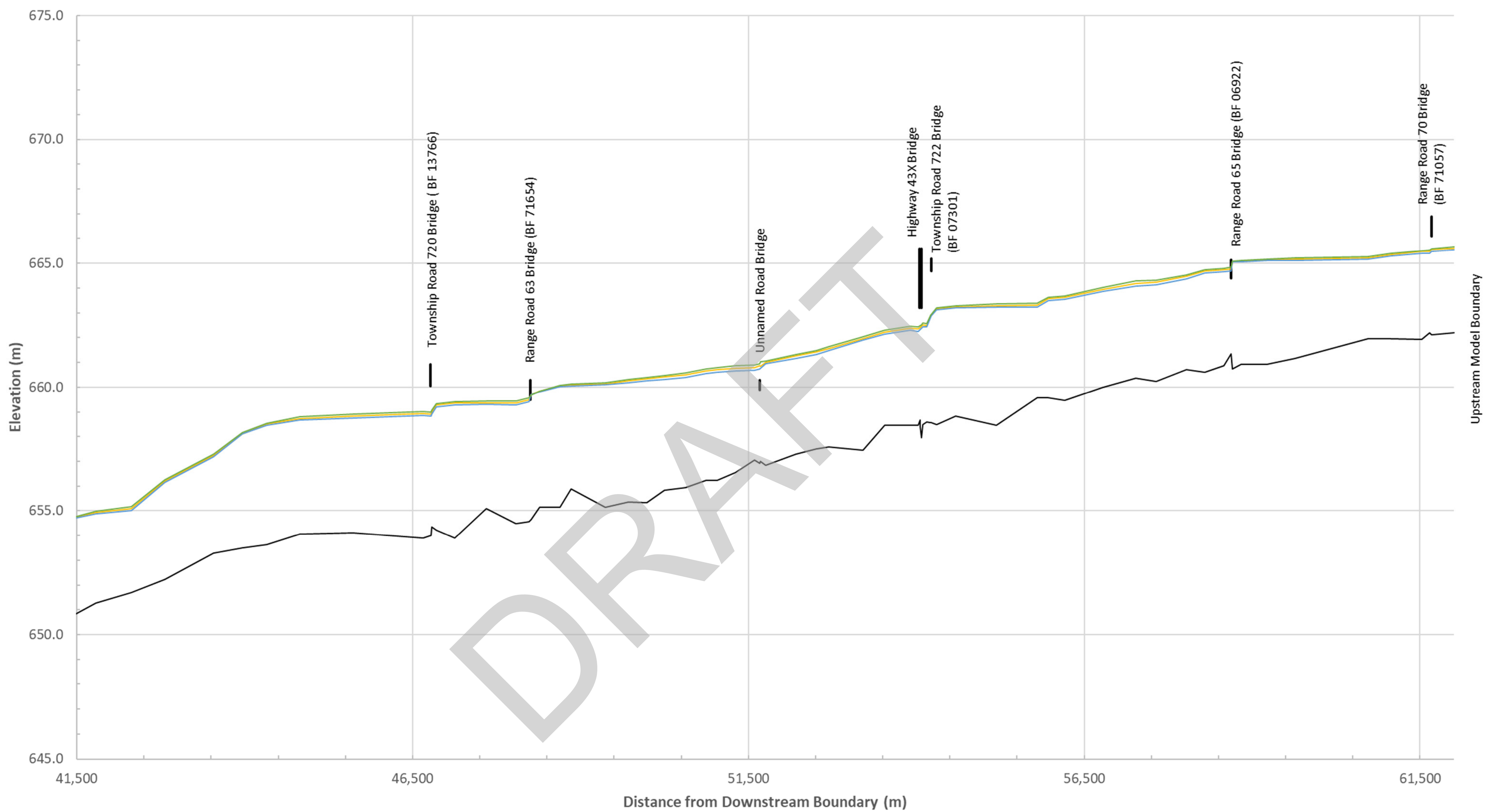


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Overbank Manning Roughness
Mid Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 7B

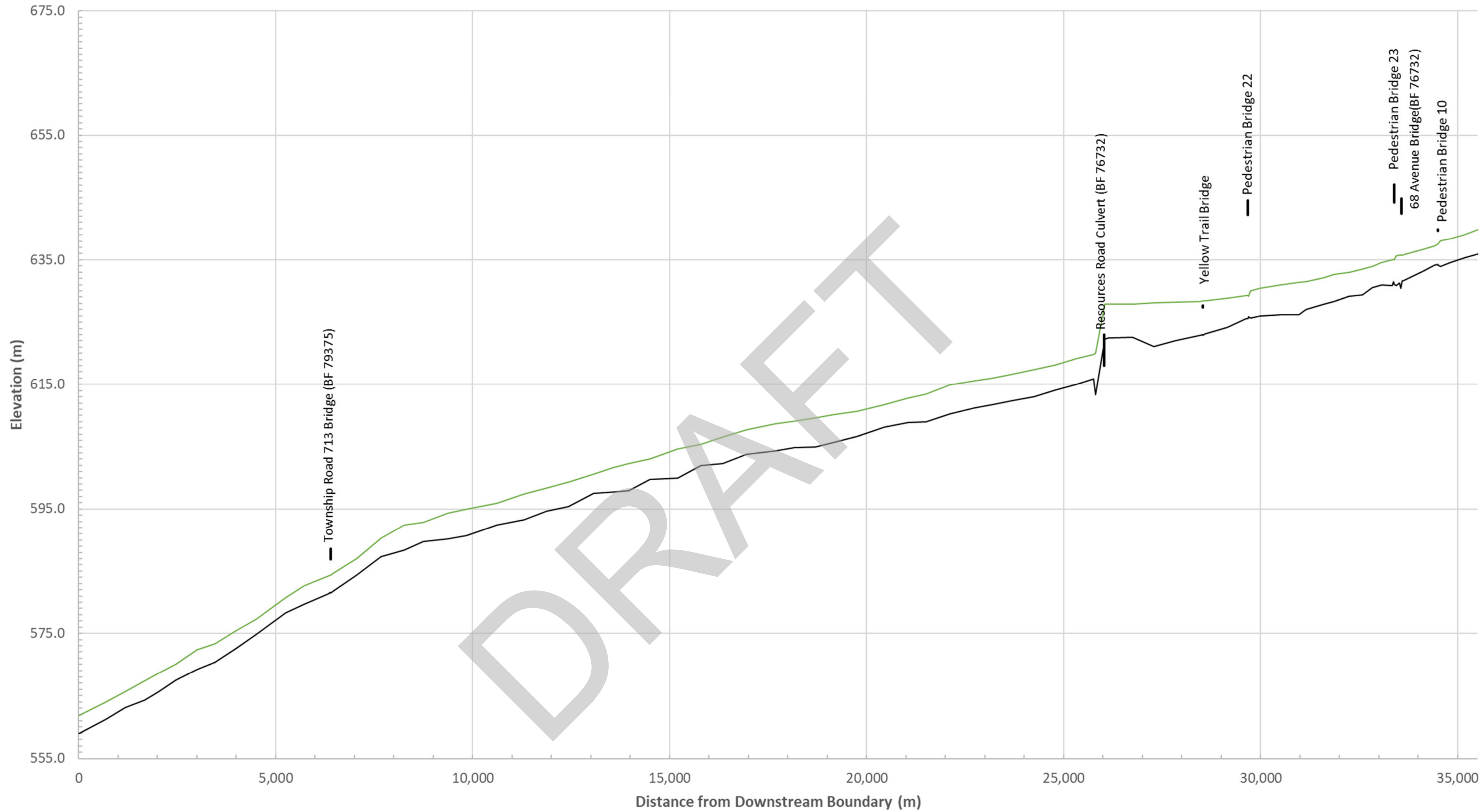


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Sensitivity Analysis Profiles
Variable Overbank Manning Roughness
Upper Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 7C

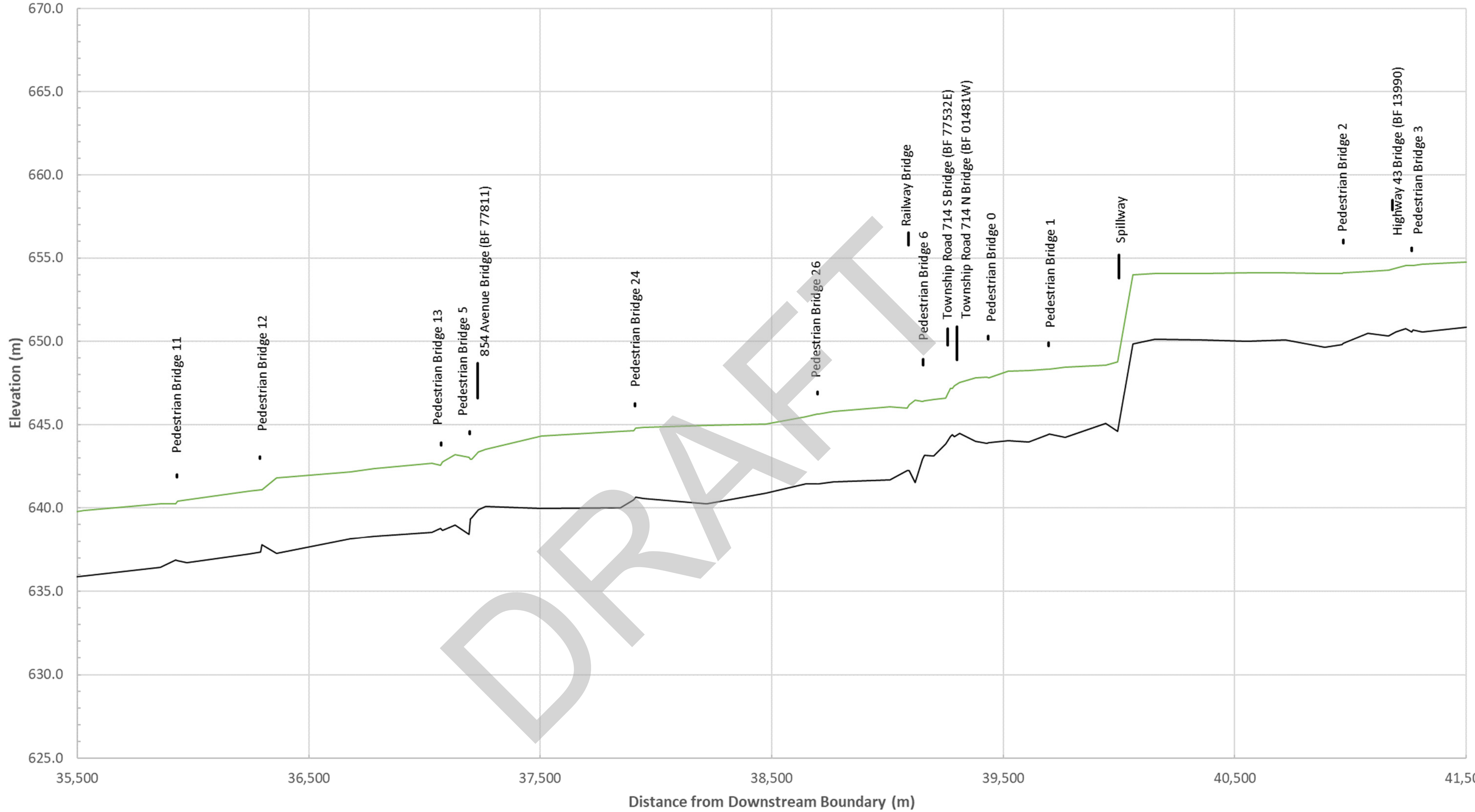


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Design Flood Profile, Lower Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 8A

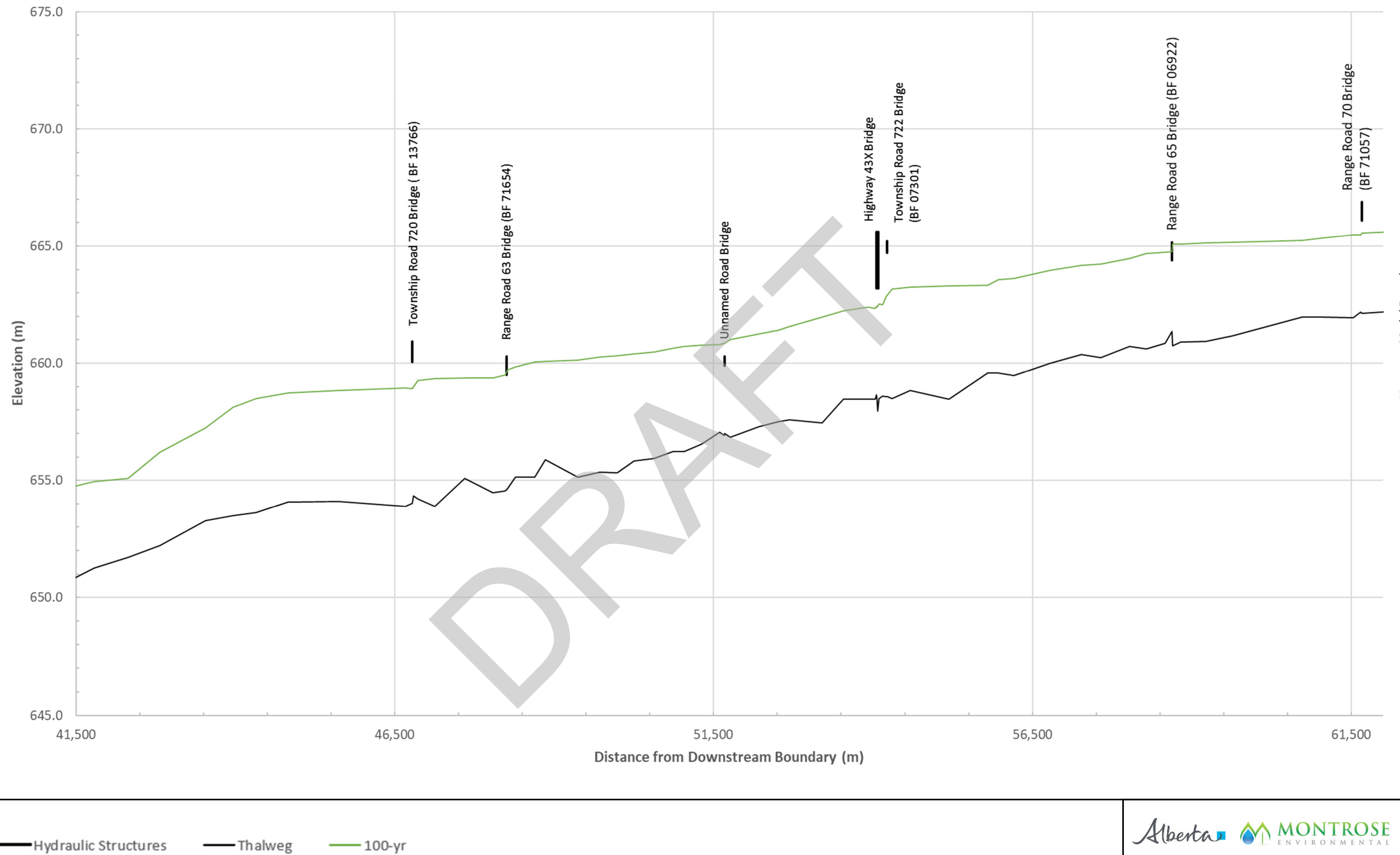


Alberta Environment and Protected Areas
Grande Prairie Flood Study

Design Flood Profile, Mid Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 8B



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Alberta Environment and Protected Areas
Grande Prairie Flood Study

Design Flood Profile, Upper Reach

Date:	Project:	Submitter:	Reviewer:
March 2025	35917	P.Rogers	M.Shome

Figure 8C

TABLE 1: HYDRAULIC STRUCTURE DETAILS

Structure Name	Bounding Cross Sections	Details
Range Road 70 Bridge (BF 06922)	61671.05 and 61644.16	• 25 m long concrete bridge with two concrete piers • Deck width of 8.6 m • Average low chord elevation, El. 666.08 m • Average high chord elevation, El. 666.90 m
Range Road 65 Bridge (BF 71057)	58702.57 and 58686.2	• 25 m long concrete bridge with two concrete piers • Deck width of 8.2 m • Average low chord elevation, El. 664.15 m • Average high chord elevation, El. 665.4 m
Township Road 722 Bridge (BF 07301)	54227.29 and 54209.73	• 36 m long timber trestle bridge with two concrete piers • Deck width of 9.8 m • Average low chord elevation, El. 664.70 m • Average high chord elevation, El. 665.2 m
Highway 43X W Bridge	54096.79 and 54072.7	• 40 m long concrete bridge • Deck width of 13.8 m • Average low chord elevation, El. 665.6 m • Average high chord elevation, El. 663.2 m
Highway 43X E Bridge	54053.88 and 54029.93	• 40 m long concrete bridge • Deck width of 13.8 m • Average low chord elevation, El. 665.6 m • Average high chord elevation, El. 663.2 m
Unnamed Road Bridge	51674.15 and 51665.33	• 18 m long concrete bridge • Deck width of 6.2 m • Average low chord elevation, El. 659.9 m • Average high chord elevation, El. 660.3 m
Range Road 63 Bridge (BF 71654)	48267.62 and 48237.6	• 31 m long concrete bridge • Deck width of 11.5 m • Average low chord elevation, El. 659.50 m • Average high chord elevation, El. 660.30 m
Township Road 720 Bridge (BF 13766)	48267.62 and 48237.6	• 26 m long concrete bridge • Deck width of 13.6 m • Average low chord elevation, El. 660.05 m • Average high chord elevation, El. 660.92 m
Pedestrian Bridge 3	41269.83 and 41263.54	• 44 m long concrete bridge • Deck width of 3.8 m • Average low chord elevation, El. 655.41 m • Average high chord elevation, El. 655.63 m
Highway 43 Bridge (BF 13990)	41194.6 and 41165.23	• 43 m long concrete bridge with two concrete piers • Deck width of 25.7 m • Average low chord elevation, El. 657.9 m • Average high chord elevation, El. 658.5 m
Pedestrian Bridge 2	40970.09 and 40964.22	• 39 m long concrete bridge • Deck width of 3.6 m • Average low chord elevation, El. 655.91 m • Average high chord elevation, El. 656.11 m
Spillway	39994.05 and 40061.16	• 70 m long concrete spillway • Spillway width of 9 m • Gate height of 3.3 m and width of 5.4 m • Gate invert elevation, El. 650.44 m
Pedestrian Bridge 1	39698.45 and 39692.72	• 32 m long concrete bridge • Deck width of 3.6 m • Average low chord elevation, El. 649.92 m • Average high chord elevation, El. 649.73 m
Pedestrian Bridge 0	39436.73 and 39430.16	• 32 m long concrete bridge • Deck width of 3.0 m • Average low chord elevation, El. 650.13 m • Average high chord elevation, El. 650.32 m
Township Road 714 N Bridge (BF 01481W)	39311 and 39288.79	• 46 m long concrete bridge with one concrete pier • Deck width of 17.9 m • Average low chord elevation, El. 648.9 m • Average high chord elevation, El. 650.9 m
Township Road 714 S Bridge (BF77532E)	39271.28 and 39252.25	• 50 m long concrete bridge with one concrete pier • Deck width of 12.0 m • Average low chord elevation, El. 649.75 m • Average high chord elevation, El. 650.75 m

Pedestrian Bridge 6	39158.74 and 39150.5	• 30 m long concrete bridge • Deck width of 3.5 m • Average low chord elevation, El. 648.58 m • Average high chord elevation, El. 648.95 m
Railway Bridge	39094.15 and 39085.34	• 110 m long concrete bridge with 24 supports • Deck width of 5.45 m • Average low chord elevation, El. 655.79 m • Average high chord elevation, El. 656.54 m
Pedestrian Bridge 26	38700.32 and 38695.54	• 28 m long concrete bridge • Deck width of 1.8 m • Average low chord elevation, El. 647 m • Average high chord elevation, El. 646.81 m
Pedestrian Bridge 24	37911.48 and 37904.65	• 28 m long concrete bridge with two concrete piers • Deck width of 3.6 m • Average low chord elevation, El. 646.10 m • Average high chord elevation, El. 646.25 m
84 Avenue Bridge (BF 77811)	37232.52 and 37204.43	• 50 m long concrete bridge • Deck width of 25.8 m • Average low chord elevation, El. 646.60 m • Average high chord elevation, El. 648.70 m
Pedestrian Bridge 5	37197.68 and 37192.23	• 27 m long concrete bridge with two concrete piers • Deck width of 3.5 m • Average low chord elevation, El. 644.45 m • Average high chord elevation, El. 644.60 m
Pedestrian Bridge 13	37076.19 and 37070	• 21 m long concrete bridge • Deck width of 3.5 m • Average low chord elevation, El. 643.75 m • Average high chord elevation, El. 643.90 m
Pedestrian Bridge 12	36298.75 and 36292.38	• 23 m long concrete bridge • Deck width of 3.5 m • Average low chord elevation, El. 642.95 m • Average high chord elevation, El. 643.10 m
Pedestrian Bridge 11	35933.33 and 35925.88	• 29 m long concrete bridge • Deck width of 3.8 m • Average low chord elevation, El. 641.85 m • Average high chord elevation, El. 642 m
Pedestrian Bridge 10	34497.99 and 34490.29	• 35 m long concrete bridge • Deck width of 3.8 m • Average low chord elevation, El. 639.65 m • Average high chord elevation, El. 639.9 m
68 Avenue Bridge N (BF 86046)	33590.46 and 33354.07	• 63 m long concrete bridge with two concrete piers • Deck width of 30.8 m • Average low chord elevation, El. 642.40 m • Average high chord elevation, El. 644.90 m
Pedestrian Bridge 23	33385.56 and 33375.55	• 90 m long concrete bridge with three concrete piers • Deck width of 4.35 m • Average low chord elevation, El. 644.25 m • Average high chord elevation, El. 647.10 m
Pedestrian Bridge 22 (BF 71060)	29682.43 and 29674.83	• 90 m long concrete bridge with three concrete piers • Deck width of 4.0 m • Average low chord elevation, El. 642.20 m • Average high chord elevation, El. 644.5 m
Yellow Trail Bridge	28535.87 and 28530.05	• 30 m long concrete bridge • Deck width of 1.9 m • Average low chord elevation, El. 627.4 m • Average high chord elevation, El. 627.65 m
Resources Road Culvert (BF 76732)	26041.09 and 25815.08	• Two 5 m diameter culverts • Culvert length of 188 m • Average low chord elevation, El. 618 m • Average high chord elevation, El. 623 m
Township Road 713 Bridge (BF 79375)	6396.193 and 6383.527	• 40 m long concrete bridge • Deck width of 9.0 m • Average low chord elevation, El. 586.94 m • Average high chord elevation, El. 588.63 m

TABLE 2: CALIBRATION RESULTS

River Station	Observed WSE (m)	Simulated WSE[1] (m)		Difference (m)	
		10-yr	20-yr	10-yr	20-yr
54227.29	662.26	662.04	662.31	0.22	-0.05
54152.35	662.64	661.88	662.10	0.76	0.54
41238.70	652.79	653.24	653.66	-0.45	-0.87
39379.67	645.90	646.79	647.12	-0.89	-1.22
39280.27	645.71	646.25	646.54	-0.54	-0.83
39252.25	645.51	645.55	645.81	-0.04	-0.30
37263.70	641.96	642.24	642.60	-0.28	-0.64
37204.43	641.82	641.63	642.03	0.19	-0.21
33375.55	634.18	633.82	634.17	0.36	0.01

1. WSE = water surface elevation

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
BR198	62105.57	664.12	664.61	664.81	665.13	665.32	665.41	665.55	665.62	665.84	665.98	666.03	666.19	666.32
BR197b	61671.05	664.10	664.59	664.78	665.06	665.25	665.33	665.48	665.55	665.84	665.98	666.03	666.19	666.32
BR197a	61644.16	664.10	664.58	664.78	665.04	665.21	665.29	665.41	665.47	665.72	665.85	665.90	666.01	666.12
BR196	61528.78	664.10	664.58	664.77	665.03	665.20	665.28	665.41	665.47	665.70	665.83	665.88	665.99	666.10
BR195	61063.56	664.08	664.56	664.75	664.95	665.11	665.18	665.29	665.35	665.55	665.67	665.72	665.84	665.94
BR194	60726.66	664.08	664.55	664.73	664.89	665.02	665.09	665.18	665.23	665.38	665.48	665.53	665.62	665.69
BR193	59636.52	664.06	664.53	664.72	664.85	664.97	665.04	665.12	665.17	665.29	665.38	665.44	665.51	665.57
BR192	59213.71	663.94	664.36	664.69	664.81	664.94	665.01	665.09	665.14	665.26	665.35	665.41	665.48	665.53
BR191	58830.53	663.74	664.31	664.65	664.77	664.90	664.97	665.04	665.09	665.20	665.29	665.35	665.42	665.46
BR190b	58702.57	663.69	664.29	664.64	664.75	664.88	664.95	665.02	665.07	665.18	665.27	665.32	665.39	665.43
BR190a	58686.20	663.67	664.20	664.45	664.47	664.57	664.64	664.72	664.77	664.90	665.03	665.10	665.21	665.29
BR189	58581.16	663.61	664.09	664.24	664.42	664.52	664.59	664.68	664.73	664.86	664.98	665.08	665.19	665.27
BR188	58291.76	663.46	664.02	664.22	664.36	664.47	664.55	664.64	664.69	664.82	664.95	665.04	665.16	665.24
BR187	58021.80	663.28	663.84	663.98	664.13	664.25	664.32	664.41	664.47	664.60	664.74	664.85	664.98	665.07
BR186	57572.61	663.03	663.69	663.71	663.81	663.96	664.06	664.15	664.23	664.43	664.60	664.72	664.88	664.98
BR185	57267.51	662.81	663.54	663.66	663.75	663.91	664.02	664.11	664.18	664.39	664.57	664.69	664.85	664.95
BR184	56773.94	662.40	663.13	663.35	663.52	663.68	663.80	663.87	663.95	664.16	664.35	664.49	664.66	664.77
BR183	56209.22	662.02	662.70	663.04	663.17	663.28	663.39	663.53	663.62	663.87	664.10	664.27	664.46	664.59
BR182	55965.68	661.82	662.52	662.87	663.11	663.21	663.33	663.47	663.57	663.83	664.08	664.24	664.43	664.56
BR181	55796.42	661.68	662.39	662.70	662.89	662.93	663.05	663.20	663.32	663.63	663.90	664.07	664.28	664.42
BR180	55195.32	661.45	662.12	662.34	662.62	662.84	662.99	663.17	663.29	663.62	663.90	664.08	664.29	664.42
BR179	54587.25	661.23	661.97	662.23	662.54	662.78	662.93	663.12	663.24	663.58	663.86	664.04	664.25	664.39
BR178	54302.34	661.06	661.82	662.13	662.45	662.70	662.86	663.04	663.17	663.51	663.80	663.98	664.19	664.33
BR177b	54227.29	661.03	661.79	662.04	662.31	662.52	662.65	662.81	662.92	663.20	663.44	663.61	663.83	663.99
BR177a	54209.73	661.02	661.78	662.02	662.29	662.49	662.62	662.77	662.87	663.15	663.38	663.53	663.72	663.85
BR176	54152.35	660.95	661.69	661.88	662.10	662.25	662.33	662.43	662.50	662.68	662.82	662.92	663.06	663.14
BR175b	54096.79	660.94	661.69	661.88	662.10	662.25	662.34	662.44	662.52	662.70	662.86	662.96	663.11	663.20
BR175a	54072.70	660.93	661.67	661.86	662.07	662.21	662.29	662.38	662.45	662.61	662.73	662.82	662.94	663.01
BR174	54061.55	660.92	661.66	661.84	662.05	662.18	662.26	662.34	662.40	662.54	662.66	662.73	662.83	662.90
BR173b	54053.88	660.92	661.66	661.84	662.05	662.19	662.27	662.35	662.41	662.55	662.67	662.75	662.85	662.91
BR173a	54029.93	660.91	661.65	661.83	662.02	662.15	662.22	662.30	662.35	662.47	662.56	662.62	662.69	662.73
BR172	53912.08	660.86	661.62	661.81	662.02	662.16	662.24	662.33	662.39	662.54	662.66	662.74	662.84	662.90
BR171	53531.90	660.67	661.42	661.61	661.84	662.00	662.08	662.17	662.23	662.38	662.50	662.58	662.68	662.75
BR170	53205.43	660.46	661.20	661.41	661.62	661.75	661.83	661.91	661.97	662.11	662.23	662.31	662.41	662.47
BR169	52695.44	660.15	660.84	661.02	661.24	661.31	661.39	661.49	661.56	661.71	661.83	661.93	662.03	662.10
BR168	52511.77	660.04	660.74	660.85	661.02	661.16	661.24	661.35	661.42	661.58	661.71	661.82	661.94	662.01
BR167	52209.14	659.86	660.51	660.67	660.84	660.98	661.07	661.18	661.26	661.42	661.55	661.67	661.79	661.86
BR166	51761.57	659.60	660.33	660.45	660.59	660.73	660.82	660.93	661.01	661.14	661.28	661.41	661.54	661.62
BR165b	51674.15	659.53	660.21	660.34	660.45	660.57	660.65	660.77	660.84	661.12	661.26	661.40	661.53	661.61
BR165a	51665.33	659.53	660.20	660.33	660.44	660.56	660.65	660.78	660.86	661.11	661.25	661.39	661.53	661.61
BR164	51591.42	659.49	660.11	660.15	660.35	660.48	660.57	660.71	660.79	661.01	661.22	661.37	661.50	661.58
BR163	51306.88	659.20	659.80	660.02	660.29	660.43	660.53	660.68	660.77	661.00	661.19	661.34	661.47	661.56
BR162	51036.21	659.00	659.68	659.89	660.20	660.34	660.45	660.62	660.71	660.95	661.15	661.30	661.44	661.52

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
BR161	50863.87	658.91	659.56	659.85	660.16	660.29	660.40	660.57	660.65	660.89	661.09	661.24	661.37	661.45
BR160	50564.16	658.74	659.38	659.65	659.94	660.12	660.22	660.41	660.49	660.73	660.93	661.09	661.22	661.30
BR159	50253.50	658.58	659.20	659.49	659.82	660.01	660.11	660.32	660.41	660.65	660.86	661.03	661.16	661.24
BR158	49988.23	658.47	659.14	659.43	659.76	659.94	660.03	660.24	660.33	660.56	660.77	660.93	661.05	661.13
BR157	49713.16	658.38	659.04	659.30	659.63	659.86	659.95	660.18	660.26	660.49	660.71	660.88	661.00	661.07
BR156	49371.68	658.30	658.92	659.10	659.39	659.61	659.77	660.07	660.14	660.38	660.60	660.79	660.90	660.97
BR155	48864.88	658.07	658.69	658.95	659.28	659.54	659.70	660.02	660.09	660.32	660.55	660.74	660.85	660.92
BR154	48695.22	657.99	658.64	658.90	659.24	659.50	659.66	659.99	660.06	660.29	660.52	660.71	660.82	660.89
BR153	48387.18	657.88	658.50	658.71	659.03	659.27	659.41	659.78	659.83	660.03	660.26	660.46	660.54	660.59
BR152b	48267.62	657.82	658.42	658.58	658.88	659.12	659.26	659.68	659.71	659.88	660.22	660.43	660.50	660.55
BR152a	48237.60	657.82	658.41	658.56	658.86	659.09	659.23	659.39	659.50	659.64	659.84	660.13	660.17	660.21
BR151	48037.52	657.75	658.32	658.42	658.69	658.93	659.08	659.25	659.37	659.65	659.89	660.13	660.19	660.22
BR150	47599.79	657.60	658.05	658.38	658.69	658.93	659.08	659.25	659.37	659.64	659.87	660.12	660.17	660.21
BR149	47126.99	657.49	658.04	658.35	658.66	658.91	659.06	659.24	659.35	659.63	659.86	660.12	660.17	660.20
BR148	46857.21	657.44	657.98	658.27	658.57	658.80	658.96	659.15	659.27	659.62	659.86	660.11	660.16	660.20
BR147b	46789.16	657.40	657.91	658.17	658.44	658.63	658.76	658.90	658.99	659.25	659.41	660.05	660.10	660.13
BR147a	46771.18	657.39	657.89	658.14	658.39	658.58	658.69	658.83	658.91	659.14	659.32	659.55	659.72	659.82
BR146	46661.28	657.35	657.83	658.08	658.34	658.55	658.68	658.84	658.94	659.22	659.43	659.56	659.72	659.82
BR145	45615.48	656.81	657.42	657.78	658.10	658.36	658.53	658.72	658.83	659.13	659.35	659.49	659.66	659.77
BR144	44821.39	656.39	657.15	657.58	657.95	658.23	658.42	658.62	658.73	659.05	659.28	659.42	659.59	659.70
BR143	44326.25	656.08	656.86	657.29	657.69	657.99	658.18	658.39	658.50	658.82	659.05	659.20	659.37	659.48
BR142	43962.83	655.76	656.53	656.96	657.36	657.64	657.83	658.03	658.12	658.40	658.59	658.71	658.84	658.91
BR141	43533.04	655.23	655.95	656.35	656.71	656.90	657.03	657.18	657.25	657.44	657.59	657.70	657.85	657.93
BR140	42812.24	654.20	654.86	655.21	655.56	655.78	655.92	656.09	656.21	656.49	656.73	656.91	657.09	657.20
BR139	42312.92	653.46	654.08	654.43	654.50	654.72	654.85	655.00	655.09	655.34	655.63	655.84	656.05	656.17
BR138	41788.43	652.92	653.52	653.89	654.16	654.45	654.64	654.81	654.94	655.27	655.63	655.89	656.11	656.23
BR137	41310.43	652.41	652.93	653.32	653.73	654.09	654.32	654.50	654.63	654.97	655.38	655.67	655.90	656.01
BR136b	41269.83	652.36	652.88	653.27	653.68	654.04	654.25	654.42	654.55	654.89	655.36	655.66	655.89	656.01
BR136a	41263.54	652.37	652.88	653.28	653.69	654.04	654.26	654.43	654.55	654.87	655.26	655.60	655.85	655.97
BR135	41238.70	652.33	652.84	653.24	653.66	654.02	654.24	654.41	654.53	654.85	655.25	655.58	655.82	655.94
BR134	41194.60	652.29	652.78	653.16	653.56	653.90	654.11	654.26	654.37	654.65	655.03	655.36	655.57	655.67
BR133	41165.23	652.26	652.73	653.10	653.49	653.83	654.03	654.16	654.27	654.53	654.91	655.26	655.47	655.56
BR132	41074.72	652.18	652.61	652.98	653.38	653.74	653.95	654.07	654.18	654.50	654.96	655.34	655.58	655.68
BR131b	40970.09	652.08	652.47	652.84	653.25	653.63	653.85	653.98	654.10	654.44	654.94	655.33	655.57	655.67
BR131a	40964.22	652.08	652.46	652.82	653.24	653.61	653.80	653.95	654.07	654.41	654.92	655.32	655.52	655.63
BR130	40887.27	652.03	652.38	652.74	653.21	653.62	653.81	653.96	654.08	654.41	654.91	655.31	655.51	655.61
BR129	40718.83	651.94	652.32	652.75	653.22	653.63	653.82	653.98	654.09	654.43	654.92	655.32	655.52	655.63
BR128	40552.65	651.77	652.27	652.73	653.22	653.62	653.82	653.97	654.09	654.42	654.92	655.32	655.52	655.63
BR127	40357.23	651.62	652.25	652.72	653.21	653.62	653.81	653.97	654.08	654.42	654.92	655.31	655.52	655.62
BR126	40153.42	651.60	652.24	652.71	653.20	653.61	653.81	653.96	654.08	654.41	654.91	655.31	655.51	655.61
BR125	40061.16	651.55	652.18	652.66	653.14	653.55	653.74	653.89	654.00	654.31	654.82	655.22	655.41	655.51
BR124	39994.05	646.52	647.15	647.56	647.94	648.24	648.42	648.64	648.78	649.18	649.45	649.62	649.84	649.99
BR123	39942.29	646.37	646.97	647.36	647.73	648.03	648.21	648.42	648.56	648.92	649.27	649.51	649.79	649.96
BR122	39767.21	646.22	646.84	647.25	647.64	647.94	648.12	648.33	648.47	648.90	649.27	649.52	649.80	649.98
BR121b	39698.45	646.16	646.77	647.17	647.54	647.84	648.01	648.22	648.35	648.73	649.06	649.24	649.52	649.77
BR121a	39692.72	646.15	646.76	647.16	647.53	647.82	648.00	648.20	648.34	648.71	649.03	649.23	649.50	649.69
BR120	39608.68	646.05	646.64	647.03	647.40	647.69	647.87	648.09	648.24	648.63	648.98	649.21	649.50	649.69
BR119	39521.91	645.99	646.58	646.98	647.35	647.64	647.83	648.06	648.21	648.62	648.98	649.20	649.49	649.68

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
BR118b	39436.73	645.91	646.46	646.82	647.14	647.38	647.53	647.71	647.82	648.12	648.37	648.53	648.76	648.91
BR118a	39430.16	645.91	646.46	646.82	647.15	647.40	647.55	647.73	647.84	648.14	648.40	648.56	648.80	648.94
BR117	39379.67	645.88	646.43	646.78	647.12	647.36	647.51	647.69	647.81	648.12	648.40	648.59	648.87	649.06
BR116b	39311.00	645.72	646.21	646.55	646.88	647.12	647.26	647.44	647.55	647.86	648.12	648.28	648.49	648.62
BR116a	39288.79	645.56	646.03	646.34	646.67	646.91	647.05	647.22	647.34	647.66	647.93	648.10	648.33	648.47
BR115	39280.27	645.49	645.93	646.24	646.53	646.75	646.90	647.07	647.18	647.52	647.81	647.99	648.23	648.37
BR114b	39271.28	645.47	645.93	646.24	646.53	646.74	646.89	647.06	647.17	647.52	647.80	647.98	648.23	648.37
BR114a	39252.25	644.87	645.30	645.55	645.81	646.04	646.20	646.42	646.57	646.97	647.31	647.53	647.82	647.96
BR113	39200.55	644.48	644.89	645.20	645.56	645.88	646.08	646.33	646.49	646.92	647.28	647.50	647.79	647.94
BR112b	39158.74	644.21	644.68	645.05	645.46	645.79	646.00	646.26	646.42	646.86	647.21	647.44	647.73	647.87
BR112a	39150.50	643.92	644.55	645.00	645.42	645.76	645.97	646.23	646.40	646.84	647.20	647.43	647.72	647.87
BR111	39120.36	643.97	644.64	645.07	645.49	645.83	646.04	646.30	646.47	646.91	647.27	647.49	647.78	647.92
BR110b	39094.15	643.88	644.52	644.92	645.30	645.61	645.80	646.03	646.18	646.57	646.90	647.10	647.37	647.50
BR110a	39085.34	643.76	644.36	644.73	645.10	645.40	645.59	645.83	645.97	646.36	646.69	646.90	647.19	647.32
BR109	39009.61	643.72	644.35	644.76	645.15	645.47	645.67	645.92	646.07	646.48	646.83	647.05	647.34	647.49
BR108	38767.08	643.42	644.08	644.49	644.88	645.19	645.38	645.62	645.77	646.16	646.49	646.69	646.98	647.11
BR107b	38700.32	643.32	643.99	644.39	644.77	645.06	645.24	645.48	645.61	645.97	646.29	646.49	646.79	646.93
BR107a	38695.54	643.32	643.98	644.39	644.76	645.06	645.24	645.48	645.61	645.97	646.28	646.49	646.78	646.92
BR106	38647.20	643.19	643.84	644.23	644.60	644.89	645.08	645.34	645.48	645.88	646.22	646.43	646.73	646.87
BR105	38475.17	642.96	643.57	643.93	644.26	644.52	644.67	644.91	645.02	645.34	645.61	645.79	646.15	646.27
BR104	38219.94	642.86	643.46	643.83	644.16	644.43	644.59	644.84	644.96	645.31	645.60	645.79	646.16	646.28
BR103	37945.44	642.69	643.26	643.67	644.01	644.28	644.44	644.71	644.83	645.17	645.48	645.68	646.07	646.19
BR102b	37911.48	642.66	643.21	643.58	643.94	644.20	644.37	644.66	644.78	645.14	645.46	645.67	646.07	646.19
BR102a	37904.65	642.65	643.20	643.56	643.90	644.15	644.31	644.52	644.64	645.02	645.34	645.56	646.02	646.14
BR101	37844.86	642.65	643.20	643.56	643.89	644.14	644.30	644.49	644.60	644.94	645.23	645.42	645.87	645.98
BR100	37504.07	642.44	642.92	643.25	643.56	643.82	643.99	644.21	644.33	644.69	645.00	645.22	645.74	645.85
BR099	37263.70	641.33	641.87	642.24	642.60	642.90	643.08	643.30	643.52	644.09	644.49	644.72	645.46	645.55
BR098b	37232.52	641.15	641.73	642.12	642.49	642.79	642.97	643.19	643.34	643.72	644.08	644.34	645.16	645.21
BR098a	37204.43	640.70	641.20	641.63	642.03	642.34	642.53	642.76	642.92	643.29	643.58	643.78	645.04	645.07
BR097b	37197.68	640.70	641.21	641.63	642.03	642.34	642.53	642.76	642.91	643.29	643.58	643.79	645.06	645.09
BR097a	37192.23	640.64	641.33	641.76	642.15	642.46	642.65	642.88	643.04	643.41	643.71	643.92	644.03	644.12
BR096	37131.10	640.60	641.32	641.79	642.24	642.59	642.79	643.04	643.21	643.62	643.94	644.16	644.31	644.44
BR095b	37076.19	640.42	641.13	641.55	641.92	642.22	642.39	642.60	642.75	643.13	643.43	643.69	643.78	643.91
BR095a	37070.00	640.36	641.07	641.47	641.82	642.08	642.23	642.42	642.55	642.85	643.13	643.33	643.59	643.79
BR094	37032.70	640.34	641.06	641.49	641.87	642.16	642.32	642.53	642.68	643.03	643.33	643.52	643.78	643.96
BR093	36782.49	639.93	640.62	641.04	641.43	641.77	641.98	642.23	642.37	642.80	643.16	643.38	643.65	643.85
BR092	36677.71	639.74	640.45	640.88	641.27	641.58	641.76	642.00	642.15	642.54	642.89	643.11	643.39	643.59
BR091	36360.77	639.39	640.08	640.52	640.92	641.24	641.44	641.67	641.82	642.29	642.68	642.93	643.24	643.45
BR090b	36298.75	639.08	639.76	640.16	640.49	640.72	640.85	640.99	641.08	641.31	641.58	641.82	642.05	642.35
BR090a	36292.38	639.10	639.77	640.16	640.49	640.72	640.84	640.98	641.07	641.29	641.43	641.51	641.61	641.67
BR089	36240.32	638.96	639.62	640.02	640.37	640.60	640.75	640.91	641.02	641.29	641.50	641.64	641.82	641.93
BR088	35974.21	638.55	639.15	639.53	639.88	640.11	640.24	640.39	640.48	640.71	640.89	641.01	641.18	641.29
BR087b	35933.33	638.43	639.06	639.46	639.83	640.05	640.18	640.33	640.41	640.65	640.86	641.00	641.19	641.32
BR087a	35925.88	638.35	638.94	639.32	639.66	639.85	639.99	640.15	640.26	640.57	640.82	640.98	641.18	641.31
BR086	35858.09	638.19	638.81	639.20	639.54	639.80	639.95	640.12	640.24	640.55	640.80	640.95	641.16	641.29
BR085	35529.54	637.62	638.29	638.70	639.08	639.37	639.55	639.74	639.87	640.20	640.46	640.63	640.85	640.99
BR084	35166.82	636.99	637.63	638.01	638.34	638.59	638.74	638.92	639.04	639.36	639.63	639.80	640.03	640.17
BR083	34823.97	636.31	636.93	637.31	637.65	637.92	638.09	638.30	638.43	638.80	639.08	639.26	639.50	639.66

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
BR082	34555.46	635.88	636.48	636.85	637.22	637.52	637.70	637.93	638.07	638.46	638.83	639.05	639.34	639.53
BR081b	34497.99	635.70	636.24	636.56	636.85	637.09	637.23	637.40	637.50	637.79	638.04	638.19	638.40	638.54
BR081a	34490.29	635.68	636.22	636.54	636.84	637.07	637.22	637.39	637.49	637.77	638.00	638.13	638.31	638.41
BR080	34409.10	635.49	636.01	636.31	636.58	636.80	636.94	637.10	637.21	637.51	637.78	637.92	638.13	638.25
BR079	34126.81	634.90	635.50	635.79	636.05	636.26	636.39	636.56	636.68	637.01	637.33	637.51	637.76	637.91
BR078	33634.63	633.39	634.01	634.41	634.84	635.19	635.43	635.71	635.89	636.38	636.80	637.03	637.32	637.50
BR077b	33590.46	633.15	633.81	634.25	634.69	635.05	635.28	635.57	635.75	636.22	636.63	636.86	637.13	637.31
BR077a	33554.07	633.16	633.84	634.29	634.72	635.07	635.29	635.56	635.73	636.19	636.59	636.81	637.08	637.25
BR076	33519.67	633.15	633.83	634.28	634.72	635.08	635.30	635.58	635.75	636.22	636.63	636.85	637.13	637.30
BR075	33435.27	633.09	633.76	634.20	634.63	634.99	635.21	635.48	635.66	636.13	636.53	636.76	637.04	637.21
BR074b	33385.56	632.91	633.49	633.86	634.21	634.50	634.68	634.88	635.02	635.34	635.65	635.81	636.03	636.16
BR074a	33375.55	632.85	633.44	633.82	634.17	634.46	634.64	634.84	634.98	635.31	635.54	635.68	635.89	636.03
BR073	33343.09	632.83	633.42	633.79	634.16	634.45	634.64	634.85	634.98	635.34	635.61	635.78	636.00	636.15
BR072	33074.16	632.45	633.00	633.37	633.74	634.03	634.21	634.43	634.57	634.93	635.24	635.43	635.69	635.87
BR071	32840.75	631.77	632.38	632.75	633.10	633.37	633.55	633.76	633.90	634.27	634.55	634.71	634.93	635.12
BR070	32583.33	631.16	631.81	632.23	632.61	632.93	633.13	633.36	633.52	633.91	634.24	634.45	634.75	635.00
BR069	32241.86	630.57	631.20	631.63	632.04	632.38	632.59	632.83	632.98	633.36	633.66	633.85	634.14	634.40
BR068	31864.66	630.06	630.75	631.21	631.66	632.02	632.24	632.48	632.63	633.02	633.32	633.52	633.86	634.16
BR067	31597.48	629.61	630.29	630.74	631.16	631.50	631.70	631.94	632.09	632.48	632.81	633.04	633.44	633.82
BR066	31155.45	628.88	629.65	630.14	630.58	630.92	631.12	631.35	631.50	631.88	632.19	632.45	632.95	633.40
BR065	30965.52	628.74	629.54	630.04	630.49	630.84	631.04	631.28	631.43	631.82	632.14	632.42	632.94	633.41
BR064	30498.08	628.47	629.24	629.71	630.14	630.46	630.65	630.87	631.00	631.35	631.66	631.97	632.58	633.14
BR063	29982.19	627.94	628.62	629.05	629.45	629.80	630.01	630.24	630.38	630.73	631.09	631.50	632.29	632.94
BR062	29733.21	627.57	628.21	628.64	629.05	629.37	629.57	629.84	630.03	630.44	630.86	631.35	632.19	632.88
BR061b	29682.43	627.24	627.75	628.10	628.42	628.70	628.89	629.15	629.13	629.52	630.46	631.10	632.08	632.80
BR061a	29674.83	627.28	627.83	628.19	628.52	628.78	628.94	629.15	629.29	629.63	630.46	631.08	632.05	632.77
BR060	29617.88	627.13	627.72	628.10	628.45	628.73	628.91	629.14	629.29	629.68	630.54	631.14	632.09	632.80
BR059	29150.09	626.19	626.88	627.32	627.74	628.12	628.35	628.66	628.87	629.44	630.44	631.08	632.06	632.78
BR058	28581.13	625.38	626.16	626.65	627.15	627.60	627.88	628.23	628.44	629.09	630.23	630.92	631.94	632.69
BR057b	28535.87	625.36	626.14	626.64	627.12	627.58	627.85	628.20	628.42	629.07	630.21	630.90	631.92	632.68
BR057a	28530.05	625.36	626.14	626.64	627.13	627.54	627.81	628.18	628.40	629.06	630.21	630.89	631.91	632.67
BR056	28470.34	625.29	626.05	626.54	627.03	627.46	627.74	628.10	628.34	629.04	630.20	630.89	631.91	632.67
BR055	27849.11	625.03	625.76	626.26	626.79	627.25	627.55	627.93	628.19	628.92	630.14	630.85	631.89	632.65
BR054	27293.26	624.84	625.56	626.09	626.63	627.11	627.42	627.82	628.08	628.83	630.09	630.80	631.86	632.63
BR053	26754.76	624.60	625.31	625.86	626.43	626.93	627.25	627.65	627.93	628.71	630.01	630.74	631.81	632.59
BR052	26126.16	624.27	625.11	625.71	626.31	626.83	627.16	627.58	627.86	628.65	629.98	630.72	631.80	632.58
BR051	26041.09	624.25	625.09	625.70	626.30	626.82	627.15	627.57	627.85	628.64	629.98	630.71	631.79	632.58
BR050	25815.08	617.50	618.17	618.62	619.03	619.37	619.58	619.83	619.99	620.43	620.78	620.99	621.26	621.42
BR049	25751.21	617.43	618.07	618.49	618.89	619.21	619.41	619.64	619.80	620.22	620.55	620.74	620.99	621.15
BR048	25333.65	616.90	617.56	617.97	618.35	618.66	618.85	619.07	619.22	619.62	619.95	620.14	620.38	620.54
BR047	24778.57	615.78	616.39	616.80	617.19	617.51	617.71	617.96	618.13	618.56	618.90	619.10	619.37	619.53
BR046	24238.27	614.87	615.53	615.96	616.39	616.74	616.96	617.22	617.39	617.82	618.16	618.36	618.61	618.77
BR045	23696.79	614.13	614.79	615.22	615.64	615.99	616.21	616.46	616.62	617.04	617.38	617.58	617.83	617.99
BR044	23192.93	613.50	614.15	614.59	615.02	615.38	615.61	615.86	616.01	616.42	616.73	616.92	617.16	617.31
BR043	22729.01	612.89	613.58	614.05	614.51	614.89	615.12	615.38	615.54	615.96	616.29	616.48	616.73	616.89
BR042	22110.36	612.08	612.86	613.37	613.85	614.22	614.46	614.72	614.90	615.35	615.69	615.90	616.15	616.32
BR041	21509.99	611.25	611.88	612.27	612.63	612.91	613.09	613.30	613.43	613.80	614.11	614.29	614.52	614.67
BR040	21058.59	610.60	611.13	611.51	611.88	612.18	612.38	612.61	612.77	613.18	613.51	613.70	613.92	614.06

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
BR039	20441.35	609.47	610.08	610.47	610.85	611.16	611.35	611.57	611.71	612.09	612.41	612.60	612.83	612.98
BR038	19752.18	608.47	609.01	609.38	609.76	610.07	610.27	610.50	610.66	611.07	611.40	611.60	611.85	612.01
BR037	19167.94	607.60	608.24	608.69	609.13	609.48	609.70	609.97	610.14	610.58	610.93	611.15	611.42	611.59
BR036	18705.98	607.03	607.72	608.19	608.62	608.97	609.19	609.45	609.62	610.07	610.42	610.64	610.91	611.08
BR035	18163.91	606.45	607.14	607.62	608.05	608.40	608.61	608.87	609.04	609.48	609.83	610.05	610.31	610.48
BR034	17680.01	606.01	606.71	607.19	607.63	607.98	608.20	608.46	608.63	609.06	609.40	609.61	609.87	610.03
BR033	16944.06	605.21	605.90	606.36	606.78	607.13	607.34	607.58	607.75	608.14	608.44	608.61	608.83	608.97
BR032	16346.02	604.34	604.93	605.32	605.69	605.99	606.18	606.40	606.54	606.88	607.15	607.32	607.53	607.66
BR031	15789.04	603.12	603.76	604.16	604.53	604.82	605.00	605.20	605.34	605.68	605.96	606.13	606.34	606.47
BR030	15196.25	602.33	602.96	603.37	603.75	604.05	604.24	604.46	604.61	604.99	605.32	605.50	605.73	605.87
BR029	14500.02	600.89	601.51	601.89	602.26	602.55	602.73	602.95	603.09	603.46	603.74	603.91	604.12	604.25
BR028	13959.76	600.04	600.66	601.06	601.44	601.74	601.93	602.15	602.29	602.66	602.94	603.10	603.30	603.43
BR027	13578.04	599.64	600.17	600.52	600.86	601.14	601.31	601.51	601.64	601.97	602.23	602.39	602.59	602.72
BR026	13061.06	598.69	599.22	599.57	599.90	600.16	600.32	600.50	600.62	600.92	601.16	601.30	601.49	601.61
BR025	12434.00	597.36	597.92	598.27	598.61	598.87	599.04	599.24	599.37	599.73	600.04	600.20	600.41	600.55
BR024	11869.63	596.20	596.80	597.18	597.54	597.84	598.02	598.23	598.37	598.74	599.03	599.21	599.45	599.59
BR023	11307.38	595.19	595.80	596.18	596.55	596.85	597.03	597.25	597.39	597.72	597.97	598.13	598.33	598.46
BR022	10619.70	593.75	594.30	594.68	595.06	595.38	595.58	595.81	595.94	596.30	596.60	596.78	597.03	597.18
BR021	9847.98	592.42	593.08	593.53	593.97	594.32	594.54	594.81	594.97	595.41	595.77	595.98	596.26	596.43
BR020	9363.83	591.95	592.59	593.02	593.44	593.77	593.97	594.22	594.36	594.74	595.04	595.21	595.44	595.57
BR019	8742.78	590.96	591.55	591.96	592.34	592.54	592.66	592.79	592.87	593.09	593.27	593.39	593.53	593.63
BR018	8258.73	590.24	590.84	591.26	591.65	591.93	592.09	592.29	592.42	592.75	593.02	593.19	593.41	593.53
BR017	7675.74	588.74	589.19	589.45	589.71	589.92	590.06	590.22	590.32	590.66	590.89	591.00	591.17	591.35
BR016	7057.36	585.47	585.85	586.12	586.39	586.60	586.73	586.89	586.99	587.26	587.48	587.62	587.79	587.90
BR015	6455.92	583.03	583.50	583.79	584.07	584.30	584.44	584.60	584.71	584.99	585.23	585.37	585.53	585.63
BR014b	6396.19	582.70	583.17	583.47	583.74	583.95	584.07	584.24	584.34	584.62	584.86	585.00	585.16	585.27
BR014a	6383.53	582.68	583.16	583.47	583.75	583.97	584.10	584.26	584.37	584.66	584.90	585.05	585.22	585.32
BR013	6341.01	582.55	583.04	583.36	583.65	583.87	584.01	584.19	584.30	584.61	584.87	585.02	585.20	585.31
BR012	5727.25	580.93	581.44	581.75	582.03	582.26	582.39	582.54	582.63	582.84	583.02	583.12	583.27	583.36
BR011	5253.23	579.24	579.61	579.86	580.13	580.34	580.47	580.62	580.73	581.02	581.26	581.41	581.56	581.67
BR010	4502.69	575.93	576.30	576.54	576.76	576.94	577.05	577.19	577.26	577.43	577.58	577.66	577.82	577.92
BR009	3985.96	573.70	574.14	574.43	574.72	574.96	575.11	575.30	575.41	575.72	575.95	576.11	576.20	576.27
BR008	3459.92	571.59	572.04	572.35	572.63	572.85	572.99	573.16	573.27	573.54	573.81	573.94	574.14	574.26
BR007	3000.37	570.48	570.99	571.35	571.68	571.94	572.07	572.25	572.36	572.68	572.96	573.15	573.34	573.46
BR006	2470.83	568.54	568.86	569.06	569.28	569.47	569.70	569.88	570.00	570.28	570.52	570.59	570.86	571.01
BR005	2011.28	566.74	567.20	567.52	567.83	568.08	568.24	568.43	568.56	568.90	569.18	569.38	569.60	569.74
BR004	1665.02	565.74	566.20	566.48	566.76	566.98	567.11	567.26	567.36	567.59	567.75	567.85	567.96	568.04
BR003	1183.19	564.11	564.55	564.85	565.11	565.30	565.42	565.56	565.64	565.86	566.03	566.13	566.27	566.36
BR002	682.11	562.45	562.94	563.27	563.51	563.68	563.79	563.91	563.99	564.19	564.35	564.46	564.58	564.67
BR001	14.77	560.38	560.89	561.16	561.39	561.57	561.67	561.79	561.87	562.08	562.25	562.36	562.48	562.57

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%
BR198	62105.57	665.62	665.62	665.62
BR197b	61671.05	665.55	665.55	665.55
BR197a	61644.16	665.47	665.47	665.47
BR196	61528.78	665.47	665.47	665.47
BR195	61063.56	665.35	665.35	665.35
BR194	60726.66	665.23	665.23	665.23
BR193	59636.52	665.17	665.17	665.17
BR192	59213.71	665.14	665.14	665.14
BR191	58830.53	665.09	665.09	665.09
BR190b	58702.57	665.07	665.07	665.07
BR190a	58686.20	664.77	664.77	664.77
BR189	58581.16	664.73	664.73	664.73
BR188	58291.76	664.69	664.69	664.69
BR187	58021.80	664.47	664.47	664.47
BR186	57572.61	664.23	664.23	664.23
BR185	57267.51	664.18	664.18	664.18
BR184	56773.94	663.95	663.95	663.95
BR183	56209.22	663.62	663.62	663.62
BR182	55965.68	663.57	663.57	663.57
BR181	55796.42	663.32	663.32	663.32
BR180	55195.32	663.29	663.29	663.29
BR179	54587.25	663.24	663.24	663.24
BR178	54302.34	663.17	663.17	663.17
BR177b	54227.29	662.92	662.92	662.92
BR177a	54209.73	662.87	662.87	662.87
BR176	54152.35	662.50	662.50	662.50
BR175b	54096.79	662.52	662.52	662.52
BR175a	54072.70	662.45	662.45	662.45
BR174	54061.55	662.40	662.40	662.40
BR173b	54053.88	662.41	662.41	662.41
BR173a	54029.93	662.35	662.35	662.35
BR172	53912.08	662.39	662.39	662.39
BR171	53531.90	662.23	662.23	662.23
BR170	53205.43	661.97	661.97	661.97
BR169	52695.44	661.56	661.56	661.56
BR168	52511.77	661.42	661.42	661.42
BR167	52209.14	661.26	661.26	661.26
BR166	51761.57	661.01	661.01	661.01
BR165b	51674.15	660.84	660.84	660.84
BR165a	51665.33	660.86	660.86	660.86
BR164	51591.42	660.79	660.79	660.79
BR163	51306.88	660.77	660.77	660.77
BR162	51036.21	660.71	660.71	660.71
BR161	50863.87	660.65	660.65	660.65
BR160	50564.16	660.49	660.49	660.49
BR159	50253.50	660.41	660.41	660.41
BR158	49988.23	660.33	660.33	660.33
BR157	49713.16	660.26	660.26	660.26
BR156	49371.68	660.14	660.14	660.14
BR155	48864.88	660.09	660.09	660.09
BR154	48695.22	660.06	660.06	660.06
BR153	48387.18	659.83	659.83	659.83

Cross-Section	River Station (m)	Simulated WSE at 1:100-yr Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope +20%
BR152b	48267.62	659.71	659.71	659.71
BR152a	48237.60	659.50	659.50	659.50
BR151	48037.52	659.37	659.37	659.37
BR150	47599.79	659.37	659.37	659.37
BR149	47126.99	659.35	659.35	659.35
BR148	46857.21	659.27	659.27	659.27
BR147b	46789.16	658.99	658.99	658.99
BR147a	46771.18	658.91	658.91	658.91
BR146	46661.28	658.94	658.94	658.94
BR145	45615.48	658.83	658.83	658.83
BR144	44821.39	658.73	658.73	658.73
BR143	44326.25	658.50	658.50	658.50
BR142	43962.83	658.12	658.12	658.12
BR141	43533.04	657.25	657.25	657.25
BR140	42812.24	656.21	656.21	656.21
BR139	42312.92	655.09	655.09	655.09
BR138	41788.43	654.94	654.94	654.94
BR137	41310.43	654.63	654.63	654.63
BR136b	41269.83	654.55	654.55	654.55
BR136a	41263.54	654.55	654.55	654.55
BR135	41238.70	654.53	654.53	654.53
BR134	41194.60	654.37	654.37	654.37
BR133	41165.23	654.27	654.27	654.27
BR132	41074.72	654.18	654.18	654.18
BR131b	40970.09	654.10	654.10	654.10
BR131a	40964.22	654.07	654.07	654.07
BR130	40887.27	654.08	654.08	654.08
BR129	40718.83	654.09	654.09	654.09
BR128	40552.65	654.09	654.09	654.09
BR127	40357.23	654.08	654.08	654.08
BR126	40153.42	654.08	654.08	654.08
BR125	40061.16	654.00	654.00	654.00
BR124	39994.05	648.78	648.78	648.78
BR123	39942.29	648.56	648.56	648.56
BR122	39767.21	648.47	648.47	648.47
BR121b	39698.45	648.35	648.35	648.35
BR121a	39692.72	648.34	648.34	648.34
BR120	39608.68	648.24	648.24	648.24
BR119	39521.91	648.21	648.21	648.21
BR118b	39436.73	647.82	647.82	647.82
BR118a	39430.16	647.84	647.84	647.84
BR117	39379.67	647.81	647.81	647.81
BR116b	39311.00	647.55	647.55	647.55
BR116a	39288.79	647.34	647.34	647.34
BR115	39280.27	647.18	647.18	647.18
BR114b	39271.28	647.17	647.17	647.17
BR114a	39252.25	646.57	646.57	646.57
BR113	39200.55	646.49	646.49	646.49
BR112b	39158.74	646.42	646.42	646.42
BR112a	39150.50	646.40	646.40	646.40
BR111	39120.36	646.47	646.47	646.47
BR110b	39094.15	646.18	646.18	646.18
BR110a	39085.34	645.97	645.97	645.97

Cross-Section	River Station (m)	Simulated WSE at 1:100-yr Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope +20%
BR109	39009.61	646.07	646.07	646.07
BR108	38767.08	645.77	645.77	645.77
BR107b	38700.32	645.61	645.61	645.61
BR107a	38695.54	645.61	645.61	645.61
BR106	38647.20	645.48	645.48	645.48
BR105	38475.17	645.02	645.02	645.02
BR104	38219.94	644.96	644.96	644.96
BR103	37945.44	644.83	644.83	644.83
BR102b	37911.48	644.78	644.78	644.78
BR102a	37904.65	644.64	644.64	644.64
BR101	37844.86	644.60	644.60	644.60
BR100	37504.07	644.33	644.33	644.33
BR099	37263.70	643.52	643.52	643.52
BR098b	37232.52	643.34	643.34	643.34
BR098a	37204.43	642.92	642.92	642.92
BR097b	37197.68	642.91	642.91	642.91
BR097a	37192.23	643.04	643.04	643.04
BR096	37131.10	643.21	643.21	643.21
BR095b	37076.19	642.75	642.75	642.75
BR095a	37070.00	642.55	642.55	642.55
BR094	37032.70	642.68	642.68	642.68
BR093	36782.49	642.37	642.37	642.37
BR092	36677.71	642.15	642.15	642.15
BR091	36360.77	641.82	641.82	641.82
BR090b	36298.75	641.08	641.08	641.08
BR090a	36292.38	641.07	641.07	641.07
BR089	36240.32	641.02	641.02	641.02
BR088	35974.21	640.48	640.48	640.48
BR087b	35933.33	640.41	640.41	640.41
BR087a	35925.88	640.26	640.26	640.26
BR086	35858.09	640.24	640.24	640.24
BR085	35529.54	639.87	639.87	639.87
BR084	35166.82	639.04	639.04	639.04
BR083	34823.97	638.43	638.43	638.43
BR082	34555.46	638.07	638.07	638.07
BR081b	34497.99	637.50	637.50	637.50
BR081a	34490.29	637.49	637.49	637.49
BR080	34409.10	637.21	637.21	637.21
BR079	34126.81	636.68	636.68	636.68
BR078	33634.63	635.89	635.89	635.89
BR077b	33590.46	635.75	635.75	635.75
BR077a	33554.07	635.73	635.73	635.73
BR076	33519.67	635.75	635.75	635.75
BR075	33435.27	635.66	635.66	635.66
BR074b	33385.56	635.02	635.02	635.02
BR074a	33375.55	634.98	634.98	634.98
BR073	33343.09	634.98	634.98	634.98
BR072	33074.16	634.57	634.57	634.57
BR071	32840.75	633.90	633.90	633.90
BR070	32583.33	633.52	633.52	633.52
BR069	32241.86	632.98	632.98	632.98
BR068	31864.66	632.63	632.63	632.63
BR067	31597.48	632.09	632.09	632.09

Cross-Section	River Station (m)	Simulated WSE at 1:100-yr Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope +20%
BR066	31155.45	631.50	631.50	631.50
BR065	30965.52	631.43	631.43	631.43
BR064	30498.08	631.00	631.00	631.00
BR063	29982.19	630.38	630.38	630.38
BR062	29733.21	630.03	630.03	630.03
BR061b	29682.43	629.13	629.13	629.13
BR061a	29674.83	629.29	629.29	629.29
BR060	29617.88	629.29	629.29	629.29
BR059	29150.09	628.87	628.87	628.87
BR058	28581.13	628.44	628.44	628.44
BR057b	28535.87	628.42	628.42	628.42
BR057a	28530.05	628.40	628.40	628.40
BR056	28470.34	628.34	628.34	628.34
BR055	27849.11	628.19	628.19	628.19
BR054	27293.26	628.08	628.08	628.08
BR053	26754.76	627.93	627.93	627.93
BR052	26126.16	627.86	627.86	627.86
BR051	26041.09	627.85	627.85	627.85
BR050	25815.08	619.99	619.99	619.99
BR049	25751.21	619.80	619.80	619.80
BR048	25333.65	619.22	619.22	619.22
BR047	24778.57	618.13	618.13	618.13
BR046	24238.27	617.39	617.39	617.39
BR045	23696.79	616.62	616.62	616.62
BR044	23192.93	616.01	616.01	616.01
BR043	22729.01	615.54	615.54	615.54
BR042	22110.36	614.90	614.90	614.90
BR041	21509.99	613.43	613.43	613.43
BR040	21058.59	612.77	612.77	612.77
BR039	20441.35	611.71	611.71	611.71
BR038	19752.18	610.66	610.66	610.66
BR037	19167.94	610.14	610.14	610.14
BR036	18705.98	609.62	609.62	609.62
BR035	18163.91	609.04	609.04	609.04
BR034	17680.01	608.63	608.63	608.63
BR033	16944.06	607.75	607.75	607.75
BR032	16346.02	606.54	606.54	606.54
BR031	15789.04	605.34	605.34	605.34
BR030	15196.25	604.61	604.61	604.61
BR029	14500.02	603.09	603.09	603.09
BR028	13959.76	602.29	602.29	602.29
BR027	13578.04	601.64	601.64	601.64
BR026	13061.06	600.62	600.62	600.62
BR025	12434.00	599.37	599.37	599.37
BR024	11869.63	598.37	598.37	598.37
BR023	11307.38	597.39	597.39	597.39
BR022	10619.70	595.94	595.94	595.94
BR021	9847.98	594.97	594.97	594.97
BR020	9363.83	594.36	594.36	594.36
BR019	8742.78	592.87	592.87	592.87
BR018	8258.73	592.42	592.42	592.42
BR017	7675.74	590.32	590.32	590.32
BR016	7057.36	586.99	586.99	586.99

Cross-Section	River Station (m)	Simulated WSE at 1:100-yr Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope +20%
BR015	6455.92	584.71	584.71	584.71
BR014b	6396.19	584.34	584.34	584.34
BR014a	6383.53	584.37	584.37	584.37
BR013	6341.01	584.30	584.30	584.30
BR012	5727.25	582.63	582.63	582.63
BR011	5253.23	580.73	580.73	580.73
BR010	4502.69	577.26	577.26	577.26
BR009	3985.96	575.41	575.41	575.41
BR008	3459.92	573.27	573.27	573.27
BR007	3000.37	572.36	572.36	572.36
BR006	2470.83	570.00	570.00	570.00
BR005	2011.28	568.56	568.56	568.56
BR004	1665.02	567.36	567.36	567.38
BR003	1183.19	565.64	565.64	565.61
BR002	682.11	563.99	563.99	564.06
BR001	14.77	561.87	561.87	561.79

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%
		$n_{channel}$ = 0.028	$n_{channel}$ = 0.035	$n_{channel}$ = 0.042
BR198	62105.57	665.56	665.62	665.68
BR197b	61671.05	665.49	665.55	665.59
BR197a	61644.16	665.42	665.47	665.51
BR196	61528.78	665.42	665.47	665.51
BR195	61063.56	665.29	665.35	665.39
BR194	60726.66	665.20	665.23	665.25
BR193	59636.52	665.15	665.17	665.18
BR192	59213.71	665.12	665.14	665.15
BR191	58830.53	665.08	665.09	665.10
BR190b	58702.57	665.05	665.07	665.08
BR190a	58686.20	664.73	664.77	664.81
BR189	58581.16	664.71	664.73	664.76
BR188	58291.76	664.68	664.69	664.71
BR187	58021.80	664.37	664.47	664.53
BR186	57572.61	664.16	664.23	664.28
BR185	57267.51	664.12	664.18	664.23
BR184	56773.94	663.85	663.95	664.02
BR183	56209.22	663.54	663.62	663.67
BR182	55965.68	663.50	663.57	663.62
BR181	55796.42	663.19	663.32	663.42
BR180	55195.32	663.20	663.29	663.38
BR179	54587.25	663.15	663.24	663.33
BR178	54302.34	663.06	663.17	663.27
BR177b	54227.29	662.80	662.92	663.03
BR177a	54209.73	662.77	662.87	662.97
BR176	54152.35	662.36	662.50	662.62
BR175b	54096.79	662.43	662.52	662.59
BR175a	54072.70	662.37	662.45	662.52
BR174	54061.55	662.32	662.40	662.47
BR173b	54053.88	662.34	662.41	662.47
BR173a	54029.93	662.29	662.35	662.40
BR172	53912.08	662.34	662.39	662.43
BR171	53531.90	662.16	662.23	662.28
BR170	53205.43	661.88	661.97	662.03
BR169	52695.44	661.46	661.56	661.63
BR168	52511.77	661.34	661.42	661.48
BR167	52209.14	661.19	661.26	661.31
BR166	51761.57	660.95	661.01	661.04
BR165b	51674.15	660.73	660.84	660.89
BR165a	51665.33	660.78	660.86	660.92
BR164	51591.42	660.70	660.79	660.86
BR163	51306.88	660.70	660.77	660.83
BR162	51036.21	660.63	660.71	660.78
BR161	50863.87	660.57	660.65	660.73
BR160	50564.16	660.41	660.49	660.57
BR159	50253.50	660.34	660.41	660.47
BR158	49988.23	660.26	660.33	660.39
BR157	49713.16	660.20	660.26	660.32
BR156	49371.68	660.09	660.14	660.21
BR155	48864.88	660.06	660.09	660.15

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
BR154	48695.22	660.03	660.06	660.12
BR153	48387.18	659.80	659.83	659.90
BR152b	48267.62	659.71	659.71	659.76
BR152a	48237.60	659.35	659.50	659.59
BR151	48037.52	659.24	659.37	659.46
BR150	47599.79	659.26	659.37	659.44
BR149	47126.99	659.24	659.35	659.44
BR148	46857.21	659.13	659.27	659.38
BR147b	46789.16	658.85	658.99	659.11
BR147a	46771.18	658.77	658.91	659.02
BR146	46661.28	658.81	658.94	659.05
BR145	45615.48	658.68	658.83	658.94
BR144	44821.39	658.56	658.73	658.87
BR143	44326.25	658.30	658.50	658.66
BR142	43962.83	657.94	658.12	658.27
BR141	43533.04	657.01	657.25	657.41
BR140	42812.24	656.02	656.21	656.34
BR139	42312.92	654.87	655.09	655.25
BR138	41788.43	654.81	654.94	655.05
BR137	41310.43	654.49	654.63	654.75
BR136b	41269.83	654.42	654.55	654.67
BR136a	41263.54	654.43	654.55	654.67
BR135	41238.70	654.42	654.53	654.65
BR134	41194.60	654.26	654.37	654.48
BR133	41165.23	654.18	654.27	654.35
BR132	41074.72	654.12	654.18	654.25
BR131b	40970.09	654.06	654.10	654.13
BR131a	40964.22	654.04	654.07	654.10
BR130	40887.27	654.06	654.08	654.09
BR129	40718.83	654.09	654.09	654.10
BR128	40552.65	654.09	654.09	654.09
BR127	40357.23	654.08	654.08	654.09
BR126	40153.42	654.08	654.08	654.08
BR125	40061.16	653.99	654.00	654.00
BR124	39994.05	648.63	648.78	648.94
BR123	39942.29	648.34	648.56	648.76
BR122	39767.21	648.33	648.47	648.64
BR121b	39698.45	648.22	648.35	648.51
BR121a	39692.72	648.21	648.34	648.49
BR120	39608.68	648.11	648.24	648.39
BR119	39521.91	648.10	648.21	648.33
BR118b	39436.73	647.74	647.82	647.94
BR118a	39430.16	647.77	647.84	647.95
BR117	39379.67	647.76	647.81	647.89
BR116b	39311.00	647.50	647.55	647.66
BR116a	39288.79	647.31	647.34	647.45
BR115	39280.27	647.10	647.18	647.36
BR114b	39271.28	647.11	647.17	647.34
BR114a	39252.25	646.38	646.57	646.83
BR113	39200.55	646.24	646.49	646.73
BR112b	39158.74	646.22	646.42	646.63
BR112a	39150.50	646.20	646.40	646.61
BR111	39120.36	646.30	646.47	646.66

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
BR110b	39094.15	645.98	646.18	646.41
BR110a	39085.34	645.64	645.97	646.25
BR109	39009.61	645.81	646.07	646.31
BR108	38767.08	645.51	645.77	646.00
BR107b	38700.32	645.36	645.61	645.84
BR107a	38695.54	645.36	645.61	645.84
BR106	38647.20	645.11	645.48	645.76
BR105	38475.17	644.69	645.02	645.26
BR104	38219.94	644.73	644.96	645.12
BR103	37945.44	644.61	644.83	644.96
BR102b	37911.48	644.53	644.78	644.92
BR102a	37904.65	644.47	644.64	644.83
BR101	37844.86	644.46	644.60	644.75
BR100	37504.07	644.23	644.33	644.44
BR099	37263.70	643.39	643.52	643.70
BR098b	37232.52	643.33	643.34	643.40
BR098a	37204.43	642.72	642.92	643.08
BR097b	37197.68	642.73	642.91	643.06
BR097a	37192.23	642.91	643.04	643.15
BR096	37131.10	643.12	643.21	643.29
BR095b	37076.19	642.58	642.75	642.90
BR095a	37070.00	642.32	642.55	642.73
BR094	37032.70	642.49	642.68	642.83
BR093	36782.49	642.18	642.37	642.55
BR092	36677.71	641.97	642.15	642.32
BR091	36360.77	641.74	641.82	641.93
BR090b	36298.75	640.90	641.08	641.27
BR090a	36292.38	640.85	641.07	641.25
BR089	36240.32	640.79	641.02	641.20
BR088	35974.21	640.44	640.48	640.59
BR087b	35933.33	640.41	640.41	640.51
BR087a	35925.88	639.98	640.26	640.47
BR086	35858.09	640.02	640.24	640.41
BR085	35529.54	639.67	639.87	640.04
BR084	35166.82	638.74	639.04	639.27
BR083	34823.97	638.22	638.43	638.64
BR082	34555.46	637.97	638.07	638.24
BR081b	34497.99	637.34	637.50	637.76
BR081a	34490.29	637.17	637.49	637.74
BR080	34409.10	636.86	637.21	637.48
BR079	34126.81	636.45	636.68	636.87
BR078	33634.63	635.71	635.89	636.10
BR077b	33590.46	635.54	635.75	635.97
BR077a	33554.07	635.57	635.73	635.93
BR076	33519.67	635.60	635.75	635.94
BR075	33435.27	635.51	635.66	635.85
BR074b	33385.56	634.68	635.02	635.34
BR074a	33375.55	634.58	634.98	635.31
BR073	33343.09	634.65	634.98	635.29
BR072	33074.16	634.31	634.57	634.83
BR071	32840.75	633.47	633.90	634.25
BR070	32583.33	633.16	633.52	633.82
BR069	32241.86	632.64	632.98	633.27

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
BR068	31864.66	632.35	632.63	632.88
BR067	31597.48	631.69	632.09	632.41
BR066	31155.45	631.21	631.50	631.76
BR065	30965.52	631.19	631.43	631.66
BR064	30498.08	630.81	631.00	631.19
BR063	29982.19	630.31	630.38	630.51
BR062	29733.21	630.11	630.03	630.07
BR061b	29682.43	629.75	629.13	629.34
BR061a	29674.83	629.00	629.29	629.42
BR060	29617.88	629.04	629.29	629.40
BR059	29150.09	628.63	628.87	629.02
BR058	28581.13	628.30	628.44	628.56
BR057b	28535.87	628.29	628.42	628.53
BR057a	28530.05	628.27	628.40	628.52
BR056	28470.34	628.20	628.34	628.47
BR055	27849.11	628.11	628.19	628.26
BR054	27293.26	628.02	628.08	628.13
BR053	26754.76	627.90	627.93	627.96
BR052	26126.16	627.85	627.86	627.86
BR051	26041.09	627.85	627.85	627.85
BR050	25815.08	619.73	619.99	620.25
BR049	25751.21	619.49	619.80	620.10
BR048	25333.65	618.90	619.22	619.54
BR047	24778.57	617.67	618.13	618.51
BR046	24238.27	616.99	617.39	617.74
BR045	23696.79	616.19	616.62	616.98
BR044	23192.93	615.64	616.01	616.33
BR043	22729.01	615.20	615.54	615.83
BR042	22110.36	614.60	614.90	615.18
BR041	21509.99	612.95	613.43	613.83
BR040	21058.59	612.41	612.77	613.09
BR039	20441.35	611.33	611.71	612.05
BR038	19752.18	610.24	610.66	611.02
BR037	19167.94	609.75	610.14	610.48
BR036	18705.98	609.19	609.62	609.99
BR035	18163.91	608.62	609.04	609.40
BR034	17680.01	608.26	608.63	608.95
BR033	16944.06	607.40	607.75	608.03
BR032	16346.02	606.16	606.54	606.83
BR031	15789.04	604.98	605.34	605.63
BR030	15196.25	604.36	604.61	604.86
BR029	14500.02	602.63	603.09	603.45
BR028	13959.76	601.97	602.29	602.58
BR027	13578.04	601.30	601.64	601.93
BR026	13061.06	600.33	600.62	600.87
BR025	12434.00	599.03	599.37	599.66
BR024	11869.63	598.03	598.37	598.66
BR023	11307.38	597.07	597.39	597.64
BR022	10619.70	595.53	595.94	596.25
BR021	9847.98	594.59	594.97	595.28
BR020	9363.83	594.05	594.36	594.62
BR019	8742.78	592.59	592.87	593.08
BR018	8258.73	592.20	592.42	592.56

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
BR017	7675.74	590.30	590.32	590.57
BR016	7057.36	586.64	586.99	587.26
BR015	6455.92	584.54	584.71	584.90
BR014b	6396.19	584.26	584.34	584.59
BR014a	6383.53	584.09	584.37	584.60
BR013	6341.01	584.02	584.30	584.53
BR012	5727.25	582.43	582.63	582.80
BR011	5253.23	580.50	580.73	580.95
BR010	4502.69	577.00	577.26	577.45
BR009	3985.96	575.21	575.41	575.60
BR008	3459.92	572.89	573.27	573.57
BR007	3000.37	572.07	572.36	572.57
BR006	2470.83	569.99	570.00	570.10
BR005	2011.28	568.33	568.56	568.77
BR004	1665.02	567.10	567.36	567.57
BR003	1183.19	565.41	565.64	565.81
BR002	682.11	563.80	563.99	564.14
BR001	14.77	561.68	561.87	562.02

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	Overbank Roughness +20%
BR198	62105.57	665.56	665.62	665.69
BR197b	61671.05	665.48	665.55	665.60
BR197a	61644.16	665.41	665.47	665.53
BR196	61528.78	665.40	665.47	665.52
BR195	61063.56	665.29	665.35	665.40
BR194	60726.66	665.17	665.23	665.28
BR193	59636.52	665.12	665.17	665.21
BR192	59213.71	665.10	665.14	665.17
BR191	58830.53	665.06	665.09	665.12
BR190b	58702.57	665.05	665.07	665.09
BR190a	58686.20	664.69	664.77	664.84
BR189	58581.16	664.65	664.73	664.80
BR188	58291.76	664.62	664.69	664.75
BR187	58021.80	664.38	664.47	664.52
BR186	57572.61	664.12	664.23	664.32
BR185	57267.51	664.08	664.18	664.28
BR184	56773.94	663.86	663.95	664.02
BR183	56209.22	663.54	663.62	663.67
BR182	55965.68	663.49	663.57	663.63
BR181	55796.42	663.23	663.32	663.39
BR180	55195.32	663.23	663.29	663.35
BR179	54587.25	663.19	663.24	663.29
BR178	54302.34	663.13	663.17	663.21
BR177b	54227.29	662.88	662.92	662.95
BR177a	54209.73	662.82	662.87	662.92
BR176	54152.35	662.43	662.50	662.56
BR175b	54096.79	662.44	662.52	662.58
BR175a	54072.70	662.37	662.45	662.52
BR174	54061.55	662.32	662.40	662.48
BR173b	54053.88	662.32	662.41	662.48
BR173a	54029.93	662.26	662.35	662.43
BR172	53912.08	662.30	662.39	662.46
BR171	53531.90	662.15	662.23	662.30
BR170	53205.43	661.90	661.97	662.03
BR169	52695.44	661.48	661.56	661.63
BR168	52511.77	661.33	661.42	661.49
BR167	52209.14	661.17	661.26	661.32
BR166	51761.57	660.94	661.01	661.05
BR165b	51674.15	660.77	660.84	661.02
BR165a	51665.33	660.74	660.86	660.94
BR164	51591.42	660.68	660.79	660.89
BR163	51306.88	660.66	660.77	660.86
BR162	51036.21	660.60	660.71	660.80
BR161	50863.87	660.55	660.65	660.74
BR160	50564.16	660.40	660.49	660.57
BR159	50253.50	660.32	660.41	660.48
BR158	49988.23	660.25	660.33	660.39
BR157	49713.16	660.19	660.26	660.31
BR156	49371.68	660.09	660.14	660.19
BR155	48864.88	660.04	660.09	660.12
BR154	48695.22	660.02	660.06	660.08

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness +20%
BR153	48387.18	659.82	659.83	659.83
BR152b	48267.62	659.71	659.71	659.69
BR152a	48237.60	659.42	659.50	659.56
BR151	48037.52	659.29	659.37	659.45
BR150	47599.79	659.30	659.37	659.44
BR149	47126.99	659.28	659.35	659.42
BR148	46857.21	659.21	659.27	659.33
BR147b	46789.16	658.91	658.99	659.07
BR147a	46771.18	658.82	658.91	658.99
BR146	46661.28	658.85	658.94	659.02
BR145	45615.48	658.75	658.83	658.90
BR144	44821.39	658.67	658.73	658.79
BR143	44326.25	658.46	658.50	658.55
BR142	43962.83	658.10	658.12	658.16
BR141	43533.04	657.19	657.25	657.30
BR140	42812.24	656.14	656.21	656.26
BR139	42312.92	655.00	655.09	655.17
BR138	41788.43	654.89	654.94	654.98
BR137	41310.43	654.61	654.63	654.64
BR136b	41269.83	654.53	654.55	654.56
BR136a	41263.54	654.53	654.55	654.57
BR135	41238.70	654.52	654.53	654.55
BR134	41194.60	654.35	654.37	654.39
BR133	41165.23	654.25	654.27	654.29
BR132	41074.72	654.17	654.18	654.20
BR131b	40970.09	654.09	654.10	654.11
BR131a	40964.22	654.06	654.07	654.08
BR130	40887.27	654.07	654.08	654.09
BR129	40718.83	654.09	654.09	654.10
BR128	40552.65	654.08	654.09	654.09
BR127	40357.23	654.08	654.08	654.09
BR126	40153.42	654.07	654.08	654.08
BR125	40061.16	654.00	654.00	653.99
BR124	39994.05	648.74	648.78	648.82
BR123	39942.29	648.53	648.56	648.59
BR122	39767.21	648.43	648.47	648.51
BR121b	39698.45	648.31	648.35	648.39
BR121a	39692.72	648.29	648.34	648.38
BR120	39608.68	648.20	648.24	648.27
BR119	39521.91	648.17	648.21	648.24
BR118b	39436.73	647.77	647.82	647.86
BR118a	39430.16	647.79	647.84	647.88
BR117	39379.67	647.76	647.81	647.85
BR116b	39311.00	647.52	647.55	647.59
BR116a	39288.79	647.29	647.34	647.38
BR115	39280.27	647.16	647.18	647.20
BR114b	39271.28	647.15	647.17	647.19
BR114a	39252.25	646.53	646.57	646.60
BR113	39200.55	646.47	646.49	646.51
BR112b	39158.74	646.39	646.42	646.44
BR112a	39150.50	646.37	646.40	646.42
BR111	39120.36	646.44	646.47	646.49

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness +20%
BR110b	39094.15	646.15	646.18	646.21
BR110a	39085.34	645.93	645.97	646.00
BR109	39009.61	646.04	646.07	646.10
BR108	38767.08	645.72	645.77	645.81
BR107b	38700.32	645.56	645.61	645.66
BR107a	38695.54	645.56	645.61	645.65
BR106	38647.20	645.46	645.48	645.50
BR105	38475.17	644.96	645.02	645.07
BR104	38219.94	644.90	644.96	645.02
BR103	37945.44	644.77	644.83	644.87
BR102b	37911.48	644.72	644.78	644.82
BR102a	37904.65	644.59	644.64	644.68
BR101	37844.86	644.55	644.60	644.65
BR100	37504.07	644.27	644.33	644.38
BR099	37263.70	643.47	643.52	643.57
BR098b	37232.52	643.26	643.34	643.39
BR098a	37204.43	642.86	642.92	642.96
BR097b	37197.68	642.86	642.91	642.96
BR097a	37192.23	642.97	643.04	643.08
BR096	37131.10	643.15	643.21	643.26
BR095b	37076.19	642.69	642.75	642.80
BR095a	37070.00	642.48	642.55	642.61
BR094	37032.70	642.62	642.68	642.73
BR093	36782.49	642.33	642.37	642.40
BR092	36677.71	642.11	642.15	642.18
BR091	36360.77	641.79	641.82	641.84
BR090b	36298.75	641.02	641.08	641.13
BR090a	36292.38	641.01	641.07	641.12
BR089	36240.32	640.96	641.02	641.06
BR088	35974.21	640.42	640.48	640.53
BR087b	35933.33	640.36	640.41	640.47
BR087a	35925.88	640.18	640.26	640.31
BR086	35858.09	640.17	640.24	640.29
BR085	35529.54	639.82	639.87	639.90
BR084	35166.82	638.98	639.04	639.08
BR083	34823.97	638.39	638.43	638.46
BR082	34555.46	638.05	638.07	638.09
BR081b	34497.99	637.48	637.50	637.52
BR081a	34490.29	637.46	637.49	637.51
BR080	34409.10	637.18	637.21	637.24
BR079	34126.81	636.61	636.68	636.73
BR078	33634.63	635.85	635.89	635.92
BR077b	33590.46	635.73	635.75	635.76
BR077a	33554.07	635.70	635.73	635.75
BR076	33519.67	635.73	635.75	635.77
BR075	33435.27	635.64	635.66	635.67
BR074b	33385.56	634.99	635.02	635.03
BR074a	33375.55	634.96	634.98	634.99
BR073	33343.09	634.97	634.98	635.00
BR072	33074.16	634.54	634.57	634.59
BR071	32840.75	633.88	633.90	633.91
BR070	32583.33	633.48	633.52	633.54

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness +20%
BR069	32241.86	632.95	632.98	633.01
BR068	31864.66	632.59	632.63	632.66
BR067	31597.48	632.05	632.09	632.11
BR066	31155.45	631.45	631.50	631.54
BR065	30965.52	631.38	631.43	631.47
BR064	30498.08	630.94	631.00	631.05
BR063	29982.19	630.34	630.38	630.40
BR062	29733.21	630.00	630.03	630.04
BR061b	29682.43	629.48	629.13	629.18
BR061a	29674.83	629.20	629.29	629.33
BR060	29617.88	629.20	629.29	629.34
BR059	29150.09	628.80	628.87	628.92
BR058	28581.13	628.38	628.44	628.49
BR057b	28535.87	628.36	628.42	628.47
BR057a	28530.05	628.33	628.40	628.46
BR056	28470.34	628.28	628.34	628.40
BR055	27849.11	628.14	628.19	628.23
BR054	27293.26	628.05	628.08	628.11
BR053	26754.76	627.92	627.93	627.94
BR052	26126.16	627.86	627.86	627.85
BR051	26041.09	627.85	627.85	627.85
BR050	25815.08	619.96	619.99	620.01
BR049	25751.21	619.77	619.80	619.82
BR048	25333.65	619.20	619.22	619.24
BR047	24778.57	618.11	618.13	618.14
BR046	24238.27	617.37	617.39	617.40
BR045	23696.79	616.61	616.62	616.64
BR044	23192.93	615.99	616.01	616.03
BR043	22729.01	615.51	615.54	615.56
BR042	22110.36	614.87	614.90	614.92
BR041	21509.99	613.43	613.43	613.44
BR040	21058.59	612.76	612.77	612.78
BR039	20441.35	611.69	611.71	611.73
BR038	19752.18	610.65	610.66	610.67
BR037	19167.94	610.12	610.14	610.16
BR036	18705.98	609.60	609.62	609.64
BR035	18163.91	609.02	609.04	609.05
BR034	17680.01	608.61	608.63	608.64
BR033	16944.06	607.72	607.75	607.77
BR032	16346.02	606.52	606.54	606.55
BR031	15789.04	605.31	605.34	605.36
BR030	15196.25	604.58	604.61	604.63
BR029	14500.02	603.08	603.09	603.10
BR028	13959.76	602.27	602.29	602.30
BR027	13578.04	601.63	601.64	601.65
BR026	13061.06	600.60	600.62	600.64
BR025	12434.00	599.35	599.37	599.39
BR024	11869.63	598.34	598.37	598.40
BR023	11307.38	597.36	597.39	597.41
BR022	10619.70	595.93	595.94	595.96
BR021	9847.98	594.97	594.97	594.98
BR020	9363.83	594.35	594.36	594.37

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness +20%
BR019	8742.78	592.80	592.87	592.93
BR018	8258.73	592.38	592.42	592.46
BR017	7675.74	590.32	590.32	590.32
BR016	7057.36	586.98	586.99	587.00
BR015	6455.92	584.70	584.71	584.72
BR014b	6396.19	584.32	584.34	584.36
BR014a	6383.53	584.35	584.37	584.39
BR013	6341.01	584.29	584.30	584.31
BR012	5727.25	582.60	582.63	582.65
BR011	5253.23	580.73	580.73	580.73
BR010	4502.69	577.24	577.26	577.28
BR009	3985.96	575.39	575.41	575.43
BR008	3459.92	573.25	573.27	573.28
BR007	3000.37	572.33	572.36	572.39
BR006	2470.83	570.01	570.00	569.99
BR005	2011.28	568.54	568.56	568.57
BR004	1665.02	567.35	567.36	567.37
BR003	1183.19	565.62	565.64	565.66
BR002	682.11	563.96	563.99	564.01
BR001	14.77	561.84	561.87	561.90

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
BR198	62105.57	3,509.7	1,127.2	1,454.7	-	-	1,127.2	1,454.7	Depth Criteria	Depth Criteria
BR197b	61671.05	3,615.7	1,387.1	1,700.6	-	-	1,387.1	1,700.6	Depth Criteria	Depth Criteria
BR197a	61644.16	3,573.6	1,437.5	1,670.6	1,444.5	1,454.6	1,437.5	1,670.6	Depth Criteria	Depth Criteria
BR196	61528.78	1,585.7	1,052.3	1,230.8	-	-	1,052.3	1,230.8	Depth Criteria	Depth Criteria
BR195	61063.56	1,468.1	1,034.6	1,051.9	1,039.0	1,045.5	1,034.6	1,051.9	Depth Criteria	Depth Criteria
BR194	60726.66	1,545.8	1,244.1	1,325.5	1,314.8	1,321.2	1,244.1	1,325.5	Depth Criteria	Depth Criteria
BR193	59636.52	1,652.2	1,289.0	1,355.9	-	-	1,289.0	1,355.9	Depth Criteria	Depth Criteria
BR192	59213.71	1,416.7	572.2	955.9	-	-	572.2	955.9	Depth Criteria	Depth Criteria
BR191	58830.53	633.8	418.8	593.3	-	-	418.8	593.3	Depth Criteria	Depth Criteria
BR190b	58702.57	308.7	82.8	263.0	-	-	82.8	263.0	Depth Criteria	Depth Criteria
BR190a	58686.20	322.5	73.0	97.5	76.2	96.7	73.0	97.5	Depth Criteria	Depth Criteria
BR189	58581.16	412.6	129.0	144.2	130.4	138.4	129.0	144.2	Depth Criteria	Depth Criteria
BR188	58291.76	475.9	192.4	207.7	-	-	192.4	207.7	Depth Criteria	Depth Criteria
BR187	58021.80	296.8	147.0	164.2	147.1	163.1	147.0	164.2	Depth Criteria	Depth Criteria
BR186	57572.61	337.0	118.5	278.5	121.1	130.0	118.5	280.9	Depth Criteria	Hydraulically Smoothed
BR185	57267.51	423.0	32.4	399.8	-	-	32.4	399.8	Depth Criteria	Depth Criteria
BR184	56773.94	210.7	20.0	137.1	25.2	38.6	20.0	137.1	Depth Criteria	Depth Criteria
BR183	56209.22	410.9	269.6	349.6	273.4	285.5	269.6	349.6	Depth Criteria	Depth Criteria
BR182	55965.68	406.7	36.8	390.7	112.4	117.6	36.8	390.7	Depth Criteria	Depth Criteria
BR181	55796.42	299.8	60.8	92.1	72.6	92.0	60.8	92.1	Depth Criteria	Depth Criteria
BR180	55195.32	486.5	38.3	468.3	-	-	38.3	468.3	Depth Criteria	Depth Criteria
BR179	54587.25	318.9	23.6	286.3	-	-	23.6	286.3	Depth Criteria	Depth Criteria
BR178	54302.34	181.4	18.9	166.1	78.7	87.2	18.9	166.1	Depth Criteria	Depth Criteria
BR177b	54227.29	262.3	146.5	170.9	151.0	168.5	146.5	170.9	Depth Criteria	Depth Criteria
BR177a	54209.73	296.0	181.7	205.5	183.8	204.1	181.7	205.5	Depth Criteria	Depth Criteria
BR176	54152.35	314.6	233.4	253.1	234.8	252.6	233.4	253.1	Depth Criteria	Depth Criteria
BR175b	54096.79	599.2	503.0	528.0	503.8	527.4	503.0	528.0	Depth Criteria	Depth Criteria
BR175a	54072.70	608.9	523.9	547.7	525.4	546.2	523.9	547.7	Depth Criteria	Depth Criteria
BR174	54061.55	568.5	490.3	513.6	491.9	512.7	490.3	513.6	Depth Criteria	Depth Criteria
BR173b	54053.88	573.2	493.9	517.8	494.3	517.4	493.9	517.8	Depth Criteria	Depth Criteria
BR173a	54029.93	571.7	497.5	520.6	497.9	520.0	497.5	520.6	Depth Criteria	Depth Criteria
BR172	53912.08	328.7	132.6	293.7	204.0	212.5	132.6	293.7	Depth Criteria	Depth Criteria
BR171	53531.90	439.6	291.4	338.1	295.9	307.4	291.4	338.1	Depth Criteria	Depth Criteria
BR170	53205.43	237.8	16.1	216.3	17.2	32.6	16.1	34.6	Depth Criteria	Depth Criteria
BR169	52695.44	292.9	129.1	178.7	163.6	176.6	129.1	178.7	Depth Criteria	Depth Criteria
BR168	52511.77	353.2	156.1	183.0	165.6	181.1	156.1	183.0	Depth Criteria	Depth Criteria
BR167	52209.14	209.4	53.1	108.3	56.2	66.5	53.1	108.3	Depth Criteria	Depth Criteria
BR166	51761.57	288.5	161.0	256.6	164.4	172.9	161.0	256.6	Depth Criteria	Depth Criteria
BR165b	51674.15	408.5	295.1	346.6	296.0	342.7	295.1	374.1	Depth Criteria	Hydraulically Smoothed
BR165a	51665.33	405.1	295.1	309.9	296.1	308.8	295.1	382.0	Depth Criteria	Hydraulically Smoothed
BR164	51591.42	271.4	88.9	153.1	116.4	129.0	114.9	218.2	Hydraulically Smoothed	Hydraulically Smoothed
BR163	51306.88	292.1	22.4	264.1	-	-	22.4	264.1	Depth Criteria	Depth Criteria
BR162	51036.21	358.1	48.4	341.9	95.6	101.9	37.1	225.4	Hydraulically Smoothed	Depth Criteria
BR161	50863.87	218.6	20.5	170.2	154.4	164.0	20.5	170.2	Depth Criteria	Depth Criteria
BR160	50564.16	390.9	70.3	233.1	215.5	230.6	70.3	233.1	Depth Criteria	Depth Criteria
BR159	50253.50	412.4	126.7	391.5	322.4	329.2	126.7	391.5	Depth Criteria	Depth Criteria
BR158	49988.23	433.4	319.0	422.2	404.0	412.4	319.0	422.2	Depth Criteria	Depth 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
BR157	49713.16	322.9	78.6	300.3	192.0	199.2	78.6	300.3	Depth Criteria	Depth Criteria
BR156	49371.68	266.4	15.8	245.5	229.3	240.5	15.8	245.5	Depth Criteria	Depth Criteria
BR155	48864.88	648.6	36.2	275.2	-	-	36.2	275.2	Depth Criteria	Depth Criteria
BR154	48695.22	444.8	144.3	347.6	-	-	144.3	347.6	Depth Criteria	Depth Criteria
BR153	48387.18	211.2	92.6	122.7	96.7	121.0	92.6	122.7	Depth Criteria	Depth Criteria
BR152b	48267.62	419.5	195.1	225.8	198.0	218.8	195.1	225.8	Depth Criteria	Depth Criteria
BR152a	48237.60	489.8	212.3	241.7	219.5	238.0	212.3	241.7	Depth Criteria	Depth Criteria
BR151	48037.52	1,037.2	540.0	632.1	615.7	630.4	540.0	632.1	Depth Criteria	Depth Criteria
BR150	47599.79	1,016.1	405.5	918.4	-	-	405.5	918.4	Depth Criteria	Depth Criteria
BR149	47126.99	872.6	311.5	790.8	-	-	311.5	790.8	Depth Criteria	Depth Criteria
BR148	46857.21	1,421.2	508.7	1,218.6	528.0	539.7	508.7	1,218.6	Depth Criteria	Depth Criteria
BR147b	46789.16	1,479.4	533.8	1,215.0	534.1	555.2	533.1	1,215.0	No Viable Flood Fringe	Depth Criteria
BR147a	46771.18	1,490.7	542.7	1,209.2	543.3	563.0	543.3	1,256.3	Velocity Criteria	Hydraulically Smoothed
BR146	46661.28	1,357.4	500.4	1,213.9	538.3	545.8	315.5	1,233.0	Previous Floodway	Hydraulically Smoothed
BR145	45615.48	706.1	308.9	652.7	-	-	294.9	658.1	No Viable Flood Fringe	Previous Floodway
BR144	44821.39	338.8	202.1	306.3	275.8	284.7	168.4	307.0	Previous Floodway	Previous Floodway
BR143	44326.25	151.5	39.1	92.8	74.1	91.1	34.7	94.9	Previous Floodway	Previous Floodway
BR142	43962.83	108.4	44.5	71.5	45.5	68.3	45.5	69.3	Velocity Criteria	Previous Floodway
BR141	43533.04	146.9	110.8	129.5	110.8	129.1	107.6	129.1	Previous Floodway	Velocity Criteria
BR140	42812.24	219.8	76.0	201.1	128.8	143.2	128.1	146.0	Previous Floodway	Previous Floodway
BR139	42312.92	108.1	11.3	47.7	30.7	45.5	9.9	49.2	No Viable Flood Fringe	Previous Floodway
BR138	41788.43	253.6	96.6	244.5	124.3	138.3	89.1	244.6	Previous Floodway	Previous Floodway
BR137	41310.43	124.3	65.3	112.5	93.2	110.9	86.1	114.1	Previous Floodway	Previous Floodway
BR136b	41269.83	193.5	77.3	109.1	85.9	105.0	77.7	105.0	Previous Floodway	Velocity Criteria
BR136a	41263.54	192.5	78.0	110.2	86.5	106.7	82.4	106.7	Previous Floodway	Velocity Criteria
BR135	41238.70	146.2	75.3	110.7	82.8	104.5	77.7	104.5	Previous Floodway	Velocity Criteria
BR134	41194.60	51.5	16.7	37.5	18.6	35.8	18.6	35.8	Velocity Criteria	Velocity Criteria
BR133	41165.23	47.0	13.2	33.2	14.4	32.0	10.2	32.3	Previous Floodway	Previous Floodway
BR132	41074.72	200.0	71.1	95.9	72.3	91.7	70.2	92.7	Previous Floodway	Previous Floodway
BR131b	40970.09	237.6	63.5	92.8	66.4	84.9	64.4	92.7	Previous Floodway	Previous Floodway
BR131a	40964.22	233.3	63.6	92.4	67.1	85.7	63.8	93.0	Previous Floodway	Previous Floodway
BR130	40887.27	142.5	41.9	121.5	98.3	113.4	43.5	118.0	Previous Floodway	Previous Floodway
BR129	40718.83	284.8	10.6	181.9	-	-	15.5	180.1	Previous Floodway	Previous Floodway
BR128	40552.65	266.7	13.6	252.4	-	-	10.9	249.6	No Viable Flood Fringe	Previous Floodway
BR127	40357.23	260.3	23.8	246.7	-	-	25.9	245.0	Previous Floodway	Previous Floodway
BR126	40153.42	201.0	43.5	182.6	-	-	36.7	178.6	Previous Floodway	Previous Floodway
BR125	40061.16	94.2	27.5	68.8	38.0	59.8	30.0	67.9	Previous Floodway	Previous Floodway
BR124	39994.05	78.2	25.2	47.9	25.5	47.4	23.8	48.2	Previous Floodway	Previous Floodway
BR123	39942.29	206.7	87.7	112.1	89.5	111.3	87.7	112.0	Depth Criteria	Previous Floodway
BR122	39767.21	335.3	214.2	244.7	218.4	240.4	214.1	244.3	Previous Floodway	Previous Floodway
BR121b	39698.45	299.7	207.1	233.2	212.4	232.1	205.4	232.6	Previous Floodway	Previous Floodway
BR121a	39692.72	291.1	209.7	234.8	212.7	233.6	208.4	235.2	Previous Floodway	Previous Floodway
BR120	39608.68	157.4	92.6	117.9	97.9	115.7	91.3	118.9	Previous Floodway	Previous Floodway
BR119	39521.91	178.9	99.5	131.1	102.0	122.7	99.4	128.1	Previous Floodway	Previous Floodway
BR118b	39436.73	246.8	144.3	162.0	145.4	163.6	142.8	163.6	Previous Floodway	Velocity Criteria
BR118a	39430.16	249.3	143.0	161.2	144.1	160.7	141.5	161.0	No Viable Flood Fringe	Previous Floodway
BR117	39379.67	252.7	132.9	156.7	136.1	156.2	130.2	156.3	Previous Floodway	Previous Floodway
BR116b	39311.00	73.6	15.3	40.8	15.0	40.5	13.8	41.7	Previous Floodway	Previous Floodway

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
BR116a	39288.79	59.4	16.3	38.5	13.9	38.3	13.5	40.1	Previous Floodway	Previous Floodway
BR115	39280.27	55.4	13.5	33.6	9.8	35.0	9.8	35.0	Previous Floodway	Velocity Criteria
BR114b	39271.28	90.1	44.9	65.5	43.4	65.3	43.4	66.0	Velocity Criteria	Previous Floodway
BR114a	39252.25	109.7	56.6	75.4	53.6	76.3	53.6	77.0	Velocity Criteria	Previous Floodway
BR113	39200.55	100.9	46.5	69.6	46.4	70.5	44.6	70.5	Previous Floodway	Velocity Criteria
BR112b	39158.74	96.3	31.8	54.4	32.4	55.0	30.5	55.1	Previous Floodway	Previous Floodway
BR112a	39150.50	96.8	30.4	53.4	30.7	53.3	29.2	54.6	Previous Floodway	Previous Floodway
BR111	39120.36	138.8	69.4	99.3	78.0	96.2	70.1	97.2	Previous Floodway	Previous Floodway
BR110b	39094.15	110.6	63.2	81.2	64.4	80.0	63.0	80.3	Previous Floodway	Previous Floodway
BR110a	39085.34	116.4	65.4	83.2	63.4	84.3	63.4	84.3	Velocity Criteria	Velocity Criteria
BR109	39009.61	153.8	32.7	75.2	47.9	74.3	32.4	75.2	Previous Floodway	Depth Criteria
BR108	38767.08	81.4	21.3	45.5	22.2	44.6	20.6	44.6	Previous Floodway	Velocity Criteria
BR107b	38700.32	113.0	52.5	72.7	53.6	71.8	51.5	72.7	Previous Floodway	Previous Floodway
BR107a	38695.54	115.5	51.4	71.6	52.3	70.9	50.9	70.9	Previous Floodway	Previous Floodway
BR106	38647.20	150.1	64.5	92.6	75.9	91.1	59.1	93.0	Previous Floodway	Previous Floodway
BR105	38475.17	191.4	145.3	162.6	146.1	161.3	144.0	164.0	No Viable Flood Fringe	Previous Floodway
BR104	38219.94	182.6	141.8	173.0	144.6	169.2	140.0	173.0	Previous Floodway	Depth Criteria
BR103	37945.44	118.7	23.8	93.7	70.9	91.3	20.0	94.8	Previous Floodway	No Viable Flood Fringe
BR102b	37911.48	156.1	9.7	130.0	107.9	128.5	106.4	132.1	Previous Floodway	Previous Floodway
BR102a	37904.65	165.2	19.0	141.5	119.5	139.6	118.7	142.4	Previous Floodway	Previous Floodway
BR101	37844.86	219.2	138.1	163.4	140.2	162.4	136.6	165.3	No Viable Flood Fringe	No Viable Flood Fringe
BR100	37504.07	219.4	24.7	124.7	98.0	123.0	96.6	123.0	Previous Floodway	Velocity Criteria
BR099	37263.70	80.7	34.0	54.5	34.8	55.9	30.4	55.9	Previous Floodway	Velocity Criteria
BR098b	37232.52	45.8	15.8	33.3	15.3	33.6	13.4	33.8	Previous Floodway	Previous Floodway
BR098a	37204.43	62.7	27.0	41.9	27.0	43.4	25.9	43.4	Previous Floodway	Previous Floodway
BR097b	37197.68	64.2	25.9	41.4	26.6	40.9	25.9	40.9	Hydraulically Smoothed	Velocity Criteria
BR097a	37192.23	68.3	27.5	43.8	27.7	43.5	26.9	43.5	Previous Floodway	Velocity Criteria
BR096	37131.10	180.8	26.0	161.8	143.0	154.7	129.5	162.1	Previous Floodway	Previous Floodway
BR095b	37076.19	156.2	122.6	142.4	125.1	142.2	120.3	144.1	Previous Floodway	No Viable Flood Fringe
BR095a	37070.00	163.2	129.0	147.9	131.5	144.6	126.0	149.7	No Viable Flood Fringe	No Viable Flood Fringe
BR094	37032.70	166.1	82.5	156.0	103.9	118.5	82.0	156.0	Previous Floodway	Previous Floodway
BR093	36782.49	244.4	17.2	73.6	22.5	36.4	17.9	89.4	Previous Floodway	Previous Floodway
BR092	36677.71	238.2	34.1	150.9	35.2	49.1	33.9	68.6	Previous Floodway	Previous Floodway
BR091	36360.77	336.4	62.9	169.6	63.6	79.1	62.3	114.8	Previous Floodway	Previous Floodway
BR090b	36298.75	354.1	143.4	160.2	144.9	158.0	140.9	162.3	No Viable Flood Fringe	No Viable Flood Fringe
BR090a	36292.38	377.7	164.5	181.2	167.0	179.1	161.9	183.2	No Viable Flood Fringe	No Viable Flood Fringe
BR089	36240.32	251.4	20.6	208.4	193.6	206.9	154.1	211.7	No Viable Flood Fringe	No Viable Flood Fringe
BR088	35974.21	236.4	107.8	205.1	190.2	204.3	157.9	210.6	Previous Floodway	No Viable Flood Fringe
BR087b	35933.33	304.9	92.8	169.4	151.5	168.0	145.4	169.5	No Viable Flood Fringe	Previous Floodway
BR087a	35925.88	300.2	88.3	259.8	131.3	145.3	128.0	151.3	No Viable Flood Fringe	No Viable Flood Fringe
BR086	35858.09	207.3	26.2	154.1	26.7	42.6	26.7	51.7	Velocity Criteria	Previous Floodway
BR085	35529.54	183.7	40.0	113.8	64.9	81.0	37.2	113.3	No Viable Flood Fringe	Previous Floodway
BR084	35166.82	131.8	49.5	68.6	54.3	68.3	24.7	68.6	No Viable Flood Fringe	Depth Criteria
BR083	34823.97	76.1	12.7	51.9	35.5	51.2	14.4	51.9	Previous Floodway	Depth Criteria
BR082	34555.46	147.8	9.2	135.7	10.4	27.4	7.7	56.5	Previous Floodway	No Viable Flood Fringe
BR081b	34497.99	75.5	26.6	46.9	31.5	45.1	23.5	49.1	No Viable Flood Fringe	No Viable Flood Fringe
BR081a	34490.29	80.3	26.3	46.7	31.5	45.7	23.3	47.1	No Viable Flood Fringe	Previous Floodway
BR080	34409.10	131.2	15.4	38.5	16.1	30.7	14.9	41.3	No Viable Flood Fringe	Previous Floodway

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
BR079	34126.81	167.3	104.4	137.2	114.0	136.8	107.3	137.2	Previous Floodway	Depth Criteria
BR078	33634.63	66.2	23.4	54.8	27.3	54.1	17.7	56.6	No Viable Flood Fringe	No Viable Flood Fringe
BR077b	33590.46	60.1	22.3	46.5	23.1	45.3	19.5	47.4	No Viable Flood Fringe	Previous Floodway
BR077a	33554.07	62.6	23.2	43.8	24.9	40.6	20.4	46.7	No Viable Flood Fringe	No Viable Flood Fringe
BR076	33519.67	93.3	34.4	67.7	49.0	66.1	29.7	69.6	No Viable Flood Fringe	No Viable Flood Fringe
BR075	33435.27	90.2	38.6	67.2	43.1	60.3	38.6	71.6	Depth Criteria	No Viable Flood Fringe
BR074b	33385.56	87.2	52.0	68.5	53.9	66.6	50.1	71.9	No Viable Flood Fringe	No Viable Flood Fringe
BR074a	33375.55	90.6	54.4	71.9	55.8	68.6	52.3	74.4	No Viable Flood Fringe	No Viable Flood Fringe
BR073	33343.09	109.3	62.0	83.3	68.3	82.2	59.4	84.1	No Viable Flood Fringe	No Viable Flood Fringe
BR072	33074.16	110.8	52.5	73.6	54.4	72.7	36.5	73.6	No Viable Flood Fringe	Depth Criteria
BR071	32840.75	70.9	22.9	42.6	25.9	41.2	20.2	50.7	No Viable Flood Fringe	No Viable Flood Fringe
BR070	32583.33	127.3	92.9	117.6	97.1	116.8	88.4	118.5	No Viable Flood Fringe	No Viable Flood Fringe
BR069	32241.86	80.8	18.5	42.4	21.7	38.6	17.4	44.5	Previous Floodway	No Viable Flood Fringe
BR068	31864.66	92.1	39.2	69.1	40.6	59.0	28.4	74.8	No Viable Flood Fringe	No Viable Flood Fringe
BR067	31597.48	113.7	56.2	74.2	57.5	70.9	27.2	74.6	Previous Floodway	Previous Floodway
BR066	31155.45	78.4	30.4	52.8	31.8	47.9	23.9	54.8	Previous Floodway	Previous Floodway
BR065	30965.52	89.1	7.8	44.9	14.8	33.0	7.8	49.7	Depth Criteria	Previous Floodway
BR064	30498.08	114.9	46.1	71.5	54.8	71.1	37.4	80.6	No Viable Flood Fringe	No Viable Flood Fringe
BR063	29982.19	90.5	31.9	72.9	56.3	70.0	25.1	75.7	Previous Floodway	No Viable Flood Fringe
BR062	29733.21	150.3	4.2	29.2	5.0	19.0	4.2	76.9	Depth Criteria	Previous Floodway
BR061b	29682.43	88.6	18.0	34.8	18.9	32.7	15.9	47.8	No Viable Flood Fringe	No Viable Flood Fringe
BR061a	29674.83	90.7	20.1	37.4	22.0	36.5	18.1	41.8	No Viable Flood Fringe	No Viable Flood Fringe
BR060	29617.88	123.6	23.8	64.5	40.9	61.6	23.3	65.6	Previous Floodway	No Viable Flood Fringe
BR059	29150.09	171.5	35.2	140.0	72.5	87.2	66.8	144.3	Previous Floodway	No Viable Flood Fringe
BR058	28581.13	82.3	32.8	69.7	50.8	66.6	32.4	69.7	Previous Floodway	Depth Criteria
BR057b	28535.87	84.2	28.9	60.7	37.7	54.1	27.5	67.4	Previous Floodway	No Viable Flood Fringe
BR057a	28530.05	79.0	21.1	52.7	30.8	48.5	20.7	59.0	Previous Floodway	Previous Floodway
BR056	28470.34	80.2	8.9	50.7	10.8	26.2	10.6	59.6	Previous Floodway	Previous Floodway
BR055	27849.11	134.2	31.1	99.4	49.5	61.9	36.0	93.7	Previous Floodway	Previous Floodway
BR054	27293.26	140.8	27.2	99.1	76.0	83.5	27.2	99.1	Depth Criteria	Depth Criteria
BR053	26754.76	147.8	42.0	100.0	54.3	69.2	42.0	100.0	Depth Criteria	Depth Criteria
BR052	26126.16	187.4	60.0	145.6	-	-	60.0	145.6	Depth Criteria	Depth Criteria
BR051	26041.09	182.4	35.3	127.7	-	-	35.3	127.7	Depth Criteria	Depth Criteria
BR050	25815.08	108.5	17.1	68.9	-	-	17.1	68.9	Depth Criteria	Depth Criteria
BR049	25751.21	91.9	9.2	43.4	10.8	32.9	9.2	43.4	Depth Criteria	Depth Criteria
BR048	25333.65	60.3	25.1	50.4	31.1	47.6	25.1	50.4	Depth Criteria	Depth Criteria
BR047	24778.57	62.6	21.5	45.2	28.8	44.0	21.5	45.2	Depth Criteria	Depth Criteria
BR046	24238.27	88.4	30.6	51.4	32.8	50.4	30.6	51.4	Depth Criteria	Depth Criteria
BR045	23696.79	92.7	47.7	68.6	51.2	66.7	47.7	68.6	Depth Criteria	Depth Criteria
BR044	23192.93	59.8	23.4	43.0	23.8	41.0	23.4	43.0	Depth Criteria	Depth Criteria
BR043	22729.01	84.1	37.1	59.6	37.5	56.0	37.1	59.6	Depth Criteria	Depth Criteria
BR042	22110.36	78.8	16.8	37.1	19.6	35.1	16.8	37.1	Depth Criteria	Depth Criteria
BR041	21509.99	65.2	35.0	49.9	37.7	48.5	35.0	49.9	Depth Criteria	Depth Criteria
BR040	21058.59	91.3	34.7	58.8	37.1	57.7	34.7	58.8	Depth Criteria	Depth Criteria
BR039	20441.35	117.5	65.3	84.5	66.2	83.0	65.3	84.5	Depth Criteria	Depth Criteria
BR038	19752.18	76.1	8.9	28.9	9.9	26.7	8.9	28.9	Depth Criteria	Depth Criteria
BR037	19167.94	85.1	33.8	60.5	35.4	59.4	33.8	60.5	Depth Criteria	Depth Criteria
BR036	18705.98	87.0	17.8	38.4	22.1	37.9	17.8	38.4	Depth Criteria	Depth 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
BR035	18163.91	81.1	15.5	40.5	16.7	33.5	15.5	40.5	Depth Criteria	Depth Criteria
BR034	17680.01	61.8	26.6	50.3	30.8	49.0	26.6	50.3	Depth Criteria	Depth Criteria
BR033	16944.06	67.5	31.7	52.6	34.8	51.3	31.7	52.6	Depth Criteria	Depth Criteria
BR032	16346.02	58.5	24.5	45.3	26.7	39.5	24.5	45.3	Depth Criteria	Depth Criteria
BR031	15789.04	65.8	9.2	28.5	10.4	27.5	9.2	28.5	Depth Criteria	Depth Criteria
BR030	15196.25	84.7	6.4	40.0	7.0	25.6	6.4	40.0	Depth Criteria	Depth Criteria
BR029	14500.02	95.1	51.3	68.5	52.1	67.3	51.3	68.5	Depth Criteria	Depth Criteria
BR028	13959.76	79.7	12.6	34.6	14.3	32.8	12.6	34.6	Depth Criteria	Depth Criteria
BR027	13578.04	89.5	7.6	28.8	9.9	26.8	7.6	28.8	Depth Criteria	Depth Criteria
BR026	13061.06	76.6	35.3	57.8	35.2	55.4	35.2	57.8	Velocity Criteria	Depth Criteria
BR025	12434.00	108.1	17.3	38.1	18.6	36.5	17.3	42.0	Depth Criteria	Hydraulically Smoothed
BR024	11869.63	78.5	43.8	69.1	48.3	67.6	43.8	69.1	Depth Criteria	Depth Criteria
BR023	11307.38	62.5	21.8	45.4	28.9	44.7	21.8	45.4	Depth Criteria	Depth Criteria
BR022	10619.70	74.3	21.1	42.1	25.9	41.6	21.1	42.1	Depth Criteria	Depth Criteria
BR021	9847.98	107.6	78.2	99.3	80.9	98.6	78.2	99.3	Depth Criteria	Depth Criteria
BR020	9363.83	183.8	32.7	50.2	33.7	49.3	32.7	50.2	Depth Criteria	Depth Criteria
BR019	8742.78	90.3	12.9	29.4	13.3	28.0	12.9	29.4	Depth Criteria	Depth Criteria
BR018	8258.73	143.4	16.3	39.8	19.2	36.2	16.3	39.8	Depth Criteria	Depth Criteria
BR017	7675.74	52.2	31.1	46.9	31.3	46.2	31.1	46.9	Depth Criteria	Depth Criteria
BR016	7057.36	67.3	21.6	40.6	21.9	40.4	21.6	40.6	Depth Criteria	Depth Criteria
BR015	6455.92	63.3	33.0	54.9	35.0	54.6	33.0	54.9	Depth Criteria	Depth Criteria
BR014b	6396.19	132.4	42.8	62.5	40.4	62.4	40.4	62.5	Velocity Criteria	Depth Criteria
BR014a	6383.53	117.4	40.0	60.9	36.3	60.8	36.3	60.9	Velocity Criteria	Depth Criteria
BR013	6341.01	133.2	21.8	71.5	50.2	71.2	21.8	71.5	Depth Criteria	Depth Criteria
BR012	5727.25	145.2	38.0	58.7	38.3	58.4	38.0	58.7	Depth Criteria	Depth Criteria
BR011	5253.23	87.9	19.0	38.1	19.7	38.0	19.0	38.1	Depth Criteria	Depth Criteria
BR010	4502.69	90.3	54.2	76.6	54.5	76.5	54.2	76.6	Depth Criteria	Depth Criteria
BR009	3985.96	133.8	82.4	116.7	96.4	115.0	82.4	116.7	Depth Criteria	Depth Criteria
BR008	3459.92	117.6	11.6	29.6	13.2	28.5	11.6	29.6	Depth Criteria	Depth Criteria
BR007	3000.37	72.1	25.2	61.2	38.3	60.6	33.1	61.2	Hydraulically Smoothed	Depth Criteria
BR006	2470.83	95.8	71.0	86.0	71.5	86.0	71.0	86.0	Depth Criteria	Velocity Criteria
BR005	2011.28	72.6	16.6	44.4	17.4	42.2	16.6	44.4	Depth Criteria	Depth Criteria
BR004	1665.02	75.3	37.1	57.8	40.3	57.2	37.1	57.8	Depth Criteria	Depth Criteria
BR003	1183.19	218.3	117.1	138.6	117.0	137.9	117.0	138.6	Velocity Criteria	Depth Criteria
BR002	682.11	294.8	18.1	38.1	18.1	39.9	18.1	39.9	Velocity Criteria	Velocity Criteria
BR001	14.77	237.9	105.7	131.3	105.5	131.5	105.5	131.5	Velocity Criteria	Depth Criteria

TABLE 8: DESIGN FLOOD WATER SURFACE ELEVATIONS

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
BR198	62105.57	665.62
BR197b	61671.05	665.55
BR197a	61644.16	665.47
BR196	61528.78	665.47
BR195	61063.56	665.35
BR194	60726.66	665.23
BR193	59636.52	665.17
BR192	59213.71	665.14
BR191	58830.53	665.09
BR190b	58702.57	665.07
BR190a	58686.20	664.77
BR189	58581.16	664.73
BR188	58291.76	664.69
BR187	58021.80	664.47
BR186	57572.61	664.23
BR185	57267.51	664.18
BR184	56773.94	663.95
BR183	56209.22	663.62
BR182	55965.68	663.57
BR181	55796.42	663.32
BR180	55195.32	663.29
BR179	54587.25	663.24
BR178	54302.34	663.17
BR176	54152.35	662.50
BR175b	54096.79	662.52
BR175a	54072.70	662.45
BR174	54061.55	662.40
BR172	53912.08	662.39
BR171	53531.90	662.23
BR170	53205.43	661.97
BR169	52695.44	661.56
BR166	51761.57	661.01
BR165b	51674.15	660.84
BR165a	51665.33	660.86
BR162	51036.21	660.71
BR161	50863.87	660.65
BR160	50564.16	660.49
BR157	49713.16	660.26
BR156	49371.68	660.14
BR155	48864.88	660.09
BR154	48695.22	660.06
BR153	48387.18	659.83
BR152b	48267.62	659.71
BR150	47599.79	659.37
BR149	47126.99	659.35
BR148	46857.21	659.27
BR147b	46789.16	658.99
BR147a	46771.18	658.91
BR146	46661.28	658.94
BR145	45615.48	658.83
BR144	44821.39	658.73
BR143	44326.25	658.50
BR142	43962.83	658.12
BR139	42312.92	655.09
BR138	41788.43	654.94

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
BR137	41310.43	654.63
BR136b	41269.83	654.55
BR136a	41263.54	654.55
BR135	41238.70	654.53
BR134	41194.60	654.37
BR133	41165.23	654.27
BR132	41074.72	654.18
BR131b	40970.09	654.10
BR131a	40964.22	654.07
BR130	40887.27	654.08
BR129	40718.83	654.09
BR128	40552.65	654.09
BR127	40357.23	654.08
BR126	40153.42	654.08
BR125	40061.16	654.00
BR124	39994.05	648.78
BR123	39942.29	648.56
BR122	39767.21	648.47
BR121b	39698.45	648.35
BR121a	39692.72	648.34
BR120	39608.68	648.24
BR119	39521.91	648.21
BR118b	39436.73	647.82
BR118a	39430.16	647.84
BR117	39379.67	647.81
BR116b	39311.00	647.55
BR116a	39288.79	647.34
BR115	39280.27	647.18
BR114b	39271.28	647.17
BR114a	39252.25	646.57
BR113	39200.55	646.49
BR112b	39158.74	646.42
BR112a	39150.50	646.40
BR111	39120.36	646.47
BR110b	39094.15	646.18
BR110a	39085.34	645.97
BR109	39009.61	646.07
BR108	38767.08	645.77
BR107b	38700.32	645.61
BR107a	38695.54	645.61
BR106	38647.20	645.48
BR105	38475.17	645.02
BR104	38219.94	644.96
BR103	37945.44	644.83
BR102b	37911.48	644.78
BR102a	37904.65	644.64
BR101	37844.86	644.60
BR100	37504.07	644.33
BR099	37263.70	643.52
BR098b	37232.52	643.34
BR098a	37204.43	642.92
BR097b	37197.68	642.91
BR097a	37192.23	643.04
BR096	37131.10	643.21
BR095b	37076.19	642.75
BR095a	37070.00	642.55

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
BR094	37032.70	642.68
BR093	36782.49	642.37
BR092	36677.71	642.15
BR091	36360.77	641.82
BR090b	36298.75	641.08
BR090a	36292.38	641.07
BR089	36240.32	641.02
BR088	35974.21	640.48
BR087b	35933.33	640.41
BR087a	35925.88	640.26
BR086	35858.09	640.24
BR085	35529.54	639.87
BR084	35166.82	639.04
BR083	34823.97	638.43
BR082	34555.46	638.07
BR081b	34497.99	637.50
BR081a	34490.29	637.49
BR080	34409.10	637.21
BR079	34126.81	636.68
BR078	33634.63	635.89
BR077b	33590.46	635.75
BR077a	33554.07	635.73
BR076	33519.67	635.75
BR075	33435.27	635.66
BR074b	33385.56	635.02
BR074a	33375.55	634.98
BR073	33343.09	634.98
BR072	33074.16	634.57
BR071	32840.75	633.90
BR070	32583.33	633.52
BR069	32241.86	632.98
BR068	31864.66	632.63
BR067	31597.48	632.09
BR066	31155.45	631.50
BR065	30965.52	631.43
BR064	30498.08	631.00
BR063	29982.19	630.38
BR062	29733.21	630.03
BR061b	29682.43	629.13
BR061a	29674.83	629.29
BR060	29617.88	629.29
BR059	29150.09	628.87
BR058	28581.13	628.44
BR057b	28535.87	628.42
BR057a	28530.05	628.40
BR056	28470.34	628.34
BR055	27849.11	628.19
BR054	27293.26	628.08
BR053	26754.76	627.93
BR052	26126.16	627.86
BR051	26041.09	627.85
BR050	25815.08	619.99
BR049	25751.21	619.80
BR048	25333.65	619.22
BR047	24778.57	618.13
BR046	24238.27	617.39

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
BR045	23696.79	616.62
BR044	23192.93	616.01
BR043	22729.01	615.54
BR042	22110.36	614.90
BR041	21509.99	613.43
BR040	21058.59	612.77
BR039	20441.35	611.71
BR038	19752.18	610.66
BR037	19167.94	610.14
BR036	18705.98	609.62
BR035	18163.91	609.04
BR034	17680.01	608.63
BR033	16944.06	607.75
BR032	16346.02	606.54
BR031	15789.04	605.34
BR030	15196.25	604.61
BR029	14500.02	603.09
BR028	13959.76	602.29
BR027	13578.04	601.64
BR026	13061.06	600.62
BR025	12434.00	599.37
BR024	11869.63	598.37
BR023	11307.38	597.39
BR022	10619.70	595.94
BR021	9847.98	594.97
BR020	9363.83	594.36
BR019	8742.78	592.87
BR018	8258.73	592.42
BR017	7675.74	590.32
BR016	7057.36	586.99
BR015	6455.92	584.71
BR014b	6396.19	584.34
BR014a	6383.53	584.37
BR013	6341.01	584.30
BR012	5727.25	582.63
BR011	5253.23	580.73
BR010	4502.69	577.26
BR009	3985.96	575.41
BR008	3459.92	573.27
BR007	3000.37	572.36
BR006	2470.83	570.00
BR005	2011.28	568.56
BR004	1665.02	567.36
BR003	1183.19	565.64
BR002	682.11	563.99
BR001	14.77	561.87

APPENDIX A
Survey and Base Data Collection

BRIDGE INFORMATION SHEET

Project: Bear Creek Flood Study Cross Section:

Location: Range Road 70 Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 25.28 m

Outside to Outside Width 8.47 m

Elevation Data

	Top Concerete of Curb or Solid Guard Rail		Low Chord	
Left Abutment	666.87	m	666.58	m
Midspan	666.90	m	666.59	m
Right Abutment	666.90	m	666.62	m

Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number 2 Width 8.48 m

Type timber truss (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape rectangular (i.e. rectangular, circular, wedge)

Note: All elevations to be referenced to geodetic datum.

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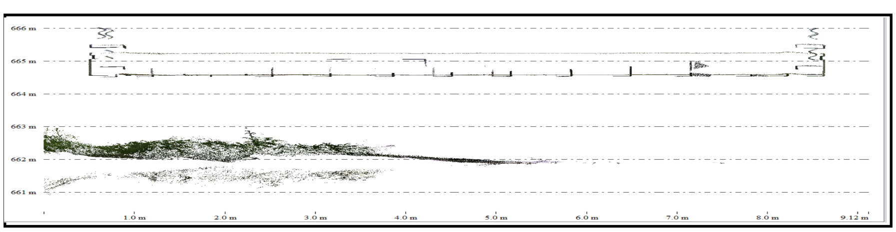

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Cross Section:
Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 25.28 m
Outside to Outside Width 8.47 m

Elevation Data

	Top Concerete of Curb or Solid Guard Rail		Low Chord	
Left Abutment	666.87	m	666.58	m
Midspan	666.90	m	666.59	m
Right Abutment	666.90	m	666.62	m

Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number 2 Width 8.48 m

Type timber truss (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape rectangular (i.e. rectangular, circular, wedge)

Note: All elevations to be referenced to geodetic datum.

BRIDGE INFORMATION SHEET

Project: Bear Creek Flood Study

Cross Section:

Location: Range Road 70

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 25.28 m

Outside to Outside Width 8.47 m

Elevation Data

	Top Concerete of Curb or Solid Guard Rail		Low Chord	
Left Abutment	666.87	m	666.58	m
Midspan	666.90	m	666.59	m
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Project: Bear Creek Flood Study

Cross Section:

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Cross Section:

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Type timber truss (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape rectangular (i.e. rectangular, circular, wedge)

Note: All elevations to be referenced to geodetic datum.

APPENDIX B
Hydrology Report

June 13, 2025

Version 3.0
Ref. 35917-531

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

Subject: Grande Prairie Flood Study, Hydrologic Assessment

Dear Jim Choles:

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 approximately 58 km of the Bear River through the City of Grande Prairie (the City) and County of Grande Prairie (the County). 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. The study area extends from the outlet at Bear Lake in NE ¼ 24-072-07 W6M, to just upstream of where an unnamed tributary joins the Bear River in SW ¼ 17-071-04 W6M, as shown on Figure 1. The key project stakeholders are the Government of Alberta, the City of Grande Prairie, and County of Grande Prairie.

A previous flood study was completed by NHC (2007); however, the mapping extents in the current study are larger than the previous completed flood hazard mapping study. The NHC (2007) flood study used flood frequencies up to a 1,000-year flood event derived from the recorded flows at Grande Prairie Creek near Sexsmith (07GE003) covering a period from 1971 to 2003. The NHC (2007) flood study encompassed approximately 21 km of the Bear River, extending from 132 Avenue (Township Road 720) at the north end of the City and continued to approximately 48 Avenue at the south end of the City. The purpose of the current study is to update the flood frequencies with return periods ranging from 2-year to 1,000-year using the available historical flood data to date and to expand the hydraulic modelling extent and flood mapping coverage.

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 (13 scenarios) with confidence intervals are required at key locations along the Bear River within the study area. The key locations include:

- at the Bear Lake outlet
- at the confluence location of the Grande Prairie Creek and the Bear River
- at the outlet of the Grande Prairie Reservoir
- at the downstream boundary of the Grande Prairie study reach
- any other locations where significant peak inflows enter the Bear 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 (FHIP)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). The estimated flood frequencies will be used as model input data for hydraulic modelling and flood inundation mapping. A detailed description of the flood frequency analysis methodology and the flood frequency estimates are provided herein.

In 2023, a hydrology report was submitted to EPA with recommended flood frequency estimates for the Bear River from its confluence with Grande Prairie Creek to the downstream study boundary for hydraulic modelling purposes (Matrix 2023). The hydrology report provided a description of two possible approaches to estimate Bear Lake outflows but did not include outflows to be used as the upstream model boundary condition. Estimated Bear Lake outflows are required to delineate flood inundation and hazard maps for the study reach from Bear Lake outlet to the Grande Prairie Creek confluence. This updated report outlines the approach used in deriving outflows from Bear Lake and recommended outflows for the 13 modelling scenarios, as described in Section 6.1 of the report.

The Matrix (2023) report provided water level frequency estimates based on recorded water levels in the lake. This method may have overestimated the magnitude of computed water levels since recorded water levels may be dependent on the previous years levels which could violate the "independence of data" requirement for statistical analysis. This updated report includes the updated water level frequency estimates for Bear Lake, determined by eliminating potential "dependency' of water levels in the lake use for hydrologic analysis, as described in Section 6.1 of this report.

2 PROJECT SETTING AND OVERVIEW OF BEAR RIVER

The Bear River basin is a part of the Wapiti, Smoky, and eventually the Peace River system. The Bear River, which is the mainstream of the Bear River basin, has several smaller tributaries and flows through two large lakes, La Glace Lake and Bear Lake (Figure 2). Most of the land use of the Bear River watershed comprises agricultural and forested areas. The drainage area of the Bear River at the downstream study boundary is 1,958 km^2 and the drainage area of the Bear River at the outlet of Bear Lake is 1,221 km^2 (i.e.,62% of the drainage area of the Bear River at the downstream study boundary is located upstream of the Bear Lake outlet). Bear Lake has a surface area of 33 km^2 and is a key natural feature that plays a significant role in the attenuation of the peak flows in the Bear River downstream of the lake.

Grande Prairie Creek, a major tributary of the Bear River drains into the Bear River 2 km downstream of the Bear Lake outlet. The drainage area of the Grande Prairie Creek above its confluence with the Bear River is 348 km^2. The drainage area of Bear River below its confluence with Grande Prairie Creek is 1,567 km^2. The peak inflows to Bear Lake are significantly attenuated because of the large storage capacity of Bear Lake. Under flood conditions, the attenuated peak outflows from this lake combined with peak flows through Grande Prairie Creek and local runoff from the surrounding lands flow through the Bear River study reach.

As discussed in various reports including the Bear Creek Watershed Study (Marshall, Macklin and Monaghan 1984) and the La Glace-Bear Lake Water Management Study (Samide Engineering Ltd. 1998), the watershed consists of two distinct hydrologic systems: (1) the drainage area above Bear Lake and (2) the Grande Prairie Creek Watershed. Through the developed hydrologic model (Marshall et. al 1984) and hydraulic model (Samide Engineering Ltd. 1998), it has been confirmed that high water levels at the confluence of Bear River and Grande Prairie Creek associated with peak flows in Grande Prairie Creek cause flow reversals in the Bear River reach below Bear Lake and a companion reduction in the Grande Prairie Creek peak flow downstream of the confluence.

In addition to natural storage features such as Bear Lake and La Glace Lake, flows along the Bear River are regulated at the Grande Prairie Reservoir, located within the City. The reservoir was built in 1948 and reconstructed in 1975-76 (SNC 2021). Its original purpose was to supply water to the City but it is currently used for recreational purposes. Releases from the reservoir are controlled by a spillway with two radial gates, each 5 m wide, and there are no separate low-level outlets. The gates are manually operated to manage spring floods and winter recreation. The reservoir normal operating level coincides with the spillway invert at the dam. In the spring, the gates are typically opened to pass flood flows. Later in the summer, the gates are often closed by mid-June to maintain higher reservoir levels for summer recreational use (i.e., near the full supply level).

A literature review indicated that with the surface area in the range of 0.16 km^2, this run-of-river reservoir facility is very small in comparison to the contributing watershed. Therefore, outflows from the reservoir are roughly equal to the inflows during normal operations. As indicated in the 2023 TOR, the hydrology assessment conducted for the 2007 flood study (NHC 2007) concluded that the reservoir had no significant flood attenuation capacity; however, the assessment did not include detailed analysis on the reservoir. Some investigation and qualitative assessment of attenuation potential is required as a part of the current study to confirm the assumption that flood attenuation capacity is negligible and because FHIP standards include modelling and mapping naturalized flood flows.

There are 33 hydraulic structures including 15 vehicle bridges, 15 pedestrian bridges, 1 rail bridge, 1 culvert, and 1 spillway structure located across the river within the study area.

The City and the County are located within the study reach and have several stormwater outfalls that discharge to the Bear River. As a result, summer storm events may result in temporarily relatively high contribution to total flow in the Bear River; however, since flooding in the Bear River is generally governed by snowmelt runoff events, the likelihood of these events occurring simultaneously is very low and thus the contribution of stormwater outfalls was not investigated further for this study.

3 OVERVIEW OF BEAR RIVER HYDROLOGY

3.1 Available Streamflow Records and Historical Floods

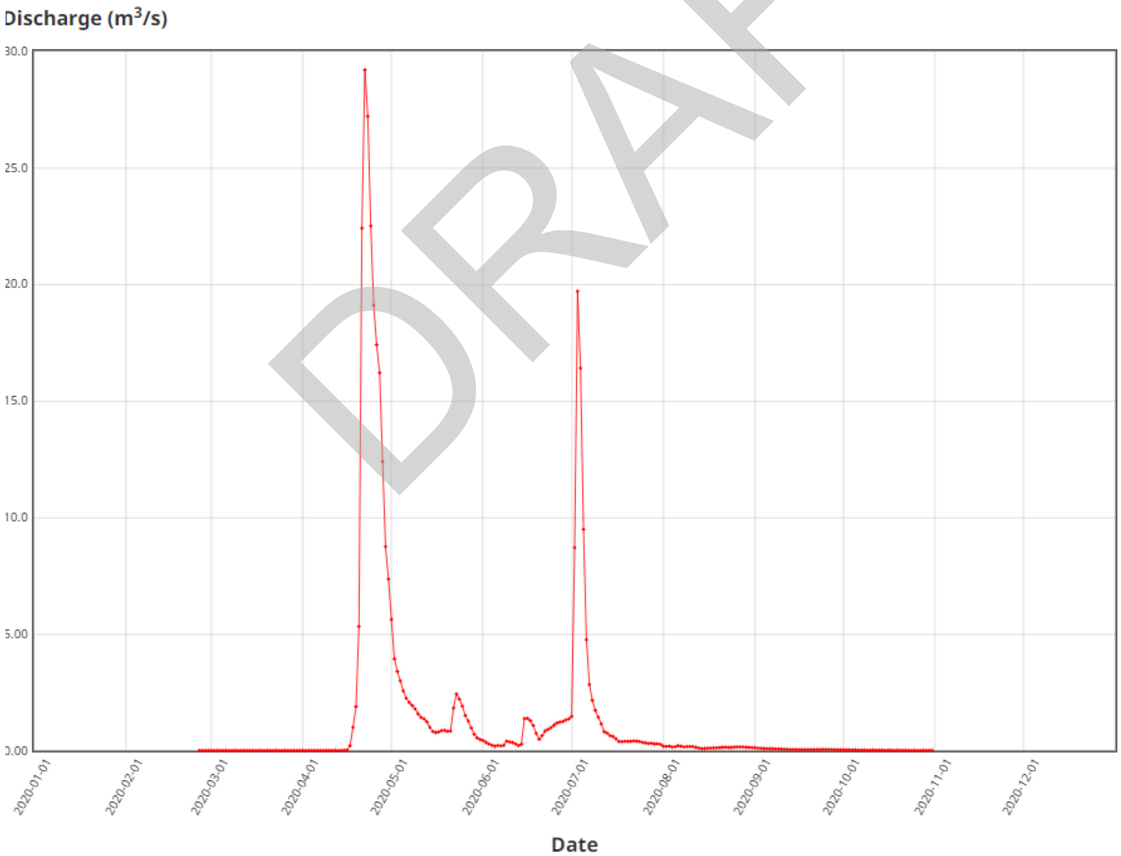
The historical recorded streamflow data were assessed to establish hydrologic characteristics and to derive flood frequency estimates associated with various return periods. A Water Survey of Canada (WSC) hydrometric gauging station, Grande Prairie Creek near Sexsmith (07GE003) has been in operation since 1969. There was a WSC station located on the Bear River near Grande Prairie (07GE005) but was only in operation from 1983 to 1987. A WSC station, Bear River near Valhalla Centre (07GE007) has been in operation since 1984 but it is located upstream of Bear Lake. There is no WSC station currently located on Bear River downstream of Bear Lake. Table A provides pertinent information on WSC stations located within the Bear River watershed and are presented on Figure 2.

TABLE A Key Hydrometric Stations

Station Name and ID	Gross Drainage Area (km^2)	Data Period
Bear River near Grande Prairie (07GE005)	1,510	1983-1987 (Flow)
Bear River near Valhalla Centre (07GE007)	181	1984-2020 (Flow and level)
Bear Lake near Clairmont (07GE004)	1,190	1969-2009 (Level)
Grande Prairie Creek near Sexsmith (07GE003)	140	1969-2022 (Flow and level)
Colquhoun Creek Near Grande Prairie (07GE006)	130	1983 to 1995 (Flow)

The Bear River near Valhalla Centre (07GE007) and Colquhoun Creek Near Grande Prairie (07GE006) WSC stations are located upstream of Bear Lake and will not provide any useful information on flows along the Bear River downstream of Bear Lake. The recorded flow data at these locations were thus not included in the hydrologic assessment. The water levels in Bear Lake at the Bear Lake near Clairmont WSC station (07GE004) are available from 1969 to 2009 and were used in the current study.

The Grande Prairie Creek near Sexsmith (07GE003) station is located 18 km upstream of the confluence of Grande Prairie Creek with the Bear River. Stream flows in Grande Prairie Creek typically peak in April and May due to snowmelt and then gradually recede. Additional peak flows also sometimes occur from June to August due to significant rainfall events (Graph A).



Graph A 2020 Daily Time Series Flow Data at 07GE003

The five largest recorded historical flood at this station occurred between 1974 and 2018 and ranged in magnitude from 26 m^3/s (2018) to 64 m^3/s (1990). Historical flood data are summarized in Appendix A.

These flow statistics provide not only information on historical floods recorded but also provide an insight into the magnitudes of floods along Bear River downstream of its confluence with Grande Prairie Creek since majority of runoff from the drainage area (1,221 km^2) of Bear River upstream of Bear Lake gets attenuated by Bear Lake.

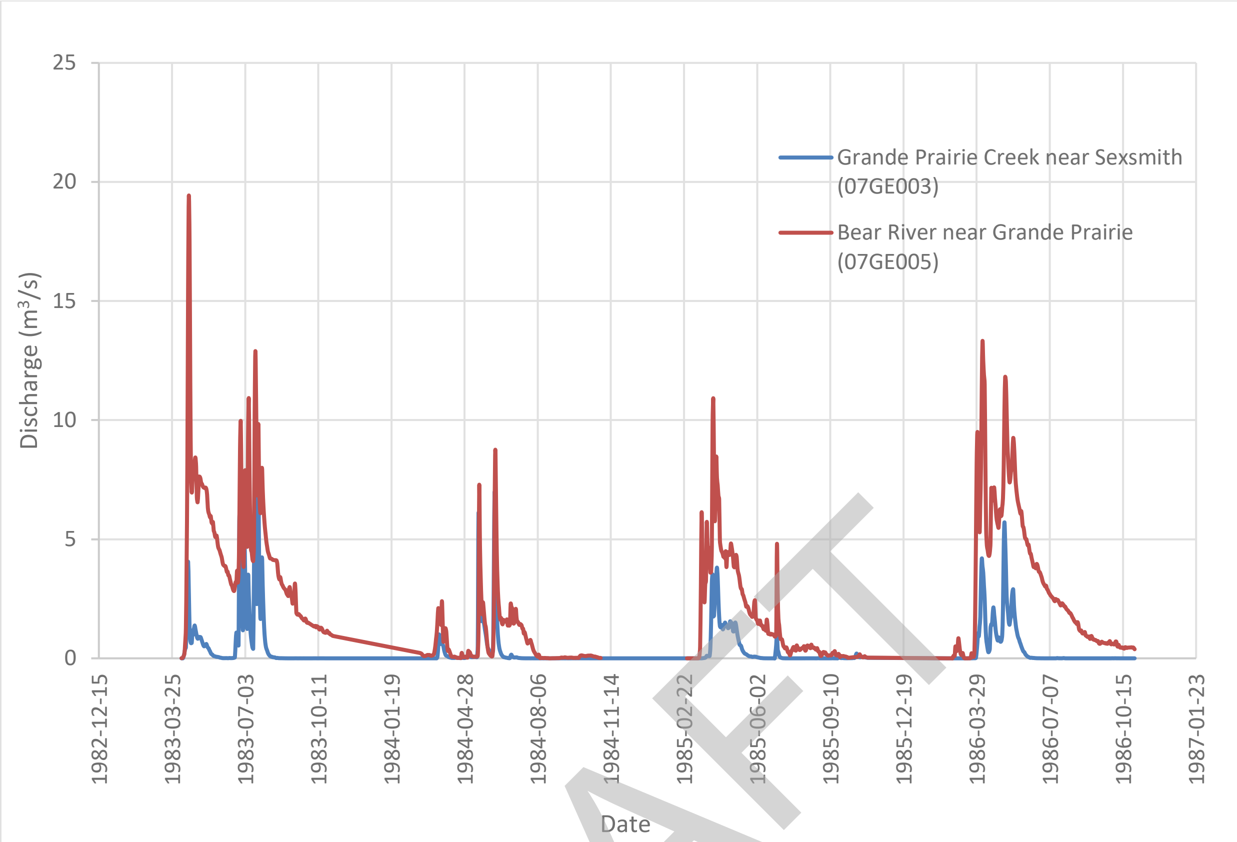
3.2 Relationship Between Grande Prairie Creek Flows and Bear Lake Water Levels

The timing of occurrence of maximum water levels in Bear Lake and maximum peak flows at Grande Prairie Creek near Sexsmith (07GE003) were compared and analyzed to assess the influence of Bear Lake and Grande Prairie Creek in peak flows along the Bear River downstream of the lake. Based on a review of recorded flow data at the WSC gauging station Bear Lake near Clairmont (07GE004), covering a period from 1969 to 2009, fluctuations of the Bear Lake water levels over the recorded period ranged from elevation 662.8 (in 2001) to 665.8 m (in 1974). Table A1 (Appendix A) presents the timing of occurrence of maximum water levels in Bear Lake and maximum peak flows in Grande Prairie Creek for a period from 1983 to 1987. Figure A1 (Appendix A) presents a graphical comparison of the daily Bear Lake water levels and Grande Prairie Creek daily flows for select years. As shown in Table A1 and Figure A1, the Grande Prairie Creek annual flood peaks primarily occur during the spring runoff period and before Bear Lake reaches its annual maximum level (i.e., in 1986). Typically, the lake level during the winter and approaching spring runoff would be in the order of 663 m as shown on Figure A2 (Appendix A). As flows in Grande Prairie Creek increase in response to snowmelt runoff, the water level at its confluence with Bear River gets higher than the lake levels, resulting in flow reversal when a portion of Grande Prairie Creek discharge begins to flow upstream along Bear River and into Bear Lake. One would expect an increase in peak flows downstream of this confluence due to the combined flows through Bear River and Grande Prairie Creek. However, this flow reversal hydraulic phenomenon actually results in a reduction of peak flows through the Bear River downstream of the confluence location during flood events.

Based on hydraulic principles, maximum outflows from Bear Lake will correspond to the maximum water levels in the lake. Consequently, based on a review of timing of historical maximum lake levels and Grande Prairie Creek peak flows presented in Table A1 and Figure A1 (Appendix A), it can be concluded that the peak outflows from Bear Lake do not normally coincide with the peak flows in Grande Prairie Creek and due to large attenuation effect of flows in Bear Lake, peak flows in Grande Prairie Creek during the annual flood runoff period dominate Bear River flows downstream of its confluence with Grande Prairie Creek.

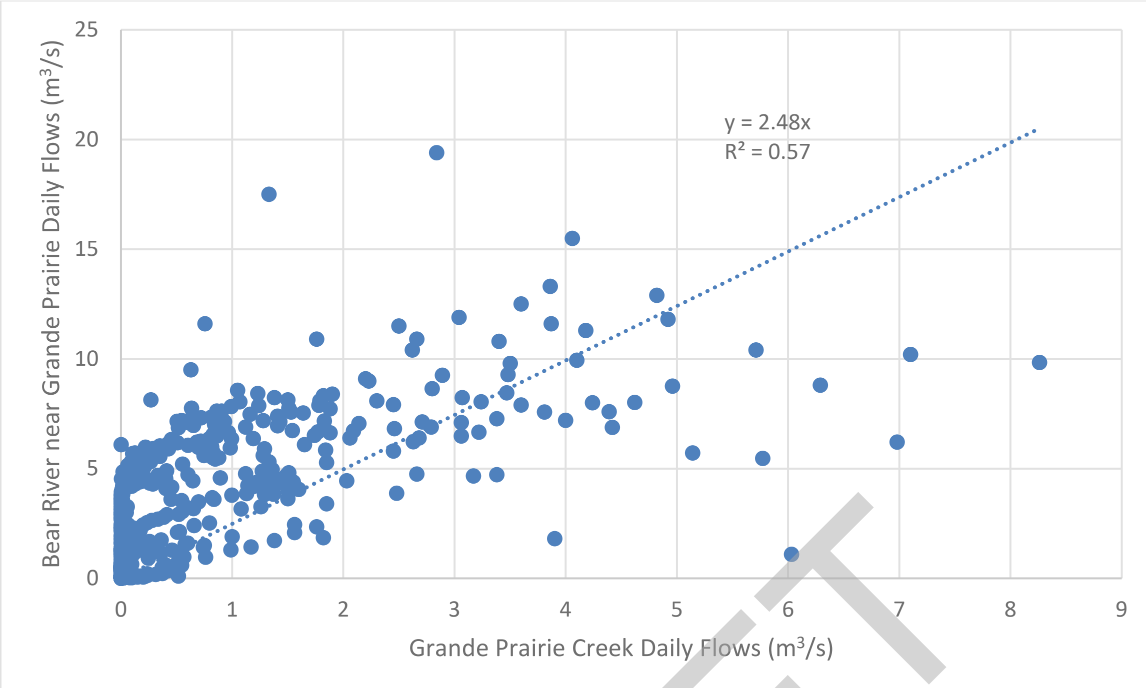
3.3 Relationship Between Grande Prairie Creek Flows and Bear River Flows

The WSC station, Bear River near Grande Prairie (07GE005) was located downstream of Bear Lake and was in operation only from 1983 to 1987. There is currently no WSC station located on the Bear River downstream of Bear Lake. The availability of this short period of data recorded at the WSC station 07GE005 in combination of the concurrent recorded flows at WSC station 07GE003 (Grande Prairie Creek near Sexsmith), and the recorded water levels at WSC Station 07GE004 (Bear Lake near Clairmont) provided valuable insight on flow attenuation due the presence of the large Bear Lake on downstream flows during the operating period from 1983 to 1987. Graph B presents a comparison of recorded flows at WSC stations 07GE003 and 07GE005 for this period.



GRAPH B Comparison of daily flows at Bear River near Grande Prairie (07GE005) and Grande Prairie Creek Near Sexsmith (07GE003)

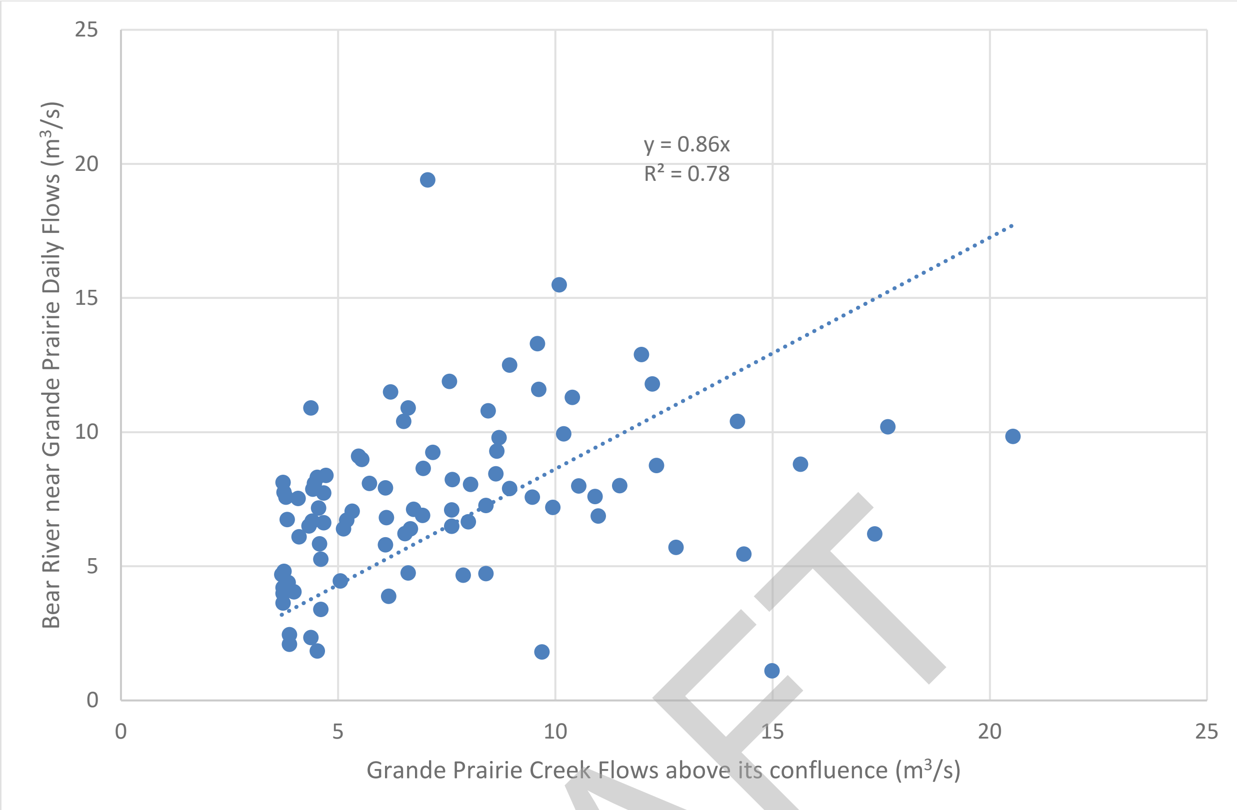
As shown on Graph B, the stations experienced peak flows from the same events. A relationship between the average flows at Grande Prairie Creek near Sexsmith (07GE003) and Bear River Near Grande Prairie (07GE005) was established using the available four-year record and is provided in Graph C below.



GRAPH C **Relationship between daily flows at Bear River near Grande Prairie (07GE005) and Grande Prairie Creek near Sexsmith (07GE003)**

Although the coefficient of determination of the linear relationship between the daily flows at Bear River and Grande Prairie Creek near Sexsmith is 0.57, Graph C does provide some insight into the influence of Grande Prairie Creek flows on the Bear River flows downstream of its confluence with Grande Prairie Creek. On average, the Bear River flows can be estimated as 2.48 times of the recorded flows at Grande Prairie Creek near Sexsmith gauging station (07GE003). The linear drainage area ratio of Grande Prairie Creek above its confluence (348 km^2) and the WSC station (140 km^2) is also 2.48. This analysis shows that, on average, the daily flows in the Bear River below its confluence with Grande Prairie Creek can be represented by the estimated flows at Grande Prairie Creek above its confluence using this linear drainage area ratio.

In order to assess the relationship between the peak flows at the Grande Prairie Creek above its confluence and the Bear River flows downstream of the confluence location, only daily flows with a magnitude greater than 1.46 m^3/s recorded at the Grande Prairie Creek gauging station (07GE003) were used. This magnitude of flow corresponds to the lowest recorded peak flow excluding an outlier (discussed in Section 5.1) at the gauging station (07GE003). The corresponding estimated peak flow at the Grande Prairie Creek above its confluence is 3.63 m^3/s using a linear drainage area ratio between the drainage area at the Grande Prairie Creek gauging station (07GE003) location and the drainage area of Grande Prairie Creek above its confluence with Bear River. Graph D presents the relationship.



GRAPH D Relationship between daily flows at Bear River near Grande Prairie (07GE005) and Grande Prairie Creek above its Confluence

As seen on Graph D, the flow in the Bear River downstream of its confluence is 0.86 times the flows of the Grande Prairie Creek above its confluence (the coefficient of determination is 0.78). In other words, during large flow events, about 14% of the flows in the Grande Prairie Creek flows backward toward Bear Lake and the remaining water flows downstream along the Bear River. Although this assessment has inherent uncertainties, the estimated percent reduction factor is based on statistical analysis of recorded flow data and is very similar to the amount of percent flow reversal estimated/used in previous studies, as discussed in Section 4.

4 PREVIOUS STUDIES

Several previously completed studies and reports were reviewed to understand and gather relevant information for the current study:

- Bear Creek Watershed Study by Marshal, Macklin, Monaghan Western Limited in 1984
- La Glace-Bear Lake Water Management Study prepared for the County of Grande Prairie by Samide Engineering Ltd. in 1998
- City of Grande Prairie flood risk mapping study submitted to EPA by Northwest Hydraulics Consulting in 2007
- 2020 Inundation Study and Dam Safety Review prepared for the City of Grande Prairie by SNC-Lavalin in 2021

Marshall Macklin Monaghan (1984) conducted a detailed hydrology study using available recorded streamflow data and through the application of a HYMO hydrologic model and HEC-RAS hydraulic model. The study concluded that during most floods, flow reversal occurs in the Bear River reach between the lake and the confluence with Grande Prairie Creek and this flow reversal significantly reduces flood peaks in the Bear River downstream of the confluence location. The study also concluded that about 7 to 15% of the total flow above the confluence of Grande Prairie Creek could flow backward and enter Bear Lake for flood flows from a 10-year to 100-year event with Bear Lake level at 665.0 m. The corresponding percentage was computed to be about 20 to 25% of total flow for a lake level of 663.5 m. The estimated peak floods in the Bear River reach in the City of Grande Prairie area are provided in Table B below.

TABLE B Flood Frequency Estimates (Marshall et al. 1984)

Return Period (year)	Peak Discharge (m^3/s)
10	68
50	95
100	106

Marshall et. al (1984) estimated the magnitude of the peak flood during the June 1972 rainfall event at 172 m^3/s in the Grande Prairie area. The peak floods in the Smoky River basin caused by this extreme rainfall event have been estimated to have return periods in the range of 100 years. A review of the recorded flow data at the Grande Prairie Creek near Sexsmith WSC station (07GE003) indicated that this rainfall event did not generate much runoff upstream of this WSC station.

Samide Engineering Ltd. (1998) developed a one-dimensional hydraulic model for the Bear River, including Bear Lake and La Glace Lake, and assessed the hydraulic response of the Bear River under 1997 flood conditions, various design flood conditions, and return periods up to a 100-year flood. The study confirmed that flow reversal in the Bear River reach between the Bear Lake outlet and the confluence with Grande Prairie Creek occurs during flood events. The study reported a maximum outflow of 53 m^3/s from Bear Lake during a 100-year flood event.

The NHC (2007) flood risk mapping study reported flood frequencies up to a 1,000-year flood event along the Bear River derived from a flood frequency analysis of the peak flows at Grande Prairie Creek near Sexsmith (07GE003). A regional frequency analysis approach using a non-linear drainage area ratio method with an exponent of 0.8 was used in estimating flood frequencies at key locations along the Bear River study reach. The study used a 20% reduction of estimated flood frequencies at Grande Prairie Creek above its confluence in determining flood frequencies along the Bear River reach downstream of its confluence. The estimated peak floods in the Bear River reach in the City of Grande Prairie area are provided in Table C below.

TABLE C Flood Frequency Estimates (NHC 2007)

Return Period (year)	Peak Discharge (m^3/s) Below Confluence	Peak Discharge (m^3/s) u/s of Grande Prairie Reservoir Dam	Peak Discharge (m^3/s) d/s of Grande Prairie Reservoir Dam
2	11.8	12	13
5	25.5	26	28
10	39.7	41	43
25	58.8	61	64
50	78.3	81	85
100	100.6	104	110
500	168.3	173	184
1,000	200	206	218

A review of the NHC (2007) report indicated that a drainage area of 301 km^2 was used for the drainage area at Grande Prairie Creek above the confluence and a drainage area of 157.5 km^2 was used at the WSC station (07GE003). The estimated drainage area at the WSC station using Alberta Flow Estimation Tools for Ungauged Watersheds is 140 km^2, which is same as the drainage area reported at the WSC website. Further, it is not clear if the contribution from the drainage area of Clairmont Lake (about 47 km^2) was excluded from the analysis. The addition of this drainage area resulted in a total drainage area of 348 km^2 at Grande Prairie Creek above the confluence and would result in a 24% increase in the estimated 100-year flood (124 m^3/s) below the confluence. Similar increases in other flood frequencies would be calculated if a drainage area of 348 km^2 instead of 301 km^2 were used in flow frequency estimates.

SNC (2021) reported flood frequency estimates ranging from 2-year to 1,000-year flood at the inlet of the Grande Prairie Reservoir. The study utilized recorded daily and peak flows at Grande Prairie Creek near Sexsmith (07GE003), Bear River near Grande Prairie (07GE005), and water levels at Bear Lake near Clairmont (07GE004) to derive relationships between: (i) recorded flows at Grande Prairie Creek and Bear River to quantify lake outflows and flow reversal along the Bear River toward Bear Lake; and (ii) flood frequencies at the inlet of the Grande Prairie Reservoir. The study assumed a maximum outflow from Bear Lake through its outlet of 20 m^3/s for return periods up to 1,000-year. The study also assumed a flow reduction of 10% of Grande Prairie Creek peak flows (due to flow reversal toward Bear Lake) along Bear River downstream of its confluence with Grande Prairie Creek for return periods up to 1,000-years.

The estimated maximum daily floods in the Bear River at the inlet of the Grande Prairie Reservoir are provided in Table D below.

TABLE D Flood Frequency Estimates (SNC 2021)

Return Period (year)	Peak Discharge (m^3/s)
2	33
5	46
10	56
100	100
500	141
1,000	162

5 HYDROLOGIC ANALYSIS AND DATA SERIES PREPARATION

The hydrologic analysis was undertaken to recommend 2- to 1,000-year return period instantaneous flood estimates for the Bear River to be used for subsequent hydraulic modelling and flood inundation mapping. The recorded streamflow data at the WSC station, Grande Prairie Creek near Sexsmith (07GE003) and the water levels data recorded at the Bear Lake near Clairmont (07GE004) were used in the hydrologic analysis. The approach used for the single station flood frequency analysis is described in detail below.

5.1 Hydrologic Analysis of Peak Flows at Grande Prairie Creek near Sexsmith (07GE003)

There is only one WSC station, Grande Prairie Creek near Sexsmith (07GE003) located in the Bear River watershed in the vicinity of the study area. The historical recorded streamflow at the Grande Prairie Creek near Sexsmith (07GE003) covering a period from 1969 to 2022 was obtained and analyzed to carry out a single station flood frequency analysis. The recorded flow data was considered natural since no structure is located on Grande Prairie Creek. Recorded maximum daily discharges and instantaneous peak discharges for the Grande Prairie Creek near Sexsmith gauging station is provided in Appendix A (Table A2).

5.1.1 Relationship between Maximum Daily Discharge and Instantaneous Peak Discharge

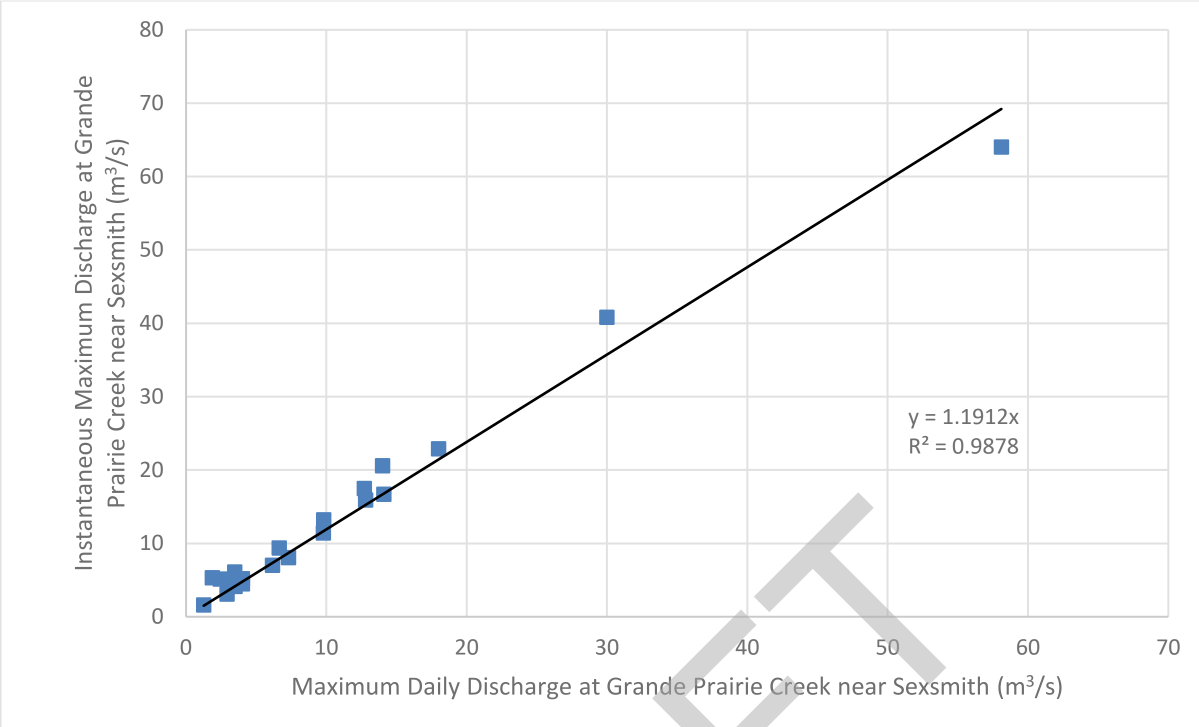
The annual maximum instantaneous discharge data series is required for flood frequency analysis to derive flood frequencies with various return periods. However, annual maximum instantaneous discharge data covering the period of record are not always available and data for the missing periods needs to be estimated based on a relationship between the annual maximum daily discharge and annual maximum instantaneous discharge data for the coincident flood events.

Flood frequency estimates are based on the instantaneous peak discharge. For those years where instantaneous peak discharge data at the Grande Prairie Creek gauging station is missing, estimates were derived based on a linear correlation between the available recorded coincident instantaneous peak discharges and the maximum daily discharges at the Grande Prairie Creek gauging station. As shown on Graph E, the following relationship was derived to extend the instantaneous peak discharge data series for the Grande Prairie Creek near Sexsmith:

In order to extend the flow data series at the WSC station, Grande Prairie Creek near Sexsmith (07GE003), the following relationship was used.

$$Q_{07GE003\_I} = 1.1912 Q_{07GE003\_M}$$

where: $Q_{07GE003\_I}$ = maximum instantaneous discharge at Grande Prairie Creek near Sexsmith (m^3/s)
$Q_{07GE003\_M}$ = maximum daily discharge at Grande Prairie Creek near Sexsmith (m^3/s)
R^2 = index of determination, 0.9878 for this relationship



GRAPH E Relationship between Annual Maximum Daily Discharges and Maximum Instantaneous Discharges at Grande Prairie Creek near Sexsmith (07GE003)

Table A3 (Appendix A) presents the extended annual maximum instantaneous discharge data series containing 49 data points. The extended annual maximum instantaneous discharge data series contains flows ranging from 0.6 m^3/s in 1988 to 64 m^3/s in 1990. Figure A3 (Appendix A) shows the annual maximum daily discharges and annual maximum instantaneous discharges. 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). The minimum recorded peak flow of 0.6 m^3/s was found to be an outlier and was excluded from further analysis. Table E summarizes the statistical parameters of the maximum instantaneous discharge dataset adopted for flood frequency analysis.

TABLE E Statistical Parameters of Maximum Instantaneous Discharge of the Grande Prairie Creek near Sexsmith (07GE003)

Parameters	Normal Data Series	Log-transformed Data Series
Years of Record	48	48
Mean (m^3/s)	13.3	1.0
Maximum Discharge (m^3/s)	64	1.8
Minimum Discharge (m^3/s)	1.46	0.16
Standard Deviation (m^3/s)	11.54	0.346
Coefficient of Variation	0.87	0.349
Coefficient of Skewness (minimum, maximum, actual)	1.74, 1.95, 2.29	0.698, 0.837, -0.071

5.2 Hydrologic Analysis of Peak Water Levels at Bear Lake near Clairmont (07GE004)

The WSC station, Bear Lake near Clairmont (07GE004) has reported historical water levels covering a period from 1969 to 2009. This data series was used to computed design water levels associated with various return periods ranging from 2-years to 1,000-years. Table F summarizes the statistical parameters of the complete annual maximum water levels dataset.

TABLE F Summaries of Statistical Parameters of Maximum Water Levels of Bear Lake near Clairmont (07GE004)

Parameters	Normal Data Series
Years of Record	41
Mean Water Level (m)	664.0
Maximum Water Level (m)	665.8
Minimum Water Level (m)	662.8
Standard Deviation (m)	0.69
Coefficient of Variation	0.001
Coefficient of Skewness	0.734

6 FLOW FREQUENCY ANALYSIS

Standard statistical analysis of the generated annual maximum instantaneous discharges for the Grande Prairie near Sexsmith (07GE003) WSC station and the derived maximum annual runoff volumes based on recorded water levels for Bear Lake near Clairmont WSC (07GE004) station was 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 for each data set 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 (Appendix A, Figures A5 and A7).

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 include method of moments and method of maximum likelihood. The Cunnane positioning formula was used to plot data points for visualization purposes (Appendix A, Figures A4.1 to A4.3).

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.

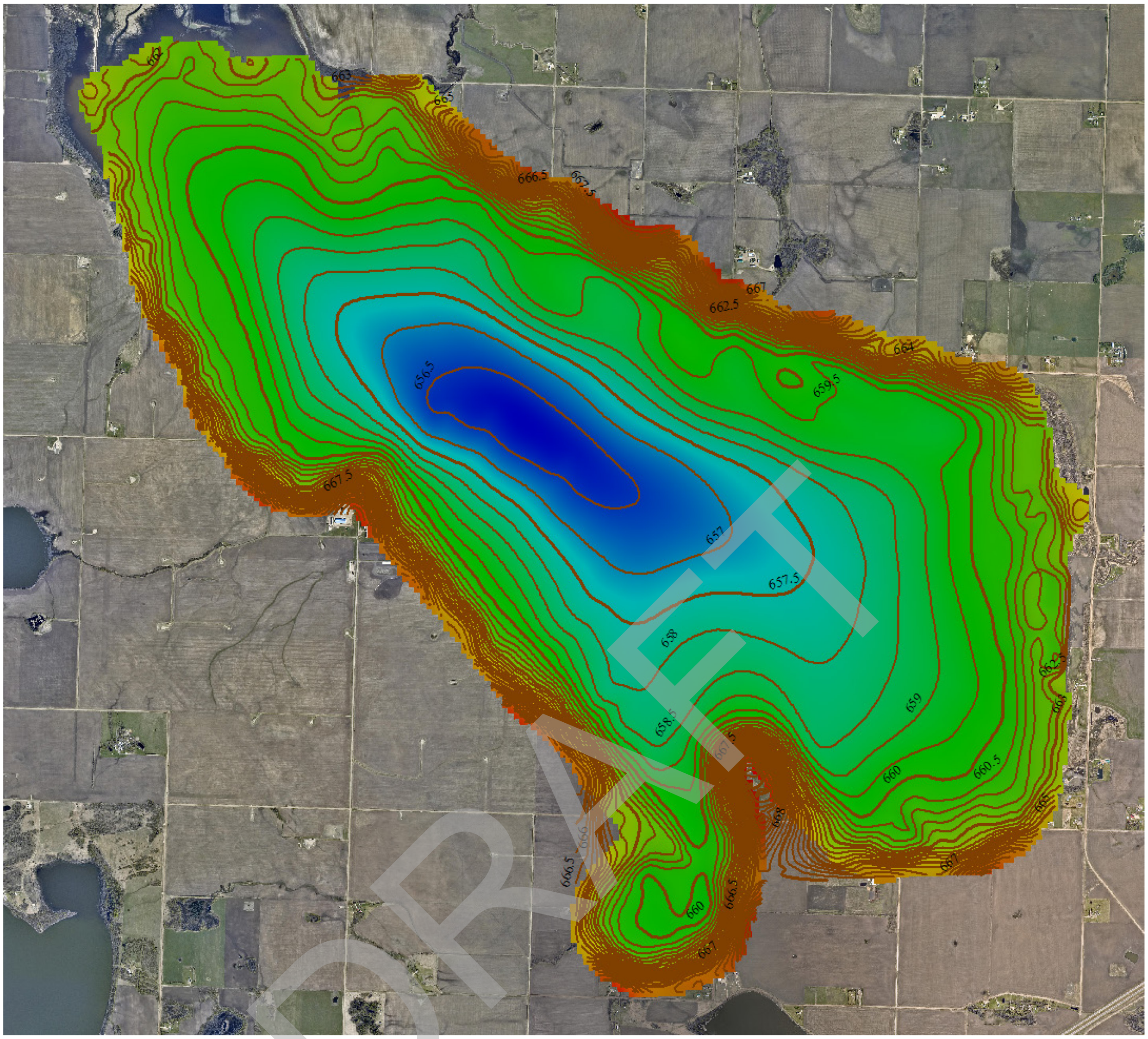
The guidelines in Bulletin 17C improve on Bulletin 17B by addressing major limitations. Bulletin 17C introduces a standardized Multiple Grubbs-Beck test to identify influential low flood outliers. A new recommended method for estimating regional skew is introduced in Bulletin 17C using the Bayesian Weighted Least Squares/Bayesian Generalized Least Squares method, which supersedes the regional skew coefficient map in Bulletin 17B. And it uses the new Expected Moments Algorithm (EMA) 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.

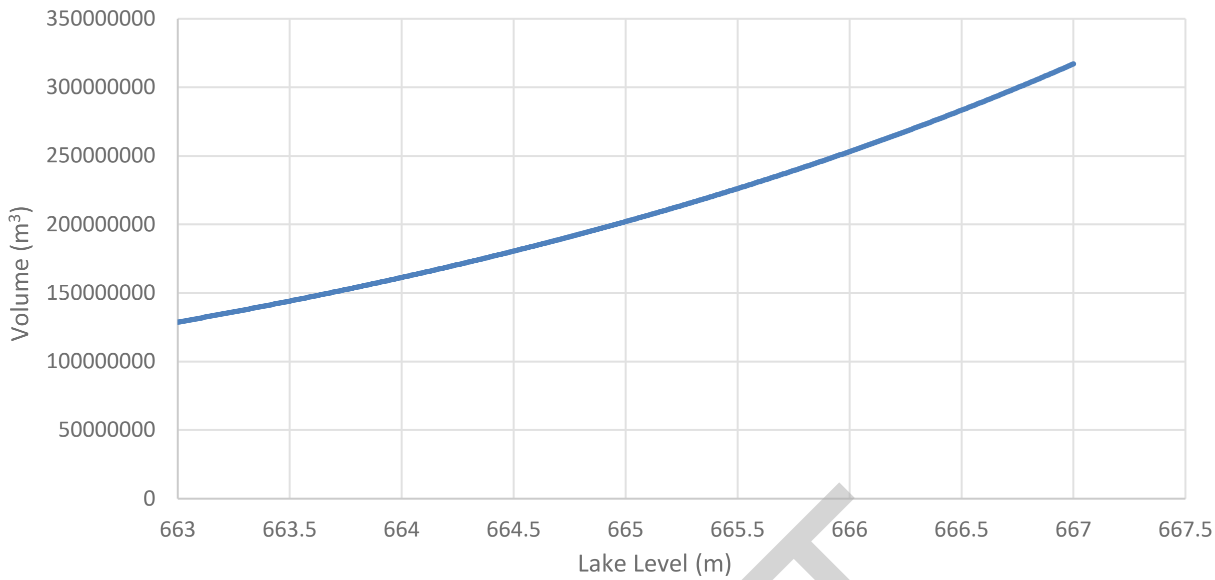
6.1 Flood Frequency Estimates for Bear Lake near Clairmont

The WSC station, Bear Lake near Clairmont (07GE004) has reported historical water levels covering a period from 1969 to 2009. The Matrix 2023 report provided water level frequency estimates based on frequency analysis of the recorded maximum water level for each year. This procedure is often used in frequency analysis for practical purposes. However, the recorded water levels might have dependency on previous years water levels and may therefore violate the “data independency” requirement for statistical frequency analysis.

An alternate approach of estimating water levels corresponding to different return periods was subsequently undertaken. Instead of performing frequency analysis of annual maximum water levels, a frequency analysis of estimated annual maximum runoff volumes was completed. The maximum annual runoff volume of Bear Lake for each year was computed using the stage-storage relationship for the corresponding recorded maximum water levels in the lake. The estimated annual maximum runoff volumes were then used for frequency analysis. Water levels with different return periods were then derived using computed runoff volumes and stage-storage relationship. The stage-storage relationships were derived from the bathymetric contours of Bear Lake (Government of Canada 2025). Graphs F and G show the lake bathymetric contour map and stage-storage relationship of Bear Lake, respectively.

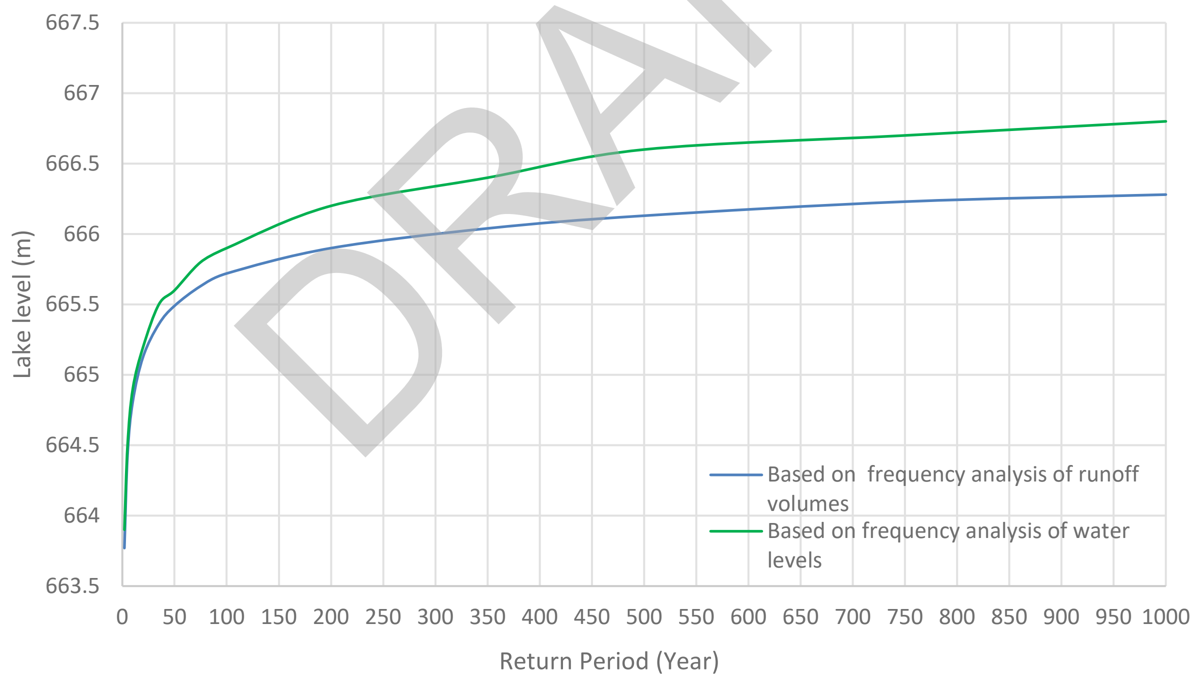


GRAPH F Bathymetric Contours of Bear Lake



GRAPH G Stage-Storage Relationship of Bear Lake

Graph H shows a comparison of computed water levels with various return periods using estimated maximum annual runoff volumes and recorded maximum water levels reported in Matrix (2023).



GRAPH H Comparison of Computed Water Levels Frequencies using two Approaches

As seen on Graph H, the computed water levels using the current approach are slightly lower than the previously reported water level frequencies. Table G presents the complete set of flood frequency estimates for water levels in Bear Lake.

TABLE G Frequency Estimates of Water Levels at Bear Lake near Clairmont (07GE004)

Return Period (years)	Flood Level (m)
2	663.77
5	664.43
10	664.81
20	665.13
35	665.36
50	665.49
75	665.63
100	665.72
200	665.9
350	666.04
500	666.13
750	666.23
1,000	666.28

The computed water level frequencies of Bear Lake were used in determining the peak outflows from Bear Lake to be used as upstream boundary conditions for hydraulic modelling as discussed in Section 9 in this report.

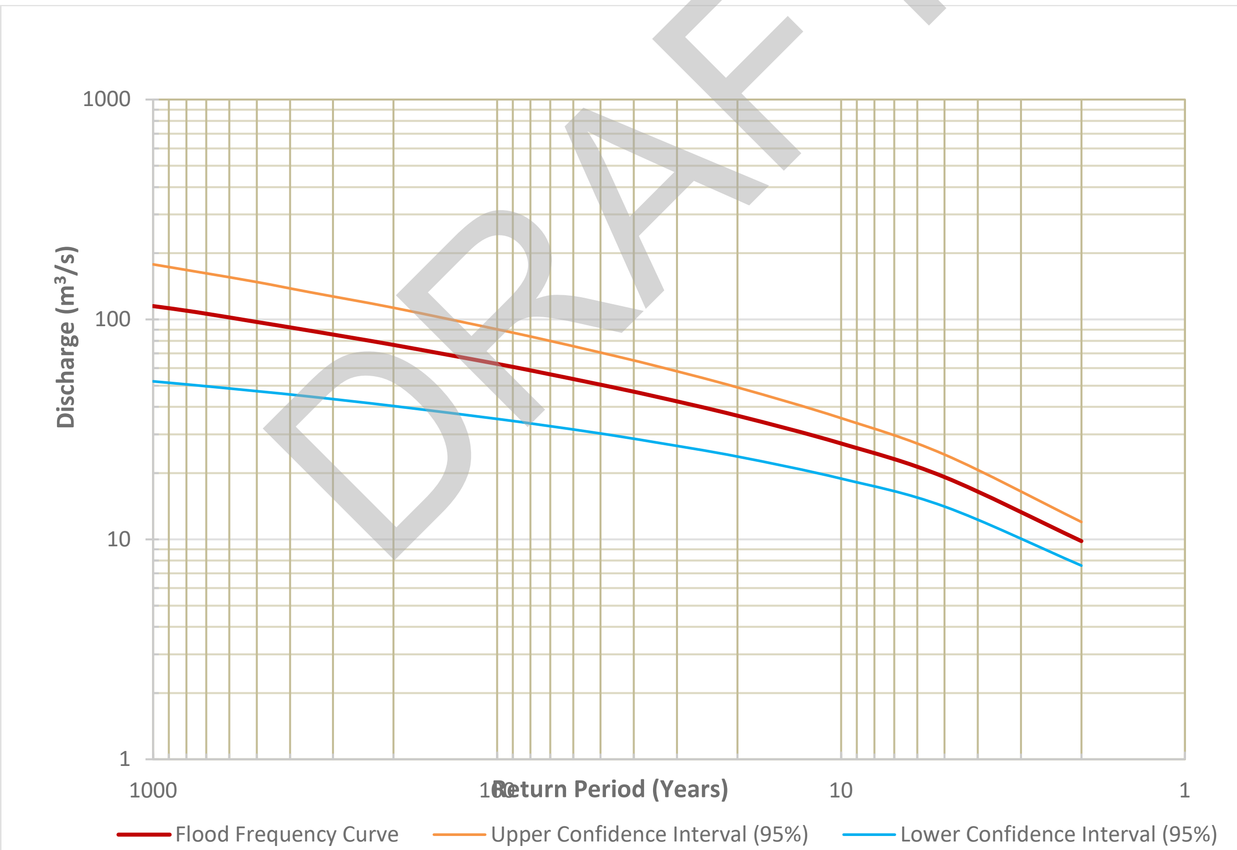
6.2 Flood Frequency Estimates for Grande Prairie Creek near Sexsmith

Figures A4.1 to A4.3 (Appendix A) illustrate the fitted distributions to the maximum instantaneous discharge data. Figure A5 shows the summary of statistical goodness of fit test results. The overall rank of the log normal distribution is first out of ten distributions tested. A visual inspection of various frequency distributions to the flow data and goodness of fit also indicates that the log normal distribution has the most representative fit to the recorded data. Therefore, the log normal distribution was selected to represent the flood frequencies for the Grande Prairie Creek near Sexsmith (07GE003).

Table H presents the complete set of flood frequency estimates at the Grande Prairie Creek near Sexsmith (07GE003); Graph I presents the flood frequency curve for the log normal distribution with 95% confidence intervals. Given that the preliminary flow data are provisional and may be subject to change, the flood frequency estimates need to be reviewed and updated, if necessary, once the maximum instantaneous discharge for 2022 is finalized and as more data become available.

TABLE H Flood Frequency Estimates at Grande Prairie Creek near Sexsmith (07GE003)

Return Period (years)	Flood Discharge (m^3/s)	95% Confidence Intervals
2	9.8	7.6 to 12.0
5	19.2	14.1 to 24.3
10	27.3	18.9 to 35.6
20	36.5	23.8 to 49.1
35	44.8	27.7 to 61.8
50	50.5	30.3 to 70.7
75	57.5	33.2 to 81.8
100	62.8	35.3 to 90.2
200	76.6	40.4 to 113
350	88.9	44.6 to 133
500	97.4	47.2 to 148
750	108	50.2 to 165
1,000	115	52.3 to 178



GRAPH I Flood Frequency Curve for Grande Prairie Creek near Sexsmith (07GE003)

7 DESIGN FLOWS AT KEY LOCATIONS ALONG BEAR RIVER REACH

The approaches used in computing flood frequency estimates with various return periods ranging from 2-year to 1,000-year at key locations along the Bear River within the study reach are discussed below.

7.1 Flood Frequency Estimates for the Bear River Reach at Bear Lake Outlet

The flood frequencies for the Bear River reach at the lake outlet are required to be used as upstream boundary conditions for hydraulic modelling. These flow frequencies represent design flows along the Bear River reach between Bear Lake outlet and above its confluence with Grande Prairie Creek and can be computed using two methods. One option is to use the design water levels at Bear Lake for 13 scenarios obtained through frequency analysis as presented in Table G. The other option is to compute design floods corresponding to design water levels for 13 scenarios using a HEC-RAS model. The details of these approaches are further discussed in Section 9 in this report.

7.2 Flood Frequency Estimates for the Bear River Reach Below Confluence

As shown in Section 3.3, the peak flows along the Bear River below the confluence with Grande Prairie Creek can be estimated by using a 14% reduction of estimated peak flows in Grande Prairie Creek above its confluence with Bear River. For reference, SNC (2021) used a 10% reduction factor and NHC (2007) used a 20% reduction factor for making such estimates. Given the high uncertainty is estimating the exact amount of reduction in Grande Prairie Creek flows due to flow reversal toward Bear Lake during extreme flood events, the percent reduction factor estimated in the current study and values used in previous two studies are very similar. However, the percent reduction factor derived in the current study is based on the recorded flow data on the Bear River and Grande Prairie Creek instead of deriving such a reduction factor through hydrologic or hydraulic modelling. Thus, a 14% reduction of estimated flood frequencies at Grande Prairie Creek above its confluence was used in determining flood frequencies at the Bear River below the confluence location. The flood frequency estimates along the Bear River study reach at key locations downstream of the confluence were then determined using a linear drainage area method under the assumption that equal area contributes equal runoff. The following relationships were used in estimating design flows at various locations.

1) Design Floods at Grande Prairie Creek above its confluence with Bear River (drainage area 348 km^2):

$$Q_{Grande\ Prarie\ Creek\ above\ confluence} = Q_{07GE003} \times \left(DA_{Grande\ Prairie\ Creek\ above\ confluence}/DA_{07GE003}\right) \wedge \mathrm{n}$$

Where:

$Q_{\text{Grande Prairie Creek above confluence}}$ and $Q_{07GE003}$ = the natural design flood magnitudes, in m^3/s, at the Grande Prairie Creek above its confluence and at WSC station 07GE003, respectively

$DA_{Grande\ Prairie\ Creek\ above\ confluence}$ and $DA_{07GE003}$ = the drainage area, in km^2 of Grande Prairie Creek above the confluence site and at WSC station 07GE003, respectively

n = an exponent with a value of 1 under the assumption that equal area contributes equal runoff

2) Design floods associated with various return periods at Bear River below its confluence with Grande Prairie Creek (drainage area 1,567 km^2):

$Q_{\text{Bear River below its confluence with Grande Prairie Creek}} = 0.86 * Q_{\text{Grande Prairie Creek above confluence}}$

3) Design floods associated with various return periods at key locations downstream of the confluence:

$$Q_{Point\ of\ interest} = Q_{Bear\ River\ below\ confluence} \times \left(DA_{Bear\ River\ point\ of\ interest}/DA_{Bear\ River\ below\ confluence}\right) ^\wedge \mathrm{n}$$

$DA_{Bear\ River\ point\ of\ interest}$ and $DA_{Bear\ River\ below\ confluence}$ = the drainage area, in km^2 of Bear River at a point of interest and Bear River below the confluence, respectively

n = an exponent with a value of 1 under the assumption that equal area contributes equal runoff

Using the above noted relationships, the design floods at two locations along the Bear River were derived. One flow change location is the downstream end of the reservoir (drainage area 1,628 km^2) and the second flow change location is near the downstream study boundary (downstream of two small tributaries located about 4 km upstream of the study boundary). The estimated drainage area at the second flow change location is 1,955 km^2. These locations are shown on Figure 2. Table I presents the computed flood frequency estimates at various locations of Bear River reach downstream of its confluence with Grande Prairie Creek and the downstream study boundary.

TABLE I Flood Frequency Estimates at select locations along Bear River

Return Period (years)	Flood Discharge in Grande Prairie Creek Above its Confluence (m^3/s)	Flood Discharge Below The Confluence (m^3/s)	Flood Discharge d/s of the Grande Prairie Reservoir (m^3/s)	Flood Discharge at d/s Study Boundary (m^3/s)
2	24.4	21	21.8	26.2
5	47.7	41	42.6	51.2
10	67.9	58.4	60.7	72.9
20	90.7	78	81	97.3
35	111	95.8	99.5	120
50	126	108	112	135
75	143	123	128	153
100	156	134	139	167
200	190	164	170	204
350	221	190	198	237
500	242	208	216	260
750	269	231	240	288
1,000	286	246	256	307

8 EFFECT OF GRANDE PRAIRIE RESERVOIR IN FLOOD ATTENUATION

As indicated in the TOR, a high-level hydraulic assessment of the effect of the Grande Prairie Reservoir on the peak floods is required. As no recorded flow data downstream of the reservoir is available, the computed flood frequencies along the Bear River are based on the natural recorded flows in Grande Prairie Creek. This means that the use of a linear drainage area ratio method in estimating flood frequencies along the Bear River downstream of the reservoir also did not consider any attenuation effect on downstream flows and that the flood frequency estimates along the Bear River reach downstream of the reservoir presented in Table I represent natural flow conditions in the river. Therefore, even if there are some level of attenuation on peak flows by the presence of this reservoir, the estimated flood frequencies two along the Bear River reach downstream of the reservoir are not affected and are considered as natural flows in the river.

9 ESTIMATION OF FLOWS AT THE BEAR LAKE OUTLET (UPSTREAM BOUNDARY)

As discussed in Section 7.2, flows associated with 13 flow scenarios downstream of the confluence of Bear River with Grande Prairie Creek are derived from the recorded flow data series at Grande Prairie Creek near Sexsmith (07GE003). However, flows associated with 13 flow scenarios are also required at the Bear Lake outlet to delineate flood inundation maps and flood hazard maps for the river reach from the Bear Lake outlet to the confluence location for a distance of about 2 km. Two approaches were considered, as discussed below.

1) Adopt the computed design water levels with various return periods as presented in Table G (Section 6.1) in this report as the upstream boundary conditions at the Bear Lake outlet for hydraulic modelling to compute water levels and flow velocities for the river reach between the Bear Lake outlet and the Bear River above its confluence with the Grande Prairie Creek.

2) Build a simple 1D HEC-RAS model to generate outflows from Bear Lake corresponding to various Bear Lake levels using the assumption that the lake outlet is a natural channel, and a hydraulic relationship exists between the lake levels and hydraulic behaviour of the downstream channel. The derived flows for 13 flow scenarios can then be used as upstream boundary conditions to compute water levels and flow velocities for the river reach between the Bear Lake outlet and the Bear River above its confluence with the Grande Prairie Creek.

The second approach was used in deriving outflows from Bear Lake for hydraulic modelling purposes as HEC-RAS requires discharge inputs at the upstream boundary. A separate hydraulic model utilizing surveyed cross sections along the Bear River from its outlet to just downstream of its confluence with Grande Prairie Creek was developed. The model was then applied to compute outflows from the lake corresponding to water levels associated with 13 scenarios. The computed outflows from Bear Lake were then used as upstream boundary conditions for hydraulic modelling and for delineating flood hazard and inundation maps along the river reach between the lake outlet and its confluence with Grande Prairie Creek.

Table J Computed Peak Outflows from Bear Lake for Hydraulic Modelling

Return Period (years)	Peak Outflows (m^3/s)
2	3
5	7
10	10
20	25
35	35
50	40
75	50
100	55
200	80
350	95
500	100
750	120
1,000	140

10 DISCUSSION

The estimated 100-year flood at the Grande Prairie Creek near Sexsmith (07GE003) in the current study is 62.8 m^3/s (Table H), compared to 75.3 m^3/s reported in NHC (2007) study. The difference is due to the fact that no major flood events took place in Grande Prairie Creek since the completion of the previous study. A comparison of the flood frequency estimates of the NHC (2007) study and the current study along the Bear River and at the Grande Prairie Creek above the confluence is provided in Table K below.

TABLE K Comparison of Flood Frequency Estimates

Return Period (Years)	Flood Frequency Estimates d/s of the reservoir in this Study (m^3/s)	Flood Frequency Estimates d/s of the reservoir using NHC (2007) approach and revised drainage areas (m^3/s)	Flood Frequency Estimates d/s of the reservoir NHC (2007) Study (m^3/s)
2	21.8	15.1	13
5	42.6	32.7	28
10	60.7	50.7	43
50	112	100	85
100	139	129	110
500	216	215	184
1,000	256	256	218

As seen in the above table (comparison of Column 2 and Column 4), the flow frequency estimates reported in NHC (2007) are lower than the flow frequency estimates of the current study. One possibility is that the current study considered the drainage area of Clairmont Lake (48 km^2) and the NHC (2007) study seemed to exclude this area. For example, the estimated 100-year flood used in NHC (2007) study is about 75% of the current study estimate. However, the flow frequency estimates using the NHC (2007) approach and revised drainage areas result in very similar flood frequencies as shown in Column 3 of Table J. It is thus concluded that given the uncertainties in statistical analysis, the attenuation effect of Bear Lake on downstream flood peaks, actual amount of flow reversals in the Bear River toward Bear Lake during extreme flood conditions, and availability of limited data for determining flow frequency estimates up to a 1,000-year flood, the flow frequency estimates derived in the current study as presented in Table I be adopted for hydraulic modelling.

11 RECOMMENDED FLOOD FREQUENCY ESTIMATES

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

TABLE L Recommended Flood Frequency Estimates

Return Period (years)	Peak Outflows at Bear Lake outlet (m)	Flood Discharge below the confluence (m^3/s)	Flood Discharge d/s of the Grande Prairie Reservoir (m^3/s)	Flood Discharge at d/s study boundary (m^3/s)
2	3	21	21.8	26.2
5	7	41	42.6	51.2
10	10	58.4	60.7	72.9
20	25	78	81	97.3
35	35	95.8	99.5	120
50	40	108	112	135
75	50	123	128	153
100	55	134	139	167
200	80	164	170	204
350	95	190	198	237
500	100	208	216	260
750	120	231	240	288
1,000	140	246	256	307

12 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 Bear 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 Bear 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. Zaghloul 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.

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%.

13 SUMMARY AND CONCLUSIONS

Flood frequency estimates are required for the Grande Prairie flood hazard study. The hydrologic analysis conducted herein shows that flows in the Bear River in the study area are significantly attenuated by the presence of Bear Lake located on the Bear River upstream of the study area. Furthermore, flow reversal occurs in the River reach between its confluence with Grande Prairie Creek and the Bear Lake outlet when the water levels in the confluence are higher than the water levels in Bear Lake. Peak flows in the Bear River downstream of its confluence with Grande Prairie Creek are mainly governed by the peak flows in Grande Prairie Creek. No active WSC station is located on the Bear River within the study area boundary. A WSC hydrometric gauging station, Bear River near Grande Prairie (07GE004), was in operation from 1984 to 1987. Another WSC station, Grande Prairie Creek near Sexsmith (07GE003) has been in operation since 1969. A relationship between recorded daily flows at these two WSC stations indicates that the daily flows in the Bear River below the confluence can be represented by the daily flows in Grande Prairie above the confluence. The hydrologic analysis also indicates that the peak flows in the Bear River below the confluence are about 86% of the peak flows in Grande Prairie Creek above the confluence. This 14% reduction in peak flows is within the range of reduction factors used in the previous studies. The flow frequency estimates at Grande Prairie Creek above the confluence can be reduced by 14% to estimate peak flows at Bear River below the confluence. A linear drainage area ratio method was then able to be used to determine flow frequencies at key downstream locations along the Bear River.

The recorded flows on the Grande Prairie Creek near Sexsmith (07GE003) were considered as natural since no structures are located on these watercourses. The extended annual maximum instantaneous discharges covering a period of 1969 to 2022 consisting of 48 data points were used for flow frequency analysis.

Given the availability of relatively long period of streamflow data at the WSC station, Grande Prairie Creek near Sexsmith (07GE003) and a relationship exists between the peak flows in Grande Prairie Creek and the Bear River, flood frequency estimates were derived in this study using a single station flood frequency analysis method and a linear drainage area ratio method.

Following standard flow frequency analysis procedures, different theoretical probability distributions to the observed data sets were tested for their suitability for the subject dataset. The most suitable theoretical distribution for each data set 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 lognormal distribution represents the annual maximum instantaneous discharges of Grande Prairie Creek near Sexsmith (07GE003).

The peak outflows from Bear Lake for various return periods were obtained through a separate hydraulic model utilizing surveyed cross sections along the Bear River from its outlet to just downstream of its confluence with Grande Prairie Creek corresponding to water levels associated with 13 scenarios. The computed peak outflows from Bear Lake for various return periods ranging from 2-year to 1,000-year flood are recommended to be used as upstream boundary conditions for hydraulic modelling purposes and derived flow frequencies at three locations downstream of the confluence of Bear River with Grande Prairie Creek are appropriate to represent flows along the Bear River within the study reach during extreme design flood conditions.

As no recorded flow data downstream of the reservoir is available, the computed flood frequencies along the Bear River are based on the natural recorded flows in Grande Prairie Creek. This means that the use of a linear drainage area ratio method in estimating flood frequencies along the Bear River downstream of the reservoir also did not consider any attenuation effect on downstream flows and that the flood frequency estimates along the Bear River reach downstream of the reservoir presented in Table I represent natural flow conditions in the river. Therefore, even if there are some level of attenuation on peak flows by the presence of this reservoir, the estimated flood frequencies along the Bear River reach downstream of the reservoir are not affected and are considered as natural flows in the river.

The flood frequency estimates reflect the most current data and methodologies available. Given the relatively short data record (in the range of 100 years of data), uncertainty exists for estimating flood frequencies with return periods greater than 200 years. The flood frequency estimates should be updated as more flood data become available.

14 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,

MATRIX SOLUTIONS INC.

23 June 2025

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

Reviewed by

June 23 2025

Brandyn Coates, M.Eng., P.Eng.
Water Resources Engineer

MS/eh
Attachments

PERMIT TO PRACTICE
MATRIX SOLUTIONS INC.
RM SIGNATURE:
RM APEGA ID #: 57054
DATE: 23 June 2025
PERMIT NUMBER: P005540
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	19-May-2023	Draft	35917-531 LR 2023-05-19 draft V0.1.docx	Issued to client for review
V1.0	30-Nov-2023	Final	35917-531 LR 2023-11-30 final V1.0.docx	Issued to client as final
V2.0	21-Mar-2025	Final Revised	35917-531 LR 2025-03-21 final V2.0.docx	Issued to client as final revised
V3.0	13-Jun-2025	Final Revised	35917-531 LR 2025-06-13 final V3.0.docx	Issued to client as final revised

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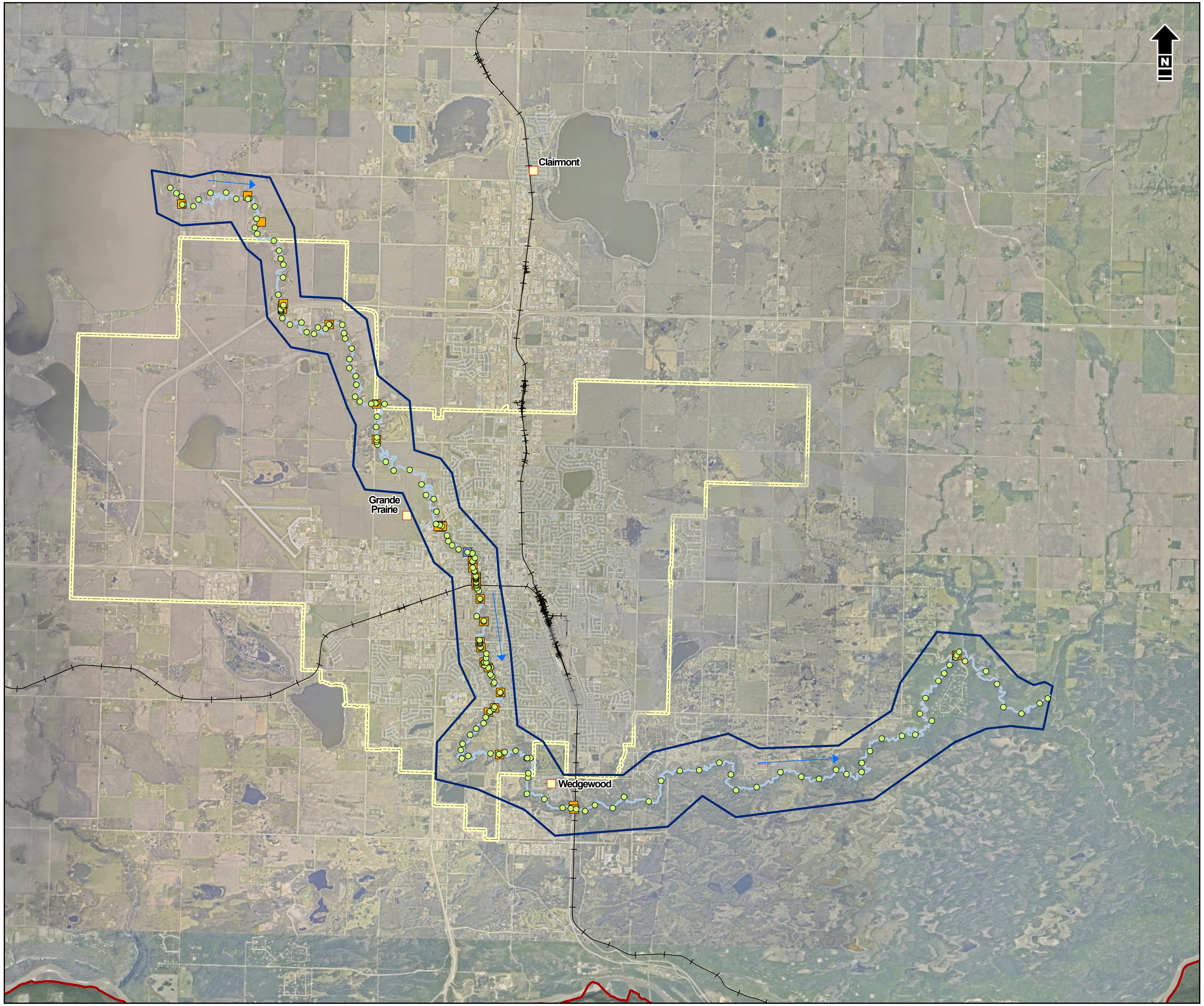
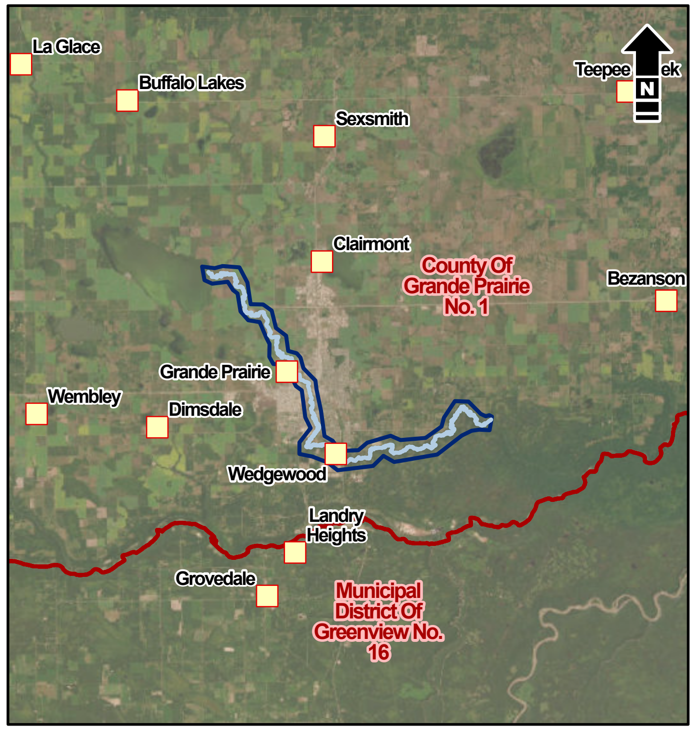


- Proposed Study Area
- Municipal District
- Urban Muncipal Boundary
- Railway
- Flow Direction
- Road
- Proposed Cross-Section Location
- Bridge/Culvert
- Spillway
- Community

Study Reaches and Extents

- Bear River



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World Imagery: City of Grande Prairie, Earthstar Geographics

1:100,000 kilometres
1 0 1 2
NAD 1983 CSRS 3TM 117

Alberta MONTROSE ENVIRONMENTAL Canada

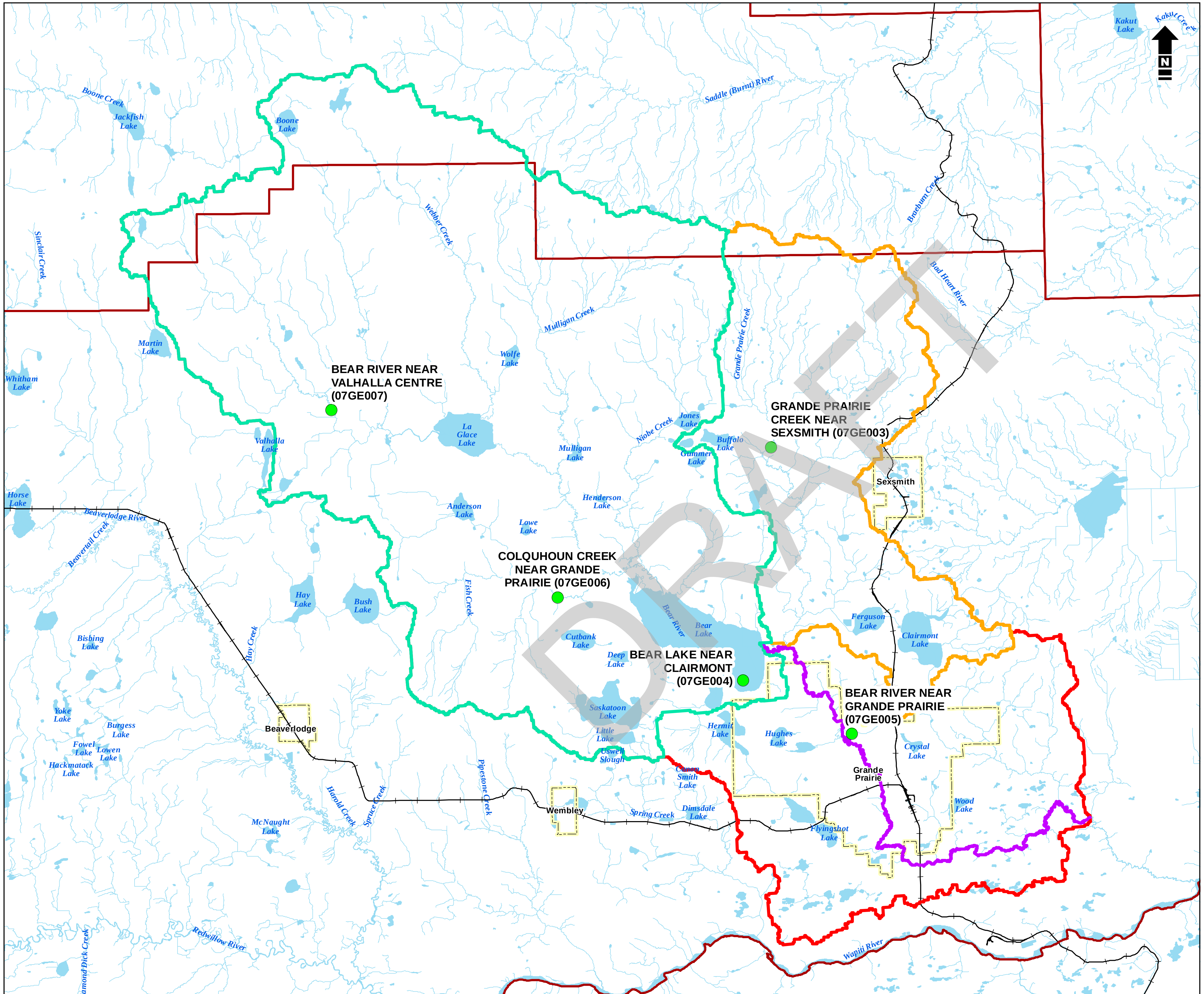
Alberta Environment and Protected Areas
Grande Prairie Flood Study

Study Reaches

Date: March 2025	Project: 35917	Submitter: M. Wilkinson	Reviewer: M. Shome

Figure 1

Classification: Public



Urban Muncipal Boundary
Municipal District
Railway
Road
Hydrometric Station

Study Reaches and Extents

Bear River

Drainage Areas | Total Cumulative Area 1,958 km²

Bear Lake Outlet (1,221 km²)
Grande Prairie Creek above confluence with Bear River (348 km²)
Remaining Study Boundary (389 km²)

Reference: Data obtained from Altalis © Government of Alberta, GeoBase® and GeoGratis © Department of Natural Resources Canada (all rights reserved) used under license. GDM transportation infrastructure data provided by IHS © 2025 used under license.

1:275,000 Kilometers
2.5 0 2.5 5
NAD 1983 CSRS 3TM 120

Alberta Government
Grande Prairie Flood Study

Bear River Watershed

Date: March 2025	Project: 35917	Submitter: M. Wilkinson	Reviewer: M. Shome

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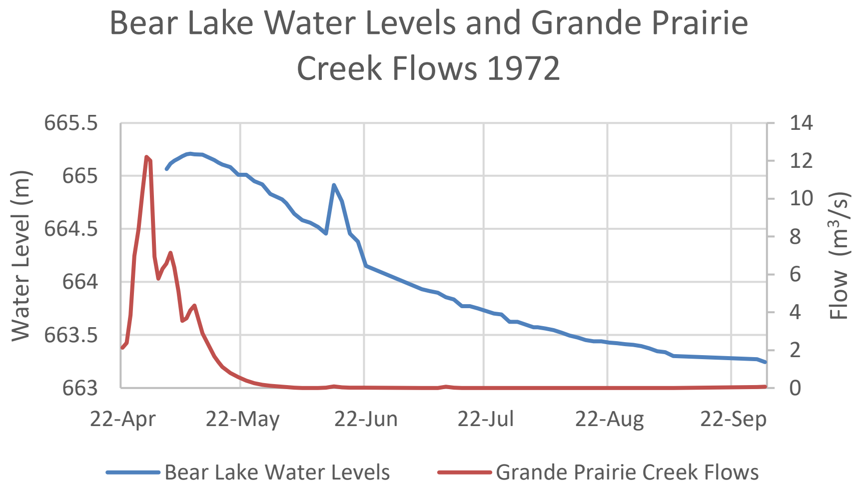
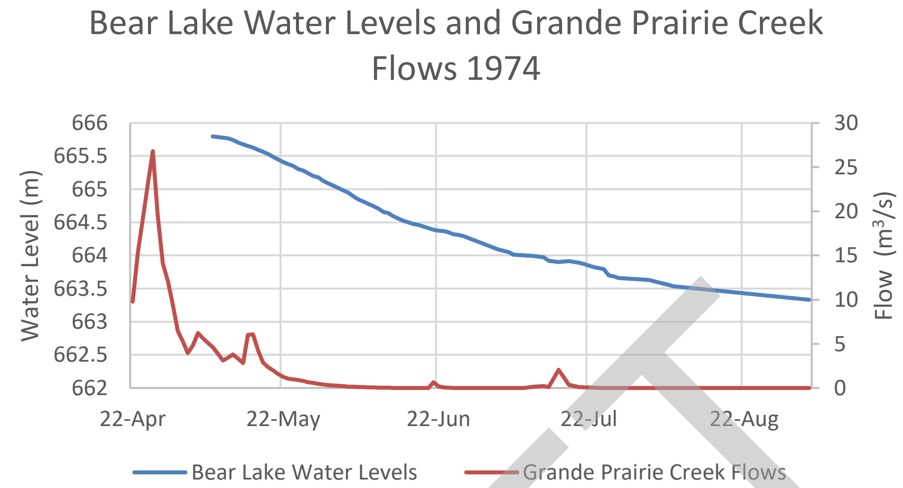
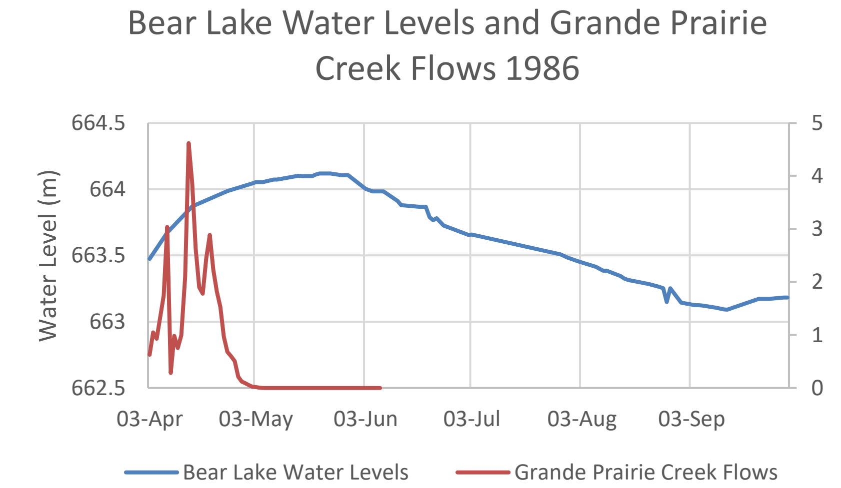
Figure 2

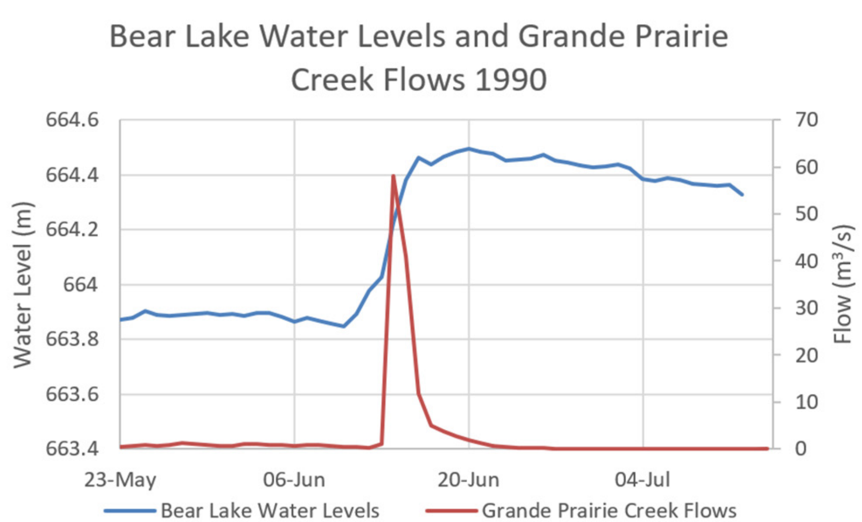
Classification: Public

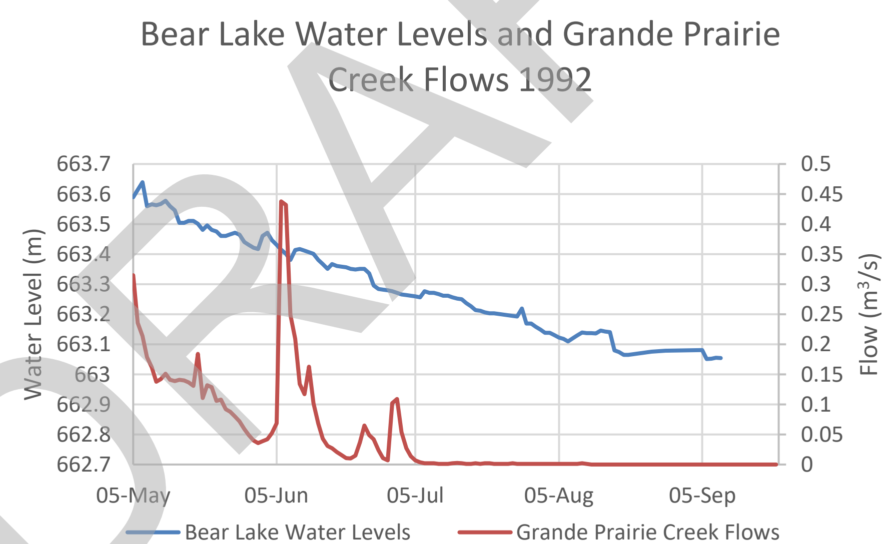
APPENDIX A
Historical Flood Data

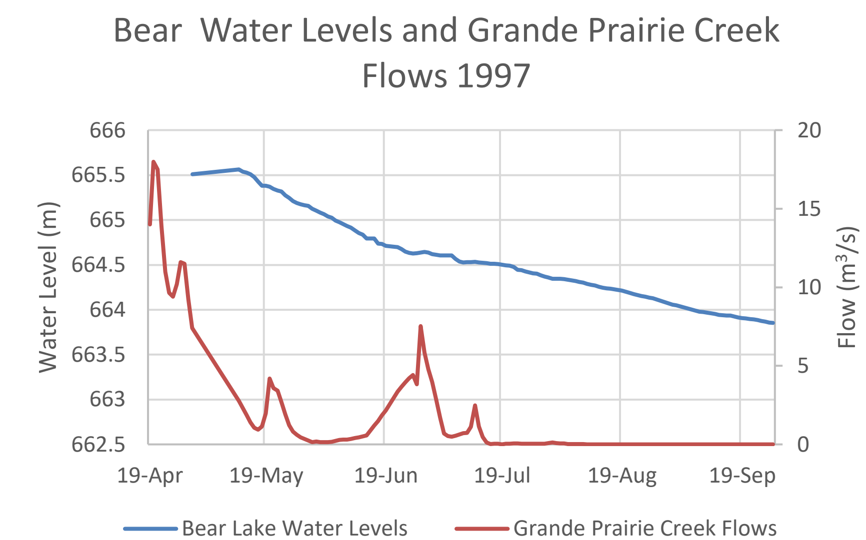












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Alberta Environment and Protected Areas

Grande Prairie Flood Study

BEAR LAKE WATER LEVELS AND GRANDE PRAIRIE CREEK FLOWS COMPARISON

Date:	Project:	Submitter:	Reviewer:
MARCH 2025	35917-531	S. R. SHEONTY	M. SHOME

Figure A1

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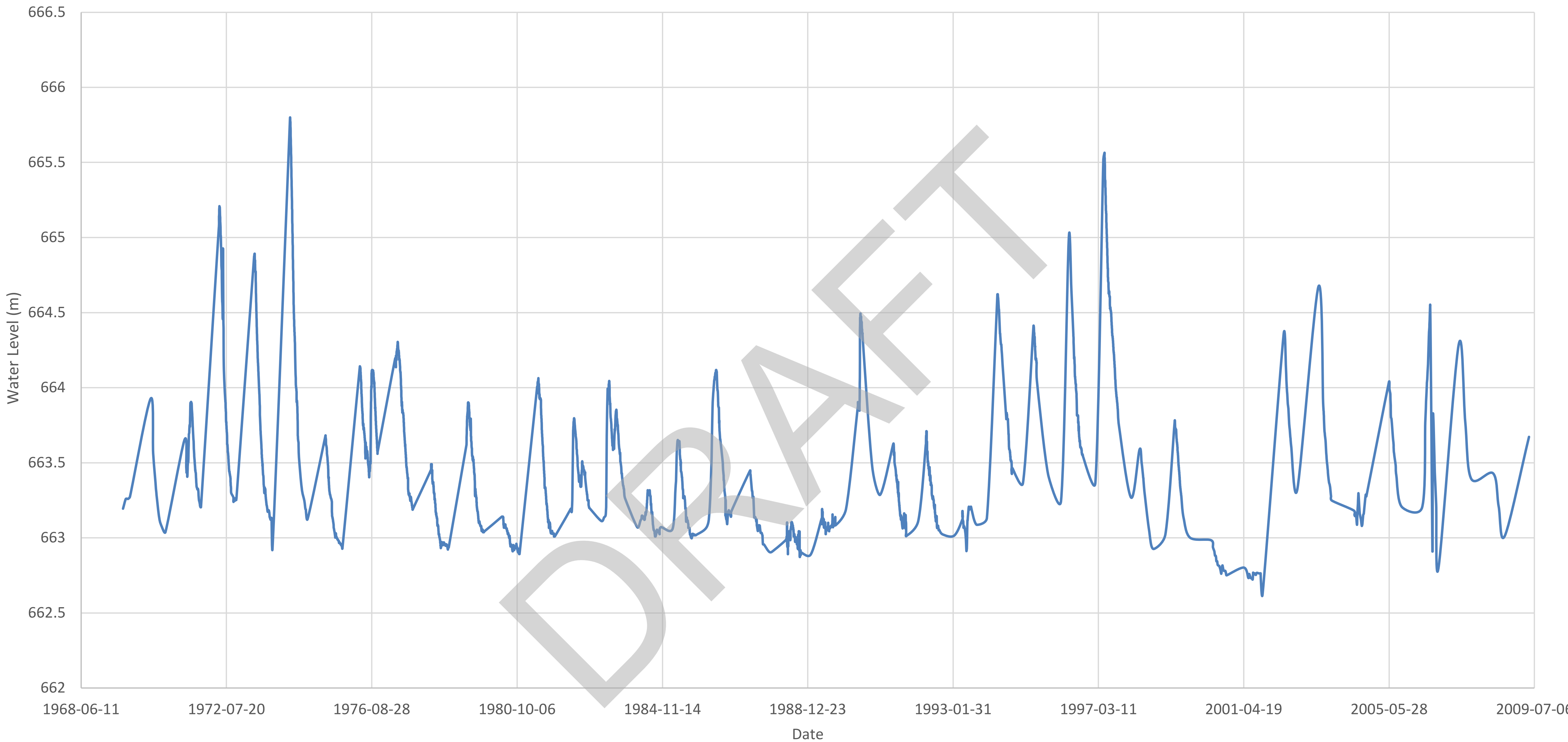

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Alberta Environment and Protected Areas

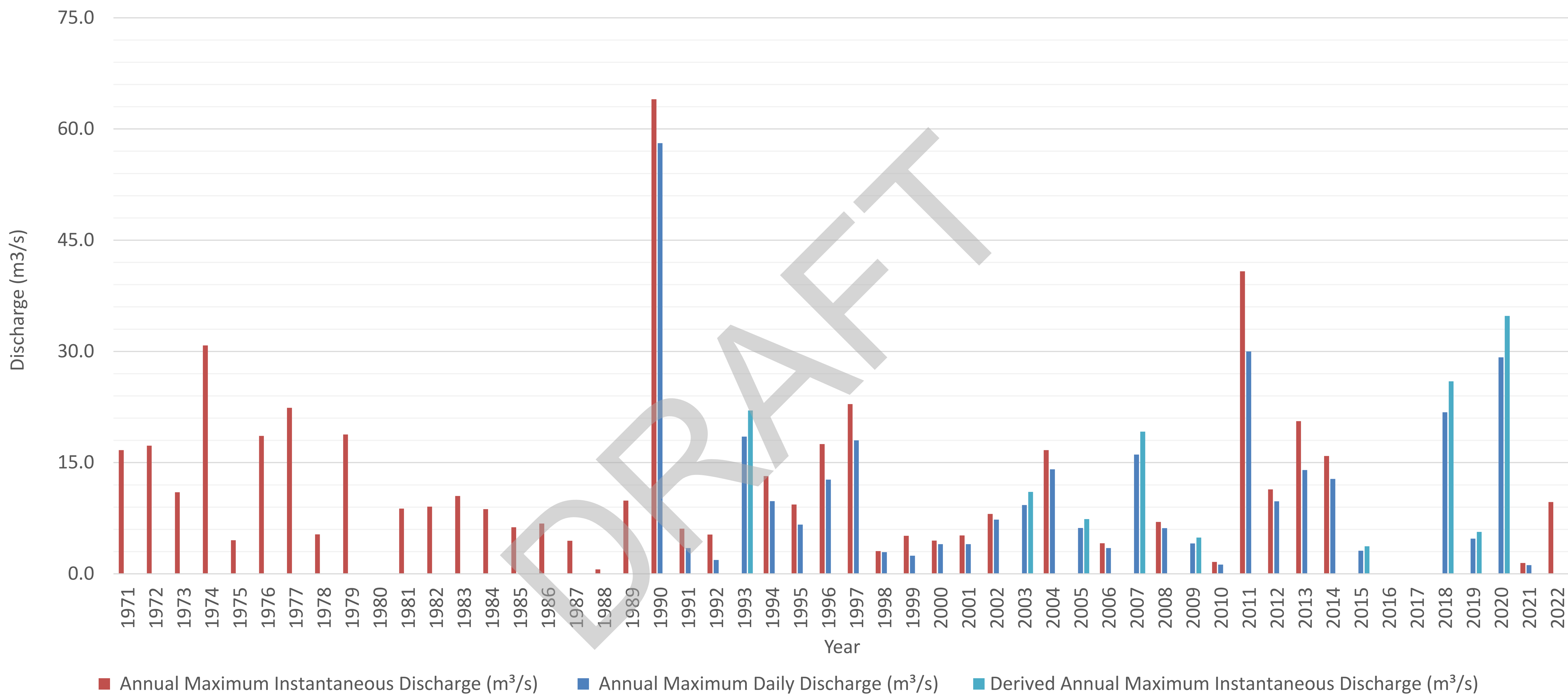
Grande Prairie Flood Study

BEAR LAKE WATER LEVELS FROM 1969 TO 2009

Date:	Project:	Submitter:	Reviewer:
MARCH 2025	35917-531	N. VAN DER VINNE	M. SHOME

Figure A2

Comparison of Annual Maximum Daily and Annual Maximum Instantaneous Discharges



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Alberta Environment and Protected Areas
Grande Prairie Flood Study

GRANDE PRAIRIE CREEK NEAR SEXSMITH HYDROLOGIC ANALYSIS

Date: MARCH 2025	Project: 35917-531	Submitter: S.R. SHEONTY	Reviewer: M. SHOME

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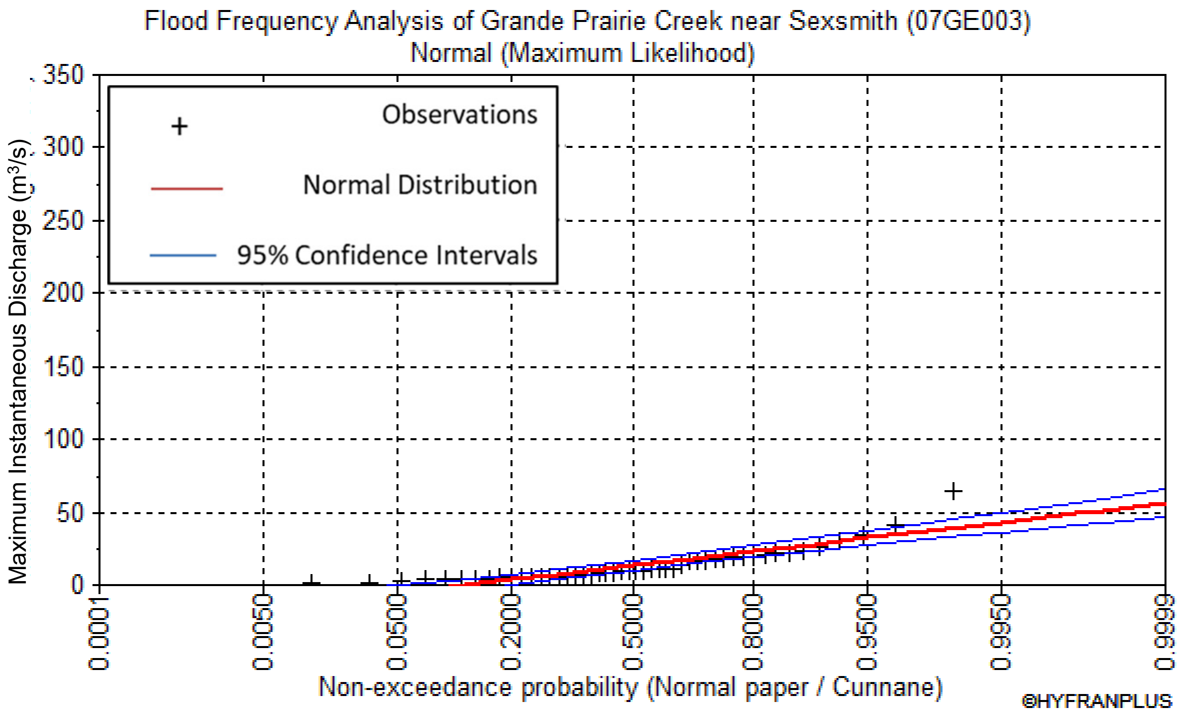
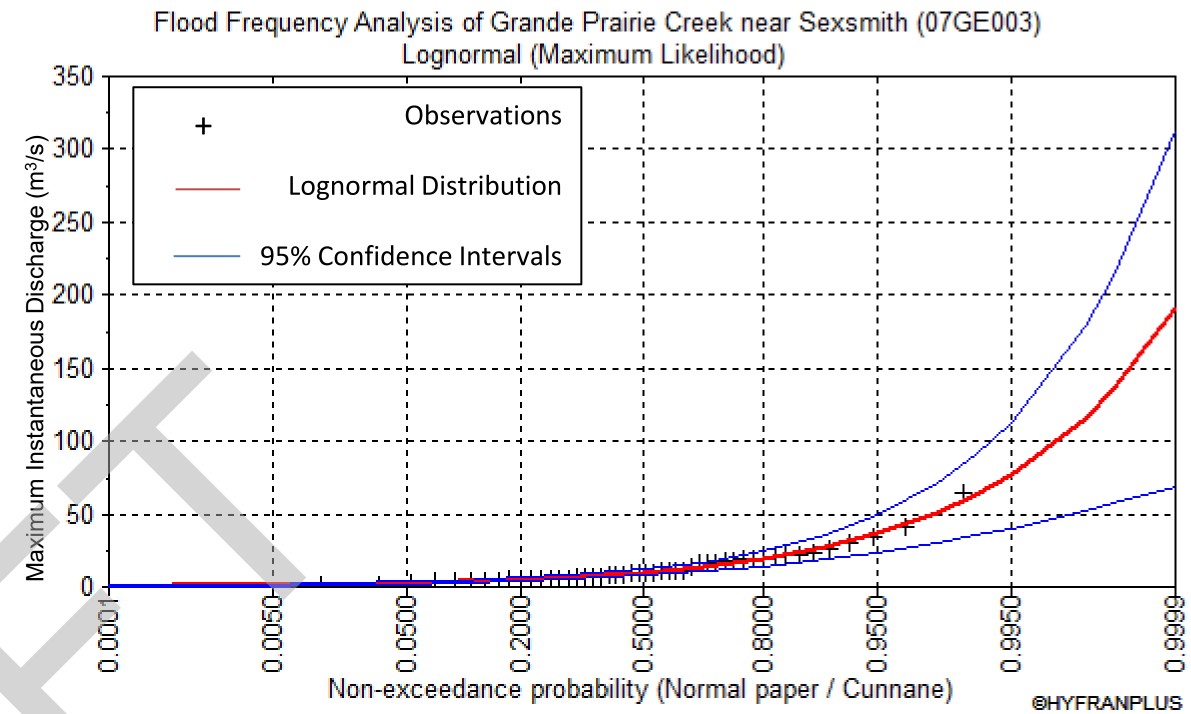
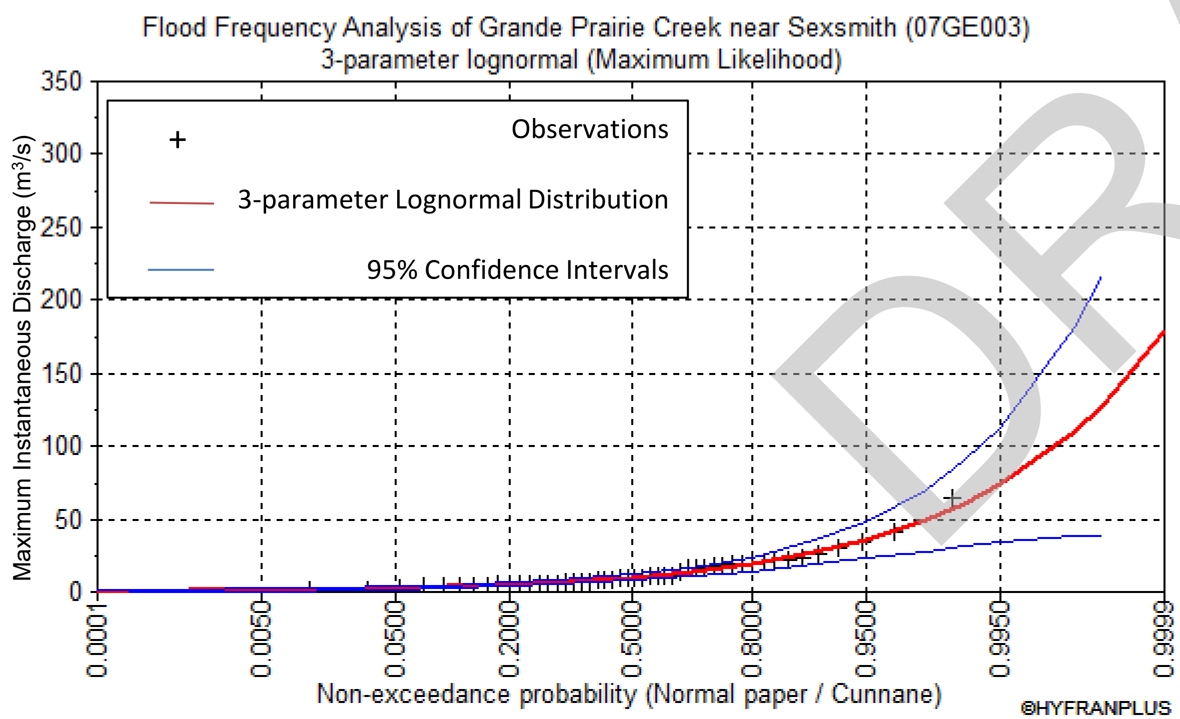
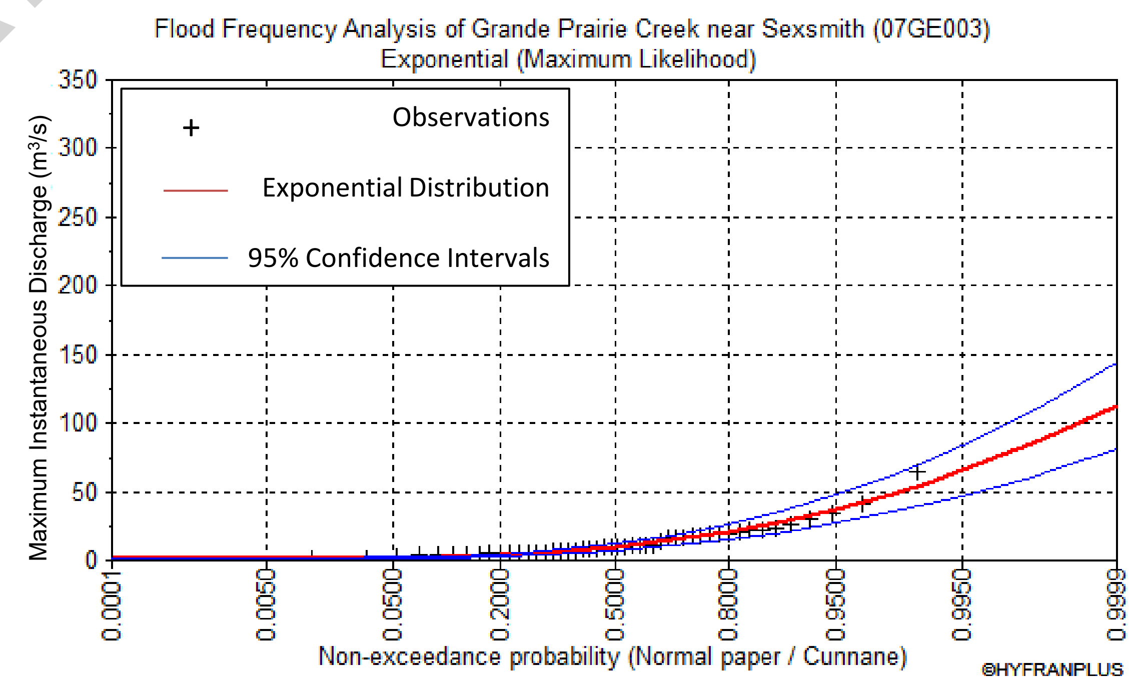
Figure A3









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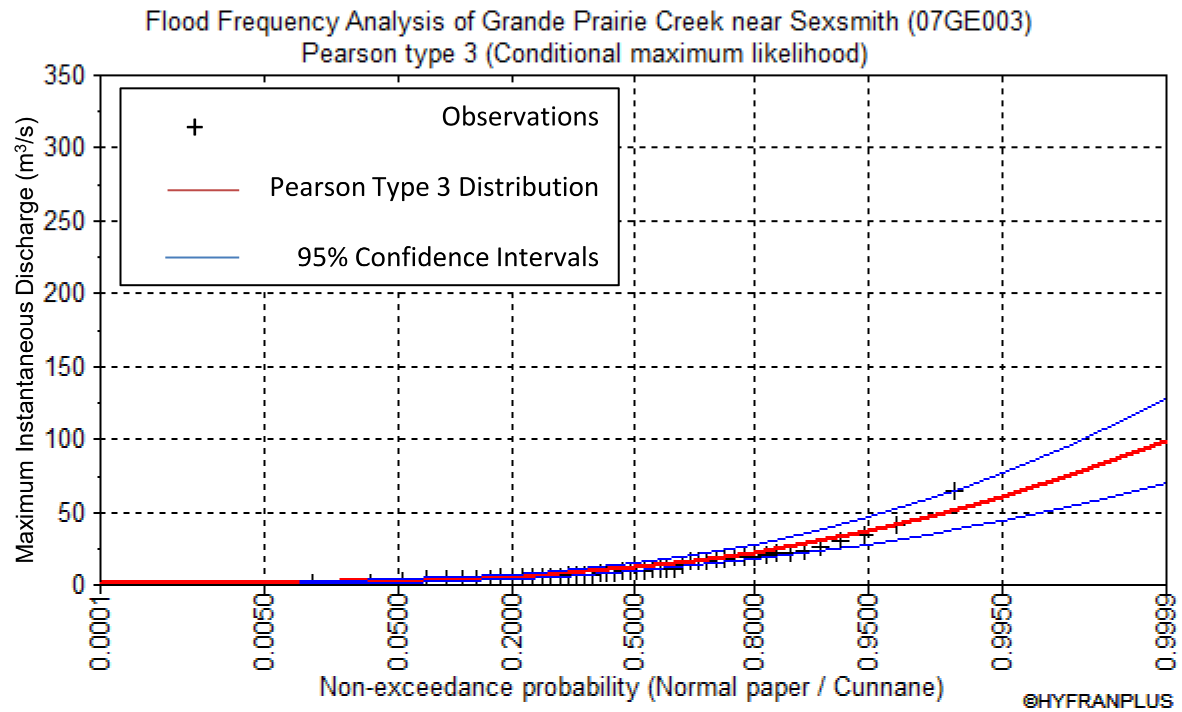
Alberta Environment and Protected Areas

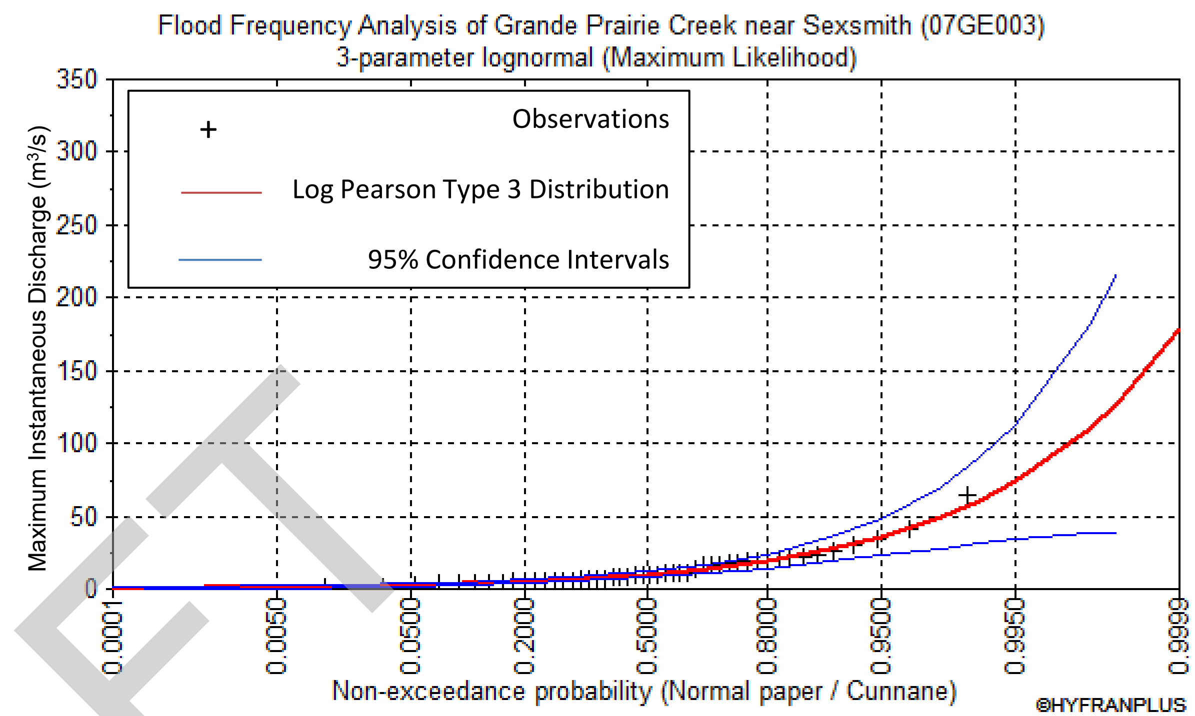
Grande Prairie Flood Study

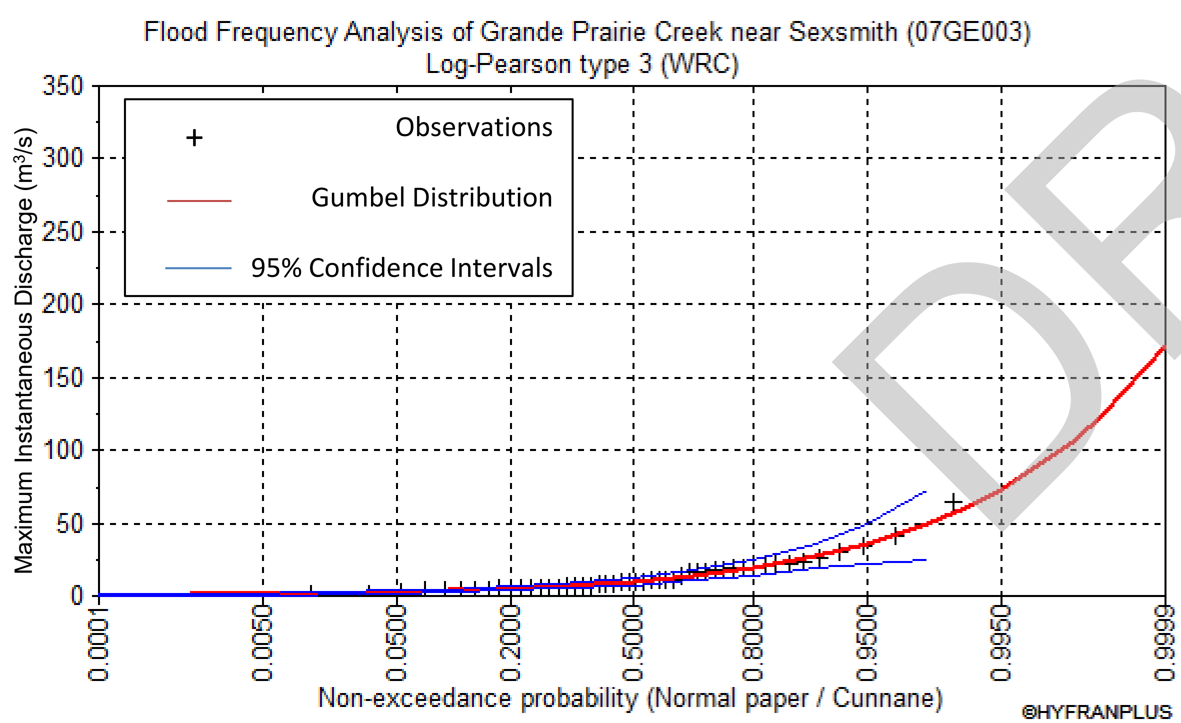
GRANDE PRAIRIE CREEK NEAR SEXSMITH COMPARISON OF FREQUENCY DISTRIBUTIONS

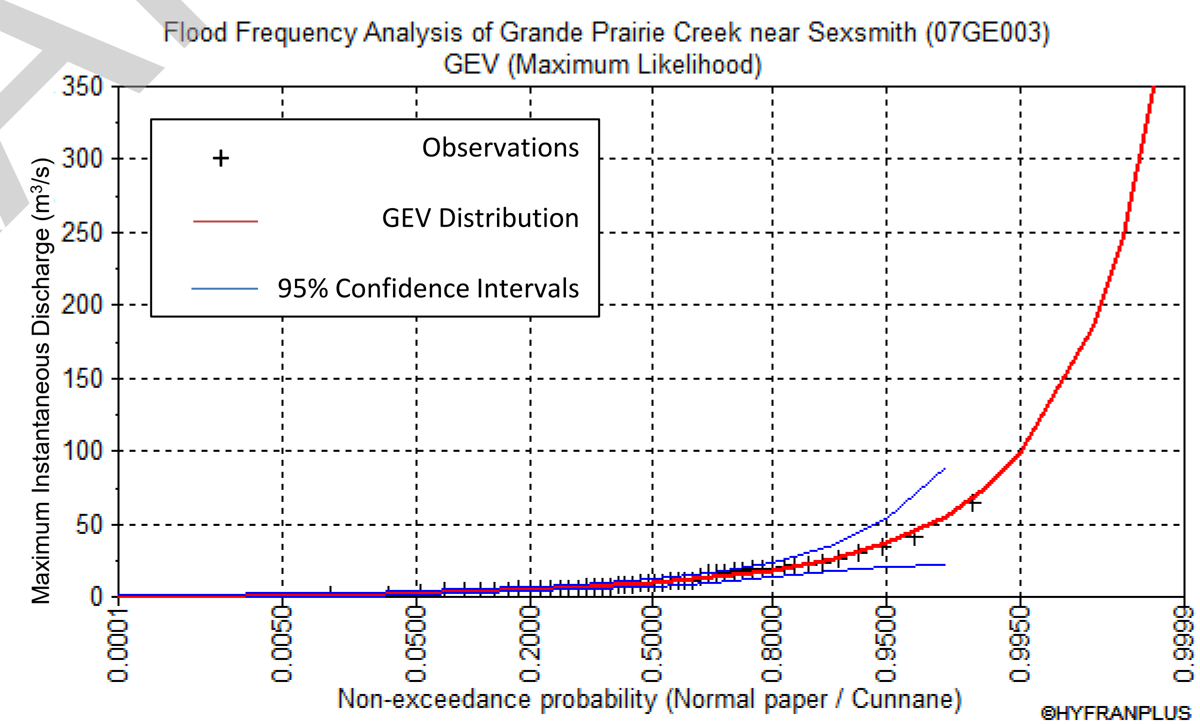
Date:	Project:	Submitter:	Reviewer:
MARCH 2025	35917-531	S.R. SHEONTY	M. SHOME

Figure A4.1









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Alberta Environment and Protected Areas

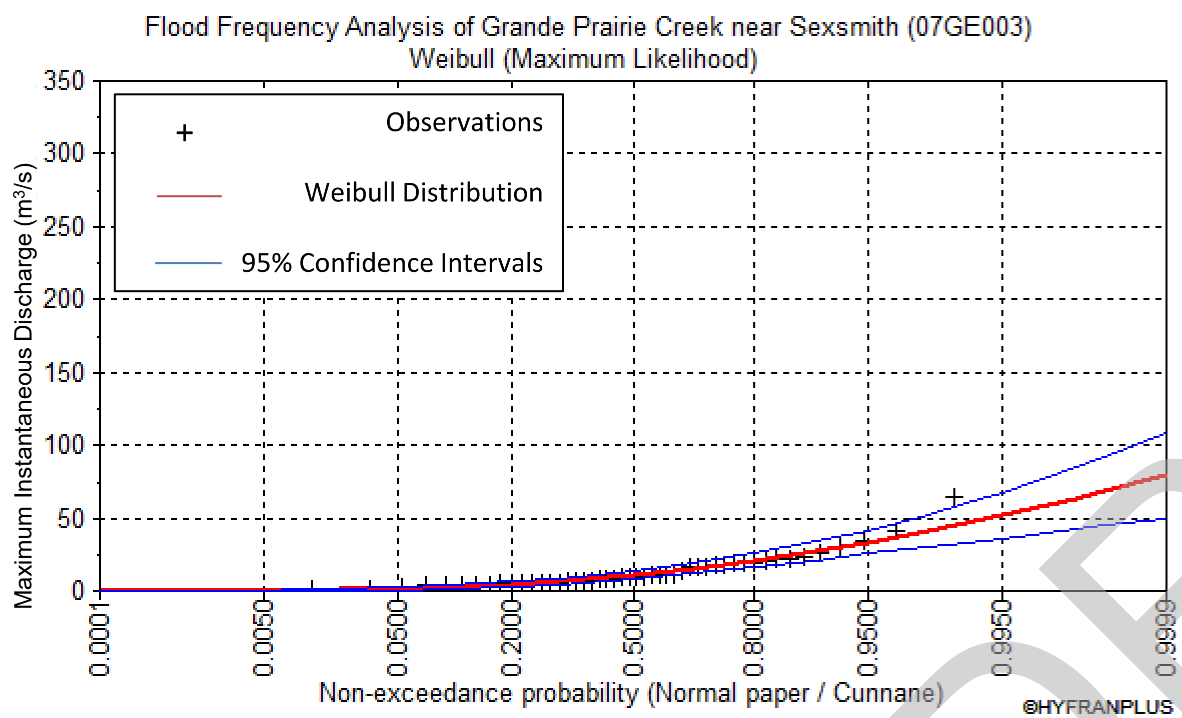
Grande Prairie Flood Study

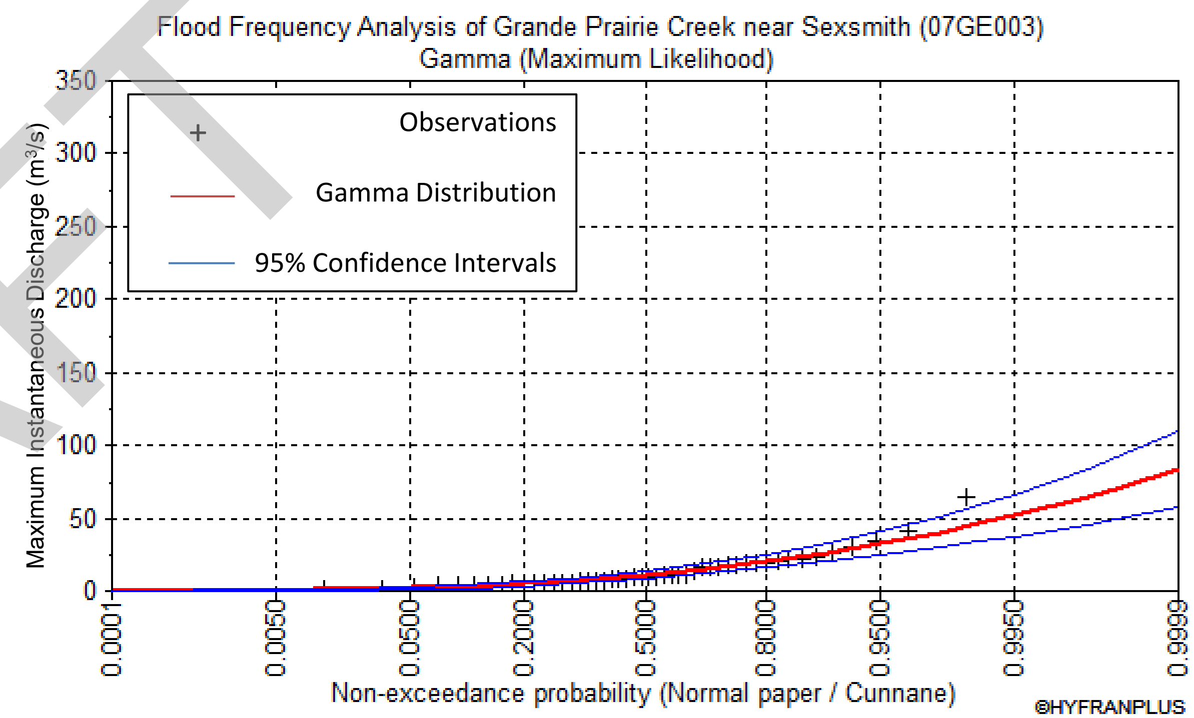
GRANDE PRAIRIE CREEK NEAR SEXSMITH COMPARISON OF FREQUENCY DISTRIBUTIONS

Date:	Project:	Submitter:	Reviewer:
MARCH 2025	35917-531	S.R. SHEONTY	M. SHOME

Figure A4.2

"F:\35917\BST 195521 (35917-531)\2 - Open Water Hydology Assessment\Hydrology\Final Frequency Analysis"





MONTROSE ENVIRONMENTAL

Alberta Environment and Protected Areas

Grande Prairie Flood Study

GRANDE PRAIRIE CREEK NEAR SEXSMITH COMPARISON OF FREQUENCY DISTRIBUTIONS

Date:	Project:	Submitter:	Reviewer:
MARCH 2025	35917-531	S.R. SHEONTY	M. SHOME

Figure A4.3

"F:\35917\BST 195521 (35917-531)\2 - Open Water Hydology Assessment\Hydrology\Final Frequency Analysis"

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	2.642	Reject H0	10
Lognormal	1.929	2.502	3.907	0.263	Accept H0	1
Lognormal III	1.929	2.502	3.907	0.268	Accept H0	3
Exponential	1.929	2.502	3.907	0.769	Accept H0	7
Pearson III	1.929	2.502	3.907	1.061	Accept H0	9
Log Pearson III	1.929	2.502	3.907	0.265	Accept H0	2
Gumbel	1.929	2.502	3.907	0.984	Accept H0	8
GEV	1.929	2.502	3.907	0.306	Accept H0	4
Weibull	1.929	2.502	3.907	0.691	Accept H0	6
Gamma	1.929	2.502	3.907	0.542	Accept H0	5

2) Kolmogorov-Smirnov Test (1933)

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

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	0.176	0.196	0.235	0.170	Accept H0	10
Lognormal	0.176	0.196	0.235	0.081	Accept H0	2
Lognormal III	0.176	0.196	0.235	0.083	Accept H0	3
Exponential	0.176	0.196	0.235	0.132	Accept H0	9
Pearson III	0.176	0.196	0.235	0.127	Accept H0	8
Log Pearson III	0.176	0.196	0.235	0.079	Accept H0	1
Gumbel	0.176	0.196	0.235	0.098	Accept H0	6
GEV	0.176	0.196	0.235	0.098	Accept H0	7
Weibull	0.176	0.196	0.235	0.091	Accept H0	5
Gamma	0.176	0.196	0.235	0.083	Accept H0	4

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	10	10.00	10
Lognormal	1	2	1	1.33	1
Lognormal III	3	3	3	3.00	3
Exponential	7	9	6	7.33	7
Pearson III	9	8	5	7.33	7
Log Pearson III	2	1	4	2.33	2
Gumbel	8	6	9	7.67	9
GEV	4	7	2	4.33	4
Weibull	6	5	7	6.00	6
Gamma	5	4	8	5.67	5

Least Squares Ranking

Distribution Type:	Standard Error	Rank
Normal	6	10
Lognormal	1	1
Lognormal III	1	3
Exponential	2	6
Pearson III	2	5
Log Pearson III	1	4
Gumbel	4	9
GEV	1	2
Weibull	3	7
Gamma	3	8

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

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**

MONTROSE ENVIRONMENTAL

Alberta Environment and Protected Areas
Grande Prairie Flood Study

GRANDE PRAIRIE CREEK STATISTICAL TEST SUMMARY

Date: MARCH 2025 | Project: 35917-531 | Submitter: S.R. SHEONTY | Reviewer: M. SHOME

Figure A5

TABLE A1: Timing of Bear Lake Levels and Grande Prairie Creek Peaks				
Year	Maximum Water Level for Bear Lake (m)	Date of Maximum Water Level	Grande Prairie Creek Maximum Flow (m^3/s)	Date of Maximum Flow
1969	n/a	n/a	n/a	n/a
1970	663.9	28-May	5.04	16-Apr
1971	663.9	20-Jul	12.6	30-Jun
1972	665.2	09-May	12.2	15-May
1973	664.9	07-May	8.98	23-Apr
1974	665.8	08-May	26.8	18-May
1975	663.7	08-May	2.77	23-Apr
1976	664.1	27-Apr	12.3	30-Jun
1977	664.3	23-May	17.3	10-May
1978	663.5	08-May	4.67	29-Apr
1979	663.9	20-May	12.7	05-Jul
1980	663.1	12-May	0.55	15-Apr
1981	664.1	14-May	5.48	20-Apr
1982	663.8	16-May	5.38	29-Apr
1983	664.0	14-May	8.26	21-Jul
1984	663.3	06-Jul	6.98	08-Jun
1985	663.7	22-Apr	3.81	08-Apr
1986	664.1	21-May	5.71	06-May
1987	663.4	06-May	3.7	04-Apr
1988	663.1	07-Jul	0.347	03-Jul
1989	663.2	20-May	5.58	24-Aug
1990	664.5	20-Jun	58.1	30-Mar
1991	663.6	24-May	3.47	05-Apr
1992	663.7	02-May	1.87	01-Apr
1993	663.2	03-Aug	18.5	08-Jul
1994	664.6	07-May	9.82	22-Apr
1995	664.4	11-May	6.65	05-Jul
1996	665.0	09-May	12.7	01-Jun
1997	665.6	12-May	18	19-May
1998	663.6	08-May	2.92	07-Apr
1999	663.8	07-May	2.44	13-Apr
2000	663.0	15-May	4.01	03-Sep
2001	662.8	19-Apr	4.01	30-May
2002	664.4	05-Jun	7.31	14-May
2003	664.7	29-May	9.28	22-Apr
2004	663.3	16-Jul	14.1	12-Sep
2005	664.0	27-May	6.2	12-Mar
2006	664.5	27-Jul	3.49	27-May
2007	664.3	15-May	16.1	10-May

TABLE A1: Timing of Bear Lake Levels and Grande Prairie Creek Peaks				
Year	Maximum Water Level for Bear Lake (m)	Date of Maximum Water Level	Grande Prairie Creek Maximum Flow (m^3/s)	Date of Maximum Flow
2008	663.4	05-May	6.16	01-May
2009	663.7	11-May	4.1	13-Apr

Note:
1. Maximum values for 1969 data is not available due to limited recordings for that year.

TABLE A2: Recorded Annual Maximum Daily and Maximum Instantaneous Discharges for WSC Gauging Station 07GE003

Year	Grande Prairie Creek near Sexsmith (07GE003)			
	Annual Maximum Instantaneous Discharge (m^3/s)	Date (mm-dd)	Annual Maximum Daily Discharge (m^3/s)	Date (mm-dd)
1971	16.7	06--26	-	-
1972	17.3	04--27	-	-
1973	11.0	04--20	-	-
1974	30.8	04--25	-	-
1975	4.5	04--22	-	-
1976	18.6	04--12	-	-
1977	22.4	04--09	-	-
1978	5.3	04--29	-	-
1979	18.8	04--27	-	-
1980	-	-	-	-
1981	8.8	04--19	-	-
1982	9.1	04--29	-	-
1983	10.5	07--21	-	-
1984	8.7	06--08	-	-
1985	6.3	04--01	-	-
1986	6.8	05--06	-	-
1987	4.5	04--04	-	-
1988	0.6	07--03	-	-
1989	9.9	08--23	-	-
1990	64.0	06--12	58.1	06--12
1991	6.1	04--05	3.5	04--05
1992	5.3	05--25	1.9	04--01
1993	-	-	18.5	06--28
1994	13.2	06--14	9.8	04--22
1995	9.4	07--05	6.7	07--05
1996	17.5	04--16	12.7	04--17
1997	22.9	04--20	18.0	04--20
1998	3.1	04--07	2.9	04--07
1999	5.1	04--12	2.4	04--13
2000	4.5	09--03	4.0	09--03
2001	5.2	05--30	4.0	05--30
2002	8.1	05--14	7.3	05--14
2003	-	-	9.3	04--22
2004	16.7	07--03	14.1	07--04
2005	-	-	6.2	03--12
2006	4.1	05--27	3.5	05--27

TABLE A2: Recorded Annual Maximum Daily and Maximum Instantaneous Discharges for WSC Gauging Station 07GE003				
Year	Grande Prairie Creek near Sexsmith (07GE003)			
	Annual Maximum Instantaneous Discharge (m^3/s)	Date (mm-dd)	Annual Maximum Daily Discharge (m^3/s)	Date (mm-dd)
2007	-	-	16.1	05--05
2008	7.0	05--01	6.2	05--01
2009	-	-	4.1	04--13
2010	1.6	05--26	1.3	05--26
2011	40.8	07--09	30.0	07--09
2012	11.4	06--07	9.8	06--07
2013	20.6	04--25	14.0	04--26
2014	15.9	04--22	12.8	04--23
2015	-	-	3.1	04--03
2016	-	-	-	-
2017	-	-	-	-
2018	-	-	21.8	04--29
2019	-	-	4.8	04--02
2020	-	-	29.2	04--22
2021	1.46	05--21	1.2	04--15
2022	10.4	05--07	7.3	05--07

Note:

1. No data is available for 2016 and 2017.

TABLE A3:Extended Annual Maximum Instantaneous and Recorded Annual Maximum Daily Discharges for WSC Gauging Station 07GE003				
Year	Grande Prairie Creek near Sexsmith (07GE003)			
	Annual Maximum Instantaneous Discharge (m^3/s)	Date (mm-dd)	Annual Maximum Daily Discharge (m^3/s)	Date (mm-dd)
1971	16.7	06--26	-	-
1972	17.3	04--27	-	-
1973	11.0	04--20	-	-
1974	30.8	04--25	-	-
1975	4.5	04--22	-	-
1976	18.6	04--12	-	-
1977	22.4	04--09	-	-
1978	5.3	04--29	-	-
1979	18.8	04--27	-	-
1980	-	-	-	-
1981	8.8	04--19	-	-
1982	9.1	04--29	-	-
1983	10.5	07--21	-	-
1984	8.7	06--08	-	-
1985	6.3	04--01	-	-
1986	6.8	05--06	-	-
1987	4.5	04--04	-	-
1988	0.6	07--03	-	-
1989	9.9	08--23	-	-
1990	64.0	06--12	58.1	06--12
1991	6.1	04--05	3.47	04--05
1992	5.3	05--25	1.87	04--01
1993	22.0	06--28	18.5	06--28
1994	13.2	06--14	9.82	04--22
1995	9.4	07--05	6.65	07--05
1996	17.5	04--16	12.7	04--17
1997	22.9	04--20	18	04--20
1998	3.1	04--07	2.92	04--07
1999	5.1	04--12	2.44	04--13
2000	4.5	09--03	4.01	09--03
2001	5.2	05--30	4.01	05--30
2002	8.1	05--14	7.31	05--14
2003	11.1	04--22	9.28	04--22
2004	16.7	07--03	14.1	07--04
2005	7.4	03--12	6.2	03--12
2006	4.1	05--27	3.49	05--27

TABLE A3:Extended Annual Maximum Instantaneous and Recorded Annual Maximum Daily Discharges for WSC Gauging Station 07GE003				
Year	Grande Prairie Creek near Sexsmith (07GE003)			
	Annual Maximum Instantaneous Discharge (m^3/s)	Date (mm-dd)	Annual Maximum Daily Discharge (m^3/s)	Date (mm-dd)
2007	19.2	05--05	16.1	05--05
2008	7.0	05--01	6.16	05--01
2009	4.9	04--13	4.1	04--13
2010	1.6	05--26	1.26	05--26
2011	40.8	07--09	30	07--09
2012	11.4	06--07	9.79	06--07
2013	20.6	04--25	14	04--26
2014	15.9	04--22	12.8	04--23
2015	3.7	04--03	3.12	04--03
2016	-	-	-	-
2017	-	-	-	-
2018	26.0	04--29	21.8	04--29
2019	5.7	04--02	4.75	04--02
2020	34.8	04--22	29.2	04--22
2021	1.5	05--21	1.19	04--15
2022	10.4	05--07	7.3	05--07

Note:

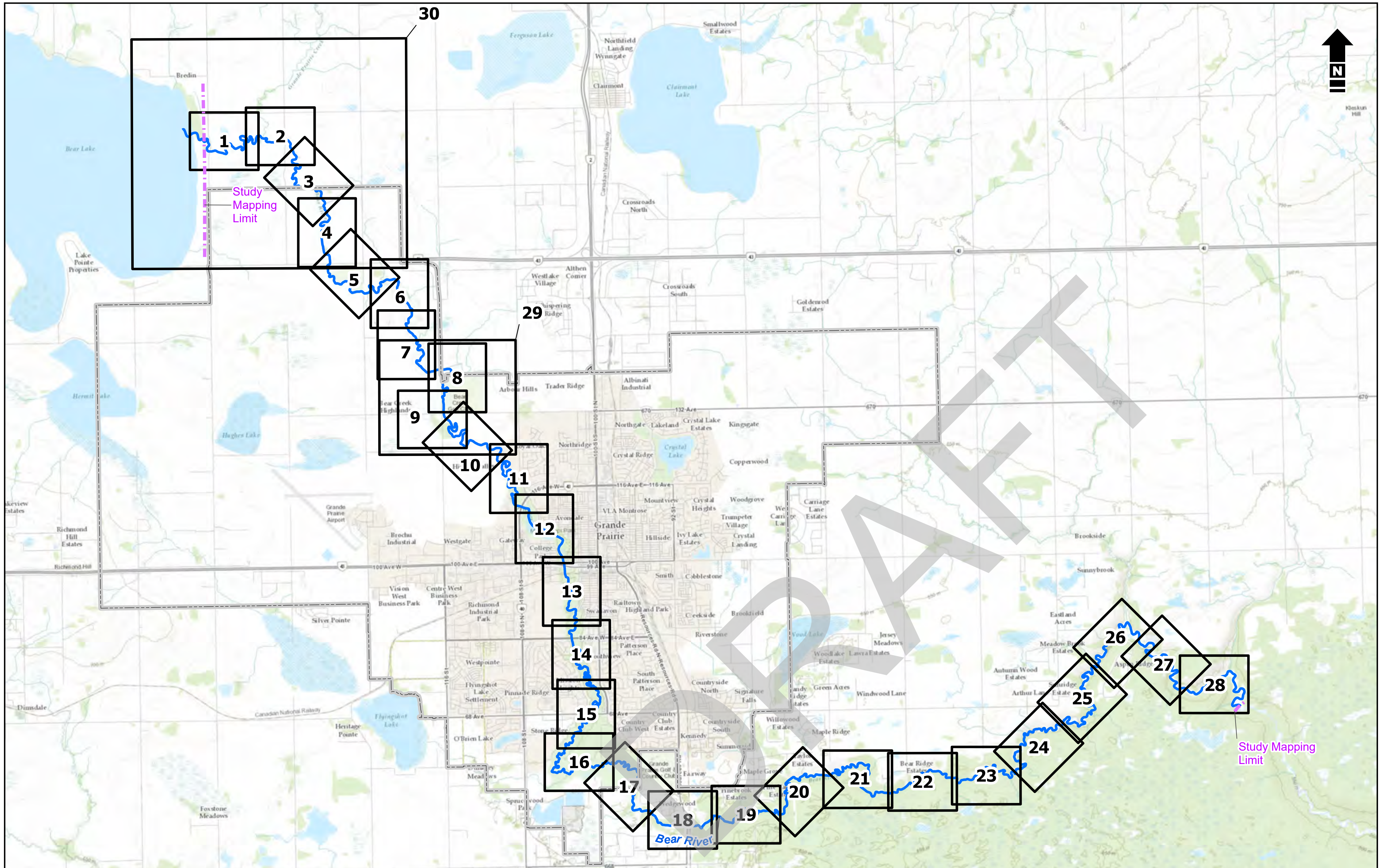
1. The underlined values are based on Qi= 1.1912Qp.
2. No data is available for 2016 and 2017.

APPENDIX C
Flood Inundation Maps

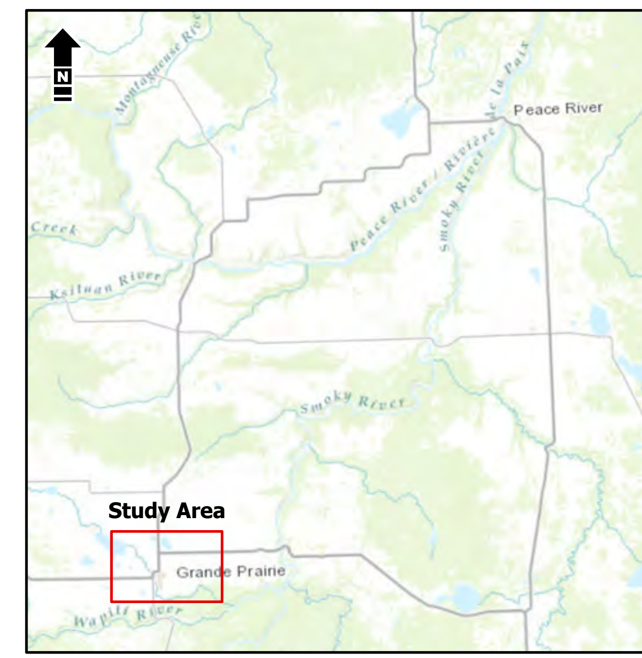
[Appendix C - Placeholder]

Inundation Library Issued Under Separate Cover

APPENDIX D
Floodway Criteria Maps



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



1:100,000 — 2.5 0 2.5 5 kilometres

NAD 1983 CSRS 3TM 120

Notes:

1. Please refer to the accompanying Grande Prairie Flood Study for important information concerning these maps.

2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.

3. Non-riverine and local sources of water have not been considered, and structures such roads 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:

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Base Mapping available ESRI Base Mapping and Imagery Services.
World Topographic Map: City of Grande Prairie, County of Grande Prairie, Province of Alberta, Province of British Columbia, Esri Canada, Esri, © OpenStreetMap contributors, HERE, Garmin, USGS, NGA, EPA, USDA, NPS, AAFC, NRCan
World Topographic Map: Esri, © OpenStreetMap contributors, HERE, Garmin, FAO, USGS, EPA, NPS, AAFC, NRCan

Alberta — MONTROSE ENVIRONMENTAL — Canada

Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Index Map

Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome

Sheet INDEX

- *RS: 24873* River Station
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- Culvert
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- Cross Section Line
- Study Mapping Limit
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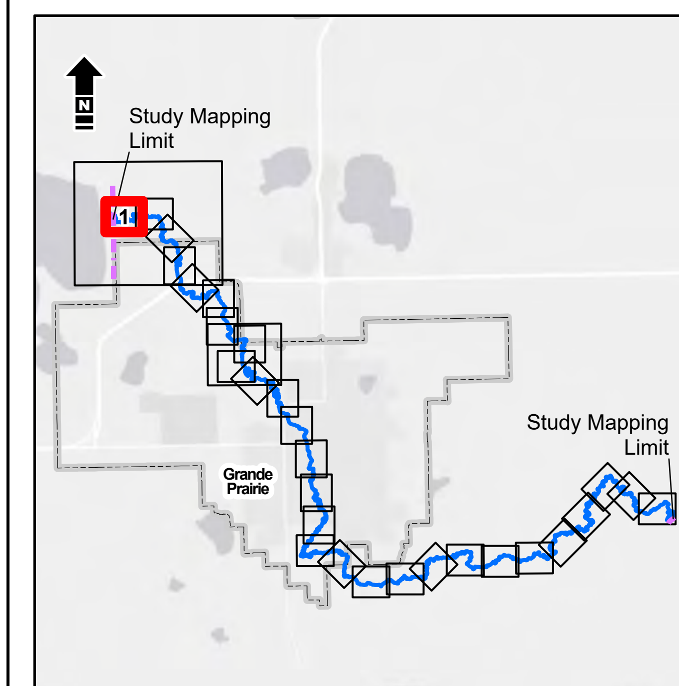
- Bank Station
- 100 Year Inundation - ≥1 m/s Velocity
- Previous Floodway
- Floodway Boundary
- 100 Year Inundation Extent
- 100 Year Inundation Extent - ≥1 m Depth



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Grande Prairie Flood Study

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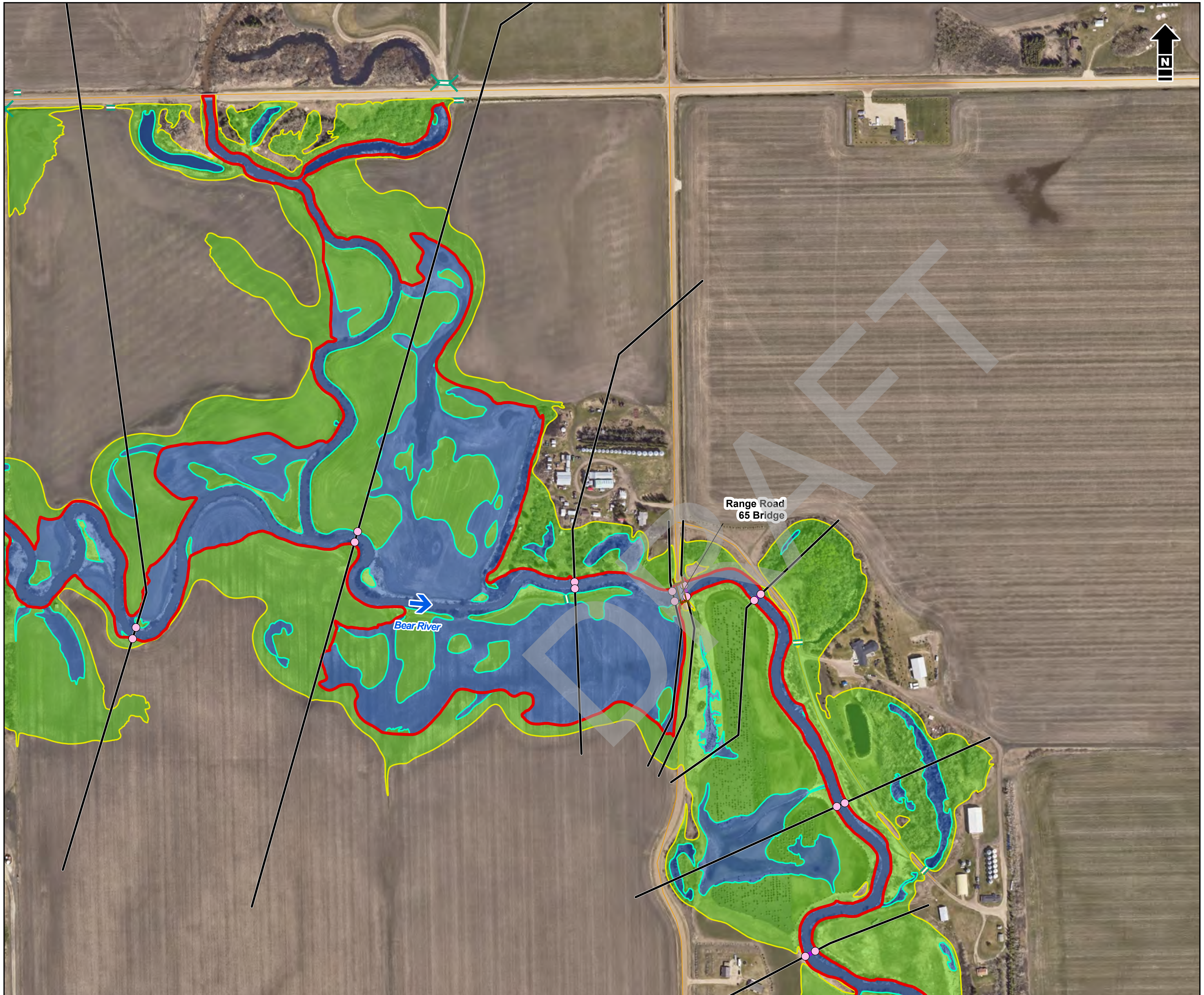

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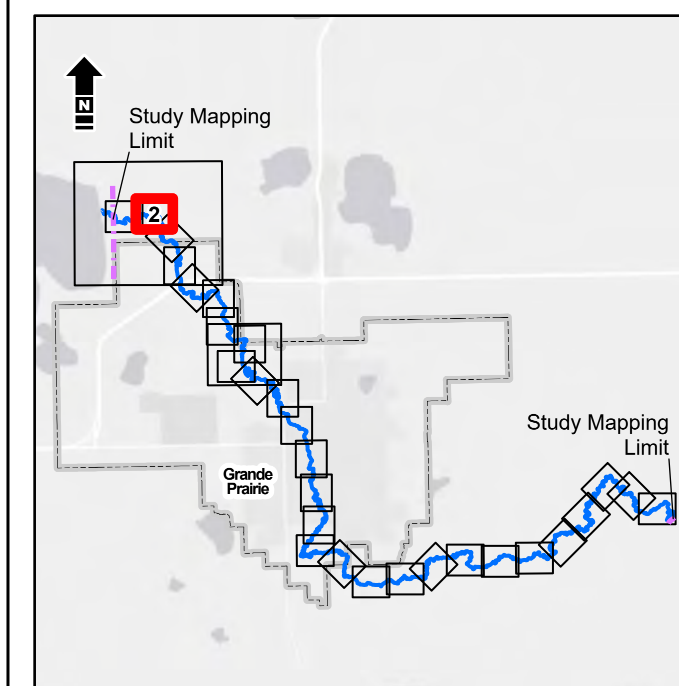

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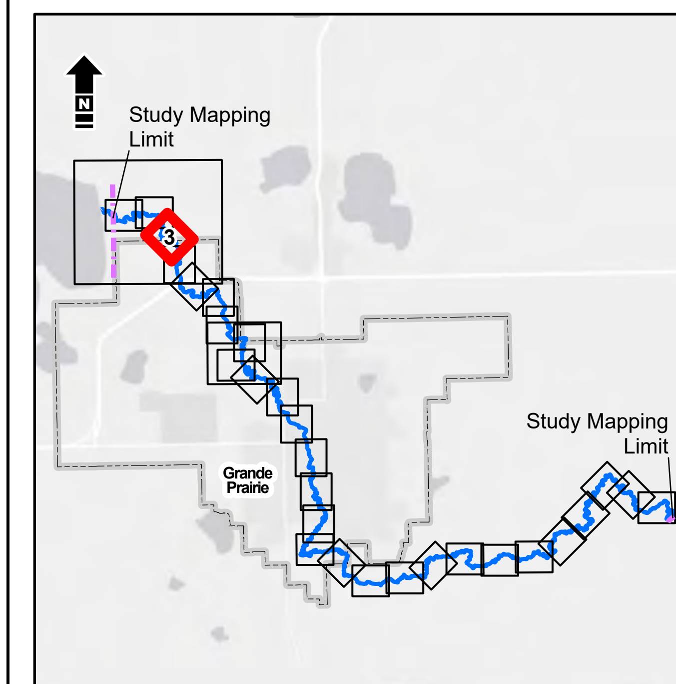

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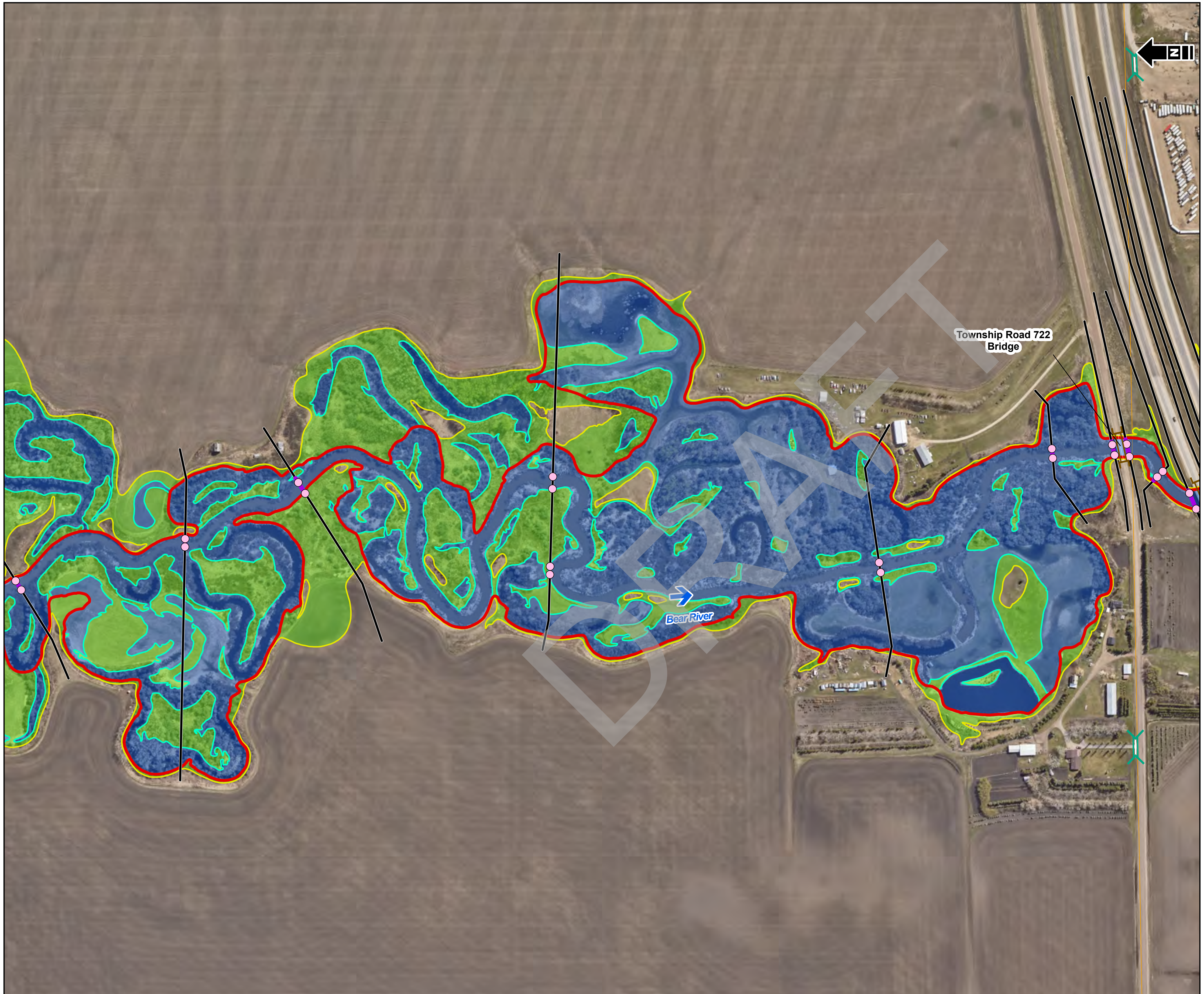

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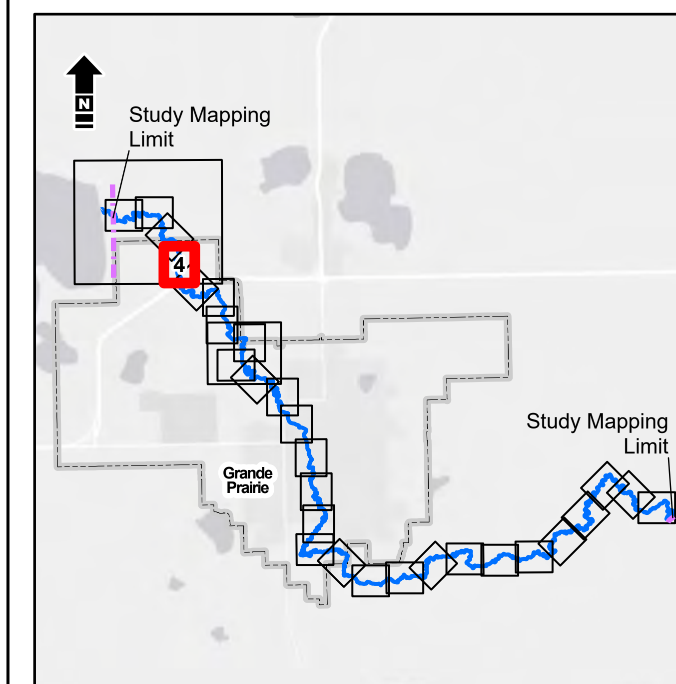

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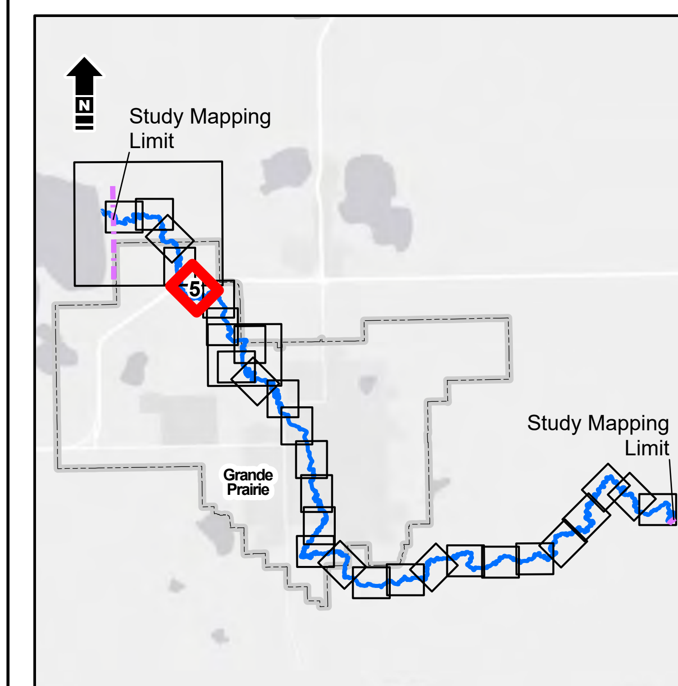

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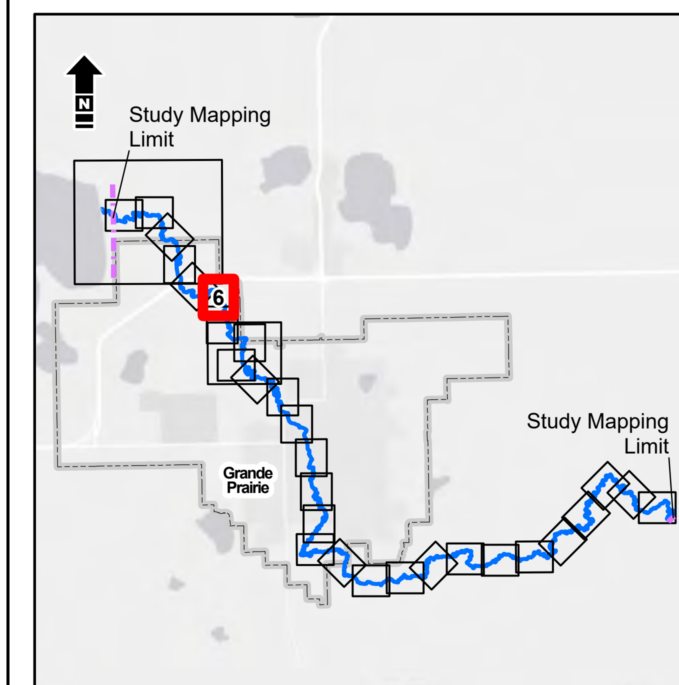

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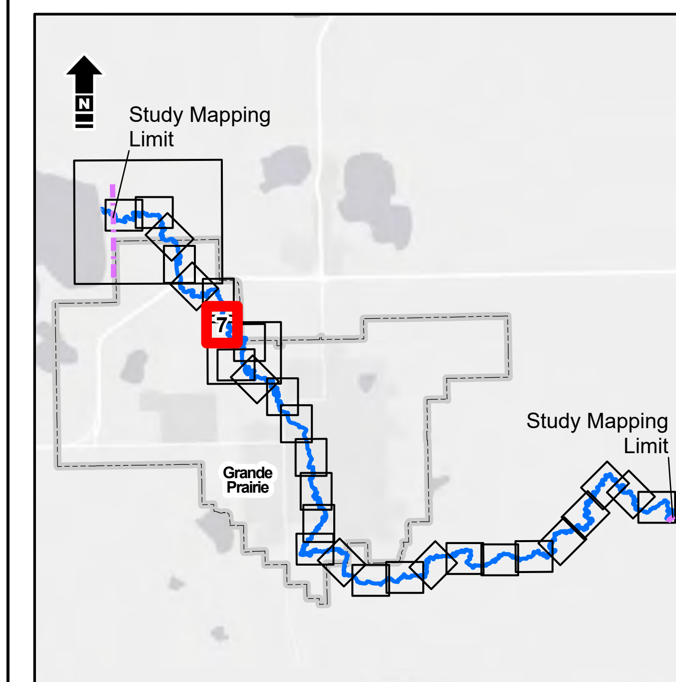

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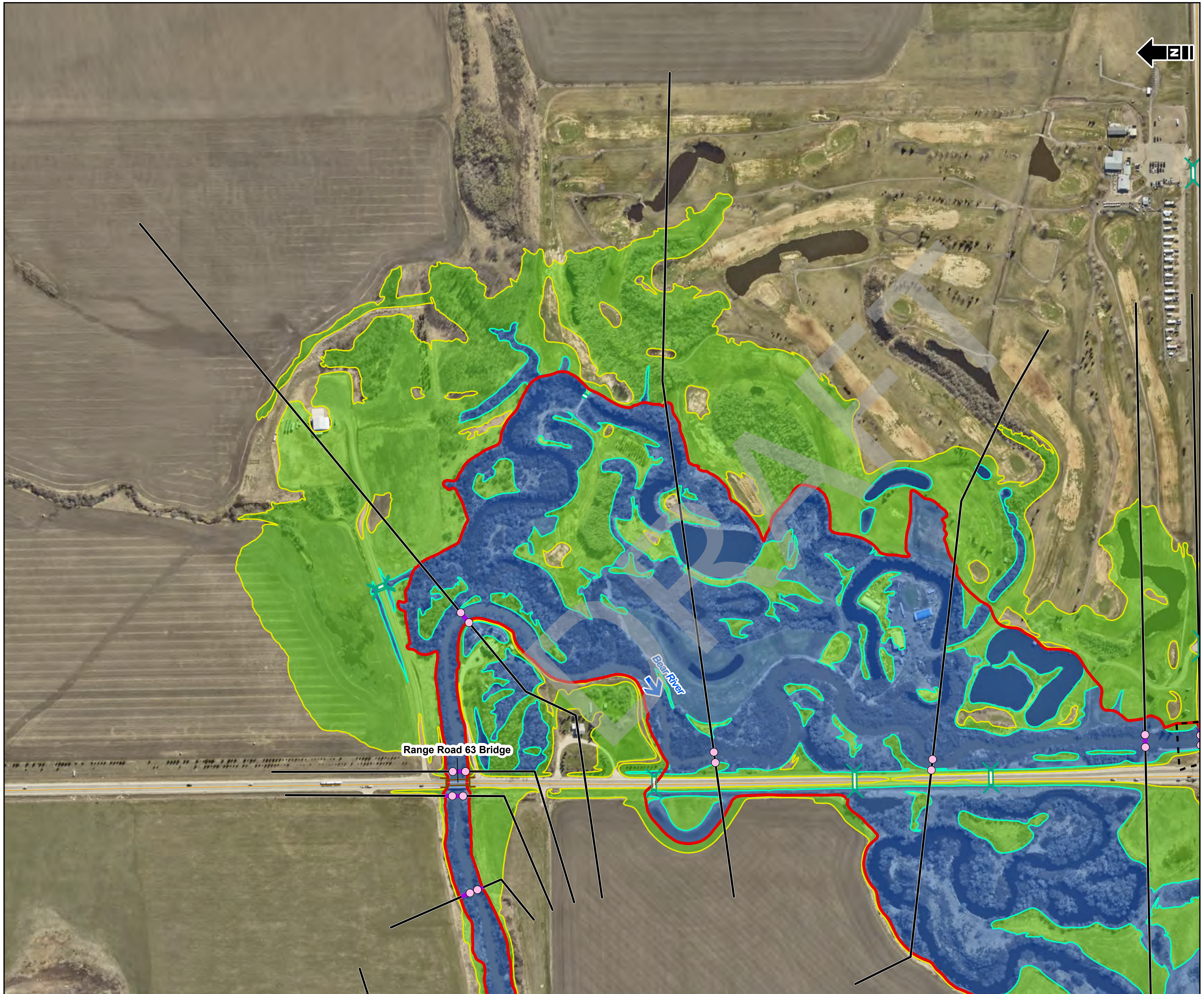

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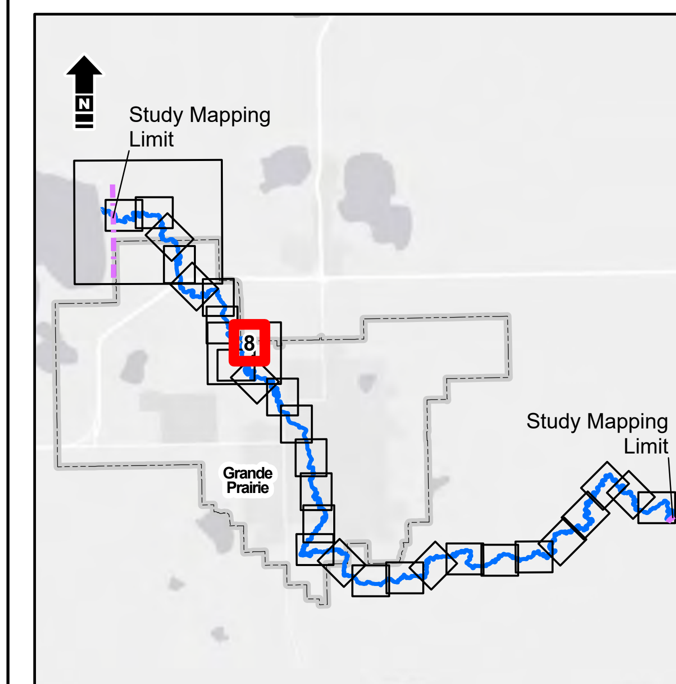

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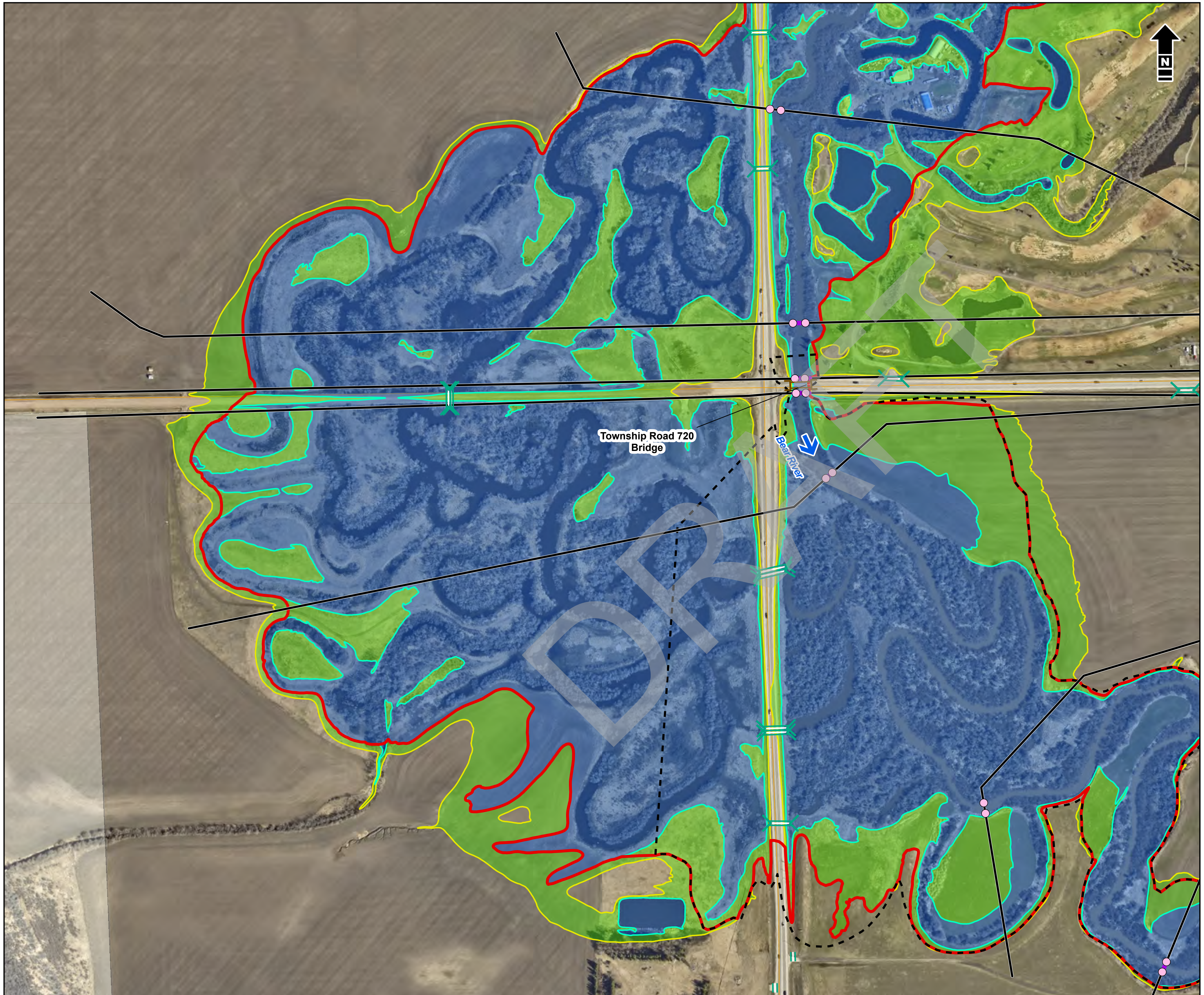

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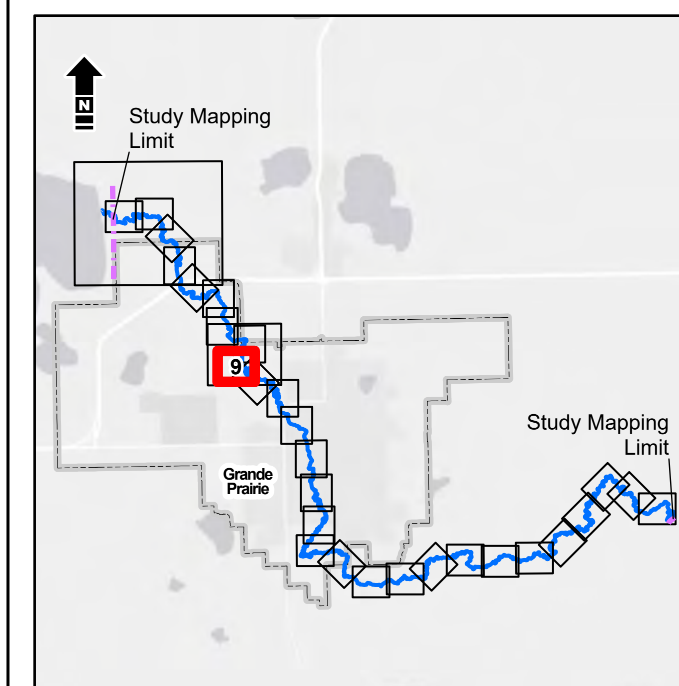

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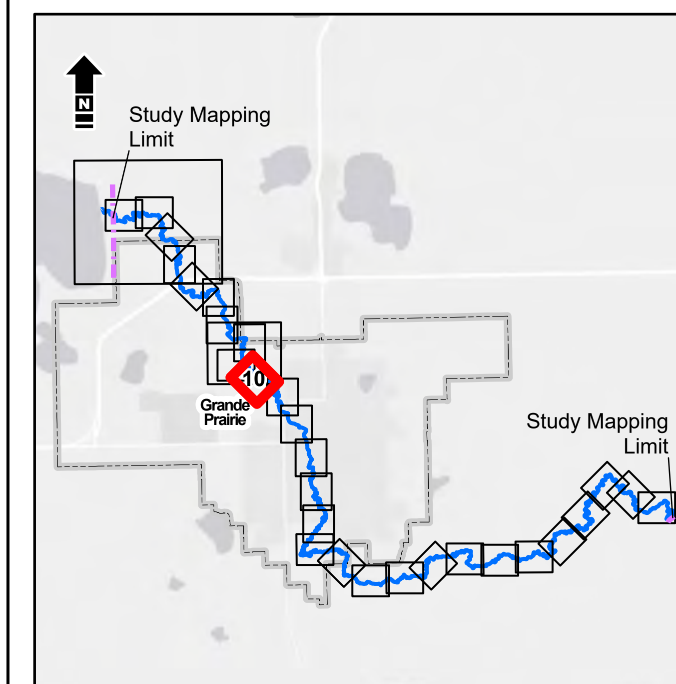

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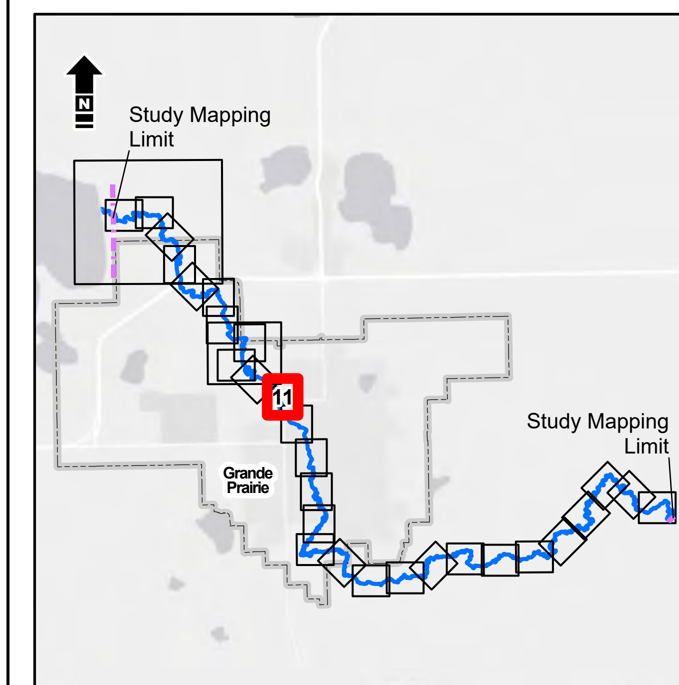

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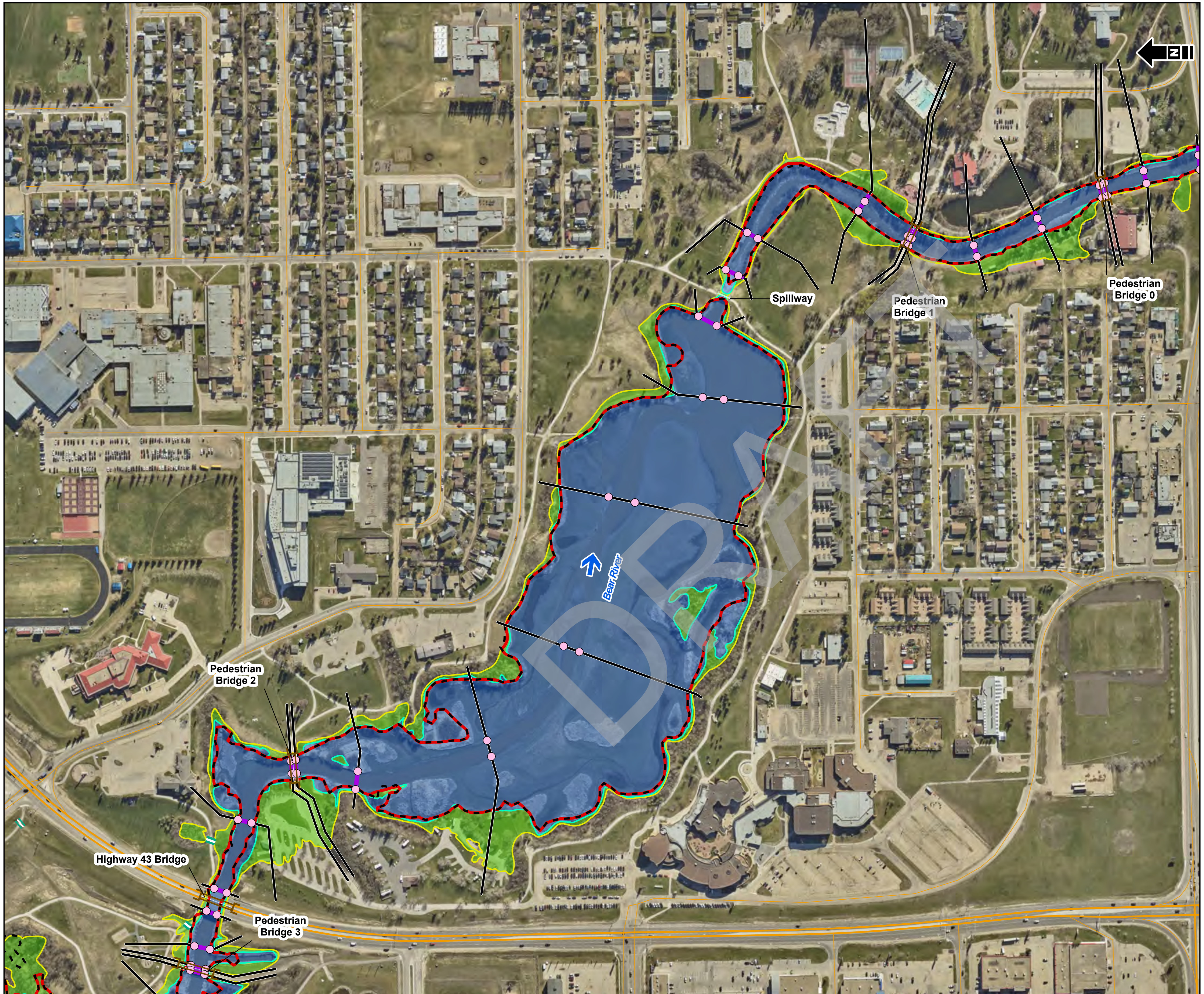

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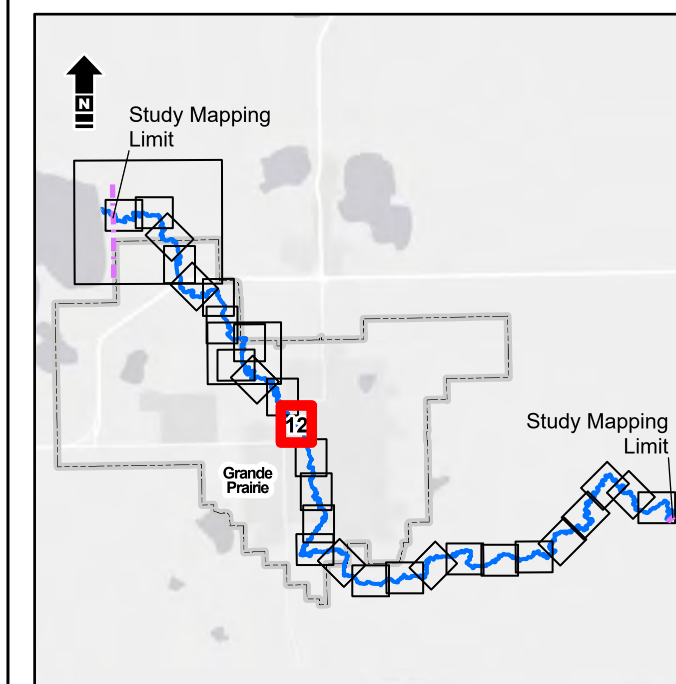

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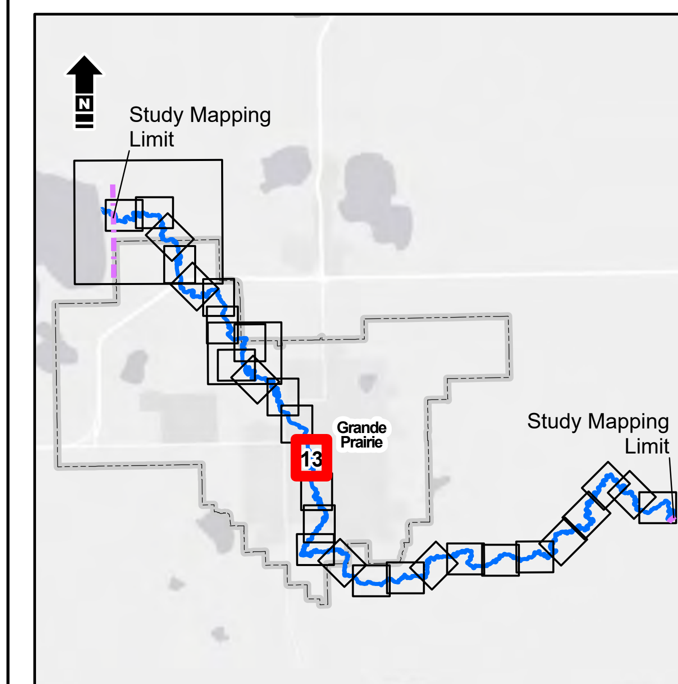

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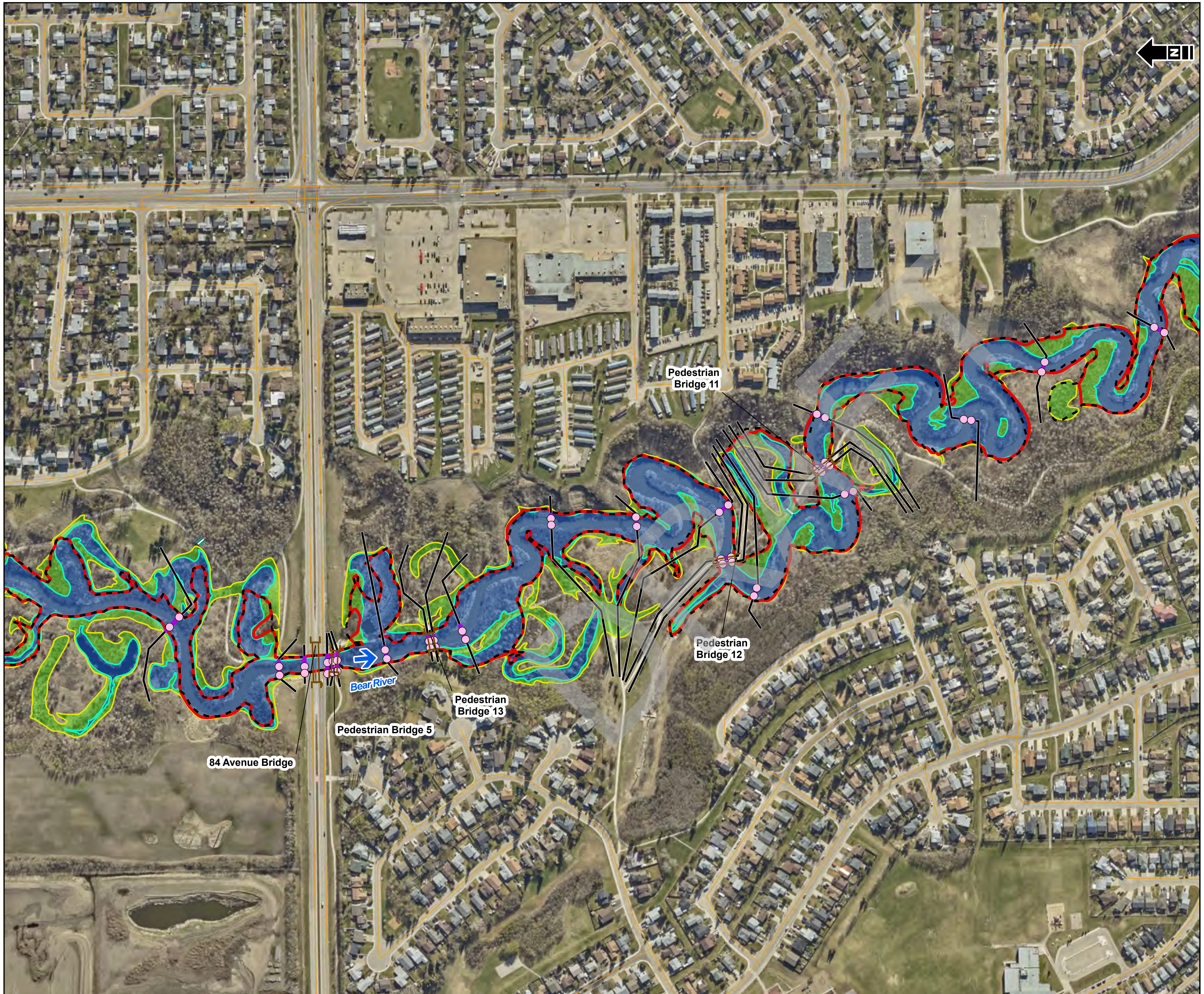

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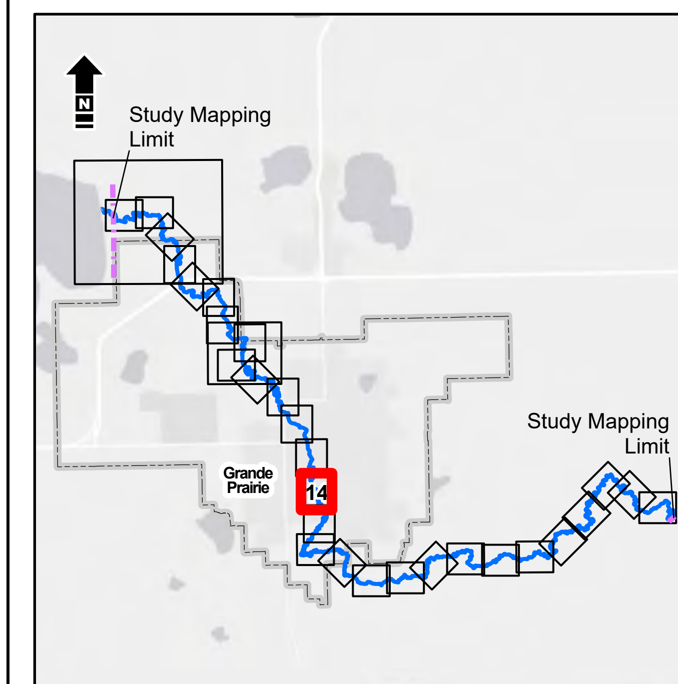

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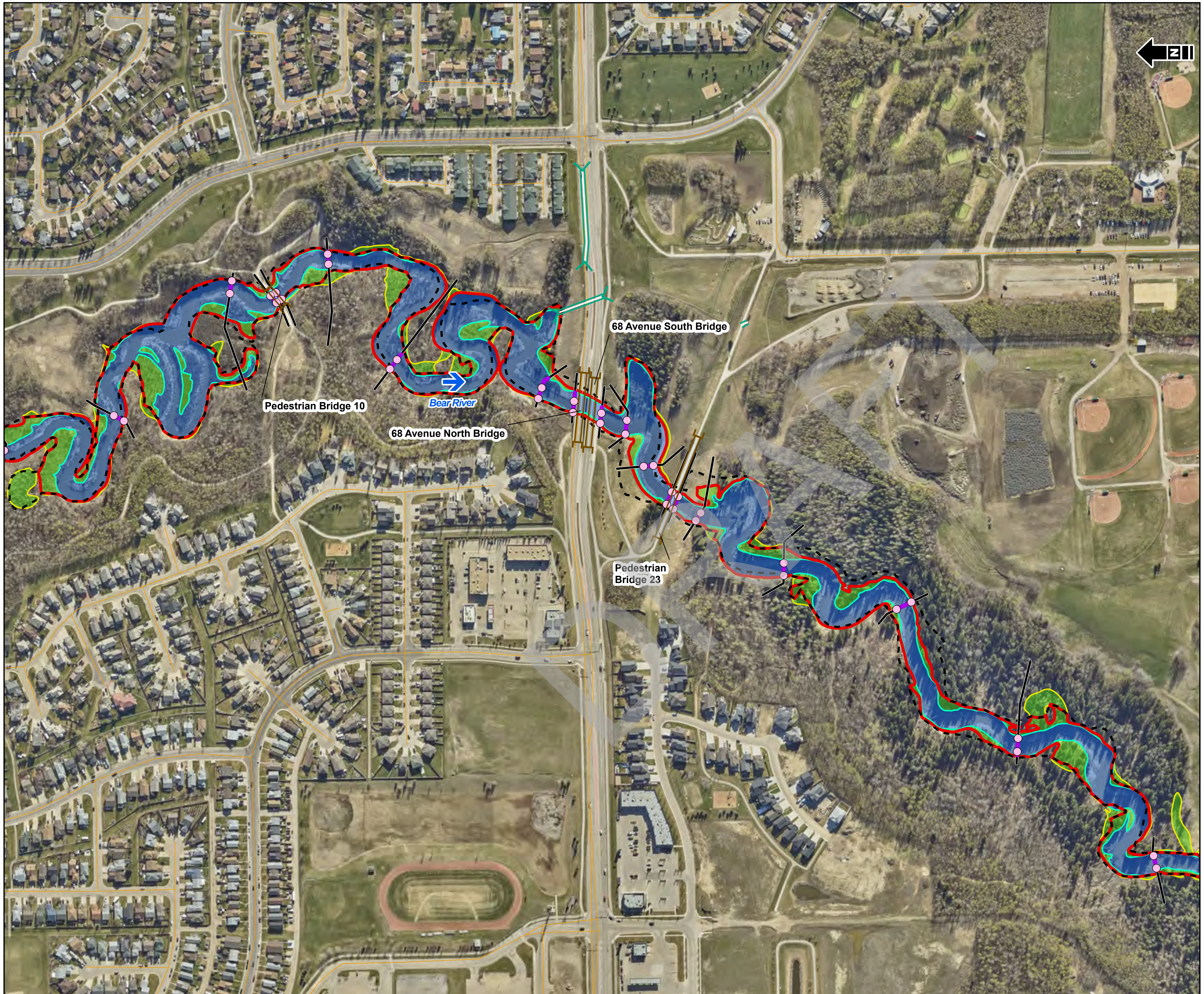
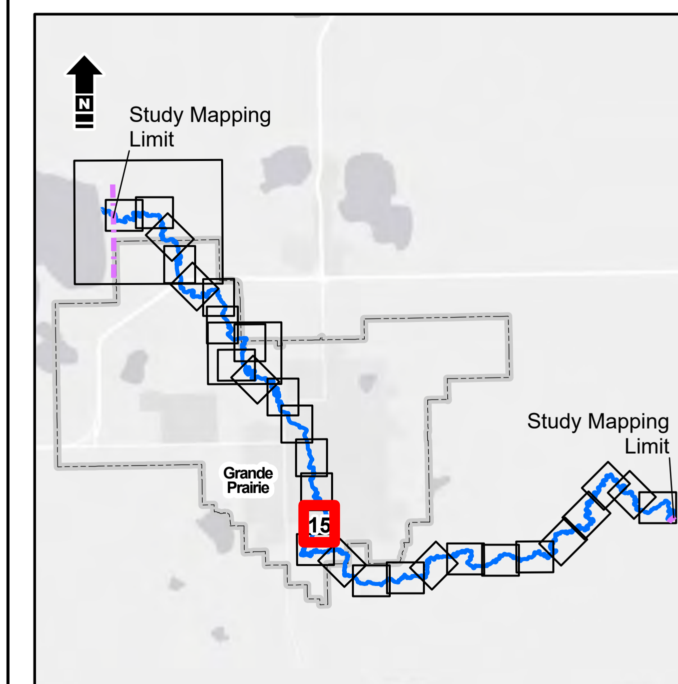


RS: 24873 River Station
Bridge
Culvert
Spillway
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Municipal Boundary (Urban)
Flow Direction
Bank Station
100 Year Inundation - ≥1 m/s Velocity
Previous Floodway
Floodway Boundary
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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1:5,000 metres
50 0 50 100
NAD 1983 CSRS 3TM 120

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Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
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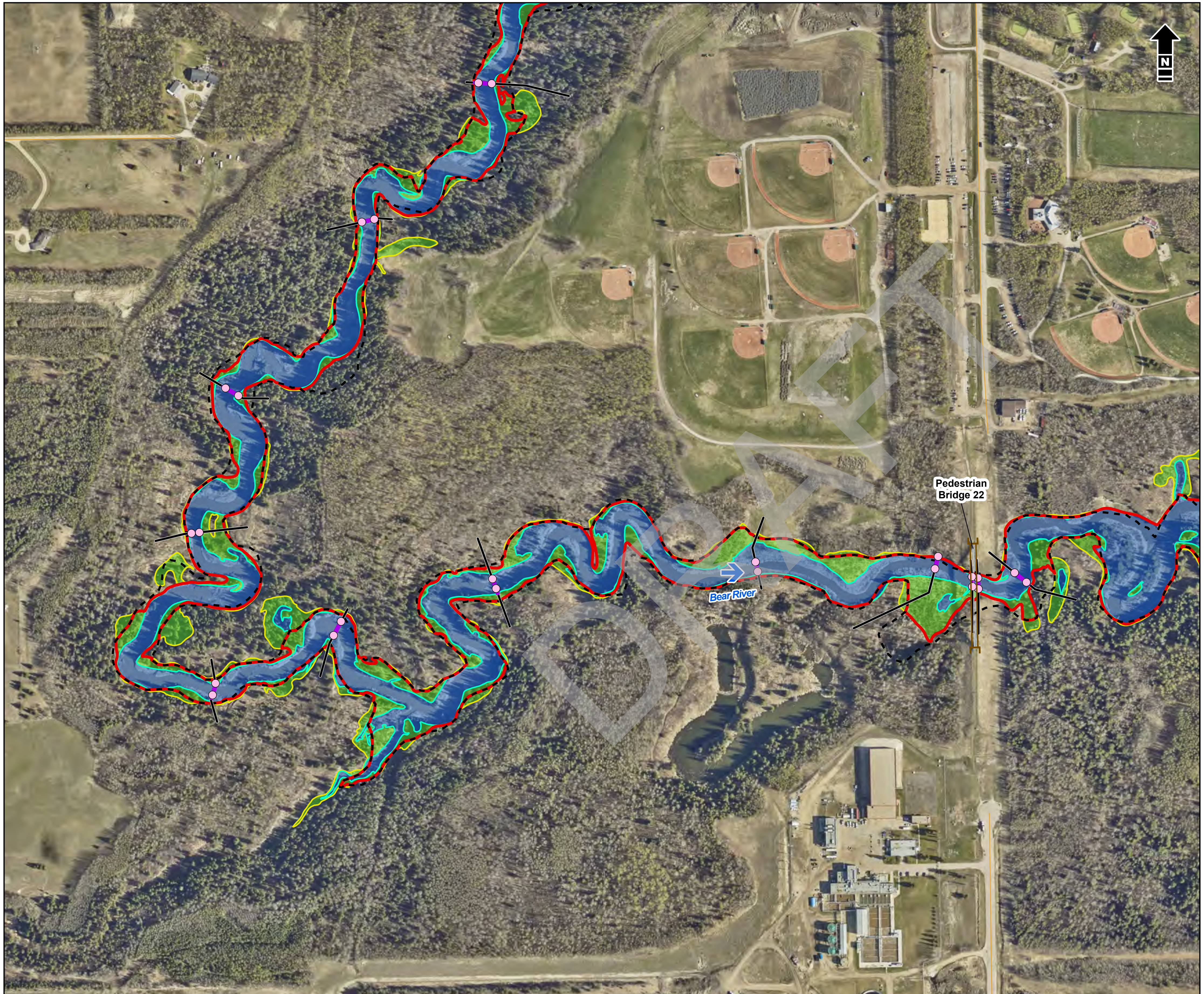

RS: 24873 River Station
Bridge
Culvert
Spillway
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Study Mapping Limit
Major Road
Local Road
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Bank Station
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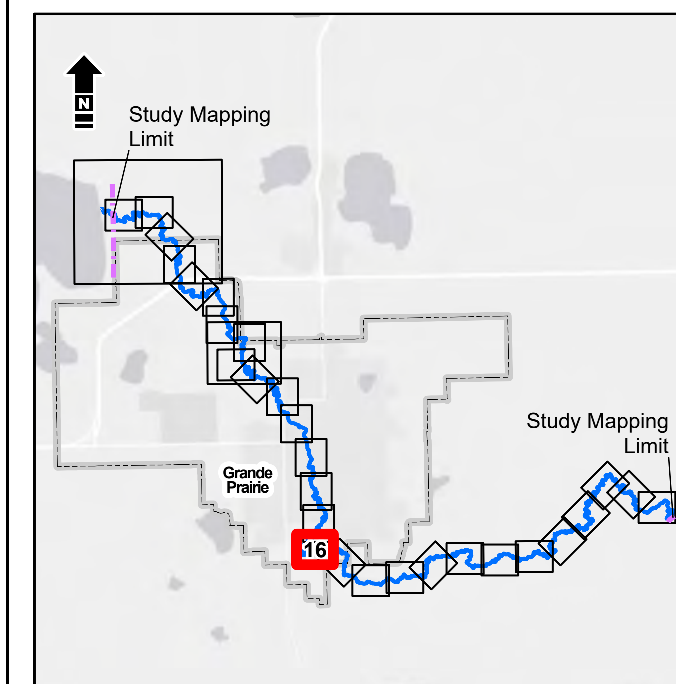
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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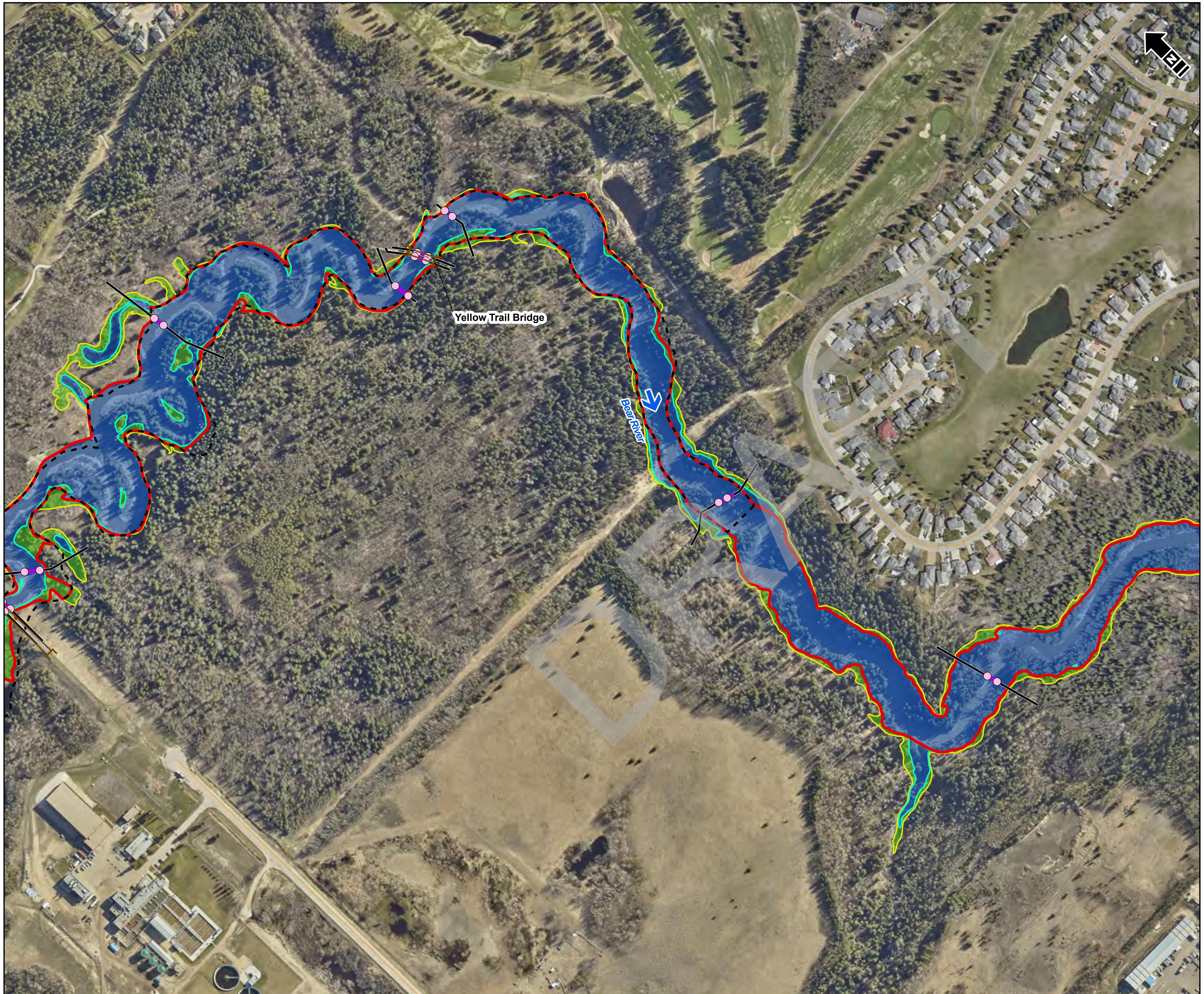

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Bank Station
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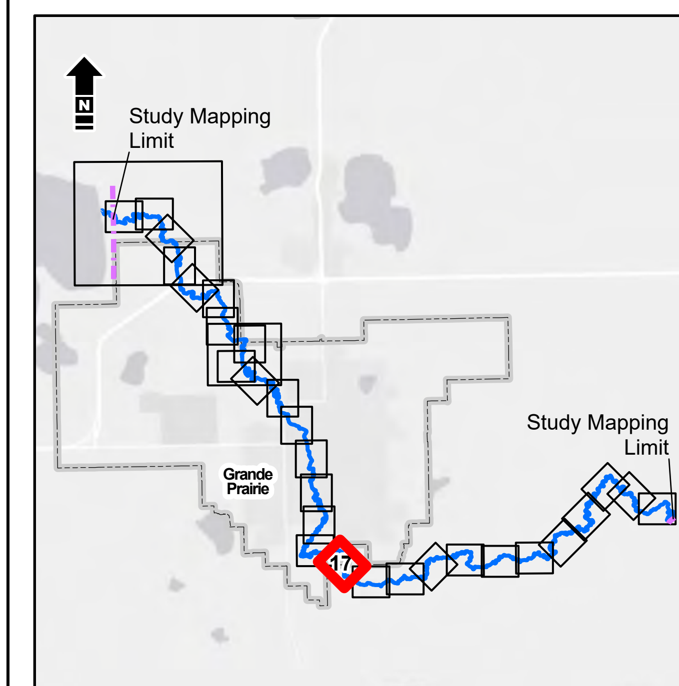
Floodway Boundary
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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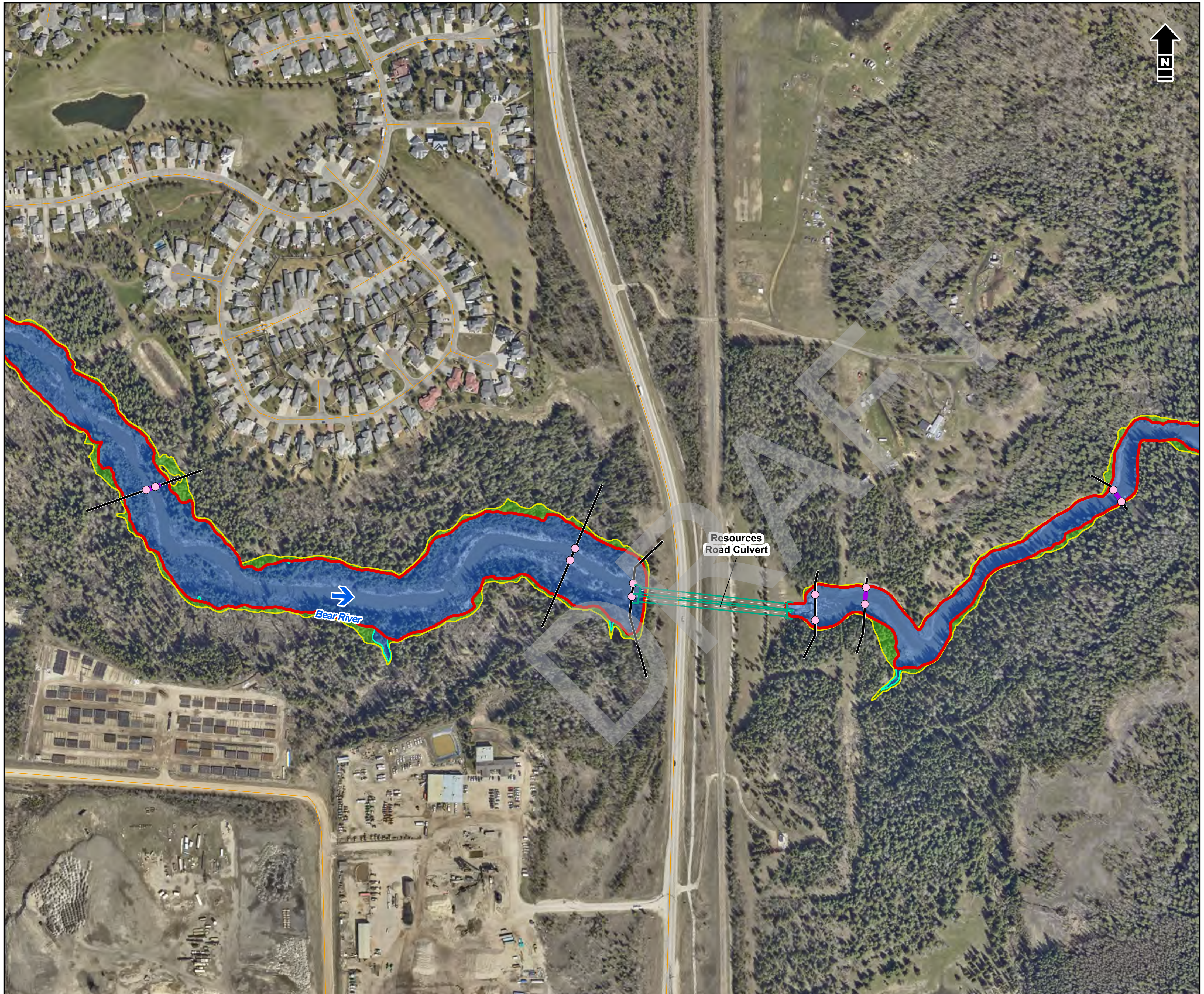

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Spillway
Cross Section Line
Study Mapping Limit
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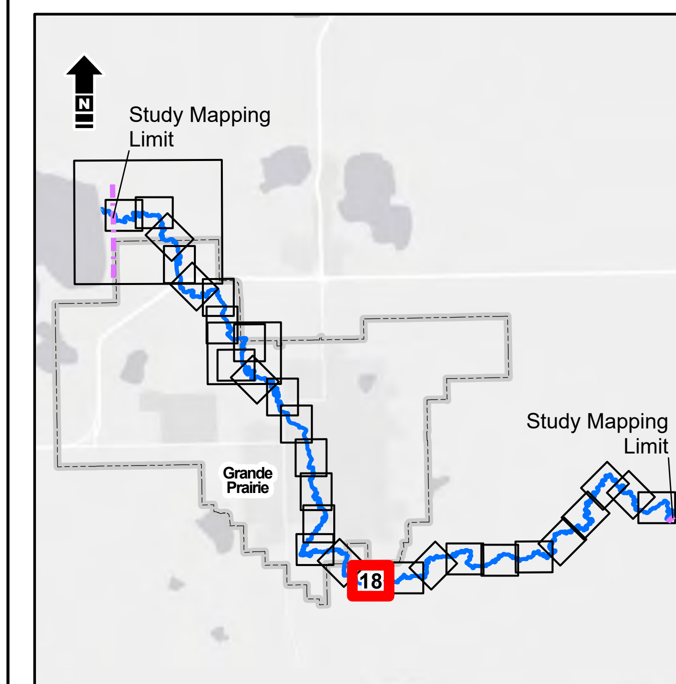
Local Road
Municipal Boundary (Urban)
Flow Direction
Bank Station
100 Year Inundation - ≥1 m/s Velocity
Previous Floodway
Floodway Boundary
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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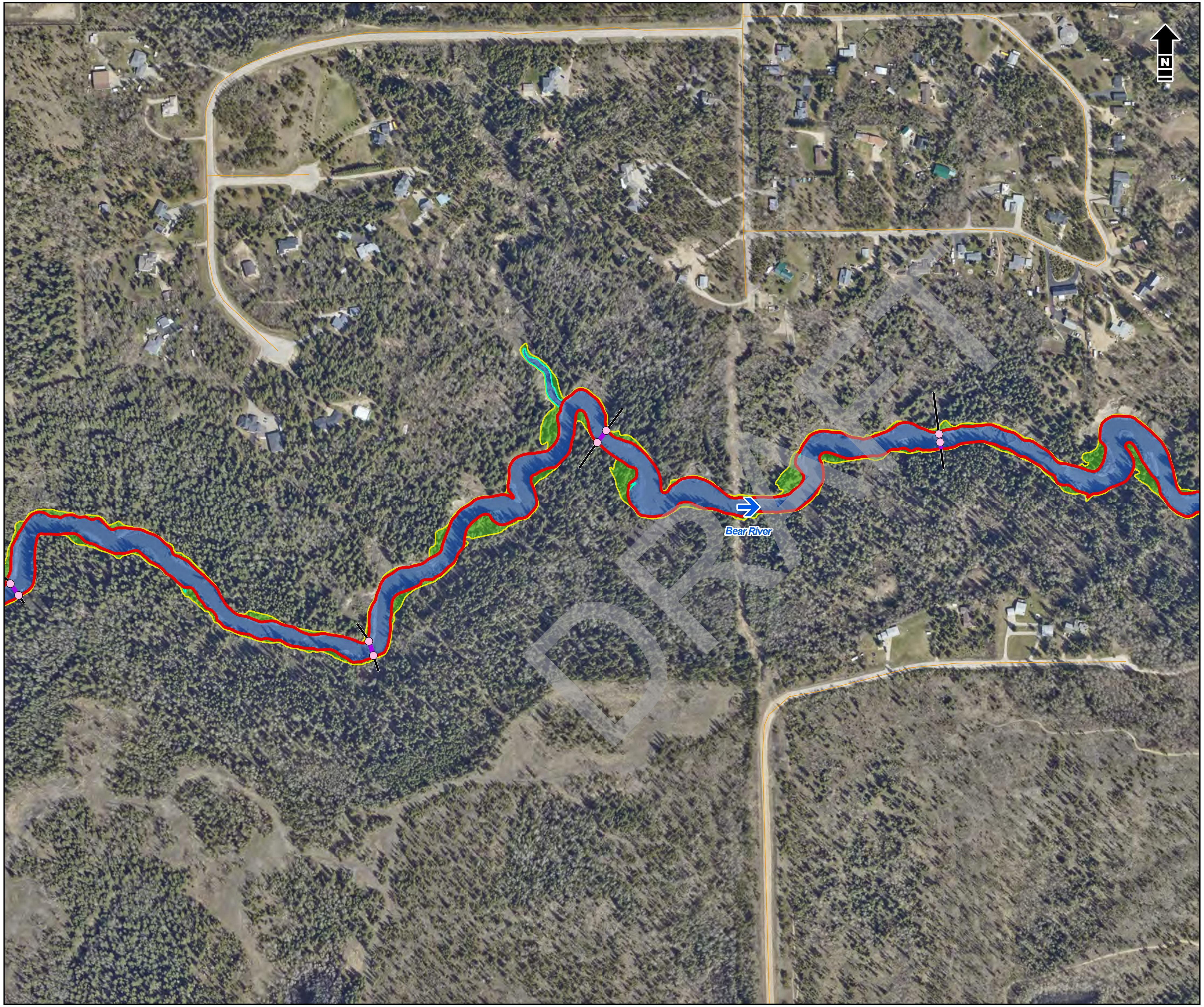
Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Map

Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome



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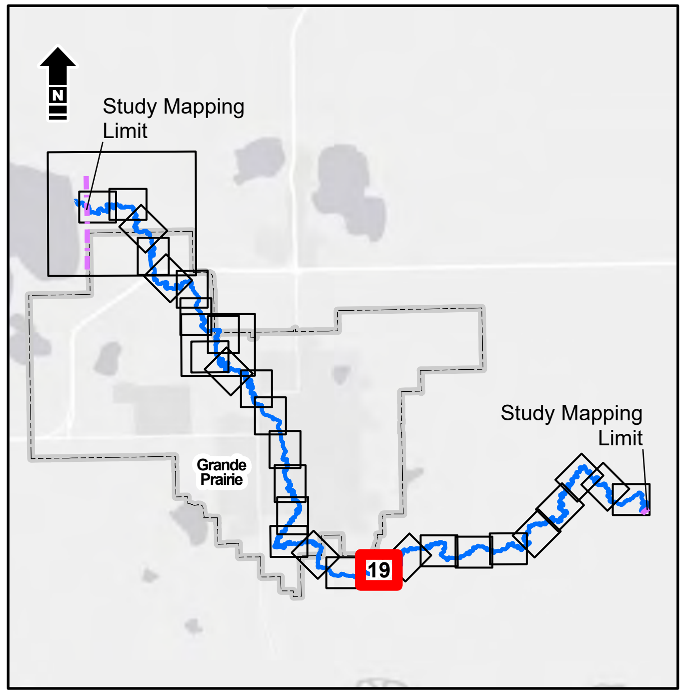
Floodway Boundary
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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Alberta Environment and Protected Areas
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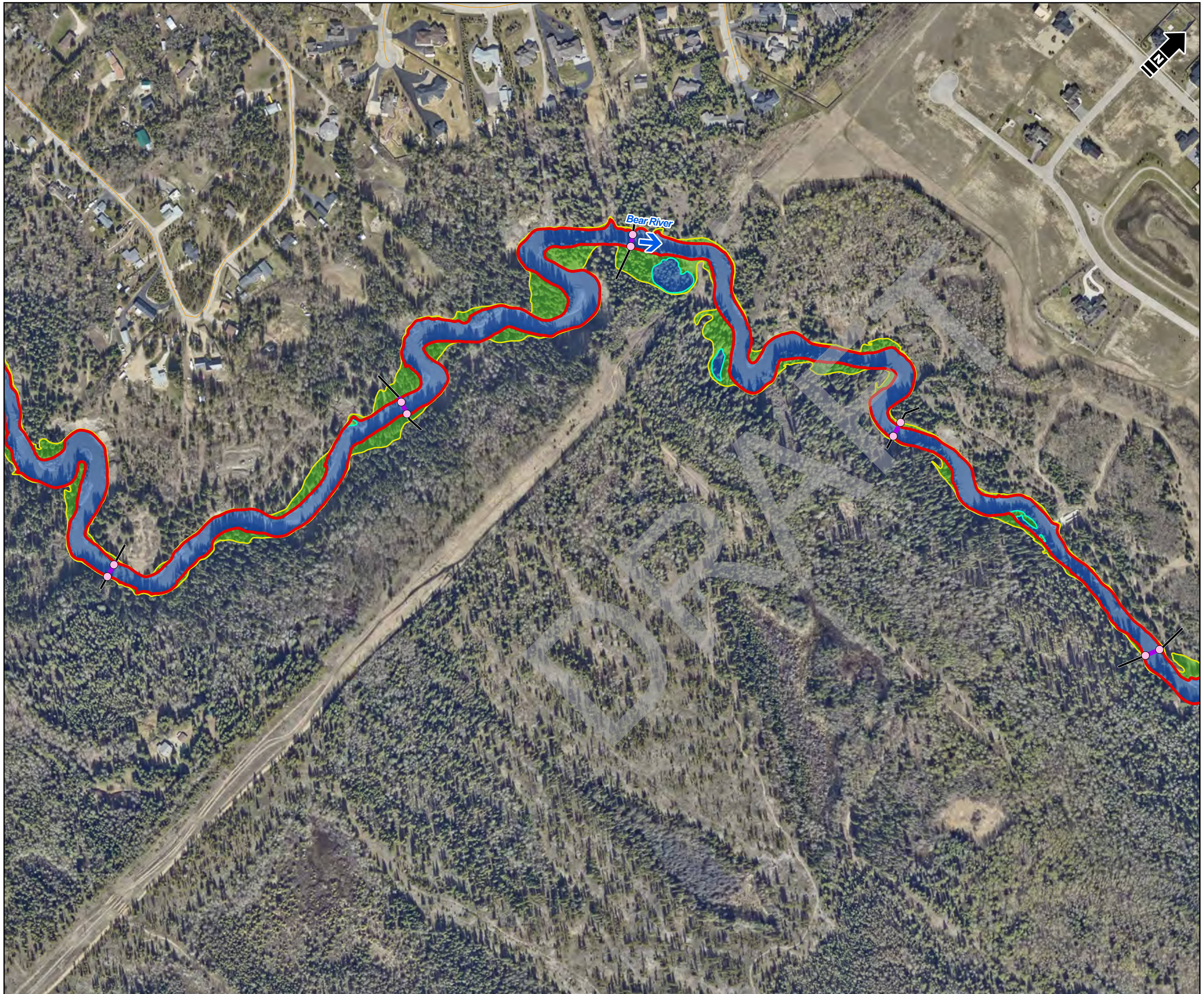

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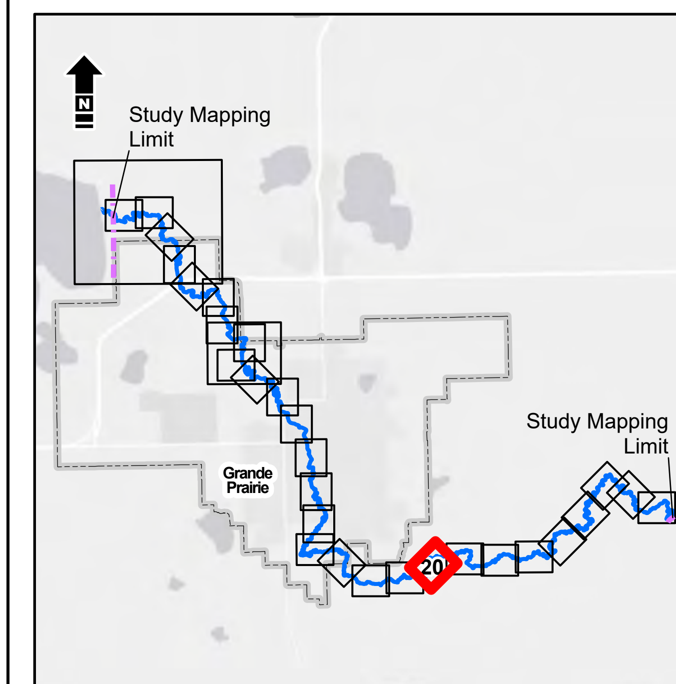
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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Grande Prairie Flood Study

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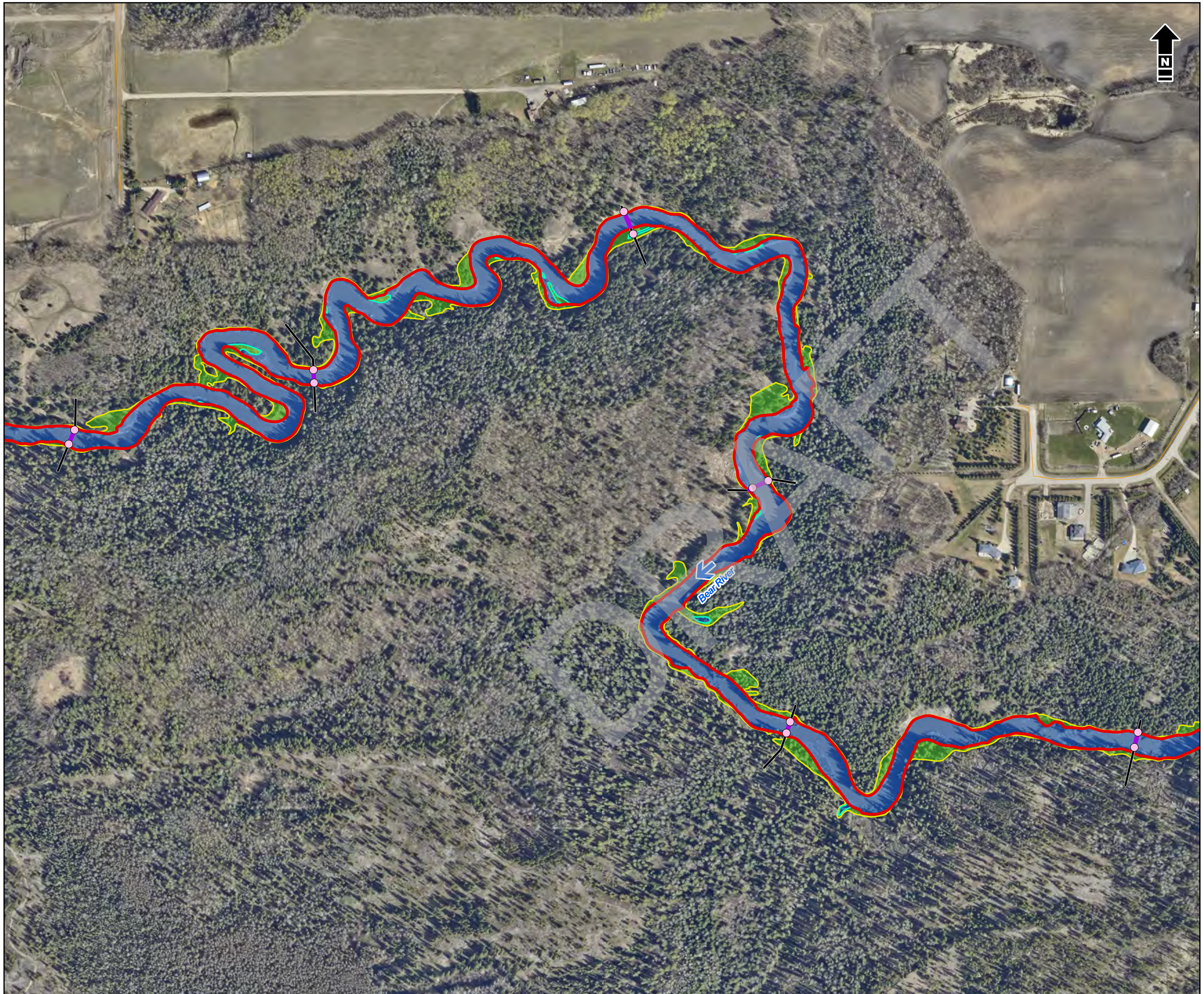

RS: 24873 River Station
Bridge
Culvert
Spillway
Cross Section Line
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Local Road
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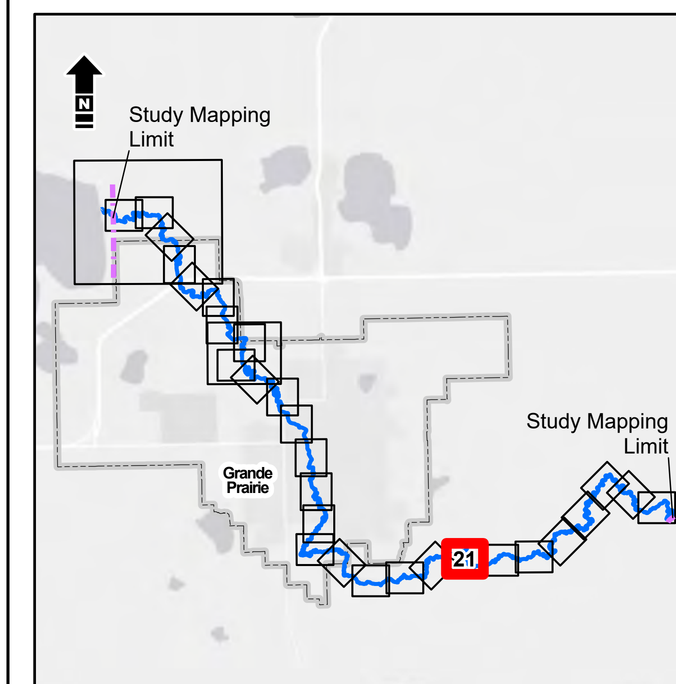
Flow Direction
Bank Station
100 Year Inundation - ≥1 m/s Velocity
Previous Floodway
Floodway Boundary
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Map

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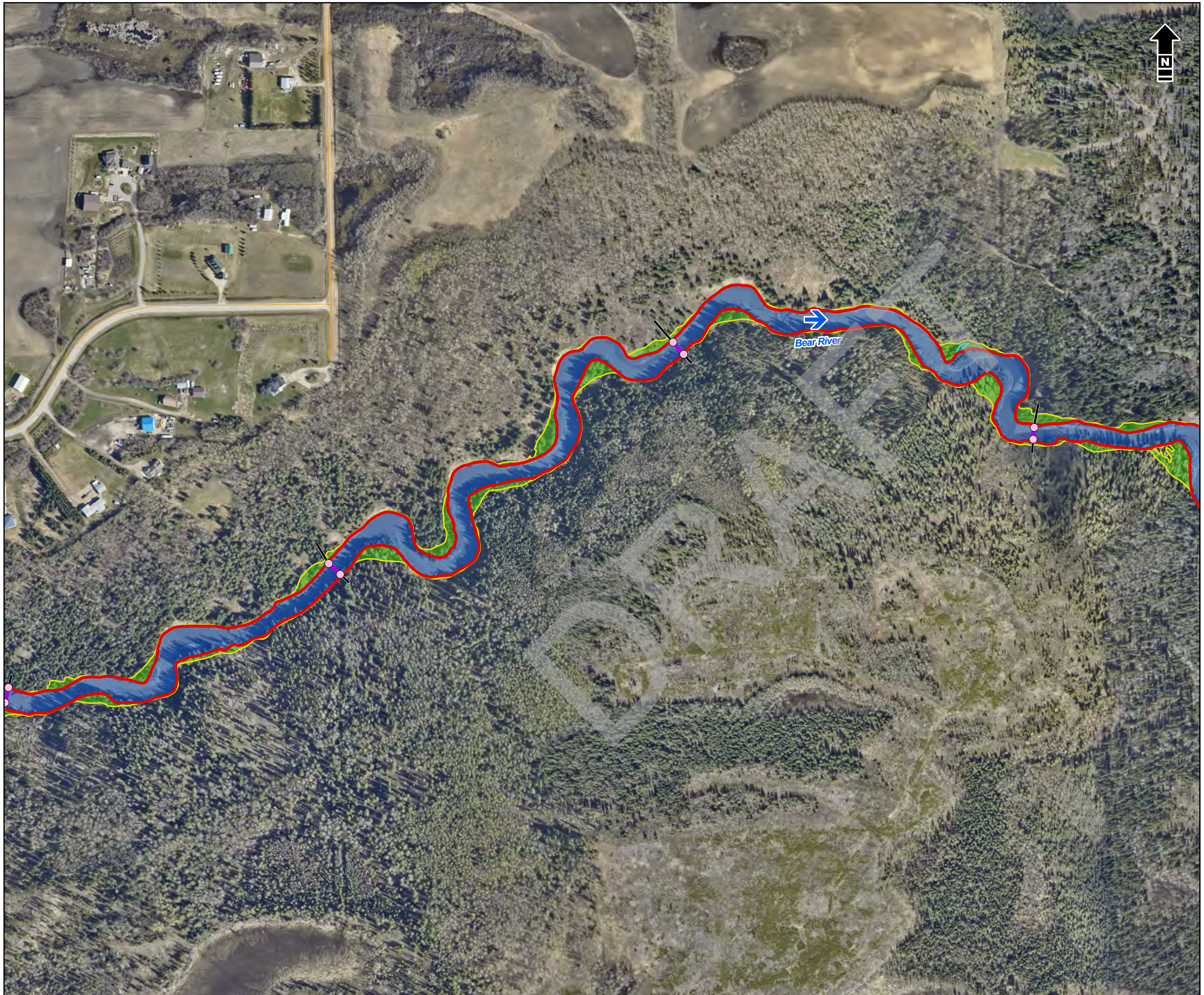

RS: 24873 River Station
Bridge
Culvert
Spillway
Cross Section Line
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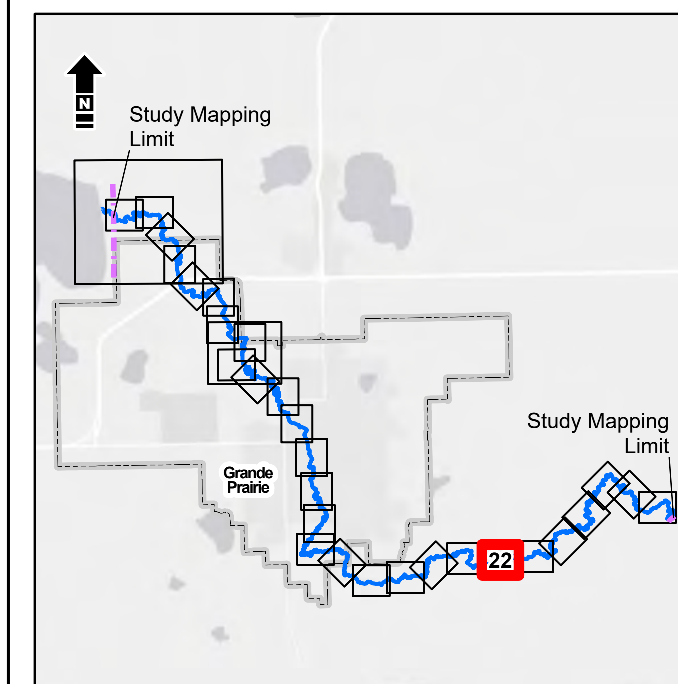
Municipal Boundary (Urban)
Flow Direction
Bank Station
100 Year Inundation - ≥1 m/s Velocity
Previous Floodway
Floodway Boundary
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Map

Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome

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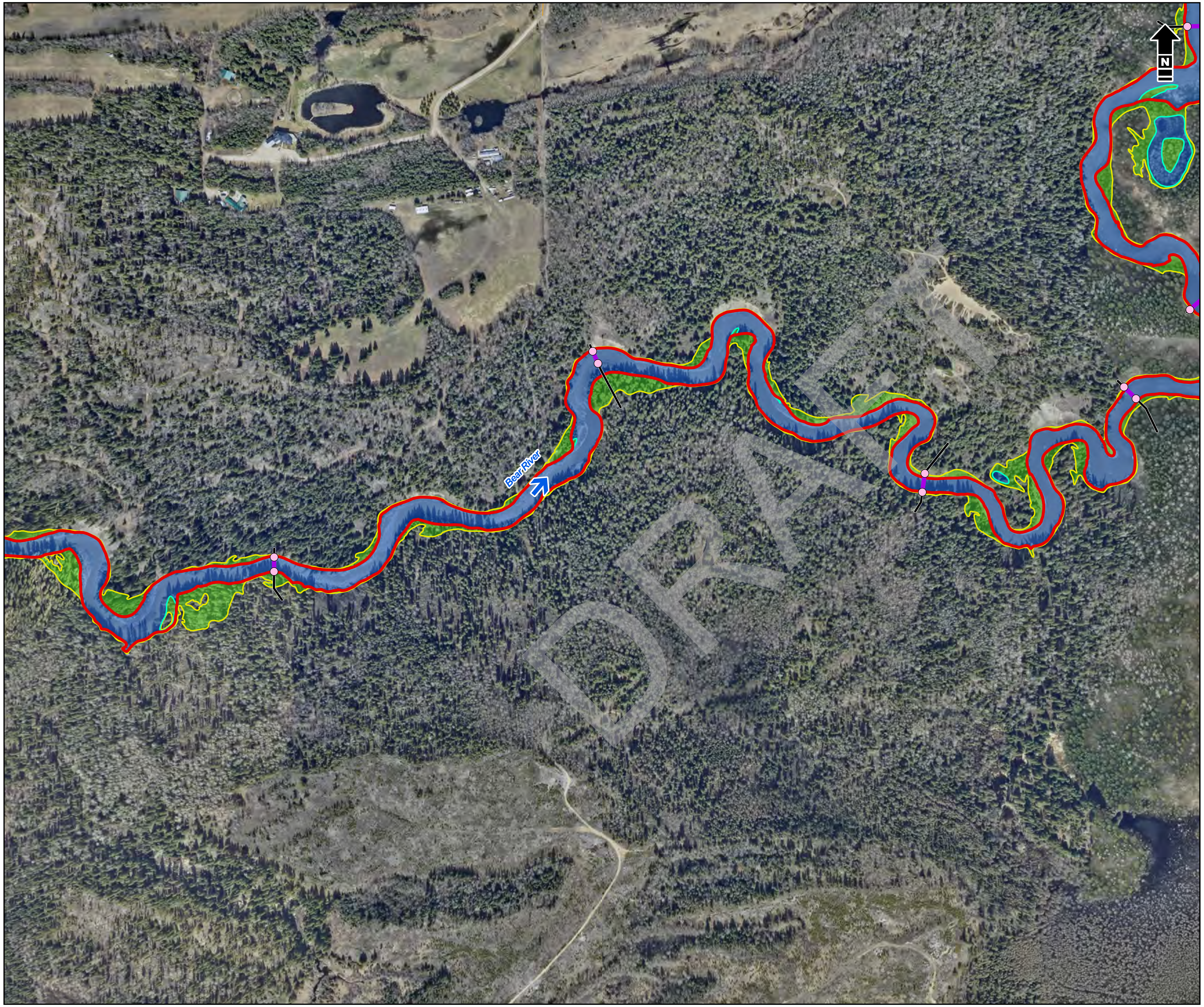
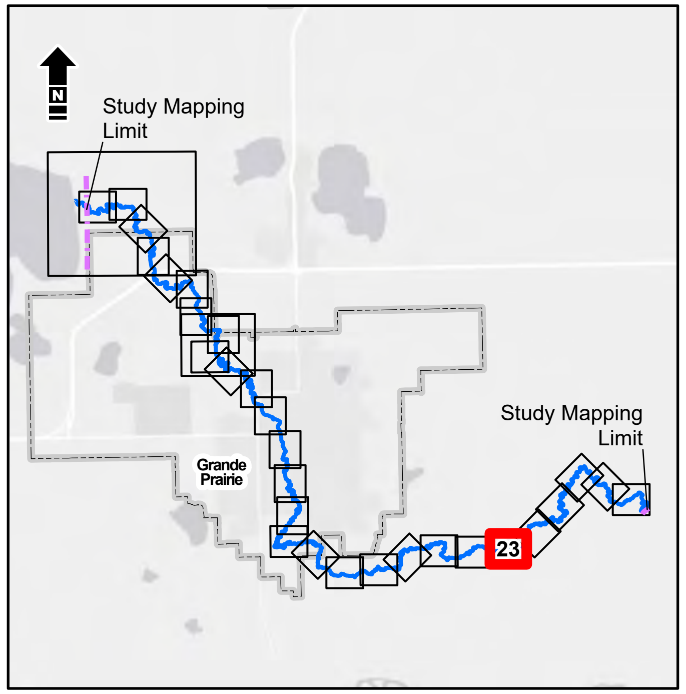


- *RS: 24873* River Station
- Bridge
- Culvert
- Spillway
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Municipal Boundary (Urban)
- Flow Direction
- Bank Station
- 100 Year Inundation - ≥1 m/s Velocity
- Previous Floodway
- Floodway Boundary
- 100 Year Inundation Extent
- 100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



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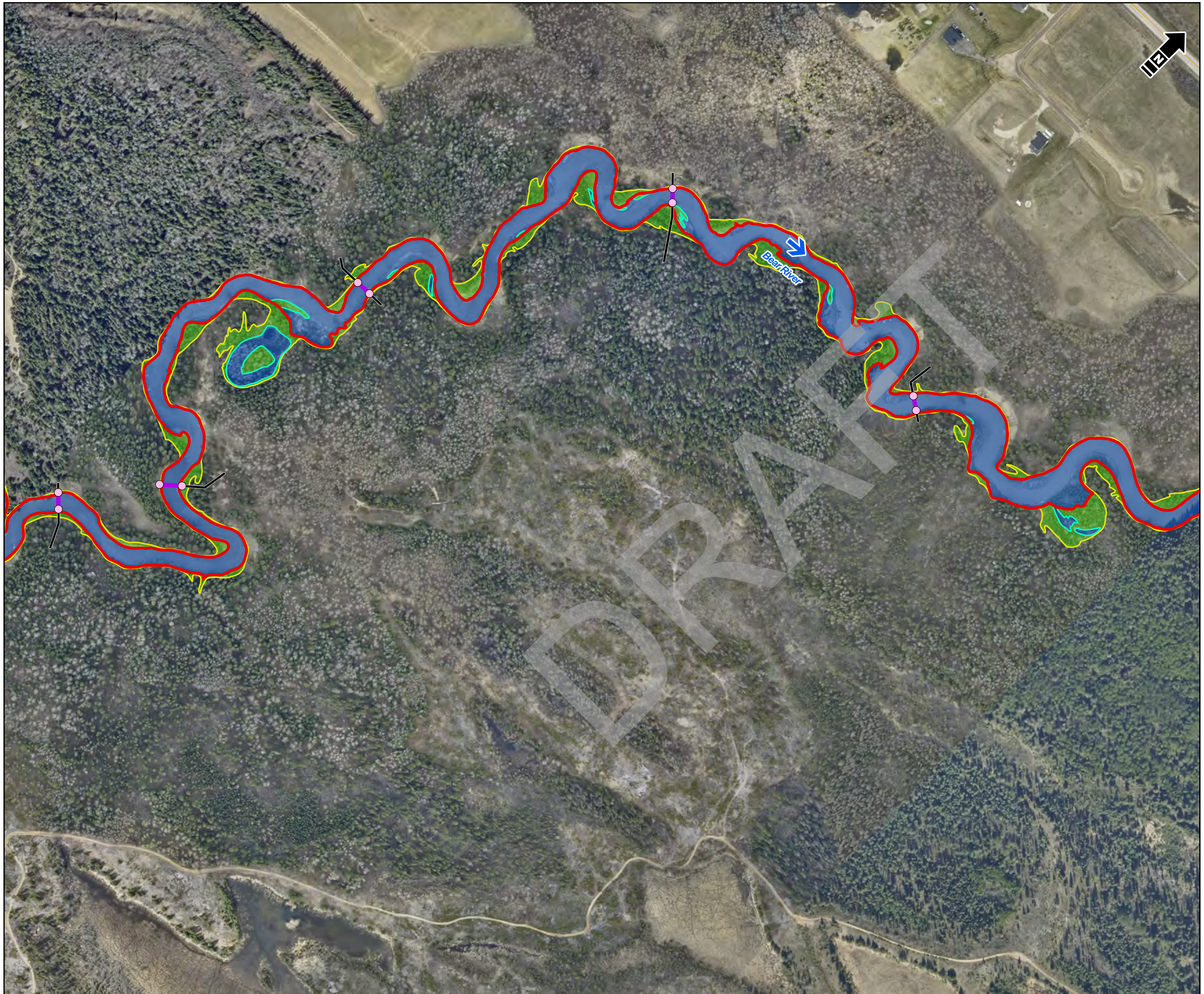
Alberta Montrose Environmental Canada

Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
June 2025	35917	P. Rogers	M. Shome



RS: 24873 River Station
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Cross Section Line
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Municipal Boundary (Urban)
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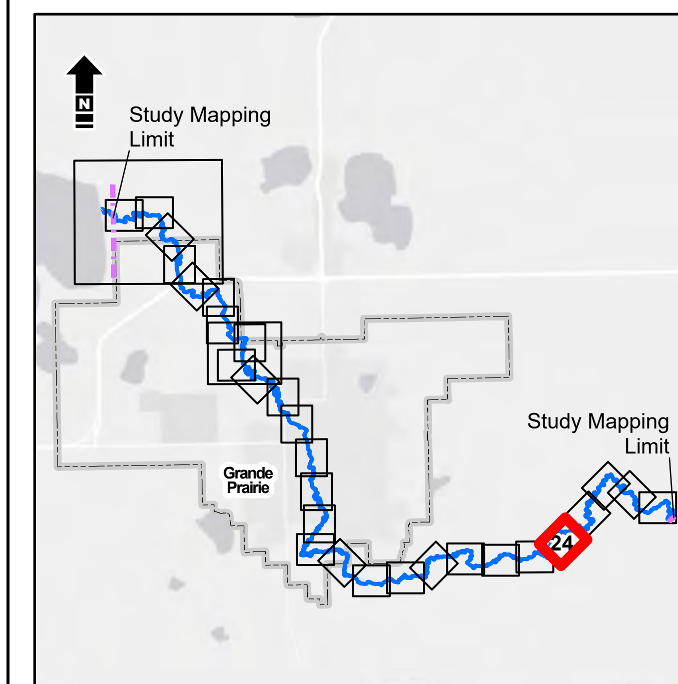
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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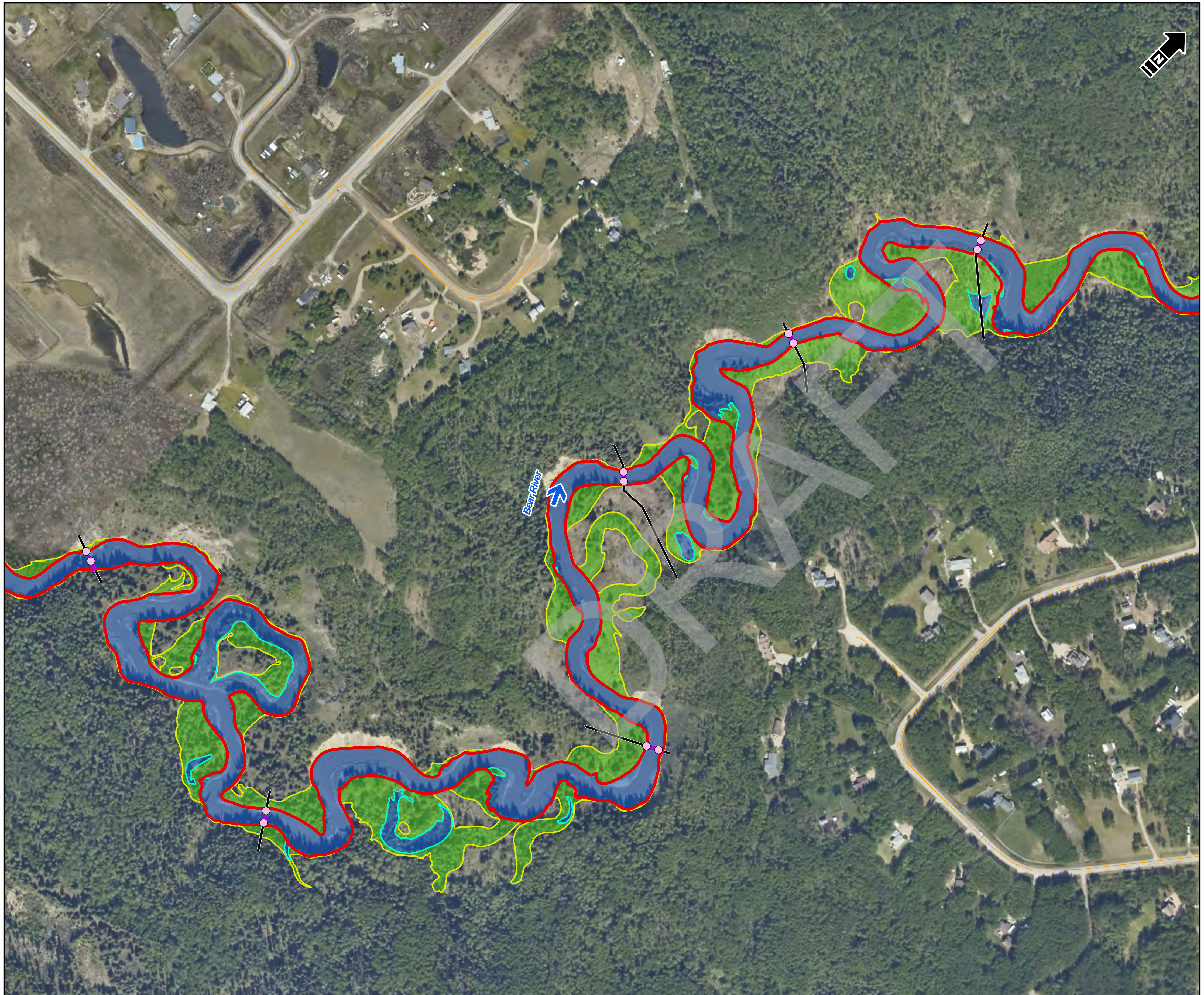
Alberta Environment and Protected Areas
Grande Prairie Flood Study

Floodway Criteria Map

Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome



RS: 24873 River Station
Bridge
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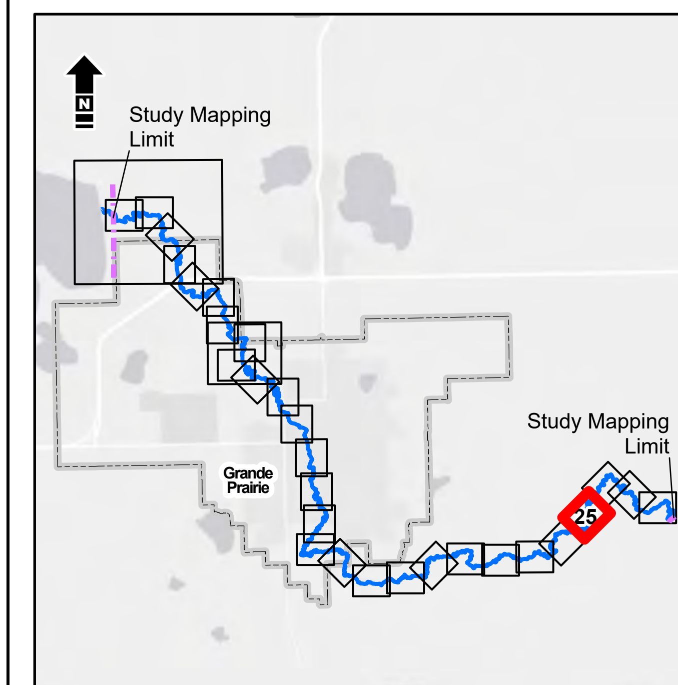
100 Year Inundation Extent - ≥1 m Depth



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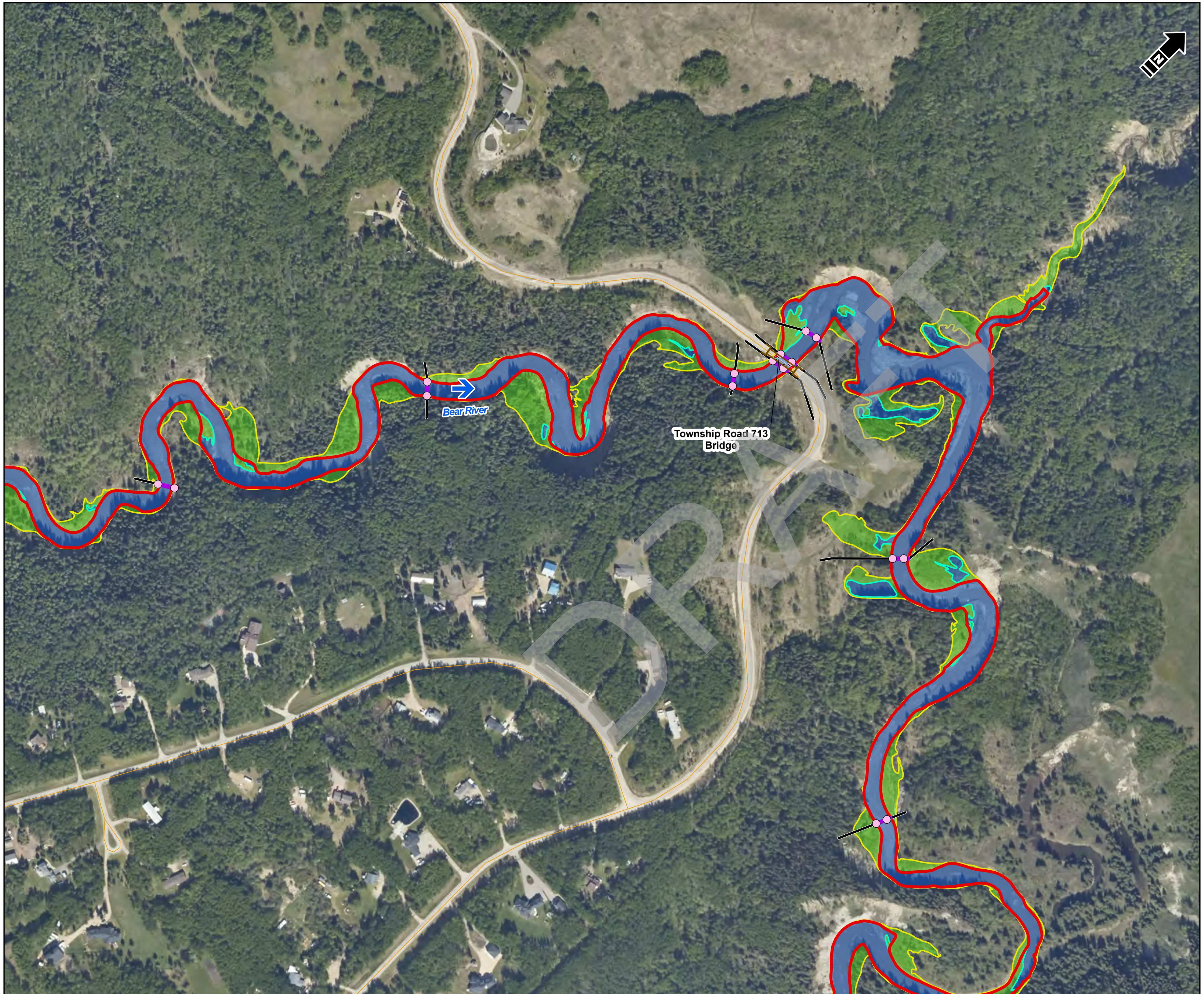

RS: 24873 River Station
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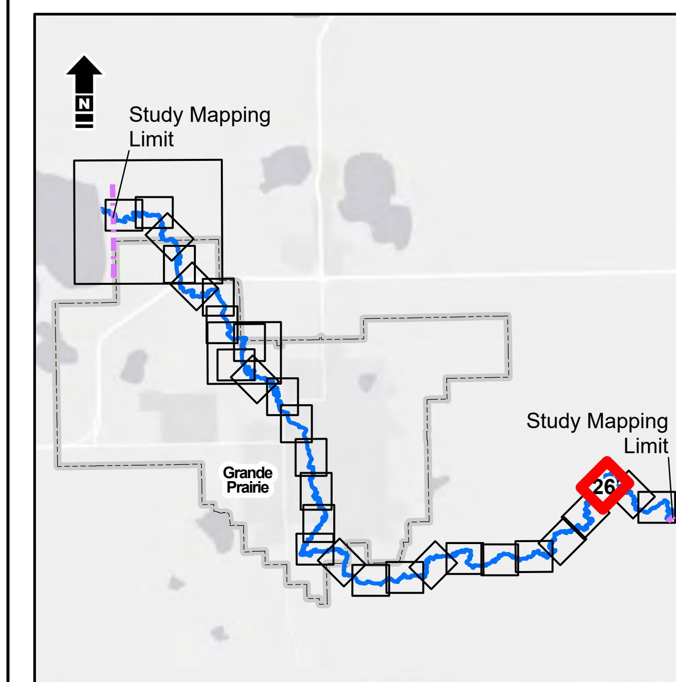
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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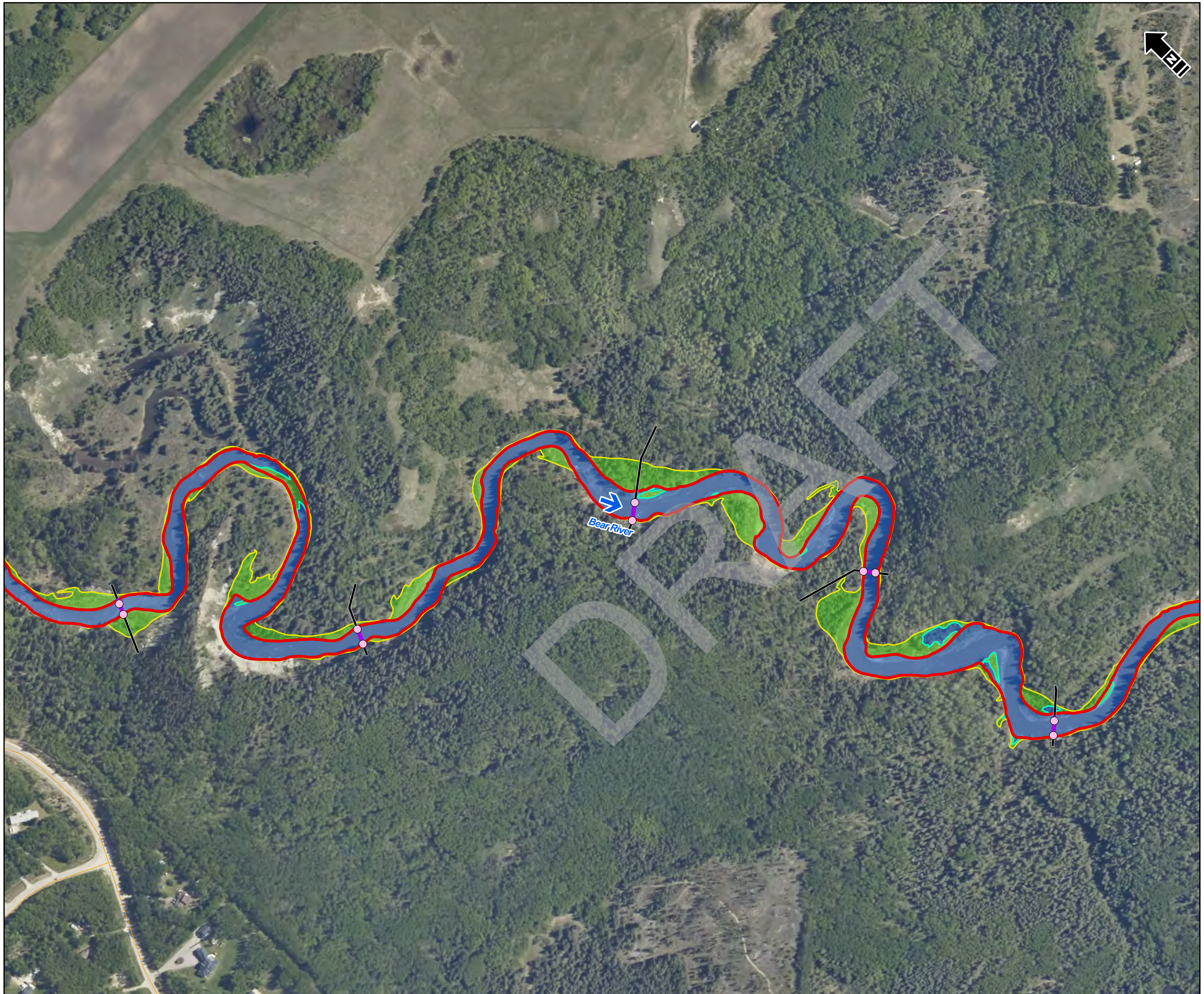

RS: 24873 River Station
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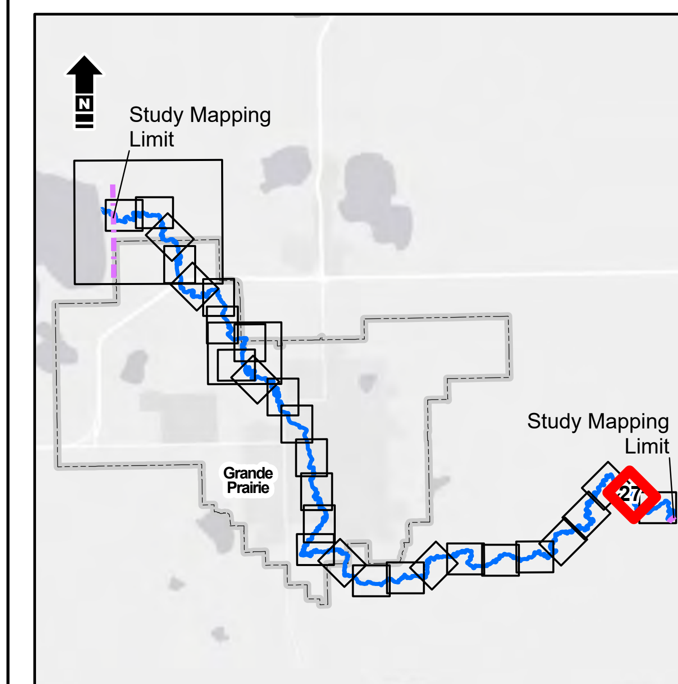
100 Year Inundation Extent
100 Year Inundation Extent - ≥1 m Depth



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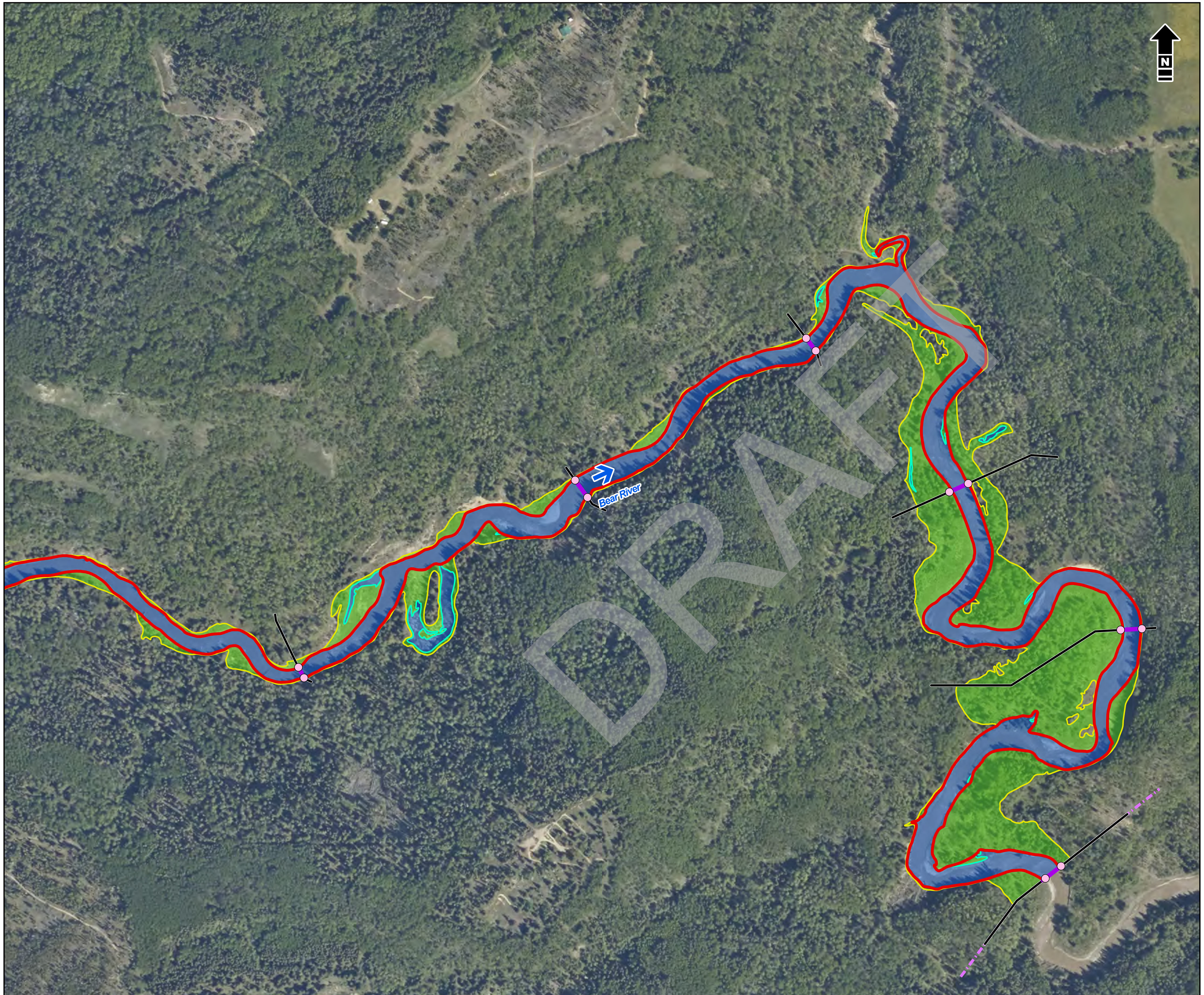

RS: 24873 River Station
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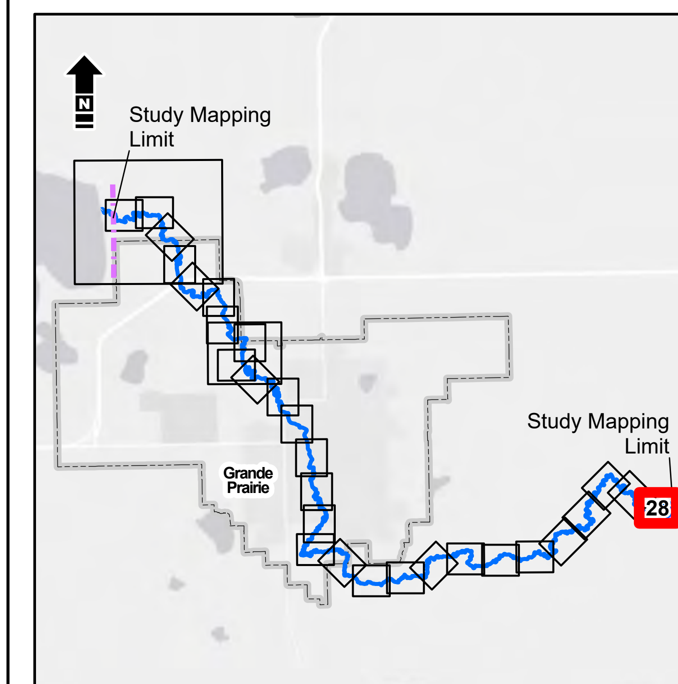

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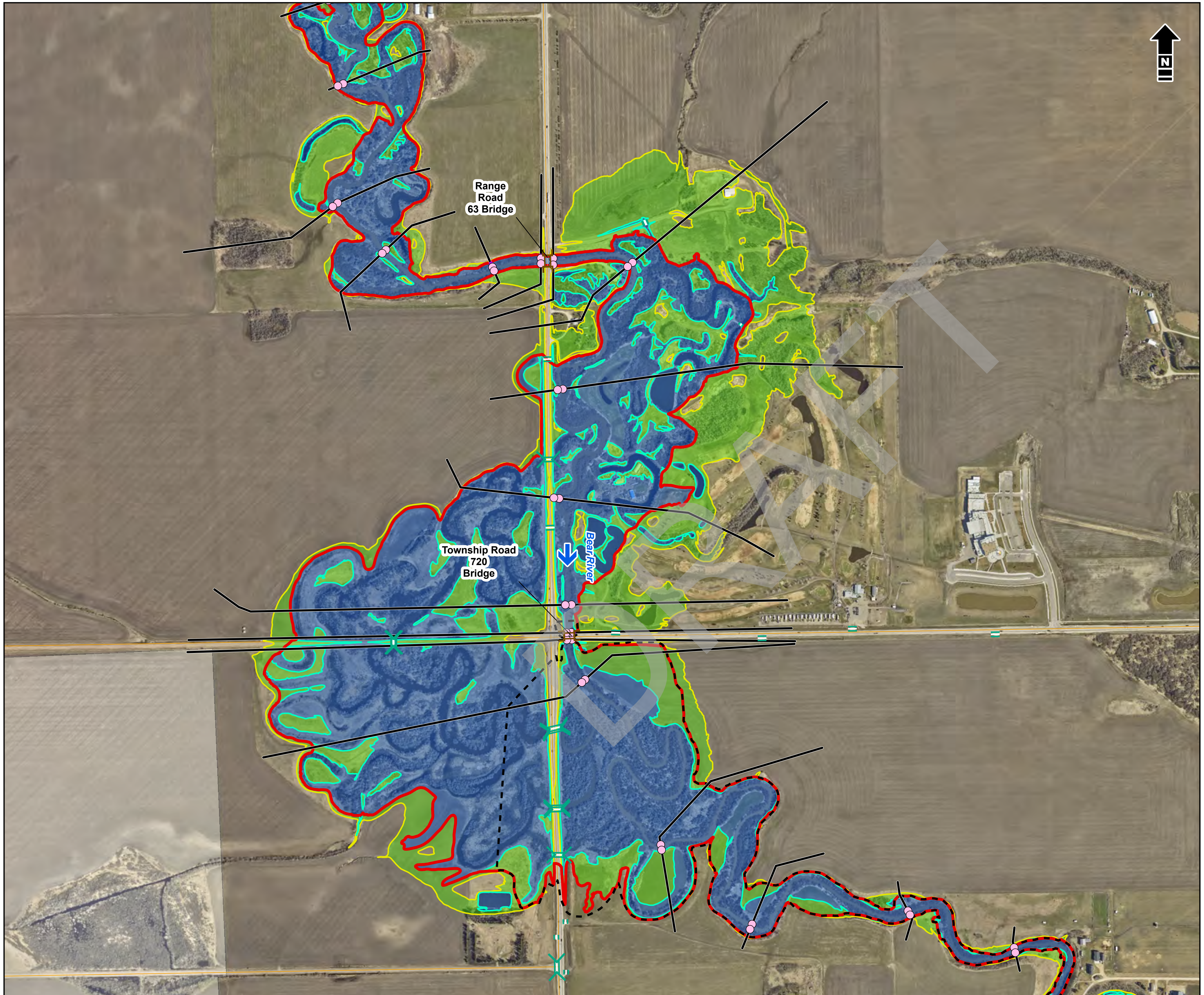

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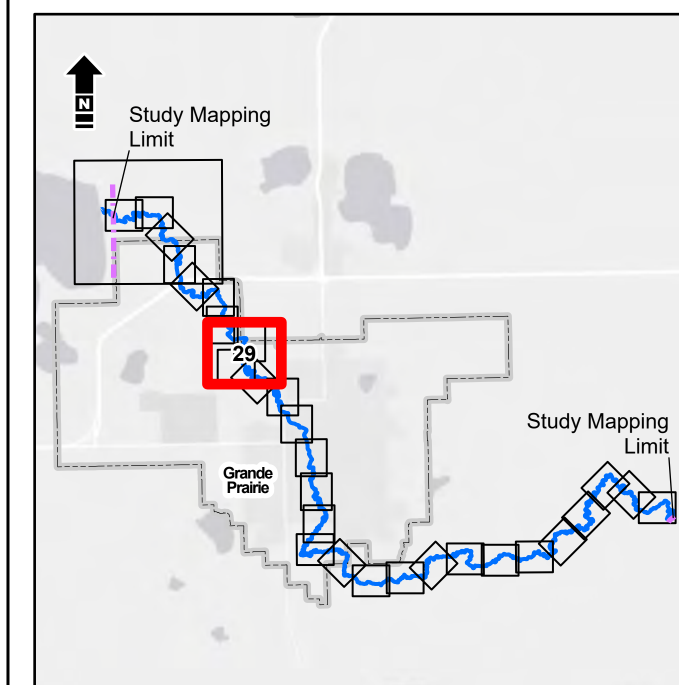

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Alberta Environment and Protected Areas

Grande Prairie Flood Study

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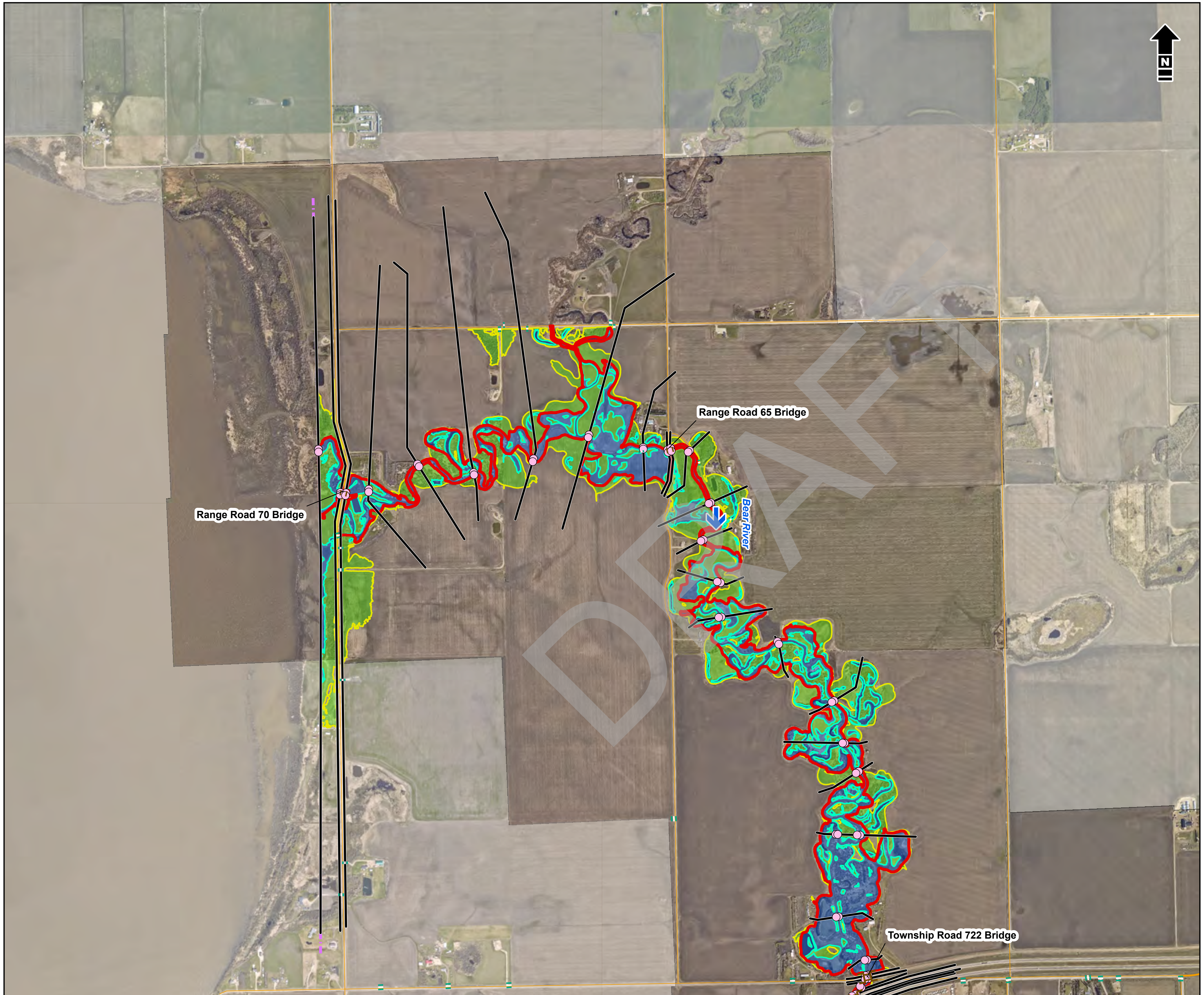

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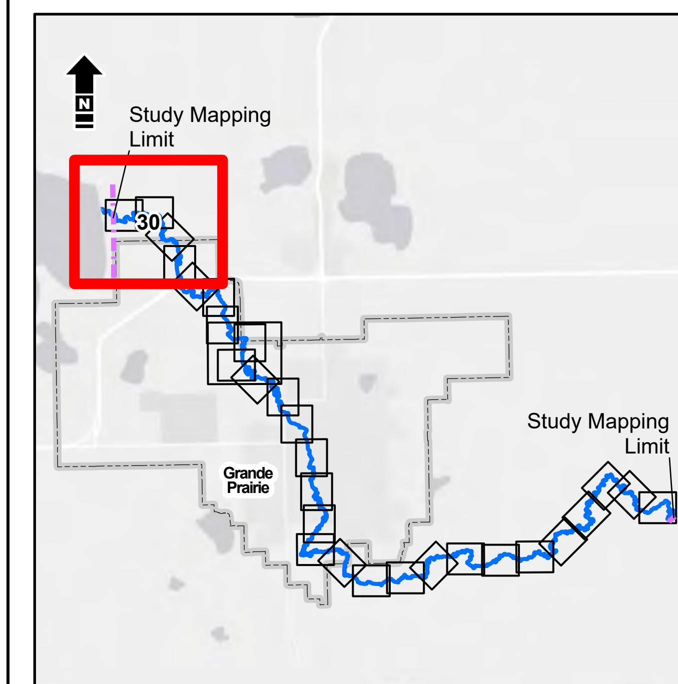

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1:20,000 metres
190 0 190 380
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Alberta Environment and Protected Areas
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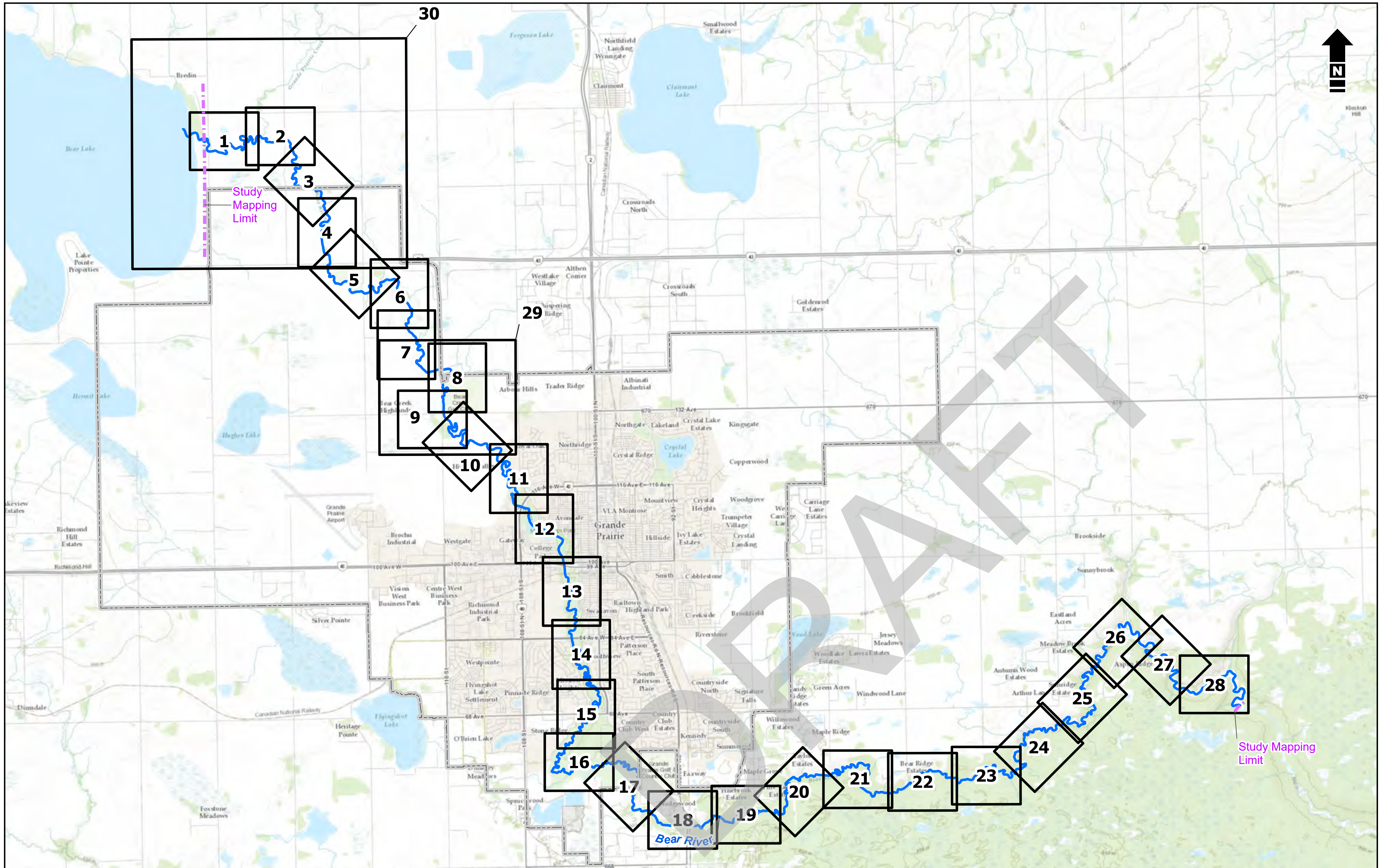
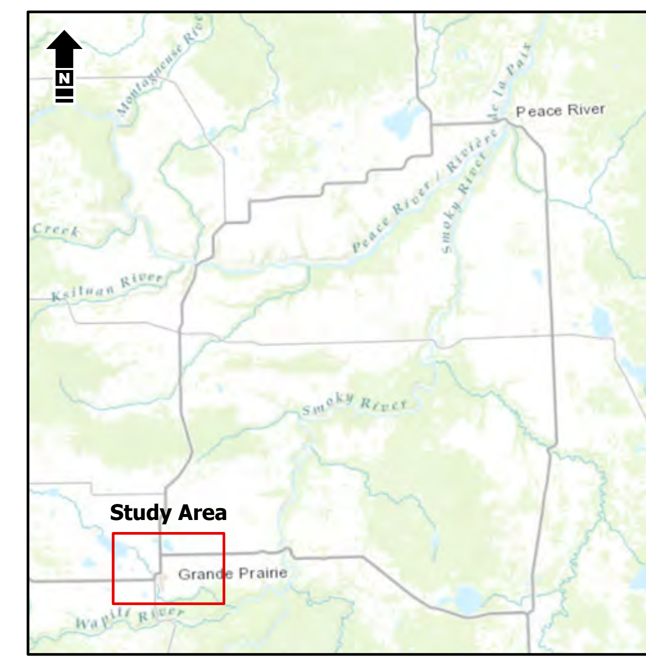
APPENDIX E
Flood Hazard Maps



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



1:100,000 kilometres
2.5 0 2.5 5
NAD 1983 CSRS 3TM 120

Notes:

1. Please refer to the accompanying Grande Prairie Flood Study for important information concerning these maps.

2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.

3. Non-riverine and local sources of water have not been considered, and features such 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:

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Base Mapping available ESRI Base Mapping and Imagery Services.
World Topographic Map: City of Grande Prairie, County of Grande Prairie, Province of Alberta, Province of British Columbia, Esri Canada, Esri, HERE, Garmin, USGS, METI/NASA, NGA, EPA, USDA, AAFC, NRCan
World Topographic Map: Esri, © OpenStreetMap contributors, HERE, Garmin, FAO, USGS, EPA, NPS, AAFC, NRCan

Alberta Environment and Protected Areas
Grande Prairie Flood Study

Governing Design Flood Hazard Index Map

Date:	Project:	Submitter:	Reviewer:
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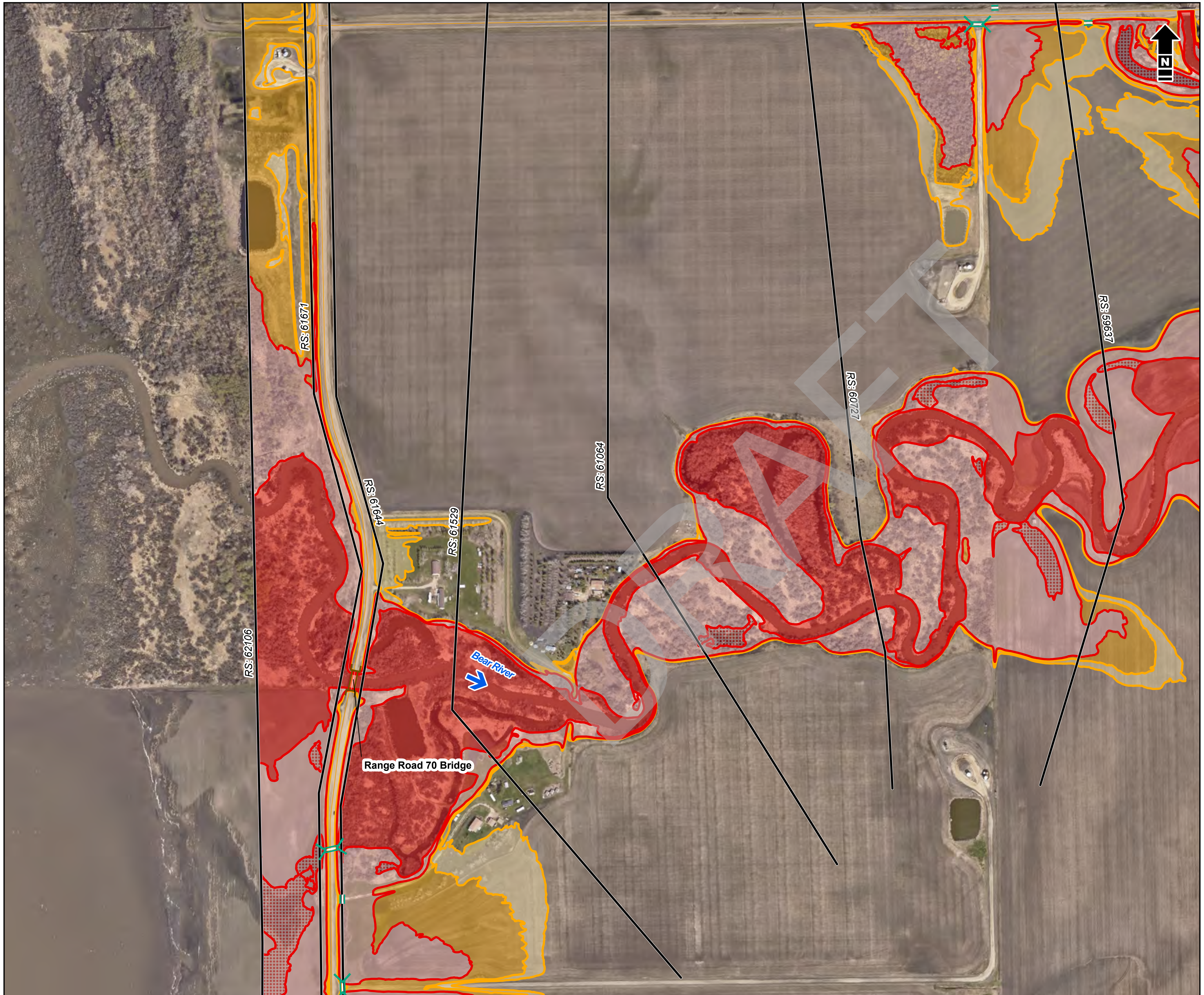
Sheet INDEX



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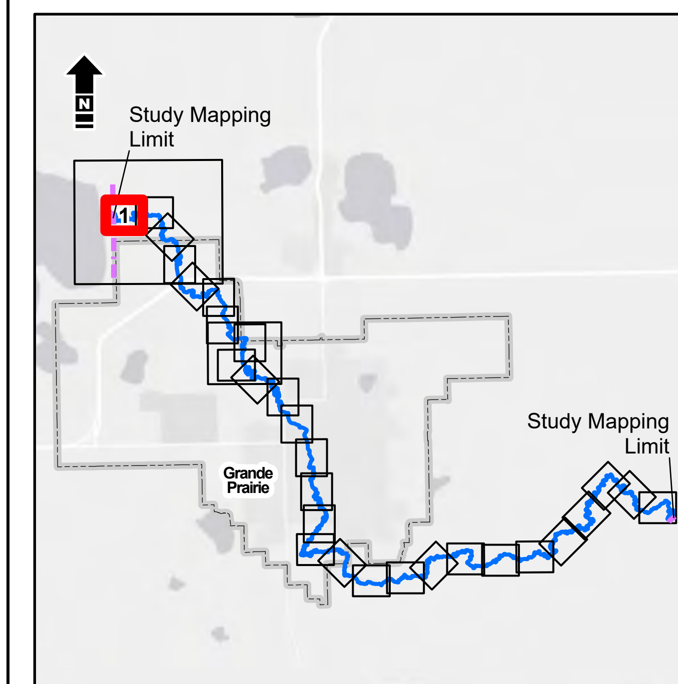
Bridge
Culvert
Spillway
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Municipal Boundary (Urban)
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation
500-Year Flood Inundation



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1:5,000 metres
50 0 50 100
NAD 1983 CSRS 3TM 120

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Alberta Environment and Protected Areas
Grande Prairie Flood Study

Governing Design Flood Hazard Map

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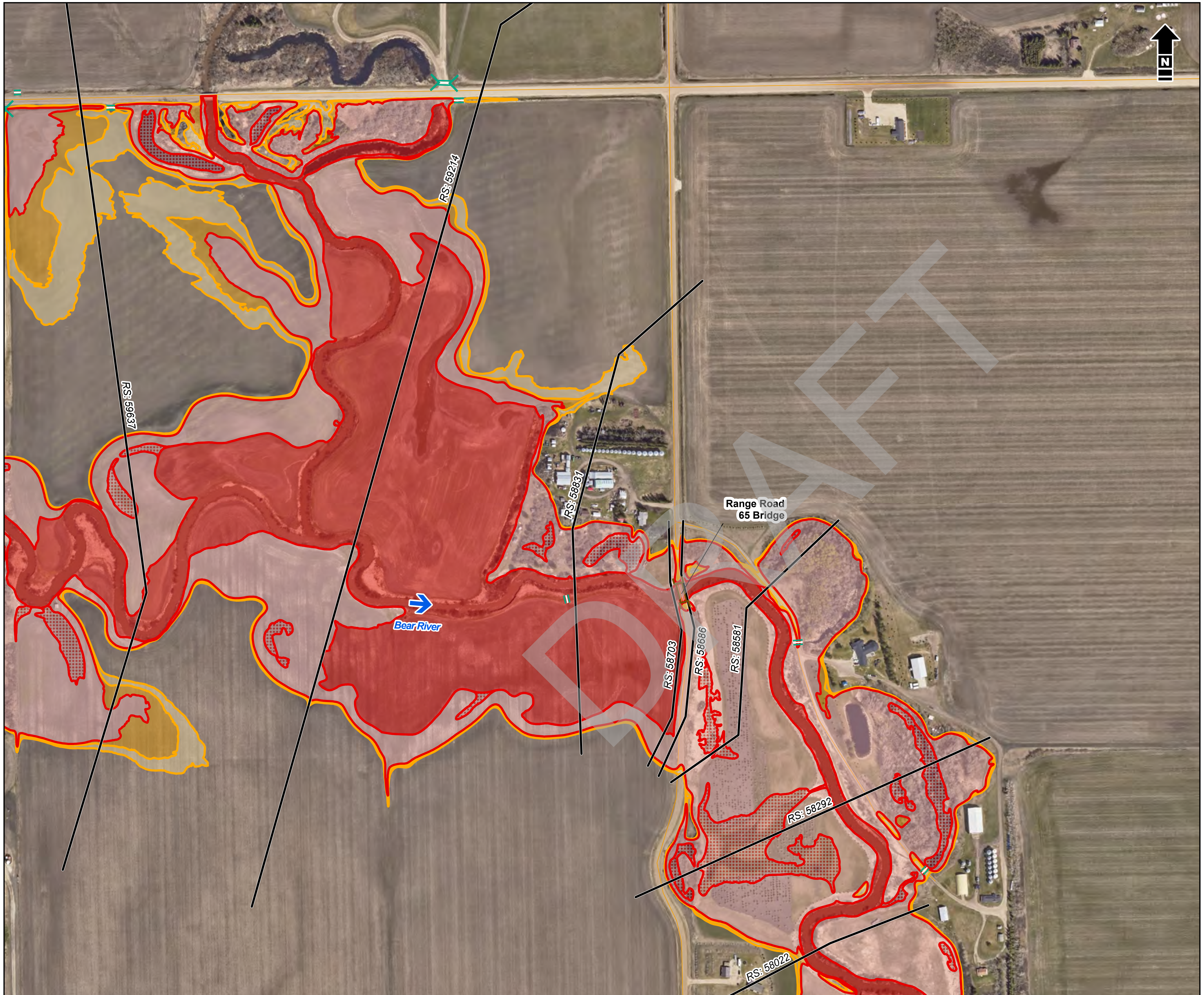

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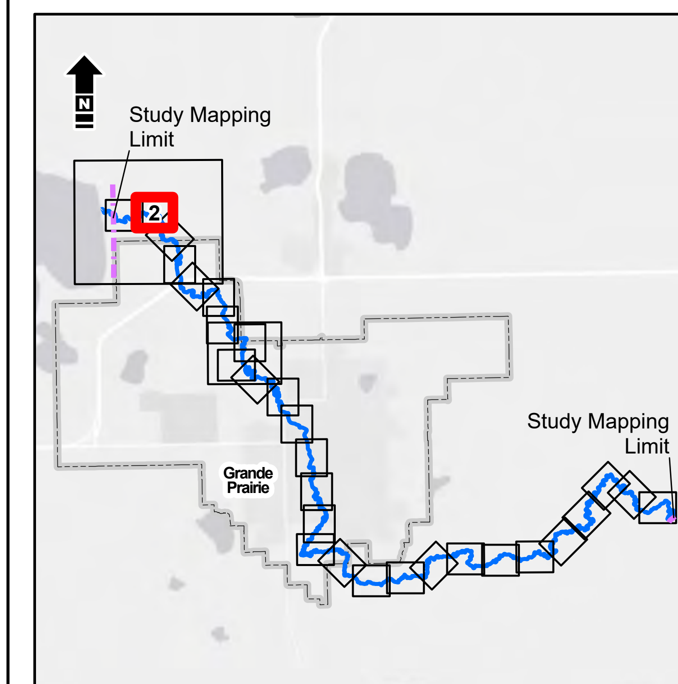

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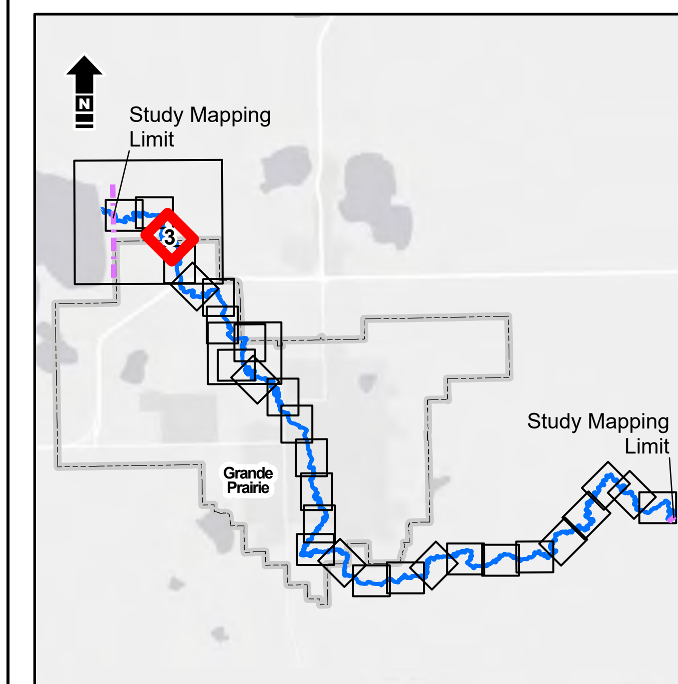

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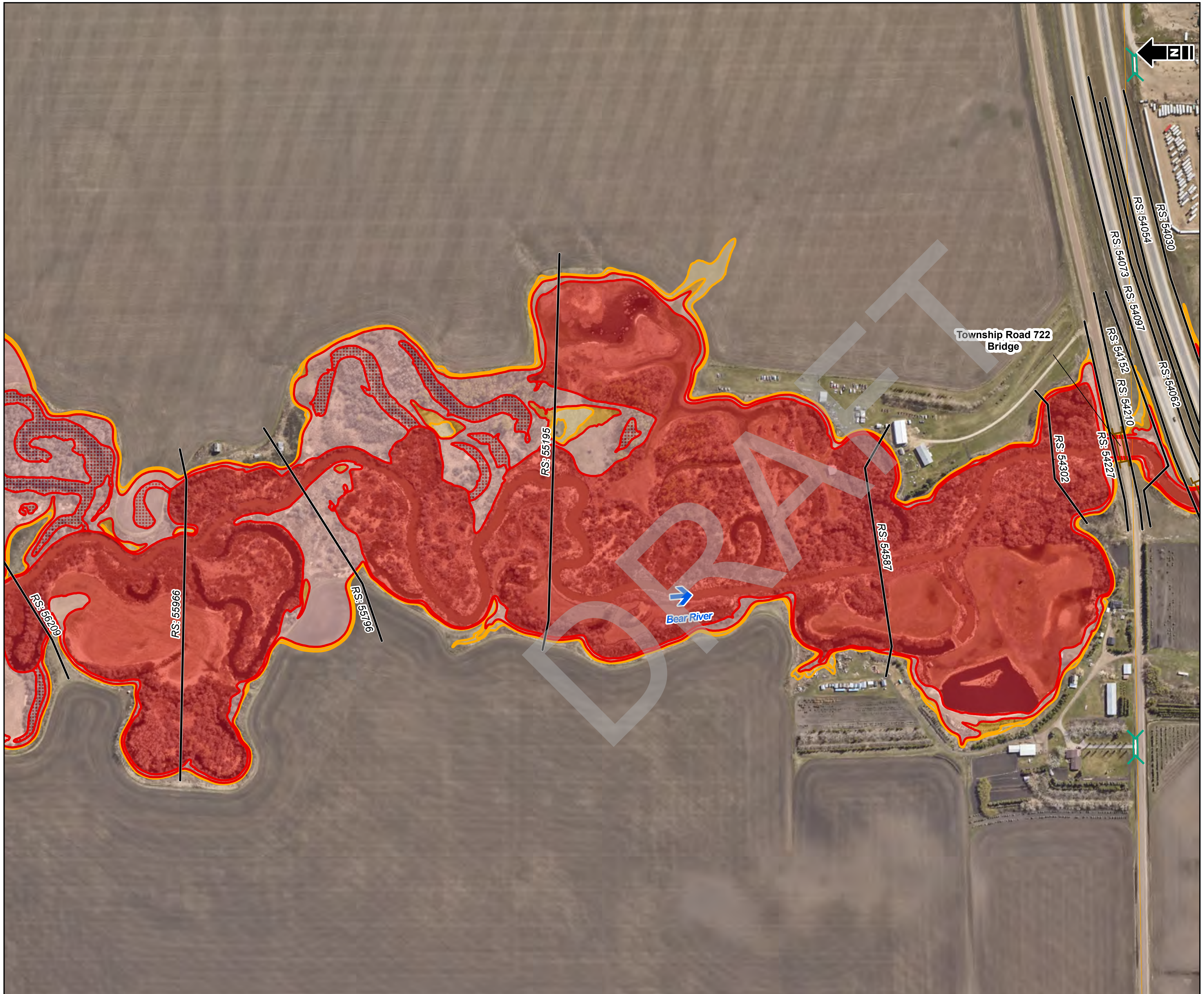

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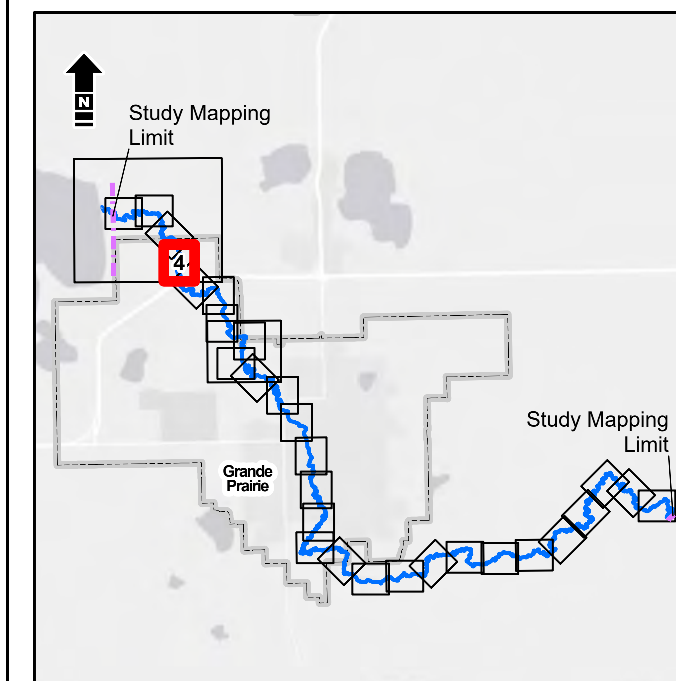

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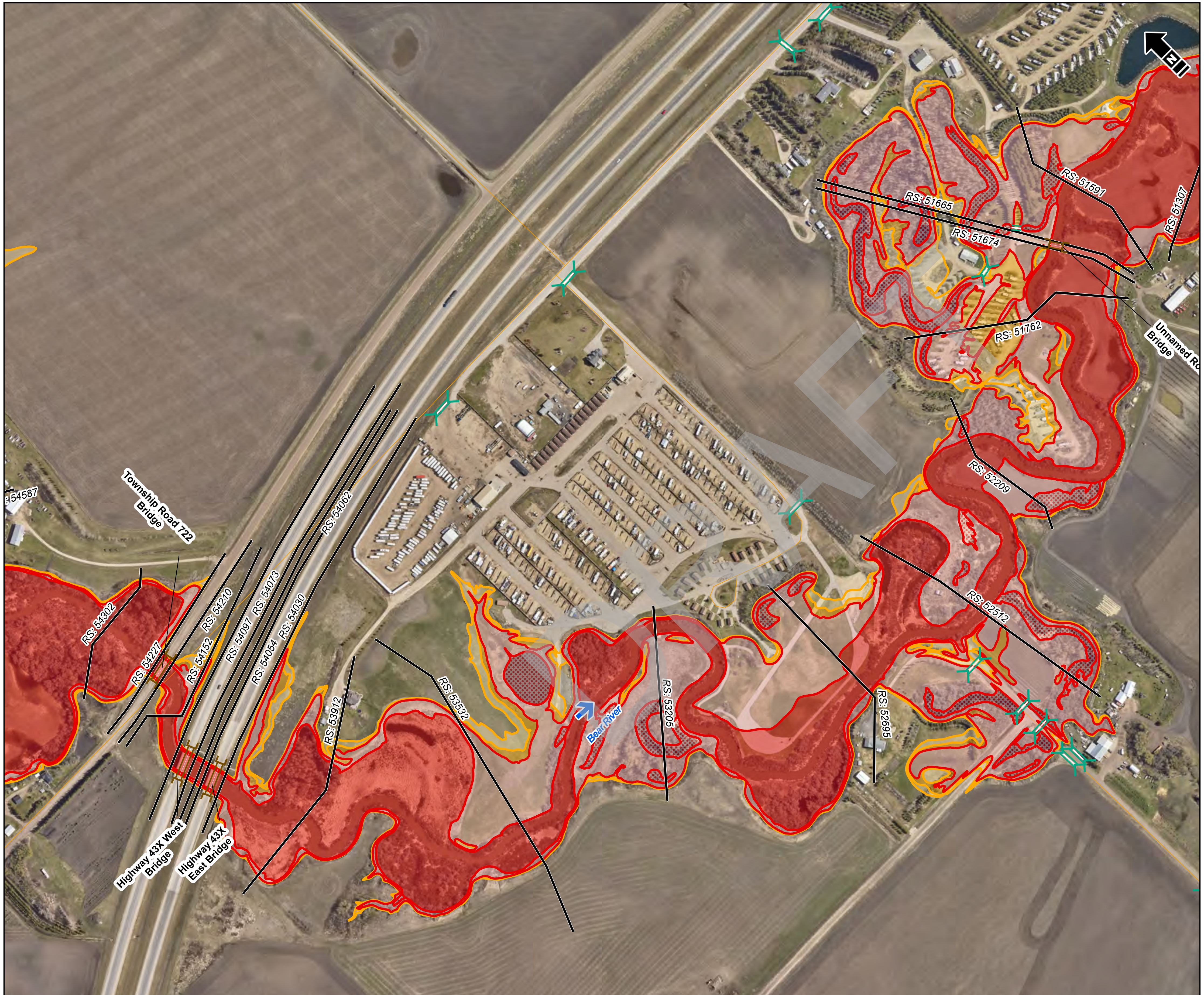

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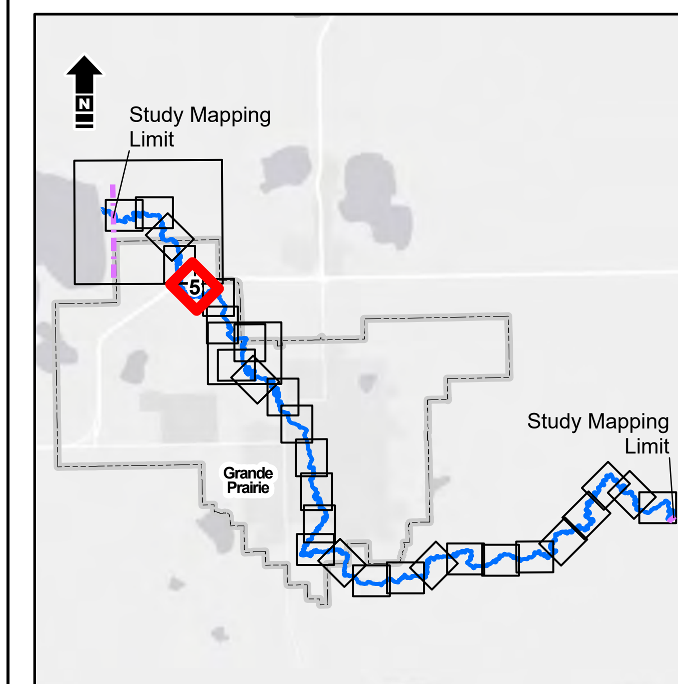

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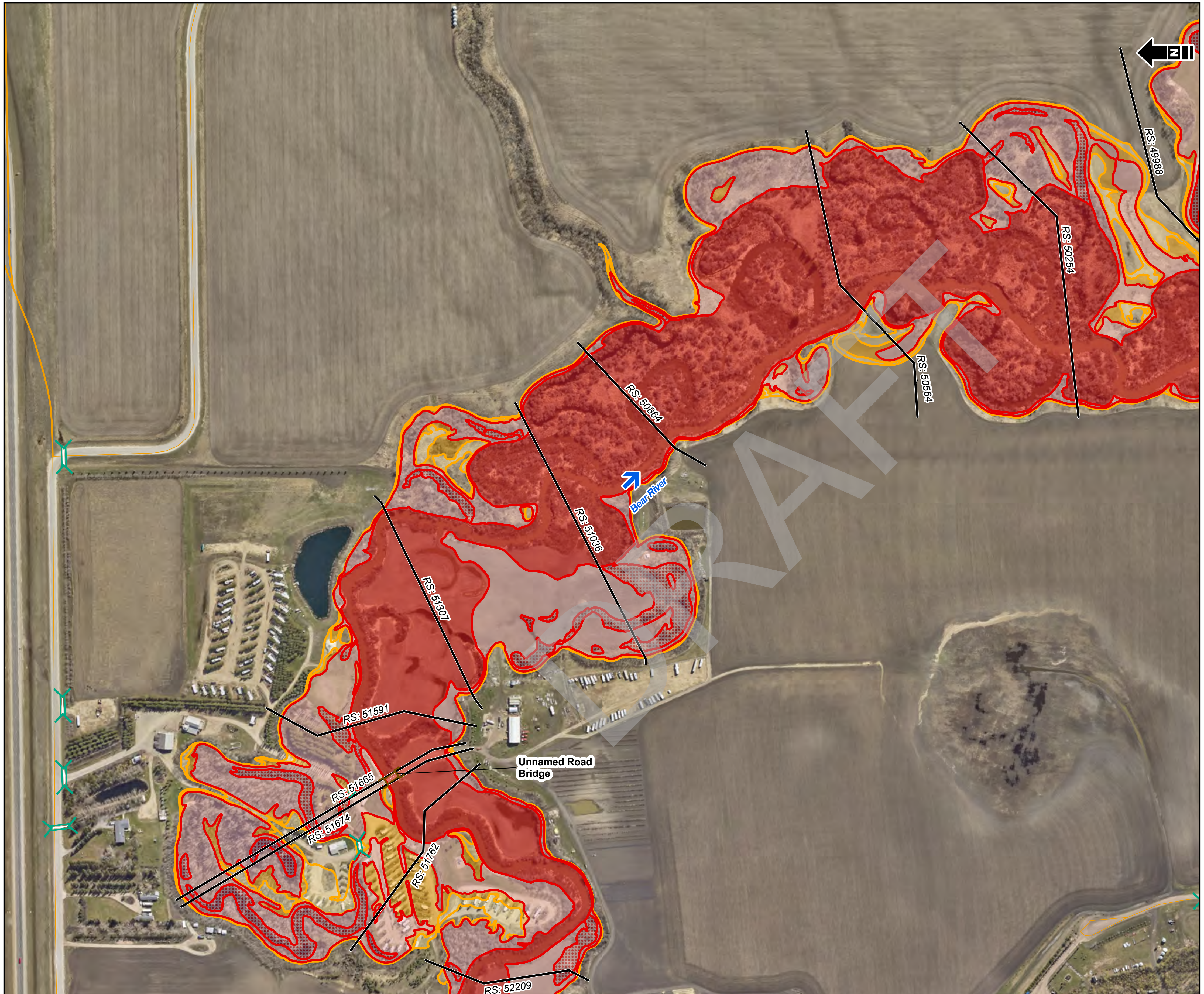

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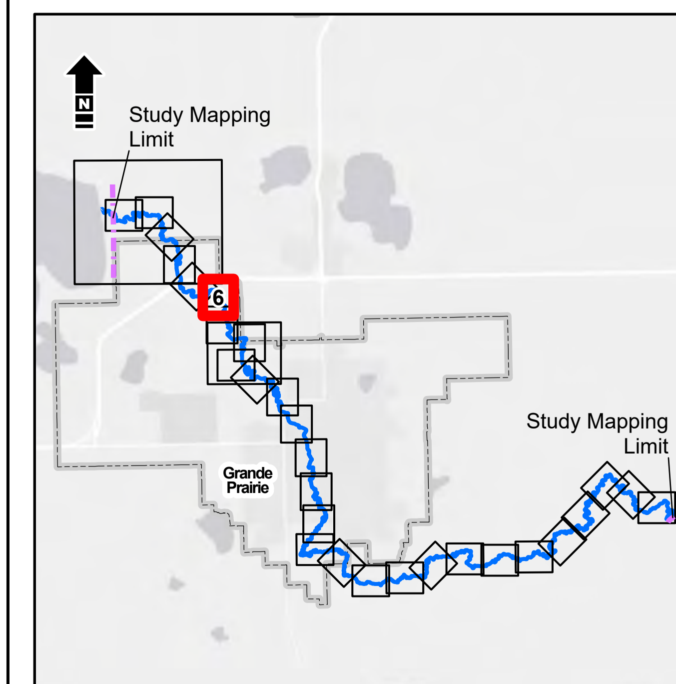

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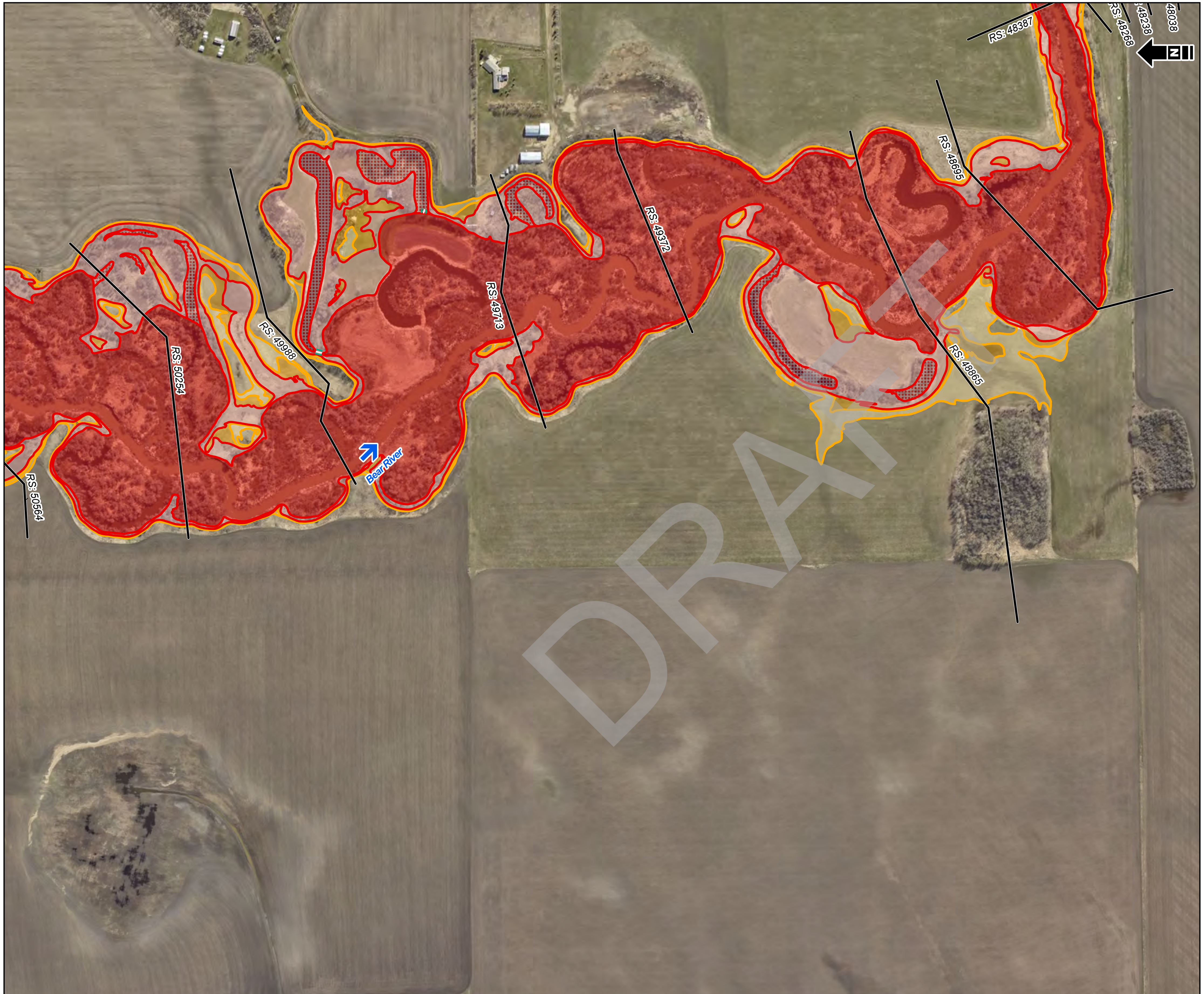

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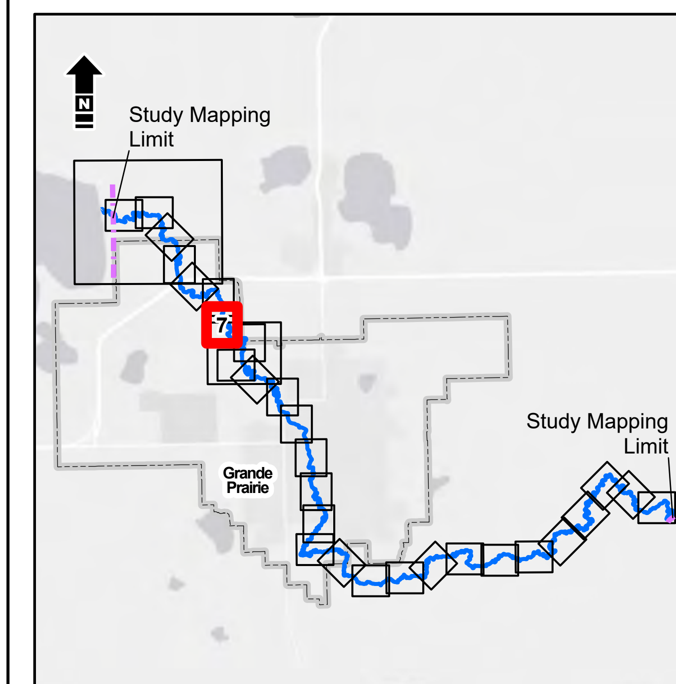

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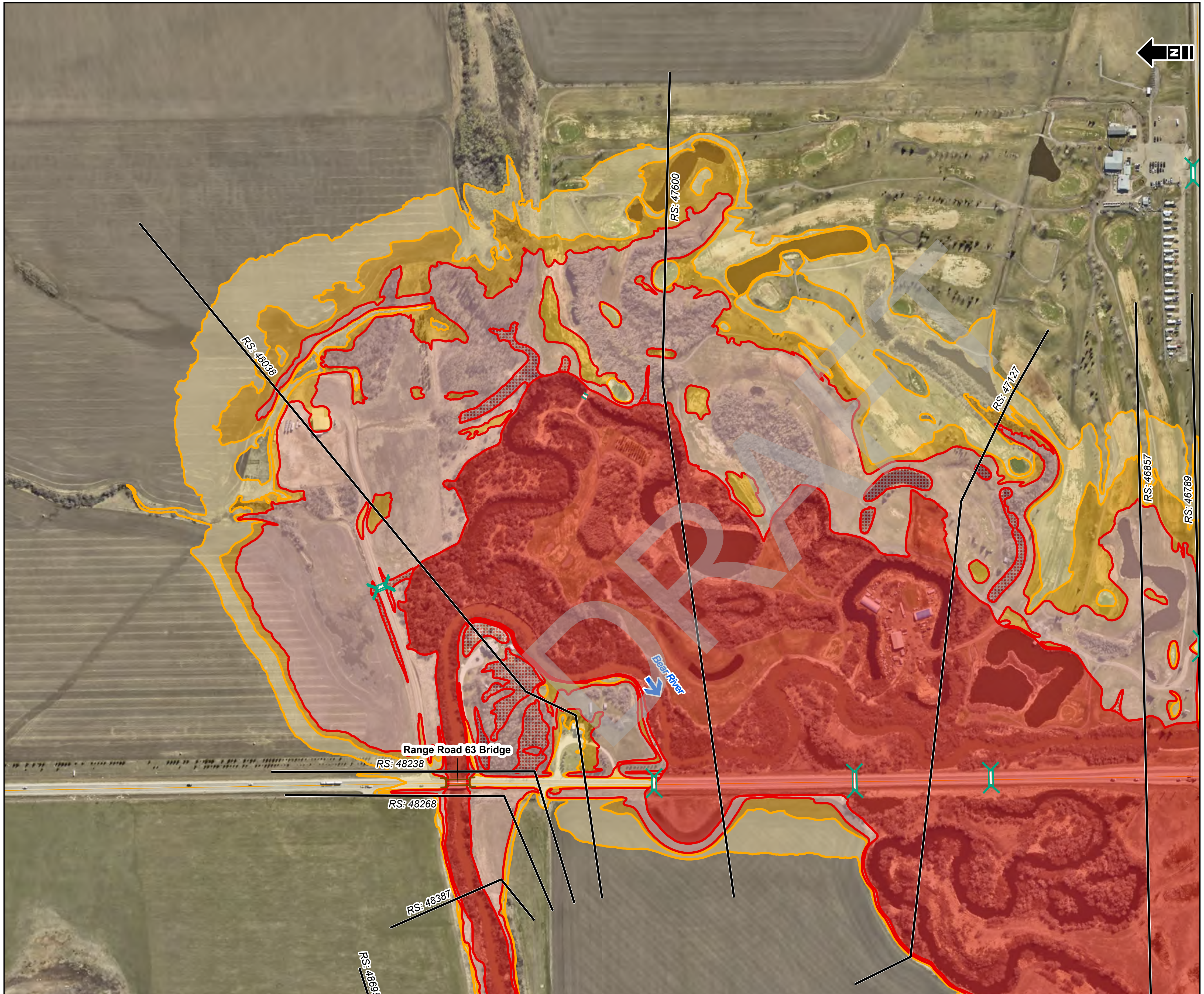

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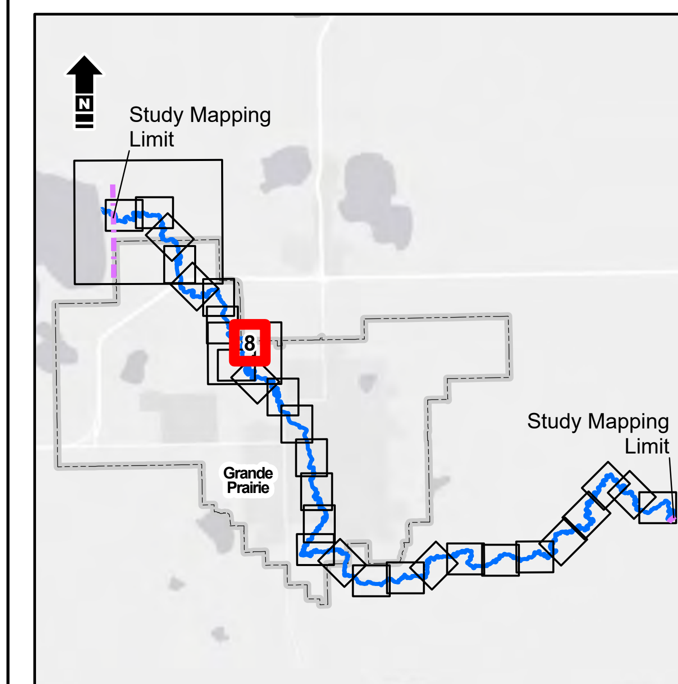

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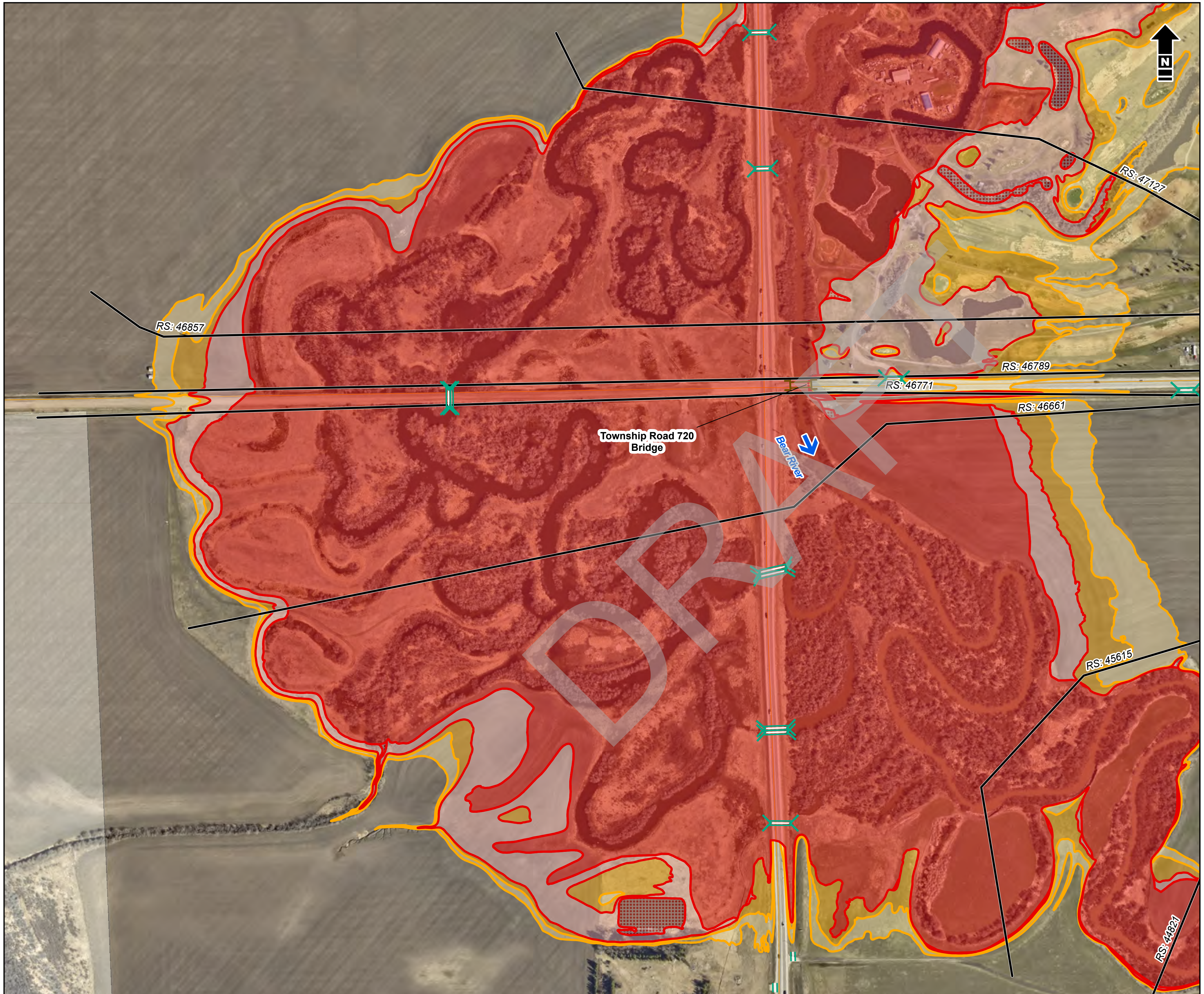

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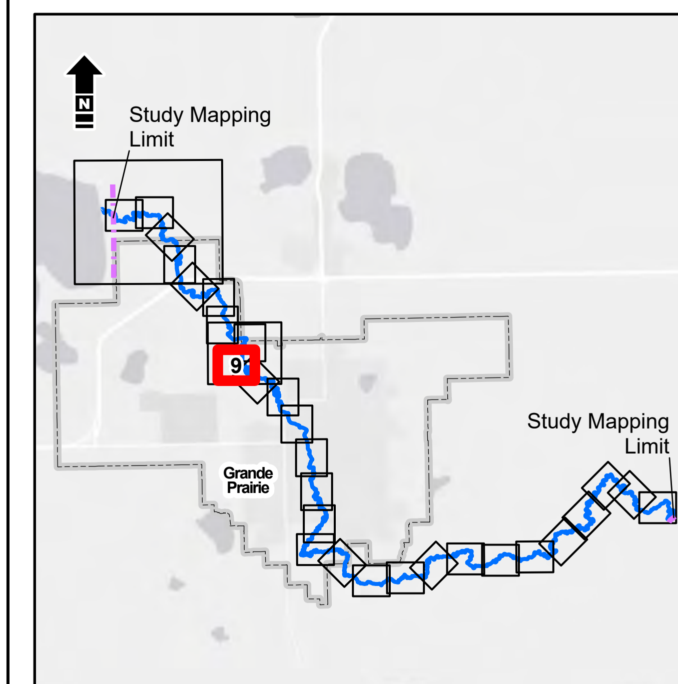

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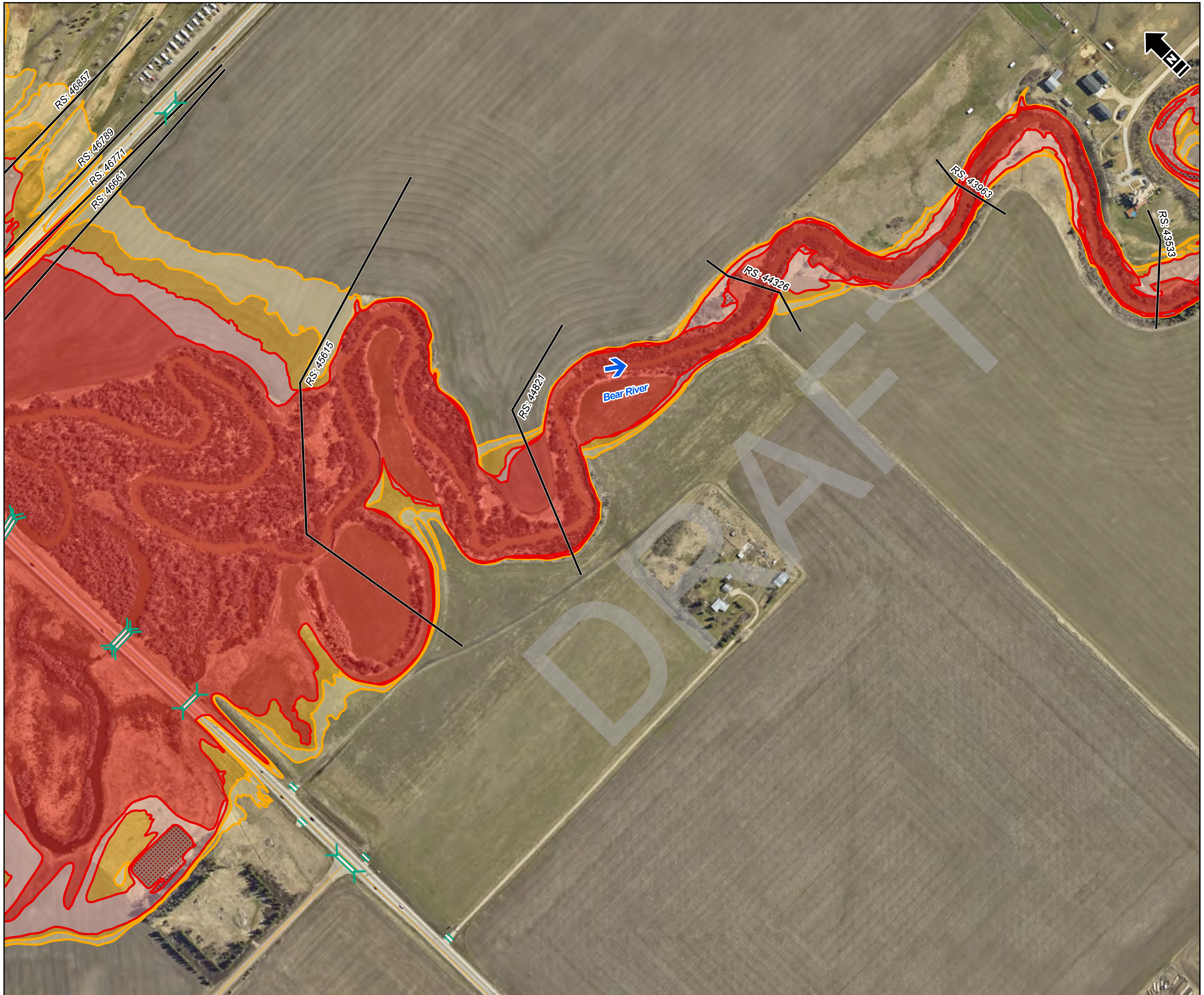

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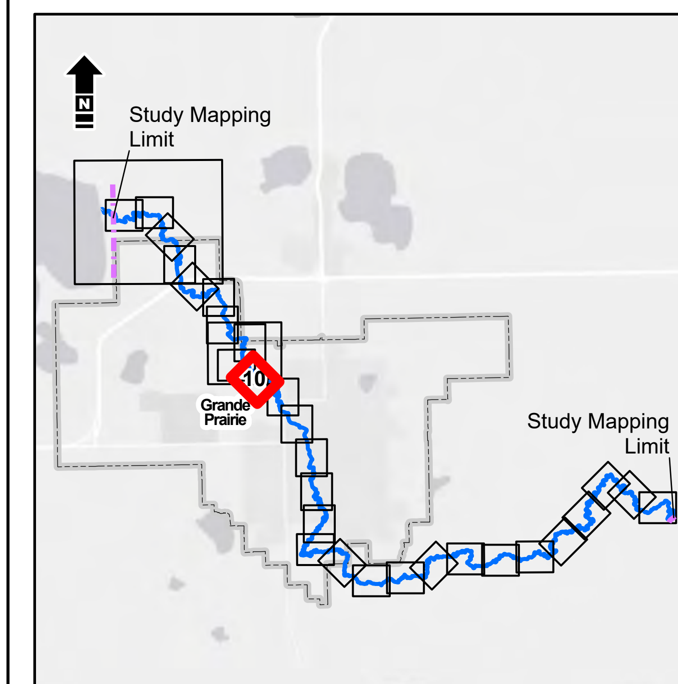

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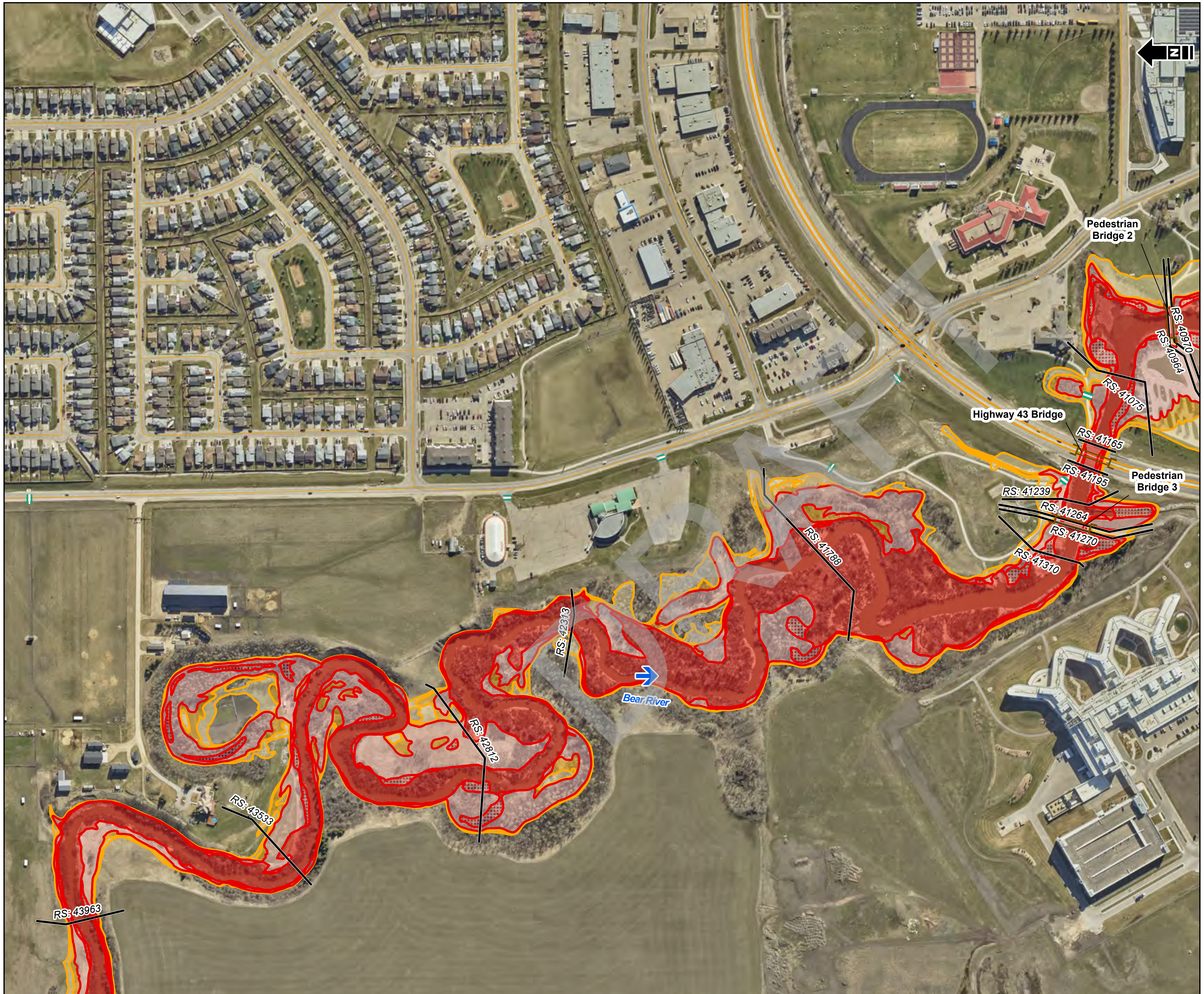

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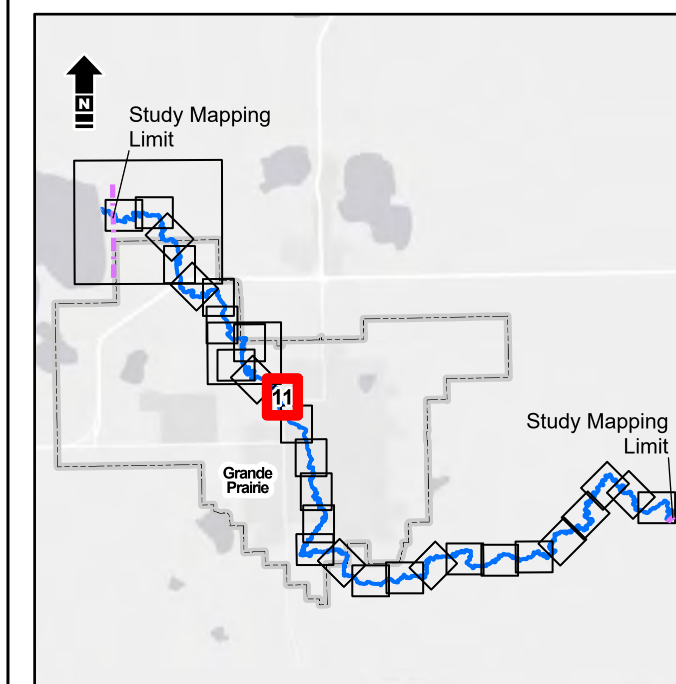

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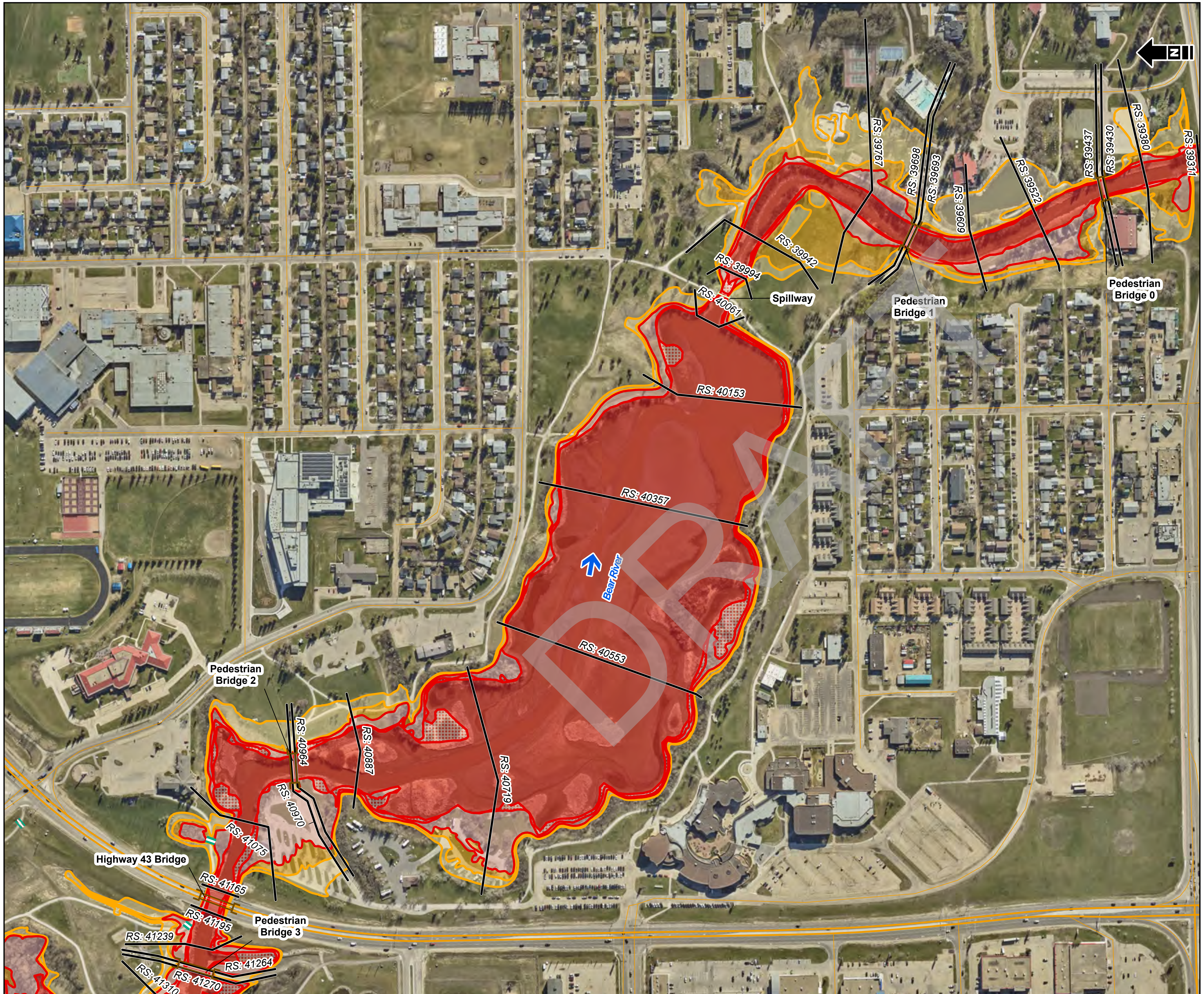

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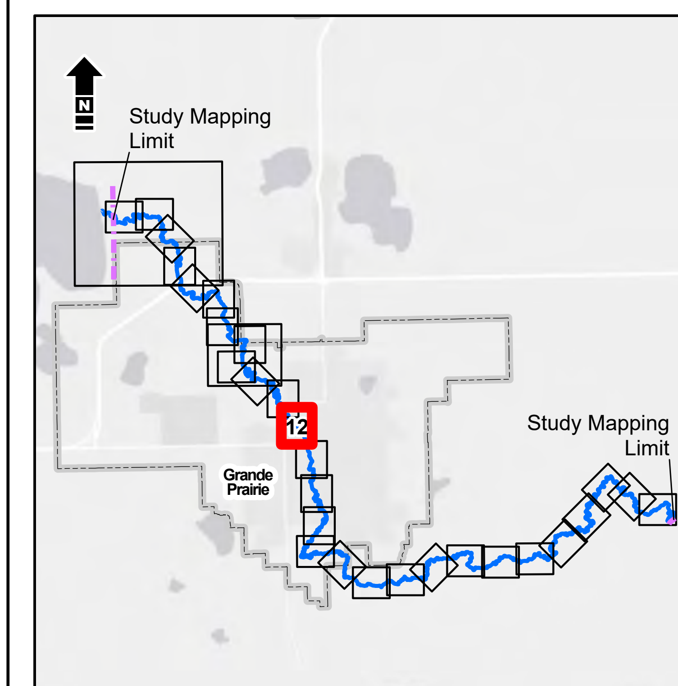

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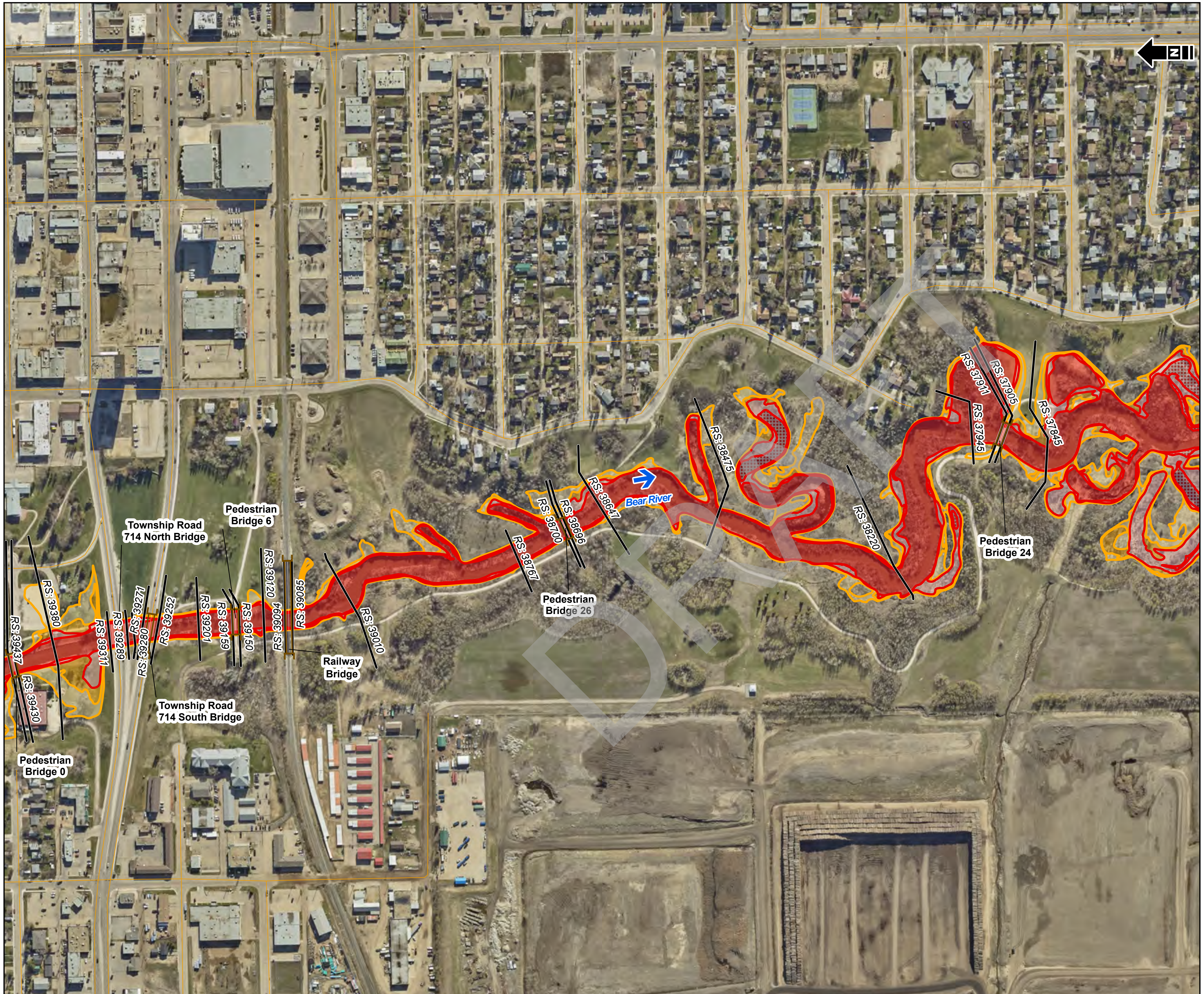

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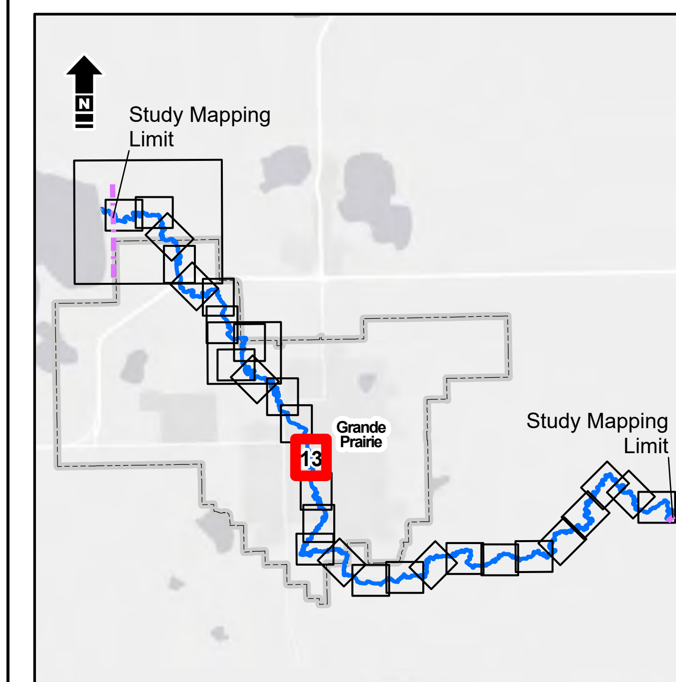

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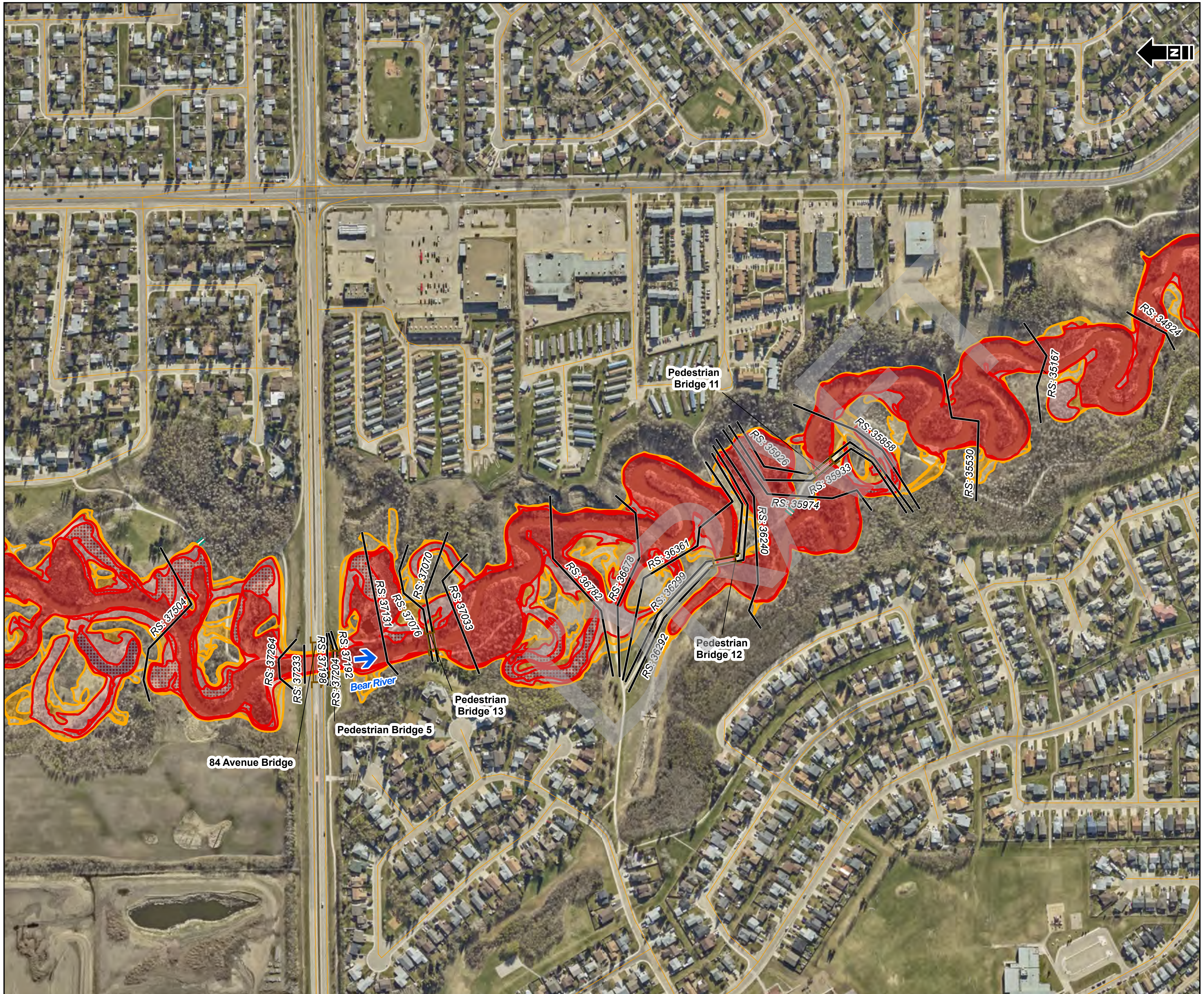

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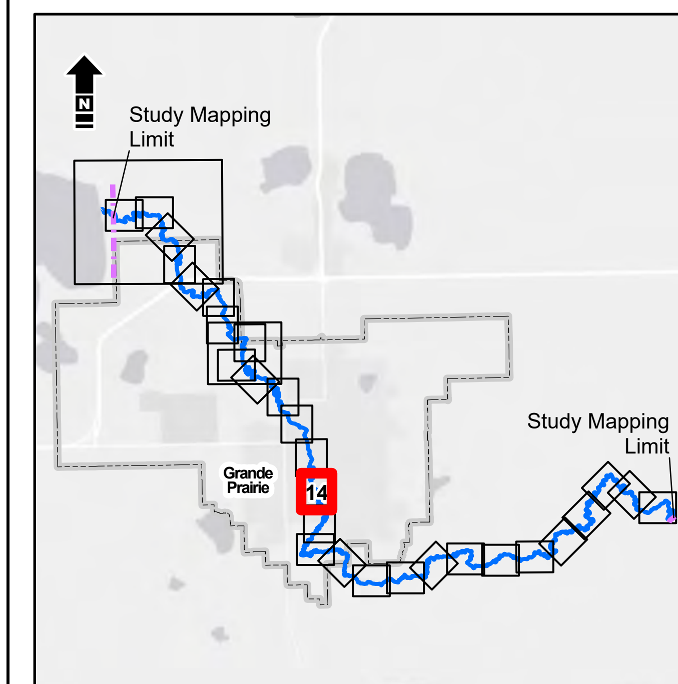

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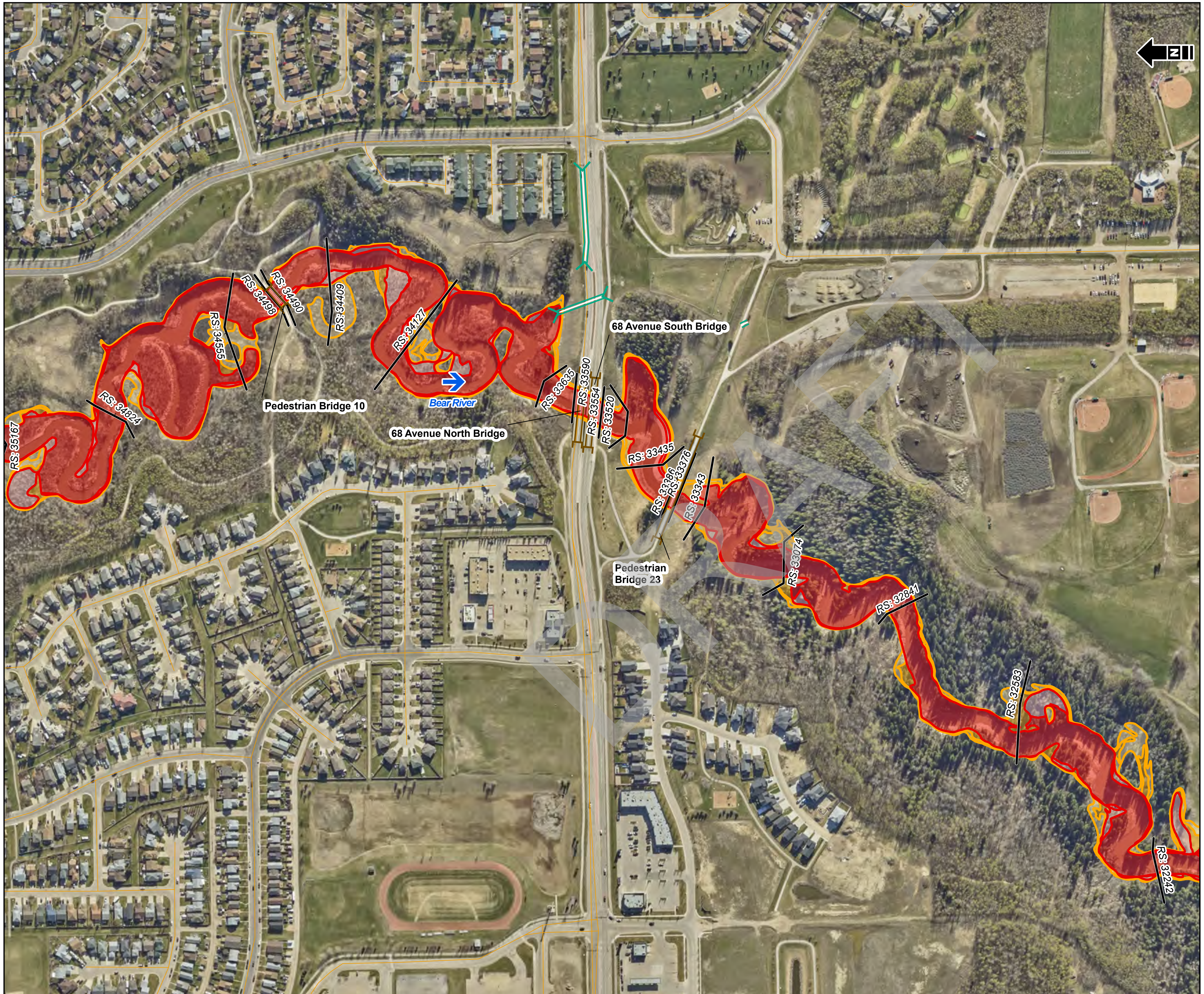
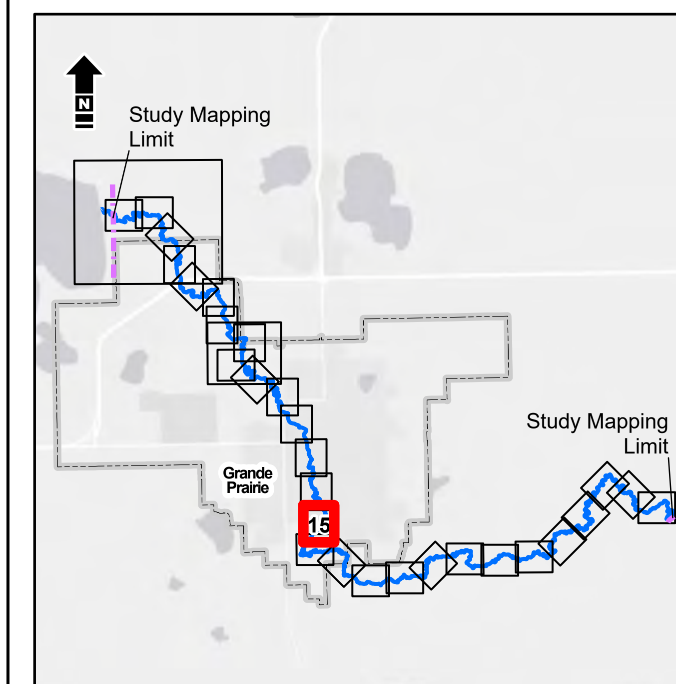


RS: 24873 River Station
Bridge
Culvert
Spillway
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Municipal Boundary (Urban)
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation
500-Year Flood Inundation



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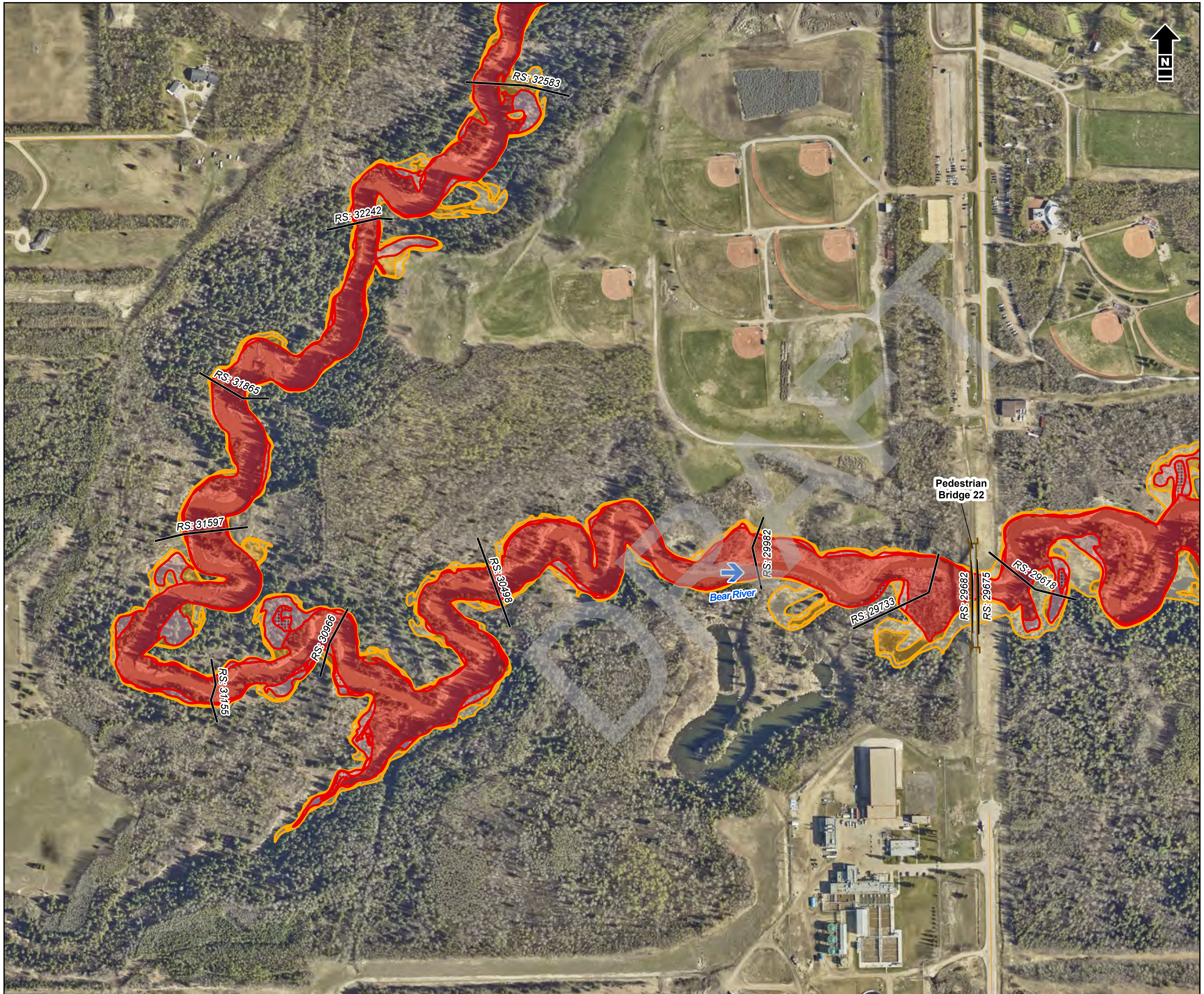
Alberta Environment and Protected Areas
Grande Prairie Flood Study

Governing Design Flood Hazard Map

Date:	Project:	Submitter:	Reviewer:
June 2025	35917	P. Rogers	M. Shome



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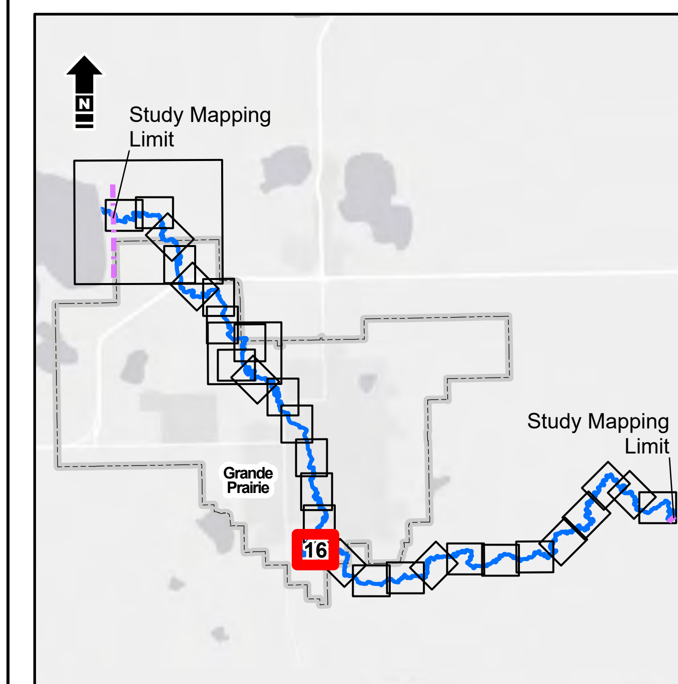

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Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome

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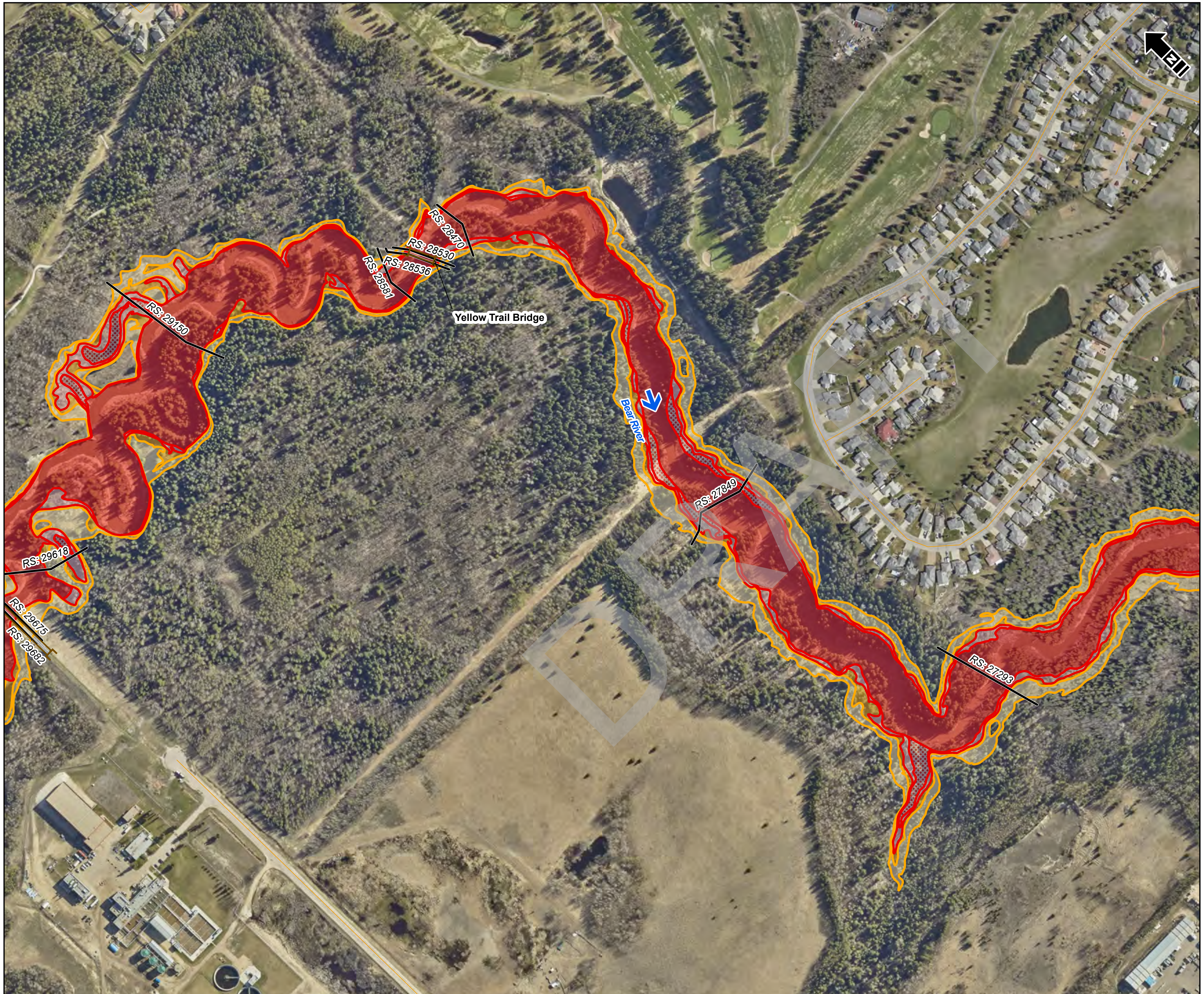

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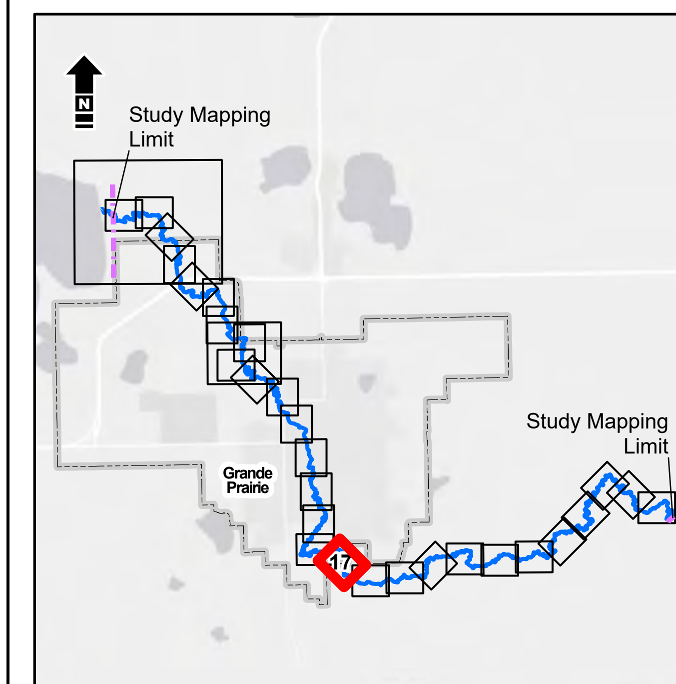
- 500-Year Flood Inundation



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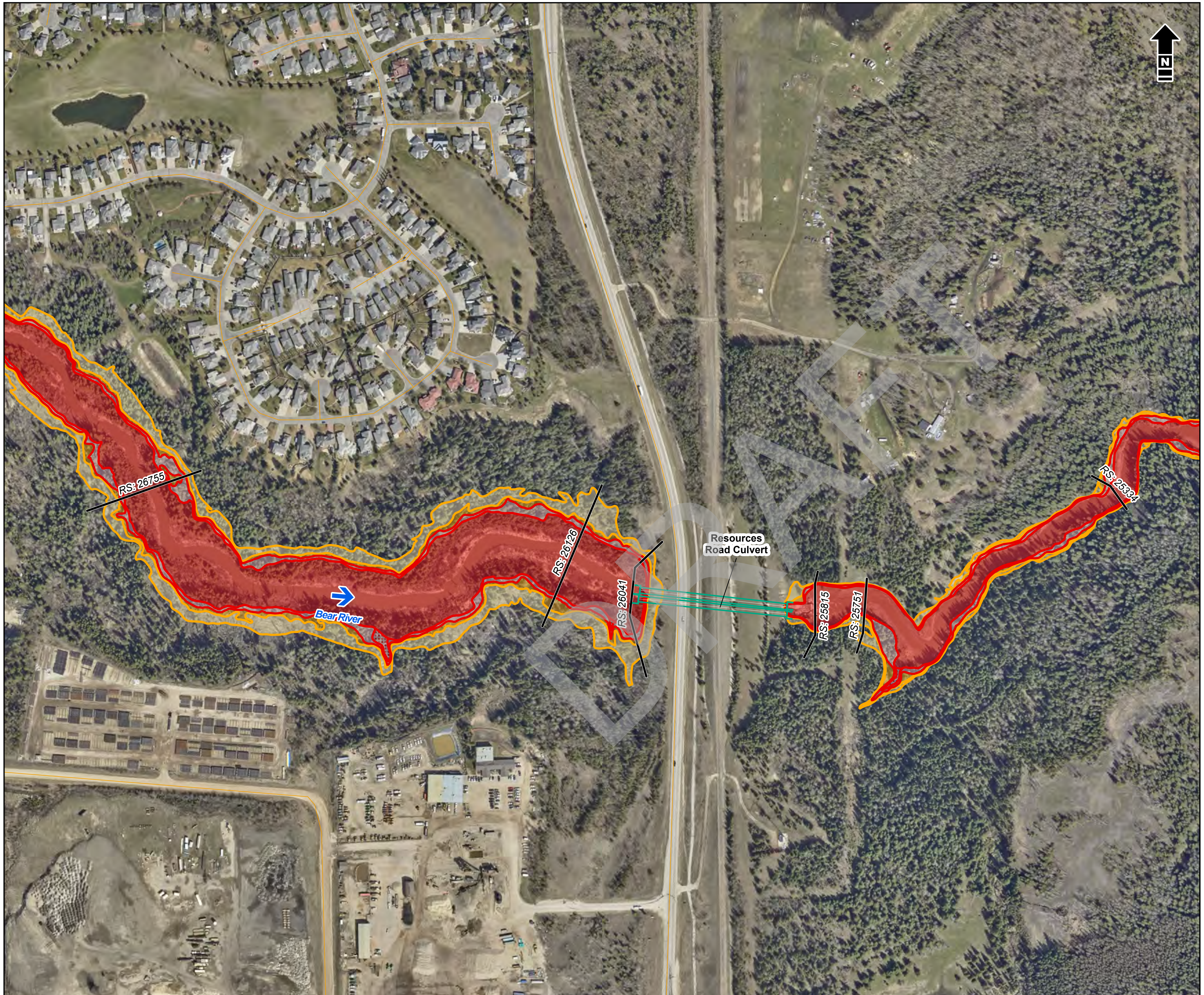
Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome



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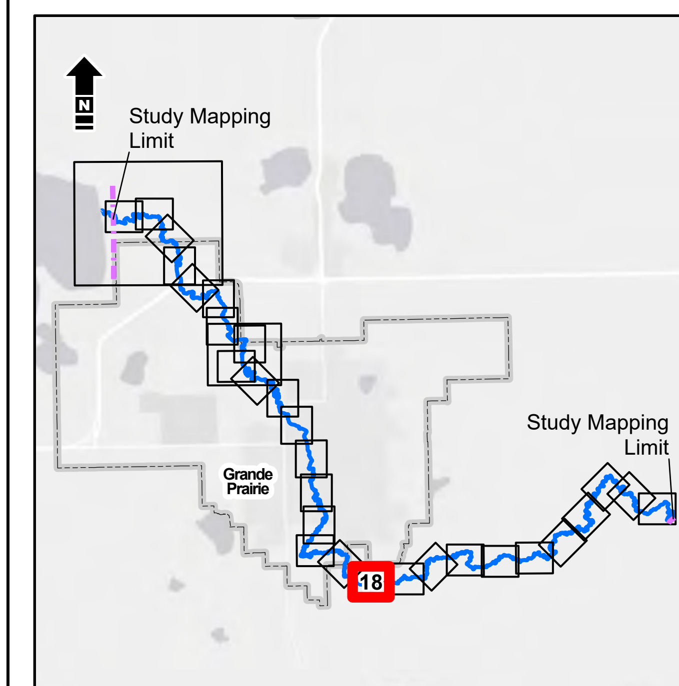

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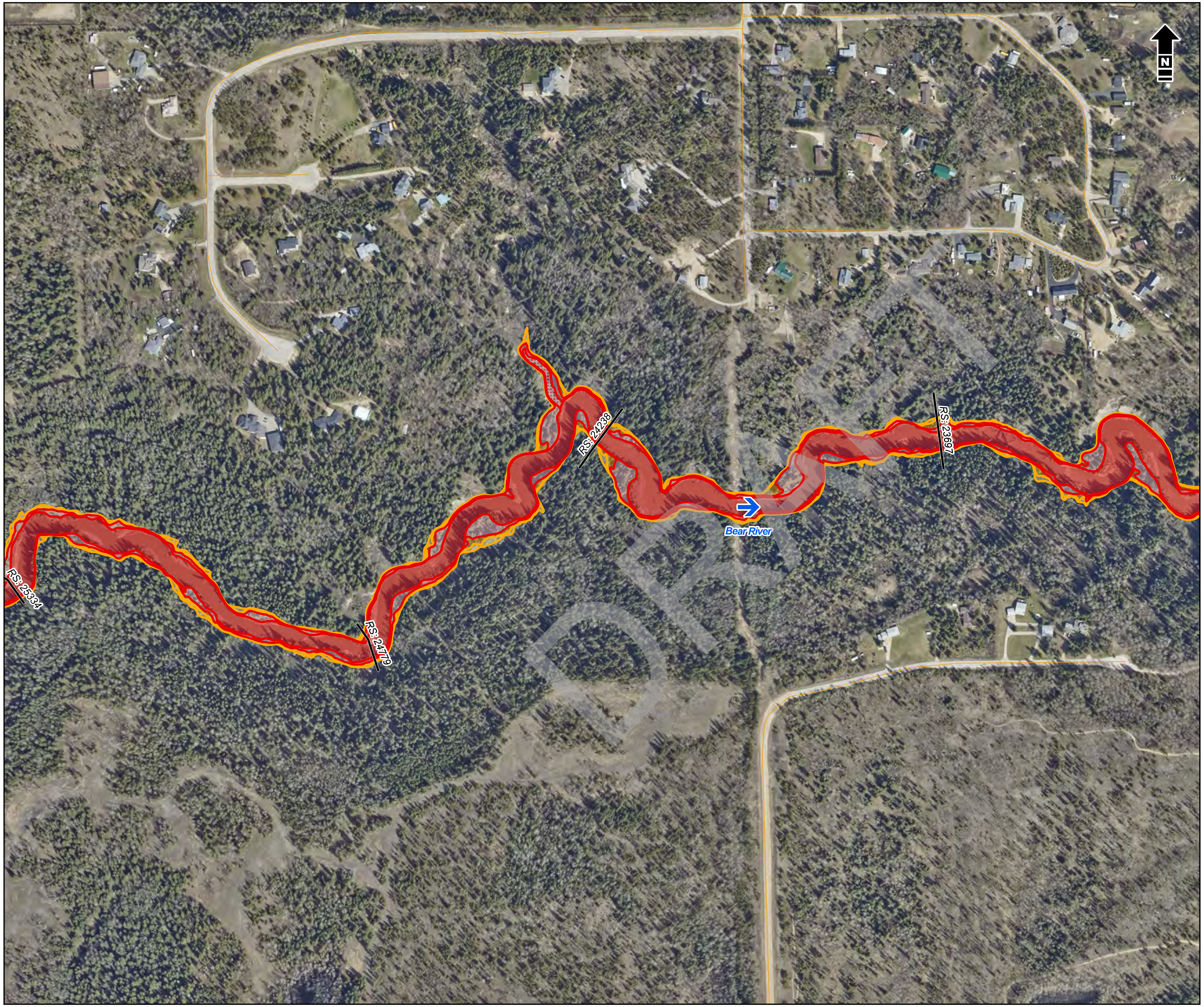

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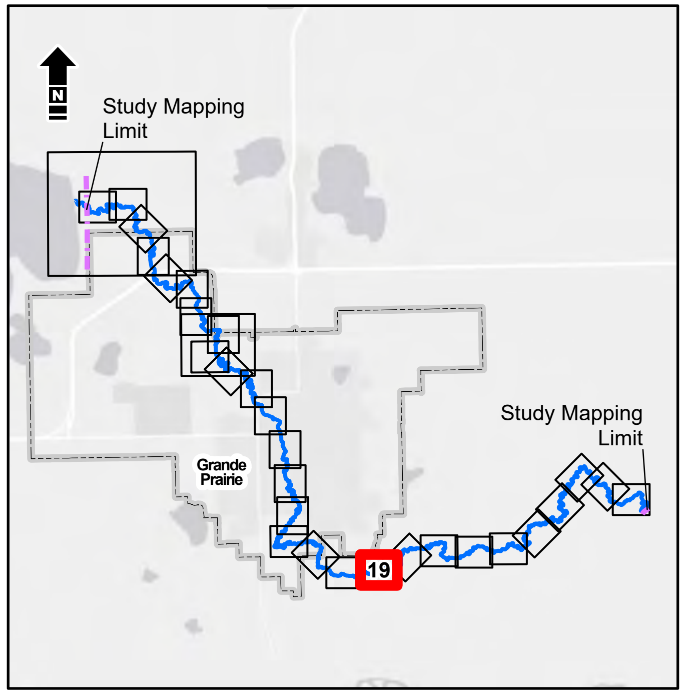

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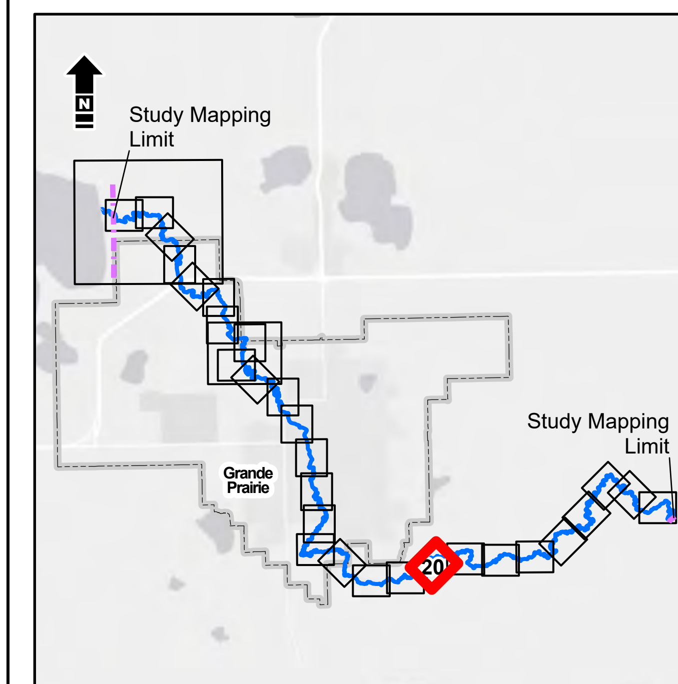

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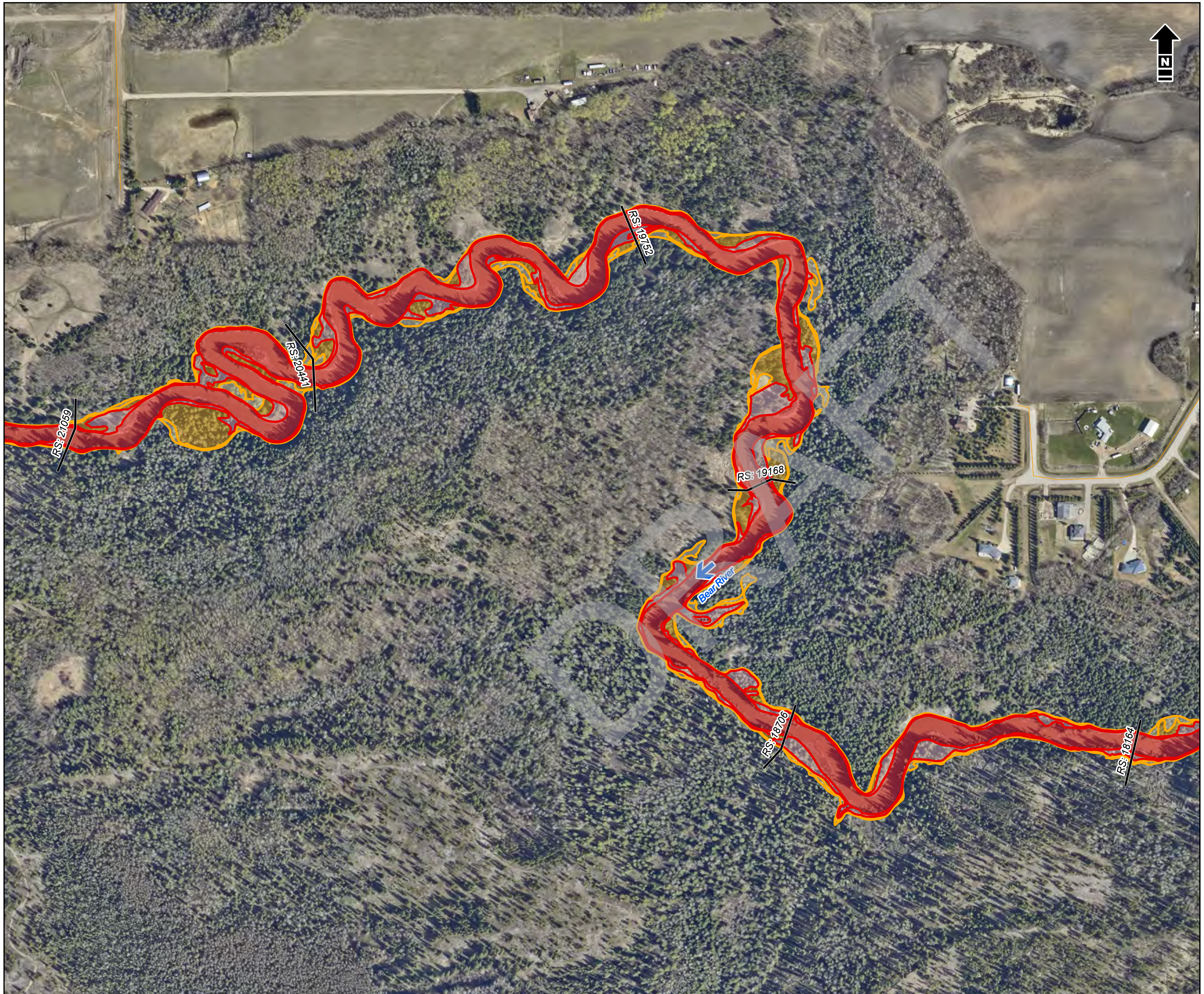
Alberta Environment and Protected Areas
Grande Prairie Flood Study

Governing Design Flood Hazard Map

Date: June 2025	Project: 35917	Submitter: P. Rogers	Reviewer: M. Shome



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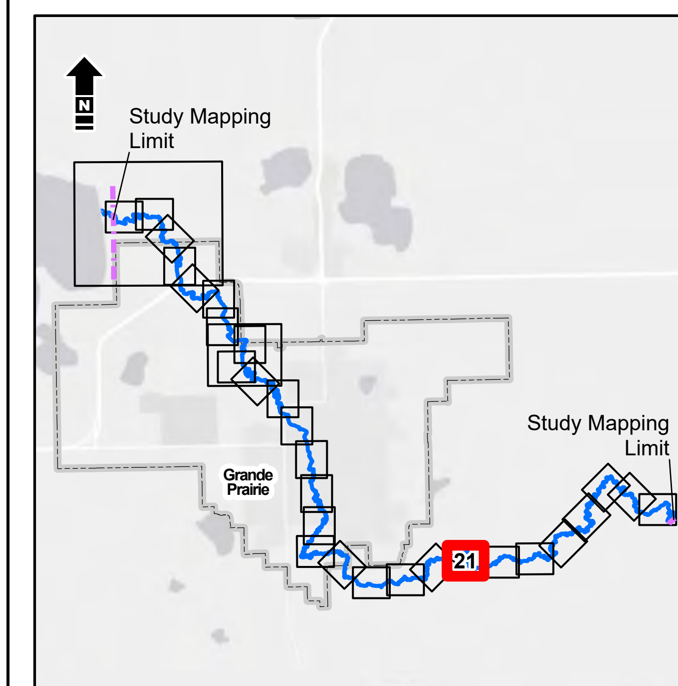

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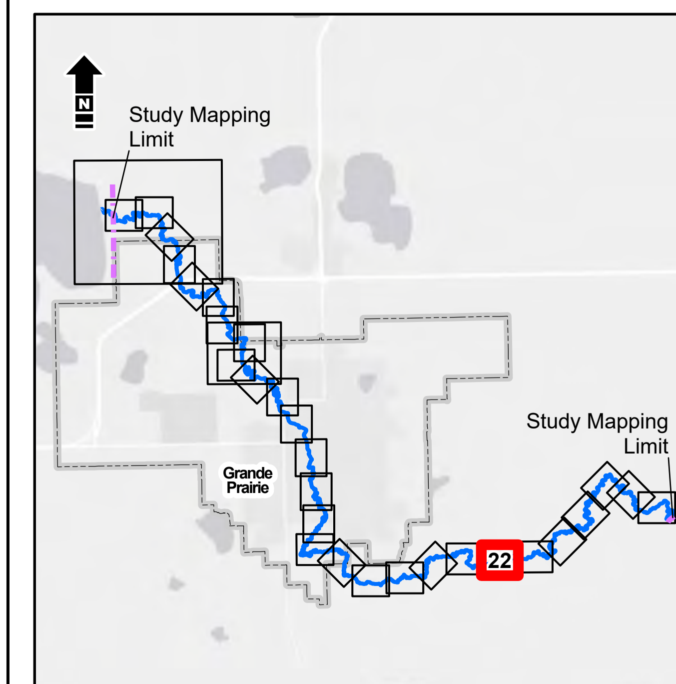

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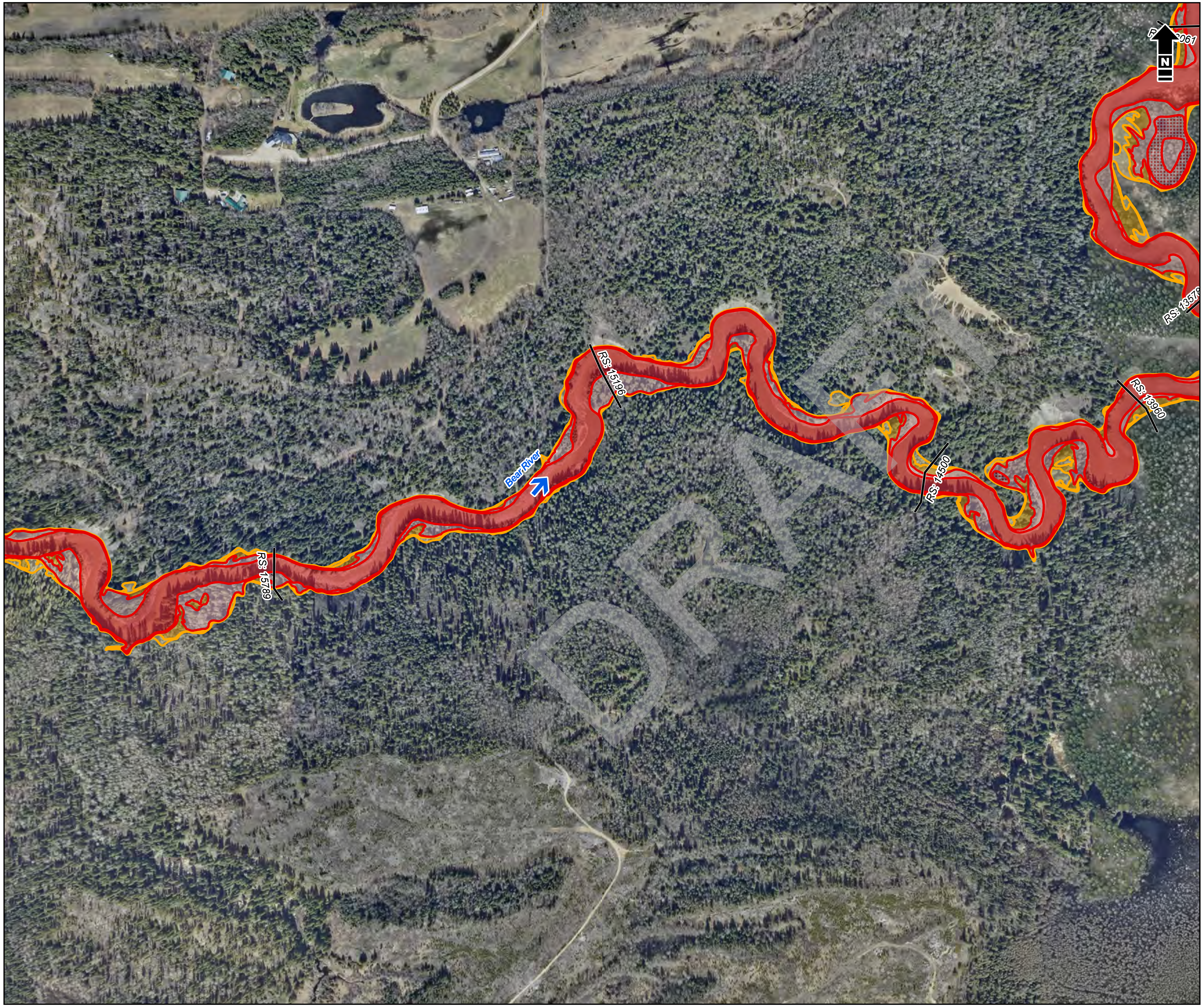

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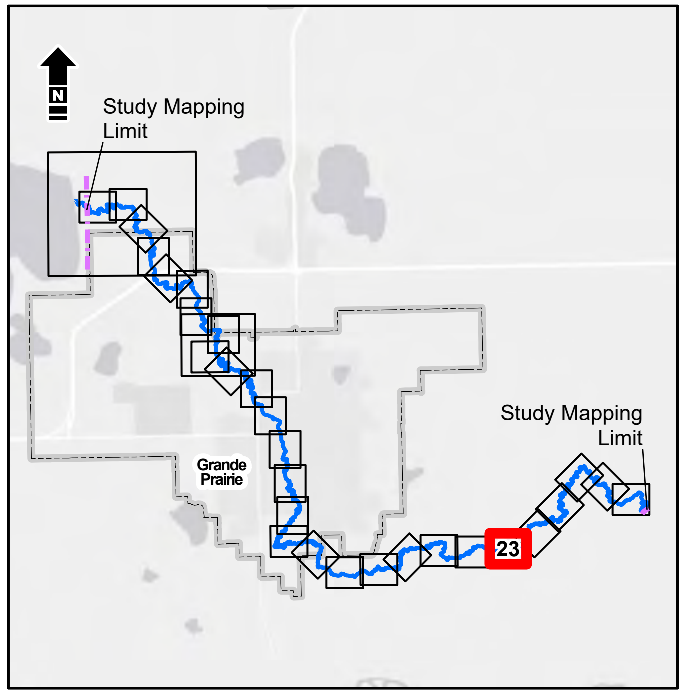

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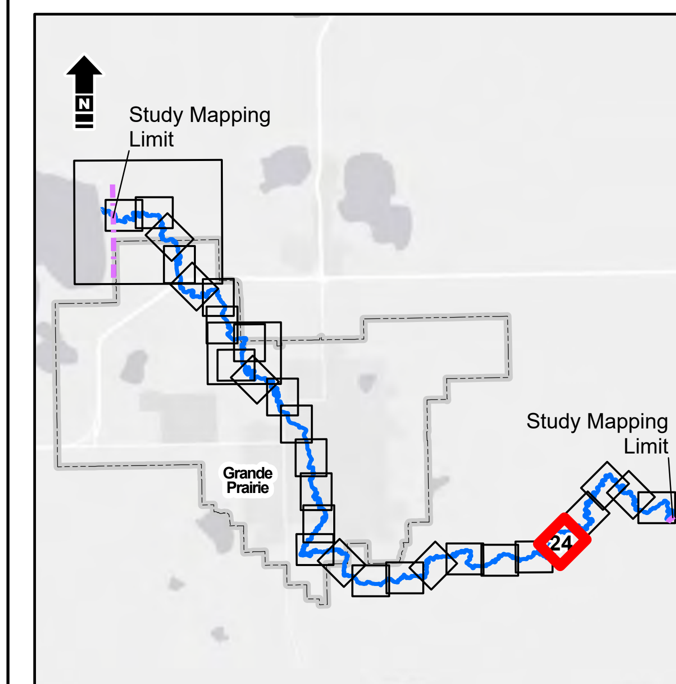

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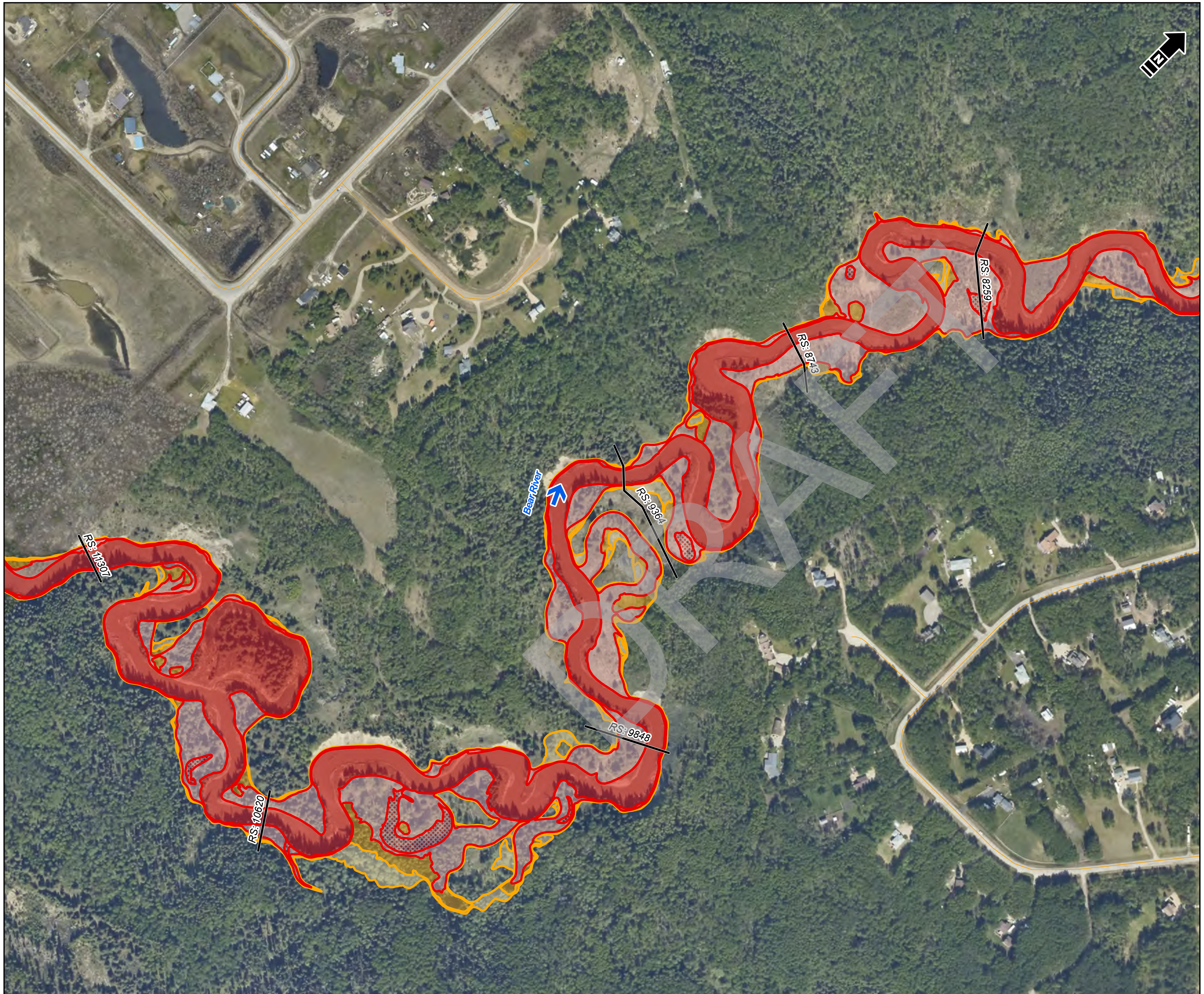

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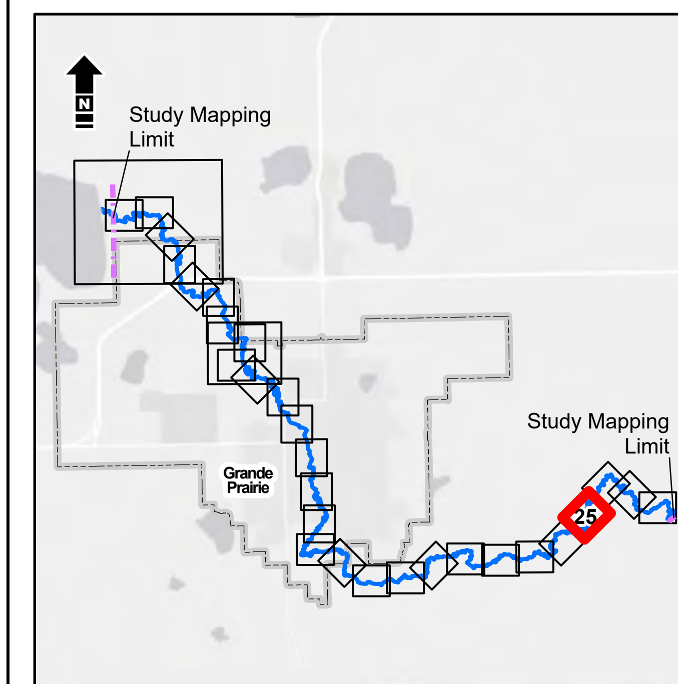

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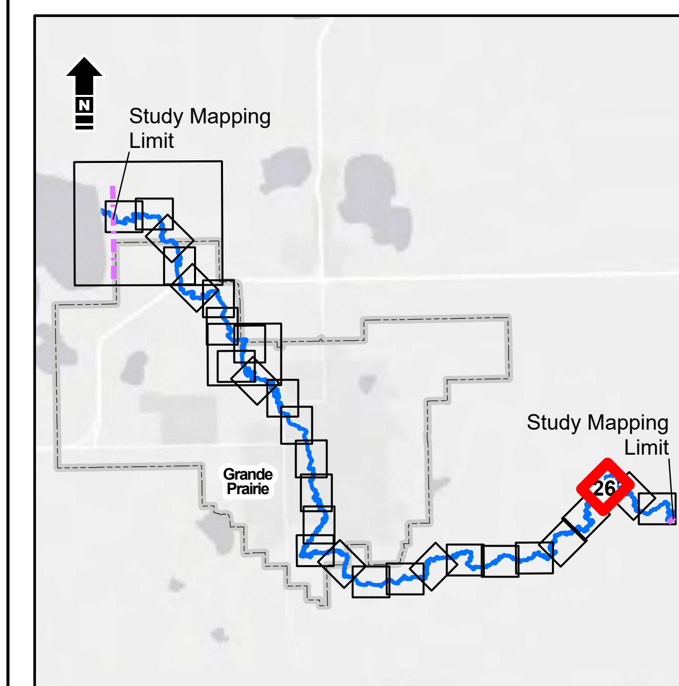

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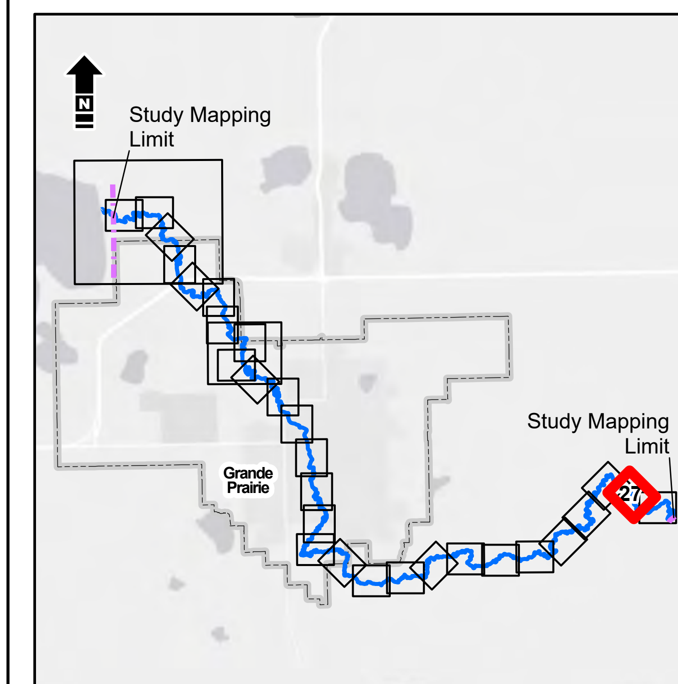

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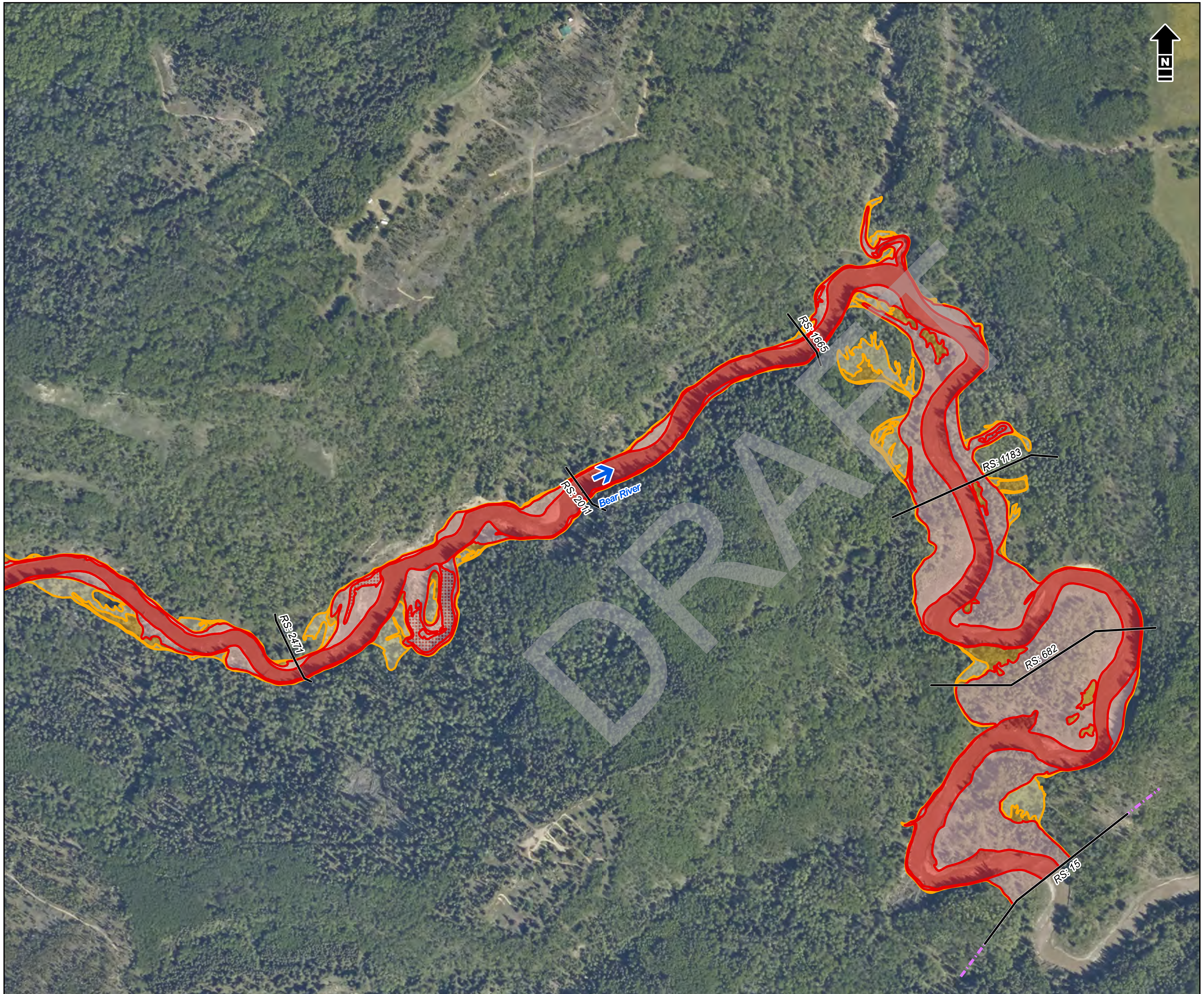

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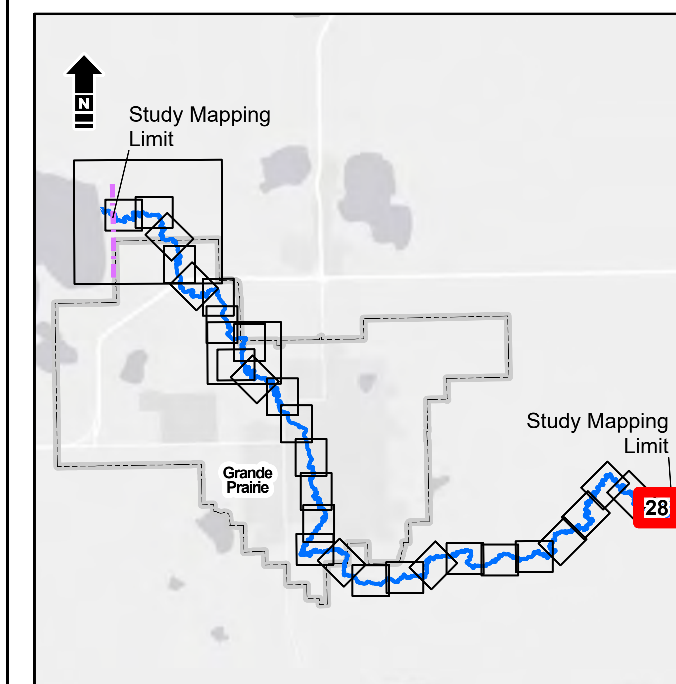

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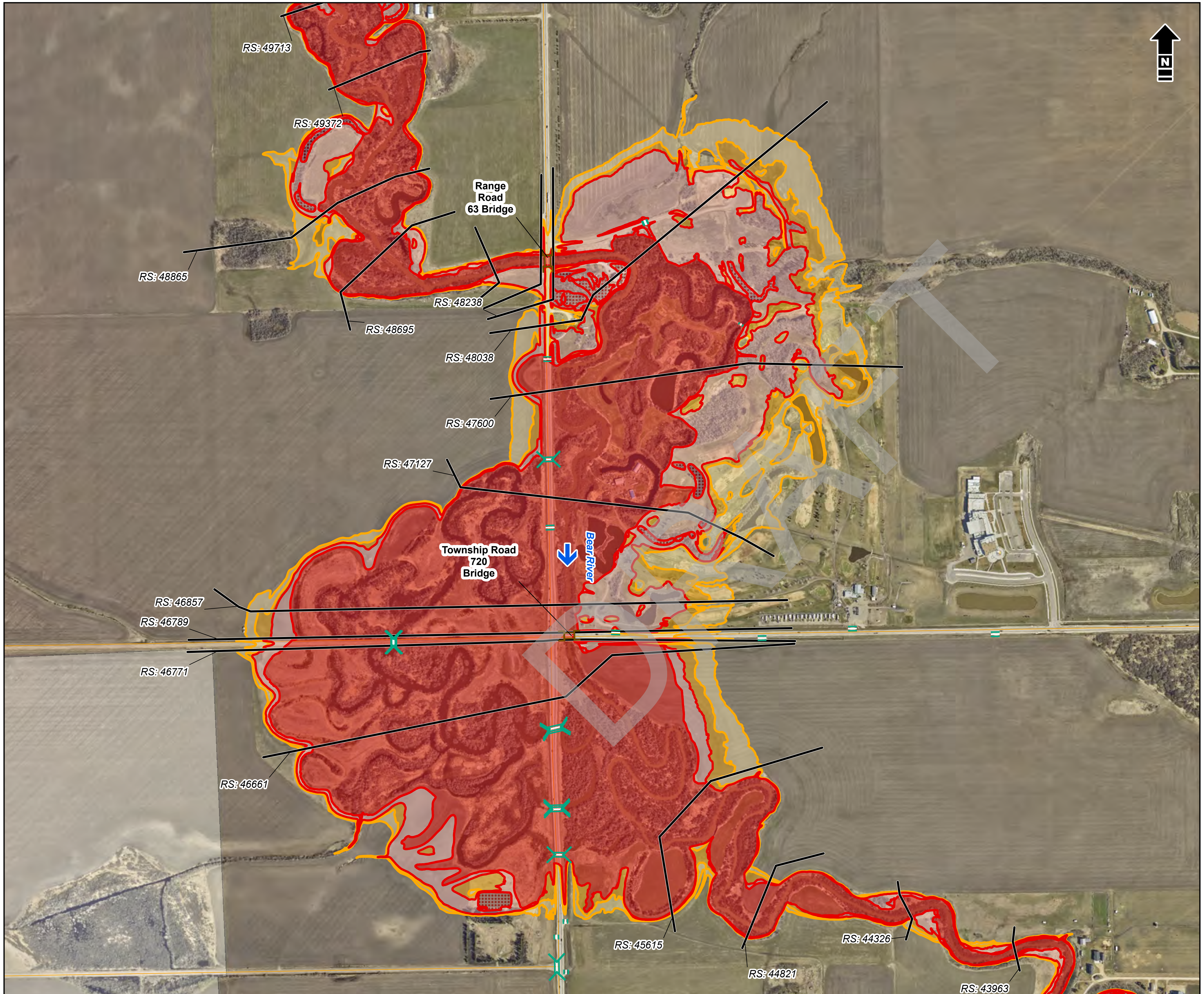

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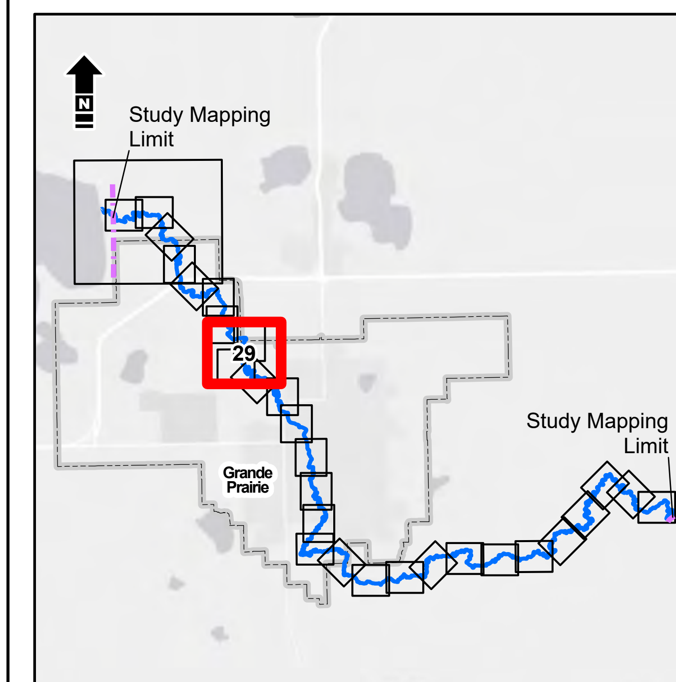

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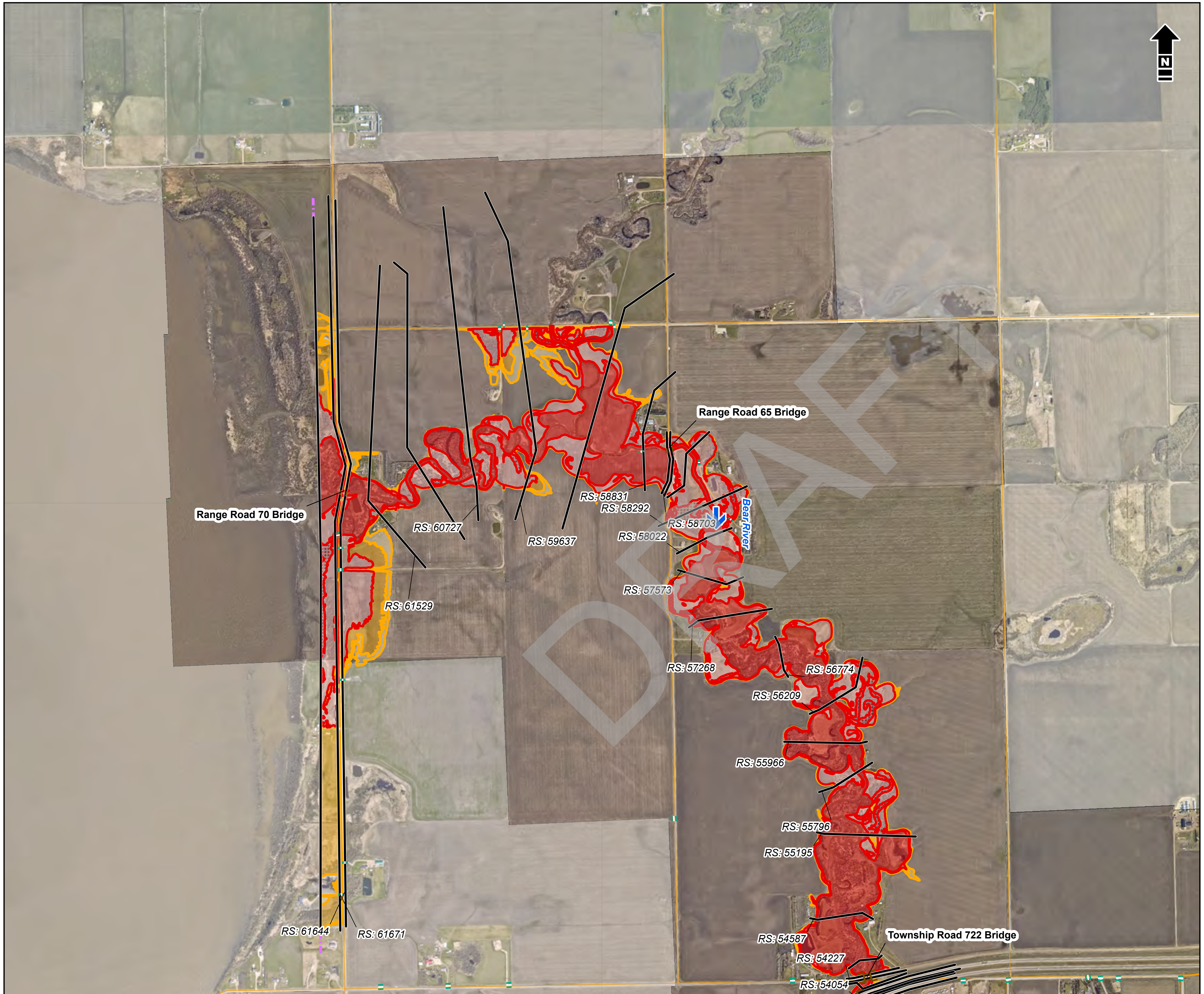

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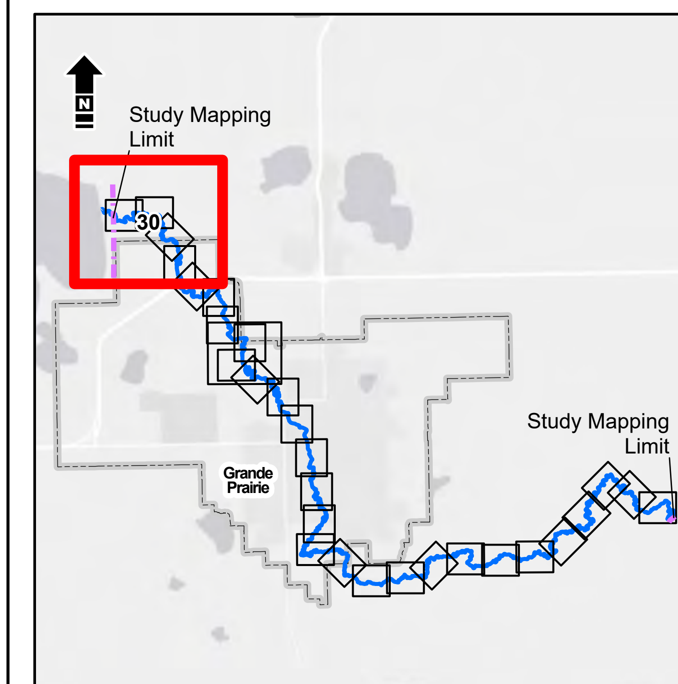

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