ST. ALBERT FLOOD HAZARD STUDY

STURGEON RIVER

Prepared for:
ALBERTA ENVIRONMENT AND PARKS

Prepared by:
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The field survey was conducted by Altus Geomatics. Hydraulic modelling was led by Pamela Rogers, with technical guidance provided by Karen Hofbauer, M.Sc., P.Eng. Map and database creation and organization was completed by Matthew Wilkinson, MGIS. Overall study management was completed by Sean Sullivan, M.Sc., P.Eng., and senior technical review and project direction was provided by Manas Shome, Ph.D., P.Eng.

EXECUTIVE SUMMARY

Matrix Solutions Inc. was retained by the Government of Alberta (GoA) to conduct a flood hazard study for Big Lake and the Sturgeon River near St. Albert, Alberta. This flood hazard 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 Matrix, Altus Group (surveying subcontractor), key project stakeholders, and GoA (including LiDAR provider Airborne Imaging).

Flow estimates for the 2-year to 1,000-year flood events on the Sturgeon River in St. Albert were estimated using frequency analysis based on a review of annual peak discharges recorded at two hydrometric stations along the Sturgeon River. Since no major tributaries enter the Sturgeon River within the study reach, a consistent flow rate was used for the entire reach for each flood event. A similar frequency analysis was conducted for available water level data collected on Big Lake. However, the frequency analysis of recorded Big Lake water levels is subject to uncertainty because some recorded water level data may not be representative of annual maximums. For example, the peak water level recorded in 1974 was taken in July whereas the 1974 flood occurred in April.

The Sturgeon River hydraulic model and resulting map products were constructed using LiDAR data provided by GoA and surveyed cross-section, flood control structure, and hydraulic structure data collected by Altus under Matrix'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. The hydraulic model was calibrated using surveyed high water marks collected during the 1974, 1982, and 2018 flood events, and Big Lake high water mark estimates using a georeferencing analysis of 1974 flood aerial photography. Calibration focused on the 1974 high water marks because the 1974 flood was most representative of the design flood used for this study. To best fit the 1974 calibration data, channel roughness ranged from 0.032 (upper reach) to 0.038 (lower reach) and overbank roughness ranged from 0.03 (landscaped parks) to 0.08 (tree/brush).

Big Lake water levels for specific return periods were mapped using the modelled water levels for the corresponding return period at the most upstream cross-section of the hydraulic model. These water levels were consistent with the results of the peak water level frequency analysis, considering the 95% confidence intervals estimated by the frequency analysis.

Open water flood frequency maps for the 2-year to 1,000-year flood events are provided in Appendix D. The 1:100-year design flood profile was used in preparing flood hazard maps for the study area. The governing floodway criterion for the flood hazard maps were the 1 m depth contour and 1 m/s flow velocity field, except for the reach between the Starkey Road Bridge and the CN Rail DS Trestle Bridge, where all inundated areas were considered undevelopable. Design flood hazard maps are provided in Appendix F.

TABLE OF CONTENTS

IN-TEXT TABLES

FIGURES

TABLES

APPENDICES

1 INTRODUCTION

Matrix Solutions Inc. was retained by the Government of Alberta (GoA) to conduct a flood hazard study for Big Lake and the Sturgeon River near St. Albert, Alberta. The four stakeholders for this project are City of St. Albert, City of Edmonton, Sturgeon County, and Parkland County.

This flood hazard 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 Matrix, Altus Group (surveying subcontractor), key project stakeholders, and GoA (including its providers of topography and aerial photography information).

1.1 Study Background

A flood hazard study to delineate the 100-year flood inundation boundaries for the Sturgeon River at City of St. Albert was completed in 1986 and updated in 1990 by GoA. Since that time, GoA has updated flood hazard identification methodology and expanded the scope of its Flood Hazard Identification Program (FHIP). This study is conducted under the Flood Hazard Identification Program, utilizing the following documents:

- *St. Albert Flood Hazard Study – Terms of Reference* (TOR; AEP 2019)
- *Flood Hazard Identification Program Guidelines* (AENV 2011)
- *Additional Work for St. Albert Flood Hazard Study Terms of Reference* (TOR; AEP 2021)

1.2 Study Objectives

The key study objectives included the following:

- Survey and base data collection:
  - surveying river cross-sections
  - surveying hydraulic structures and flood control structures
  - integrating survey and digital terrain model (DEM) data
- Open water hydrology assessment:
  - conducting a hydrologic analysis to provide flood water level and flow frequency estimates for Big Lake and the Sturgeon River, respectively
  - documenting open water flood history

- Open water hydraulic modelling:
  - creating, calibrating, and validating a HEC-RAS hydraulic model for the Sturgeon River
  - simulating 13 flood flow 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
- 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 area includes Big Lake (which lies within the jurisdiction of all four project stakeholders) and the Sturgeon River through the City of St. Albert and a portion of Sturgeon County (Figure 1).

The Sturgeon River originates about 75 km west of Big Lake at Hoople Lake and flows generally east through Isle Lake and Lac Ste. Anne before entering the north shore of Big Lake. Another major tributary to Big Lake is Atim Creek, which enters on the west shore. The Sturgeon River then continues northeast from the Big Lake Outlet, through the City of St. Albert, past the Town of Gibbons, before its confluence with the North Saskatchewan River just downstream of Fort Saskatchewan.

An approximately 31 km reach of the Sturgeon River is included in this study (the modelled reach), extending from the Big Lake Outlet to just downstream of Highway 37 (Figure 2). No major tributaries enter the Sturgeon River within this reach, nor are there any distributaries/bifurcations. The reach can be divided into two generalized sub-reaches: the upstream sub-reach and the downstream sub-reach. The upstream sub-reach extends from the Big Lake Outlet to approximately the downstream corporate limit of (northeast) of City of St. Albert and is characterized by a neutral channel profile that is occasionally confined and exhibits a winding channel pattern. The downstream sub-reach extends from the downstream corporate limit of City of St. Albert through Sturgeon County to Highway 37 and is characterized by an irregular channel profile that is frequently confined and exhibits irregular and distorted meanders.

2 SURVEY AND BASE DATA COLLECTION

Matrix conducted a site visit with GoA and City of St. Albert representatives on May 7, 2019 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 flood control structures and hydraulic structures to be included in the project, and refining the survey scope.

The survey work was completed between May 30 and June 18, 2019; Altus Group led the data collection and quality management process under Matrix's supervision and direction. Data collected along the study reach during the survey included the following:

- river cross-sections
- flood control structure geometry
- hydraulic structure (bridges) geometry
- Water Survey of Canada (WSC) hydrometric station benchmarks
- GoA high water mark benchmarks
- Alberta Survey Control Network (ASCN) benchmarks
- flow measurements
- 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 collected by Airborne Imaging (Airborne 2020) on behalf of GoA and was subsequently provided to Matrix to inform the St. Albert Flood Hazard Study.

2.1 Procedures and Methodology

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

- 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.

- Survey data is reported in 3-Degree Transverse Mercator (3TM) zone 114°, referenced horizontally to the Canadian Spatial Reference System, 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 were 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 A1.

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 both Altus Group and Airborne Imaging. A comparison of elevations confirmed consistency across the two surveys. The Altus Group benchmark elevations were adopted for this project.

TABLE A ASCN Benchmarks for Survey Control

ASCN Benchmark ID	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 114)		Airborne Imaging Ground Surveyed Elevation (m)	Altus Group 2019 Ground Surveyed Elevation (m)	Difference (m)
	Easting	Northing			
466110	18,965	5,939,664	665.333	665.337	+0.004
394965	26,878	5,947,245	662.609	662.581	-0.028
468702	23,401	5,943,177	659.290	659.243	-0.047
459172	24,488	5,945,178	672.536	672.516	-0.020
428896	25,489	5,947,106	681.615	681.667	+0.052

Benchmarks established during the 2018 GoA high water mark survey were also measured by Altus Group (Table B), except for benchmark Sturg-6, which was destroyed prior to the 2019 survey. A comparison of elevations indicated some disagreement between the two surveys and as a result the Altus Group surveyed elevations were adopted as directed by GoA. An elevation of 654.876 m was used for benchmark Sturg-6, representing a 0.08 m increase from the GoA 2018 measured elevation, approximately equal to the average difference for all other benchmarks.

TABLE B 2018 High Water Mark Benchmarks

GoA 2018 Benchmark ID	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 114)		GoA 2018 Surveyed Elevation (m)	Altus Group 2019 Surveyed Elevation (m)	Difference (m)
	Easting	Northing			
Sturg-1	22,736	5,943,022	656.356	656.409	0.053
Sturg-2	24,131	5,944,240	652.258	652.339	0.081
Sturg-3	24,347	5,944,461	654.461	654.550	0.089
Sturg-4	24,662	5,944,847	653.701	653.804	0.103
Sturg-5	24,898	5,944,941	654.485	654.544	0.059
Sturg-6	25,113	5,945,534	654.076	-	-
Sturg-7	25,590	5,946,169	655.329	655.458	0.129
Sturg-8	26,149	5,946,660	654.805	654.848	0.043
Sturg-9	28,515	5,950,459	658.902	658.995	0.093
Sturg-10	29,466	5,953,786	654.490	654.531	0.041

2.1.2 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 (Figure 2).

A Trimble® R10 GNSS Real-Time Kinematic (RTK) GPS System (Appendix A2) was used for the collection of most survey data and a Sonarmite MILSpec Single Beam Echosounder (Appendix A3) was used for the portions of the bathymetry where RTK equipment was not practical. The Sonarmite was used in conjunction with a Zodiac inflatable boat that was navigated along the river for the survey. Data collected by the Sonarmite were validated or corrected using overlapping data collected by the RTK in the portions of the channel nearest the bank. The combined accuracy of points collected through use of RTK GPS with echo-sounder meet the requirements listed in Section 2.1.

2.1.3 Hydraulic Structures

Hydraulic structure surveys were completed using the Leica P40 scanner (Appendix A4). At each structure, the scanner was set up once or multiple times to adequately capture the entire structure geometry as well as control points established at each hydraulic structure. An inventory of surveyed hydraulic structures is provided in Table C, listed upstream to downstream, and the structures are shown on Figure 2.

TABLE C Hydraulic Structure Details

Hydraulic Structure Name	Approximate River Station (m)	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 114)	
		Northing	Easting
Ray Gibbon Drive Bridge	32,644	5,943,045	22,696
CN Rail US Trestle Bridge	30,608	5,944,305	24,246
Children's Pedestrian Bridge	30,421	5,944,451	24,360
Perron Street Bridge	29,932	5,944,810	24,665
St. Albert Trail (Highway 2) Bridge	29,664	5,944,970	24,874
Benoit Pedestrian Bridge	28,987	5,945,500	25,134
Boudreau Road Bridge	28,089	5,946,156	25,535
Otter Crescent Pedestrian Bridge	27,078	5,946,643	26,163
Starkey Road (Range Road 251) Bridge	18,193	5,950,449	28,507
CN Rail DS Trestle Bridge	7,885	5,952,180	30,597
Highway 37 Bridge	3,613	5,953,786	29,488

2.1.4 Flood Control Structures

Flood control structure surveys were completed using standard RTK equipment and included toe and crest elevations at the start and end of the structures and at all locations where alignment or profile changes were evident. Locations and photographs of the identified flood control structures are provided in Appendix B. An inventory of surveyed flood control structures is provided in Table D, listed upstream to downstream.

TABLE D Flood Control Structure Details

Flood Control Structure Name	Description
Millennium Park Dyke	Right (south) bank of Sturgeon River between CN Rail US Trestle Bridge and St. Albert Place
St. Albert Professional Building Dyke	Right (south) bank of Sturgeon River between Perron Street Bridge and St. Albert Trail Bridge
Red Willow Park Dyke	Right (south) bank of Sturgeon River between St. Albert Trail Bridge and Burns Street Cul-de-sac

2.1.5 Flow Measurements

Flow measurements were collected by Matrix using either the Sontek RiverSurveyor M9 Acoustic Doppler Current Profiler (ADCP) or the Sontek FlowTracker Acoustic Doppler Velocimeter (ADV; Appendix A5). A summary of flow measurement timing and locations is presented in Table E. Concurrent water level surveys were conducted at approximately the same time as the flow measurements.

TABLE E Flow Measurements During Survey

Date and Time (MDT)	Location	Equipment and Method	Measured Flow (m^3/s)	Estimated Flow at WSC Sturgeon River at St. Albert Gauge (m^3/s)
Jun 4, 2019 @ 14:30	Perron Street	ADV by Wading	1.4	1.7
Jun 6, 2019 @ 14:30	Perron Street	ADCP from Bridge	1.5	1.6
Jun 6, 2019 @ 16:00	Ray Gibbon Drive	ADCP from Bridge	1.0	1.5
Jun 9, 2019 @ 14:00	River Station 26530	ADV by Wading	1.3	1.1
Jun 12, 2019 @ 10:00	Highway 37	ADV by Wading	1.2	0.8

3 FLOOD HYDROLOGY

3.1 Flooding History

3.1.1 General Information

The WSC maintains two hydrometric stations on the Sturgeon River, either in close proximity or within the study reach: Sturgeon River at St. Albert (05EA002), located 3 km downstream of the Big Lake outlet and Sturgeon River near Fort Saskatchewan (05EA001), located just upstream of the Sturgeon River/North Saskatchewan River confluence. A third hydrometric station operated by GoA is located on Big Lake (05EA902), near the Big Lake outlet, at which miscellaneous water levels have been recorded. The periods of available data for these stations is presented in Table F and locations of the stations are shown on Figure 1.

TABLE F Periods of Available Data

Gauging Station	Gross Drainage Area (km^2)	Data Type	Data Period
Sturgeon River at Fort Saskatchewan (05EA001)	3,250	Flow and level	1914 – 1922; 1928-1930; 1936 – 2018
Sturgeon River at St. Albert (05EA002)	2,610	Flow and level	1913-1927; 1976-1986; 2005 – 2018
Big Lake near St. Albert (05EA902)	2,640	Level	1958 – 2018

3.1.2 Historical Floods

Several historical floods along the Sturgeon River have been documented during the period of record, the three largest of which occurred in 1936, 1948, and 1974. Though these flood events were not measured directly at the St. Albert gauge (05EA002), they were estimated using measurements recorded downstream at the Fort Saskatchewan gauge (05EA001).

The largest flood event on the Sturgeon River occurred on April 27, 1974 with an estimated magnitude of 104 m^3/s (Alberta Environment 1990) at the St. Albert gauge. The 1974 flood represents a return period higher than the 100-year event based on flood frequency estimates provided in the 1990 floodplain study (Alberta Environment 1990). High water mark measurements were collected by Alberta Transportation during the April 1974 flood (exact date unknown) at the Perron Street Bridge, St. Albert Trail Bridge, Starkey Road Bridge, and CN Rail DS trestle bridge, as detailed in Section 4.1.3. Further, aerial imagery was collected on April 25, 1974 and was used to estimate high water mark elevations occurring around Big Lake, as discussed in Section 3.3.2.

The second and third highest floods on record occurred on May 7, 1948 and April 25, 1936, with estimated instantaneous peak discharges of 78.2 m^3/s and 50.5 m^3/s, respectively. Another notable flood also occurred on May 1, 1982, with an estimated instantaneous peak discharge of 33.6 m^3/s; high water mark measurements were collected by Alberta Transportation on April 30, 1982 at the CN Rail US trestle bridge, Perron Street Bridge, St. Albert Trail Bridge, and Boudreau Road Bridge, as detailed in Section 4.1.3.

Flood peaks on the Sturgeon River are typically associated with spring snowmelt and usually occur in late April/early May. Several stormwater outfalls located within the City of St. Albert discharge to the Sturgeon River. Consequently, summer rainfall events may result in relatively high contribution to total flow in the Sturgeon River; however, since flooding in the Sturgeon River is governed by snowmelt, the likelihood of these events occurring simultaneously is very low and thus the contribution of stormwater outfalls was not investigated further for this study.

3.1.3 Recent Floods

In 2018, a maximum instantaneous discharge of 20.2 m^3/s was recorded on April 29 at the St. Albert gauge, which represents a return period between the 2-year and 5-year flood events. Several high water mark measurements were collected by GoA throughout the study reach, as detailed in Section 4.1.3.

3.1.4 Ice Jam Floods

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

3.2 Flood Frequency Analysis (Sturgeon River)

3.2.1 Flood Frequency Flow Estimates

Hydrologic analysis was undertaken to determine 2-year to 1,000-year return period instantaneous flood estimates for the Sturgeon River to be used for subsequent hydraulic modelling and flood inundation mapping (Appendix D). Given the availability of flow data records, extending flood frequency estimates beyond approximately the 200-year return period is highly speculative; significant uncertainty exists for estimated flood frequencies with such infrequent return periods. This analysis involves evaluation of regional discharge data, extension of the hydrometric record based on a correlation between the St. Albert and Fort Saskatchewan gauging stations, analysis of the extended data series for statistical outliers, and selection of the most suitable probability distribution. A summary of the flood frequency estimates adopted for this study are provided below in Table G.

TABLE G Sturgeon River at St. Albert (05EA002), Flood Frequency Estimates

Return Period (years)	Instantaneous Peak Discharge[1] (m^3/s)	Lower 95% Confidence Limit (m^3/s)	Upper 95% Confidence Limit (m^3/s)
2	14	12	16
5	27	22	32
10	39	30	47
20	52	39	64
35	64	47	81
50	72	52	92
75	82	58	106
100	90	62	117
200	110	74	146
350	130	83	172
500	140	90	190
750	155	97	212
1,000	166	103	229

1 Rounded to nearest whole number

3.2.2 Comparison to Previous Study

Table H presents a comparison of the flood frequency estimates determined for this study to the 1990 flood estimates (Alberta Environment 1990). The majority of high flood events occurred prior to 1984; thus, the additional data reviewed for this study tended to lower the flood frequency estimates. Nonetheless, the current flood frequency estimates are generally in agreement with the 1990 study. The current estimate of the 100-year instantaneous peak discharge decreased by only 2% as compared to the 1990 study.

TABLE H Comparison of 2019 and 1990 Flood Frequency Estimates

Return Period (years)	Instantaneous Peak Discharge[1] (m^3/s)	
	1990 Study[2]	Current Study
2	15	14
5	30	27
10	42	39
20	55	52
50	75	72
100	92	90
200	111	110

1 Rounded to nearest whole number
2 Alberta Environment (1990)

3.3 Water Level Frequency Analysis (Big Lake)

Estimates of water levels corresponding to various return periods are required for flood inundation mapping around Big Lake. Annual maximum water levels are normally required to conduct a frequency analysis and to compute water levels associated with various return periods. Water level data has been intermittently collected at WSC station 05EA902 (Big Lake near St. Albert) by AEP since 1958. However, the dataset is not continuous and thus the recorded data may not be representative of annual maximums. For instance, the maximum 1974 water level was collected on July 19, 1974 and not during the April 1974 flood of record. As a result, there is uncertainty when using the maximum recorded water levels for each year to conduct a frequency analysis of peak lake levels. To improve the available water level dataset, an effort was made to estimate the Big Lake water level for the 1974 flood event based on historical aerial imagery. This estimated value replaced the maximum recorded value for 1974 and was then used in subsequent water level frequency analysis, as discussed below.

3.3.1 Flood Photography

Aerial imagery covering the entire Sturgeon River study reach was collected by AEP on April 25, 1974. Imagery was imported to GIS and georeferenced based on fixed ground features that appeared to be consistent with 1974 conditions. The georeferenced images were then compared against the digital terrain model (DTM) to determine approximate high water mark elevations around the perimeter of Big Lake. The locations and values of these high water mark measurements are provided on Figure 3 and Table I.

TABLE I Big Lake High Water Marks Derived from 1974 Aerial Imagery

High Water Mark ID	Location	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 114)		Estimated Water Surface Elevation (m)
		Northing	Easting	
N01	Big Lake | North Shore	5,942,217	18,045	653.2
N02		5,942,243	18,206	653.1
N03		5,942,214	18,386	653.0
N04		5,942,275	18,466	653.2
N05		5,942,450	18,604	653.5
N06		5,942,487	18,628	653.6
N07		5,942,517	18,673	653.7
N08		5,942,598	18,773	653.2
N09		5,943,182	19,545	653.2
N10		5,943,224	19,965	652.9
S01	Big Lake | South Shore	5,941,562	22,480	653.6
S02		5,941,942	22,760	653.3
S03		5,942,008	22,829	653.1
S04		5,942,091	22,893	653.4
S05		5,942,200	22,965	653.3
S06		5,942,252	23,010	653.2
S07		5,942,298	23,043	653.4
S08		5,942,339	23,063	653.5

3.3.2 Flood Level Frequency Estimates

The high water marks interpreted from the aerial imagery range from 652.9 m to 653.7 m. Given that the observed 1974 high water mark at the St. Albert gauge is recorded as 653.25 m, any estimated values below this were discarded from consideration. As such, the revised range of estimated Big Lake water levels is 653.25 m to 653.70 m; these two potential values were used for two separate frequency analyses in place of the 1974 recorded maximum water level.

Water level frequency analysis considered several theoretical probability distributions including log-normal, 3 parameter log-normal, Pearson III, and log-Pearson III. Based on comparative assessment of various theoretical frequency distributions to the water level data, the 3-parameter log-normal distribution was considered the most representative distribution and was selected to determine water level frequency estimates in Big Lake.

HYFRAN Version 1.2 software was used to compute the water level frequency estimates and generate curves for each distribution. Table J presents the water level frequency estimates using both the high and low 1974 estimates.

TABLE J Big Lake Water Level Frequency Estimates

Return Period (years)	1974 Big Lake WSE = 653.25 m			1974 Big Lake WSE = 653.70 m		
	Estimated WSE (m)	Lower 95% Confidence Limit (m)	Upper 95% Confidence Limit (m)	Estimated WSE (m)	Lower 95% Confidence Limit (m)	Upper 95% Confidence Limit (m)
2	650.92	650.73	651.11	650.91	650.71	651.10
5	651.55	651.31	651.80	651.57	651.31	651.83
10	651.93	651.62	652.25	651.97	651.63	652.31
20	652.27	651.86	652.69	652.34	651.88	652.79
35	652.53	652.02	653.04	652.61	652.06	653.17
50	652.69	652.11	653.26	652.79	652.15	653.42
75	652.86	652.20	653.52	652.98	652.26	653.70
100	652.98	652.26	653.70	653.11	652.32	653.90
200	653.28	652.40	654.13	653.43	652.47	654.39
350	653.49	652.49	654.49	653.68	652.57	654.80
500	653.63	652.54	654.72	653.84	652.63	655.06
750	653.79	652.60	654.98	654.02	652.69	655.35
1,000	653.90	652.64	655.16	654.15	652.73	655.57

The estimated Big Lake water level frequency estimates were subsequently compared to Big Lake water levels simulated in the hydraulic model. This comparison and further discussion regarding the adopted methodology for flood inundation mapping around Big Lake is included in Section 5.1.

4 HYDRAULIC MODELLING

4.1 Available Data

4.1.1 Digital Terrain Model

A 0.5 m grid DTM was procured by AEP and provided to Matrix 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. Though there was generally good agreement between the DTM and overbank surveyed elevations, some areas were identified where a higher difference in elevation was observed. Generally, Light Detection and Ranging (LiDAR) derived elevations in areas where the overbank is vegetated with tall grasses/shrubs were 0.1 to 0.3 m higher than ground surveyed elevations, which indicates that the vegetation in these areas was not penetrated by the LiDAR. Larger differences in elevation (ranging from 0.3 m to 0.5 m) were observed in areas of steep/vertical surfaces/embankments such as near bridge decks/abutments. In discussion with AEP, these elevation differences were found to be 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 hazard study was undertaken in 1986 and updated in 1990 for the Sturgeon River at St. Albert. For the 1990 study, a Hec-2 hydraulic model was developed to calculate water surface profiles and delineate the floodway and flood fringe boundary for the 100-year flood. This Hec-2 model was provided to Matrix by AEP and was reviewed to compare and verify hydraulic parameters selected for use in the current hydraulic model.

4.1.3 High Water Marks

The largest recorded flood event in the Sturgeon River occurred on April 27, 1974 with a magnitude of 104 m^3/s (Alberta Environment 1990) at the St. Albert gauge. High water mark measurements were collected by Alberta Transportation during the 1974 flood event, though the exact date of survey is unknown. Two additional significant floods occurred on May 1, 1982 and April 29, 2018, with estimated instantaneous peak discharges of 33 m^3/s and 20.2 m^3/s, respectively. High water marks during the 1982 flood event were collected by Alberta Transportation on April 30, 1982 and measurements during the 2018 event were collected by AEP. The locations of the high water mark measurements are provided on Figure 4; Table K provides a summary of the high water mark data and corresponding flows.

TABLE K High Water Mark Data and Flows

AEP High Water Mark[1]	River Station	Observed Water Surface Elevation (m)
2018 Event (Q = 20.2 m^3/s)[1]		
Sturg-01-WL1	32632	651.85
Sturg-02-WL2	30765	651.79
Sturg-02-WL4	30670	651.79
Sturg-03-WL4	30605	651.82
Sturg-03-WL5	30573	651.81
Sturg-03-WL6	30487	651.80
Sturg-03-WL2	30422	651.80
Sturg-03-WL1	30382	651.78
Sturg-04-WL5	29939	651.76
Sturg-04-WL1	29916	651.75
Sturg-04-WL2	29882	651.72
Sturg-04-WL4	29817	651.76
Sturg-05-WL6	29642	651.68
Sturg-05-WL5	29602	651.67
Sturg-05-WL2	29563	651.66
Sturg-06-WL2	29048	651.65
Sturg-06-WL4	28983	651.64
Sturg-06-WL5	28939	651.60

AEP High Water Mark[1]	River Station	Observed Water Surface Elevation (m)
Sturg-07-WL3	28192	651.63
Sturg-07-WL4	28102	651.61
Sturg-08-WL4	27341	651.45
Sturg-08-WL3	27167	651.45
Sturg-08-WL1	27081	651.45
Sturg-08-WL2	27075	651.44
Sturg-09-WL1	18262	651.04
Sturg-09-WL5	18192	651.02
Sturg-09-WL3	18178	651.02
Sturg-09-WL4	18142	651.03
Sturg-10-WL4	3669	649.33
Sturg-10-WL1	3604	649.34
1982 Event (Q = 33 m^3/s)		
1982-STU-009-a	30605	652.06
1982-STU-011-c	29984	652.15
1982-STU-008-b	29712	652.09
1982-STU-008-c	29642	652.08
1982-STU-012-a	28076	651.94
1974 Event (Q = 104 m^3/s)		
1974-STU-011-a	29916	653.25
1974-STU-008-a	29642	653.15
1974-STU-010-a	18178	652.94
1974-STU-007-a	3619	651.36

1. Given a discrepancy in benchmarks surveyed in 2018 and 2019, the 2018 high water marks have been corrected to 2019 surveyed benchmarks, as directed by AEP. The Sturg-6 benchmark has been destroyed since 2018; therefore, a correction value of 0.08 m has been applied to these high water marks.

4.1.4 Gauge Data and Rating Curves

As discussed in Section 3, WSC gauge 05EA002 (Sturgeon River at St. Albert) is located within the study reach at the Perron Street Bridge. Field recorded stage and discharge data for the gauge was provided by the WSC for a period spanning April 1982 to September 2019. The maximum recorded discharge at the gauge was 33.7 m^3/s, which represents a return period between the 5-year and 10-year flood events. The stage data was transformed to geodetic elevations based on a gauge datum elevation of 649.547 m. The rating curve based on recorded discharge-elevation data at the St. Albert gauge is presented on Figure 5.

4.2 River and Valley Features

4.2.1 General Description

The modelled reach can be divided into two generalized sub-reaches: the upstream sub-reach and the downstream sub-reach. The upstream sub-reach extends from the Big Lake Outlet to approximately the downstream (northeast) end of St. Albert and is characterized by a neutral channel profile that is occasionally confined and exhibits a mildly winding channel pattern. The channel bed slope within the upstream sub-reach is approximately 0.00005 m/m.

The downstream sub-reach extends from the downstream end of St. Albert to Highway 37 and is characterized by an irregular channel profile that is frequently confined and exhibits irregular and distorted meanders. The channel bed slope within the downstream sub-reach is approximately 0.00015 m/m. The characteristics described in the following sections reflect those common to both the upstream and downstream sub-reaches.

4.2.2 Channel Characteristics

The channel cross-section is generally stable with gently sloped banks and an average bankfull width and depth of about 21 m and 2.5 m, respectively. The substrate is composed predominantly of silt. For most of the reach, bank vegetation consists of short grasses with interspersed areas of typical riparian vegetation (i.e., cattails, shrubs, occasional trees, etc.). Vegetation is irregularly present in the wetted width of the channel, typically in small wetland vegetation communities that extend from the bank into the channel. Due to its mild slope, corresponding low velocities, and, in part, to high nutrient loading from upstream agricultural activities, vegetation will grow on the channel bed throughout the growing season generally reaching a maximum in the late summer.

For the selection of a roughness coefficient, the channel was described as clean with some pools and shoals. The upstream sub-reach was defined as straight and the downstream sub-reach was defined as winding, for which Manning roughness values could vary between 0.025 and 0.045.

4.2.3 Floodplain Characteristics

In the vicinity of the modelled reach, the Sturgeon River valley is approximately 40 m deep and ranges from 1.5 km to 2.8 km wide.

In the upstream sub-reach, the left and right natural floodplains are moderately sloping as they transition from the straight channel to the surrounding urban areas. The left floodplain is generally bounded by fill for development whereas the right floodplain is bounded by flood control structures, steeper valley walls, or fill for development. Ground cover just downstream of Big Lake consists of trees, shrubs, and tall grasses, which transitions to short grass and parks within St. Albert.

In the downstream sub-reach, the irregular channel profile and meandering has resulted in a flat floodplain that is generally bounded on each side by a steep valley wall. Remnant oxbows are apparent throughout the floodplain as a result of the meander to cutoff channel process. Ground cover for this floodplain generally consists of tall grasses and shrubs with some agricultural areas and interspersed naturally forested areas.

4.2.4 Anthropogenic Features

Numerous anthropogenic features exist within the study reach. A description of the key anthropogenic features and their interpreted impact on flood hydraulics are described below:

- Rail and road bridges – construction of these bridges require areas of fill that are adjacent to the channel banks. As a result, the floodplains are constricted at these bridge crossings, resulting in some backwater effects on the upstream end, particularly at extreme flood events.

- Flood control structures and other pathways – numerous pedestrian and bike pathways exist near the channel within the floodplains. Several of these pathways are raised above natural ground elevation, either to act as a flood control structure or to provide enough cover for water mains to prevent freezing. These features generally result in very minor impacts to channel and floodplain conveyance capacity as they are perpendicular to flow and located generally in areas of shallower or slower moving water.

4.3 Model Construction

4.3.1 Methodology

The HEC-RAS hydraulic modelling software (version 5.0.7; USACE 2016) was used to simulate flood levels through the model reach for design floods associated with various return periods. HEC-RAS is a one-dimensional, fixed bed model that solves 1D 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 dykes or levees. 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 study reach is 30.6 km long extending from the Big Lake outlet to the Highway 37 Bridge; low channel slopes are present throughout the study reach such that subcritical flow conditions are expected. The downstream model boundary has been extended 3.5 km 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 136 channel cross-sections were surveyed along the Sturgeon River for inclusion in the model. Individual surveyed points were projected perpendicularly to the linear cross-section alignments provided in the approved survey plan and surveyed cross-sections were extended into the floodplain based on the

DTM provided to Matrix by AEP. Table 1 provides a summary of cross-sections included in the model. The combined channel and floodplain data often amounted to more than 500 points per cross-section (i.e., the maximum allowable number of data 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.

4.3.2.2 Bridge Data

All bridges along the study reach were included in the hydraulic model, including two rail (trestle) bridges, six vehicle bridges, and three pedestrian bridges, as detailed in Table 2. It should be noted that piers for the future twinning of Ray Gibbon Drive Bridge have already been constructed in the Sturgeon River immediately upstream of the existing bridge. Given the relative certainty of construction, Ray Gibbon Drive Bridge has been simulated in its future (twinned) geometry.

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 major crossings (including rail and vehicle bridges), at which abrupt changes in the effective flow area are encountered. Contraction and expansion coefficients of 0.2 and 0.4, respectively, were adopted for pedestrian bridges, which are deemed to experience moderate contraction and expansion transitions. With the exception of Ray Gibbon Drive Bridge, all coefficients are consistent with those adopted in the 1990 flood hazard study.

4.3.2.3 Flood Control Structures

Three flood control structures within the study reach were identified by the City of St. Albert, as detailed in Table D. Topographic survey data defining the flood control structures was collected during the survey program for inclusion in the hydraulic model, as discussed in Section 2.1.3.

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 defined upstream and downstream of bridge crossings as well as through the inside of meander bends where near zero velocities were expected. Ineffective flow areas were initially defined based on visual inspection of the DTM and were adjusted slightly during the calibration process. Though sufficient adjustment to these parameters may be feasible to match observed water levels very closely, it is important to maintain gradual variations in roughness throughout the study reach and prescribe reasonable values for the given conditions.

For this study, the HEC-RAS model was calibrated to surveyed high water marks for the 1974 flood event and validated against the 1982 and 2018 flood events. The 1974 flood was selected as the primary calibration event as this discharge is similar to the 100-year flood, which is the discharge of interest for flood hazard mapping. The calibration events and their associated high water marks are detailed below:

- 2018 peak flood event
  - high water marks measured at all bridge crossing locations (with the exception of CN Rail DS trestle bridge)
  - Q = 20.2 m^3/s on April 29, 2018 at the St. Albert gauging station (between the 2-year and 5-year flood)
- 1974 peak flood event
  - high water marks measured at Perron Street Bridge, St. Albert Trail Bridge, Starkey Road Bridge and Highway 37 Bridge
  - Q = 104 m^3/s on April 27, 1974 at the St. Albert gauging station (between the 100-year and 200-year flood)
- 1982 peak flood event
  - high water marks measured at CN Rail US trestle bridge, Perron Street Bridge, St. Albert Trail Bridge, and Boudreau Road Bridge
  - Q = 33 m^3/s on May 1, 1982 at the St. Albert gauging station (between the 5-year and 10-year flood)

Though Ray Gibbon Drive Bridge was constructed in 2005, it was included in the model geometry (in its future twinned geometry) for the all calibration simulations. For all calibration runs, the presence of Ray Gibbon Drive Bridge had a negligible effect on model calibration results, as detailed in Section 4.3.3.2.

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 0.000075 m/m, which is equivalent to the average lower channel reach bed slope. Channel roughness values of 0.032 for the upper model reach (Big Lake outlet to downstream end of St. Albert at RS 24674) and 0.038 for the lower model reach (from downstream end of St. Albert to the downstream model limits) provided the best fit to the observed high water marks for all discharges.

Independent calibration of the overbank roughness values was not feasible for the following reasons: though several observed water levels are available for the 2018 event, this discharge is primarily contained within the channel; and limited observed water levels are available for the 1982 and 1974 events. Rather, overbank roughness values were selected based on aerial imagery and photographs collected during the survey based on guidance provided in Chow (1959).

4.3.3.2 Calibration Results

Figure 6 provides a comparison of the simulated water surface profiles and observed high water marks for the calibration and validation model runs. Table 3 provides a summary of the simulated and observed water surface elevations.

For the 2018 event, the average and maximum water level differences are 0.20 m and 0.29 m, respectively. The largest difference occurred at RS 28102 (Boudreau Road Bridge). For the 1982 event, the average absolute and maximum water level differences are 0.15 m and 0.24 m, respectively. The largest difference occurred at RS 28076 (Boudreau Road Bridge). For the 1974 event, the average absolute and maximum water level differences are 0.04 m and 0.55 m, respectively. The largest difference occurred at RS 18178 (Starkey Road Bridge).

4.3.4 Flood Frequency Profiles

Figure 7 provides the simulated water surface profiles for the 2-year to 1,000-year flood discharges; Table 4 provides the simulated water surface elevations at each model cross-section for the range of flood events. The St. Albert WSC gauging station rating curve with hydraulic model outputs for the range of modelled discharges is presented on Figure 5. Normal depth was adopted as the downstream boundary condition based on an assumed energy slope 0.000075 m/m for all model simulations. A channel roughness of 0.032 and 0.038 was adopted for the upper and lower model reaches, respectively, for all model simulations; variable overbank roughness values were selected based on visual inspection of aerial imagery and field observations and ranged from 0.03 to 0.08 corresponding for landscaped park space and tree/brush covered areas, respectively.

4.3.5 Model Sensitivity

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

- variation of the downstream water level slope (± 20%)
- variation of the Manning roughness values (± 20%)

Figure 8 and Table 5 provides a comparison of the simulated water surface profiles for the variable downstream boundary conditions. The deviation in water surface elevation from the calibrated 100-year flood profile converges to less than 0.05 m by RS 7509.

The channel roughness for the upper and lower sub-reaches adopted for the calibrated profile are 0.032 and 0.038, respectively; the alternate channel roughness values investigated here are 20% above and below these values, which represents a reasonable range for the Sturgeon River. Figure 9 and Table 6 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 0.10 m and 0.15 m, respectively, for the lower values of n = 0.026/0.03, while these differences are 0.09 m and 0.13 m, respectively, for the higher values of n = 0.038/0.046.

Figure 10 and Table 7 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 0.10 m and 0.14 m, respectively, for the lowered overbank roughness values, while these differences are 0.09 m and 0.12 m, respectively, for the elevated overbank roughness values.

These variations are considered to be within the expected modelling accuracy. It is concluded that the hydraulic model based on the assigned overbank roughness values and the channel roughness values of 0.032/0.038 can be confidently used for developing flood inundation maps and flood hazard maps for the study reach.

5 FLOOD INUNDATION MAPS

5.1 Methodology

5.1.1 Sturgeon River

The flood surface profiles for all open water inundation scenarios modelled along the Sturgeon River were interpolated and translated to inundation boundaries through ArcGIS Desktop using the 3D Analyst extension. 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. 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 hydro-flattened DTM product compared against the interpolated water surface does not have the bathymetry of the channel and the lake 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 and the lake 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.

5.1.2 Big Lake

For generation of the flood inundation boundaries around Big Lake, two approaches were considered: 1) using the water level frequency analysis results (see Section 3.3) and 2) using the water levels predicted by the calibrated hydraulic model under various design flood events at its upstream boundary (RS 33252; corresponding to the Big Lake Outlet). A discussion of both potential methods is provided below.

5.1.2.1 Water Level Frequency Analysis

As discussed in Section 3.3, frequency analysis of recorded Big Lake water levels is subject to uncertainty because some recorded water level data may not be representative of annual maximums. Of particular note, the maximum 1974 water level was measured in July, while the 1974 flood of record on the Sturgeon River occurred in April. Because of this, efforts were made to estimate the peak 1974 water level from post-flood aerial photography. Due to the uncertainty inherent in this approach, a potential range (maximum and minimum) of water levels during the 1974 flood were estimated, as opposed to one single value. These resulting peak estimates were used for the water level frequency analysis in place of the recorded maximum 1974 water level. The frequency analysis results using the revised 1974 values are deemed to be more reliable than using the recorded 1974 peak; however, given that other maximum annual water levels are not adjusted similarly, the frequency analysis results are likely somewhat lower than what could be expected if actual peak water levels were used.

5.1.2.2 Water Levels Computed by Hydraulic Model

There is a hydraulic relationship between Big Lake and the Sturgeon River: the water level in Big Lake governs the hydraulics at the Outlet and thus the flow entering the Sturgeon River. In other words, it is a reasonable assumption that the X-year return period flow in the Sturgeon River would occur simultaneously with the X-year return period water level in Big Lake. As such, the modelled water levels at the Big Lake Outlet (RS 33252) during each of the 2-year through 1,000-year return periods on the Sturgeon River could provide approximate water levels for the corresponding return periods in Big Lake.

5.1.2.3 Selected Method

The results from both methods described above are presented on Figure 11. It is observed that for the 1,000-year flood, the water level simulated in the hydraulic model (654.45 m) is 0.30 m higher than the Big Lake frequency analysis estimate (654.15 m[1]). It is not surprising that the frequency analysis results are lower, due to the lack of actual peak water levels, as stated above. In addition, the difference between the results is within the uncertainty of the water level frequency analysis.

[1] As determined using the estimated 1974 Big Lake water level of 653.70 m.

The computed water levels at model RS 33252 were selected for flood inundation mapping around Big Lake because of the following:

- the water level frequency analysis was expected to underestimate the water levels associated with various return periods because recorded water level data may not be representative of true annual maximums due to measurement timing
- the hydraulic relationship between Big Lake water levels and Sturgeon River flows should be reasonably approximated by the calibrated hydraulic model
- the hydraulic model water levels were within the 95% confidence interval from the water level frequency analysis for the 10-year flood and higher
- the 1974 flood was estimated to be between the 100-year and 200-year flood; the 100-year and 200-year water level frequency analysis estimates using a 1974 value of 653.70 m (the upper end of the range) were 653.11 m and 653.43 m, respectively, further suggesting the frequency analysis results may be too low

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. 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. Table L describes where and what type of manual TIN modifications were applied.

TABLE L TIN Profile Modification Summary Table

Location	Description	Side of Channel	Inundation Scenario	Overtopping Point
Highway 44 to RS: 33,252	Big Lake	Both	All	Not Applicable[1]
RS: 25,031 to RS: 24,674	East Municipal Boundary	Left	2-Year	Single
RS: 25,654 to RS: 24,674	East Municipal Boundary	Left	5-Year	Single
RS: 3,761 to RS: 3,669	South of Highway 37	Left	5-Year	Single
RS: 4,172 to RS: 3,669	South of Highway 37	Left	10-Year	Single
RS: 30,605 to RS: 30,251	Millennium Park Dyke	Right	200-Year	Single
RS: 30,056 to RS: 29,984	Red Willow Dyke	Right	1,000-Year	Single
RS: 39,602 to RS: 29,563	Red Willow Dyke	Right	750-Year	Single
RS: 39,602 to RS: 29,563	St. Anne Street Between Millennium Park and St. Albert Professional Building Dyke	Right	1,000-Year	Single

1. Big Lake was manual TIN profile adjustment but would not be considered an overtopping point.

5.3 Flood Inundation Areas

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

5.3.1 Key Observations

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

- Several residences located along the north shore of Big Lake immediately south of Meadowview Drive are impacted by flooding at the 35-year flood and higher (see map sheet 4 of 20).
- Residences within the subdivision east of Range Road 264 and north of Township Road 532, at the southwest corner of Big Lake, are impacted by flooding at the 350-year flood and higher (see map sheet 2 of 20).
- The Riel Industrial Park, located on the right bank upstream of CN Rail US trestle bridge, is impacted by flooding at the 100-year flood at higher (see map sheet 9 of 20). However, only a small portion of the industrial area is flooded at the 1,000-year flood.
- The Red Willow Place Senior Citizens Club is impacted by flooding at the 200-year flood and higher (see map sheet 9 of 20).
- Downtown St. Albert is impacted by flooding at the 350-year flood and higher (see map sheet 10 of 20).
- Given the lack of development near the bottom of the river valley downstream of St. Albert, only minimal permanent infrastructure is impacted by any flood events.
- Overtopping of the vehicle bridges occurs at the following flood events and higher:
  - Ray Gibbon Drive – road segment to the northwest overtopped at the 500-year flood
  - Perron Street Bridge – bridge/road not overtopped
  - St. Albert Trail Bridge – road segment to the southwest overtopped at the 500-year flood
  - Boudreau Road Bridge – bridge/road not overtopped
  - Starkey Road Bridge – bridge/road not overtopped
  - Highway 37 Bridge – bridge/road not overtopped

5.3.2 Flood Control Structures

A summary of the inundation related to the flood control structures is presented below:

- Millennium Park Dyke
  - The toe of dyke is above the simulated water surface for the 50-year flood and lower. Therefore, no potential failure inundation is mapped for these flood events.
  - The dyke is subject to potential flood control structure failure inundation at the 75-year and 100-year floods.
  - At the 200-year flood and higher, the area behind the dyke is directly connected to the main channel, with adjacent buildings and parking areas impacted by flooding.
- St. Albert Professional Building Dyke
  - The toe of dyke is above the simulated water surface for the 200-year flood and lower. Therefore, no potential failure inundation is mapped for these flood events.
  - For the 350-year flood, the simulated water surface is above the toe of dyke, which would result in potential failure inundation. However, the dyke crest elevation is not consistent along its alignment; the dyke is outflanked at both the upstream and downstream ends (which are lower than the middle section of the dyke). As a result, there is direct inundation behind the dyke at the 350-year flood and higher.
- Red Willow Park Dyke
  - The toe of dyke is above the simulated water surface for the 500-year flood and lower. Therefore, no potential failure inundation is mapped for these flood events.
  - For the 750-year flood, the simulated water surface is above the toe of dyke, which would result in potential failure inundation. However, the dyke crest elevation is not consistent along its alignment; a low section exists near the upstream end where a pedestrian pathway crosses the dyke. As a result, there is direct inundation behind the dyke at the 750-year flood and higher.

5.3.3 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.

Several culverts affecting otherwise isolated areas were identified throughout the study area during the site visit or by reviewing aerial imagery. All of these identified culverts are shown on the open water flood inundation maps and their associated isolated areas were included in the inundation mapping. There are potentially other culverts that were not identified during the site visit and aerial imagery review that may result in inundation of isolated areas that are not shown on the maps. However, these areas were reviewed by Matrix and GoA and were removed from the maps because hydraulic connection could not be confirmed, or because inundation within these areas would not meaningfully affect nearby landowners or stakeholders.

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 (AENV 2011), 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 (AENV 2011), incorporating technical changes implemented in 2021 (AEP 2021) 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 GHIP 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.
  - In no case should the floodway extend into the main channel area.
  - For reaches of supercritical flow, the floodway boundary should correspond to the edge of inundation or the main channel, whichever is larger.
- When a flood hazard map is updated, an existing floodway will not change in most circumstances. Exceptions to this would be:
  - 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 the design flood levels along the river (Table 8).

6.3.2 Design Flood Profile

Table 9 lists the water surface elevations computed for the 100-year design flood on the Sturgeon River. The water surface profiles are plotted on Figure 12.

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 20, Appendix E) provided in the Maps and Drawings section of this report show:

- inundation extents of the 100-year open water design flood
- areas where the depth of water is 1 m or greater and the corresponding 1 m depth contour
- the portions of each cross-section where the computed velocity is 1 m/s or greater
- the proposed floodway boundary, as well as the floodway stations corresponding to the floodway determination criteria
- isolated areas of non-flooded, high ground (i.e. "dry" areas) within the design flood extent
- the location and extent of all cross-sections used in the HEC-RAS model
- the previously mapped floodway boundary (where it exists)
- 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 F. The floodway is primarily governed by the 1 m depth contour for the Sturgeon River. Manual adjustments to the floodway boundary were made in some locations in consultation with AEP 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. There were also occurrences of depth greater or equalled to 1 m outside the previously mapped floodway. These areas are categorized as high hazard flood fringe zone.

6.3.4.1 Areas within the Floodway

Along the upper study reach (from the Big Lake outlet to CN Rail US Trestle Bridge), the floodway extends up to 200 m into the floodplain beyond the main channel and ranges in width from 60 to 320 m. Through the developed area of the City of St. Albert (between the CN Rail US Trestle Bridge and the Otter Crescent Pedestrian Bridge), the floodway is situated just beyond the main channel and has an average width of about 45 m. In the lower sub-reach, the floodway extends up to 800 m beyond the main channel through the wide meander bends into the floodplain; the floodway has an average width of 350 m. The floodway encompasses the entire inundation area between Starkey Road and CN Rail DS trestle bridge as this area is considered undevelopable.

6.3.4.2 Areas within the Flood Fringe

Around Big Lake, the flood fringe is generally quite narrow with the exception of some low-lying areas located immediately east of Highway 44 and near the Sturgeon River/Big Lake confluence. Several residences are partially located within the flood fringe along the north shore of Big Lake. Areas of high hazard flood fringe are present around the two inlets to Big Lake in a series of isolated deep areas. The area behind the Millennium Park Dyke along the Sturgeon River is identified as protected flood fringe area.

Through the developed area of the City of St. Albert, the flood fringe is narrow and consists generally of park space and treed areas. Along the lower sub-reach downstream of the City of St. Albert, the flood fringe is composed of undeveloped, low lying areas. High hazard flood fringe is also present consistently along the reach where the floodway was previously mapped. However, there are some areas where the 1 m depth contour covers a smaller area than the previous floodway boundary meaning that the floodway is reduced. High hazard flood fringe zones exist at RS 25031, RS 20978 and at the hydraulically connected feature at RS 3761 by the Highway 37 Bridge.

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. Table M provides a summary of the water level differences (as compared to baseline water levels) in the upper and lower sub-reaches for an increase of 10% and 20% to the 100-year flood discharge. Based on these results, and the similar impacts in water surface rise in the upper and lower river reaches, it would be reasonable to apply a freeboard 0.3 m to simulated design water levels when attempting to account for climate change concerns.

TABLE M Computed Water Levels for Potential Climate Change Impacts

	Water Level Difference (m) [1]	
	10% Increase (Q = 99 m^3/s)	20% Increase (Q = 108 m^3/s)
Upper Sub-Reach (RS 33252 to 24674)		
Average	0.13	0.29
Maximum	0.14	0.32
Lower Sub-Reach (RS 23024 to 3604)		
Average	0.10	0.22
Maximum	0.11	0.25

1. As compared to baseline water levels.

8 CONCLUSIONS

Flow estimates for the 2-year to 1,000-year flood events on the Sturgeon River in St. Albert were estimated using frequency analysis based on a review of annual peak discharges recorded at two hydrometric stations along the Sturgeon River. A similar frequency analysis was conducted for available water level data collected on Big Lake.

The Sturgeon River hydraulic model and resulting map products were constructed using LiDAR data provided by GoA and surveyed cross-section, flood control structure, and hydraulic structure data collected by Altus under Matrix's supervision. All surveyed data was tied together using ASCN benchmarks that were surveyed independently during the various data collection phases. The hydraulic model was calibrated using surveyed high water marks collected during the 1974, 1982, and 2018 flood events, and Big Lake high water mark estimates using a georeferencing analysis of 1974 flood aerial photography. Calibration focused on the 1974 high water marks because the 1974 flood was most representative of the design flood used for this study. To best fit the 1974 calibration data, channel roughness ranged from 0.032 (upper reach) to 0.038 (lower reach), and overbank roughness ranged from 0.03 (landscaped parks) to 0.08 (tree/brush).

Big Lake water levels for specific return periods were mapped using the modelled water levels for the corresponding return period at the most upstream cross-section of the hydraulic model. These water levels were consistent with the results of the peak water level frequency analysis, considering the 95% confidence intervals estimated by the frequency analysis, and are more conservative than the frequency analysis results.

Open water flood frequency maps for the 2-year to 1,000-year flood events are provided in Appendix D. A summary of major conclusions from the open water inundation maps is presented below:

- Several residences located along the north shore of Big Lake immediately south of Meadowview Drive are impacted by flooding at the 35-year flood and higher.
- Residences within the subdivision east of Range Road 264 and north of Township Road 532, at the southwest corner of Big Lake, are impacted by flooding at the 350-year flood and higher.
- The Riel Industrial Park, located on the right bank upstream of CN Rail US Trestle Bridge, is impacted by flooding at the 100-year flood and higher. However, only a small portion of the industrial area is flooded at the 1,000-year flood.
- The Red Willow Place Senior Citizens Club is impacted by flooding at the 200-year flood and higher.
- Downtown St. Albert is impacted by flooding at the 350-year flood and higher.

- Given the lack of development near the bottom of the river valley downstream of St. Albert, only minimal permanent infrastructure is impacted by any flood events.

- Overtopping of the vehicle bridges occurs at the following flood events and higher:

  - Ray Gibbon Drive – road segment to the northwest overtopped at the 500-year flood
  - Perron Street Bridge – bridge/road not overtopped
  - St. Albert Trail Bridge – road segment to the southwest overtopped at the 500-year flood
  - Boudreau Road Bridge – bridge/road not overtopped
  - Starkey Road Bridge – bridge/road not overtopped
  - Highway 37 Bridge – bridge/road not overtopped

The 100-year design flood profile was used to develop the flood hazard maps for the Sturgeon River. The governing floodway criterion for the flood hazard maps was the 1 m depth contour except for the reach between the Starkey Road Bridge and the CN Rail DS Trestle Bridge, where all inundated areas were considered undevelopable and included within the floodway. Design flood hazard maps are provided in Appendix F.

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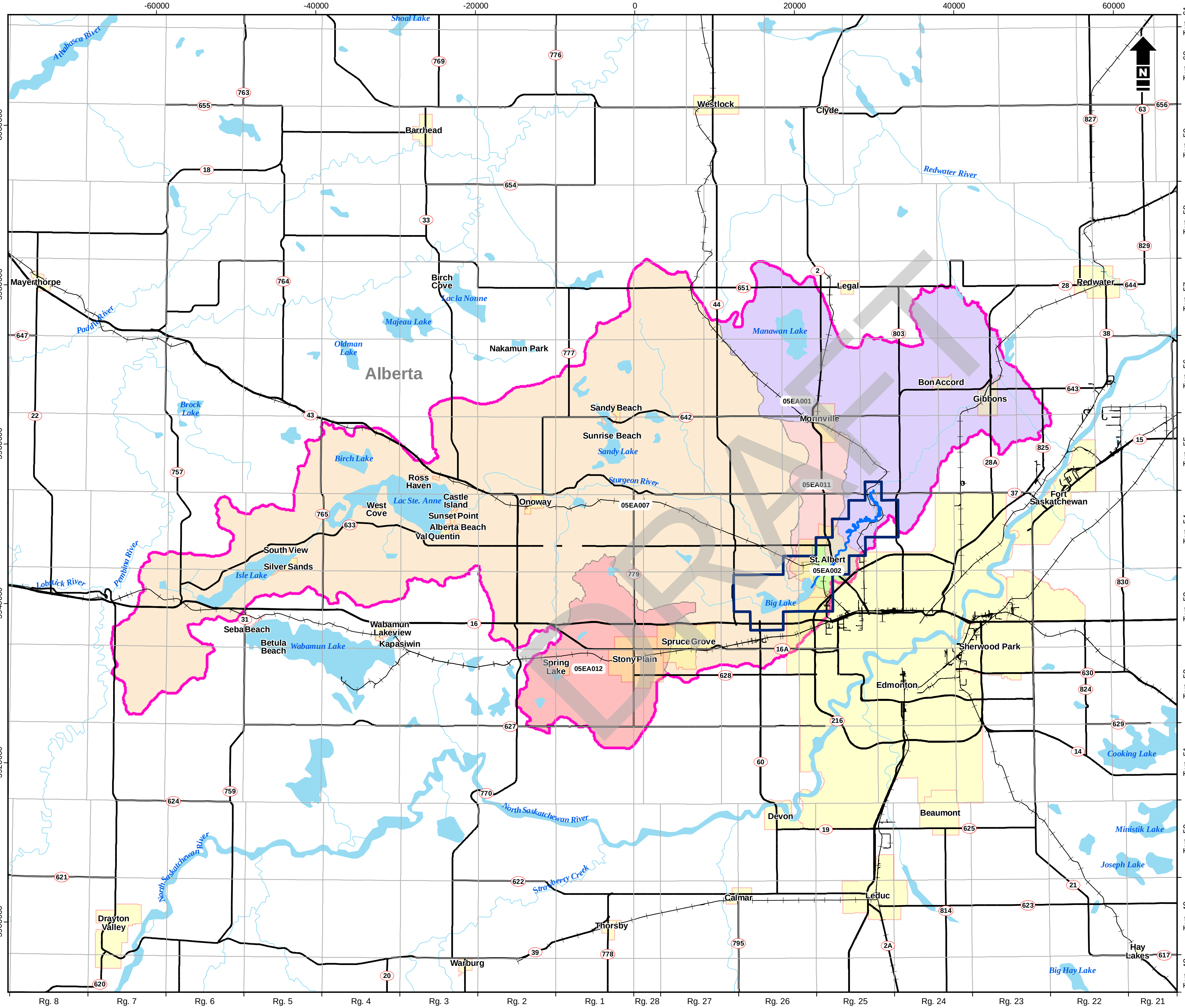

Sturgeon River Basin
LiDAR and Aerial Image Acquisition Extent
Community
Water Body
Watercourse
Sturgeon River Study Reach
Highway
Railway

WSC Subwatershed ID, WSC Subwatershed Name

05EA001, STURGEON RIVER NEAR FORT SASKATCHEWAN
05EA002, STURGEON RIVER AT ST. ALBERT
05EA007, BIG LAKE NEAR ST. ALBERT
05EA011, CARROT CREEK NEAR THE MOUTH
05EA012, ATIM CREEK AT CENTURY ROAD

1:500,000 metres
5,000 0 5,000 10,000
NAD 1983 CSRS 3TM 114

Reference: Data obtained from AltaLIS © Government of Alberta and GeoBase® used under license. Water Survey of Canada watershed boundaries obtained from Agriculture and Agri-foods Canada (2013) used under license.

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Alberta

Alberta Government
St. Albert Flood Hazard Study

Location Plan

Date:	Project:	Submitter:	Reviewer:
March 2020	28312	P. Rogers	M. Shome

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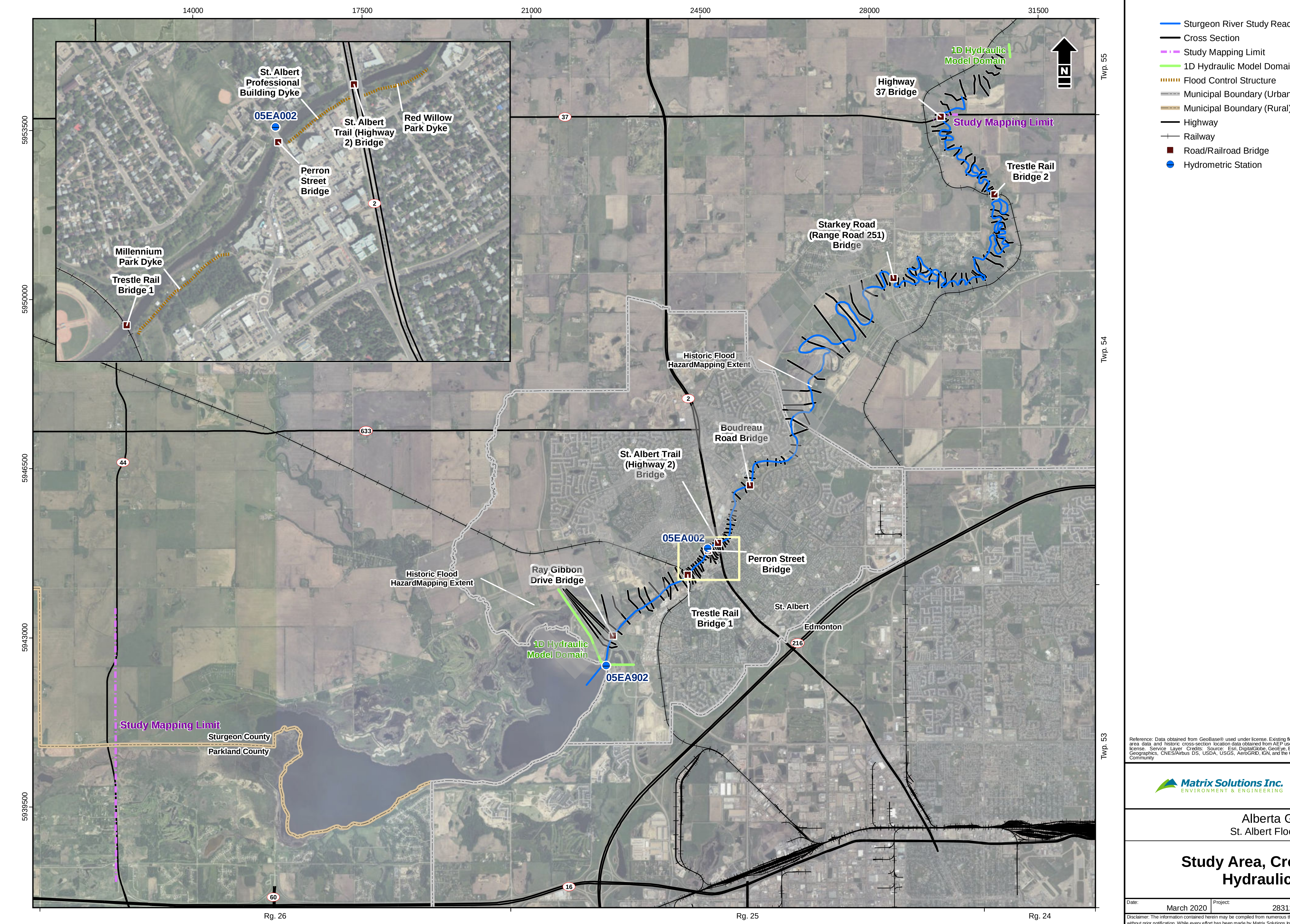
Figure 1

Classification: Public



Reference: Data obtained from GeoBase® used under license. Existing flood hazard area data and historic cross-section location data obtained from AEP used under license. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

1:75,000 metres
750 0 750 1,500
NAD 1983 CSRS 3TM 114

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St. Albert Flood Hazard Study

Study Area, Cross Sections and Hydraulic Structures

Date:	Project:	Submitter:	Reviewer:
March 2020	28312	P. Rogers	M. Shome

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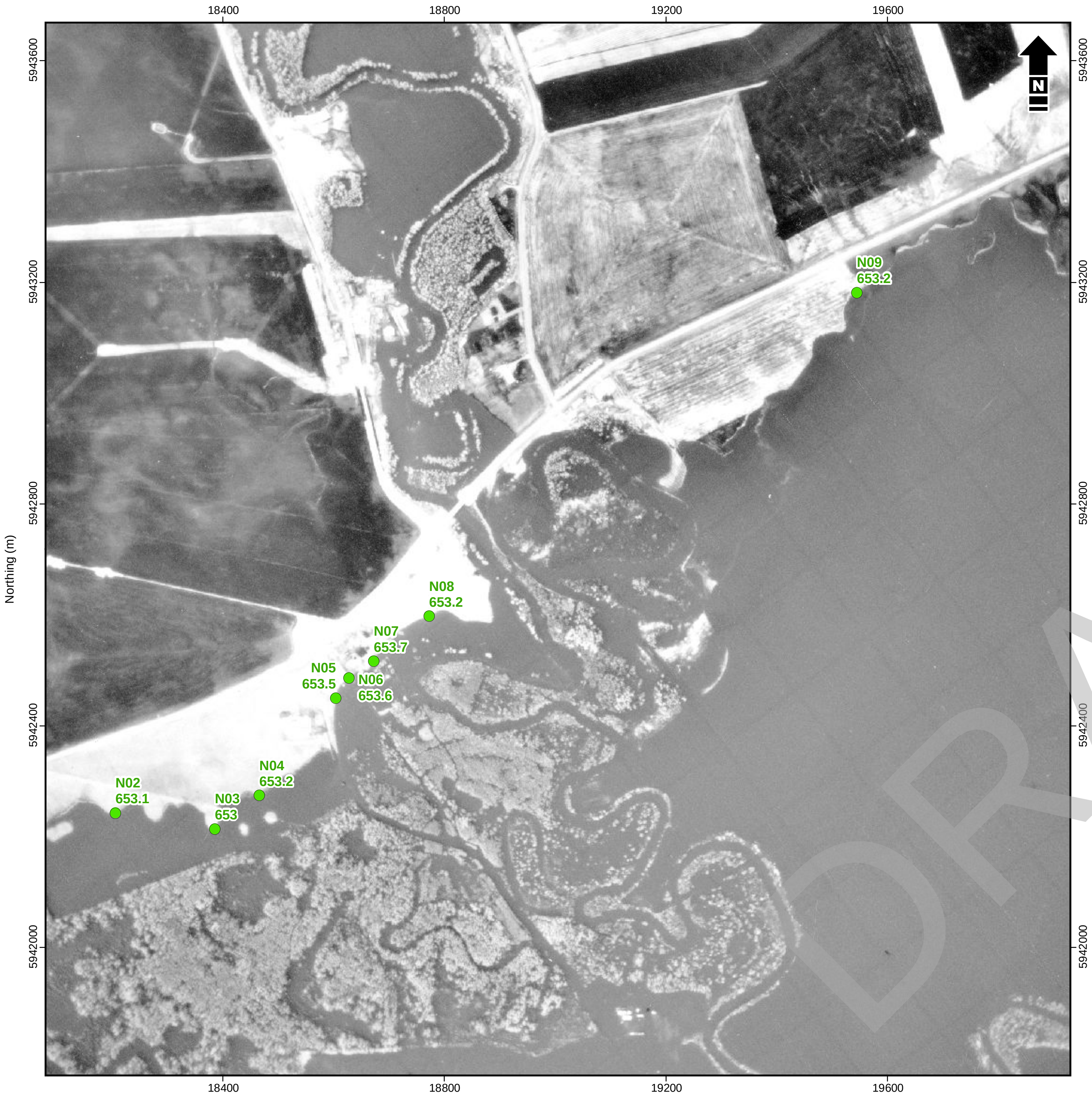
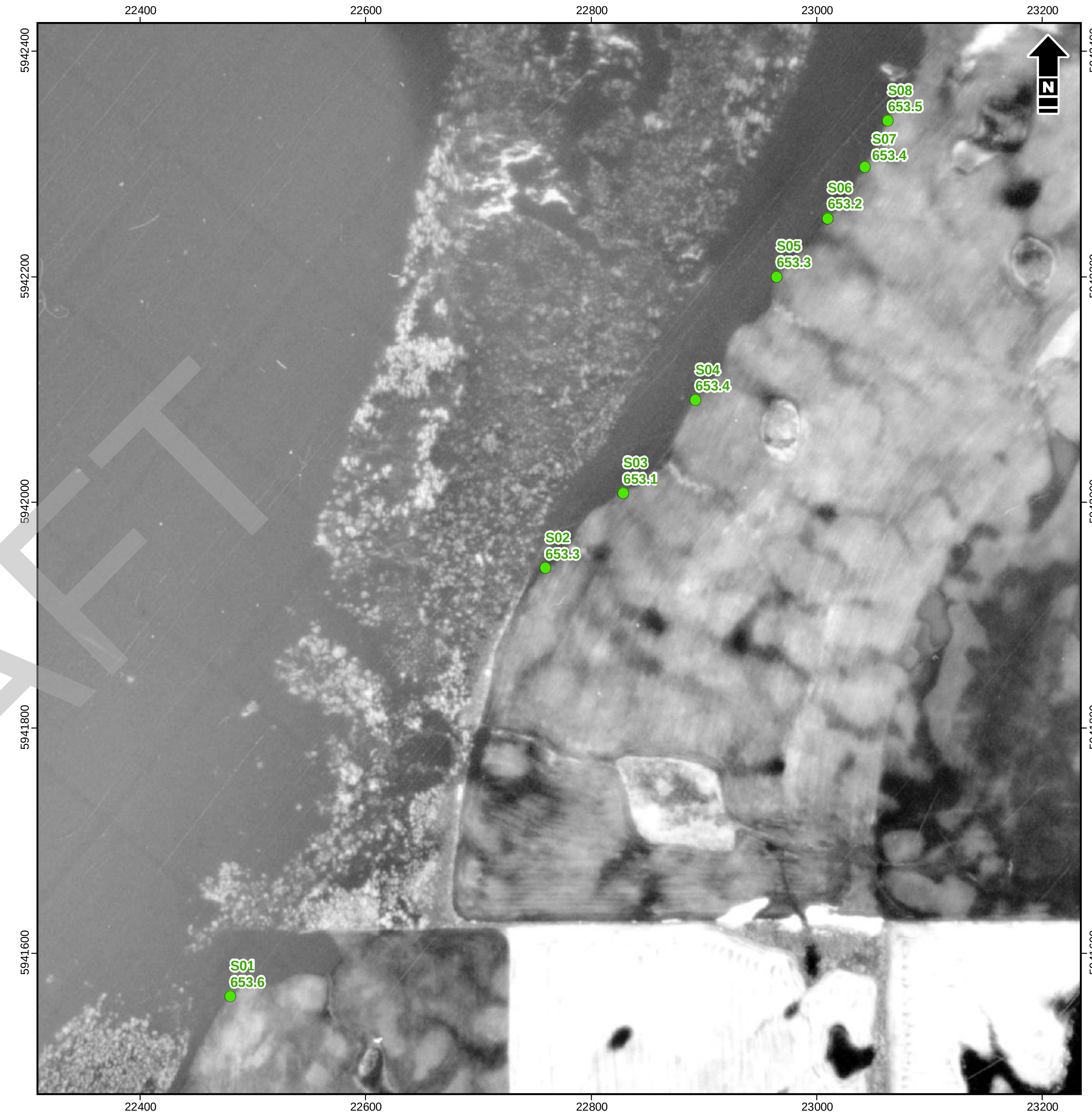
Figure 2

Classification: Public

Easting (m)



Big Lake | North Shore | r1286_269_ep



Big Lake | South Shore | r1286_274_ep

● High Water Mark Location | 1974 Georeferenced Imagery

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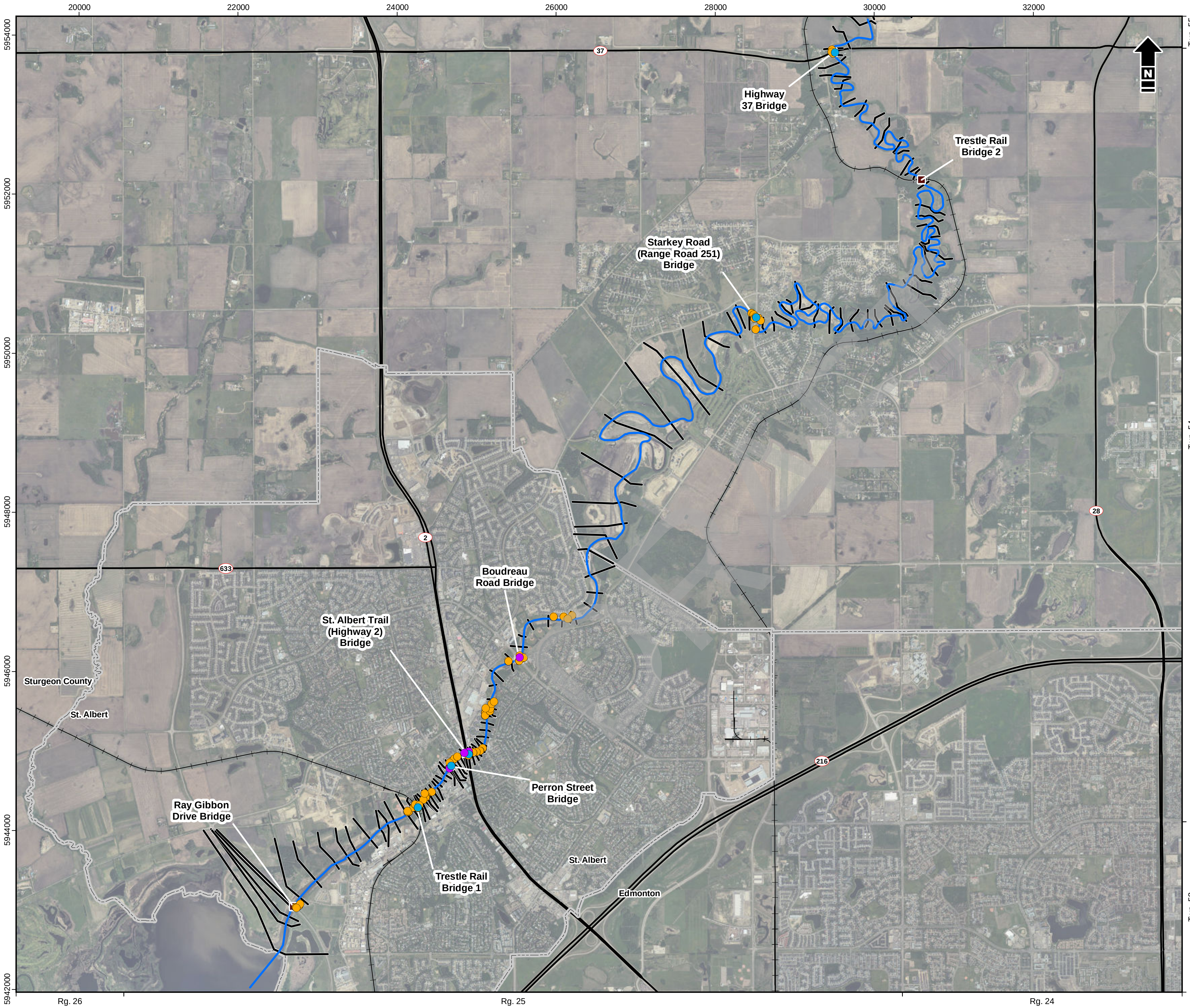
Big Lake High Water Mark Locations April 1974

Date:	Project:	Submitter:	Reviewer:
March 2020	28312	P. Rogers	M. Shome

Figure 3

Reference: Historical Air Photos (1974) provided by Alberta Environment and Parks (2020). Historic AEP Highwater Mark Database (2020). Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



- Sturgeon River Study Reach
- Cross Section
- Municipal Boundary (Urban)
- Municipal Boundary (Rural)
- Highway
- Railway
- Road/Railroad Bridge
- High Water Mark Location | 1974 Survey
- High Water Mark Location | 1982 Survey
- High Water Mark Location | 2018 Survey

Reference: Data obtained from GeoBase® used under license. Existing flood hazard area data and historic cross-section location data obtained from AEP used under license. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

1:50,000 metres
500 0 500 1,000
NAD 1983 CSRS 3TM 114

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St. Albert Flood Hazard Study

Sturgeon River High Water Mark Locations

Date: March 2020	Project: 28312	Submitter: P. Rogers	Reviewer: M. Shome

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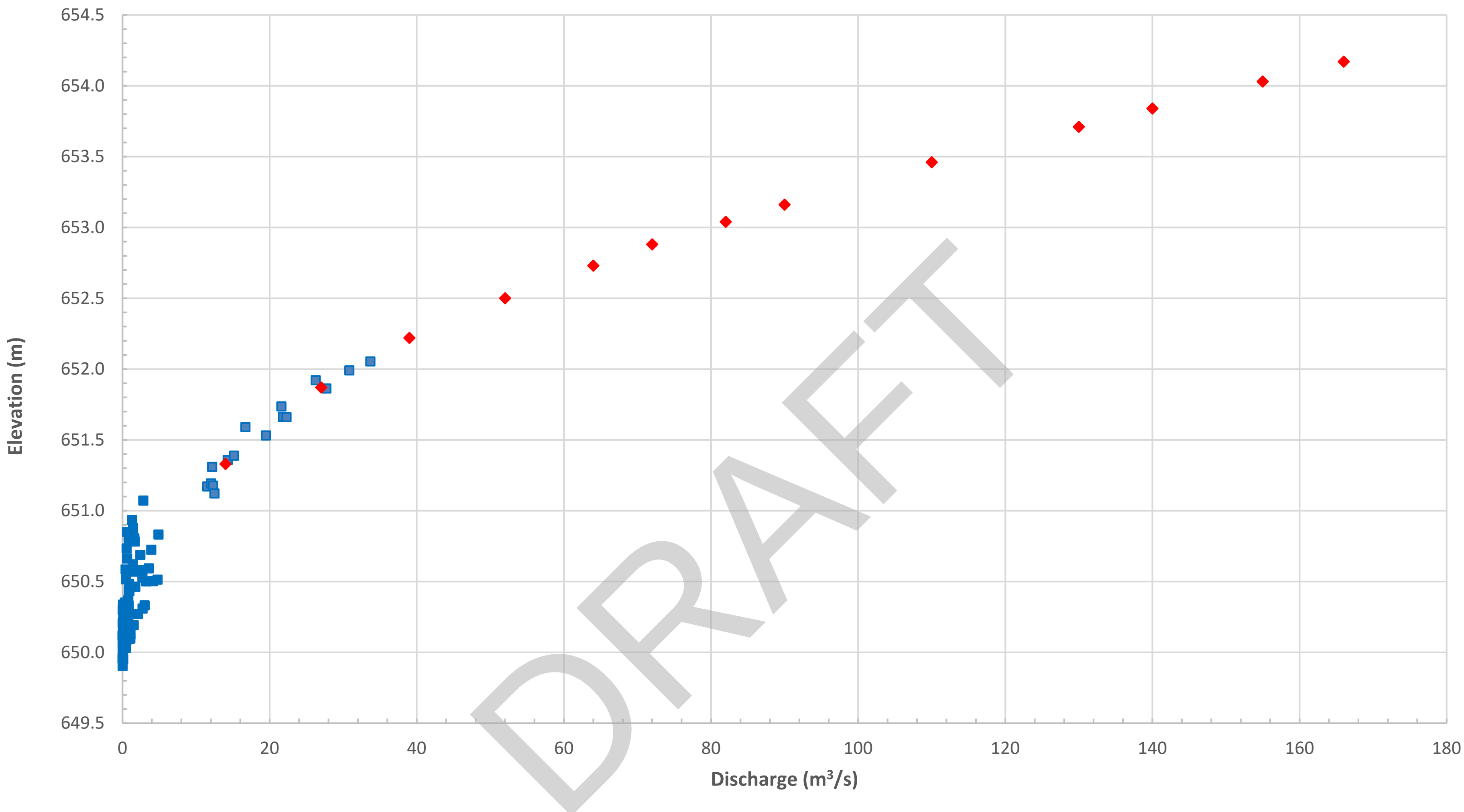
Figure 4

Classification: Public



■ 05EA002_Observed

◆ 05EA002_Simulated

NOTE: Ice impacted observations were excluded from the observed dataset.

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Sturgeon River at St. Albert (05EA002)
Rating Curve

Date: March 2020	Project: 28312	Submitter: P.Rogers	Reviewer: M.Shome

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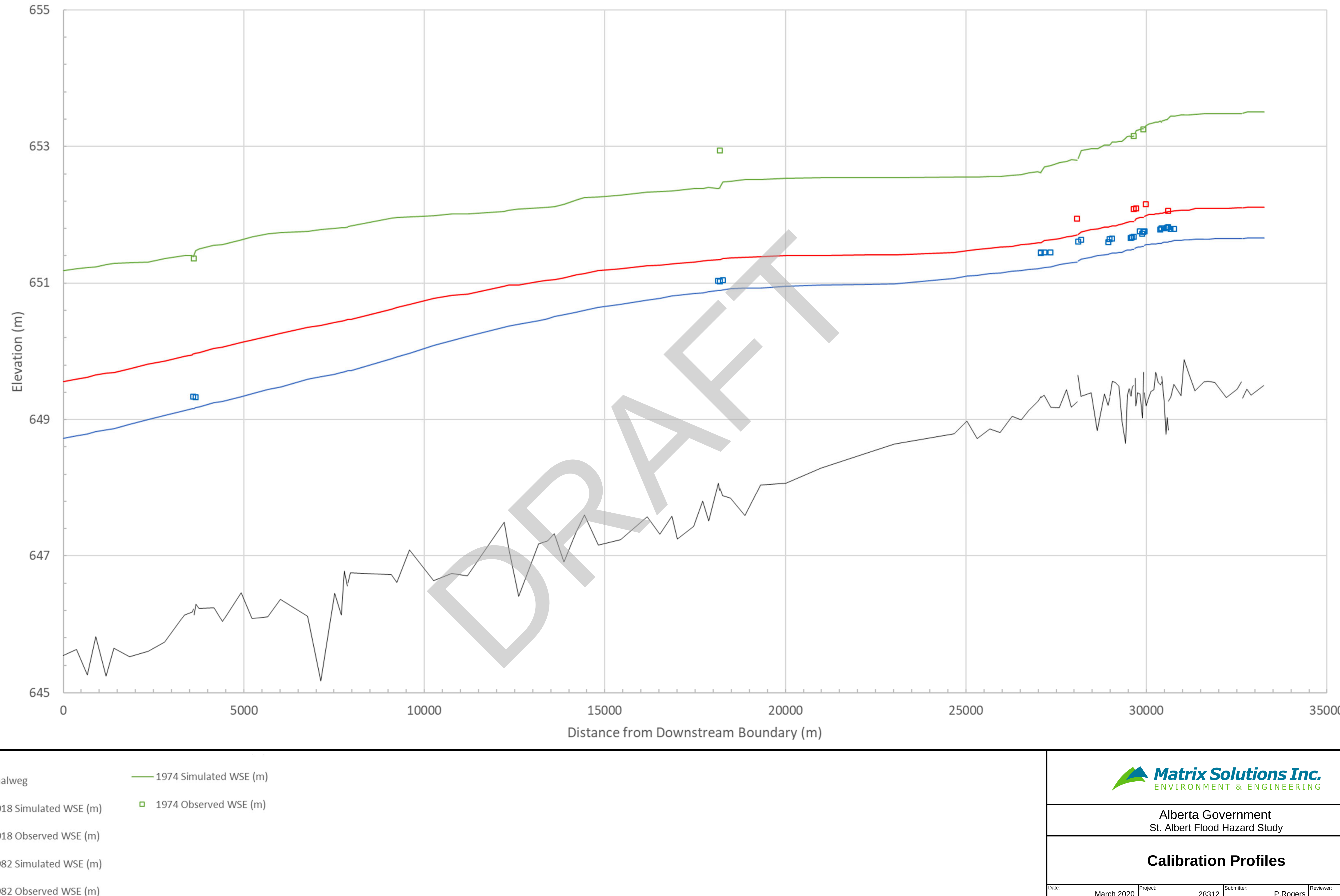
Figure 5

SS1



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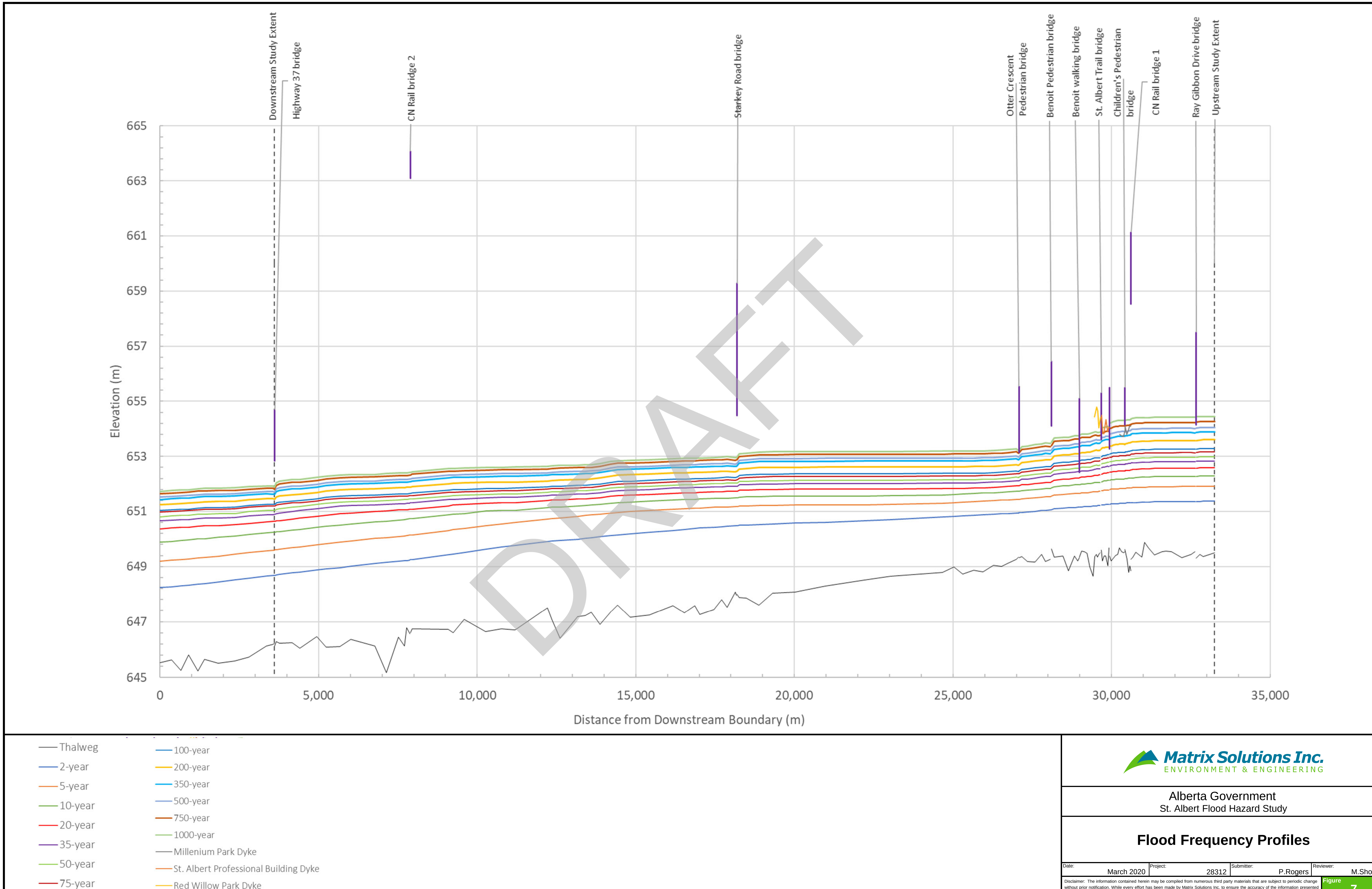
St. Albert Flood Hazard Study

Calibration Profiles

Date: March 2020	Project: 28312	Submitter: P.Rogers	Reviewer: M.Shome

Figure 6



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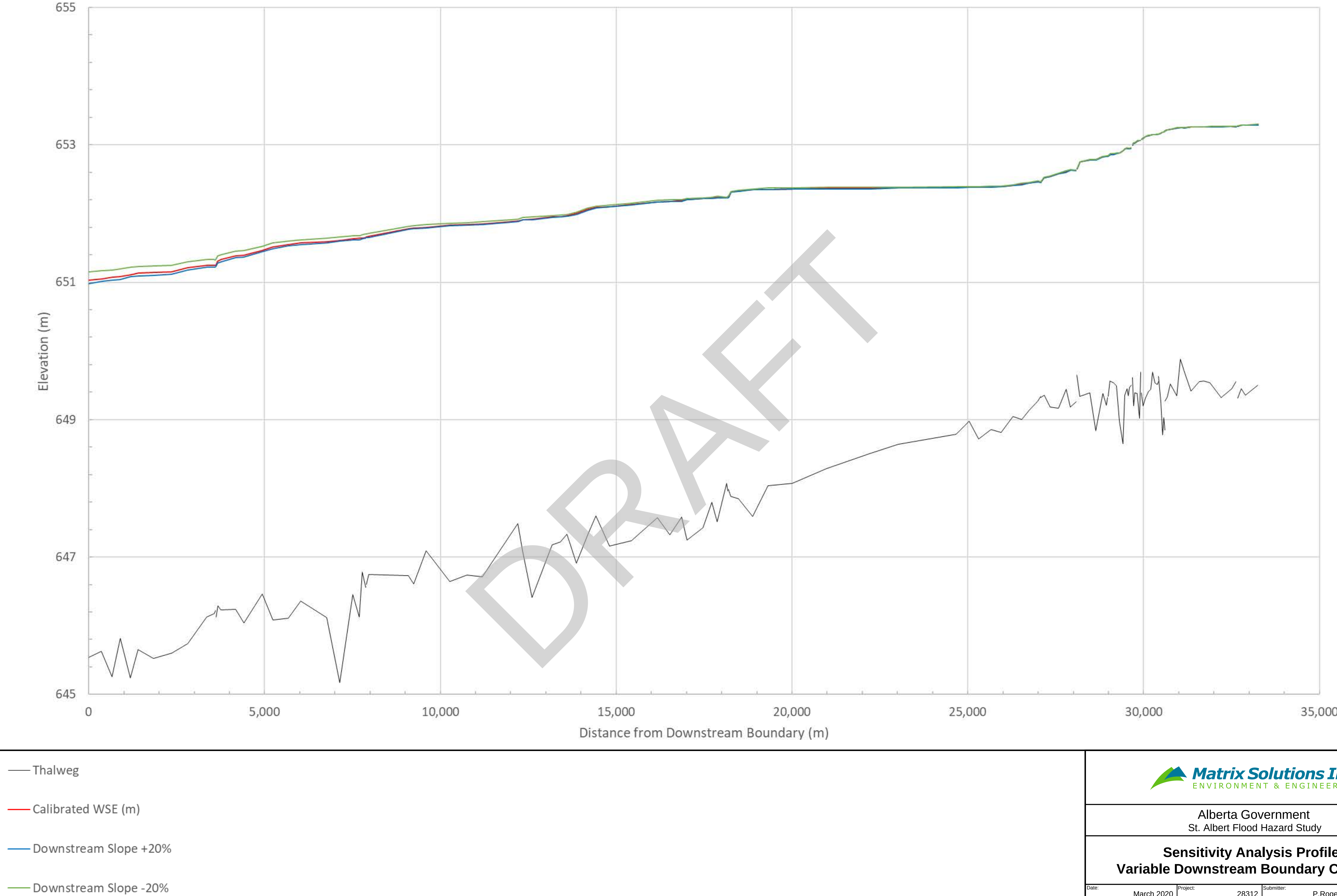
St. Albert Flood Hazard Study

Flood Frequency Profiles

Date: March 2020	Project: 28312	Submitter: P.Rogers	Reviewer: M.Shome

Figure 7



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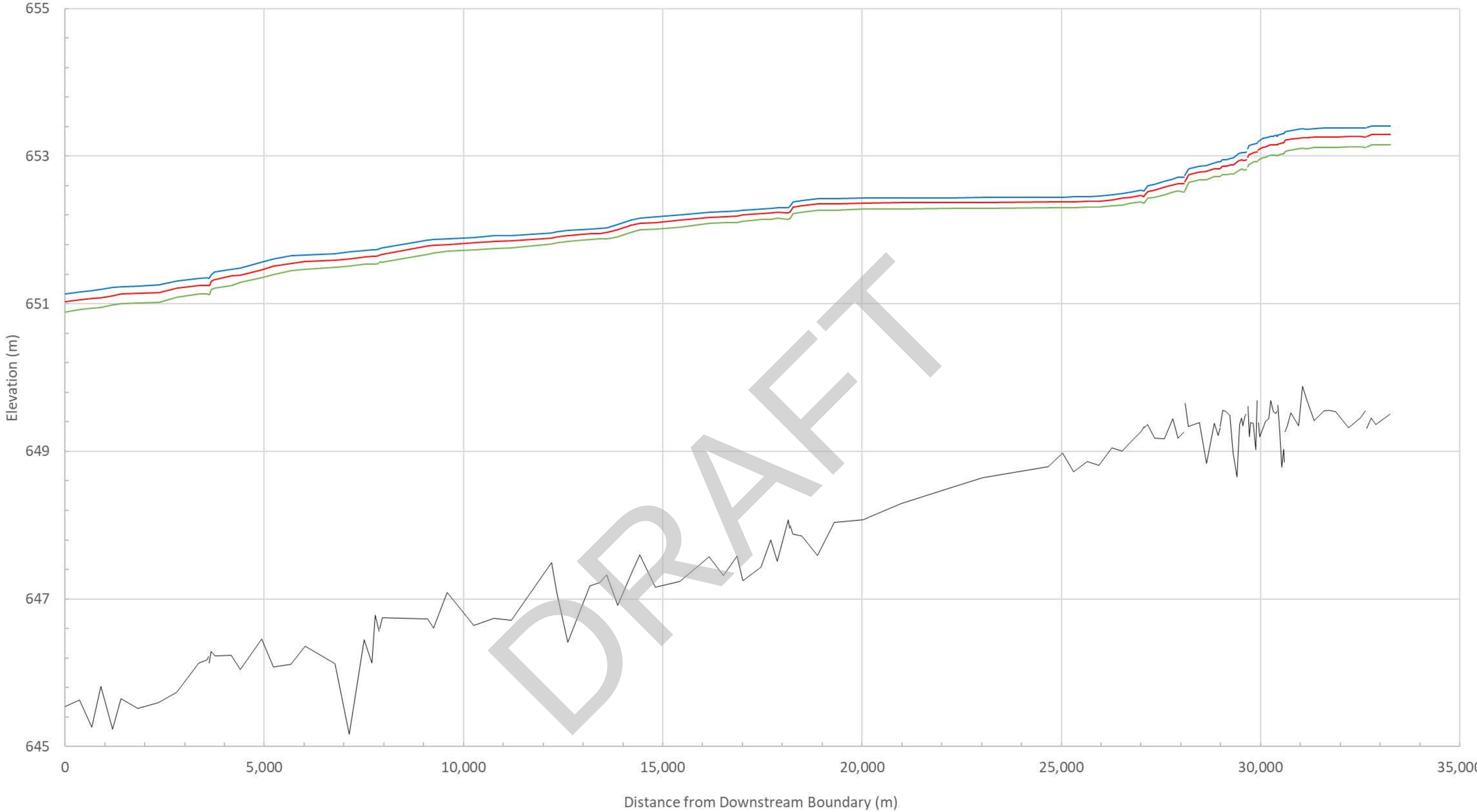
St. Albert Flood Hazard Study

Sensitivity Analysis Profiles
Variable Downstream Boundary Condition

Date:	Project:	Submitter:	Reviewer:
March 2020	28312	P.Rogers	M.Shome

Figure 8



Thalweg

Calibrated WSE (m)

Channel Roughness +20%

Channel Roughness -20%

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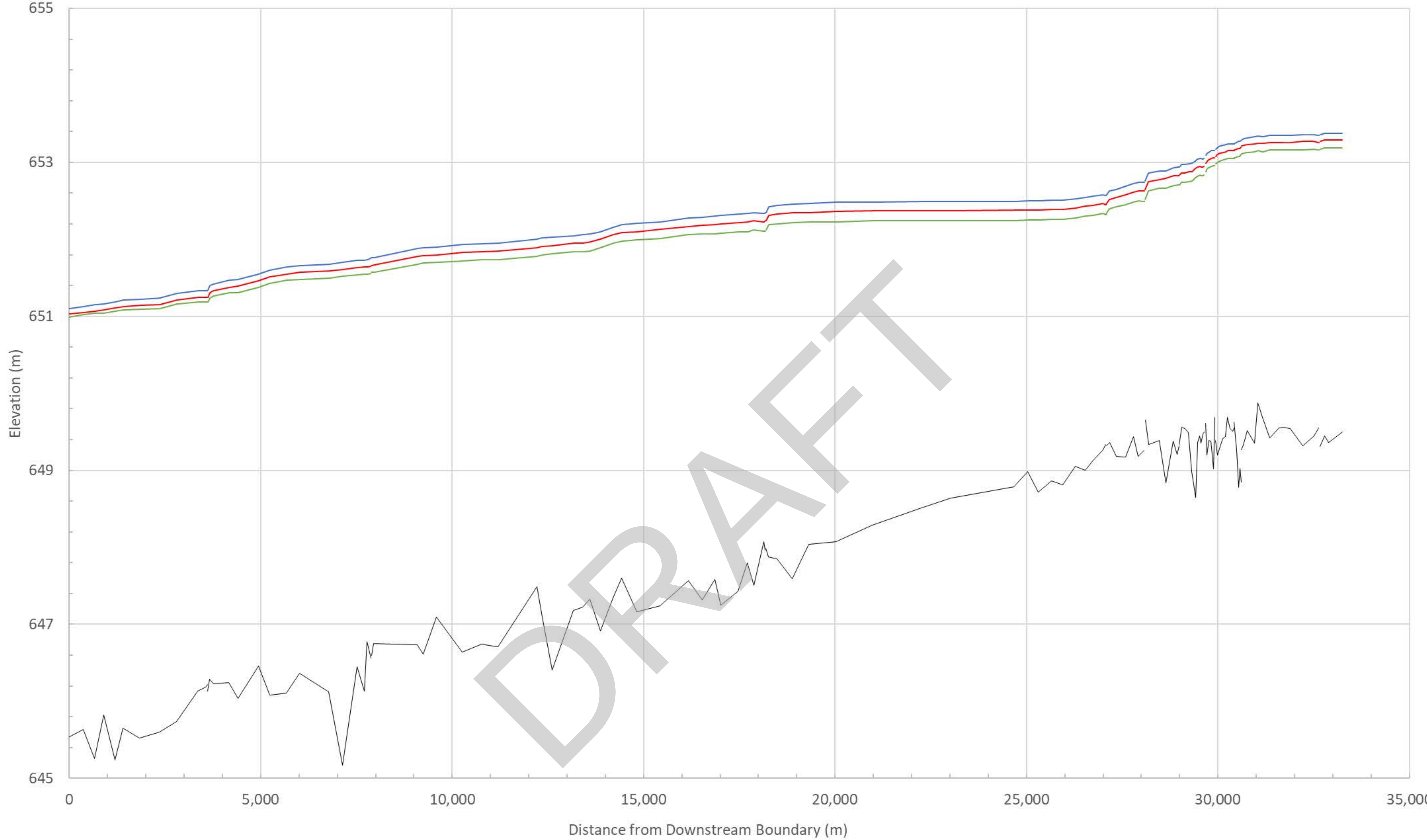
Sensitivity Analysis Profiles
Variable Channel Manning Roughness

Date: March 2020	Project: 28312	Submitter: P.Rogers	Reviewer: M.Shome

Figure 9



—Thalweg

—Calibrated WSE (m)

—Overbank Roughness +20%

—Overbank Roughness -20%

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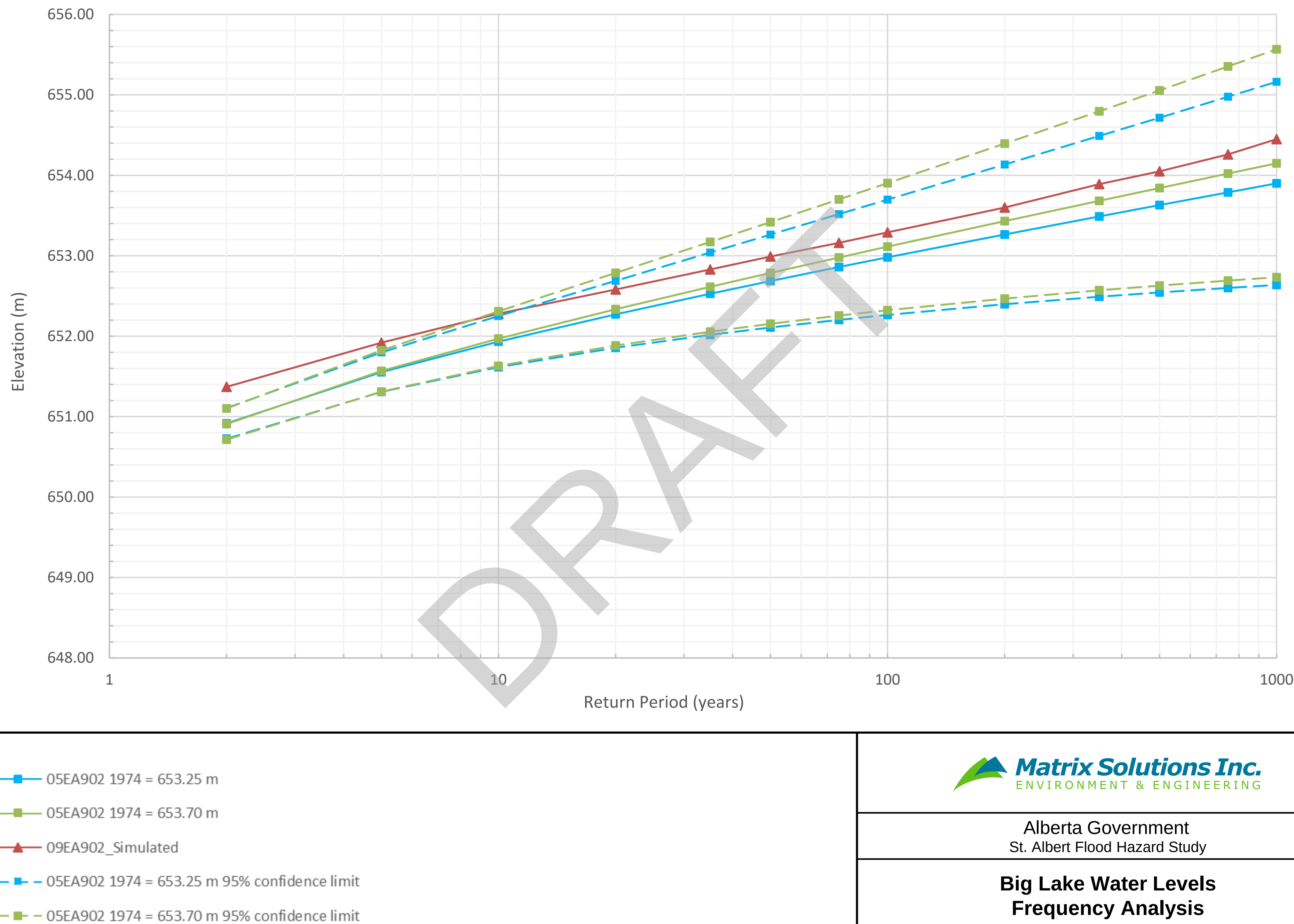
Sensitivity Analysis Profiles
Variable Overbank Manning Roughness

Date:	Project:	Submitter:	Reviewer:
March 2020	28312	P.Rogers	M.Shome

Figure 10



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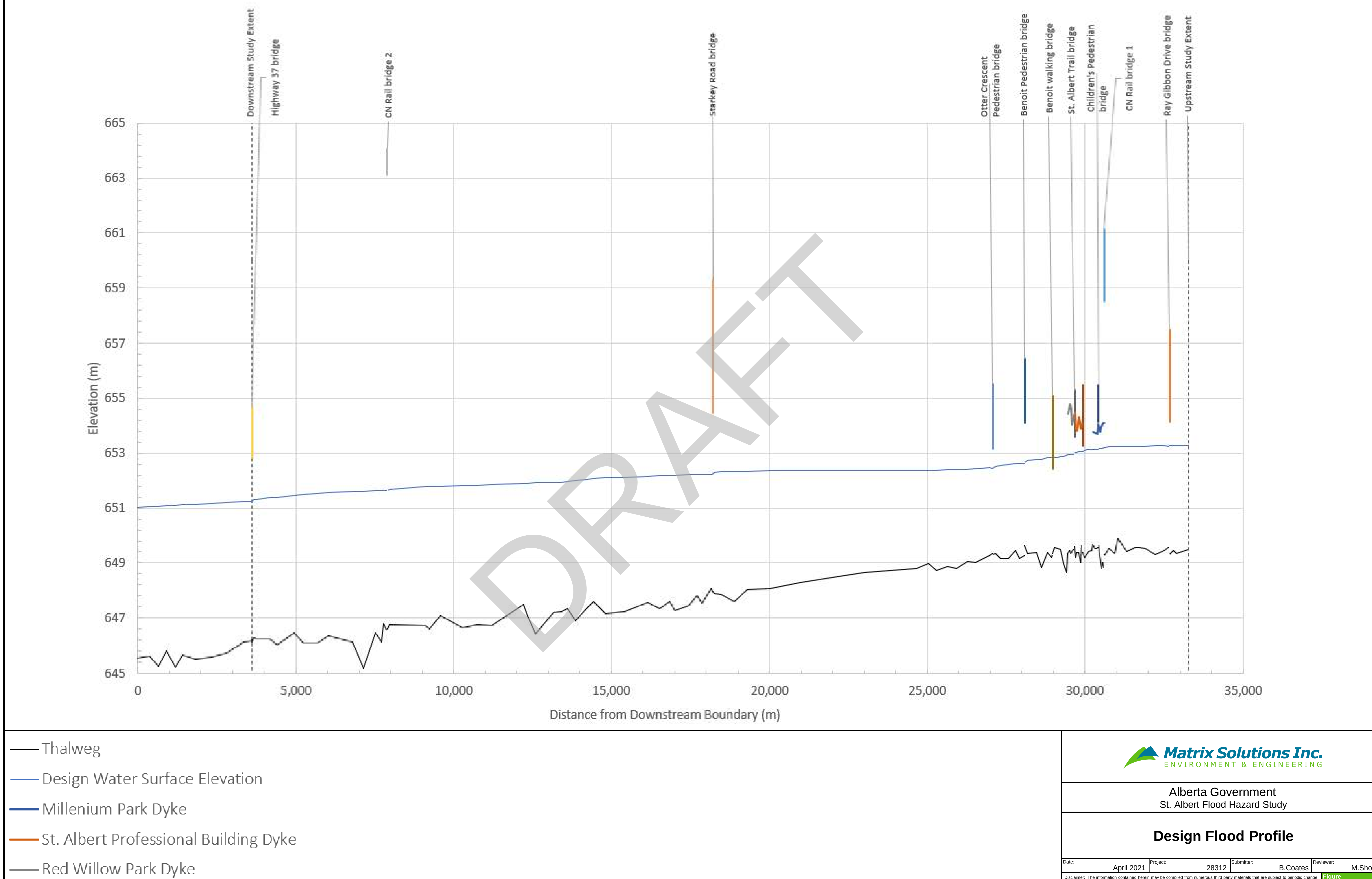
St. Albert Flood Hazard Study

Big Lake Water Levels
Frequency Analysis

Date: March 2020	Project: 28312	Submitter: P.Rogers	Reviewer: M.Shome

Figure 11



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St. Albert Flood Hazard Study

Design Flood Profile

Date:	Project:	Submitter:	Reviewer:
April 2021	28312	B.Coates	M.Shome

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Figure 12

TABLE 1 Summary of Model Cross-sections

Cross-section	River Station[1]	Channel Thalweg Elevation (m)	Channel Width (m)	Description
2	33252	649.50	113	upstream model boundary
3	32889	649.36	69	
4	32783	649.45	72	
5a	32669	649.31	44	upstream of Ray Gibbon bridge
5b	32632	649.55	41	downstream of Ray Gibbon bridge
6	32504	649.45	68	
7	32213	649.32	77	
8	31887	649.54	69	
9	31710	649.56	65	
10	31589	649.55	61	
11	31344	649.42	39	
12	31163	649.69	26	
13	31046	649.88	27	
14	30951	649.35	47	
15	30765	649.52	25	
16	30670	649.33	16	
17a	30611	649.27	16	upstream of CN Rail bridge 1
17b	30605	648.85	12	downstream of CN Rail bridge 1
18	30573	649.03	22	
19	30533	648.78	25	
20	30487	649.26	25	
21a	30426	649.63	35	upstream of Children's walking bridge
21b	30422	649.55	31	downstream of Children's walking bridge
22	30382	649.51	32	
23	30317	649.54	36	
24	30251	649.69	21	
25	30203	649.44	25	
26	30129	649.41	20	
27	30056	649.31	31	
28	29984	649.20	29	
29a	29939	649.39	29	upstream of Perron Street Bridge
29b	29916	649.69	27	downstream of Perron Street Bridge
30	29882	649.02	30	
31	29817	649.38	31	
32	29757	649.39	27	
33	29712	649.20	19	
34a	29682	649.61	23	upstream of St. Albert Trail (Hwy 2) bridge
34b	29642	649.50	22	downstream of St. Albert Trail (Hwy 2) bridge
35	29602	649.47	23	
36	29563	649.35	28	
37	29525	649.45	30	
38	29468	649.36	30	
39	29415	648.65	25	
40	29316	648.98	22	
41	29230	649.49	29	

Cross-section	River Station[1]	Channel Thalweg Elevation (m)	Channel Width (m)	Description
42	29139	649.54	36	
43	29048	649.56	24	
44a	28990	649.34	23	upstream of Benoit walking bridge
44b	28983	649.32	22	downstream of Benoit walking bridge
45	28939	649.21	30	
46	28835	649.38	29	
47	28639	648.84	15	
48	28462	649.39	28	
49	28192	649.34	23	
50a	28102	649.65	19	upstream of Boudreau Road bridge
50b	28076	649.26	18	downstream of Boudreau Road bridge
51	27923	649.18	24	
52	27791	649.44	20	
53	27587	649.17	16	
54	27341	649.18	18	
55	27167	649.36	22	
56a	27081	649.32	27	upstream of Otter Crescent walking bridge
56b	27075	649.34	28	downstream of Otter Crescent walking bridge
57	26993	649.27	52	
58	26733	649.13	19	
59	26530	649.00	19	
60	26276	649.05	27	
61	25946	648.81	36	
62	25654	648.86	46	
63	25306	648.72	27	
64	25031	648.98	46	
65	24674	648.79	20	
66	23024	648.64	20	
67	22196	648.50	26	
68	20978	648.29	16	
69	20015	648.07	30	
70	19311	648.04	13	
71	18883	647.59	12	
72	18482	647.85	14	
73	18262	647.88	17	
74a	18192	647.99	15	upstream of Starkey Road (Range Road 251) bridge
74b	18178	647.96	18	downstream of Starkey Road (Range Road 251) bridge
75	18142	648.07	19	
76	17874	647.51	16	
77	17715	647.80	12	
78	17466	647.43	18	
79	17008	647.25	15	
80	16857	647.58	16	
81	16527	647.32	16	
82	16165	647.57	18	

Cross-section	River Station[1]	Channel Thalweg Elevation (m)	Channel Width (m)	Description
83	15432	647.24	21	
84	14817	647.16	17	
85	14428	647.60	20	
86	14203	647.34	21	
87	13868	646.91	19	
88	13599	647.33	20	
89	13411	647.22	21	
90	13172	647.18	18	
91	12608	646.41	18	
92	12344	647.09	18	
93	12208	647.49	17	
94	11200	646.71	14	
95	10762	646.74	14	
96	10264	646.64	19	
97	9593	647.09	15	
98	9240	646.61	17	
99	9095	646.73	14	
100	7955	646.75	16	
101a	7890	646.60	13	upstream of CN Rail bridge 2
101b	7876	646.56	15	downstream of CN Rail bridge 2
102	7782	646.78	16	
103	7699	646.13	16	
104	7509	646.45	13	
105	7133	645.17	15	
106	6773	646.12	17	
107	6021	646.36	15	
108	5671	646.11	13	
109	5234	646.08	15	
110	4934	646.46	16	
111	4406	646.04	14	
112	4172	646.24	21	
113	3761	646.23	16	
114	3669	646.29	16	
115a	3619	646.13	9	upstream of Hwy 37 bridge
115b	3604	646.22	9	downstream of Hwy 37 bridge
116	3567	646.18	13	
117	3361	646.13	19	
118	2808	645.74	13	
119	2354	645.60	13	
120	1834	645.52	13	
121	1409	645.65	14	
122	1187	645.24	18	
123	896	645.82	16	
124	664	645.26	14	
125	364	645.63	13	
126	0	645.54	18	

1 River station 0 is located at the downstream end of the model and increases moving upstream.

TABLE 2 Bridge Details

Bridge Name	Bounding Cross-section	Details
Ray Gibbon bridge[1]	32669 and 32632	• 81 m long three-span concrete bridge with 14 × 1.2 m diameter concrete cylinder piers (7 in series) • Deck width (future) of 35.45 m • Average low chord elevation, El. 654.50 m • Average guard rail elevation, El. 657.08 m
CN Rail bridge 1	30611 and 30605	• 86 m long timber trestle bridge with timber pile piers • Deck width of 3.6 m • Average low chord elevation, El. 659.52 m • Average high chord elevation, El. 661.02 m
Children's walking bridge	30426 and 30422	• 63.2 m long steel and concrete bridge with 0.3 m wide steel pier/suspension support • Deck width of 3.0 m • Average low chord elevation, El. 654.31 m • Average high chord elevation, El. 654.87 m
Perron Street Bridge	29939 and 29916	• 47.8 m long three-span concrete bridge with 0.9 m wide rounded nose full span concrete piers • Deck width of 19.5 m • Average low chord elevation, El. 653.44 m • Average guard rail elevation, El. 655.09 m
Highway 2 (St. Albert Trail) bridge	29682 and 29642	• 49 m long three-span concrete bridge with 0.6 m wide rounded nose full span concrete piers • Deck width of 38.1 m • Average low chord elevation, El. 653.87 m • Average guard rail elevation, El. 655.10 m
Benoit walking bridge	28990 and 28983	• 70 m long single span arched concrete bridge • Deck width of 3.3 m • Average low chord elevation, El. 653.41 m • Average guard rail elevation, El. 654.90 m
Boudreau Road bridge	28102 and 28076	• 68 m long three-span concrete bridge with 1.0 m wide rounded nose full span concrete piers • Deck width of 23.7 m • Average low chord elevation, El. 654.29 m • Average guard rail elevation, El. 656.16 m
Otter Crescent walking bridge	27081 and 27075	• 47 m long single span concrete bridge • Deck width of 2.55 m • Average low chord elevation, El. 653.39 m • Average guard rail elevation, El. 655.35 m
Starkey Road (Range Road 251) bridge	18192 and 18178	• 65.6 m long single span concrete bridge • Deck width of 11 m • Average low chord elevation, El. 653.63 m • Average guard rail elevation, El. 658.31 m

Bridge Name	Bounding Cross-section	Details
Trestle Rail bridge 2	7890 and 7876	• 102 m long timber trestle bridge with timber pile piers • Deck width of 5.57 m • Average low chord elevation, El. 663.18 m • Average high chord elevation, El. 666.03 m
Highway 37 bridge	3619 and 3604	• 48 m long three-span concrete bridge with 10 0.5 m diameter concrete cylinder piers (5 in series) • Deck width of 12.1 m • Average low chord elevation, El. 652.78 m • Average guard rail elevation, El. 653.67 m

1. Piers for the future twinning of Ray Gibbon bridge have already been constructed in the Sturgeon River immediately upstream of the existing bridge. Given the relative certainty of construction, Ray Gibbon bridge has been simulated in its future (twinned) geometry.

TABLE 3 Calibration Results

AEP High Water Mark	River Station	Simulated Water Surface Elevation (m)	Observed Water Surface Elevation (m)	Difference (m)
2018 Event (Q = 20.2 m^3/s)[1]				
Sturg-01-WL1	32632	651.65	651.85	0.17
Sturg-02-WL2	30765	651.62	651.79	0.18
Sturg-02-WL4	30670	651.61	651.79	0.22
Sturg-03-WL4	30605	651.60	651.82	0.21
Sturg-03-WL5	30573	651.60	651.81	0.20
Sturg-03-WL6	30487	651.60	651.80	0.22
Sturg-03-WL2	30422	651.58	651.80	0.20
Sturg-03-WL1	30382	651.58	651.78	0.21
Sturg-04-WL5	29939	651.55	651.76	0.21
Sturg-04-WL1	29916	651.54	651.75	0.18
Sturg-04-WL2	29882	651.54	651.72	0.23
Sturg-04-WL4	29817	651.53	651.76	0.19
Sturg-05-WL6	29642	651.49	651.68	0.18
Sturg-05-WL5	29602	651.49	651.67	0.18
Sturg-05-WL2	29563	651.48	651.66	0.21
Sturg-06-WL2	29048	651.44	651.64	0.21
Sturg-06-WL4	28983	651.43	651.64	0.18
Sturg-06-WL5	28939	651.42	651.60	0.28
Sturg-07-WL3	28192	651.35	651.63	0.29
Sturg-07-WL4	28102	651.32	651.61	0.21
Sturg-08-WL4	27341	651.24	651.45	0.22
Sturg-08-WL3	27167	651.23	651.45	0.23
Sturg-08-WL1	27081	651.22	651.45	0.22
Sturg-08-WL2	27075	651.22	651.44	0.14
Sturg-09-WL1	18262	650.90	651.04	0.13
Sturg-09-WL5	18192	650.89	651.02	0.13
Sturg-09-WL3	18178	650.89	651.02	0.14
Sturg-09-WL4	18142	650.89	651.03	0.15
Sturg-10-WL4	3669	649.18	649.33	0.18
Sturg-10-WL1	3604	649.16	649.34	0.17
1982 Event (Q = 33 m^3/s)				
1982-STU-009-a	30605	652.05	652.06	0.01
1982-STU-011-c	29984	651.99	652.15	0.16
1982-STU-008-b	29712	651.94	652.09	0.15
1982-STU-008-c	29642	651.90	652.08	0.18
1982-STU-012-a	28076	651.70	651.94	0.24
1974 Event (Q = 104 m^3/s)				
1974-STU-011-a	29916	653.26	653.25	-0.01
1974-STU-008-a	29642	653.15	653.15	0.00
1974-STU-010-a	18178	652.39	652.94	0.55
1974-STU-007-a	3619	651.40	651.36	-0.04

1. Given a discrepancy in benchmarks surveyed in 2018 and 2019, the 2018 highwater marks have been corrected to 2019 surveyed benchmarks, as directed by AEP. The Sturg-6 benchmark has been destroyed since 2018; therefore, a correction value of 0.08 m has been applied to these highwater marks.

TABLE 4 Computed Flood Frequency Water Levels

Cross-section	River Station[1]	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	1,000-year flood
2	33252	651.37	651.92	652.28	652.58	652.83	652.99	653.16	653.29	653.60	653.89	654.05	654.26	654.45
3	32889	651.37	651.92	652.28	652.58	652.83	652.98	653.16	653.29	653.60	653.89	654.05	654.26	654.45
4	32783	651.36	651.92	652.28	652.58	652.83	652.98	653.16	653.29	653.59	653.89	654.05	654.26	654.45
5a	32669	651.36	651.91	652.27	652.57	652.82	652.97	653.14	653.27	653.57	653.86	654.03	654.25	654.44
5b	32632	651.36	651.91	652.27	652.56	652.81	652.96	653.13	653.26	653.56	653.85	654.01	654.23	654.42
6	32504	651.36	651.91	652.27	652.57	652.81	652.97	653.14	653.27	653.57	653.86	654.02	654.23	654.42
7	32213	651.36	651.91	652.27	652.56	652.81	652.96	653.14	653.27	653.57	653.86	654.02	654.23	654.42
8	31887	651.35	651.90	652.26	652.56	652.81	652.96	653.13	653.26	653.57	653.86	654.02	654.23	654.42
9	31710	651.35	651.90	652.26	652.56	652.81	652.96	653.13	653.26	653.56	653.85	654.01	654.23	654.42
10	31589	651.35	651.90	652.26	652.56	652.81	652.96	653.13	653.26	653.56	653.85	654.01	654.22	654.42
11	31344	651.35	651.90	652.26	652.56	652.80	652.96	653.13	653.26	653.56	653.85	654.01	654.22	654.42
12	31163	651.34	651.89	652.24	652.54	652.79	652.94	653.12	653.25	653.55	653.84	654.00	654.22	654.41
13	31046	651.33	651.88	652.24	652.54	652.79	652.94	653.12	653.25	653.55	653.84	654.00	654.22	654.41
14	30951	651.33	651.88	652.24	652.54	652.79	652.94	653.11	653.24	653.55	653.84	654.00	654.21	654.41
15	30765	651.32	651.87	652.23	652.53	652.77	652.93	653.10	653.23	653.53	653.83	653.99	654.20	654.40
16	30670	651.32	651.87	652.22	652.52	652.76	652.91	653.09	653.22	653.52	653.82	653.98	654.19	654.39
17a	30611	651.31	651.86	652.22	652.51	652.76	652.91	653.08	653.21	653.51	653.80	653.96	654.17	654.36
17b	30605	651.31	651.86	652.21	652.51	652.75	652.90	653.07	653.20	653.50	653.78	653.94	654.15	654.35
18	30573	651.31	651.85	652.21	652.49	652.74	652.88	653.05	653.18	653.48	653.76	653.92	654.14	654.33
19	30533	651.31	651.85	652.21	652.49	652.74	652.88	653.05	653.18	653.48	653.76	653.92	654.13	654.33
20	30487	651.31	651.85	652.20	652.49	652.73	652.87	653.04	653.17	653.47	653.75	653.91	654.13	654.32
21a	30426	651.30	651.84	652.19	652.48	652.72	652.86	653.03	653.16	653.45	653.74	653.90	654.11	654.31
21b	30422	651.30	651.84	652.19	652.47	652.71	652.86	653.02	653.15	653.44	653.73	653.89	654.10	654.30
22	30382	651.29	651.83	652.18	652.47	652.71	652.86	653.03	653.15	653.45	653.74	653.90	654.11	654.31
23	30317	651.29	651.83	652.18	652.47	652.71	652.86	653.02	653.15	653.45	653.73	653.90	654.11	654.31
24	30251	651.29	651.83	652.18	652.46	652.70	652.85	653.02	653.15	653.45	653.73	653.89	654.11	654.31
25	30203	651.28	651.82	652.17	652.46	652.70	652.85	653.01	653.14	653.44	653.72	653.88	654.09	654.30
26	30129	651.28	651.82	652.17	652.45	652.69	652.84	653.01	653.13	653.43	653.71	653.87	654.09	654.28
27	30056	651.28	651.81	652.16	652.44	652.68	652.83	653.00	653.12	653.41	653.69	653.85	654.06	654.26
28	29984	651.27	651.81	652.15	652.43	652.67	652.81	652.97	653.10	653.38	653.66	653.82	654.03	654.22
29a	29939	651.26	651.80	652.14	652.42	652.65	652.80	652.96	653.08	653.37	653.64	653.80	654.01	654.20
29b	29916	651.25	651.78	652.13	652.40	652.63	652.78	652.94	653.06	653.34	653.60	653.72	653.90	654.07
30	29882	651.25	651.78	652.13	652.40	652.64	652.78	652.94	653.06	653.34	653.60	653.72	653.90	654.08
31	29817	651.25	651.78	652.12	652.39	652.63	652.77	652.93	653.05	653.34	653.60	653.72	653.90	654.07
32	29757	651.24	651.77	652.11	652.38	652.61	652.75	652.92	653.03	653.32	653.58	653.69	653.87	654.05
33	29712	651.24	651.76	652.10	652.37	652.60	652.74	652.90	653.02	653.31	653.57	653.69	653.87	654.04
34a	29682	651.23	651.75	652.08	652.35	652.58	652.72	652.88	652.99	653.27	653.52	653.64	653.81	653.99
34b	29642	651.21	651.73	652.06	652.32	652.54	652.68	652.84	652.95	653.23	653.48	653.59	653.76	653.88
35	29602	651.21	651.73	652.06	652.32	652.54	652.67	652.83	652.94	653.22	653.47	653.58	653.74	653.86
36	29563	651.21	651.72	652.05	652.31	652.54	652.67	652.83	652.94	653.22	653.47	653.58	653.74	653.86
37	29525	651.20	651.72	652.05	652.31	652.54	652.68	652.83	652.95	653.23	653.48	653.60	653.76	653.88
38	29468	651.20	651.72	652.05	652.30	652.53	652.66	652.82	652.94	653.22	653.47	653.59	653.76	653.88
39	29415	651.19	651.71	652.03	652.29	652.51	652.65	652.80	652.92	653.20	653.45	653.57	653.74	653.86
40	29316	651.18	651.69	652.01	652.26	652.48	652.61	652.77	652.88	653.15	653.40	653.52	653.69	653.82
41	29230	651.17	651.68	652.01	652.26	652.47	652.61	652.76	652.88	653.15	653.40	653.52	653.69	653.81

Cross-section	River Station[1]	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	1,000-year flood
42	29139	651.17	651.68	652.00	652.25	652.46	652.60	652.75	652.86	653.14	653.39	653.51	653.68	653.81
43	29048	651.16	651.67	651.99	652.24	652.46	652.60	652.75	652.86	653.14	653.39	653.51	653.68	653.80
44a	28990	651.16	651.66	651.98	652.23	652.44	652.57	652.72	652.84	653.11	653.35	653.47	653.64	653.76
44b	28983	651.16	651.66	651.98	652.22	652.44	652.57	652.72	652.83	653.10	653.34	653.45	653.62	653.74
45	28939	651.15	651.66	651.97	652.22	652.44	652.57	652.72	652.83	653.10	653.35	653.46	653.63	653.75
46	28835	651.14	651.65	651.97	652.21	652.43	652.56	652.71	652.83	653.09	653.34	653.45	653.62	653.74
47	28639	651.13	651.63	651.94	652.18	652.40	652.53	652.68	652.79	653.05	653.29	653.40	653.57	653.69
48	28462	651.11	651.61	651.93	652.17	652.38	652.52	652.67	652.78	653.05	653.29	653.40	653.57	653.69
49	28192	651.09	651.59	651.90	652.14	652.35	652.49	652.64	652.75	653.02	653.26	653.38	653.54	653.66
50a	28102	651.06	651.55	651.85	652.08	652.28	652.40	652.54	652.65	652.90	653.13	653.24	653.40	653.51
50b	28076	651.05	651.54	651.84	652.06	652.26	652.38	652.52	652.63	652.87	653.10	653.21	653.36	653.47
51	27923	651.04	651.53	651.83	652.06	652.26	652.38	652.52	652.63	652.88	653.11	653.22	653.38	653.49
52	27791	651.03	651.52	651.82	652.04	652.24	652.37	652.50	652.61	652.86	653.08	653.19	653.35	653.46
53	27587	651.00	651.50	651.80	652.01	652.21	652.34	652.48	652.58	652.83	653.05	653.16	653.32	653.43
54	27341	650.98	651.47	651.77	651.98	652.18	652.30	652.44	652.54	652.79	653.01	653.12	653.27	653.38
55	27167	650.97	651.46	651.76	651.97	652.17	652.29	652.42	652.52	652.77	652.99	653.10	653.25	653.36
56a	27081	650.96	651.44	651.73	651.93	652.12	652.24	652.36	652.46	652.69	652.90	652.99	653.14	653.24
56b	27075	650.95	651.44	651.73	651.93	652.12	652.23	652.36	652.45	652.68	652.88	652.98	653.12	653.22
57	26993	650.95	651.44	651.73	651.93	652.12	652.24	652.37	652.47	652.70	652.92	653.02	653.17	653.27
58	26733	650.93	651.42	651.71	651.91	652.10	652.22	652.35	652.44	652.68	652.89	653.00	653.14	653.25
59	26530	650.92	651.41	651.70	651.89	652.08	652.20	652.33	652.43	652.66	652.87	652.98	653.12	653.23
60	26276	650.91	651.39	651.68	651.88	652.07	652.18	652.31	652.41	652.64	652.86	652.96	653.11	653.21
61	25946	650.89	651.37	651.67	651.86	652.05	652.17	652.30	652.39	652.63	652.85	652.95	653.10	653.20
62	25654	650.87	651.36	651.65	651.85	652.04	652.16	652.29	652.39	652.63	652.84	652.94	653.09	653.20
63	25306	650.85	651.34	651.63	651.84	652.03	652.15	652.29	652.38	652.62	652.84	652.94	653.09	653.19
64	25031	650.83	651.32	651.61	651.83	652.03	652.15	652.28	652.38	652.62	652.83	652.94	653.09	653.19
65	24674	650.80	651.30	651.59	651.83	652.03	652.15	652.28	652.38	652.61	652.83	652.93	653.08	653.19
66	23024	650.70	651.25	651.57	651.82	652.02	652.14	652.27	652.37	652.61	652.83	652.93	653.08	653.18
67	22196	650.66	651.24	651.56	651.82	652.02	652.14	652.27	652.37	652.61	652.83	652.93	653.08	653.18
68	20978	650.61	651.24	651.56	651.82	652.01	652.14	652.27	652.37	652.61	652.82	652.93	653.08	653.18
69	20015	650.58	651.23	651.56	651.81	652.01	652.13	652.27	652.36	652.60	652.82	652.92	653.07	653.18
70	19311	650.54	651.22	651.55	651.80	652.00	652.12	652.26	652.35	652.59	652.81	652.91	653.06	653.17
71	18883	650.53	651.21	651.54	651.80	652.00	652.12	652.25	652.35	652.59	652.81	652.91	653.06	653.16
72	18482	650.51	651.20	651.53	651.78	651.98	652.10	652.23	652.33	652.56	652.77	652.87	653.02	653.12
73	18262	650.50	651.19	651.52	651.77	651.97	652.09	652.21	652.31	652.54	652.75	652.85	653.00	653.10
74a	18192	650.49	651.18	651.50	651.74	651.92	652.03	652.15	652.24	652.46	652.65	652.74	652.87	652.97
74b	18178	650.49	651.18	651.49	651.73	651.92	652.03	652.15	652.24	652.45	652.64	652.73	652.87	652.96
75	18142	650.49	651.17	651.49	651.73	651.91	652.03	652.14	652.23	652.44	652.63	652.72	652.86	652.95
76	17874	650.46	651.16	651.48	651.73	651.91	652.03	652.15	652.24	652.46	652.66	652.75	652.89	652.99
77	17715	650.45	651.15	651.47	651.72	651.90	652.02	652.14	652.23	652.45	652.64	652.74	652.87	652.97
78	17466	650.43	651.15	651.47	651.71	651.90	652.01	652.13	652.22	652.44	652.64	652.73	652.87	652.96
79	17008	650.40	651.12	651.45	651.69	651.88	651.99	652.11	652.20	652.42	652.62	652.71	652.85	652.94
80	16857	650.38	651.11	651.44	651.68	651.87	651.98	652.10	652.19	652.41	652.61	652.70	652.83	652.93
81	16527	650.35	651.09	651.43	651.67	651.86	651.98	652.10	652.18	652.40	652.60	652.69	652.83	652.93
82	16165	650.31	651.08	651.42	651.66	651.85	651.96	652.08	652.17	652.39	652.59	652.68	652.82	652.91
83	15432	650.25	651.04	651.37	651.62	651.80	651.92	652.04	652.13	652.35	652.55	652.64	652.78	652.88
84	14817	650.19	651.00	651.34	651.59	651.78	651.89	652.02	652.10	652.33	652.53	652.62	652.76	652.86

Cross-section	River Station[1]	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	1,000-year flood
85	14428	650.14	650.96	651.31	651.57	651.76	651.88	652.00	652.09	652.31	652.51	652.61	652.75	652.84
86	14203	650.12	650.95	651.30	651.55	651.74	651.85	651.97	652.06	652.28	652.48	652.57	652.71	652.81
87	13868	650.08	650.91	651.25	651.50	651.68	651.80	651.91	652.00	652.22	652.41	652.50	652.64	652.73
88	13599	650.05	650.88	651.23	651.47	651.65	651.77	651.88	651.97	652.18	652.38	652.47	652.60	652.70
89	13411	650.03	650.86	651.22	651.46	651.64	651.76	651.87	651.95	652.17	652.37	652.46	652.59	652.69
90	13172	649.99	650.82	651.20	651.45	651.63	651.75	651.86	651.95	652.17	652.36	652.45	652.59	652.68
91	12608	649.95	650.77	651.16	651.42	651.60	651.72	651.84	651.92	652.14	652.34	652.43	652.57	652.67
92	12344	649.92	650.75	651.16	651.41	651.60	651.71	651.83	651.91	652.13	652.33	652.42	652.56	652.66
93	12208	649.90	650.73	651.13	651.39	651.57	651.69	651.81	651.89	652.11	652.31	652.40	652.54	652.64
94	11200	649.77	650.61	651.04	651.31	651.51	651.64	651.76	651.85	652.07	652.27	652.37	652.51	652.61
95	10762	649.71	650.55	651.03	651.31	651.51	651.63	651.75	651.84	652.07	652.27	652.37	652.51	652.60
96	10264	649.63	650.49	651.01	651.29	651.49	651.62	651.74	651.83	652.06	652.26	652.35	652.49	652.59
97	9593	649.52	650.39	650.93	651.25	651.46	651.59	651.72	651.80	652.04	652.24	652.33	652.47	652.57
98	9240	649.46	650.34	650.90	651.23	651.44	651.58	651.70	651.79	652.02	652.23	652.32	652.46	652.56
99	9095	649.43	650.31	650.88	651.20	651.43	651.56	651.69	651.78	652.01	652.22	652.31	652.45	652.55
100	7955	649.25	650.14	650.74	651.08	651.31	651.45	651.58	651.67	651.90	652.11	652.20	652.35	652.44
101a	7890	649.25	650.15	650.74	651.08	651.31	651.45	651.57	651.66	651.89	652.09	652.19	652.32	652.42
101b	7876	649.24	650.15	650.74	651.08	651.30	651.45	651.57	651.65	651.89	652.08	652.18	652.31	652.41
102	7782	649.22	650.12	650.72	651.06	651.29	651.43	651.56	651.64	651.88	652.07	652.17	652.30	652.40
103	7699	649.22	650.11	650.71	651.05	651.28	651.43	651.55	651.64	651.87	652.07	652.16	652.30	652.40
104	7509	649.19	650.09	650.69	651.05	651.28	651.42	651.55	651.63	651.87	652.07	652.16	652.30	652.39
105	7133	649.16	650.05	650.65	651.02	651.26	651.40	651.53	651.61	651.85	652.04	652.14	652.27	652.37
106	6773	649.12	650.02	650.63	651.00	651.23	651.38	651.51	651.59	651.82	652.02	652.11	652.25	652.34
107	6021	649.01	649.92	650.54	650.94	651.21	651.36	651.48	651.57	651.80	652.00	652.10	652.24	652.33
108	5671	648.96	649.88	650.50	650.92	651.19	651.34	651.47	651.55	651.79	651.99	652.08	652.22	652.32
109	5234	648.91	649.82	650.46	650.87	651.14	651.30	651.43	651.51	651.75	651.95	652.04	652.18	652.28
110	4934	648.87	649.79	650.42	650.83	651.10	651.25	651.38	651.46	651.69	651.89	651.99	652.13	652.23
111	4406	648.80	649.71	650.35	650.76	651.03	651.18	651.31	651.39	651.62	651.83	651.93	652.07	652.17
112	4172	648.77	649.69	650.33	650.73	651.00	651.15	651.31	651.38	651.61	651.82	651.92	652.06	652.16
113	3761	648.71	649.63	650.27	650.67	650.94	651.09	651.26	651.33	651.56	651.76	651.86	652.00	652.10
114	3669	648.70	649.62	650.26	650.67	650.93	651.08	651.24	651.31	651.53	651.72	651.82	651.95	652.04
115a	3619	648.68	649.61	650.25	650.64	650.90	651.04	651.19	651.25	651.45	651.63	651.71	651.83	651.91
115b	3604	648.68	649.60	650.24	650.64	650.90	651.03	651.19	651.25	651.45	651.62	651.70	651.81	651.89
116	3567	648.68	649.60	650.24	650.64	650.89	651.04	651.19	651.25	651.46	651.63	651.72	651.84	651.92
117	3361	648.65	649.58	650.22	650.62	650.89	651.03	651.19	651.25	651.46	651.64	651.72	651.84	651.93
118	2808	648.57	649.51	650.16	650.57	650.85	650.99	651.15	651.21	651.42	651.61	651.69	651.81	651.90
119	2354	648.51	649.45	650.11	650.52	650.78	650.93	651.10	651.15	651.37	651.56	651.65	651.77	651.86
120	1834	648.44	649.38	650.06	650.49	650.77	650.92	651.08	651.14	651.36	651.54	651.63	651.76	651.85
121	1409	648.38	649.33	650.01	650.48	650.76	650.91	651.07	651.13	651.35	651.54	651.63	651.75	651.84
122	1187	648.36	649.31	650.00	650.46	650.74	650.90	651.06	651.11	651.33	651.52	651.61	651.74	651.82
123	896	648.33	649.28	649.97	650.43	650.71	650.87	651.03	651.08	651.30	651.49	651.58	651.70	651.79
124	664	648.30	649.26	649.94	650.42	650.70	650.86	651.02	651.07	651.29	651.48	651.57	651.69	651.78
125	364	648.27	649.23	649.91	650.40	650.68	650.84	651.00	651.05	651.27	651.46	651.54	651.67	651.76
126	0	648.24	649.20	649.88	650.37	650.66	650.81	650.98	651.03	651.24	651.43	651.52	651.64	651.73

1 River station 0 is located at the downstream end of the model and increases moving upstream.

TABLE 5 Sensitivity Analysis, Variable Downstream Boundary Condition at 100-year Flood

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope + 20%
		S = 0.00006	S = 0.000075	S = 0.00009
2	33252	653.30	653.29	653.29
3	32889	653.29	653.29	653.29
4	32783	653.29	653.29	653.29
5a	32669	653.28	653.27	653.27
5b	32632	653.27	653.26	653.26
6	32504	653.27	653.27	653.27
7	32213	653.27	653.27	653.26
8	31887	653.27	653.26	653.26
9	31710	653.26	653.26	653.26
10	31589	653.26	653.26	653.26
11	31344	653.26	653.26	653.26
12	31163	653.25	653.25	653.24
13	31046	653.25	653.25	653.25
14	30951	653.25	653.24	653.24
15	30765	653.23	653.23	653.23
16	30670	653.22	653.22	653.22
17a	30611	653.21	653.21	653.20
17b	30605	653.20	653.20	653.20
18	30573	653.18	653.18	653.18
19	30533	653.18	653.18	653.18
20	30487	653.17	653.17	653.17
21a	30426	653.16	653.16	653.16
21b	30422	653.15	653.15	653.15
22	30382	653.16	653.15	653.15
23	30317	653.15	653.15	653.15
24	30251	653.15	653.15	653.15
25	30203	653.14	653.14	653.14
26	30129	653.14	653.13	653.13
27	30056	653.12	653.12	653.12
28	29984	653.10	653.10	653.09
29a	29939	653.08	653.08	653.08
29b	29916	653.06	653.06	653.06
30	29882	653.06	653.06	653.06
31	29817	653.06	653.05	653.05
32	29757	653.04	653.03	653.03
33	29712	653.03	653.02	653.02
34a	29682	653.00	652.99	652.99
34b	29642	652.96	652.95	652.95
35	29602	652.95	652.94	652.94
36	29563	652.95	652.94	652.94
37	29525	652.96	652.95	652.95
38	29468	652.94	652.94	652.94
39	29415	652.92	652.92	652.92

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope + 20%
		S = 0.00006	S = 0.000075	S = 0.00009
40	29316	652.88	652.88	652.88
41	29230	652.88	652.88	652.87
42	29139	652.87	652.86	652.86
43	29048	652.87	652.86	652.86
44a	28990	652.84	652.84	652.83
44b	28983	652.84	652.83	652.83
45	28939	652.84	652.83	652.83
46	28835	652.83	652.83	652.82
47	28639	652.79	652.79	652.78
48	28462	652.79	652.78	652.78
49	28192	652.75	652.75	652.75
50a	28102	652.66	652.65	652.65
50b	28076	652.63	652.63	652.62
51	27923	652.64	652.63	652.63
52	27791	652.62	652.61	652.60
53	27587	652.59	652.58	652.58
54	27341	652.55	652.54	652.54
55	27167	652.53	652.52	652.52
56a	27081	652.47	652.46	652.46
56b	27075	652.46	652.45	652.45
57	26993	652.48	652.47	652.46
58	26733	652.45	652.44	652.44
59	26530	652.44	652.43	652.42
60	26276	652.42	652.41	652.41
61	25946	652.40	652.39	652.39
62	25654	652.40	652.39	652.38
63	25306	652.39	652.38	652.38
64	25031	652.39	652.38	652.38
65	24674	652.39	652.38	652.37
66	23024	652.38	652.37	652.37
67	22196	652.38	652.37	652.36
68	20978	652.38	652.37	652.36
69	20015	652.37	652.36	652.36
70	19311	652.37	652.35	652.35
71	18883	652.36	652.35	652.35
72	18482	652.34	652.33	652.32
73	18262	652.32	652.31	652.31
74a	18192	652.26	652.24	652.24
74b	18178	652.25	652.24	652.23
75	18142	652.24	652.23	652.23
76	17874	652.25	652.24	652.23
77	17715	652.24	652.23	652.22
78	17466	652.23	652.22	652.22
79	17008	652.22	652.20	652.20
80	16857	652.20	652.19	652.18

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope + 20%
		S = 0.00006	S = 0.000075	S = 0.00009
81	16527	652.20	652.18	652.18
82	16165	652.19	652.17	652.17
83	15432	652.15	652.13	652.12
84	14817	652.12	652.10	652.10
85	14428	652.11	652.09	652.08
86	14203	652.08	652.06	652.05
87	13868	652.02	652.00	651.99
88	13599	651.99	651.97	651.96
89	13411	651.98	651.95	651.95
90	13172	651.97	651.95	651.94
91	12608	651.95	651.92	651.91
92	12344	651.94	651.91	651.91
93	12208	651.92	651.89	651.88
94	11200	651.88	651.85	651.84
95	10762	651.87	651.84	651.83
96	10264	651.86	651.83	651.82
97	9593	651.84	651.80	651.79
98	9240	651.82	651.79	651.78
99	9095	651.81	651.78	651.77
100	7955	651.71	651.67	651.65
101a	7890	651.70	651.66	651.65
101b	7876	651.70	651.65	651.64
102	7782	651.69	651.64	651.63
103	7699	651.68	651.64	651.62
104	7509	651.68	651.63	651.62
105	7133	651.66	651.61	651.60
106	6773	651.64	651.59	651.57
107	6021	651.62	651.57	651.55
108	5671	651.60	651.55	651.53
109	5234	651.57	651.51	651.49
110	4934	651.52	651.46	651.44
111	4406	651.46	651.39	651.37
112	4172	651.45	651.38	651.36
113	3761	651.40	651.33	651.30
114	3669	651.38	651.31	651.28
115a	3619	651.33	651.25	651.23
115b	3604	651.32	651.25	651.22
116	3567	651.33	651.25	651.22
117	3361	651.33	651.25	651.22
118	2808	651.30	651.21	651.18
119	2354	651.25	651.15	651.12
120	1834	651.24	651.14	651.10
121	1409	651.23	651.13	651.09
122	1187	651.22	651.11	651.08
123	896	651.19	651.08	651.04

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Downstream Slope -20%	Calibrated Profile	Downstream Slope + 20%
		S = 0.00006	S = 0.000075	S = 0.00009
124	664	651.18	651.07	651.03
125	364	651.17	651.05	651.01
126	0	651.15	651.03	650.98
average difference		0.02		-0.01
maximum difference		0.12		-0.05

[1] River station 0 is located at the downstream end of the model and increases moving upstream.

TABLE 6 Sensitivity Analysis, Variable Channel Manning Roughness at 100-year Flood

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness + 20%
2	33252	653.15	653.29	653.41
3	32889	653.15	653.29	653.41
4	32783	653.15	653.29	653.41
5a	32669	653.13	653.27	653.39
5b	32632	653.12	653.26	653.38
6	32504	653.13	653.27	653.38
7	32213	653.13	653.27	653.38
8	31887	653.12	653.26	653.38
9	31710	653.12	653.26	653.38
10	31589	653.12	653.26	653.38
11	31344	653.12	653.26	653.37
12	31163	653.10	653.25	653.36
13	31046	653.11	653.25	653.37
14	30951	653.10	653.24	653.36
15	30765	653.08	653.23	653.35
16	30670	653.07	653.22	653.34
17a	30611	653.06	653.21	653.33
17b	30605	653.05	653.20	653.32
18	30573	653.03	653.18	653.30
19	30533	653.03	653.18	653.30
20	30487	653.02	653.17	653.29
21a	30426	653.01	653.16	653.28
21b	30422	653.00	653.15	653.27
22	30382	653.01	653.15	653.28
23	30317	653.01	653.15	653.27
24	30251	653.01	653.15	653.27
25	30203	653.00	653.14	653.26
26	30129	652.99	653.13	653.25
27	30056	652.98	653.12	653.24
28	29984	652.96	653.10	653.21
29a	29939	652.94	653.08	653.20
29b	29916	652.92	653.06	653.18
30	29882	652.92	653.06	653.17
31	29817	652.92	653.05	653.16
32	29757	652.90	653.03	653.15
33	29712	652.89	653.02	653.14
34a	29682	652.85	652.99	653.10
34b	29642	652.82	652.95	653.06
35	29602	652.81	652.94	653.05
36	29563	652.82	652.94	653.05
37	29525	652.83	652.95	653.05
38	29468	652.81	652.94	653.04
39	29415	652.79	652.92	653.02
40	29316	652.76	652.88	652.98
41	29230	652.76	652.88	652.97
42	29139	652.75	652.86	652.95

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness + 20%
43	29048	652.75	652.86	652.95
44a	28990	652.73	652.84	652.92
44b	28983	652.72	652.83	652.92
45	28939	652.72	652.83	652.92
46	28835	652.72	652.83	652.91
47	28639	652.68	652.79	652.87
48	28462	652.68	652.78	652.86
49	28192	652.64	652.75	652.83
50a	28102	652.53	652.65	652.74
50b	28076	652.51	652.63	652.71
51	27923	652.53	652.63	652.71
52	27791	652.51	652.61	652.69
53	27587	652.48	652.58	652.66
54	27341	652.44	652.54	652.62
55	27167	652.43	652.52	652.60
56a	27081	652.36	652.46	652.53
56b	27075	652.36	652.45	652.53
57	26993	652.38	652.47	652.54
58	26733	652.36	652.44	652.51
59	26530	652.34	652.43	652.49
60	26276	652.33	652.41	652.48
61	25946	652.31	652.39	652.46
62	25654	652.31	652.39	652.45
63	25306	652.30	652.38	652.45
64	25031	652.30	652.38	652.44
65	24674	652.30	652.38	652.44
66	23024	652.29	652.37	652.44
67	22196	652.29	652.37	652.43
68	20978	652.28	652.37	652.43
69	20015	652.28	652.36	652.43
70	19311	652.27	652.35	652.42
71	18883	652.27	652.35	652.42
72	18482	652.24	652.33	652.40
73	18262	652.22	652.31	652.38
74a	18192	652.15	652.24	652.32
74b	18178	652.15	652.24	652.31
75	18142	652.14	652.23	652.30
76	17874	652.16	652.24	652.30
77	17715	652.14	652.23	652.29
78	17466	652.14	652.22	652.28
79	17008	652.12	652.20	652.27
80	16857	652.10	652.19	652.26
81	16527	652.10	652.18	652.25
82	16165	652.09	652.17	652.24
83	15432	652.04	652.13	652.20
84	14817	652.01	652.10	652.18
85	14428	652.00	652.09	652.16

Cross-section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness + 20%
86	14203	651.97	652.06	652.13
87	13868	651.91	652.00	652.07
88	13599	651.88	651.97	652.03
89	13411	651.88	651.95	652.02
90	13172	651.87	651.95	652.01
91	12608	651.84	651.92	651.99
92	12344	651.83	651.91	651.98
93	12208	651.81	651.89	651.96
94	11200	651.76	651.85	651.92
95	10762	651.75	651.84	651.92
96	10264	651.73	651.83	651.90
97	9593	651.71	651.80	651.88
98	9240	651.69	651.79	651.87
99	9095	651.67	651.78	651.86
100	7955	651.56	651.67	651.76
101a	7890	651.56	651.66	651.75
101b	7876	651.55	651.65	651.74
102	7782	651.54	651.64	651.73
103	7699	651.54	651.64	651.73
104	7509	651.54	651.63	651.72
105	7133	651.51	651.61	651.70
106	6773	651.49	651.59	651.68
107	6021	651.47	651.57	651.66
108	5671	651.45	651.55	651.65
109	5234	651.40	651.51	651.61
110	4934	651.35	651.46	651.56
111	4406	651.29	651.39	651.48
112	4172	651.25	651.38	651.47
113	3761	651.21	651.33	651.43
114	3669	651.19	651.31	651.40
115a	3619	651.12	651.25	651.35
115b	3604	651.12	651.25	651.34
116	3567	651.13	651.25	651.35
117	3361	651.13	651.25	651.34
118	2808	651.09	651.21	651.31
119	2354	651.02	651.15	651.26
120	1834	651.01	651.14	651.24
121	1409	651.00	651.13	651.23
122	1187	650.98	651.11	651.22
123	896	650.95	651.08	651.19
124	664	650.94	651.07	651.18
125	364	650.92	651.05	651.16
126	0	650.89	651.03	651.13
average difference		-0.10		0.09
maximum difference		-0.15		0.13

1 River station 0 is located at the downstream end of the model and increases moving upstream.

TABLE 7 Sensitivity Analysis, Variable Overbank Manning Roughness at 100-year Flood

Cross -section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness + 20%
2	33252	653.19	653.29	653.38
3	32889	653.19	653.29	653.38
4	32783	653.19	653.29	653.38
5a	32669	653.17	653.27	653.36
5b	32632	653.16	653.26	653.35
6	32504	653.17	653.27	653.36
7	32213	653.16	653.27	653.36
8	31887	653.16	653.26	653.35
9	31710	653.16	653.26	653.35
10	31589	653.16	653.26	653.35
11	31344	653.16	653.26	653.35
12	31163	653.14	653.25	653.33
13	31046	653.15	653.25	653.34
14	30951	653.14	653.24	653.33
15	30765	653.13	653.23	653.32
16	30670	653.12	653.22	653.31
17a	30611	653.11	653.21	653.29
17b	30605	653.10	653.20	653.28
18	30573	653.08	653.18	653.27
19	30533	653.08	653.18	653.27
20	30487	653.07	653.17	653.26
21a	30426	653.06	653.16	653.25
21b	30422	653.05	653.15	653.24
22	30382	653.05	653.15	653.24
23	30317	653.05	653.15	653.24
24	30251	653.05	653.15	653.24
25	30203	653.04	653.14	653.23
26	30129	653.03	653.13	653.22
27	30056	653.02	653.12	653.21
28	29984	653.00	653.10	653.19
29a	29939	652.98	653.08	653.17
29b	29916	652.96	653.06	653.15
30	29882	652.96	653.06	653.15
31	29817	652.95	653.05	653.15
32	29757	652.93	653.03	653.13
33	29712	652.92	653.02	653.12
34a	29682	652.88	652.99	653.09
34b	29642	652.84	652.95	653.05
35	29602	652.83	652.94	653.04
36	29563	652.83	652.94	653.05
37	29525	652.84	652.95	653.05
38	29468	652.82	652.94	653.04
39	29415	652.80	652.92	653.02
40	29316	652.76	652.88	652.99
41	29230	652.75	652.88	652.98
42	29139	652.74	652.86	652.97

Cross -section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness + 20%
43	29048	652.74	652.86	652.97
44a	28990	652.71	652.84	652.94
44b	28983	652.71	652.83	652.94
45	28939	652.71	652.83	652.94
46	28835	652.70	652.83	652.93
47	28639	652.66	652.79	652.89
48	28462	652.66	652.78	652.89
49	28192	652.63	652.75	652.86
50a	28102	652.52	652.65	652.76
50b	28076	652.49	652.63	652.74
51	27923	652.50	652.63	652.74
52	27791	652.48	652.61	652.72
53	27587	652.45	652.58	652.69
54	27341	652.42	652.54	652.65
55	27167	652.40	652.52	652.63
56a	27081	652.33	652.46	652.57
56b	27075	652.32	652.45	652.57
57	26993	652.34	652.47	652.58
58	26733	652.31	652.44	652.56
59	26530	652.30	652.43	652.54
60	26276	652.28	652.41	652.53
61	25946	652.26	652.39	652.51
62	25654	652.26	652.39	652.51
63	25306	652.25	652.38	652.50
64	25031	652.25	652.38	652.50
65	24674	652.24	652.38	652.49
66	23024	652.24	652.37	652.49
67	22196	652.24	652.37	652.49
68	20978	652.24	652.37	652.48
69	20015	652.23	652.36	652.48
70	19311	652.23	652.35	652.47
71	18883	652.22	652.35	652.46
72	18482	652.20	652.33	652.44
73	18262	652.19	652.31	652.42
74a	18192	652.12	652.24	652.35
74b	18178	652.11	652.24	652.35
75	18142	652.11	652.23	652.34
76	17874	652.12	652.24	652.35
77	17715	652.10	652.23	652.34
78	17466	652.10	652.22	652.33
79	17008	652.08	652.20	652.31
80	16857	652.07	652.19	652.30
81	16527	652.07	652.18	652.29
82	16165	652.06	652.17	652.28
83	15432	652.01	652.13	652.23
84	14817	651.99	652.10	652.21
85	14428	651.98	652.09	652.19

Cross -section	River Station[1]	Simulated Water Surface Elevation at 100-year Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Overbank Roughness + 20%
86	14203	651.95	652.06	652.16
87	13868	651.89	652.00	652.10
88	13599	651.85	651.97	652.07
89	13411	651.84	651.95	652.06
90	13172	651.84	651.95	652.05
91	12608	651.81	651.92	652.03
92	12344	651.80	651.91	652.02
93	12208	651.78	651.89	652.00
94	11200	651.74	651.85	651.95
95	10762	651.74	651.84	651.94
96	10264	651.72	651.83	651.93
97	9593	651.70	651.80	651.90
98	9240	651.69	651.79	651.89
99	9095	651.68	651.78	651.88
100	7955	651.57	651.67	651.76
101a	7890	651.57	651.66	651.76
101b	7876	651.56	651.65	651.75
102	7782	651.55	651.64	651.74
103	7699	651.55	651.64	651.73
104	7509	651.54	651.63	651.73
105	7133	651.52	651.61	651.70
106	6773	651.50	651.59	651.68
107	6021	651.48	651.57	651.66
108	5671	651.47	651.55	651.64
109	5234	651.43	651.51	651.60
110	4934	651.38	651.46	651.55
111	4406	651.31	651.39	651.48
112	4172	651.31	651.38	651.47
113	3761	651.26	651.33	651.42
114	3669	651.24	651.31	651.40
115a	3619	651.19	651.25	651.34
115b	3604	651.19	651.25	651.33
116	3567	651.19	651.25	651.33
117	3361	651.19	651.25	651.33
118	2808	651.16	651.21	651.30
119	2354	651.10	651.15	651.24
120	1834	651.09	651.14	651.22
121	1409	651.08	651.13	651.21
122	1187	651.07	651.11	651.19
123	896	651.04	651.08	651.16
124	664	651.04	651.07	651.15
125	364	651.02	651.05	651.13
126	0	650.99	651.03	651.10
	average difference	-0.10		0.09
	maximum difference	-0.14		0.12

1 River station 0 is located at the downstream end of the model and increases moving upstream.

TABLE 8 Floodway Stations and Limiting Floodway Determination Criteria

		Floodway Stations (m)		Governing Floodway Criterion	
Cross-Section	River Station	Left Station	Right Station	Left Station	Right Station
2	33252	296.59	1888.05	Inundation Limit	Inundation Limit
3	32889	248.31	1596.42	Historic Floodway	Inundation Limit
4	32783	237.95	1528.21	Historic Floodway	Historic Floodway
5a	32669	1340.06	1402.43	Inundation Limit	Inundation Limit
5b	32632	1336.30	1396.53	Inundation Limit	Inundation Limit
6	32504	612.04	910.10	Historic Floodway	Inundation Limit
7	32213	323.18	664.47	Historic Floodway	Inundation Limit
8	31887	210.78	531.89	Historic Floodway	Inundation Limit
9	31710	136.41	485.20	Historic Floodway	Historic Floodway
10	31589	188.77	438.10	Inundation Limit	Inundation Limit
11	31344	162.41	460.22	Historic Floodway	Inundation Limit
12	31163	122.33	391.85	Historic Floodway	Historic Floodway
13	31046	80.67	353.55	Historic Floodway	Historic Floodway
14	30951	117.74	342.46	Historic Floodway	Historic Floodway
15	30765	232.15	334.51	Historic Floodway	Historic Floodway
16	30670	142.44	218.16	Historic Floodway	Inundation Limit
17a	30611	15.16	75.48	Historic Floodway	Inundation Limit
17b	30605	14.11	76.57	Historic Floodway	Inundation Limit
18	30573	90.00	147.30	Historic Floodway	Historic Floodway
19	30533	71.88	128.47	Inundation Limit	Historic Floodway
20	30487	62.76	121.00	Inundation Limit	Historic Floodway
21a	30426	56.16	105.59	Inundation Limit	Inundation Limit
21b	30422	55.37	104.22	Inundation Limit	Inundation Limit
22	30382	19.33	111.13	Inundation Limit	Historic Floodway
23	30317	18.05	107.56	Inundation Limit	Historic Floodway
24	30251	15.28	115.58	Inundation Limit	Inundation Limit
25	30203	48.66	118.93	Inundation Limit	Historic Floodway
26	30129	55.91	123.51	Inundation Limit	Inundation Limit
27	30056	119.56	167.67	Inundation Limit	Inundation Limit
28	29984	121.83	160.85	Inundation Limit	Inundation Limit
29a	29939	72.92	111.69	Inundation Limit	Inundation Limit
29b	29916	52.20	91.81	Historic Floodway	Inundation Limit
30	29882	23.29	68.31	Inundation Limit	Inundation Limit
31	29817	24.48	75.46	Historic Floodway	Inundation Limit
32	29757	19.45	68.63	Inundation Limit	Inundation Limit
33	29712	61.23	113.79	Historic Floodway	Historic Floodway
34a	29682	20.43	58.87	Inundation Limit	Inundation Limit
34b	29642	48.46	89.53	Historic Floodway	Historic Floodway
35	29602	47.58	84.53	Inundation Limit	Historic Floodway
36	29563	32.55	71.44	Inundation Limit	Historic Floodway
37	29525	54.69	123.55	Inundation Limit	Historic Floodway
38	29468	85.05	160.02	Historic Floodway	Inundation Limit
39	29415	73.46	136.67	Historic Floodway	Historic Floodway
40	29316	78.16	128.88	Historic Floodway	Inundation Limit
41	29230	46.51	105.84	Historic Floodway	Inundation Limit
42	29139	37.73	94.86	Historic Floodway	Inundation Limit

		Floodway Stations (m)		Governing Floodway Criterion	
Cross-Section	River Station	Left Station	Right Station	Left Station	Right Station
43	29048	41.62	157.30	Historic Floodway	Historic Floodway
44a	28990	12.73	67.11	Historic Floodway	Historic Floodway
44b	28983	11.45	65.72	Historic Floodway	Historic Floodway
45	28939	31.55	118.27	Historic Floodway	Historic Floodway
46	28835	22.45	113.68	Historic Floodway	Historic Floodway
47	28639	22.62	78.79	Historic Floodway	Inundation Limit
48	28462	22.17	121.59	Historic Floodway	Historic Floodway
49	28192	104.33	207.94	Historic Floodway	Historic Floodway
50a	28102	19.16	59.33	Inundation Limit	Historic Floodway
50b	28076	15.83	57.11	Historic Floodway	Historic Floodway
51	27923	82.01	178.33	Historic Floodway	Inundation Limit
52	27791	14.90	87.15	Inundation Limit	Inundation Limit
53	27587	22.48	116.29	Inundation Limit	Historic Floodway
54	27341	18.76	106.50	Inundation Limit	Inundation Limit
55	27167	16.17	117.68	Inundation Limit	Historic Floodway
56a	27081	10.09	45.29	Inundation Limit	Inundation Limit
56b	27075	11.53	46.95	Inundation Limit	Inundation Limit
57	26993	26.20	159.35	Inundation Limit	Inundation Limit
58	26733	16.46	148.84	Inundation Limit	Inundation Limit
59	26530	26.09	174.81	Inundation Limit	Inundation Limit
60	26276	39.16	195.66	Inundation Limit	Historic Floodway
61	25946	44.38	297.27	Historic Floodway	Historic Floodway
62	25654	202.29	521.28	Historic Floodway	Historic Floodway
63	25306	340.61	622.79	Historic Floodway	Inundation Limit
64	25031	368.09	660.25	Historic Floodway	Historic Floodway
65	24674	134.79	785.57	1 m Depth	1 m Depth
66	23024	84.36	918.78	1 m Depth	1 m Depth
67	22196	301.76	1193.55	1 m Depth - Manually Smoothed	1 m Depth
68	20978	321.57	1022.40	1 m Depth	1 m Depth
69	20015	468.90	914.19	1 m Depth	1 m Depth
70	19311	207.74	454.19	1 m Depth	1 m Depth
71	18883	53.49	325.48	1 m Depth	1 m Depth
72	18482	21.26	273.08	1 m Depth	1 m Depth
73	18262	28.74	190.50	1 m Depth	1 m Depth
74a	18192	19.51	51.97	1 m Depth - Manually Smoothed	1 m Depth - Manually Smoothed
74b	18178	20.59	57.00	Inundation Limit	Inundation Limit
75	18142	63.71	10.72	Inundation Limit	Inundation Limit
76	17874	25.36	186.84	Inundation Limit	Inundation Limit
77	17715	12.08	159.24	Inundation Limit	Inundation Limit
78	17466	60.03	312.75	Inundation Limit	Inundation Limit
79	17008	21.92	216.99	Inundation Limit	Inundation Limit
80	16857	16.05	185.60	Inundation Limit	Inundation Limit
81	16527	12.44	338.05	Inundation Limit	Inundation Limit
82	16165	206.18	28.96	Inundation Limit	Inundation Limit
83	15432	24.43	294.43	Inundation Limit	Inundation Limit
84	14817	26.17	245.70	Inundation Limit	Inundation Limit
85	14428	29.57	341.41	Inundation Limit	Inundation Limit

		Floodway Stations (m)		Governing Floodway Criterion	
Cross-Section	River Station	Left Station	Right Station	Left Station	Right Station
86	14203	132.02	298.22	Inundation Limit	Inundation Limit
87	13868	108.76	209.00	Inundation Limit	Inundation Limit
88	13599	99.98	214.56	Inundation Limit	Inundation Limit
89	13411	19.39	242.68	Inundation Limit	Inundation Limit
90	13172	25.87	339.10	Inundation Limit	Inundation Limit
91	12608	16.53	497.58	Inundation Limit	Inundation Limit
92	12344	18.03	471.30	Inundation Limit	Inundation Limit
93	12208	13.71	279.87	Inundation Limit	Inundation Limit
94	11200	11.87	453.40	Inundation Limit	Inundation Limit
95	10762	13.23	465.43	Inundation Limit	Inundation Limit
96	10264	12.87	250.27	Inundation Limit	Inundation Limit
97	9593	28.00	361.60	Inundation Limit	Inundation Limit
98	9240	12.24	362.36	Inundation Limit	Inundation Limit
99	9095	13.22	397.00	Inundation Limit	Inundation Limit
100	7955	16.90	138.52	Inundation Limit	Inundation Limit
101a	7890	25.92	75.10	Inundation Limit	1 m Depth
101b	7876	25.14	72.87	Inundation Extent	1 m Depth
102	7782	135.67	44.11	1 m Depth	1 m Depth - Manually Smoothed
103	7699	25.76	157.07	1 m Depth - Manually Smoothed	1 m Depth
104	7509	241.82	14.19	1 m Depth	1 m Depth
105	7133	12.35	174.03	1 m Depth	1 m Depth
106	6773	161.61	13.76	1 m Depth - Manually Smoothed	1 m Depth - Manually Smoothed
107	6021	410.60	11.04	1 m Depth	1 m Depth
108	5671	18.49	293.75	1 m Depth	1 m Depth
109	5234	206.06	22.19	1 m Depth - Manually Smoothed	1 m Depth
110	4934	17.87	96.36	1 m Depth	1 m Depth - Manually Smoothed
111	4406	24.91	201.27	1 m Depth - Manually Smoothed	1 m Depth - Manually Smoothed
112	4172	88.55	330.69	1 m Depth	1 m Depth
113	3761	90.24	307.50	1 m Depth	1 m Depth
114	3669	27.54	86.26	1 m Depth	1 m Depth
115a	3619	13.21	46.49	1 m Depth	1 m Depth

1 Based on hydraulic smoothing
2 No viable flood fringe

TABLE 9 Design Flood Water Surface Elevations

Cross-Section[1]	River Station[2]	Water Surface Elevation (m)
2	33252	653.29
3	32889	653.29
4	32783	653.29
5a	32669	653.27
5b	32632	653.26
6	32504	653.27
7	32213	653.27
8	31887	653.26
9	31710	653.26
10	31589	653.26
11	31344	653.26
12	31163	653.25
13	31046	653.25
14	30951	653.24
15	30765	653.23
16	30670	653.22
17a	30611	653.21
17b	30605	653.20
18	30573	653.18
19	30533	653.18
20	30487	653.17
21a	30426	653.16
21b	30422	653.15
22	30382	653.15
23	30317	653.15
24	30251	653.15
25	30203	653.14
26	30129	653.13
27	30056	653.12
28	29984	653.10
29a	29939	653.08
29b	29916	653.06
30	29882	653.06
31	29817	653.05
32	29757	653.03
33	29712	653.02
34a	29682	652.99
34b	29642	652.95
35	29602	652.94
36	29563	652.94
37	29525	652.95
38	29468	652.94
39	29415	652.92
40	29316	652.88
41	29230	652.88
42	29139	652.86
43	29048	652.86

Cross-Section[1]	River Station[2]	Water Surface Elevation (m)
44a	28990	652.84
44b	28983	652.83
45	28939	652.83
46	28835	652.83
47	28639	652.79
48	28462	652.78
49	28192	652.75
50a	28102	652.65
50b	28076	652.63
51	27923	652.63
52	27791	652.61
53	27587	652.58
54	27341	652.54
55	27167	652.52
56a	27081	652.46
56b	27075	652.45
57	26993	652.47
58	26733	652.44
59	26530	652.43
60	26276	652.41
61	25946	652.39
62	25654	652.39
63	25306	652.38
64	25031	652.38
65	24674	652.38
66	23024	652.37
67	22196	652.37
68	20978	652.37
69	20015	652.36
70	19311	652.35
71	18883	652.35
72	18482	652.33
73	18262	652.31
74a	18192	652.24
74b	18178	652.24
75	18142	652.23
76	17874	652.24
77	17715	652.23
78	17466	652.22
79	17008	652.20
80	16857	652.19
81	16527	652.18
82	16165	652.17
83	15432	652.13
84	14817	652.10
85	14428	652.09
86	14203	652.06
87	13868	652.00

Cross-Section[1]	River Station[2]	Water Surface Elevation (m)
88	13599	651.97
89	13411	651.95
90	13172	651.95
91	12608	651.92
92	12344	651.91
93	12208	651.89
94	11200	651.85
95	10762	651.84
96	10264	651.83
97	9593	651.80
98	9240	651.79
99	9095	651.78
100	7955	651.67
101a	7890	651.66
101b	7876	651.65
102	7782	651.64
103	7699	651.64
104	7509	651.63
105	7133	651.61
106	6773	651.59
107	6021	651.57
108	5671	651.55
109	5234	651.51
110	4934	651.46
111	4406	651.39
112	4172	651.38
113	3761	651.33
114	3669	651.31
115a	3619	651.25

1 Cross-sections downstream of the Highway 37 bridge (CS-115a) are outside of the mapping boundary.

2 River station 0 is located at the downstream end of the model and increases moving upstream.

APPENDIX A
Survey and Base Data Collection Documentation

APPENDIX A1
Survey Control and RTK Survey Quality Assurance Documentation

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 3, 2019

File Name: 215489 MN MAY31 2019.vce **CSF:** 0.999 807

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:	**Known Point:**	**Reference File:**
Sta: 333229	Sta: ASCM 333229	
Check:		
Sta: 418756	Sta: ASCM 418756	
		Δ N: 0.010 **Δ E:** 0.040

Vertical Adjustment:		
Sta: same as above	Sta: same as above	same as above
	Published: 658.321	
Check:		
Sta: same as above	Sta: same as above	same as above
	Published: 655.679 **Observed:** 655.696	**Δ Z:** 0.017

DRAFT

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ◉ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 BC JUN04 2019.vce **CSF:** 0.999 808

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 333229

Known Point:

Sta: 333229

Reference File:

EDITED RTK 215489 MN MAY31 2019

Check:

Sta: 1000

Sta: 1

EDITED RTK 215489 MN MAY31 2019

Δ N: 0.000 **Δ E:** 0.010

Vertical Adjustment:

Sta: same as above

Sta: same as above

same as above

Published: 658.321

Check:

Sta: same as above

Sta: same as above

same as above

Published: 657.959 **Observed:** 657.956 **Δ Z:** -0.003

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 BC JUN05 2019.vce **CSF:** 0.999 808

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 1

Known Point:

Sta: 1

Reference File:

EDITED RTK 215489 MN MAY31 2019

Check:

Sta: MC-CHK1

Sta: ChkMC

EDITED RTK 215489 RS JUN06 2019

Δ N: 0.010 **Δ E:** 0.010

Vertical Adjustment:

Sta: same as above

Sta: same as above

same as above

Published: 657.959

Check:

Sta: same as above

Sta: same as above

same as above

Published: 655.256 **Observed:** 655.255 **Δ Z:** -0.001

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

AltusGeomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 BC JUN06 2019.vce **CSF:** 0.999 808

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:	**Known Point:**	**Reference File:**
Sta: 1	Sta: 1	EDITED RTK 215489 MN MAY31 2019
Check:		
Sta: none	Sta:	
		Δ N: **Δ E:**

Vertical Adjustment:		
Sta: same as above	Sta: same as above	same as above
	Published: 657.959	
Check:		
Sta: same as above	Sta: same as above	same as above
	Published:	**Observed:** **Δ Z:**

Check:

- ◯ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ◯ Total Station Data
- ◯ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 BC JUN07 2019.vce **CSF:** 0.999 | 809

Reference Station:

Horizontal: ASCM 185223 **Vertical:** ASCM 185223, 655.52 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 185223

Check:

Sta: none

Known Point:

Sta: ASCM 185223

Sta:

Reference File:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: same as above

Sta: same as above | same as above

Published: 655.520

Check:

Sta: same as above

Sta: same as above | same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

AltusGeomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 BC JUN08 2019.vce **CSF:** 0.999 | 80

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 4

Known Point:

Sta: 4

Reference File:

EDITED RTK 215489 MN MAY31 2019

Check:

Sta: 5chk

Sta: 5

EDITED RTK 215489 MN MAY31 2019

Δ N: 0.010 **Δ E:** 0.020

Vertical Adjustment:

Sta: same as above

Sta: same as above

same as above

Published: 651.190

Check:

Sta: same as above

Sta: same as above

same as above

Published: 651.283 **Observed:** 651.304 **Δ Z:** 0.021

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

AltusGeomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 BC JUN09 2019.vce **CSF:** 0.999 | 810

Reference Station:

Horizontal: ASCM 418756 **Vertical:** ASCM 418756, 655.679 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 418756

Check:

Sta: none

Known Point:

Sta: ASCM 418756

Sta:

Reference File:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: same as above

Check:

Sta: same as above

Sta: same as above | same as above

Published: 655.679

Sta: same as above | same as above

Published: **Observed:** **Δ Z:**

Check:

- ◯ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ◯ Total Station Data
- ◯ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun10 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Known Point:

Sta: 10

Reference File:

EDITED 215489 MN MAY31 2019

Check:

Sta: None

Sta:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Sta: same as above

same as above

Published:

Check:

Sta: None

Sta: same as above

same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ● RMS / Float Solutions
- ● Duplicate points
- ● Antenna Height Change
- ● Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

DRAFT

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun11 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: 8

Sta:

Reference File:

EDITED 215489 MN MAY31 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above

same as above

Published:

Sta: same as above

same as above

Published: **Observed:** **Δ Z:**

Check:

- ◯ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ◯ Total Station Data
- ◯ Static Solutions / PPP Results

Comments:

DRAFT

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun11 2019_2 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: 8, 10

Sta:

Reference File:

EDITED 215489 MN MAY31 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above same as above

Published:

Sta: same as above same as above

Published: **Observed:** **Δ Z:**

DRAFT

Check:

- ◯ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ◯ Total Station Data
- ◯ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun12 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: 9

Sta:

Reference File:

EDITED 215489 MN MAY31 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above

same as above

Published:

Sta: same as above

same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments: Changed base ant. ht from 0.000m to 1.352m as shown in field notes.

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun13 2019 **CSF:** 0.999 808

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: MC

Sta:

Reference File:

EDITED RTK 215489 BC JUN04 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above — same as above

Published:

Sta: same as above — same as above

Published: **Observed:** **Δ Z:**

Check:

- ◯ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ◯ Total Station Data
- ◯ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun14 2019 **CSF:** 0.999 | 808

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Known Point:

Sta: MC

Reference File: EDITED RTK 215489 BC JUN04 2019

Check:

Sta: 4CHK

Sta: 4

EDITED RTK 215489 BC JUN08 2019

Δ N: 0.013 **Δ E:** 0.019

Vertical Adjustment:

Sta: None

Sta: same as above — same as above

Published:

Check:

Sta: 4CHK

Sta: same as above — same as above

Published: 651.190 **Observed:** 651.157 **Δ Z:** -0.033

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun15 2019 **CSF:** 0.999 | 809

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Known Point:

Sta: MC, 8

Reference File:

EDITED RTK 215489 BC JUN04 2019

Check:

Sta: ?

Sta:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Sta: same as above

same as above

Published:

Check:

Sta: ?

Sta: same as above

same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

DRAFT

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 BC Jun18 2019 **CSF:** 0.999 813

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:	**Known Point:**	**Reference File:**
Sta: None	Sta: 10	EDITED 215489 MN MAY31 2019
Check:		
Sta: 9CHK	Sta: 9	EDITED 215489 MN MAY31 2019
		Δ N: 0.003 **Δ E:** 0.014

Vertical Adjustment:		
Sta: None	Sta: same as above	same as above
	Published:	
Check:		
Sta: 9CHK	Sta: same as above	same as above
	Published: 651.848 **Observed:** 651.843	**Δ Z:** -0.005

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

DRAFT

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Sep 19, 2019

File Name: RTK 215489 BC SEP19 2019.vce **CSF:** 0.999 808

Reference Station:

Horizontal: ? **Vertical:** ? **Zone:** 114 W

Projection: 3TM **Frame:** **Epoch:** **Vert. Datum:** **Geoid:**

Horizontal Adjustment:

Sta: 394965

Known Point:

Sta: 394965

Reference File:

Edited RTK 215489 MT Jun10 2019

Check:

Sta:

Sta:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: same as above

Sta: same as above

same as above

Published:

Check:

Sta:

Sta:

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

entered base coordinates do not match refernce file or ASCM card

left as entered

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 CT JUN07 2019.vce **CSF:** 0.999 809

Reference Station:

Horizontal: ASCM 185223 **Vertical:** ASCM 185223, 655.52 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 185223

Check:

Sta: none

Known Point:

Sta: ASCM 185223

Sta:

Reference File:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: same as above

Sta: same as above — same as above

Published: 655.520

Check:

Sta: same as above

Sta: same as above — same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 CT Jun10 2019 **CSF:** 0.999 | 810

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:	**Known Point:**	**Reference File:**
Sta: None	Sta: 394965	EDITED 215489 MN MAY31 2019
Check:		
Sta: 418756ch	Sta: 418756	EDITED 215489 MN MAY31 2019
		Δ N: 0.008 **Δ E:** 0.014

Vertical Adjustment:		
Sta: None	Sta: same as above	same as above
	Published:	
Check:		
Sta: 418756ch	Sta: same as above	same as above
	Published: 655.696	**Observed:** 655.696 **Δ Z:**

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 CT Jun11 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: 8

Sta:

Reference File:

EDITED 215489 MN MAY31 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above — same as above

Published:

Sta: same as above — same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 CT Jun12 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Known Point:

Sta: 9

Reference File:

EDITED 215489 MN MAY31 2019

Check:

Sta: 10chk

Sta: 10

EDITED 215489 MN MAY31 2019

Δ N: 0.029 **Δ E:** 0.004

Vertical Adjustment:

Sta: None

Sta: same as above

same as above

Published:

Check:

Sta: 10chk

Sta: same as above

same as above

Published: 651.918 **Observed:** 651.917 **Δ Z:** -0.001

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

Changed base ant. ht from 0.000m to 1.352m as shown in field notes.

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 JL Jun10 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: 10

Sta:

Reference File:

EDITED 215489 MN MAY31 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above — same as above

Published:

Sta: same as above — same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 JL Jun11 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment: | **Known Point:** | **Reference File:**

Sta: None | Sta: 8 | EDITED 215489 MN MAY31 2019

Check:

Sta: 7chk | Sta: 7 | EDITED 215489 MN MAY31 2019

Δ N: 0.001 **Δ E:** 0.003

Vertical Adjustment:

Sta: None | Sta: same as above | same as above

Published:

Check:

Sta: 7chk | Sta: same as above | same as above

Published: 650.713 **Observed:** 650.711 **Δ Z:** -0.002

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 JL Jun12 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:	**Known Point:**	**Reference File:**
Sta: None	Sta: 9	EDITED 215489 MN MAY31 2019
Check: Sta: 10chk	Sta: 10	EDITED 215489 MN MAY31 2019
		Δ N: 0.029 **Δ E:** 0.001

Vertical Adjustment:		
Sta: None	Sta: same as above	same as above
	Published:	
Check: Sta: 10chk	Sta: same as above	same as above
	Published: 651.918 **Observed:** 651.905	**Δ Z:** -0.013

DRAFT

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments: Changed base ant. ht from 0.000m to 1.352m as shown in field notes.

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 3, 2019

File Name: RTK 215489 MN MAY31 2019.vce **CSF:** 0.999 807

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: 333229

Check:

Sta: see comments

Known Point:

Sta: ASCM 333229

Sta:

Reference File:

Δ N: **Δ E:**

Vertical Adjustment:

Sta: same as above

Check:

Sta: same as above

Sta: same as above

same as above

Published: 658.321

Sta: same as above

same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

refer to static / infill file for check info
215489 MN MAY31 2019.vce

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 MT Jun10 2019 **CSF:** 0.999 | 810

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: 15000

Known Point:

Sta: 394965

Sta: 418756

Reference File:

EDITED 215489 MN MAY31 2019

EDITED 215489 MN MAY31 2019

Δ N: 0.007 **Δ E:** 0.002

Vertical Adjustment:

Sta: None

Check:

Sta: 15000

Sta: same as above | same as above

Published:

Sta: same as above | same as above

Published: 655.696 **Observed:** 655.687 **Δ Z:** -0.009

Check:

- (●) RTK Base Elevation Check
- (●) RMS / Float Solutions
- (●) Duplicate points
- (●) Antenna Height Change
- (●) Export Base and Measured Points only
- ( ) Total Station Data
- ( ) Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: JN **Date:** Jun 21, 2019

File Name: Edited RTK 215489 MT Jun11 2019 **CSF:** 0.999 812

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: UTM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:

Sta: None

Check:

Sta: None

Known Point:

Sta: 8

Sta:

Reference File:

EDITED 215489 MN MAY31 2019

Δ N: **Δ E:**

Vertical Adjustment:

Sta: None

Check:

Sta: None

Sta: same as above — same as above

Published:

Sta: same as above — same as above

Published: **Observed:** **Δ Z:**

Check:

- ○ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ○ Total Station Data
- ○ Static Solutions / PPP Results

Comments:

Altus Geomatics

GNSS Check List

Job Number: 215489

Compiled By: CH **Date:** Jun 10, 2019

File Name: RTK 215489 RS JUN06 2019.vce **CSF:** 0.999 | 808

Reference Station:

Horizontal: ASCM 333229 **Vertical:** ASCM 333229, 658.321 **Zone:** 114 W

Projection: 3TM **Frame:** Original **Epoch:** **Vert. Datum:** CGVD28 **Geoid:** GSD95

Horizontal Adjustment:	**Known Point:**	**Reference File:**
Sta: 1	Sta: 1	EDITED RTK 215489 MN MAY31 2019
Check:		
Sta: none	Sta:	
		Δ N: **Δ E:**

Vertical Adjustment:		
Sta: same as above	Sta: same as above	same as above
	Published: 657.959	
Check:		
Sta: same as above	Sta: same as above	same as above
	Published:	**Observed:** **Δ Z:**

DRAFT

Check:

- ◯ RTK Base Elevation Check
- ◉ RMS / Float Solutions
- ◉ Duplicate points
- ◉ Antenna Height Change
- ◉ Export Base and Measured Points only
- ◯ Total Station Data
- ◯ Static Solutions / PPP Results

Comments:

APPENDIX A2
Survey Control and Ground Survey Equipment Specifications

TRIMBLE R6 GNSS SYSTEM

KEY FEATURES

Trimble R-Track satellite tracking technology

Includes Trimble Maxwell 6 chip with **220 channels**

Industry-leading GNSS positioning with **GPS L2C, L5 and QZSS**

Scalable to add capability as your business needs change

Flexible, integrated system design

FLEXIBLE, SCALABLE, READY FOR ANYTHING

Sometimes one size doesn't fit all, and you require a customized solution that can grow with your business. The Answer? The Trimble® R6 GNSS system. It combines advanced GNSS technology with the scalability and freedom to adapt and grow as your business needs change. Featuring Trimble R-Track™ technology, integrated communications choices, and GNSS upgrade options, the Trimble R6 works the way you want it today, but is positioned to offer what you may need tomorrow.

INTEGRATED SYSTEM DESIGN

The Trimble R6 combines a highly integrated and advanced GNSS receiver, precision antenna, long-life battery and integrated communications into a rugged and reliable body.

Integrated communications options provide you the flexibility to choose the type of communications that best fit how your crews work. An integrated cellular modem streamlines operation inside VRS networks while integrated UHF RX or RX/TX streamlines RTK base/rover applications.

GNSS TECHNOLOGY THAT MAKES THE DIFFERENCE

Powered with a Trimble Maxwell™ 6 chip with 220 channels, the Trimble R6 delivers the accuracy and reliability required for precision surveying with superior tracking and RTK performance. With GPS L2C, L5, and the Japanese QZSS included, and GLONASS, Galileo, and BeiDou (COMPASS) upgrade options, you can track more satellites and measure more successfully in challenging environments. Plus, L2C provides more than just additional signals – the advanced signal structure also provides better strength for more reliable satellite tracking.

The third civil GPS frequency L5 provides a higher power level than other frequencies, and uses a larger bandwidth, enabling longer codes. As a result, acquiring and tracking weak signals is much easier.

This advanced tracking and positioning technology from Trimble reduces the time it takes to re-initialize and downtime caused by loss of lock.

ADVANCED TRIMBLE R-TRACK TECHNOLOGY

Integrated into the Trimble R6, Trimble R-Track technology delivers reliable, precise positioning performance. Trimble R-Track with Signal Prediction™ compensates for intermittent or marginal RTK correction signals, enabling extended precision operation after an RTK signal is interrupted.

The CMRx communications protocol provides correction compression for optimized bandwidth and full utilization of all the satellites in view, giving you reliable positioning performance.

SCALABILITY TO MEET YOUR CHANGING NEEDS

This fully upgradable receiver allows you to choose the level of GNSS support that suits your needs today with the flexibility to upgrade as your requirements evolve.

GPS, L1, L2, L2C, L5 and the Japanese QZSS signals are supported as standard in the Trimble R6. For additional constellation support, add optional GLONASS, GALILEO and BeiDou (COMPASS) support.

THE MOST FLEXIBLE FIELD SOLUTION

For the most flexible field solution, partner the Trimble R6 with a Trimble controller—such as the TSC3, Trimble Tablet Rugged PC, or Trimble CU—featuring Trimble Access™ field software. These rugged controllers bring the power of the office to the field through an intiutive Windows-based interface.

Trimble Access field software offers numerous features and capabilities to streamline the flow of everyday surveying work. Streamlined workflows such as Roads, Monitoring, Mines, and Tunnels—guide crews through common project types and allows crews to get the job done faster with less distractions. Choose the workflow relevant to your business and begin working. Survey companies can also implement their unique workflows by taking advantage of the customization capabilities available in the Trimble Access Software Development Kit (SDK).

Need to get data back to the office immediately? Benefit from real-time data sharing via Trimble Access Services, now available with any valid Trimble Access maintenance agreement.

Back in the office, seamlessly transfer your field data using Trimble Business Center software. Edit, process, and adjust collected data with confidence.

The Trimble R6 GNSS System. Positioned for your business needs today...and tomorrow.

Trimble

TRIMBLE R6
GNSS SYSTEM

PERFORMANCE SPECIFICATIONS

Measurements

- Advanced Trimble Maxwell 6 Custom Survey GNSS chip with 220 channels
- Trimble R-Track technology
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- Satellite signals tracked simultaneously:
  - GPS: L1C/A, L1C, L2C, L2E, L5
  - GLONASS[1]: L1C/A, L1P, L2C/A, L2P, L3
  - SBAS: L1C/A, L5 (for SBAS satellites that support L5)
  - Galileo[1]: E1, E5A, E5
  - BeiDou (COMPASS)[1]: B1, B2
- SBAS: QZSS, WAAS, EGNOS, GAGAN
- Positioning rates: 1 Hz, 2 Hz, 5 Hz, and 10 Hz

POSITIONING PERFORMANCE[2]

Code differential GNSS positioning

Horizontal . . . . 0.25 m + 1 ppm RMS
Vertical . . . . 0.50 m + 1 ppm RMS
SBAS differential positioning accuracy[3] . . . . typically <5 m 3DRMS

STATIC GNSS SURVEYING

High-precision static

Horizontal . . . . 3 mm + 0.1 ppm RMS
Vertical . . . . 3.5 mm + 0.4 ppm RMS

Static and FastStatic

Horizontal . . . . 3 mm + 0.5 ppm RMS
Vertical . . . . 5 mm + 0.5 ppm RMS

POSTPROCESSED KINEMATIC (PPK) GNSS SURVEYING

Horizontal . . . . 8 mm + 1 ppm RMS
Vertical . . . . 15 mm + 1 ppm RMS

REAL TIME KINEMATIC SURVEYING

Single Baseline <30 km

Horizontal . . . . 8 mm + 1 ppm RMS
Vertical . . . . 15 mm + 1 ppm RMS

NETWORK RTK[4]

Horizontal . . . . 8 mm + 0.5 ppm RMS
Vertical . . . . 15 mm + 0.5 ppm RMS
Initialization time[5] . . . . typically <8 seconds
Initialization reliability[5] . . . . typically >99 9%

1 Optional upgrade.
2 Precision and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. The specifications stated recommend the use of stable mounts in an open sky view, EMI and multipath clean environment, optimal GNSS constellation configurations, along with the use of survey practices that are generally accepted for performing the highest-order surveys for the applicable application including occupation times appropriate for baseline length. Baselines longer than 30 km require precise ephemeris and occupations up to 24 hours may be required to achieve the high precision static specification.
3 Depends on SBAS system performance.
4 Network RTK PPM values are referenced to the closest physical base station.
5 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
6 Receiver will operate normally to –40 °C, internal batteries are rated to –20 °C, optional internal GSM modem operates to -30 °C.
7 Tracking GPS, GLONASS and SBAS satellites. Optional upgrade required for GLONASS.
8 Varies with temperature and wireless data rate. When using a receiver and internal radio in the transmit mode, it is recommended that an external 6 Ah or higher battery is used.
9 Varies with terrain and operating conditions.
10 Bluetooth type approvals are country specific.

PN 022543-259H (04/13)

HARDWARE

Physical

Dimensions (W×H) . . . . 19 cm × 10.2 cm (7.5 in x 4.0 in), including connectors
Weight . . . . 1.52 kg (3.35 lb) with internal battery, internal radio with UHF antenna
3.81 kg (8.40 lb) items above plus range pole, controller, and bracket
Temperature[6]
  Operating . . . . –40 °C to +65 °C (–40 °F to +149 °F)
  Storage . . . . –40 °C to +75 °C (–40 °F to +167 °F)
Humidity . . . . 100%, condensing
Water/dustproof . . . . IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)
Shock and vibration . . . . Tested and meets the following environmental standards:
  Shock . . . . Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
  Vibration MIL-STD-810F, FIG.514.5C-1

Electrical

- Power 11 V DC to 28 V DC external power input with over-voltage protection on Port 1 (7-pin Lemo)
- Rechargeable, removable 7.4 V, 2.6 Ah Lithium-Ion battery. Power consumption[7] is 3.2 W, in RTK rover mode with internal radio and Bluetooth in use.
- Operating times on internal battery[8]:
  - 450 MHz receive only option . . . . 5.0 hours
  - 450 MHz receive/transmit option (0.5 W) . . . . 2.5 hours
  - Cellular receive option . . . . 4.7 hours

Communications and Data Storage

- Serial: 3-wire serial (7-pin Lemo) on Port 1; full RS-232 serial on Port 2 (Dsub 9 pin)
- Radio modem: fully Integrated, fully sealed internal 450 MHz receiver/transmitter option:
  - Transmit power: 0.5 W
  - Range[9]: 3–5 km typical / 10 km optimal
- Cellular: fully integrated, fully sealed internal GSM/GPRS option
- Bluetooth: fully integrated, fully sealed 2.4 GHz communications port (Bluetooth®)[10]
- External communication devices for corrections supported on Serial and Bluetooth ports
- Data storage: 11 MB internal memory, 188.6 hours of raw observables (approx. 1.4 MB/day), based on recording every 15 seconds from an average of 14 satellites

Data formats

- CMR: CMR+, CMRx input and outputs
- RTCM: RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1 input and outputs
- Other outputs: 23 NMEA outputs, GSOF, RT17 and RT27 outputs, supports BINEX and smoothed carrier

Supported Trimble Controllers

- Trimble TSC3 controller, Trimble CU controller, Trimble Tablet Rugged PC

Certifications

FCC Part 15 (Class B device), 22, 24, 90; CE Mark; C-Tick; 850/1900 MHz; Class 10 GSM/GPRS module; Bluetooth EPL

Specifications subject to change without notice.

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Trimble R10

GNSS SYSTEM

A NEW LEVEL OF PRODUCTIVITY

Collect more accurate data faster and easier – no matter what the job or the environment, with the Trimble® R10 GNSS System. Built with powerful technologies integrated into a sleek design, this unique system provides Surveyors with a powerful way to increase productivity in every job, every day.

Trimble HD-GNSS Processing Engine

The advanced Trimble HD-GNSS processing engine provides markedly reduced convergence times as well as high position and precision reliability while reducing measurement occupation time. Transcending traditional fixed/float techniques, it provides a more accurate assessment of error estimates than traditional GNSS technology.

Trimble SurePoint

With Trimble SurePoint™ technology, advanced sensors onboard the Trimble R10 continuously stream pole tilt and heading information that is used to display an electronic level bubble on the Trimble controller screen, allowing surveyors to maintain focus where it matters most. Full tilt compensation allows the survey pole to be tilted up to 15° when measuring, allowing the Trimble R10 to capture points that would be inaccessible to other GNSS surveying systems.

Trimble 360 Receiver

Powerful Trimble 360 receiver technology in the Trimble R10 supports signals from all existing and planned GNSS constellations and augmentation systems. With two integrated Trimble Maxwell™ 6 chips, the Trimble R10 offers 440 GNSS channels.

Trimble CenterPoint RTX

Trimble CenterPoint® RTX delivers RTK level precision anywhere in the world without the use of a local base station or VRS network. Survey using satellite delivered, CenterPoint RTX corrections in areas where terrestrial based corrections are not available. When surveying over a great distance in a remote area, such as a pipeline or utility right of way, CenterPoint RTX eliminates the need to continuously move base stations or maintain connection to a cellular network.

Trimble xFill

Leveraging a worldwide network of Trimble GNSS reference stations and satellite datalinks, Trimble xFill® seamlessly fills in for gaps in your RTK or VRS connection stream. Maintain centimeter level accuracy beyond five minutes with a CenterPoint RTX subscription.

Smart, Versatile

A smart lithium-ion battery inside the Trimble R10 system delivers extended battery life and more reliable power. A built-in LED battery status indicator allows the user to quickly check remaining battery life.

The Trimble R10 system provides a number of communications options to support any workflow. Receive VRS corrections and connect to the Internet from the field with the integrated cellular modem. Using Wi-Fi, easily connect to the Trimble R10 system using a laptop or smartphone to configure the receiver without a Trimble controller.

The Complete Solution

Bring the power and speed of the Trimble R10 system together with trusted Trimble software solutions, including Trimble Access™ and Trimble Business Center.

Trimble Access field software provides specialized and customized workflows to make surveying tasks quicker and easier while enabling teams to communicate vital information between field and office in real time. Back in the office, users can seamlessly process data with Trimble Business Center software.

Key Features

- Cutting-edge Trimble HD-GNSS processing engine
- Precise position capture and full tilt compensation with Trimble SurePoint technology
- Trimble CenterPoint RTX provides RTK level precision anywhere without the need for a base station or VRS network
- Trimble xFill technology provides centimeter-level positioning during connection outages
- Advanced satellite tracking with Trimble 360 receiver technology
- Sleek ergonomic design for easier handling

PERFORMANCE SPECIFICATIONS		
MEASUREMENTS		
	Measuring points sooner and faster with Trimble HD-GNSS technology	
	Increased measurement productivity and traceability with Trimble SurePoint electronic tilt compensation	
	Worldwide centimeter level positioning using Trimble CenterPoint RTX satellite delivered corrections	
	Reduced downtime due to loss of radio signal with Trimble xFill technology	
	Advanced Trimble Maxwell 6 Custom Survey GNSS chips with 440 channels	
	Future-proof your investment with Trimble 360 GNSS tracking	
	Satellite signals tracked simultaneously:	GPS: L1C/A, L1C, L2C, L2E, L5 GLONASS: L1C/A, L1P, L2C/A, L2P, L3 SBAS: L1C/A, L5 (For SBAS satellites that support L5) Galileo: E1, E5A, E5B, E5 AltBOC BeiDou: B1, B2
	CenterPoint RTX, OmniSTAR® HP, XP, G2, VBS positioning	
	QZSS, WAAS, EGNOS, GAGAN, MSAS	
	Positioning Rates	1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz
POSITIONING PERFORMANCE[1]		
CODE DIFFERENTIAL GNSS POSITIONING		
	Horizontal	0.25 m + 1 ppm RMS
	Vertical	0.50 m + 1 ppm RMS
	SBAS differential positioning accuracy[2]	typically <5 m 3DRMS
STATIC GNSS SURVEYING		
High-Precision Static		
	Horizontal	3 mm + 0.1 ppm RMS
	Vertical	3.5 mm + 0.4 ppm RMS
STATIC AND FAST STATIC		
	Horizontal	3 mm + 0.5 ppm RMS
	Vertical	5 mm + 0.5 ppm RMS
REAL TIME KINEMATIC SURVEYING		
Single Baseline <30 km		
	Horizontal	8 mm + 1 ppm RMS
	Vertical	15 mm + 1 ppm RMS
Network RTK[3]		
	Horizontal	8 mm + 0.5 ppm RMS
	Vertical	15 mm + 0.5 ppm RMS
RTK start-up time for specified precisions[4]		2 to 8 seconds
TRIMBLE RTX™ TECHNOLOGY (SATELLITE AND CELLULAR/INTERNET (IP))		
CenterPoint RTX[5]		
	Horizontal	2 cm RMS
	Vertical	5 cm RMS
	RTX convergence time for specified precisions - Worldwide	< 15 min
	RTX QuickStart convergence time for specified precisions	< 1 min
	RTX convergence time for specified precisions in select regions (Trimble RTX Fast Regions)	< 1 min
TRIMBLE XFILL[6]		
	Horizontal	RTK[7] + 10 mm/minute RMS
	Vertical	RTK[7] + 20 mm/minute RMS

HARDWARE		
PHYSICAL		
Dimensions (W×H)	11.9 cm x 13.6 cm (4.6 in x 5.4 in)	
Weight	1.12 kg (2.49 lb) with internal battery, internal radio with UHF antenna, 3.57 kg (7.86 lb) items above plus range pole, controller & bracket	
Temperature[8]		
	Operating	−40° C to +65° C (−40° F to +149° F)
	Storage	−40° C to +75° C (−40° F to +167° F)
Humidity		100%, condensing
Ingress Protection		IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)
Shock and vibration (Tested and meets the following environmental standards)		
	Shock	Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
	Vibration	MIL-STD-810F, FIG.514.5C-1
ELECTRICAL		
	Power 11 to 24 V DC external power input with over-voltage protection on Port 1 and Port 2 (7-pin Lemo)	
	Rechargeable, removable 7.4 V, 3.7 Ah Lithium-ion smart battery with LED status indicators	
	Power consumption is 5.1 W in RTK rover mode with internal radio[9]	
Operating times on internal battery[10]		
	450 MHz receive only option	5.5 hours
	450 MHz receive/transmit option (0.5 W)	4.5 hours
	450 MHz receive/transmit option (2.0 W)	3.7 hours
	Cellular receive option	5.0 hours
COMMUNICATIONS AND DATA STORAGE		
Serial	3-wire serial (7-pin Lemo)	
USB v2.0	Supports data download and high speed communications	
Radio Modem	Fully Integrated, sealed 450 MHz wide band receiver/transmitter with frequency range of 403 MHz to 473 MHz, support of Trimble, Pacific Crest, and SATEL radio protocols:	
	Transmit power: 2 W	
	Range: 3–5 km typical / 10 km optimal[11]	
Cellular	Integrated, 3.5 G modem, HSDPA 7.2 Mbps (download), GPRS multi-slot class 12, EDGE multi-slot class 12, UMTS/HSDPA (WCDMA/FDD) 850/1900/2100MHz, Quad-band EGSM 850/900/1800/1900 MHz, GSM CSD, 3GPP LTE	
Bluetooth	Fully integrated, fully sealed 2.4 GHz communications port (Bluetooth®)[12]	
Wi-Fi	802.11 b,g, access point and client mode, WPA/WPA2/WEP64/WEP128 encryption	
USB v2.0	Supports data download and high speed communications	
External communication devices for corrections supported on	Serial, USB, TCP/IP and Bluetooth ports	
Data storage	4 GB internal memory; over seven years of raw observables (approx. 1.4 MB /day), based on recording every 15 seconds from an average of 14 satellites	
	CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1, RTCM 3.2 input and output	
	24 NMEA outputs, GSOF, RT17 and RT27 outputs	
WEBUI		
	Offers simple configuration, operation, status, and data transfer	
	Accessible via Wi-Fi, Serial, USB, and Bluetooth	
SUPPORTED TRIMBLE CONTROLLERS		
	Trimble TSC7, Trimble T10, Trimble TSC3, Trimble Slate, Trimble CU, Trimble Tablet Rugged PC	
CERTIFICATIONS		
	IEC 60950-1 (Electrical Safety); FCC OET Bulletin 65 (RF Exposure Safety); FCC Part 15.105 (Class B), Part 15.247, Part 90; PTCRB (AT&T); Bluetooth SIG; WFA IC ES-003 (Class B); Radio Equipment Directive 2014/53/EU, RoHS, WEEE; Australia & New Zealand RCM; Japan Radio and Telecom MIC	

Trimble R10 GNSS SYSTEM

DRAFT

1 Precision and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. The specifications stated recommend the use of stable mounts in an open sky view, EMI and multipath clean environment, optimal GNSS constellation configurations, along with the use of survey practices that are generally accepted for performing the highest-order surveys for the applicable application including occupation times appropriate for baseline length. Baselines longer than 30 km require precise ephemeris and occupations up to 24 hours may be required to achieve the high precision static specification.
2 Depends on WAAS/EGNOS system performance.
3 Network RTK PPM values are referenced to the closest physical base station.
4 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
5 RMS performance based on repeatable in field measurements. Achievable accuracy and initialization time may vary based on type and capability of receiver and antenna, user's geographic location and atmospheric activity, scintillation levels, GNSS constellation health and availability and level of multipath including obstructions such as large trees and buildings.
6 Accuracies are dependent on GNSS satellite availability. xFill positioning without a Trimble CenterPoint RTX subscription ends after 5 minutes of radio downtime. xFill positioning with a CenterPoint RTX subscription will continue beyond 5 minutes providing the Trimble RTX solution has converged, with typical precisions not exceeding 6 cm horizontal, 14 cm vertical or 3 cm horizontal, 7 cm vertical in Trimble RTX Fast regions. xFill is not available in all regions, check with your local sales representative for more information.
7 RTK refers to the last reported precision before the correction source was lost and xFill started.
8 Receiver will operate normally to –40° C, internal batteries are rated to –20° C.
9 Tracking GPS, GLONASS and SBAS satellites.
10 Varies with temperature and wireless data rate. When using a receiver and internal radio in the transmit mode, it is recommended that an external 6 Ah or higher battery is used.
11 Varies with terrain and operating conditions.
12 Bluetooth type approvals are country specific.

Specifications subject to change without notice.

Contact your local Trimble Authorized Distribution Partner for more information

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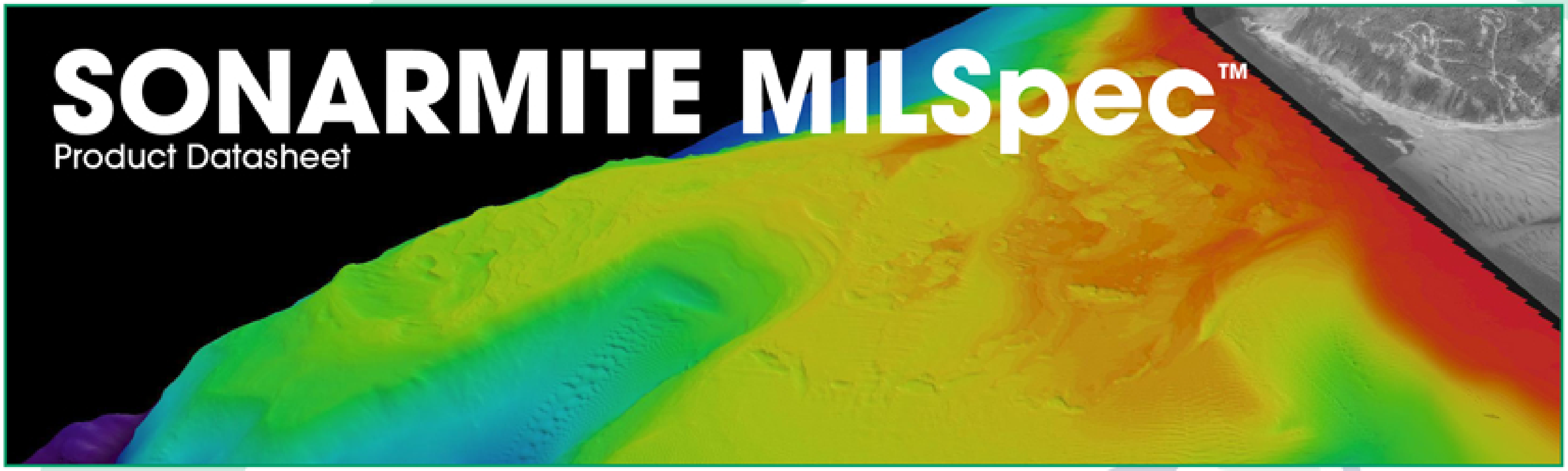
APPENDIX A3
Bathymetry Sonar Equipment Specifications

Seafloor

SONARMITE MILSpec™

Product Datasheet



ABOUT

The SonarMite MILSpec™ Echo Sounder is result of nearly two years research and development to further extend the boundaries of shallow water hydrographic surveying equipment. The introduction by Ohmex in 1997 of the SonarLite, the world's first truly portable echosounder system, has been a hard act to follow and it remains the portable instrument of choice in many survey companies around the world. The release of the SonarMite instrument marks the next stage introducing a series of equipment designed around the WinSTRUMENT concept using the latest portable computer integrated with new measurement technologies.

FEATURES

- Rugged, field-proven survey grade echosounder
- Bluetooth technology integrated with Windows Pocket PC devices
- Proven 'Smart' transducer design with QA output
- Internal rechargeable battery for all day use
- Easily integrated with other modern software & GPS technology

OPTIONS

- Data collection software
- Heave, Pitch and Roll measurements
- Sound velocimeter
- Portable mounting bracket
- Rugged shipping case
- Extended warranty

SPECS

ECHOSOUNDER

- Frequency: 200-KHz
- Beam width: 4-degrees
- Ping Rate: 6 Hz
- Depth Accuracy: 1cm /0.1% of depth
- Output Formats: NMEA, ASCII
- Range: 0.3m-75m
- I/O: Serial, Bluetooth
- Environmental: IP-65
- Power: Rechargeable 12V battery

PHOTOS

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APPENDIX A4
Hydraulic Structure Survey Equipment Specifications

Leica ScanStation P30/P40

Because every detail matters

HDS

The right choice
Whether you need an as-built representation of a large industry complex, a detailed scan of a piping system or a 3D point cloud of a ship hull, you know you'll need accurate life cycle representations in plant engineering and ship building. The combination of speed, range, accuracy and ruggedness make the new ScanStation laser scanners from Leica Geosystems the right choice, because every detail matters.

High performance under harsh conditions
The Leica ScanStations deliver highest quality 3D data and HDR imaging at an extremely fast scan rate of 1 mio points per second at ranges of up to 270 m. Unsurpassed range and angular accuracy paired with low range noise and survey-grade dual-axis compensation form the foundation for highly detailed 3D colour point clouds mapped in realistic clarity.

Reduced downtime
The extremely durable new laser scanners perform even under the toughest environmental conditions, such as extreme temperatures ranging from – 20°C to + 50°C and comply with the IP54 rating for dust and water resistance.

Complete scanning solution
Leica Geosystems offers the new Leica ScanStation portfolio as an integrated part of a complete scanning solution including hardware, software, service, training and support. 3D laser scanner data can be processed in the industry's leading 3D point cloud software suite, which consists of Leica Cyclone stand-alone software, Leica CloudWorx plug-in tools for CAD systems and the free Leica TruView.

Leica ScanStation P30/P40
Product specifications

System Accuracy	
Accuracy of single measurement *	
Range accuracy	1.2 mm + 10 ppm over full range
Angular accuracy	8" horizontal; 8" vertical
3D position accuracy	3 mm at 50 m; 6 mm at 100 m
Target acquisition **	2 mm standard deviation at 50 m
Dual-axis compensator	Liquid sensor with real-time onboard compensation, selectable on/off, resolution 1", dynamic range ±5', accuracy 1.5"

Distance Measurement System	
Type	Ultra-high speed time-of-flight enhanced by Waveform Digitising (WFD) technology
Wavelength	1550 nm (invisible) / 658 nm (visible)
Laser class	1 (in accordance with IEC 60825:2014)
Beam divergence	< 0.23 mrad (FWHM, full angle)
Beam diameter at front window	≤ 3.5 mm (FWHM)
Range and reflectivity	Minimum range 0.4 m

	Maximum range at reflectivity		
	120 m	180 m	270 m
P30	18 %	–	–
P40	8 %	18 %	34 %

Scan rate	Up to 1'000'000 points per second
Range noise *	0.4 mm rms at 10 m 0.5 mm rms at 50 m
Field-of-View	
Horizontal	360°
Vertical	290°
Data storage capacity	256 GB internal solid-state drive (SSD) or external USB device
Communications/ Data transfer	Gigabit Ethernet, integrated Wireless LAN or USB 2.0 device
Onboard display	Touchscreen control with stylus, full colour VGA graphic display (640 × 480 pixels)
Laser plummet	Laser class 1 (IEC 60825:2014) Centring accuracy: 1.5 mm at 1.5 m Laser dot diameter: 2.5 mm at 1.5 m Selectable ON/OFF

Imaging System	
Internal camera	
Resolution	4 megapixels per each 17° × 17° colour image; 700 megapixels for panoramic image
Pixel size	2.2 μm
Video	Streaming video with zoom; auto-adjusts to ambient lighting
White balancing	Sunny, cloudy, warm light, cold light, custom
HDR	Tonemapped / full range
External camera	Canon EOS 60D/70D/80D supported

Power	
Power supply	24 V DC, 100 – 240 V AC
Battery type	2× Internal: Li-Ion; External: Li-Ion (connect via external port, simultaneous use, hot swappable)
Duration	Internal > 5.5 h (2 batteries) External > 7.5 h (room temp.)

Environmental	
Operating temperature	–20°C to +50°C / –4°F to 122°F
Storage temperature	–40°C to +70°C / –40°F to 158°F
Humidity	95 %, non-condensing
Dust/Water	Solid particle/liquid ingress protection IP54 (IEC 60529)

Physical	
Scanner	
Dimensions (D × W × H)	238 mm × 358 mm × 395 mm / 9.4" × 14.1" × 15.6"
Weight	12.25 kg / 27.0 lbs, nominal (w/o batteries)
Battery (internal)	
Dimensions (D × W × H)	40 mm × 72 mm × 77 mm / 1.6" × 2.8" × 3.0"
Weight	0.4 kg / 0.9 lbs
Mounting	Upright or inverted

Control Options

Full colour touchscreen for onboard scan control.
Remote control: Leica CS10/CS15/CS20/CS35 controller or any other remote desktop capable device, including iPad, iPhone and other SmartPhones; external simulator.

Functionality	
Survey workflows and onboard registration	Quick orientation, Set azimuth, Known backsight, Resection (4 and 6 parameters), Traverse
Check & Adjust	Field procedure for checking of angular parameters, tilt compensator and range offset
Onboard target acquisition	Target selection from video or scan
Onboard user interface	Switchable from standard to advanced
One button scan control	Scanner operation with one button concept
Scan area definition	Scan area selection from video or scan; batch job scanning

Ordering Information

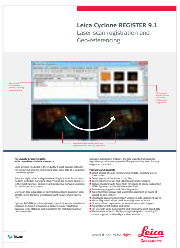
Contact your local Leica Geosystems representative or an authorised Leica Geosystems dealer.

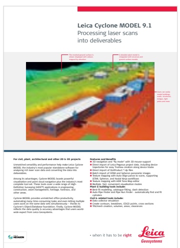
All specifications are subject to change without notice.
All accuracy specifications are one sigma unless otherwise noted.
* At 78 % albedo
** Algorithmic fit to planar HDS 4,5" B&W targets

Scanner: Laser class 1 in accordance with IEC 60825:2014
Laser plummet: Laser class 1 in accordance with IEC 60825:2014

iPhone and iPad are trademarks of Apple Inc.


Leica ScanStation P16


Leica Cyclone REGISTER


Leica Cyclone MODEL

active » Customer Care

Your Trusted Active Customer Care
Active Customer care is a true partnership between Leica Geosystems and its customers. Customer Care Packages (CCPs) ensure optimally maintained equipment and the most up-to-date software to deliver the best results for your business. The myWorld @ Leica Geosystems customer portal provides a wealth of information 24/7.

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- when it has to be **right**

Leica Geosystems

APPENDIX A5
Flow Measurement Equipment Specifications

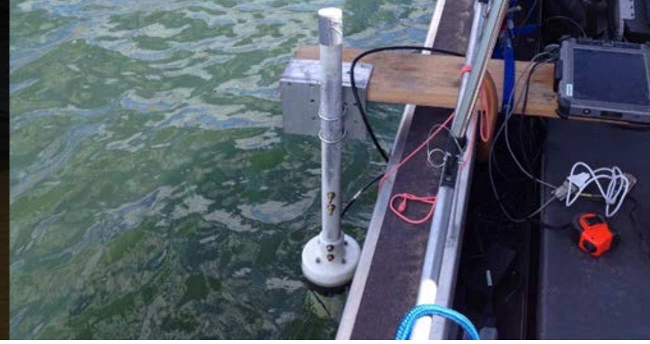
RiverSurveyor®

S5 M9

DISCHARGE, BATHYMETRY AND CURRENT PROFILING

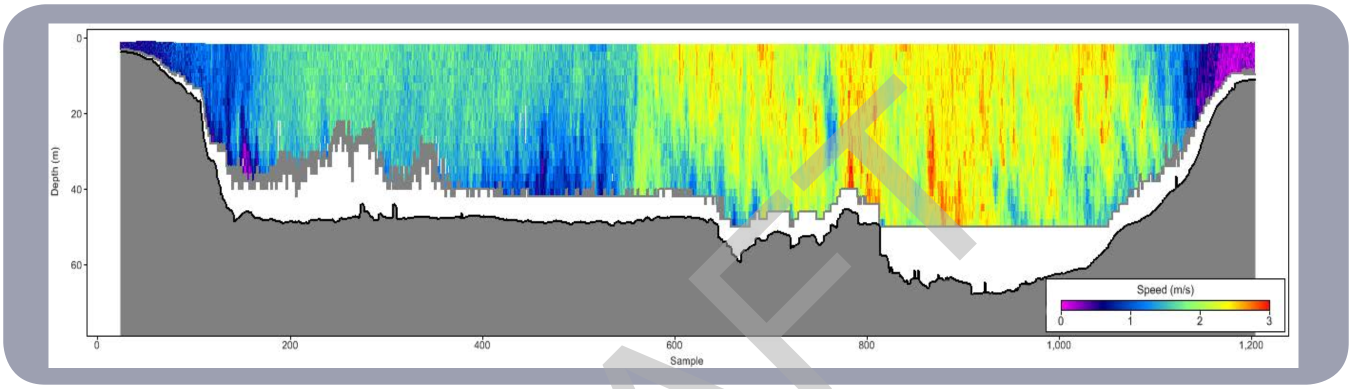
SonTek
a xylem brand

Classification: Public


Taken to Incredible Extremes.

The RiverSurveyor S5/M9 is a river discharge measurement system without the traditional limitations. Small, portable and easy to use, the patented and award-winning RiverSurveyor measures in extreme flood or drought situations within a single instrument, and without changing user settings. The results speak for themselves - the RiverSurveyor S5/M9 has revolutionized the way discharge is measured in rivers and canals.



"Meeting of the Waters" Amazon River near Manaus, Brazil

It's a SonTek exclusive - multiple acoustic frequencies with SmartPulseHD® make for the most robust and continuous shallow-to-deep measurements ever. An array of four deterministic microcontrollers expertly apportion the proper acoustics, pulse scheme, and cell size so you can focus on the measurement - not the instrument setup. The system even has a vertical beam for accurate channel definition and it's all designed to work intuitively. Slow to fast, shallow to deep, the RiverSurveyor S5/M9 handles it all on the fly.

Features	Benefits
Multi-band (Multiple acoustic frequencies)[1,2]	Balances the highest resolution with the greatest range of depths.
Vertical acoustic beam[1]	Superior channel definition for both bathymetric and discharge applications. Extends maximum discharge depth when bottom-tracking is out of range.
SmartPulseHD®[3]	An intelligent algorithm that looks at water depth, velocity and turbulence, and then acoustically adapts to those conditions using pulse-coherent, broadband, and incoherent techniques. High-def cell sizes down to 2 cm.
Microprocessor computed discharge and secure data[1]	All discharge computations are simultaneously done both within the S5 or M9, and on the host computer. No lost data if communications drop out.
Standard 360° compass and two-axis tilt sensor	Compensates for vessel motion due to surface conditions.
Reverberation control with ping rates to 70Hz	High ping rates ensure extremely robust data collection.
Bottom-tracking	Acoustically track vessel speed over ground independent of DGPS. Also supplies redundant depth measurement.
RTK GPS (optional)	Ultra precise positioning as an alternative to bottom tracking in moving bed or other difficult situations.

[1]RiverSurveyor technology patent number 8,125,849
[2]RiverSurveyor technology patent number 8,411,530
[3]Patent Pending

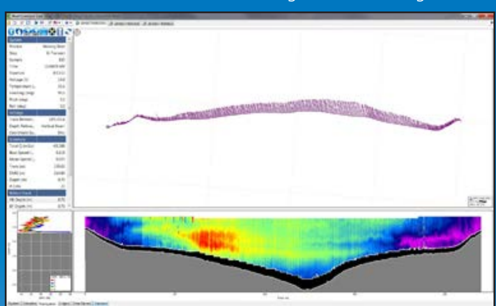
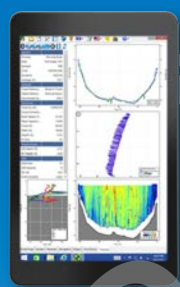


Display. Process. Analyze.

Exceed your expectations both during and after the measurement with the RiverSurveyor Live! software suite for both PC and mobile platforms. All programs take full advantage of SmartPulseHD and the intelligent software ensures no loss of data during telemetry dropouts. Easily switch between computer or mobile devices during mid-measurement. Several quality indicators and statistics with selectable graphics provide instant feedback on data collection. Multi-language support includes Afrikaans, Catalan, Chinese, English (UK & US), French, German, Hungarian, Italian, Japanese, Korean, Polish, Portuguese, Spanish and Turkish. Need your language? Let us know at inquiry@sontek.com.

Moving Boat

Standard with every system and used for underway measurements that calculate discharge from a moving vessel.

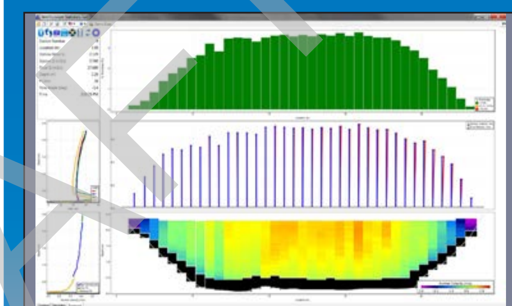
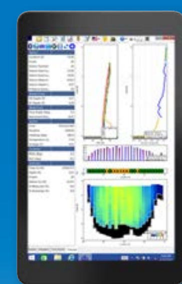



RiverSurveyor Live
Mobile Multi-language Display

- Enables you to efficiently transect from one bank to the other with a full contour plot of the water velocity profile and bottom bathymetry.
- View multiple data results (bottom-track, vertical beam, GPS-GGA, and GPS-VTG) simultaneously.
- Supports USGS Loop Correction Method and Stationary Moving Bed Analysis for moving bed conditions.

Stationary (Section-by-Section)

Optional add-on program that uses traditional USGS/ISO mid section or mean section methods.

RiverSurveyor Stationary Live
Mobile Display

- An alternative to moving boat method for highly turbulent areas or moving bed environments where GPS is unavailable.
- Supports discharge measurements through ice holes.
- Supports sections that are braided or have islands.

Get More Value.

The SonTek HydroSurveyor

Own a RiverSurveyor system, but need survey data as well? Upgrade your current M9 system and collect bathymetric, water column velocity profile, and acoustic bottom tracking data. The upgrade includes:

- Full water column velocity mapping,
- Exclusive 5-beam depth sounding
- Acoustic bottom tracking (for speed over ground when GPS is lost)
- Sound speed integration and interpolation (when using with the CastAway-CTD®)

The SonTek HydroBoard II.

One of the great sources of error in an ADP discharge measurement is excessive and irregular speed. The Hydroboard II's sleek and sturdy design provides the user with the platform to achieve the controlled speed and tracking conducive to quality ADP discharge measurements.

A dive-resistant, flexible body design allows the HydroBoard II to be used anywhere from low velocity irrigation canals to high-velocity mountain streams. Every HydroBoard comes equipped with reinforced mounting hardware, perfect for securing your instrument during unpredictable conditions.

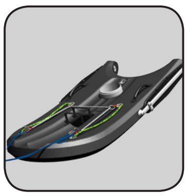
RiverSurveyor ACCESSORIES AND SPECIFICATIONS

Handheld Tablet :
Running on a tablet available from SonTek, RiverSurveyor Live software makes one-man system operation simple.

(Model subject to change.)

Power/Communications:
The Power/Communications Module (PCM) for the S5/M9 operates on standard AA batteries[5]. It can be factory-configured with 2.4 GHz telemetry, SBAS-GPS, or RTK GPS.

RTK GPS:
The optional SonTek RTK GPS[3] solution is easy to use and offers an incredibly precise, fully integrated boat speed solution to augment, or be an alternative to, bottom tracking.

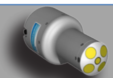


SonTek HydroBoard II:
All-in-one, rugged and easy to transport, this dive-resistant design allows the RiverSurveyor to be used in challenging flow conditions.

HydroBoard II Bags:
Ready to go where you are, these rugged bags are outfitted with shoulder straps and offer the perfect storage protection for the HydroBoard II.

Boat Mount:
Delrin/aluminum fixture that is custom designed for the M9 or S5 to facilitate mounting over the side of a boat. (Attachment to boat not included.)

Trimaran:
Contact SonTek for trimaran solutions to fit special applications.



	RiverSurveyor S5	RiverSurveyor M9
Velocity Measurement		
Profiling Range (Distance)	0.06m to 5m	0.06m to 40m
Profiling Range[1] (Velocity)	+/- 20 m/s	+/- 20 m/s
Accuracy[1]	Up to +/- 0.25% of measured velocity; +/- 0.2cm/s	Up to +/- 0.25% of measured velocity; +/- 0.2cm/s
Resolution	0.001 m/s	0.001 m/s
Number of Cells	Up to128	Up to128
Cell Size	0.02m to 0.5m	0.02m to 4m
Transducer Configuration	Five (5) Transducers;	Nine (9) Transducers;
	4-beam 3.0 MHz Janus at 25° Slant Angle;	Dual 4-Beam 3.0 MHz/1.0 MHz Janus at 25° Slant Angle;
	1.0 MHz Vertical Beam Echosounder	0.5 MHz Vertical Beam Echosounder
Depth Measurement		
Range	0.20m to 15m	0.20m to 80m
Accuracy	1%	1%
Resolution	0.001m	0.001m
Discharge Measurement		
Range with Bottom-Track	0.3m to 5m	0.3m to 40m
Range with RTK GPS or DGPS	0.3m to 15m	0.3m to 80m
Computations	Internal	Internal

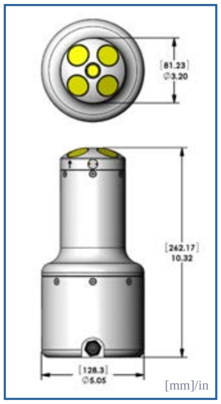
S5/M9 Additional Specifications

- Temperature Sensor
  - Resolution: ± 0.01° C
  - Accuracy: ± 0.1° C
- Compass/Tilt (Solid State Type)
  - Range: 360°
  - Heading Accuracy: ± 2°
  - Pitch/Roll: ± 1°
- Internal Recorder Size: 8GB
- Power/Communications
  - 12 - 18v DC
  - RS232 Communications
  - RS232 Serial GPS Input
  - Max Data Output Rate: 2 Hz
  - Internal Sampling Rate: Up to 70 Hz
- Physical/Environmental
  - Depth Rating: 50m
  - Operating Temperature: -5° to 45° C
  - Storage Temperature: -20° to 70° C

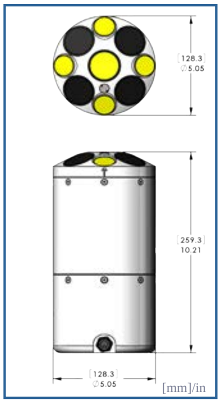
Power Communications Module

- Batteries
  - Type: Standard AA batteries[5]
  - Average duration: 8 hours of continuous operation (6 hours with RTK GPS enabled)
- GPS Options
  - SBAS GPS Horizontal Accuracy[2]: <1.0m
  - RTK GPS Horizontal Accuracy[2]: <0.02m ; Vertical Accuracy <0.04m[2,3]

	Range (Std.; 10 dBm)[4]	Range (High; 22dBm)[4]
• Base to Rover	1000 m	3000 m
• PC to Rover	450 m	1500 m
• Bridge to Rover	200 m	400 m



RiverSurveyor-S5
- Weight in Air: 1.1 kg (2.5 lb)
- Weight in Water: -0.3 kg (-0.7 lb)



RiverSurveyor-M9
- Weight in Air: 2.3 kg (5.0 lb)
- Weight in Water: -0.6 kg (-1.3 lb)

[1]Please contact SonTek for accuracies better than 1%, or velocities >10 m/s.
[2]Depends on multipath environment, antenna selection, number of satellites in view, satellite geometry, and ionospheric activity.
[3]Requires absolute RTK solution. Only available with HydroSurveyor.
[4]High power may not be available in all countries; all ranges with default 2 dBi antenna and line-of-sight.
[5]Standard AA batteries are defined as alkaline or NiMH rechargeables, with a diameter up to 14.5mm.

xylem
Let's Solve Water

Founded in 1992 and advancing environmental science globally, SonTek manufactures acoustic Doppler instrumentation for water velocity measurement in oceans, rivers, lakes, harbors, canals, estuaries, industrial pipes and laboratories. SonTek's sophisticated and proprietary technology serves as the foundation for some of the industry's most trusted flow data collection systems. SonTek is headquartered in San Diego, California, and is a division of Xylem Inc.

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S05-03

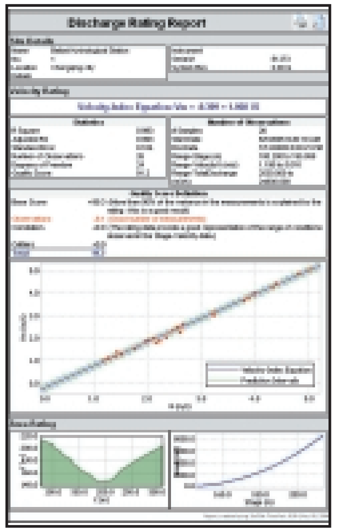
FlowTracker® Handheld ADV®

FlowTracker®

No other wading discharge device on the market comes with more useful options and accessories, making the FlowTracker a complete, turn-key solution.

The SonTek Deluxe wading rod, featuring a sturdy grip and bubble level

Rugged case provided with optional top-setting rod



FlowPack Velocity Indexing report software

Standard Features

- Low-profile 2-D ADV water velocity sensor on 2m flexible cable (measure in depths down to 2cm (1 inch))
- Automatic discharge computation protocols (ISO/USGS mid-section, mean-section, and Japanese)
- Handheld keypad interface with real-time display
- Velocity methods: ISO, USGS, under ice, Kreps, 5-point, and multipoint
- Languages supported: English, Spanish, German, Italian, and French
- Recorder space: up to 64 discharge measurements or over 150,000 individual velocity samples
- Data Set Documentation: up to 20 values of time-stamped user comments including gauge height and rated flow
- QA/QC: automated data review and discharge uncertainty calculations
- Communication protocol: RS232
- Software: Windows software with diagnostic beam-check, recorder access, data visualization and customizable reports
- Compatible with FlowPack Velocity Indexing software
- Temperature sensor
- Hard plastic case

SonTek®
A YSI Environmental Company

SonTek/YSI Inc.
9940 Summers Ridge Road
San Diego, CA 92121
Tel: +1 (858) 546-8327
Fax: + (858) 546-8150
Email: inquiry@sontek.com
www.sontek.com

Optional Features

- 2-D/3-D ADV side-looking probe
- 3m flexible cable
- Deluxe SonTek two piece, top-setting wading rod kit (1.2m Metric or 4 ft English) including case and mounting brackets
- Wading rod mounting bracket for controller/keypad
- Offset mounting bracket for ADV probe

Specifications

- Velocity range: ±0.001 to 4.0 m/s (±0.003 to 13 ft/s)
- Velocity resolution: 0.0001 m/s
- Velocity accuracy: ±1% of measured velocity, ±0.25 cm/s
- Sampling volume location: 10 cm from center transducer
- Power supply: 8 AA batteries
- Typical battery life: 25+ hours continuous operation (alkaline batteries)
- Weight: 1.8 kg/4.0 lbs
- Probe width: 130 mm (5.1 inches)
- Handheld controller/keypad: temporarily submersible to 1m
- Operating temperature: -20° to 50° C
- Storage temperature: -20° to 50° C

SmartQC is a built-in quality control feature that gives you the added assurance your FlowTracker data is correct. With each measurement, data is compared to a variety of adaptive QC criteria to ensure the best measurement possible.

SmartQC is our exclusive promise your SonTek/YSI system is performing at optimum standards and that your data is precise, reliable and exceeds your service expectations.

SonTek/YSI, founded in 1992 and advancing environmental science in over 100 countries, manufactures affordable, reliable acoustic Doppler instrumentation for water velocity measurement in oceans, rivers, lakes, harbors, estuaries, and laboratories. Headquarters are located in San Diego, California. Additional information can be found at www.sontek.com. SonTek/YSI is an employee-owned company.

The FlowTracker is made in the USA. FT Brochure 10/06, Rev. 4 - Oxford Group

FlowTracker®

Handheld ADV®

Sound Principles. Good Advice.

Wading Discharge Measurement Device

Portable. Precise. Practical.

Designed with the field user in mind, this handheld ADV® (Acoustic Doppler Velocimeter) measures 2D or 3D currents, attaches easily to wading rods, and features an automatic discharge computation using a variety of international methods, including ISO and USGS standards. At the end of the data run, just press a button and the FlowTracker calculates the discharge for you!

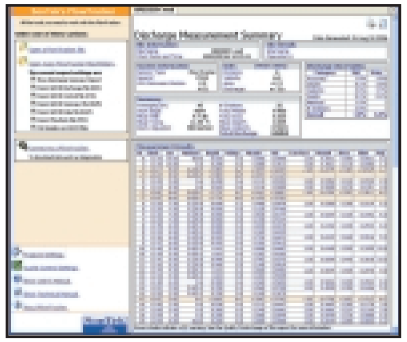
The FlowTracker is the ideal solution if you're looking for:

- Help in challenging outdoor conditions
- A way to avoid recurring calibration/maintenance
- Tough equipment that doesn't break down all the time
- Unmatched performance in shallow water and low flows
- An easy-to-use interface
- Fewer steps to follow
- Built-in quality checks (SmartQC) so you know your data is right.

The handy FlowTracker keypad is custom-designed for both discharge measurements and general purpose water velocity. Featuring provisions for starting edges, multiple channels, and even ice covered water, it is ready for any environmental situation. In addition, the FlowTracker's intelligent algorithm automatically prompts you for the proper measurement method based on your previous measurement stations.

FlowTracker Software Speaks Your Language

The FlowTracker comes with user-friendly, data analysis software that helps you produce attractive, customizable and professional reports in minutes. FlowTracker software also supports several languages, making it an ideal solution for international applications.



Example of FlowTracker discharge software and reports

FlowTracker in the Field

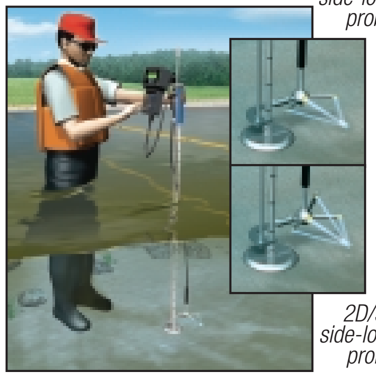
With rugged construction for any climate and a backlit display easily read during both day and night, the FlowTracker goes wherever you need it to go.

- Natural Streams
- Irrigation Canals
- Mining Channels
- Water Treatment
- Weirs/Flumes
- Storm Water
- Open Channels
- Lakes

The FlowTracker Advantage

It doesn't matter if you are new to acoustic Doppler technology, or an old familiar friend, the FlowTracker provides unparalleled benefits you will only find with SonTek/YSI systems. Here is some of what sets the FlowTracker apart.

- Multi-language instrument and software (English, Spanish, French, Italian, and German)
- Proven velocity precision - accurate to as low as 0.001 m/s (0.003 ft/s) and up to 4.0 m/s (13 ft/s)
- Automatic discharge calculation - International techniques, including ISO and USGS standards
- Record changing gauge heights and rated flows, with comments in each measurement
- Automatic discharge uncertainty calculation to ISO standard. **A FlowTracker First!**
- Measure velocities in water as shallow as 2 cm (less than an 1 inch)
- Keypad interface with real-time velocity and flow display
- Automatic quality control for accurate data collection
- Two or three dimensional velocity measurement
- Recorded data is shielded from power loss
- Lightweight, rugged, and waterproof
- No calibration required - ever!
- Built-in temperature sensor



Example of typical stance and technique when using the FlowTracker

River Discharge and Flow

Spot Current Sampling

Irrigation Canals

SonTek®

A YSI Environmental Company

OBSERVATOR
instruments

**We represent this supplier.
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APPENDIX B
Flood Control Structure Memorandum

MEMORANDUM

TO: Kurt Morrison, Alberta Environment and Parks

FROM: Sean Sullivan, Matrix Solutions Inc.
Manas Shome, Matrix Solutions Inc.

SUBJECT: St. Albert Flood Hazard Study – City of St. Albert Flood Control Structures

DATE: March 13, 2020

VERSION: 1.0

1 INTRODUCTION

Matrix Solutions Inc. is undertaking the St. Albert Flood Hazard Study on behalf of Alberta Environment and Parks (AEP). One goal of the project is to identify dedicated flood control structures (i.e., structures that have a primary purpose of reducing the flooding potential in specific locations) along the Sturgeon River that are owned and maintained by stakeholders. Of the stakeholders consulted by AEP in the early stages of the project, only the City of St. Albert identified potential flood control structures within the study reach.

2 IDENTIFIED FLOOD CONTROL STRUCTURES

Preliminary LiDAR data was used to identify potential flood control structures to be observed/assessed during the site visit. The site visit was conducted on May 7, 2019 and was attended by Matrix, AEP, and two representatives from the City of St. Albert: Melissa Logan and Larry Galye. During the site visit, the potential flood control structures were observed, and all parties have since agreed on the flood control structures identified in Table A. Locations, alignments, and photographs of the flood control structures are presented on Figures 1-1 and 1-2.

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Calgary, AB, Canada T2R 0K1
T 403.237.0606 F 403.263.2493
www.matrix-solutions.com

TABLE A City of St. Albert Flood Control Structure Summary

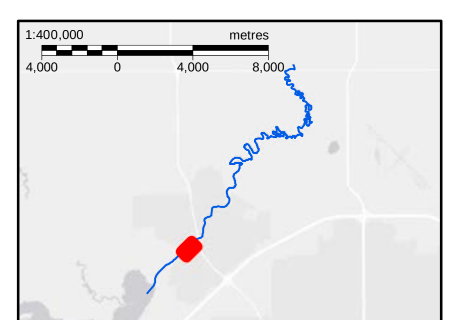
Flood Control Structure Name	Description	Upstream River Station[1] (m)	Downstream River Station[1] (m)	Crest Length[2] (m)
Millennium Park Dyke	Right (south) bank of Sturgeon River between CN Railroad Bridge and St. Albert Place	30,608	30,251	342
St. Albert Professional Building Dyke	Right (south) bank of Sturgeon River between Perron Street Bridge and Highway 2 Bridge	29,921	29,689	217
Red Willow Park Dyke	Right (south) bank of Sturgeon River between Highway 2 Bridge and Burns Street Cul-de-sac	29,647	29,468	192

[1] River station 0 is located at the downstream end of the model and increases moving upstream
[2] Crest length is not necessarily the difference between the upstream and downstream river station

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	29-Aug-2019	Draft	28312-531 FCS Memo 2019-08-29 draft V0.1	Issued to client for review
V1.0	13-Mar-2020	Final	28312-531 FCS Memo 2020-03-13 final V1.0	Issued to client as final

Bridge
Flood Control Structure
Image Location
Flow Direction



1:2,000 metres
20 0 20 40
NAD 1983 CSRS 3TM 114

Reference: Aerial imagery acquired by OGL Engineering on May 26, 2019 for Alberta Environment and Parks. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Alberta

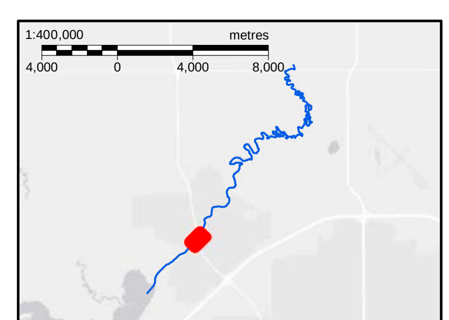
Alberta Government
St. Albert Flood Hazard Study

Flood Control Structure
Millennium Park Dyke

Date: March 2020	Project: 28312	Submitter: S. Sullivan	Reviewer: M. Shome

Figure A1-1

- Bridge
- Flood Control Structure
- Image Location
- Flow Direction



1:2,000 metres
20 0 20 40
NAD 1983 CSRS 3TM 114

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Alberta

Alberta Government
St. Albert Flood Hazard Study

Flood Control Structures St. Albert Professional Building Dyke and Red Willow Park Dyke

Date:	Project:	Submitter:	Reviewer:
March 2020	28312	S. Sullivan	M. Shome

Figure A1-2

Reference: Aerial imagery acquired by OGL Engineering on May 26, 2019 for Alberta Environment and Parks. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

APPENDIX C
Hydrologic Assessment Memorandum

Version 1.0

July 3, 2019 Matrix 28312-531

Mr. Kurt Morrison, M.Eng., P.Eng., CFM
ALBERTA ENVIRONMENT AND PARKS
Floor 11, Oxbridge Place
9820 - 106 St. NW
Edmonton, AB T5K 2J6

Subject: St. Albert Flood Hazard Study, Hydrologic Assessment

Dear Mr. Morrison:

1 INTRODUCTION

Matrix Solutions Inc. was retained by Alberta Environment and Parks (AEP) to assess and identify flood hazards along the Sturgeon River through the City of St. Albert, Alberta, and adjacent areas of Sturgeon 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. Previous flood hazard studies have been completed by AEP in 1975 (Alberta Environment 1975) and 1990 (Alberta Environment 1990) for the Sturgeon River through the City of St. Albert. The purpose of the current study is to assess and identify flood hazards along a 31 km reach of the Sturgeon River, originating at the Big Lake outlet, continuing through the City of St. Albert, and terminating near the Highway 37 crossing.

This hydrology report has been prepared to support the flood hazard study by providing 2- to 1000-year return period instantaneous flood estimates for the Sturgeon River downstream of the Big Lake Outlet. Hydrologic analysis conducted herein has been guided by the *Flood Hazard Identification Program Guidelines* (AENV 2011), the *St. Albert Flood Hazard Study Terms of Reference* (AEP 2019), 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. Frequency analysis of Big Lake water levels will be addressed under separate cover.

2 PROJECT SETTING

Figure 1 depicts the Sturgeon River Basin with locations of some key gauging stations. The Sturgeon River originates at Hoople Lake, approximately 90 km west of the City of St. Albert, and generally flows east toward the North Saskatchewan River (NSR). Several major lakes are located within the basin upstream of the study area, including Isle Lake, Lac St. Anne, Matchayaw Lake, and Big Lake. The Sturgeon River is a non-glacier fed prairie river with floods generally associated with spring snowmelt. Topographic relief within the basin is limited, resulting in relatively slow drainage and significant internal drainage into lakes, wetlands, or sloughs rather than direct discharge to rivers.

The City of St. Albert is located within the study reach and has several stormwater outfalls which discharge to the Sturgeon River. As a result, summer storm events may result in relatively high contribution to total flow in the Sturgeon River; however, since flooding in the Sturgeon River is governed by snowmelt, 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 AVAILABLE STREAMFLOW RECORDS

Recorded historical streamflow data is required to derive flood frequency estimates associated with various return periods. The Water Survey of Canada (WSC) maintains two hydrometric stations on the Sturgeon River either in close proximity or within the study reach: Sturgeon River at St. Albert (05EA002) located 3 km downstream of the Big Lake outlet and Sturgeon River near Fort Saskatchewan (05EA001), just upstream of the Sturgeon River/NSR confluence. The periods of available data for these stations is presented in Table A.

TABLE A Periods of Available Data

Gauging Station	Gross Drainage Area (km^2)	Data Type	Data Period
Sturgeon River at Fort Saskatchewan (05EA001)	3,250	Flow and level	1914 – 1922; 1928-1930; 1936 – 2018
Sturgeon River at St. Albert (05EA002)	2,610	Flow and level	1913-1927; 1976-1986; 2005 – 2018

Reported data at the St. Albert gauging station (2016 to 2018) and at the Fort Saskatchewan gauging station (2017 to 2018) is preliminary and may be subject to change. The largest recorded flood event in the Sturgeon River occurred in 1974 with a magnitude of 104 m^3/s[1] at the St. Albert gauging station (05EA002) and a magnitude of 115 m^3/s at the Fort Saskatchewan gauging station (05EA001). The 1974 flood represents a return period higher than the 100-year event based on previous flood frequency estimates. The ratio of the 1974 flood discharges at the two gauging stations is 1.1, as compared to the gross drainage area ratio of 1.25 (i.e., the flood magnitude has only increased by 10% though the drainage area has increased by 25%). The mean annual discharge at the St. Albert and Fort Saskatchewan gauging stations are about 3.5 and 3.8 m^3/s, respectively, representing an increase by only 8%. It can be inferred that the recorded flows at both gauging stations consist primarily of runoff generated upstream of the City of St. Albert. The presence of Big Lake immediately upstream of the City of St. Albert provides attenuation of upstream flooding events, as demonstrated during the 1974 flood. The Sturgeon River near

[1] As reported in the 1990 flood hazard study.

Villeneuve gauging station (05EA005) has a drainage area of 1,890 km^2 and is located approximately 13 km upstream of Big Lake. The recorded peak flow at the Villeneuve gauging station was 136 m^3/s during the 1974 flood, whereas the estimated corresponding discharge at the St. Albert gauging station was 104 m^3/s, a reduction of 25%. The attenuating effect of Big Lake on extreme flood events (greater than the 200-year event) is not known as no such extreme flood data is available.

4 HYDROLOGIC ANALYSIS

Hydrologic analysis was undertaken to recommend 2- to 1000-year return period instantaneous flood estimates for the Sturgeon River to be used for subsequent hydraulic modelling and flood inundation mapping. Since the Sturgeon River at the St. Albert gauging station is located within the study reach, the flood frequency estimates at this location will be used for this flood hazard mapping study. This analysis involves evaluation of regional discharge data, extension of the hydrometric record based on a correlation between the St. Albert and Fort Saskatchewan gauging stations, analysis of the extended data series for statistical outliers, and selection of the most suitable probability distribution.

4.1 Data Series Preparation

Though the Sturgeon River at St. Albert station has been gauged since 1913, only 39 years of recorded data is available due to extended periods during which no data was recorded. The Sturgeon River near Fort Saskatchewan has 96 years of record. As such, the recorded flow data at the Sturgeon River near Fort Saskatchewan gauging station has been used to extend the data at the St. Albert gauging station. The Sturgeon River near Fort Saskatchewan gauging station was chosen to extend the data series at the St. Albert gauging station, not only due to the availability of data, but also because the recorded flows at both these gauging stations consist primarily of runoff generated upstream of the City of St. Albert, and a high correlation exists between discharges at these two gauging stations. Recorded maximum daily discharges and instantaneous peak discharges for the St. Albert and Fort Saskatchewan gauging stations are provided in Appendix A (Table A1).

Maximum daily discharges for observations of the same flood event at both gauging stations (Appendix A, Table A2) were analyzed to determine the correlation between the two data series using a linear regression by method of least squares. As shown on Figure A, the following relationship was derived and used to extend the data series for the Sturgeon River at St. Albert:

$$Q_{05EA002} = 0.857Q_{05EA001}$$

where:
$Q_{05EA002}$ = discharge at Sturgeon River at St. Albert (m^3/s)
$Q_{05EA001}$ = discharge at Sturgeon River near Fort Saskatchewan (m^3/s)
R^2 = index of determination, 0.977 for this relationship

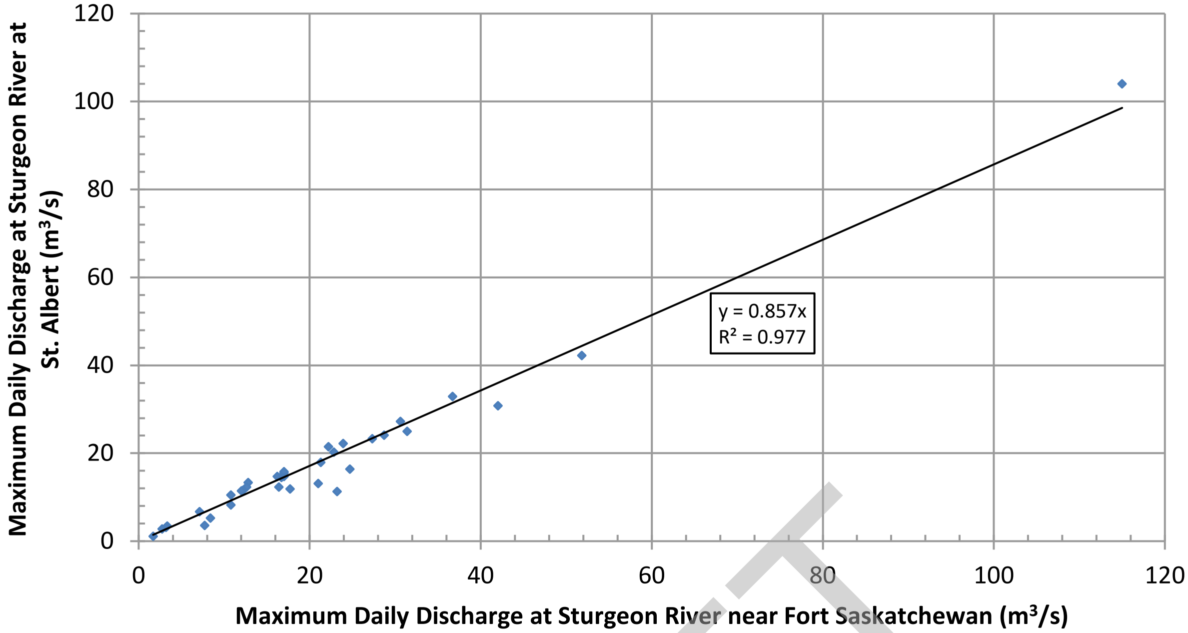


FIGURE A Relationship between Maximum Daily Discharge at Sturgeon River at St. Albert (05EA002) and Sturgeon River near Fort Saskatchewan (05EA001)

The maximum daily discharge data at the St. Albert gauging station was extended from 39 years of record to 100 years of record using this relationship.

Flood frequency estimates are based on the instantaneous peak discharge. For those years where instantaneous peak discharge data at the St. Albert 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 St. Albert gauging station. As shown on Figure B, the following relationship was derived to extend the instantaneous peak discharge data series for the Sturgeon River at St. Albert:

$$Q_{05EA002\_I} = 1.0156Q_{05EA002\_M}$$

where: $Q_{05EA002\_I}$ = instantaneous peak discharge at Sturgeon River at St. Albert (m^3/s)

$Q_{05EA001\_M}$ = maximum daily discharge at Sturgeon River at St. Albert (m^3/s)

R^2 = index of determination, 0.9966 for this relationship

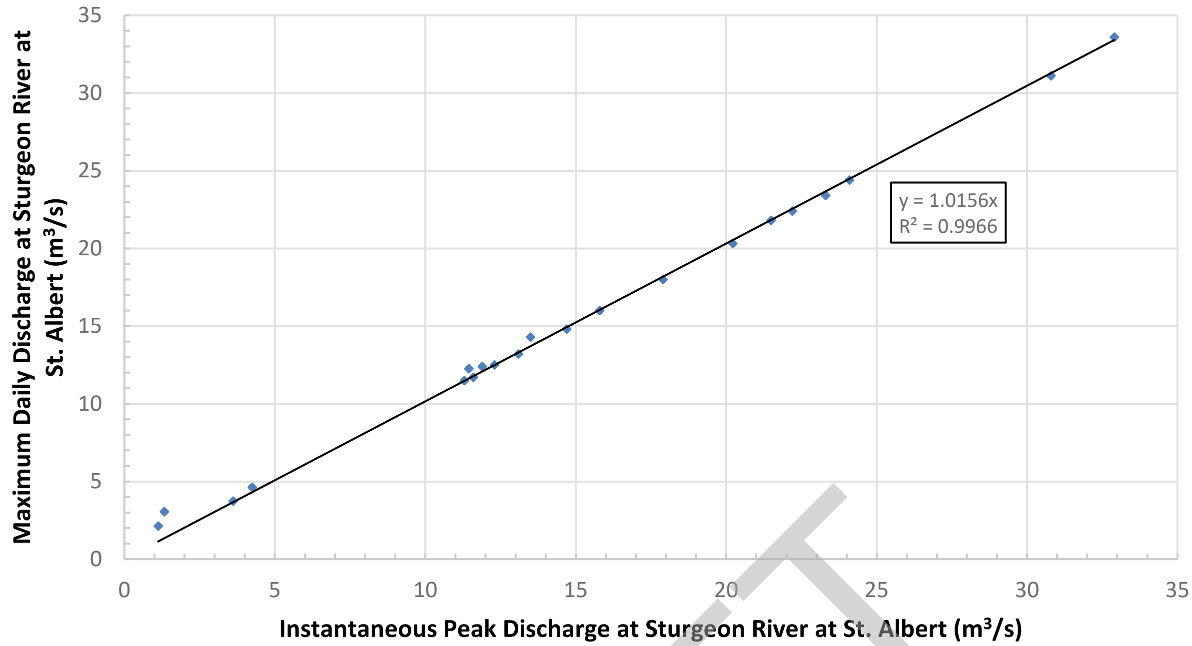


FIGURE B **Relationship between Maximum Daily Discharge and Instantaneous Peak Discharge at Sturgeon River at St. Albert (05EA002)**

Table A3 (Appendix A) presents the extended instantaneous peak discharge data series adopted for flood frequency analysis. The extended instantaneous peak discharge data series contains discharges ranging from 2.1 m^3/s to 104 m^3/s. Extreme high and low events were evaluated to determine whether they should be declared outliers. Standard outlier analysis was conducted following the *Bulletin 17B* detection procedure (McCuen 2004). This analysis confirmed that these observations belong to the same population as the remainder of the data series (Table B).

TABLE B **Outlier Analysis for Sturgeon River at St. Albert**

Peak Event	Record Length	Outlier Test Deviates (K_o)[1]	Logarithm of Discharge	Mean of Logarithm Transformed Discharge Data	Standard Deviation of Logarithm Transformed Discharge Data	Logarithm of Threshold Peak	Outlier (Yes/No)
1974 (extreme high)	100	3.017	2.024	1.139	0.349	2.19	No
2010 (extreme low)	100	3.017	0.32	1.139	0.349	0.08	No

1 (McCuen 2004)

4.2 Flood Frequency Estimates

4.2.1 Previous Studies

Flood frequency estimates have been completed at the St. Albert gauging station for return periods ranging from 2- to 200-year. The estimated 1:100-year flood adopted in the 1990 study (Alberta Environment 1990) was 92 m^3/s; Associated Engineering (Associated Engineering 2004) estimated the 1:100-year flood magnitude to 86 m^3/s by using a longer period of recorded discharges.

The flood frequency analysis in the 1990 flood hazard study considered several theoretical probability distributions including Gumble I, log-Gumble I, normal, log-normal, 3 parameter log-normal, Pearson III, and log-Pearson III. Based on comparative assessment of various theoretical frequency distributions to the discharge data, the log-normal and 3 parameter log-normal distributions were considered acceptable. Since these two distributions produced identical results, the log-normal distribution was selected to determine flood frequency estimates at the St. Albert gauging station.

4.2.2 Current Study

For this study, flood frequency estimates are required for return periods up to the 1000-year return period. Flood frequency estimates were assessed using the following theoretical probability distributions, selected to represent a range of probability distributions typically used for frequency analysis in Canada:

- log-normal
- 3 parameter log-normal
- log-Pearson type III
- Gumble I (extreme value type I)

Hyfran Version 1.2 software was used to compute flood frequency estimates and generate curves for each distribution. Best fitting curve methods considered include method of moments and method of maximum likelihood. Table C presents the flood frequency estimates for each of these distributions.

TABLE C Sturgeon River at St. Albert Flood Frequency Estimates Using Various Distributions (m^3/s)

Return Period (years)	Log-Normal (maximum likelihood)	3-parameter Log-Normal (maximum likelihood)	3-parameter Log-Normal (method of moments)	Log-Pearson III (method of moments)	Gumble I (maximum likelihood)
2	13.8	13.9	14.6	14.2	16
5	27.1	27.0	27.5	27.3	26.9
10	38.6	38.1	37.5	37.7	34.1
20	51.8	50.6	48.2	48.7	41.1
50	72.0	69.5	63.5	64.3	50.1
100	89.6	85.9	76.2	76.8	56.8
200	110.0	104.0	89.8	90.0	63.5
1000	166.0	155.0	126.0	123.0	79.1

The flood frequency estimates for smaller return periods (20-year or less) are very similar for all these distributions. In addition, the flood frequency estimates by three distributions (3-parameter log-normal using method of moments and Log-Pearson III) are much lower than those based on the log-normal distributions using maximum likelihood method for return periods of 100 years and greater. The log-normal and 3-parameter log-normal frequency distributions using maximum likelihood fitting methods provide similar flood frequency estimates for all return periods; however, the flood frequency estimates by the log-normal distribution is slightly greater than those based on the 3-parameter log-normal distribution.

Figure A1 (Appendix A) illustrates the fitted distributions to the instantaneous peak discharge data. Based on a visual inspection of various frequency distributions to the flow data and goodness of fit, the log normal distribution was determined to provide the most representative fit to the recorded data and has been selected to represent the instantaneous peak discharges for the Sturgeon River at St. Albert. This is consistent with the distribution selected in the 1990 study.

Figure C presents a comparison of the flood frequency estimates recommended for this study to the 1990 flood estimates. Though the current flood frequency estimates are generally in agreement with the 1990 study, the current estimates are slightly lower. This is largely due to the longer period of hydrologic record evaluated for this study; the length of data for the current study is 100 years (1914 to 2014) as compared to 65 years (1914 to 1983) used in the 1990 study, and the majority of high flood events occurred prior to 1984.

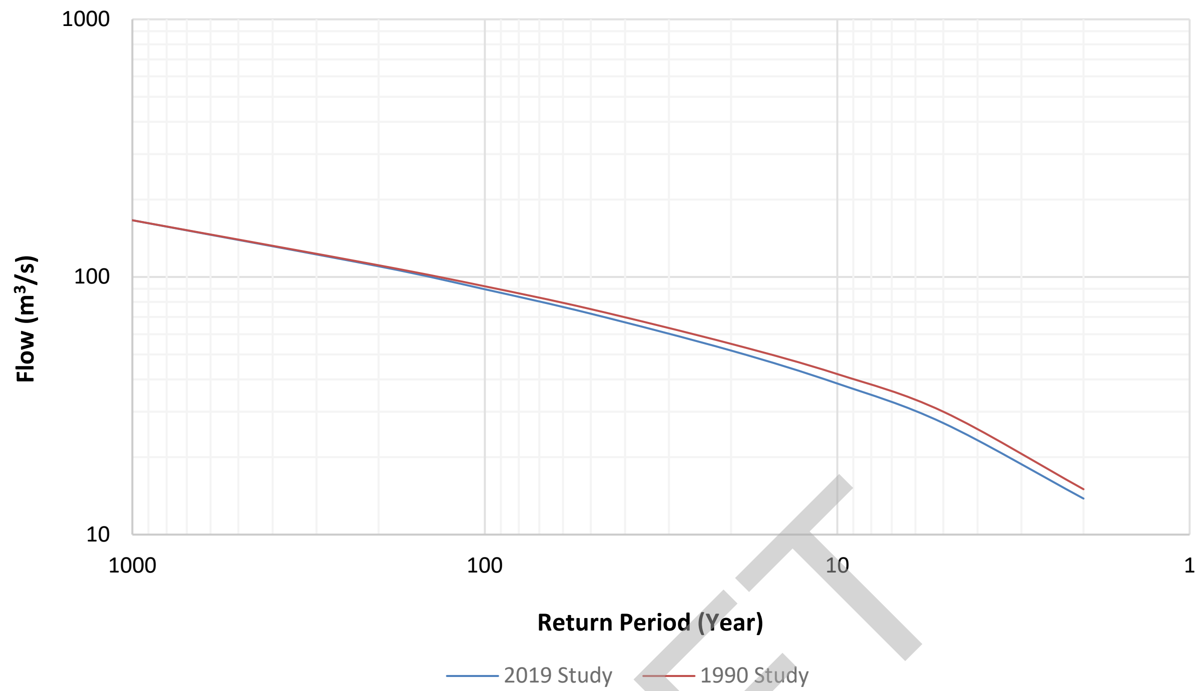


FIGURE C Comparison of 2019 and 1990 Flood Frequency Estimates

Preliminary discharge data was obtained from the WSC for the St. Albert (2016 to 2018) and Fort Saskatchewan (2017 to 2018) gauging stations; the dataset used to derive the flood frequency estimates herein include this preliminary data. Given that the preliminary discharge data is provisional and may be subject to change, the flood frequency analysis was repeated with this data excluded. After rounding to the nearest whole number, the flood frequency estimates were identical due to the absence of large flood events post-2015.

4.3 Recommended Flood Frequency Estimates

The flood frequency estimates of the Sturgeon River are derived at the St. Albert gauging station (05EA002). The upstream study area boundary is located approximately 3 km upstream of this gauging station location. The drainage area of the Sturgeon River at the downstream study area boundary is 2,680 km^2, amounting to an increase of only 40 km^2 (or 1.5%) compared to the drainage area at the gauging station location. No tributaries enter the Sturgeon River through the study reach. Due to this small increase in drainage area between the upstream and downstream study boundaries resulting in an insignificant increase in peak flows, the flood frequencies estimated at the St. Albert gauging station are considered representative for the entire study reach.

Table D presents the complete set of flood frequency estimates recommended for adoption for the flood risk mapping study; Figure D presents the flood frequency curve for the log-normal distribution with 95% confidence limits.

TABLE D Sturgeon River at St. Albert (05EA002), Flood Frequency Estimates

Return Period (years)	Instantaneous Peak Discharge[1] (m^3/s)
2	14
5	27
10	39
20	52
35	64
50	72
75	82
100	90
200	110
350	130
500	140
750	155
1000	166

1. Rounded to nearest whole number.

FIGURE D Flood Frequency Curve for Sturgeon River at St. Albert (05EA002)

4.4 Potential Effects of Climate Change

Though occasional summer storms produce large summer flood peaks, flooding on the Sturgeon 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 Sturgeon River watershed; however, 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. 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). Though it is difficult to predict how these changes will interact and what impact that may have on future floods, potential scenarios have been identified based on these projected trends, as follows:

- An increase in winter precipitation would increase the snowpack and higher winter temperatures would result in increased and earlier snowmelt, thereby producing larger and earlier spring flood peaks.

- Warmer temperatures would increase the probability of extreme rainfall events, which could result in more extreme rain or snow events producing larger spring flood peaks (Sauchyn and Kulshreshtha 2008).

These scenarios take a conservative stance by assuming that annual increases in precipitation are experienced in the winter or during spring snowmelt and do not consider any increase in evaporation or sublimation losses resulting from increased temperatures. Climate science is not well-developed as of 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 (Natural Resources Canada 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) use of 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 (Natural Resources Canada 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 (Natural Resources Canada 2019). Current practices in British Columbia are governed by 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 discharge by up to 20% to account for uncertainties on future conditions. The province of Ontario does not prescribe a process to deal with climate change adaptation; Matrix is currently working with the Ontario Ministry of Natural Resources and Forestry to provide guidance on the inclusion of climate change resiliency in flood hazard assessments. The suggested approach may include sensitivity analysis and resiliency testing methods to account for potential impacts of a changing climate.

5 CONCLUSIONS

Flood frequency estimates are required for the St. Albert flood hazard study. A WSC hydrometric gauging station, the Sturgeon River at St. Albert (05EA002) is located near the upstream boundary of the study reach. A flood frequency analysis of the recorded and extended annual flood data series at this station was conducted. The recorded annual flood data series (39 years of complete record) at the Sturgeon River at St. Albert gauging station was extended by correlation with the recorded annual flood data series at the Sturgeon River near Fort Saskatchewan gauging station (05EA001), resulting in 100 years of extended data series. Among various theoretical probability distributions investigated, the log-normal distribution provided the best fit to the extended flood data series. The flood frequency estimates for 2-year to 1000-year return periods were derived using this distribution. The estimated 1:100 year flood is 90 m^3/s with the 95% confidence interval ranging from 62 m^3/s to 117 m^3/s. Given the small increase in drainage area between the St. Albert gauging station and the downstream study boundary and the absence of any tributary entering the Sturgeon River within the study reach, the flood frequency estimates at the St. Albert gauging station are considered representative for the entire study reach.

The flood frequency estimates reflect the most current data and methodologies available. Given the relatively short data record (100 years of data), uncertainty exists for estimating flood frequencies with return periods greater than 200 years. In addition, the attenuating response of Big Lake and other upstream lakes during extreme events with greater return periods is unknown. The flood frequency estimates should be updated as more flood data become available.

6 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 403.237.0606.

Yours truly,

MATRIX SOLUTIONS INC. **Reviewed by**

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PR/hb
Attachments

APEGA Permit to Practice
Permit No. P5540

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VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	31-May-2019	Draft	28312-531 LR 2019-05-31 draft V0.1.docx	Issued to client for review
V1.0	03-Jul-2019	Final	28312-531 LR 2019-07-03 final V1.0.docx	Issued to client

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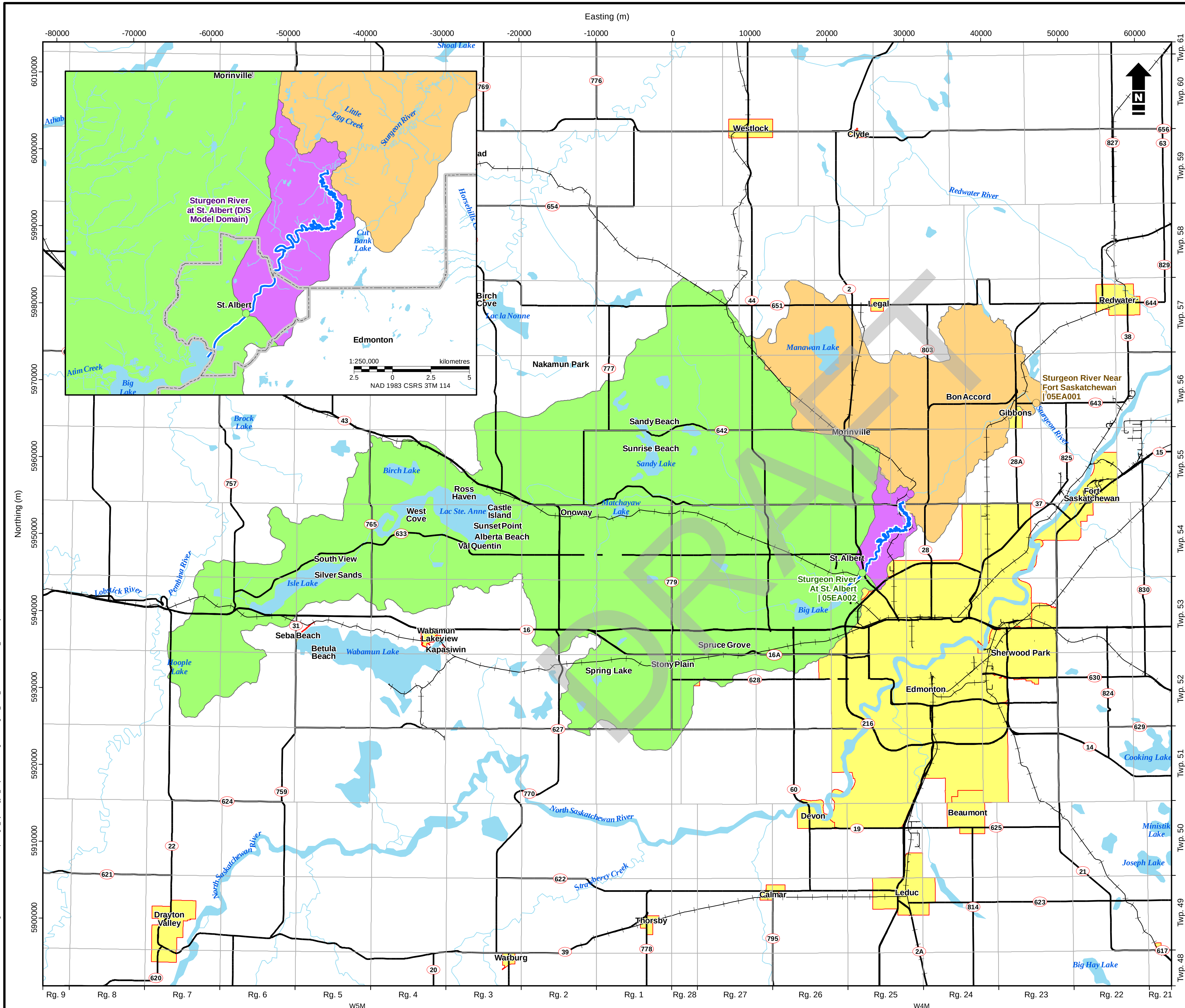

- Community
- Water Body
- Watercourse
- Sturgeon River Study Reach
- Highway
- Railway

Watershed Area

- Sturgeon River near Fort Saskatchewan | 05EA001
- Sturgeon River at St. Albert | 05EA002
- Sturgeon River at St. Albert (D/S Model Domain)

Watershed Outlet

- Sturgeon River near Fort Saskatchewan | 05EA001
- Sturgeon River at St. Albert | 05EA002
- Sturgeon River at St. Albert | DS Model Domain

Station Number	Station Name	Total Gross Drainage Area (km²)	Source
05EA001	Sturgeon River near Fort Saskatchewan	3250	WSC / AAFC*
05EA002	Sturgeon River at St. Albert	2610	WSC / AAFC*
N/A	Sturgeon River at St. Albert (D/S Model Domain)	2650	WSC / AAFC / MSI^

Reference: Data obtained from AltaLIS © Government of Alberta and GeoGratis © Department of Natural Resources Canada (all rights reserved) used under license. GDM transportation infrastructure data provided by IHS © 2019 used under licence. Watersheds obtained through AAFC/WSC unless otherwise indicated.

1:500,000 kilometres
NAD 1983 CSRS 3TM 114

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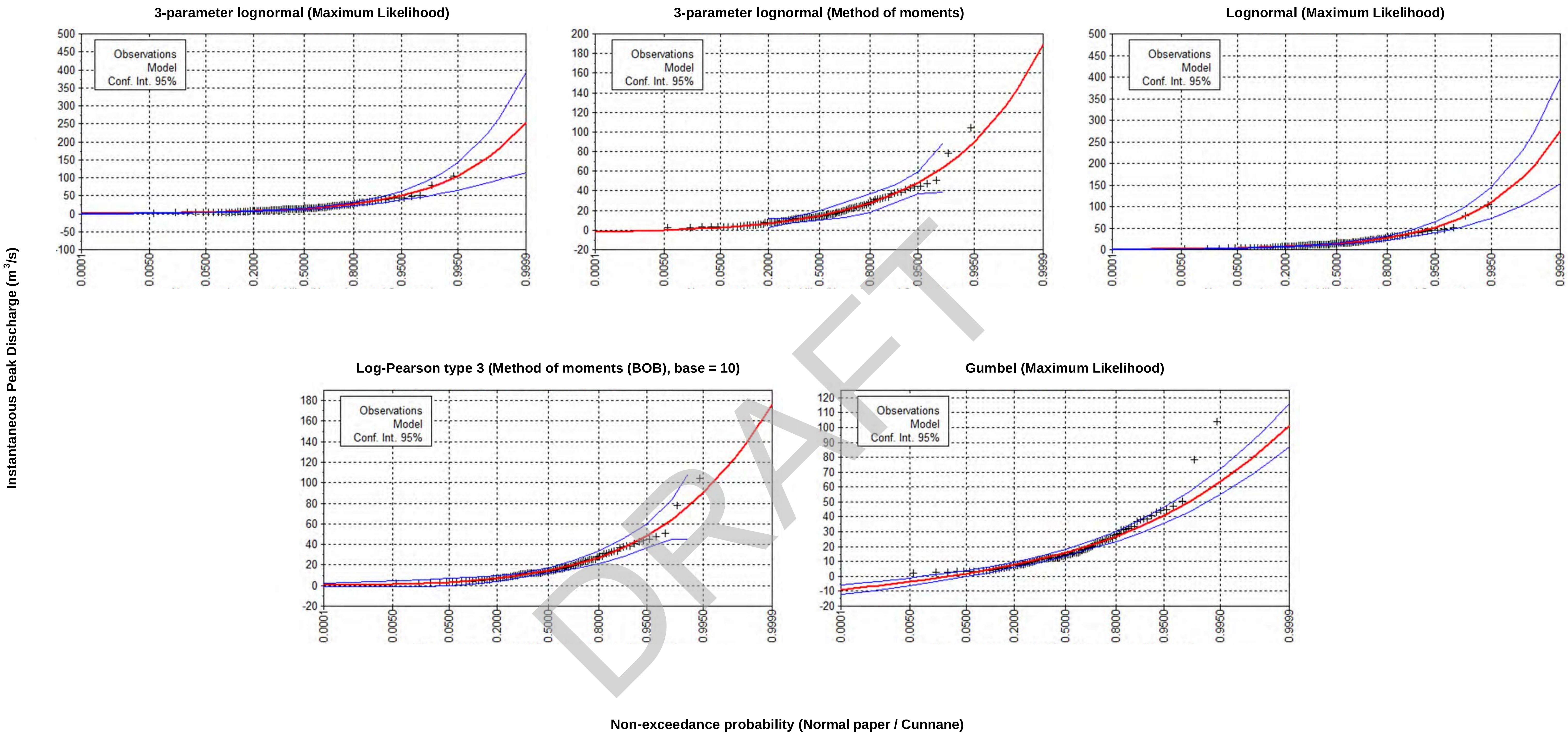
St. Albert Flood Hazard Study

Sturgeon River Basin

Date:	Project:	Submitter:	Reviewer:
May 2019	28312	P. Rogers	M. Shome

Figure 1

APPENDIX A
Recorded Annual Flow Data Series and Flood Frequency Distributions



Reference: Plots generated in Hyfran.

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St. Albert Flood Hazard Study

Comparison of Frequency Distributions

Date:	Project:	Submitter:	Reviewer:
May 2019	28312	P. Rogers	M. Shome

Figure
A1

TABLE A1: Recorded Maximum Daily and Instantaneous Peak Discharge for WSC Gauging Stations

Year	Sturgeon River at St. Albert (05EA002)		Sturgeon River near Fort Saskatchewan (05EA001)	
	Maximum Daily Discharge (m^3/s)	Instantaneous Peak Discharge (m^3/s)	Maximum Daily Discharge (m^3/s)	Instantaneous Peak Discharge (m^3/s)
1914	42.2	-	51.8	-
1915	27.2	-	30.6	-
1916	15.5	-	17.0	-
1917	25.0	-	31.4	-
1918	12.3	-	16.4	-
1919	8.2	-	10.8	-
1920	-	-	28.9	-
1921	14.7	-	17.0	-
1922	3.5	-	3.8	-
1923	3.1	-	3.2	-
1924	4.1	-	-	-
1925	37.4	-	-	-
1926	5.6	-	-	-
1927	30.9	-	-	-
1928	-	-	-	-
1929	-	-	8.7	-
1930	-	-	4.4	-
1931	-	-	-	-
1932	-	-	-	-
1933	-	-	-	-
1934	-	-	-	-
1935	-	-	32.8	-
1936	-	-	58.0	-
1937	-	-	9.2	-
1938	-	-	20.3	-
1939	-	-	5.2	-
1940	-	-	47.3	-
1941	-	-	12.8	-
1942	-	-	4.0	-
1943	-	-	54.4	-
1944	-	-	38.5	-
1945	-	-	5.5	-
1946	-	-	13.7	-
1947	-	-	10.5	-
1948	-	-	89.8	-
1949	-	-	13.6	-
1950	-	-	6.7	-
1951	-	-	11.4	-
1952	-	-	29.4	-
1953	-	-	33.4	-
1954	-	-	28.9	31.1
1955	-	-	18.3	-
1956	-	-	51.3	-
1957	-	-	14.0	-
1958	-	-	42.2	63.7
1959	-	-	13.5	15.0
1960	-	-	14.1	-
1961	-	-	18.9	20.8
1962	-	-	25.2	-
1963	-	-	17.6	-
1964	-	-	10.6	-
1965	-	-	37.1	-
1966	-	-	36.8	-
1967	-	-	22.4	-
1968	-	-	8.5	-
1969	-	-	18.4	-
1970	-	-	27.3	-
1971	-	-	51.0	-
1972	-	-	44.5	-
1973	-	-	12.1	-
1974	104.0	-	115.0	-
1975	-	-	21.1	-

TABLE A1: Recorded Maximum Daily and Instantaneous Peak Discharge for WSC Gauging Stations

Year	Sturgeon River at St. Albert (05EA002)		Sturgeon River near Fort Saskatchewan (05EA001)	
	Maximum Daily Discharge (m^3/s)	Instantaneous Peak Discharge (m^3/s)	Maximum Daily Discharge (m^3/s)	Instantaneous Peak Discharge (m^3/s)
1976	13.3	-	13.5	-
1977	9.5	-	21.7	-
1978	13.1	13.2	21.0	-
1979	17.9	18	32.3	-
1980	14.7	14.8	16.7	-
1981	23.3	23.4	29.5	29.8
1982	32.9	33.6	42.1	51.9
1983	11.9	12.4	17.7	22.0
1984	5.3	-	8.4	9.5
1985	24.1	24.4	33.7	43.4
1986	22.2	22.4	27.4	-
1987	-	-	19.8	-
1988	-	-	8.4	18.7
1989	-	-	8.4	-
1990	-	-	10.7	-
1991	-	-	26.0	-
1992	-	-	17.1	-
1993	-	-	3.4	-
1994	-	-	20.9	-
1995	-	-	7.0	-
1996	-	-	22.6	-
1997	-	-	44.0	-
1998	-	-	9.1	-
1999	-	-	16.0	-
2000	-	-	3.6	-
2001	-	-	3.1	-
2002	-	-	12.7	-
2003	-	-	15.4	-
2004	-	-	14.3	-
2005	12.3	12.5	24.4	-
2006	3.6	3.7	7.7	-
2007	15.8	16.0	26.4	-
2008	2.75	7.7	3.6	4.0
2009	4.3	4.6	6.4	-
2010	1.1	2.1	1.7	1.9
2011	21.5	21.8	28.7	30.4
2012	13.5	14.3	8.7	9.0
2013	30.8	31.1	42.0	43.4
2014	11.6	11.7	13.2	-
2015	11.3	11.5	37.5	-
2016	1.3*	3.1*	2.9	-
2017	11.4*	12.3*	13.1*	-
2018	20.2*	20.3*	24.5*	-

* Reported data is preliminary and may be subject to change.

TABLE A2: Maximum Daily Discharges for Coincident Observations at WSC Gauging Stations

Sturgeon River near Fort Saskatchewan (05EA001)			Sturgeon River at St. Albert (05EA002)		
Date		Maximum Daily Flows (m^3/s)	Date		Maximum Daily Flows (m^3/s)
1914	16-Apr	10.8	1914	16-Apr	10.5
1914	22-Jun	51.8	1914	19-Jun	42.2
1915	03-Apr	24.7	1915	30-Mar	16.4
1915	23-Jun	30.6	1915	18-Jun	27.2
1916	18-Apr	17.0	1916	16-Apr	15.5
1917	24-Apr	31.4	1917	22-Apr	25.0
1917	28-May	16.7	1917	27-May	14.5
1918	14-Apr	16.4	1918	12-Apr	12.3
1919	15-Apr	10.8	1919	14-Apr	8.2
1921	13-Apr	17.0	1921	13-Apr	14.7
1922	04-May	3.3	1922	4-May	3.5
1923	04-May	3.2	1923	30-Apr	3.1
1974	27-Apr	115.0	1974	26-Apr	104.0
1976	14-Apr	12.8	1976	13-Apr	13.3
1978	11-Apr	21.0	1978	11-Apr	13.1
1979	28-Apr	21.3	1979	27-Apr	17.9
1980	17-Apr	16.2	1980	16-Apr	14.7
1981	06-Apr	27.3	1981	04-Apr	23.3
1982	3-May	36.7	1982	01-May	32.9
1983	07-Jul	17.7	1983	03-Jul	11.9
1984	06-Apr	8.4	1984	04-Apr	5.3
1985	13-Apr	28.7	1985	13-Apr	24.1
1986	03-Apr	23.9	1986	03-Apr	22.2
2005	09-Apr	12.6	2005	8-Apr	12.3
2006	14-Apr	7.7	2006	13-Apr	3.6
2007	12-May	17.0	2007	12-May	15.8
2008	06-May	2.7	2008	5-May	2.8
2010	23-May	1.7	2010	21-May	1.1
2011	03-May	22.2	2011	1-May	21.5
2012	22-Apr	7.1	2012	20-Apr	6.7
2013	04-May	42.0	2013	2-May	30.8
2014	16-Apr	12.2	2014	16-Apr	11.6
2015	04-Apr	23.2	2015	4-Apr	11.3*
2017	30-Apr	12.0*	2017	30-Apr	11.4*
2018	29-Apr	22.8*	2018	29-Apr	20.2*

* Reported data is preliminary and may be subject to change.

TABLE A3: Extended Maximum Daily Discharge and Extended Instantaneous Peak Discharge for Sturgeon River at St. Albert (05EA002)

Year	Extended Maximum Daily Discharge (m^3/s)	Extended Instantaneous Peak Discharge (m^3/s)
1914	42.2	42.9
1915	27.2	27.6
1916	15.5	15.7
1917	25.0	25.4
1918	12.3	12.5
1919	8.2	8.3
1920	24.8	25.2
1921	14.7	14.9
1922	3.5	3.5
1923	3.1	3.2
1924	4.1	4.1
1925	37.4	38.0
1926	5.6	5.7
1927	30.9	31.4
1928	-	-
1929	7.4	7.5
1930	3.7	3.8
1931	-	-
1932	-	-
1933	-	-
1934	-	-
1935	28.1	28.5
1936	49.7	50.5
1937	7.9	8.0
1938	17.4	17.7
1939	4.5	4.6
1940	40.5	41.1
1941	11.0	11.2
1942	3.4	3.5
1943	46.6	47.3
1944	33.0	33.5
1945	4.7	4.8
1946	11.7	11.9
1947	9.0	9.1
1948	77.0	78.2
1949	11.7	11.9
1950	5.8	5.9
1951	9.8	10.0
1952	25.2	25.6
1953	28.6	29.0
1954	24.8	25.2
1955	15.7	15.9
1956	44.0	44.7
1957	12.0	12.2
1958	36.2	36.8
1959	11.6	11.8
1960	12.1	12.3
1961	16.2	16.5
1962	21.6	21.9
1963	15.1	15.3
1964	9.1	9.2
1965	31.8	32.3
1966	31.5	32.0
1967	19.2	19.5
1968	7.3	7.4
1969	15.8	16.0

TABLE A3: Extended Maximum Daily Discharge and Extended Instantaneous Peak Discharge for Sturgeon River at St. Albert (05EA002)

Year	Extended Maximum Daily Discharge (m^3/s)	Extended Instantaneous Peak Discharge (m^3/s)
1970	23.4	23.8
1971	43.7	44.4
1972	38.1	38.7
1973	10.4	10.6
1974	104.0	104.0
1975	18.1	18.4
1976	13.3	13.5
1977	9.5	9.6
1978	13.1	13.2
1979	17.9	18.0
1980	14.7	14.8
1981	23.3	23.4
1982	32.9	33.6
1983	11.9	12.4
1984	5.3	5.4
1985	24.1	24.4
1986	22.2	22.4
1987	17.0	17.3
1988	7.2	7.3
1989	7.2	7.3
1990	9.2	9.3
1991	22.3	22.6
1992	14.7	14.9
1993	2.9	2.9
1994	17.9	18.2
1995	6.0	6.1
1996	19.4	19.7
1997	37.7	38.3
1998	7.8	7.9
1999	13.7	13.9
2000	3.1	3.1
2001	2.6	2.6
2002	10.9	11.1
2003	13.2	13.4
2004	12.3	12.5
2005	12.3	12.5
2006	3.6	3.7
2007	15.8	16.0
2008	2.8	7.7
2009	4.3	4.6
2010	1.1	2.1
2011	21.5	21.8
2012	13.5	14.3
2013	30.8	31.1
2014	11.6	11.7
2015	11.3	11.5
2016	1.3*	3.1*
2017	11.4*	12.3*
2018	20.2*	20.3*

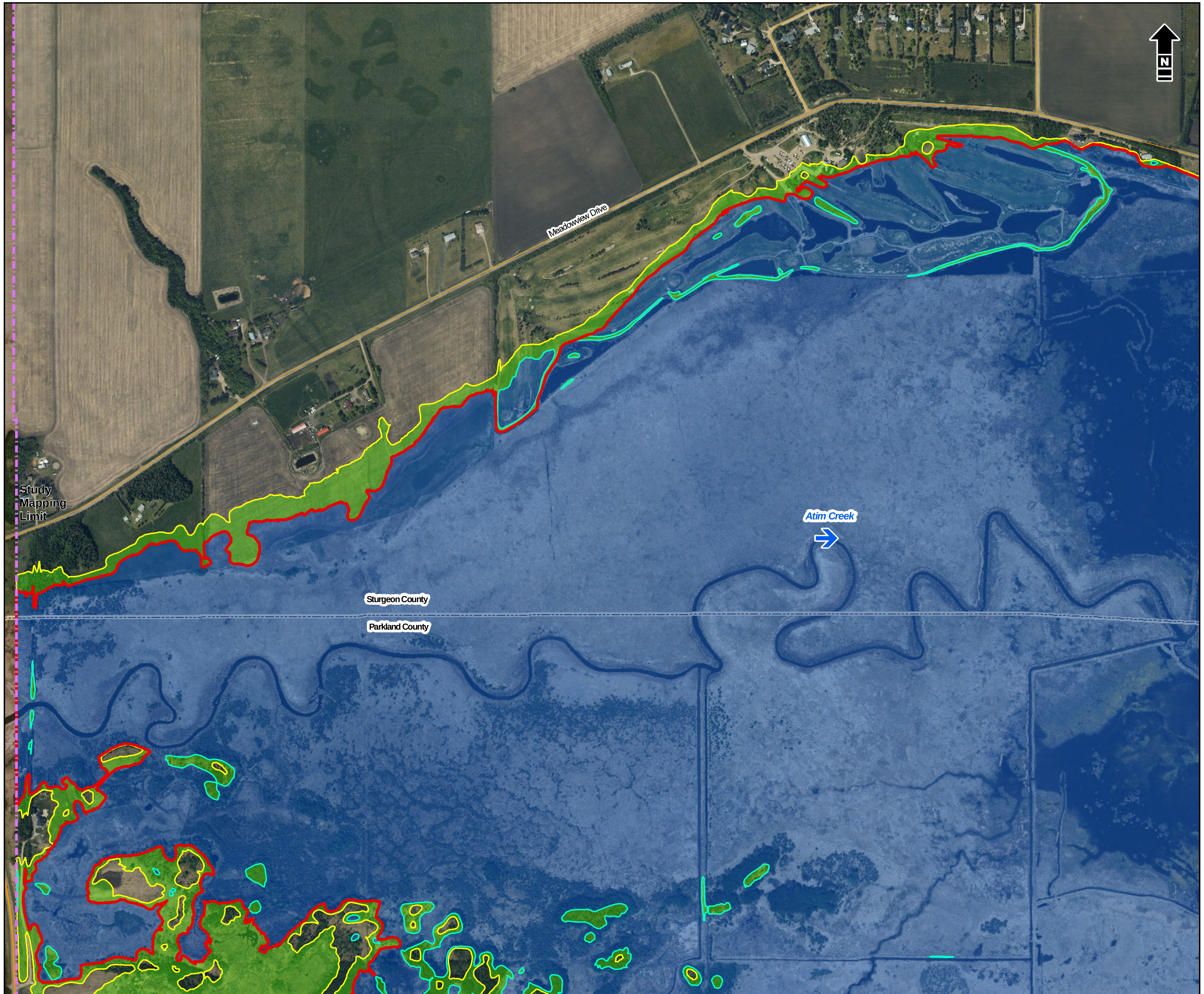
* Reported data is preliminary and may be subject to change.

APPENDIX D
Flood Inundation Maps

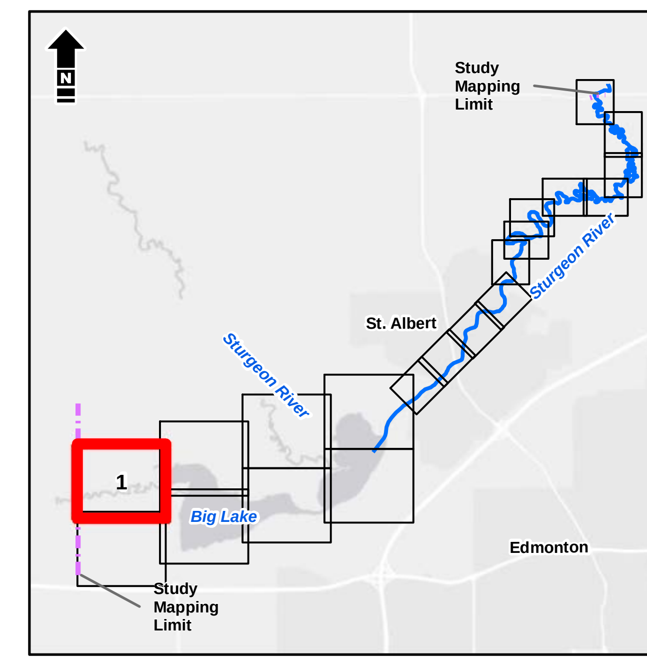
[Placeholder]

Appendix D presented under separate cover

APPENDIX E
Floodway Criteria Maps



Bridge
Culvert
Cross Section Line
Study Mapping Limit
Flood Control Structure
Municipal Boundary (Urban)
Municipal Boundary (Rural)
Major Road
Local Road
Railway
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - 1m/s Velocity
100 Year Inundation Extent - ≥1m Depth
100 Year Inundation Extent
Protected Flood Area



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Floodway Criteria Map

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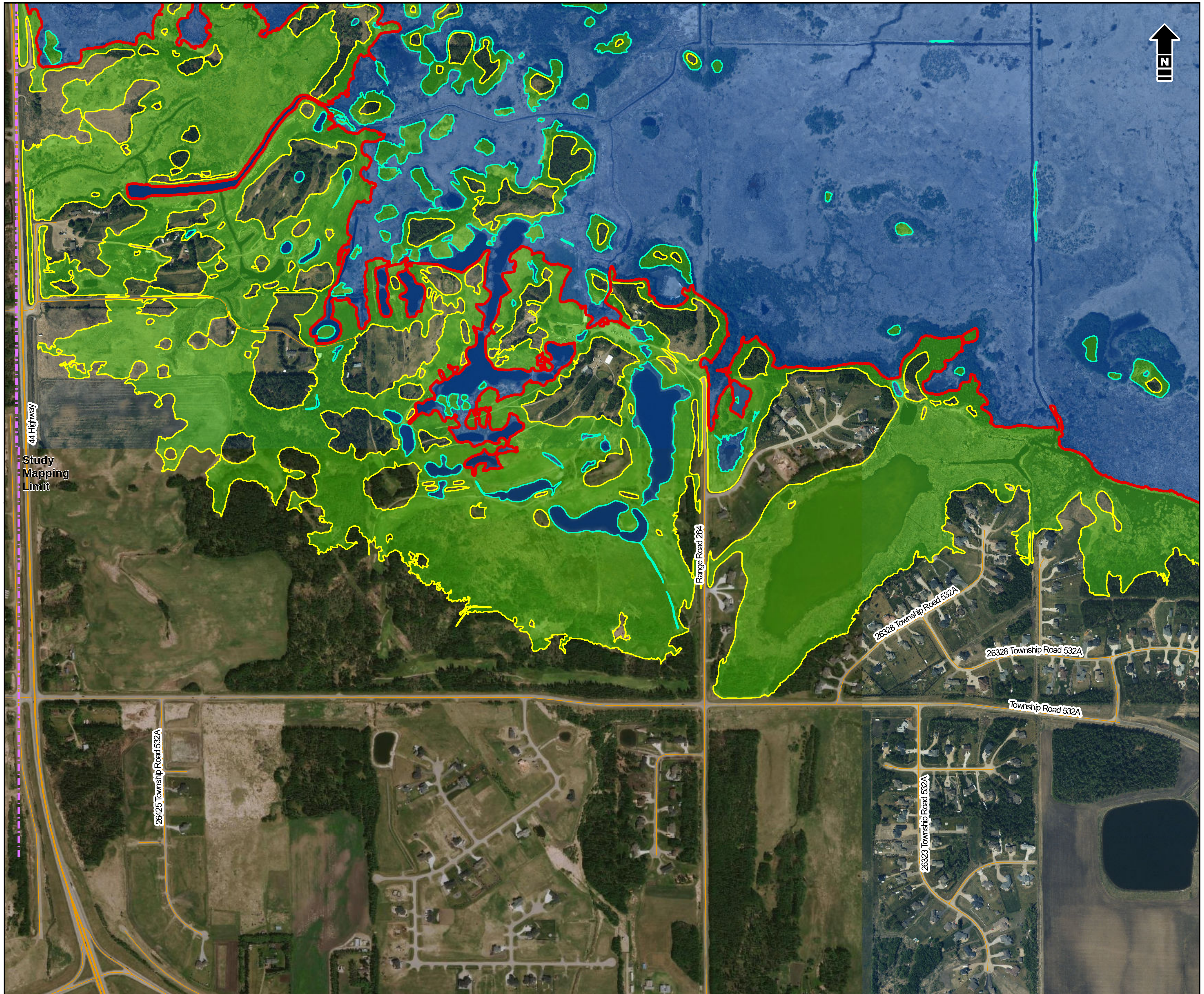

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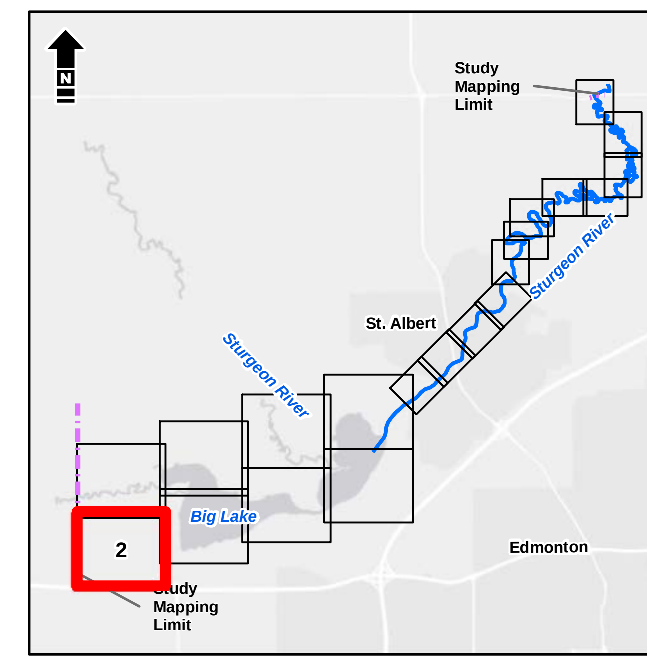
100 Year Inundation Extent
Protected Flood Area



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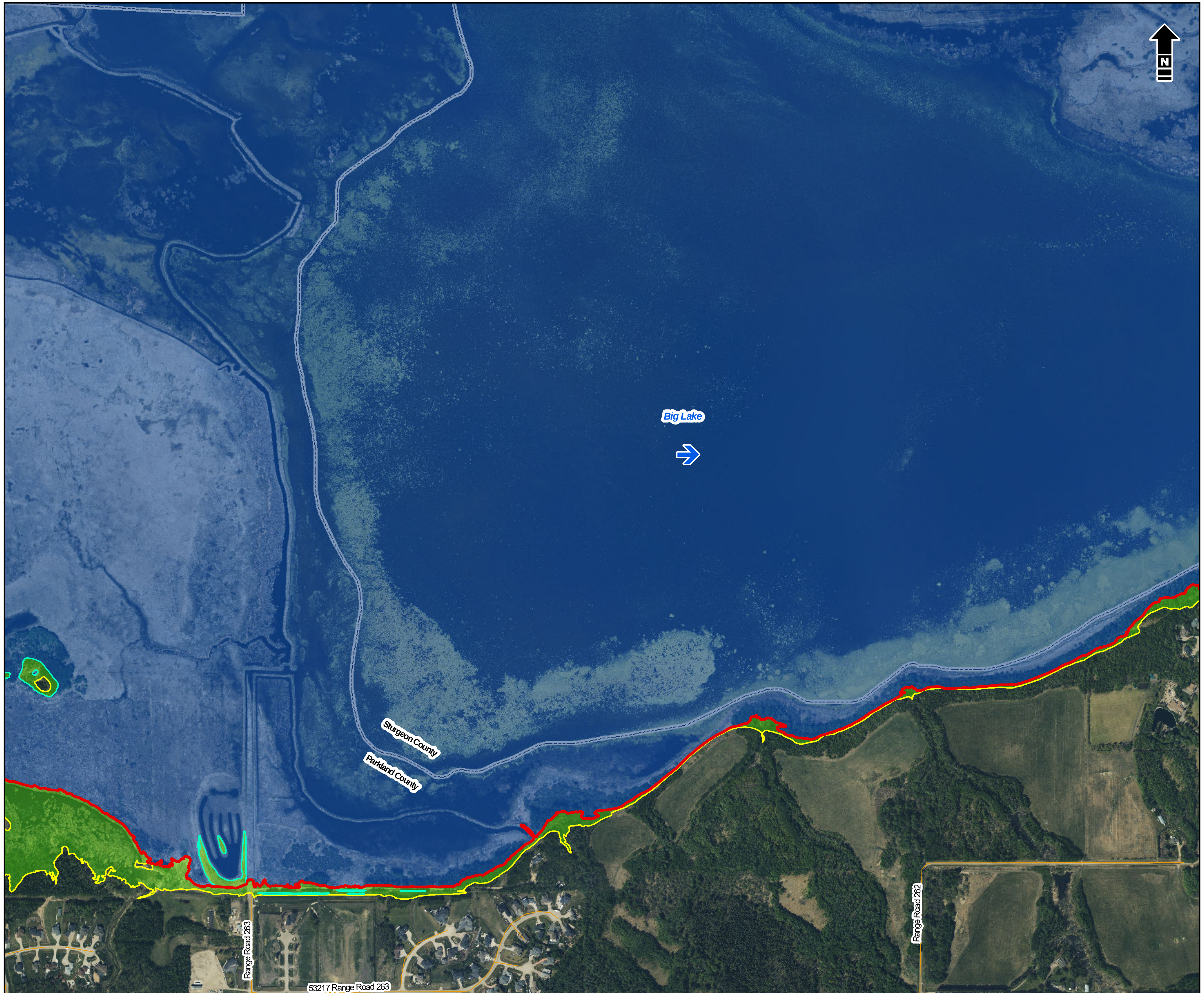

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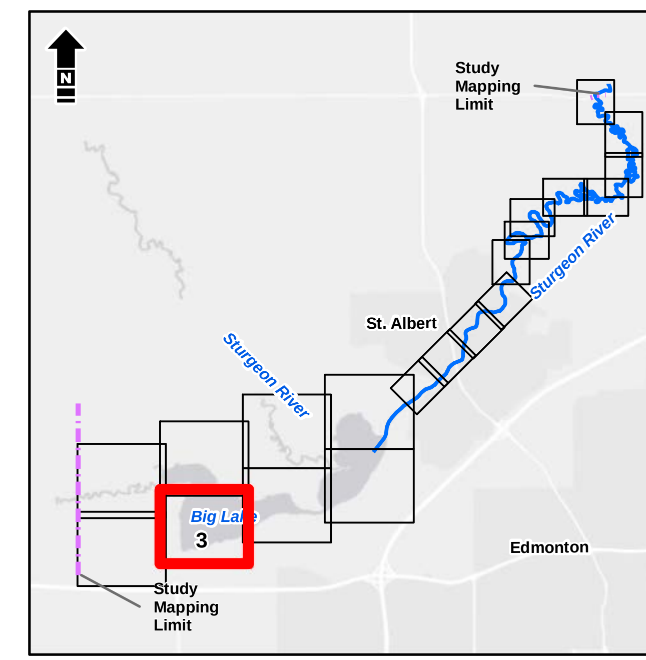

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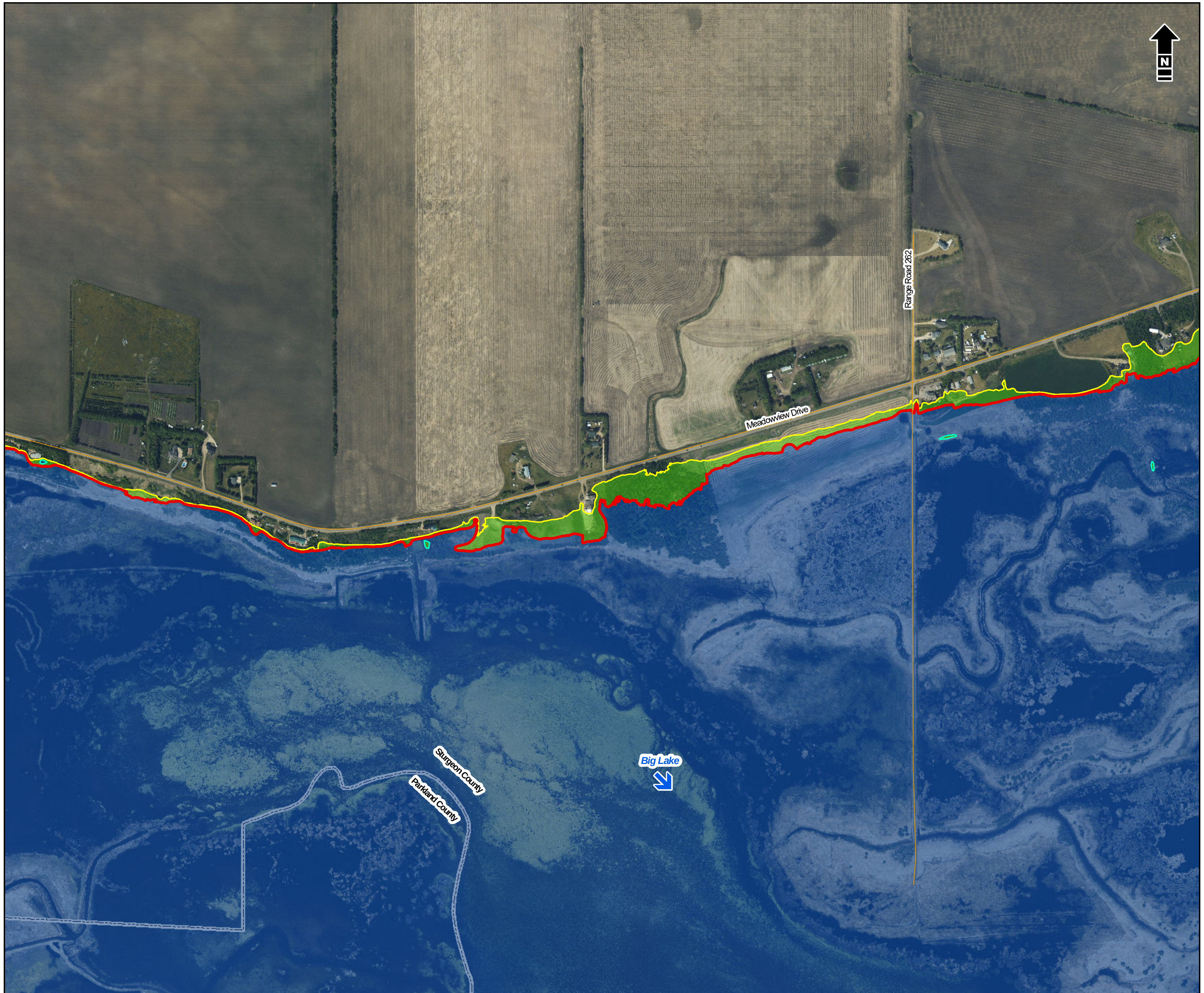

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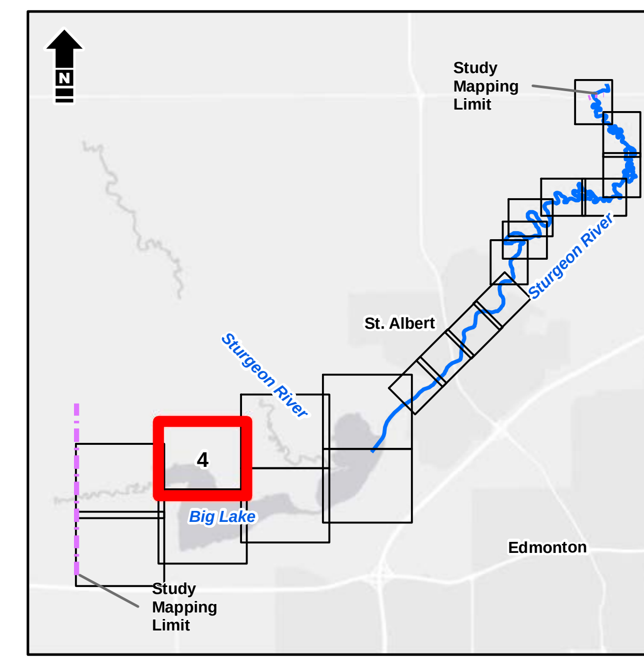

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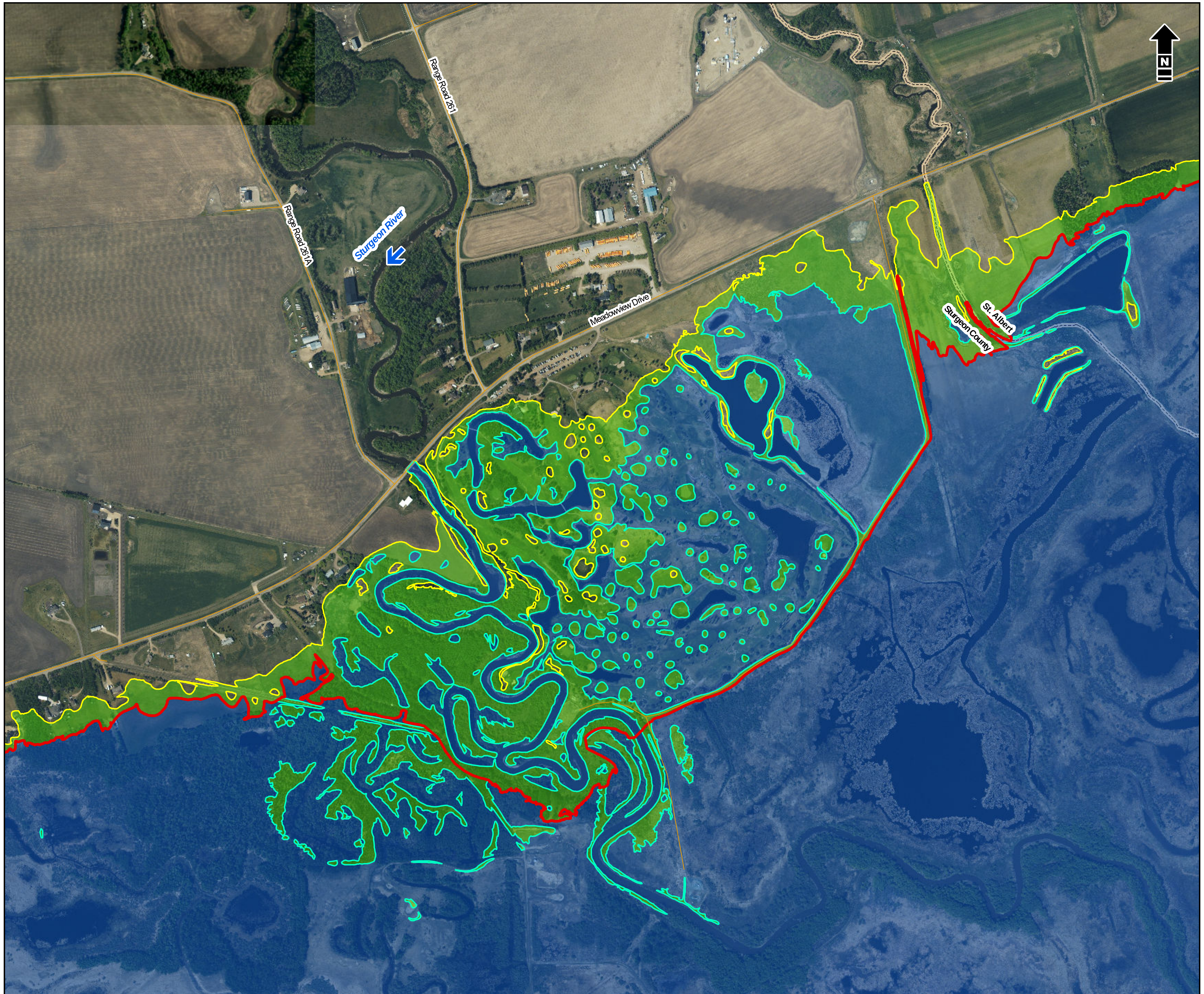

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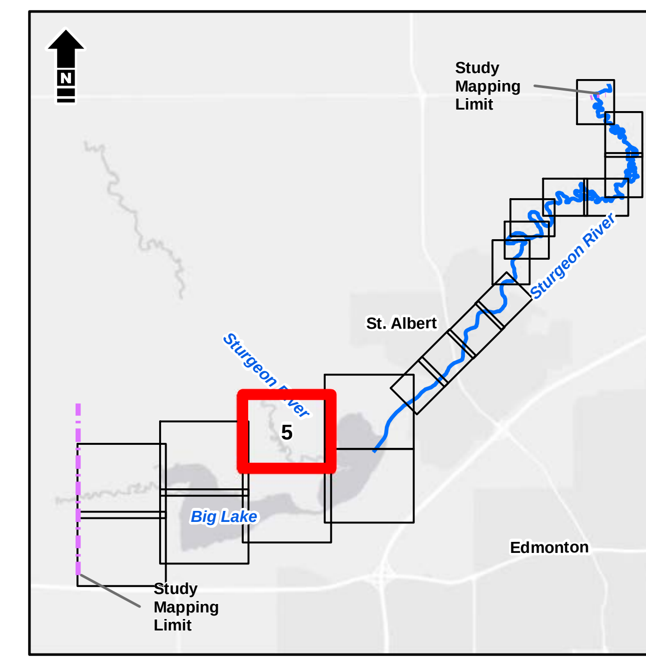

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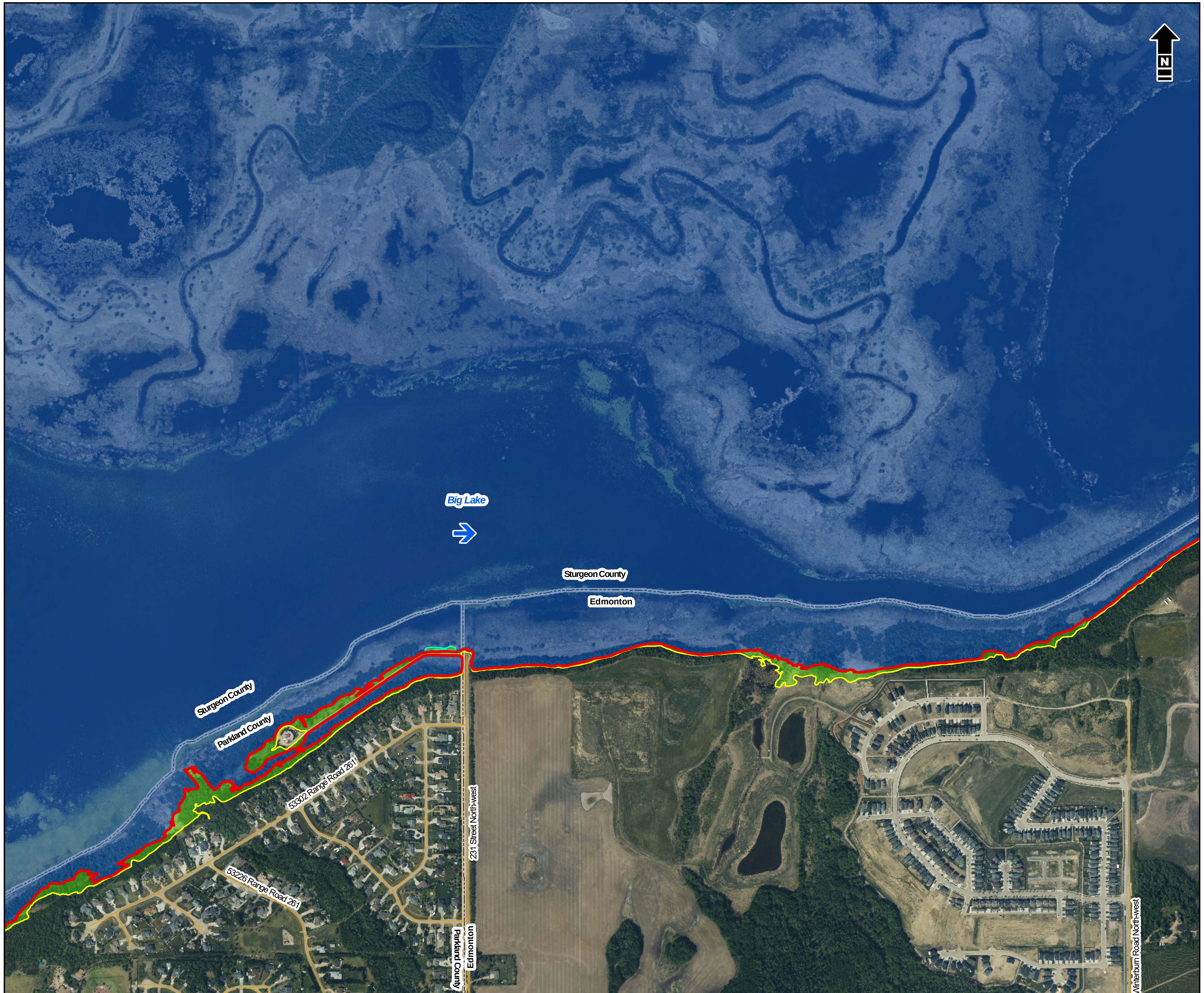

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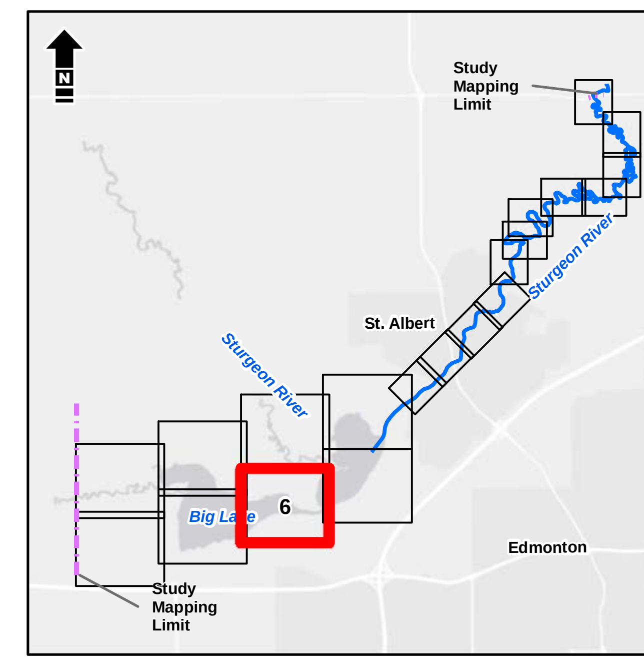

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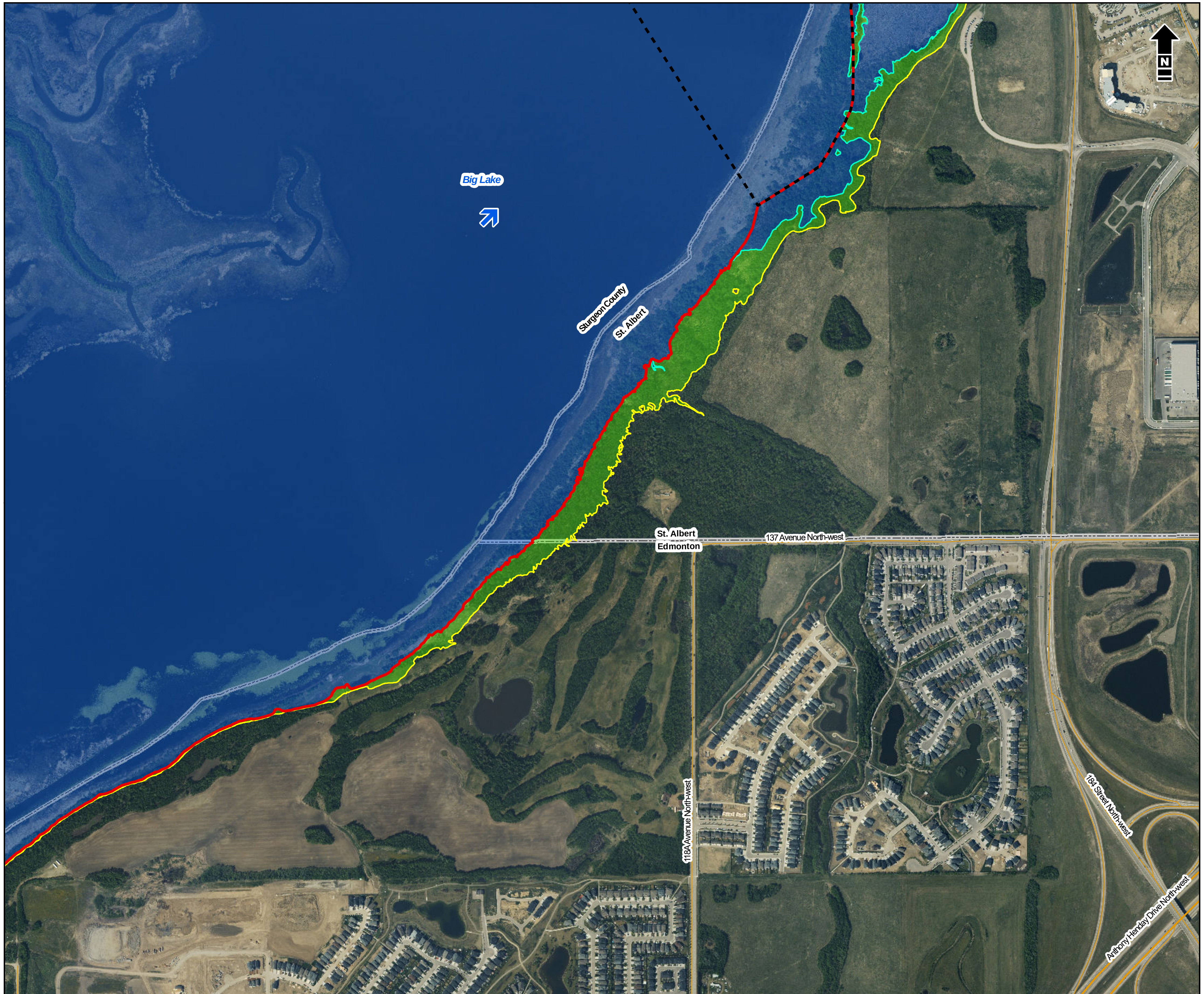

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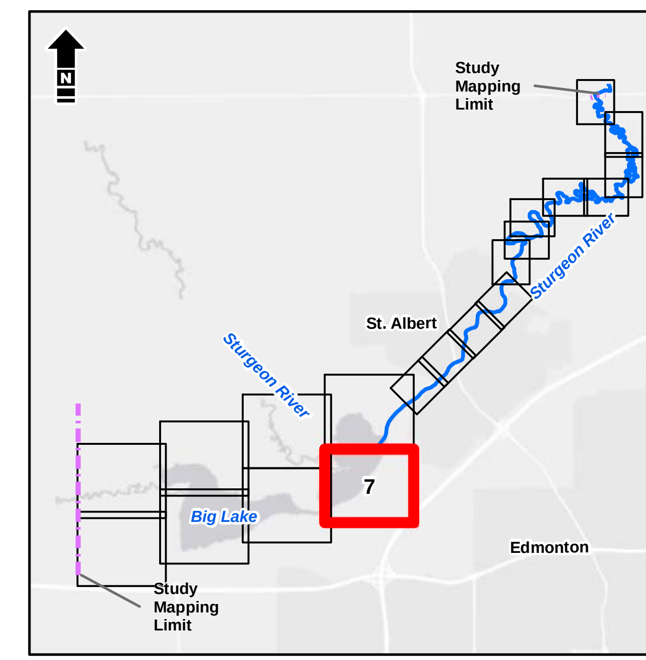

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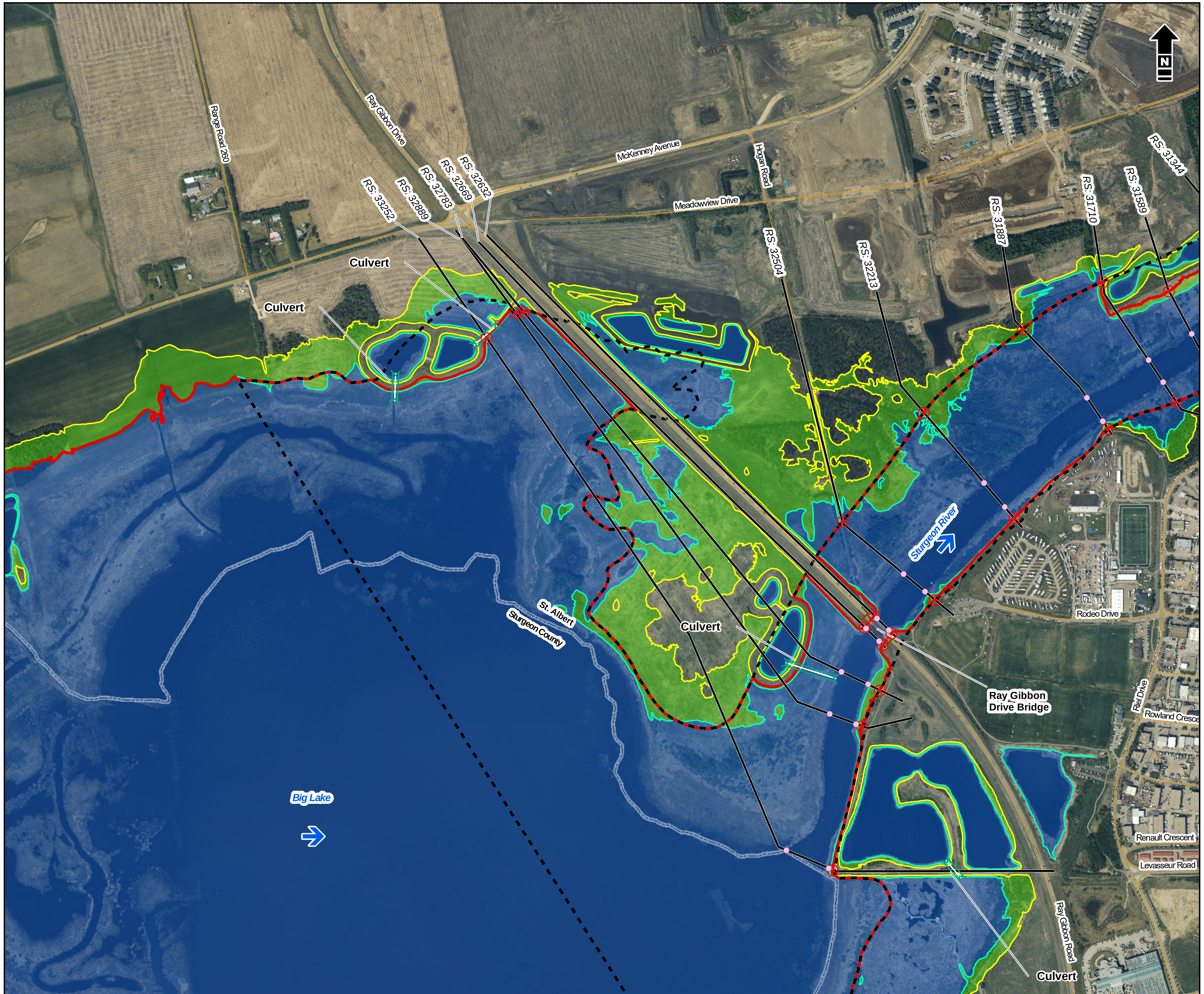

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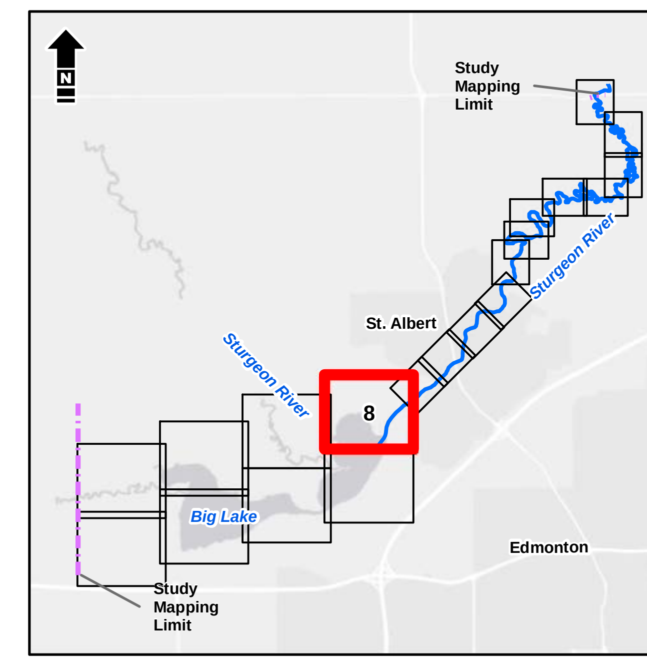

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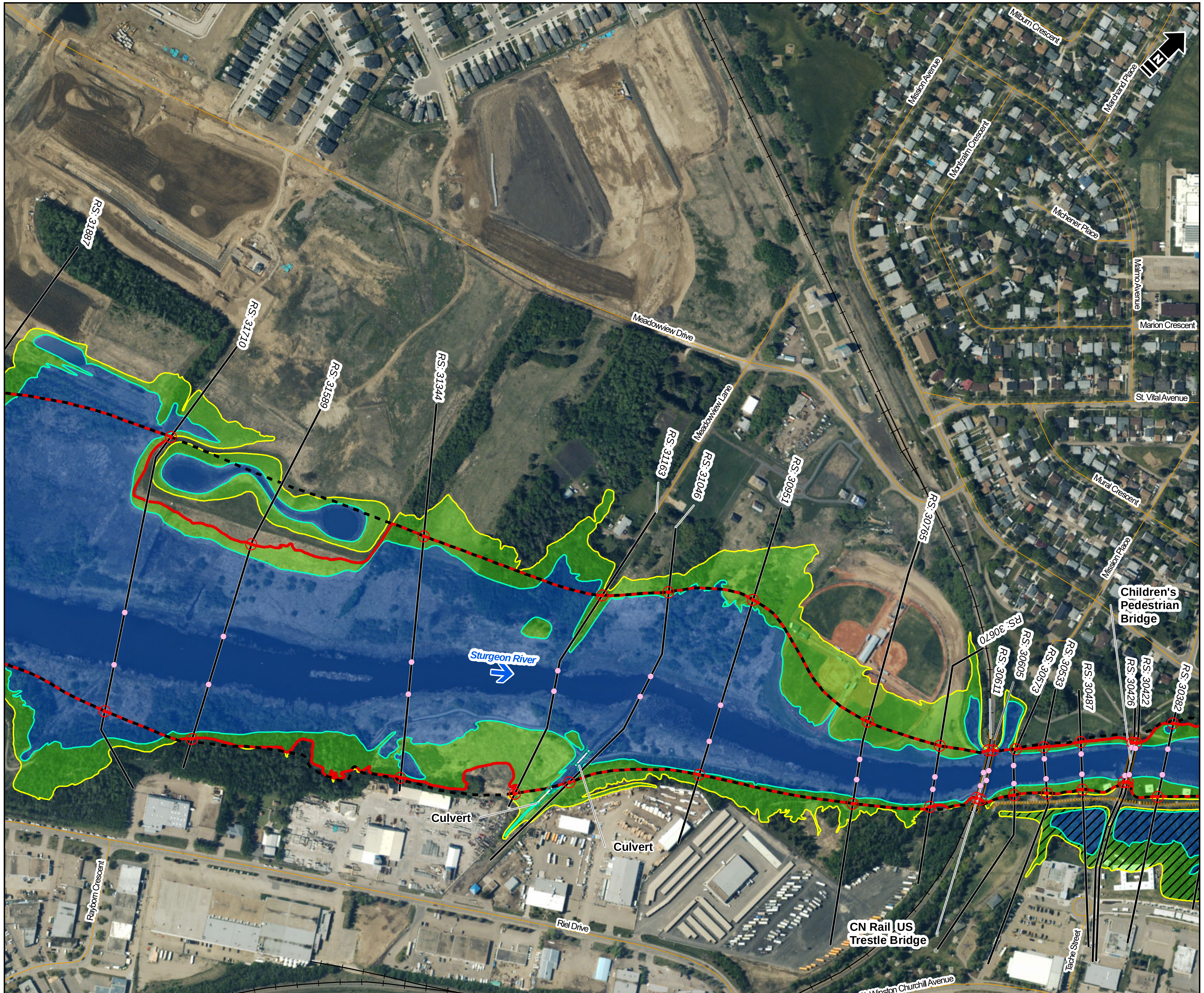

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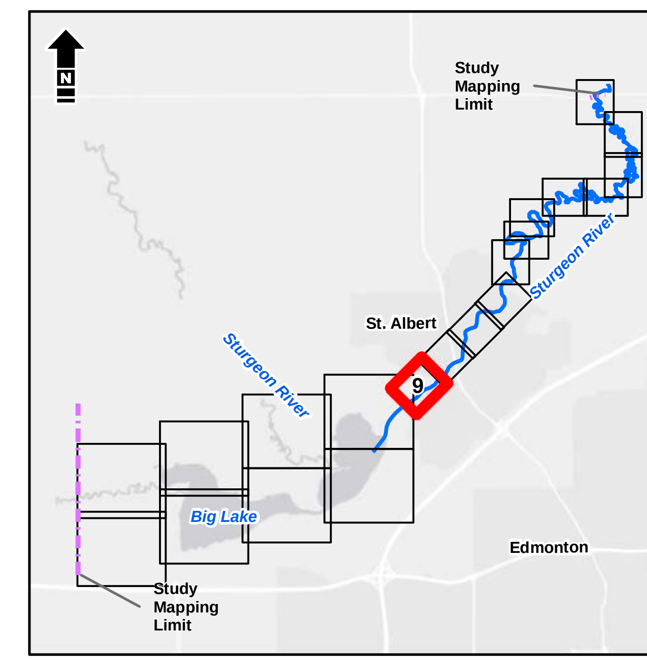

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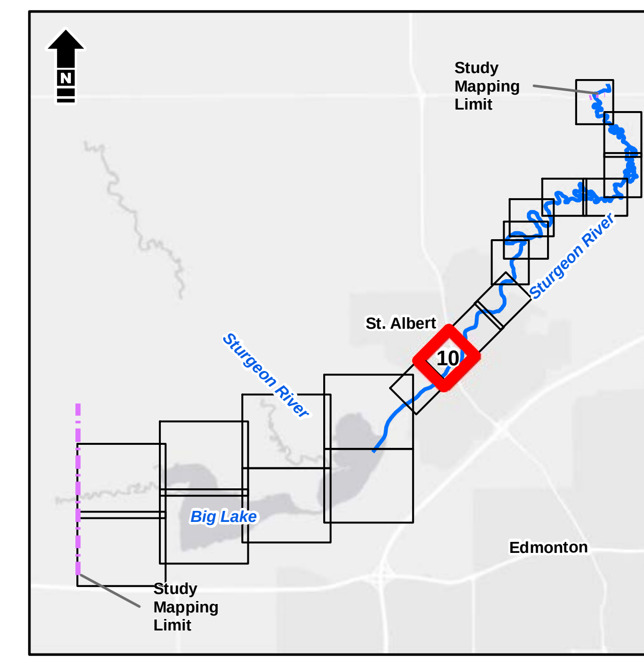

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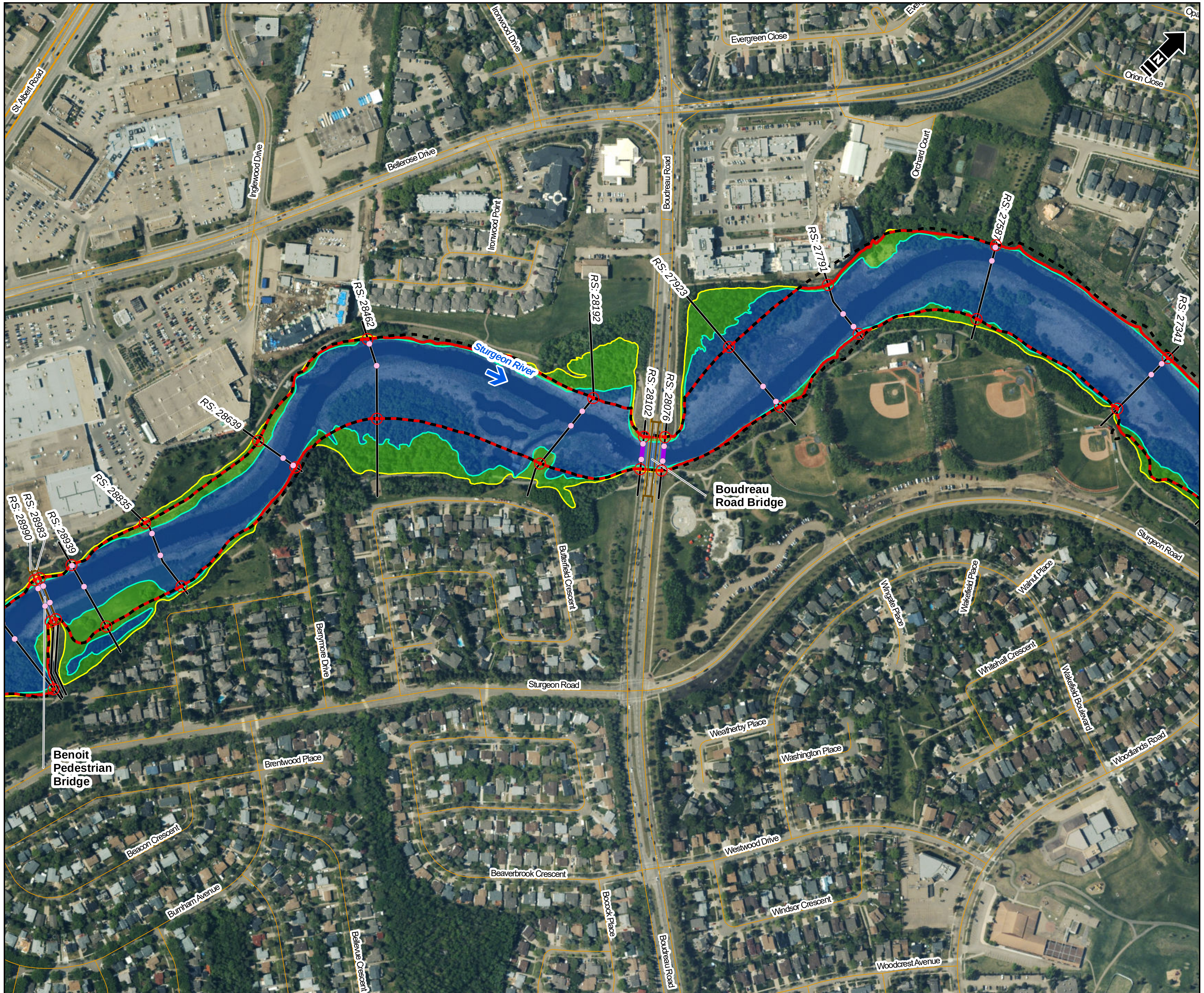

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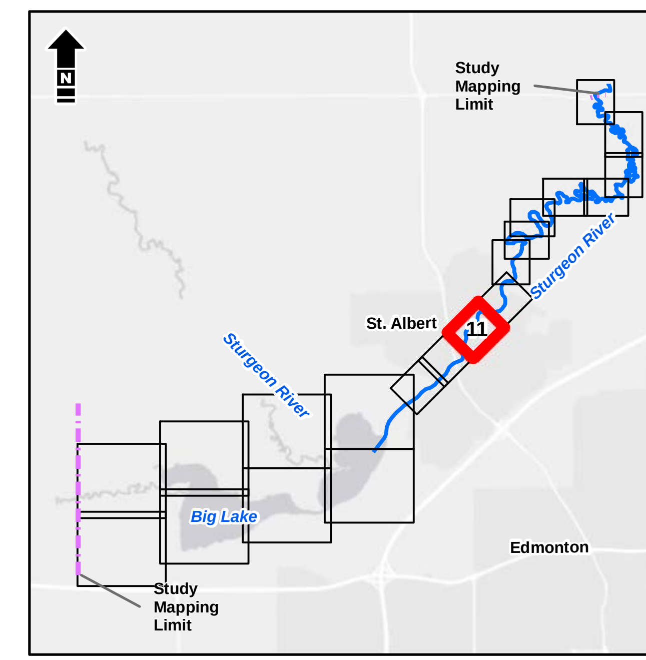

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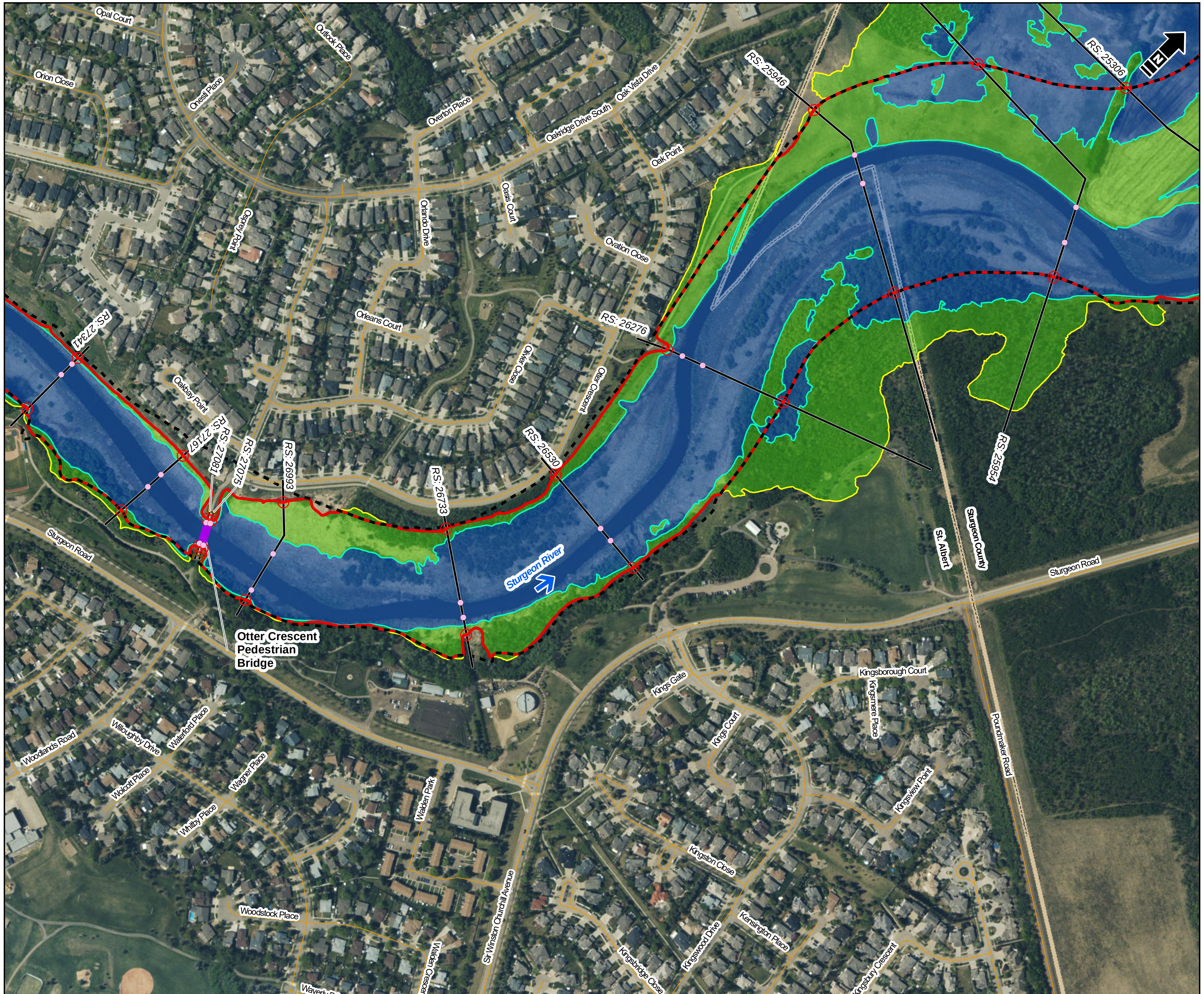

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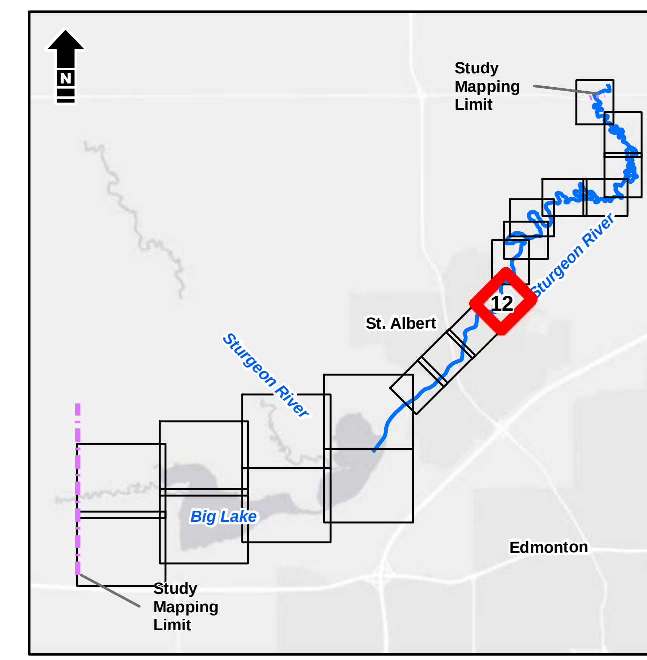

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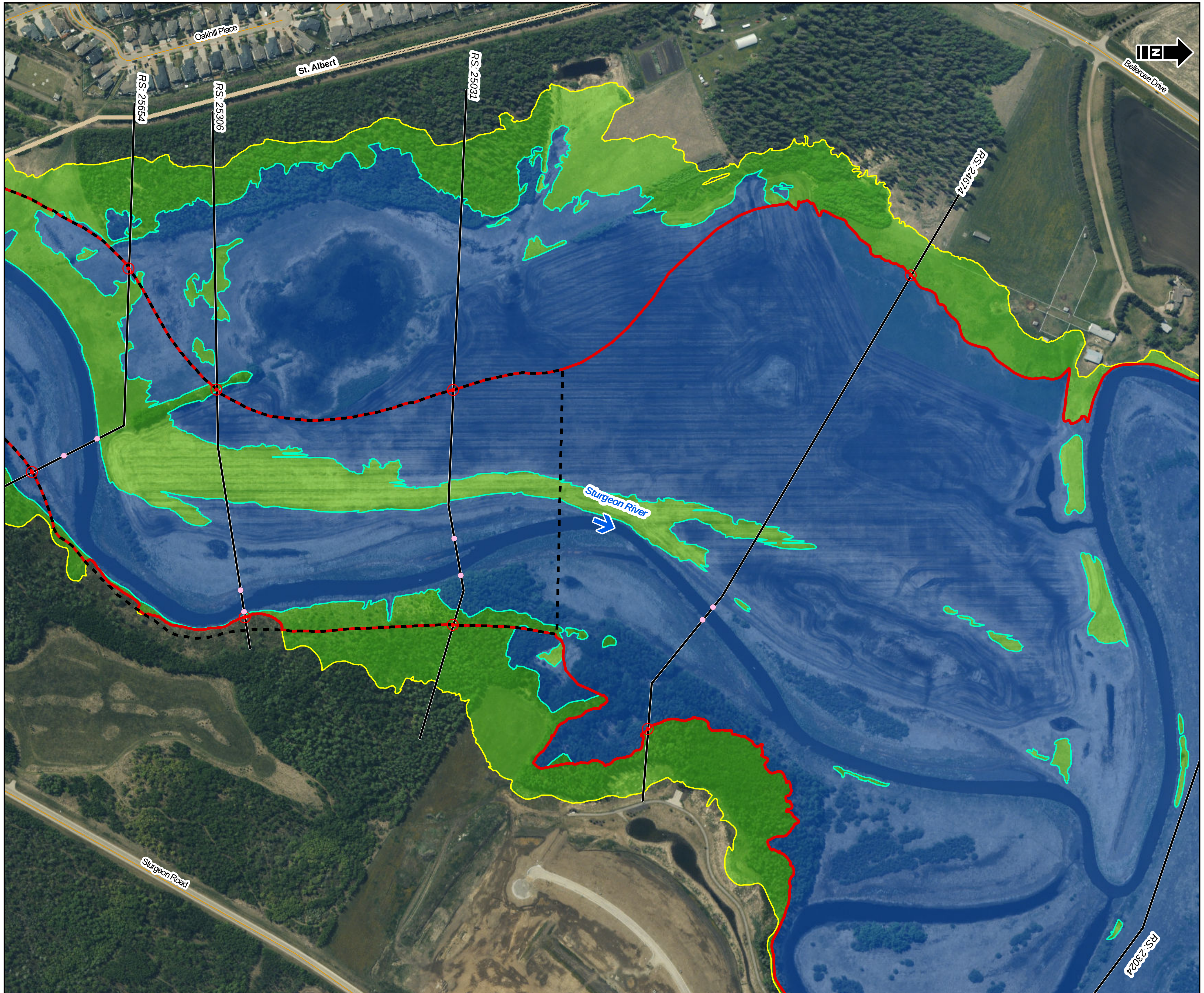

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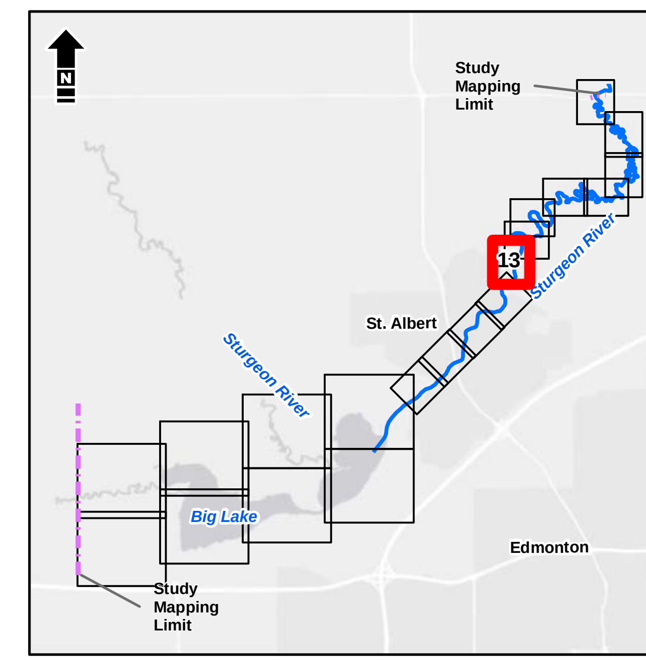
100 Year Inundation Extent
Protected Flood Area



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NAD 1983 CSRS 3TM 114

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ENVIRONMENT & ENGINEERING

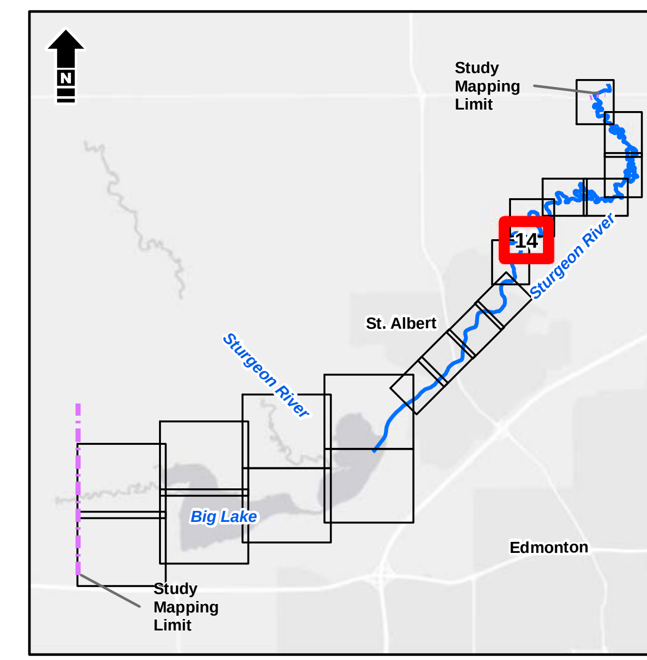
Alberta

Alberta Government
St. Albert Flood Hazard Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
May 2022	28312	B. Coates	M. Shome

Bridge
Culvert
Cross Section Line
Study Mapping Limit
Flood Control Structure
Municipal Boundary (Urban)
Municipal Boundary (Rural)
Major Road
Local Road
Railway
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - 1m/s Velocity
100 Year Inundation Extent - ≥1m Depth
100 Year Inundation Extent
Protected Flood Area



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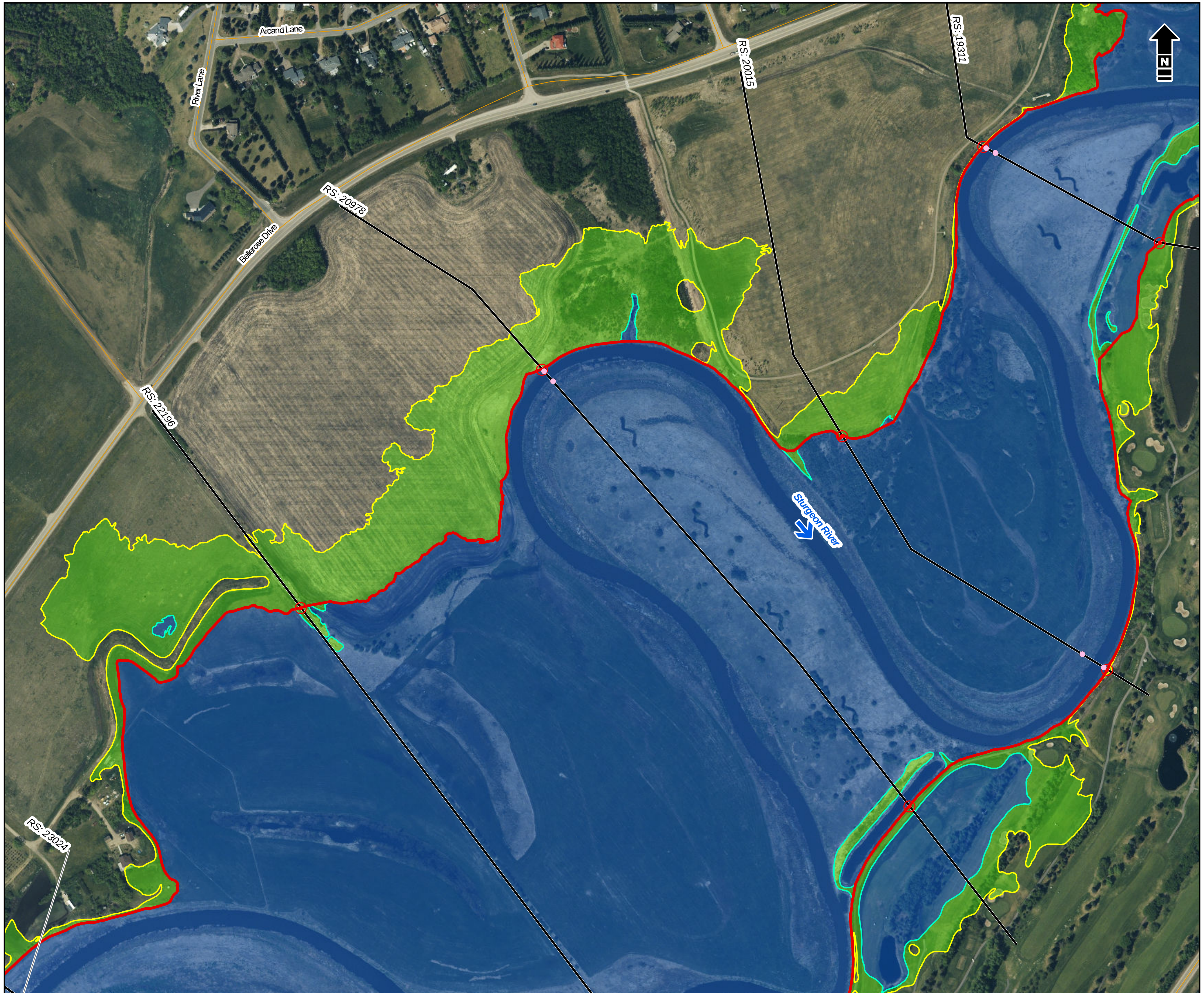
Alberta Government
St. Albert Flood Hazard Study

Floodway Criteria Map

Date: May 2022	Project: 28312	Submitter: B. Coates	Reviewer: M. Shome



Bridge
Culvert
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100 Year Inundation Extent
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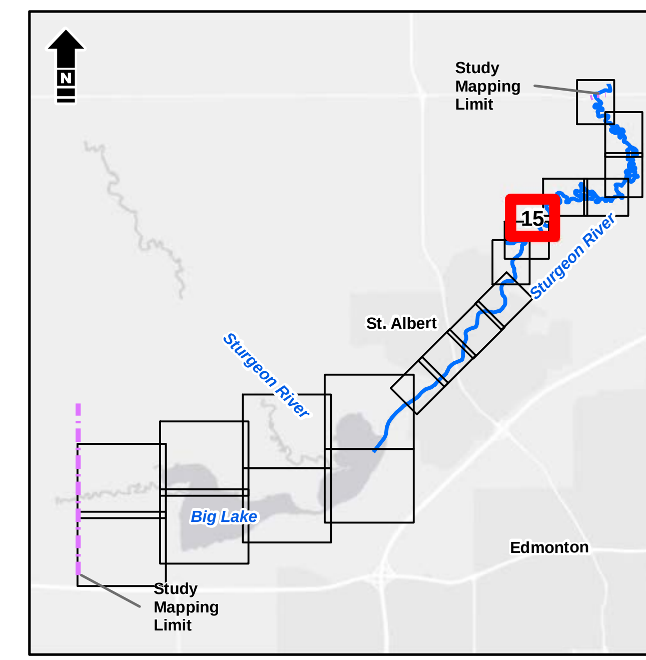

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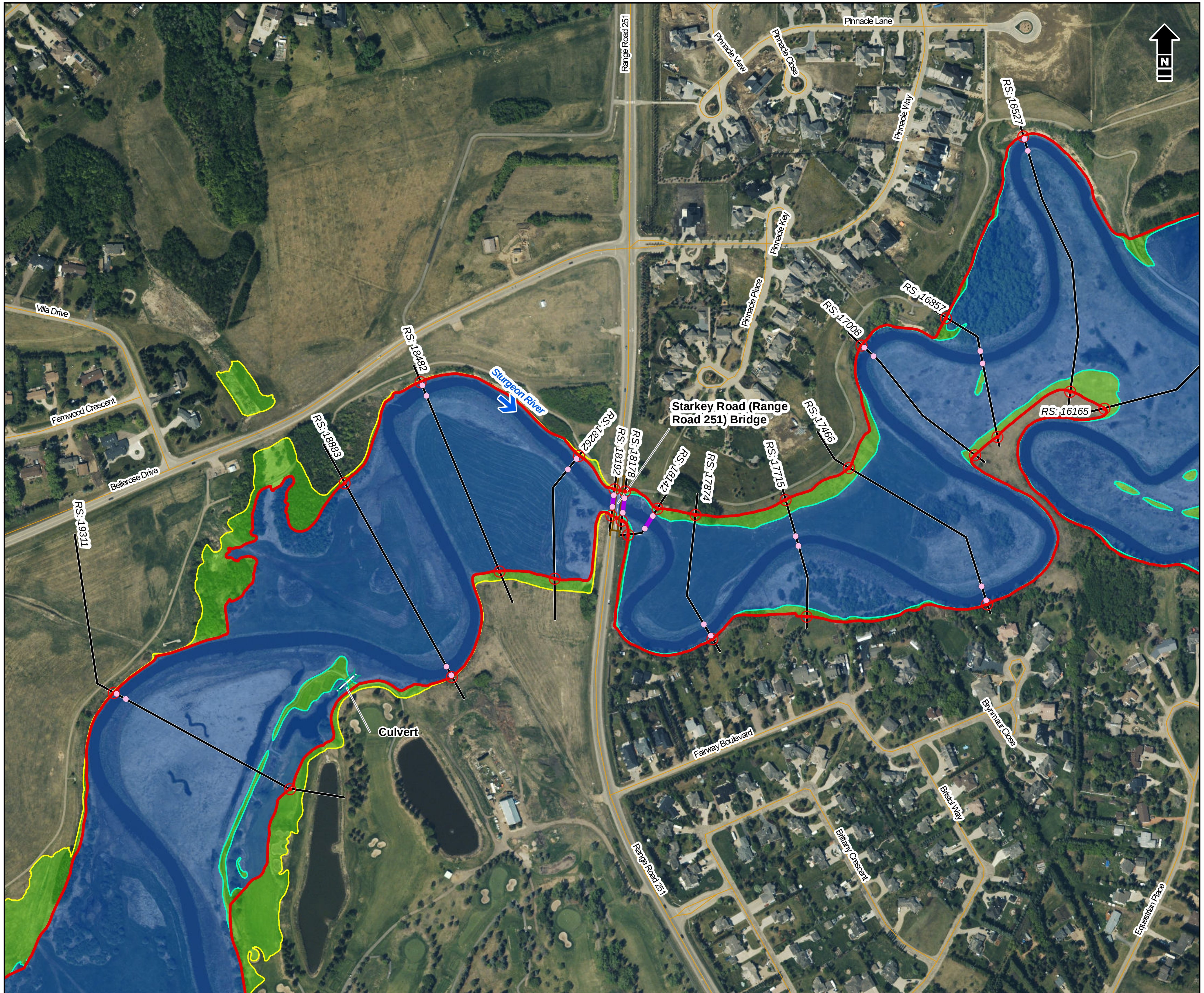

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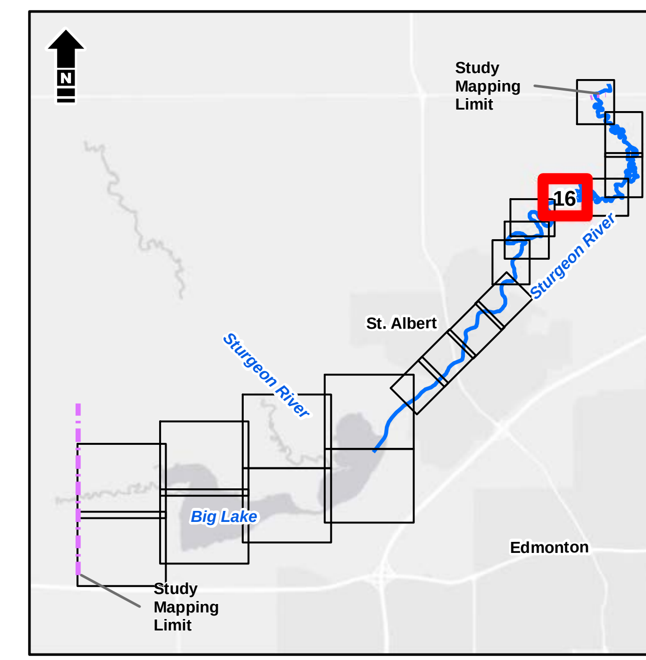

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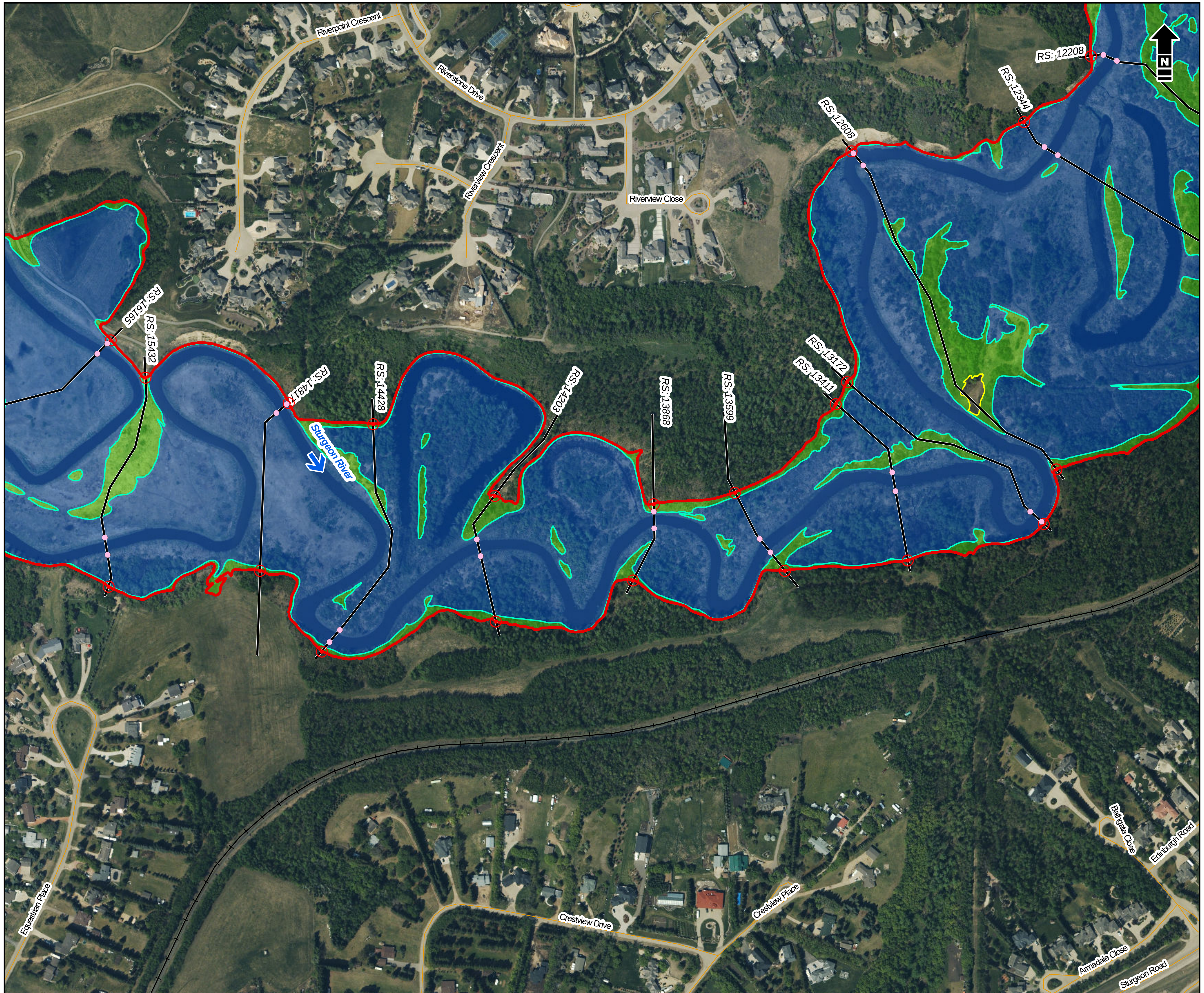

Bridge
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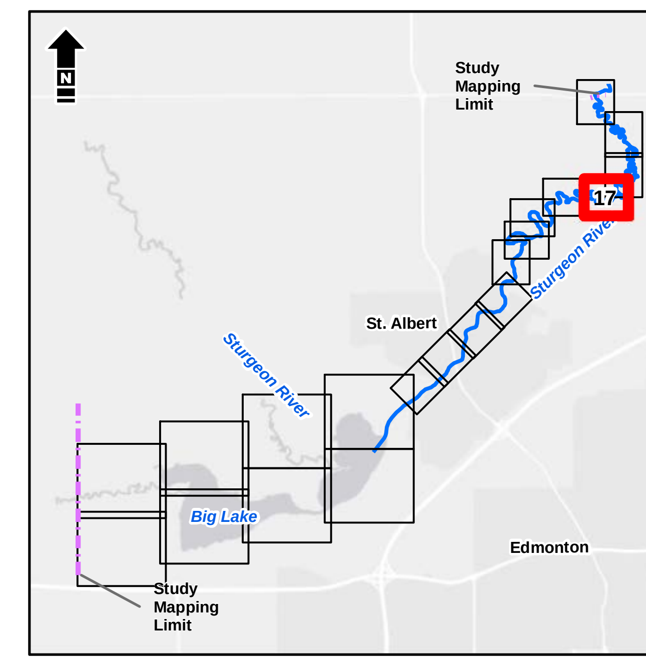

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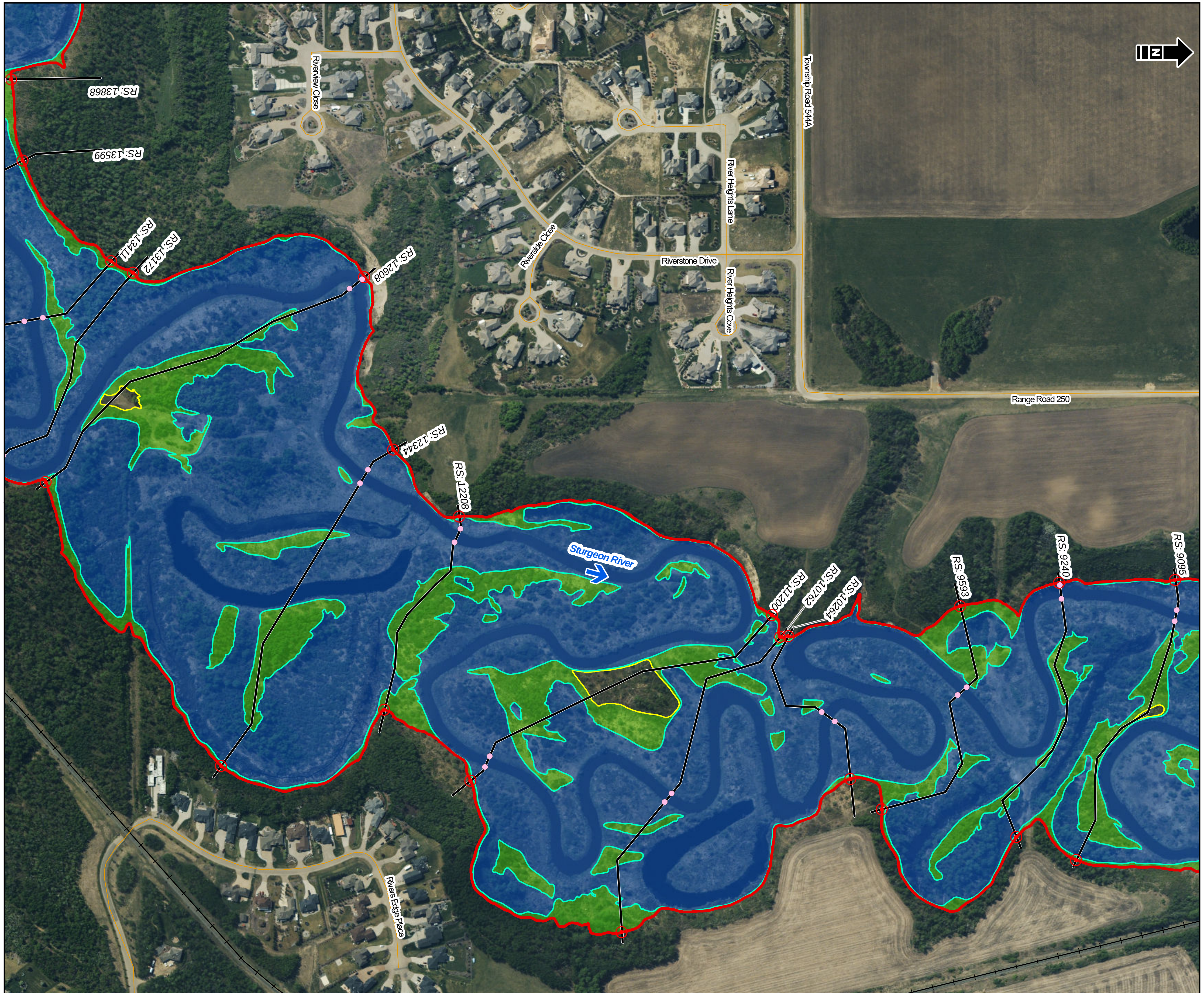

- Bridge
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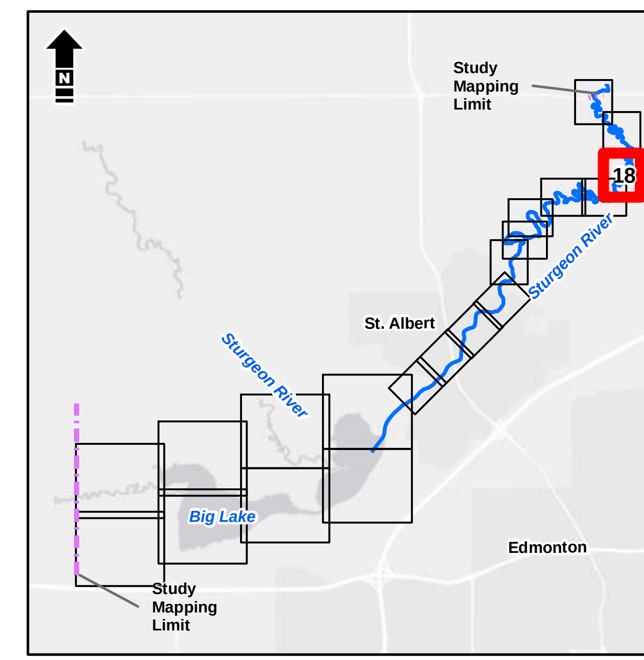

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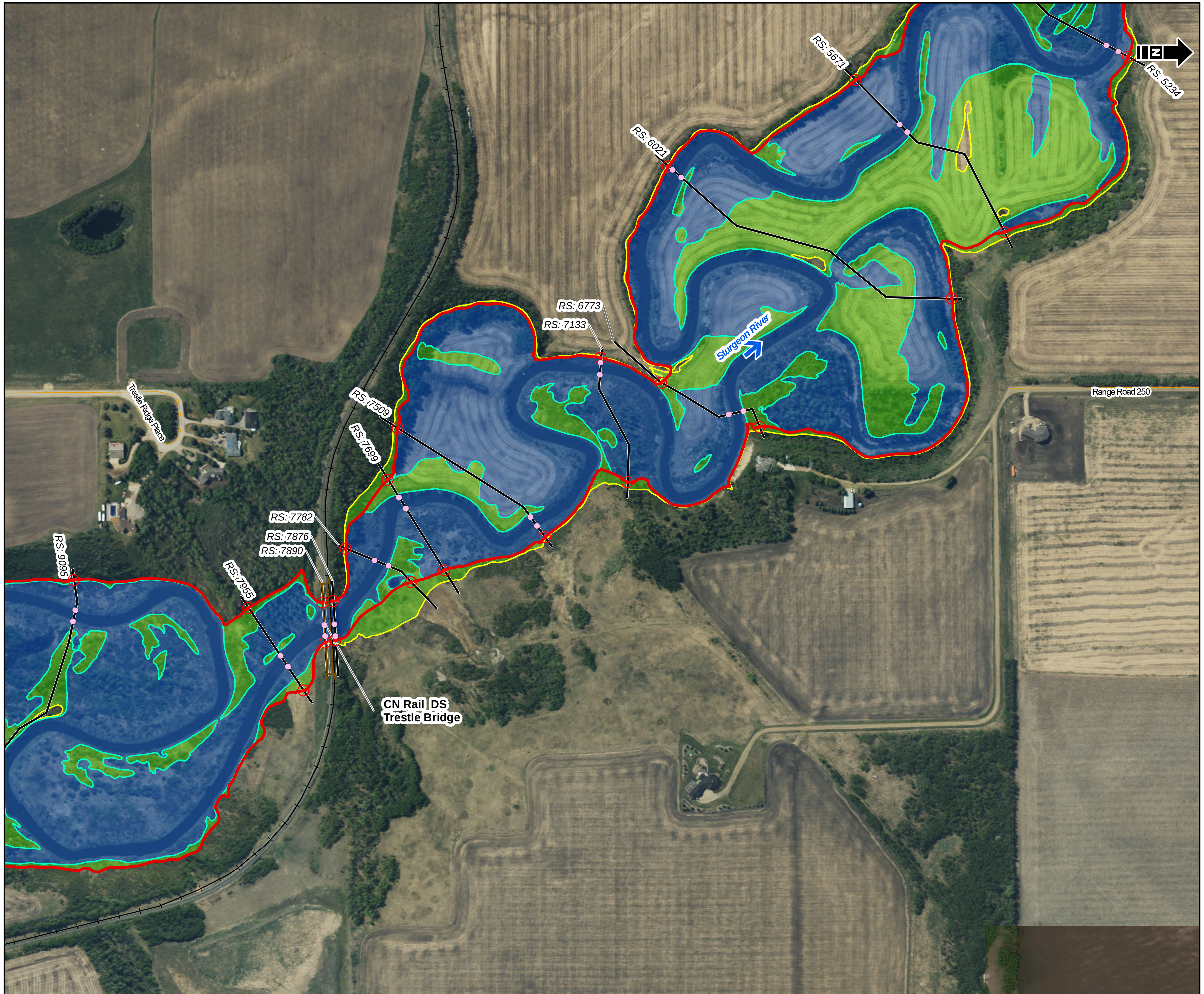

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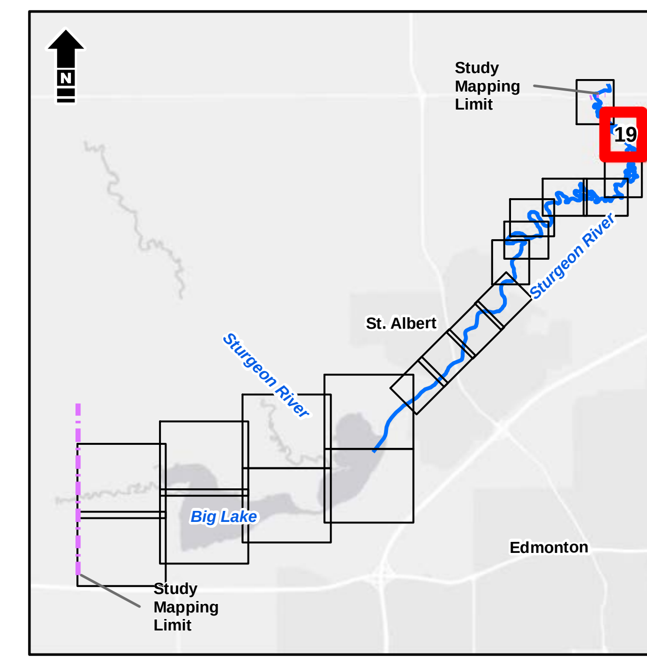

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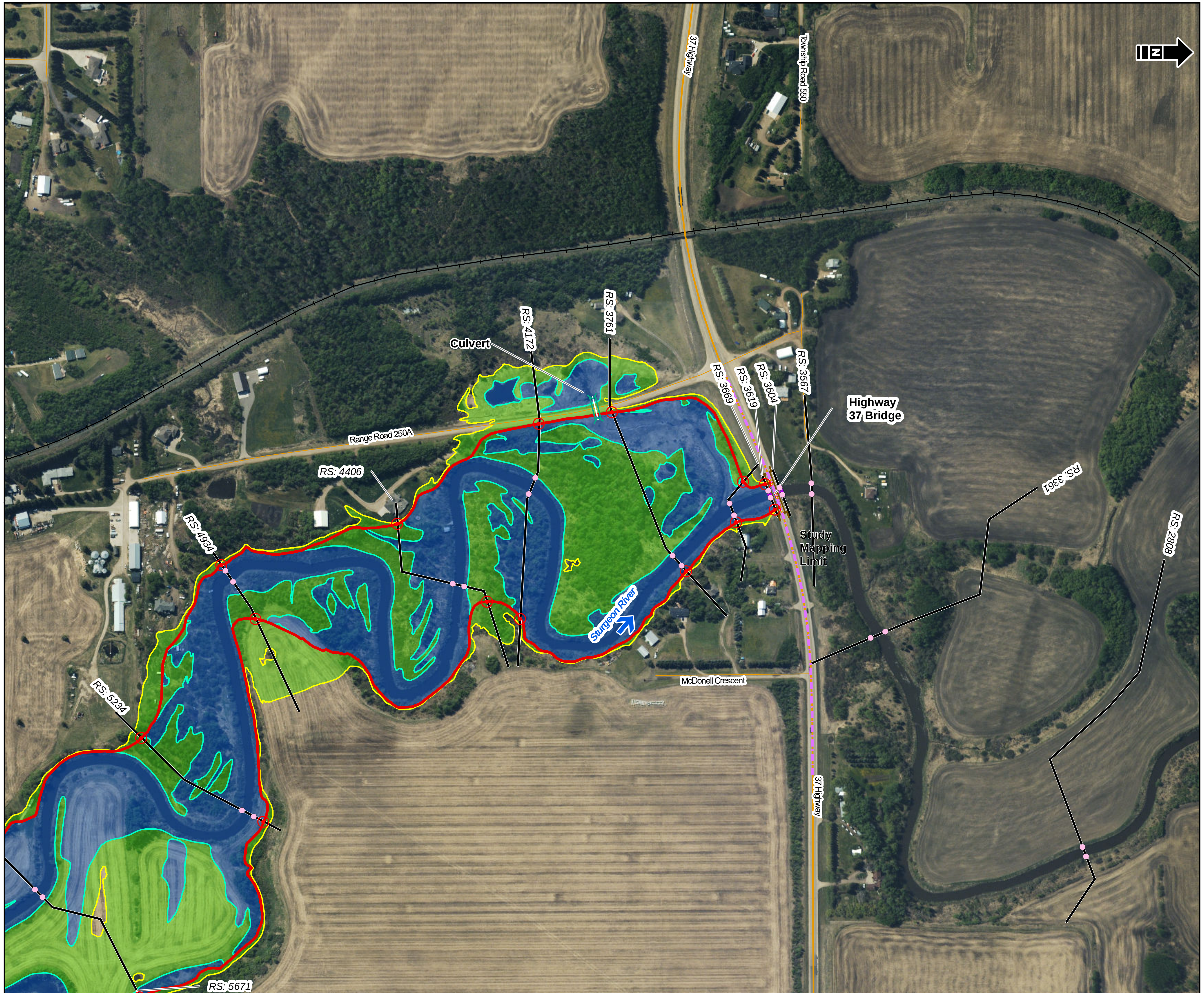
St. Albert Flood Hazard Study

Floodway Criteria Map

Date: May 2022	Project: 28312	Submitter: B. Coates	Reviewer: M. Shome



Bridge
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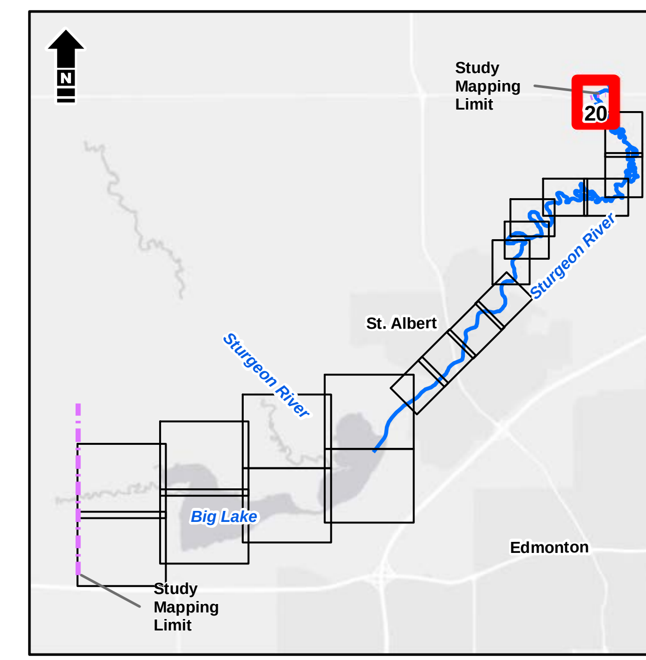

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Floodway Criteria Map

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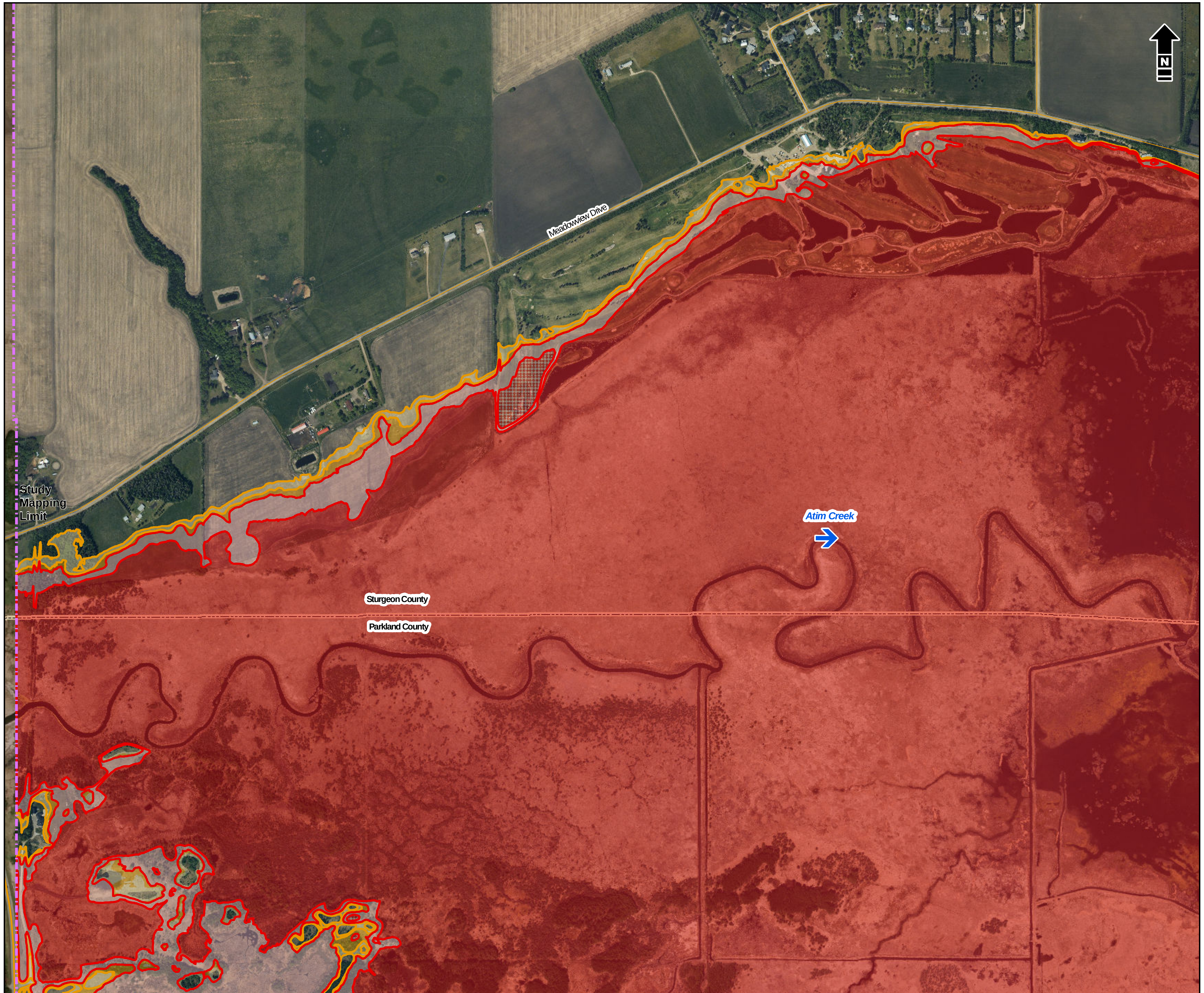
APPENDIX F
Flood Hazard Maps



Bridge
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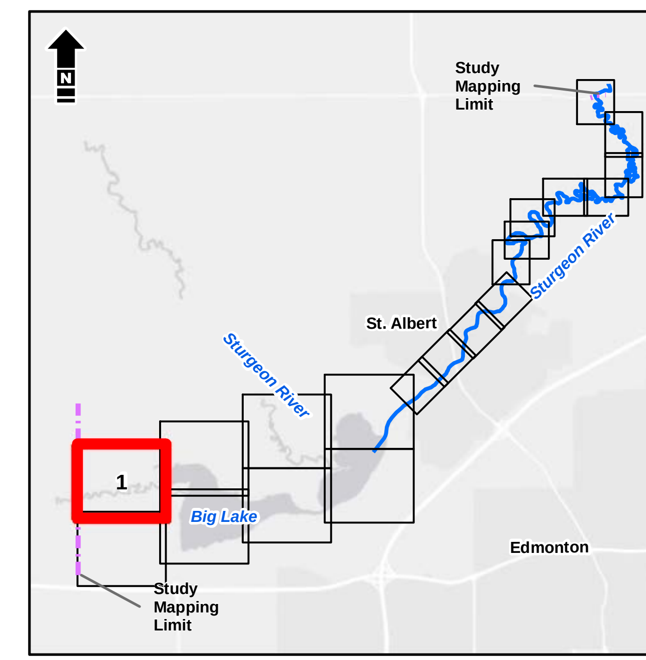
Floodway
Flood Fringe
High Hazard Flood Fringe
Protected Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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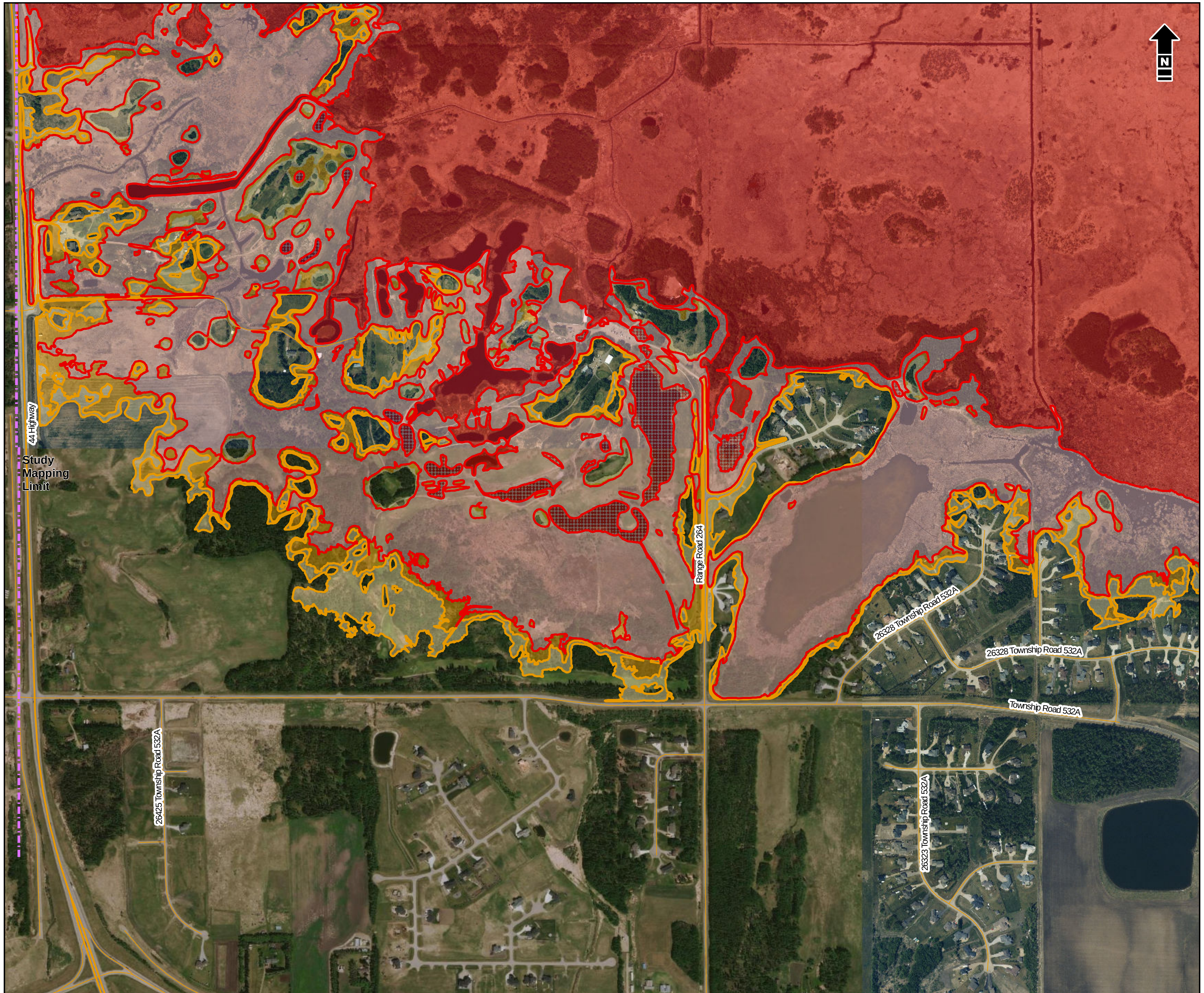

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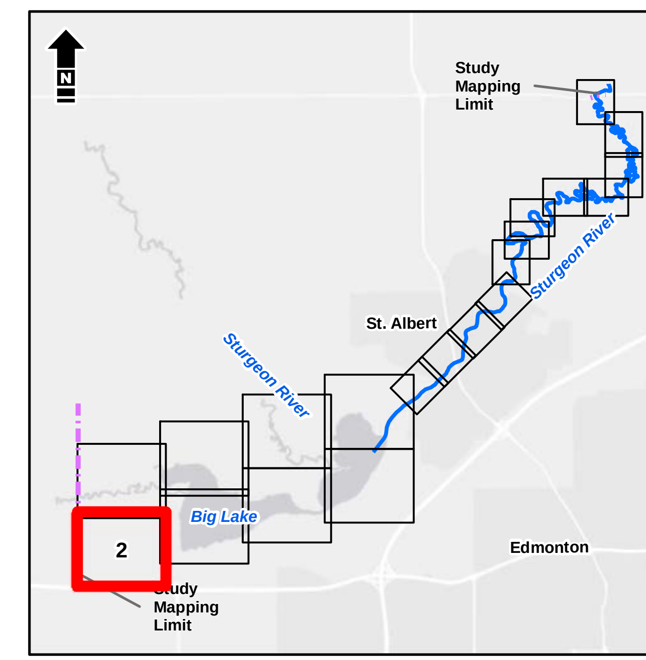

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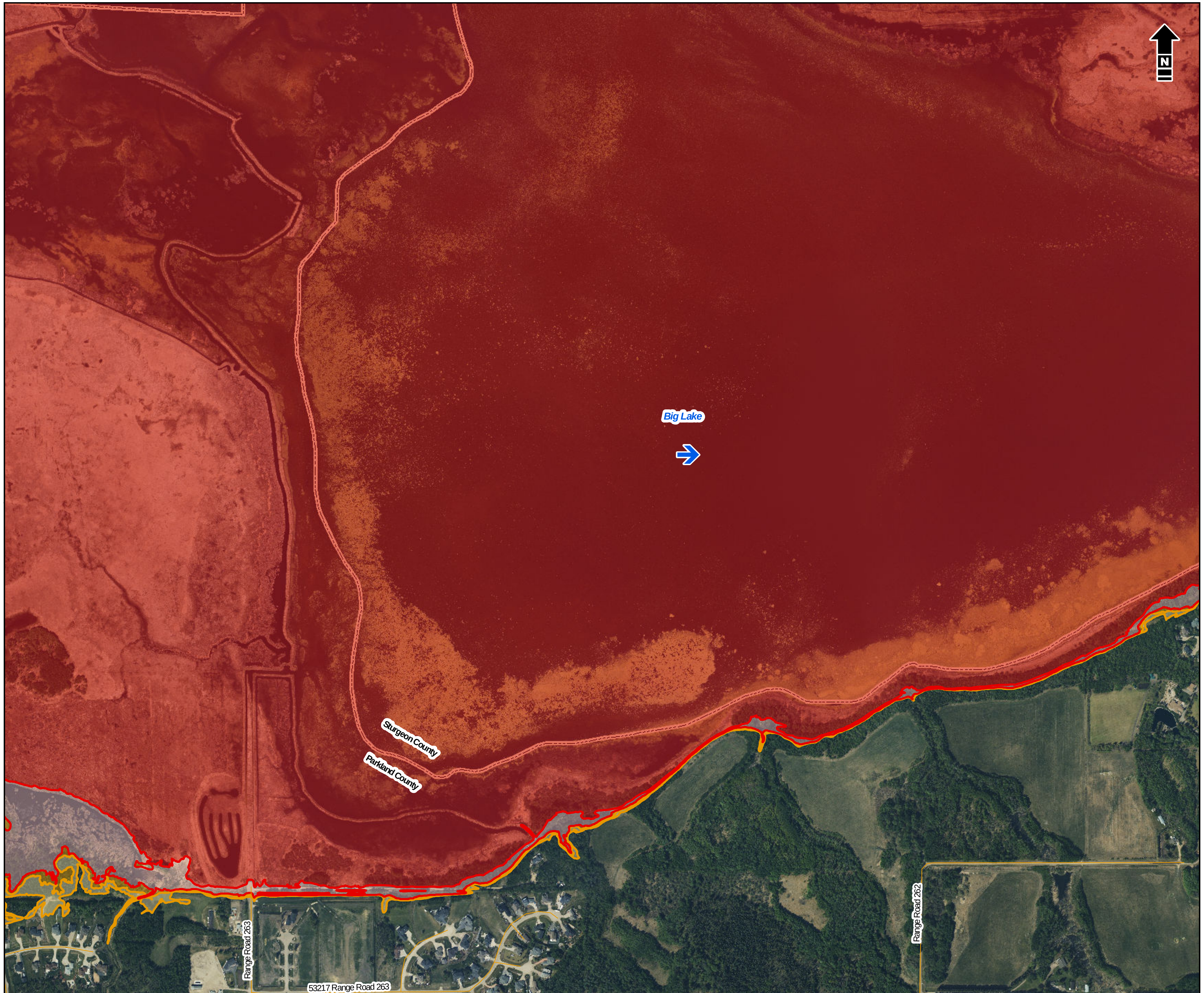

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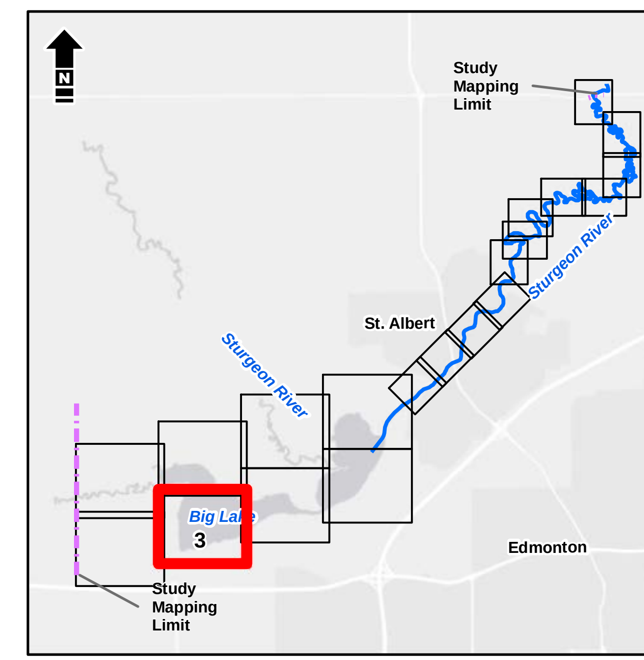

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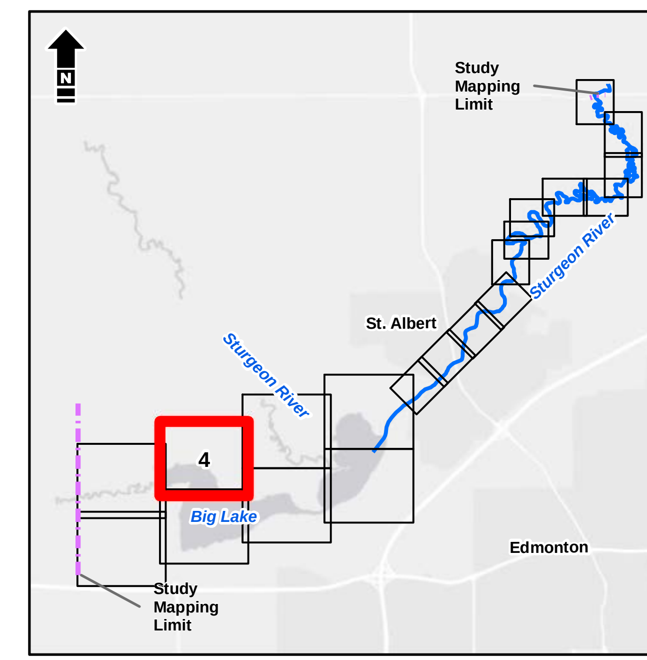

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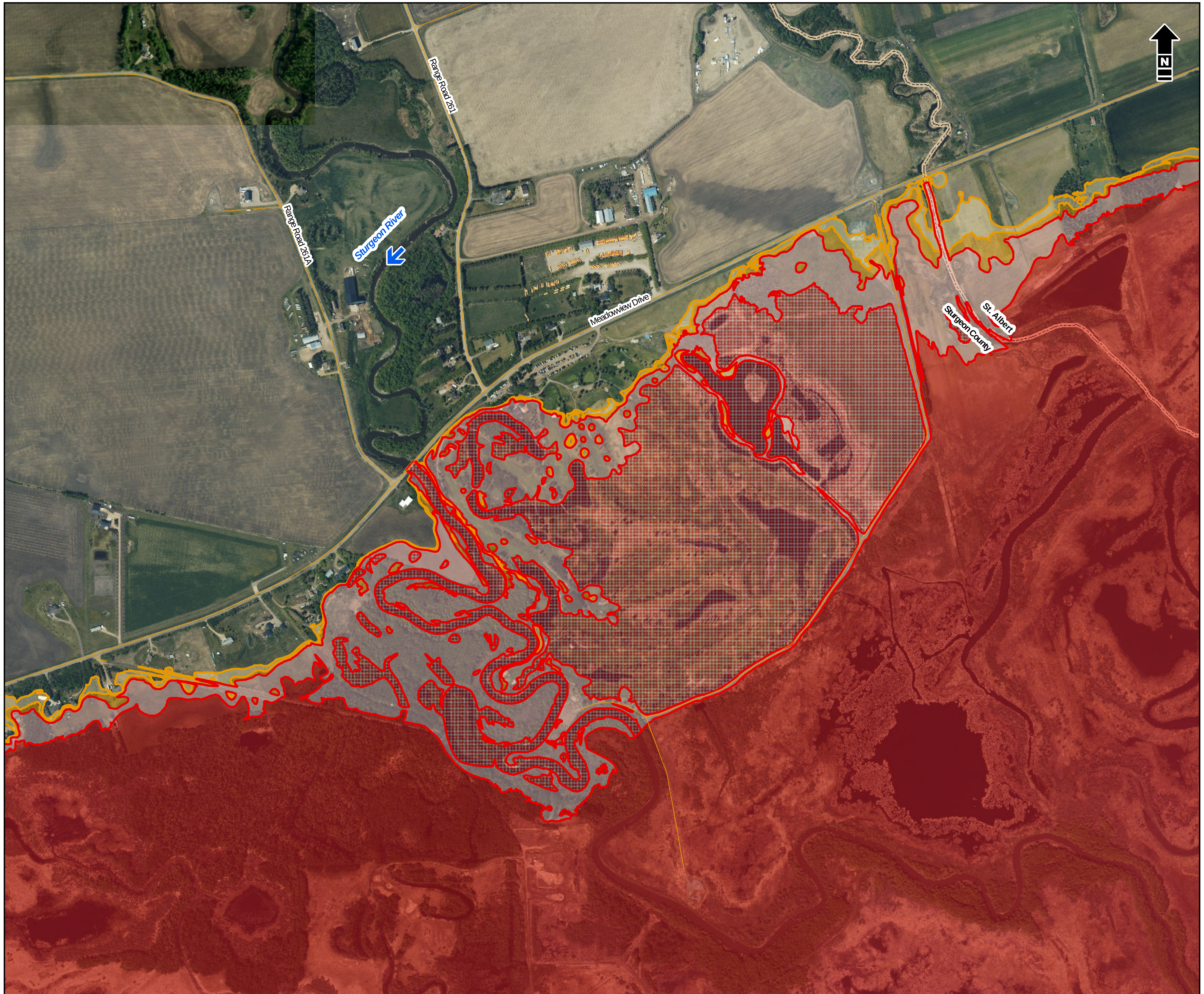

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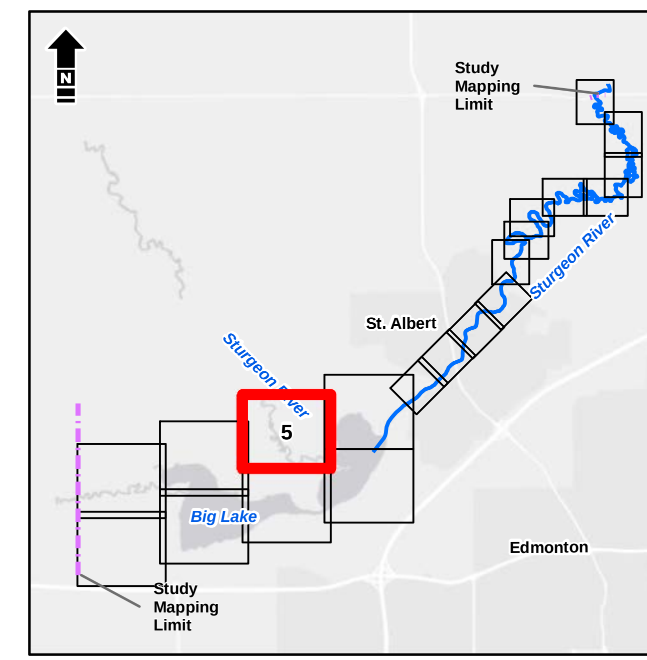

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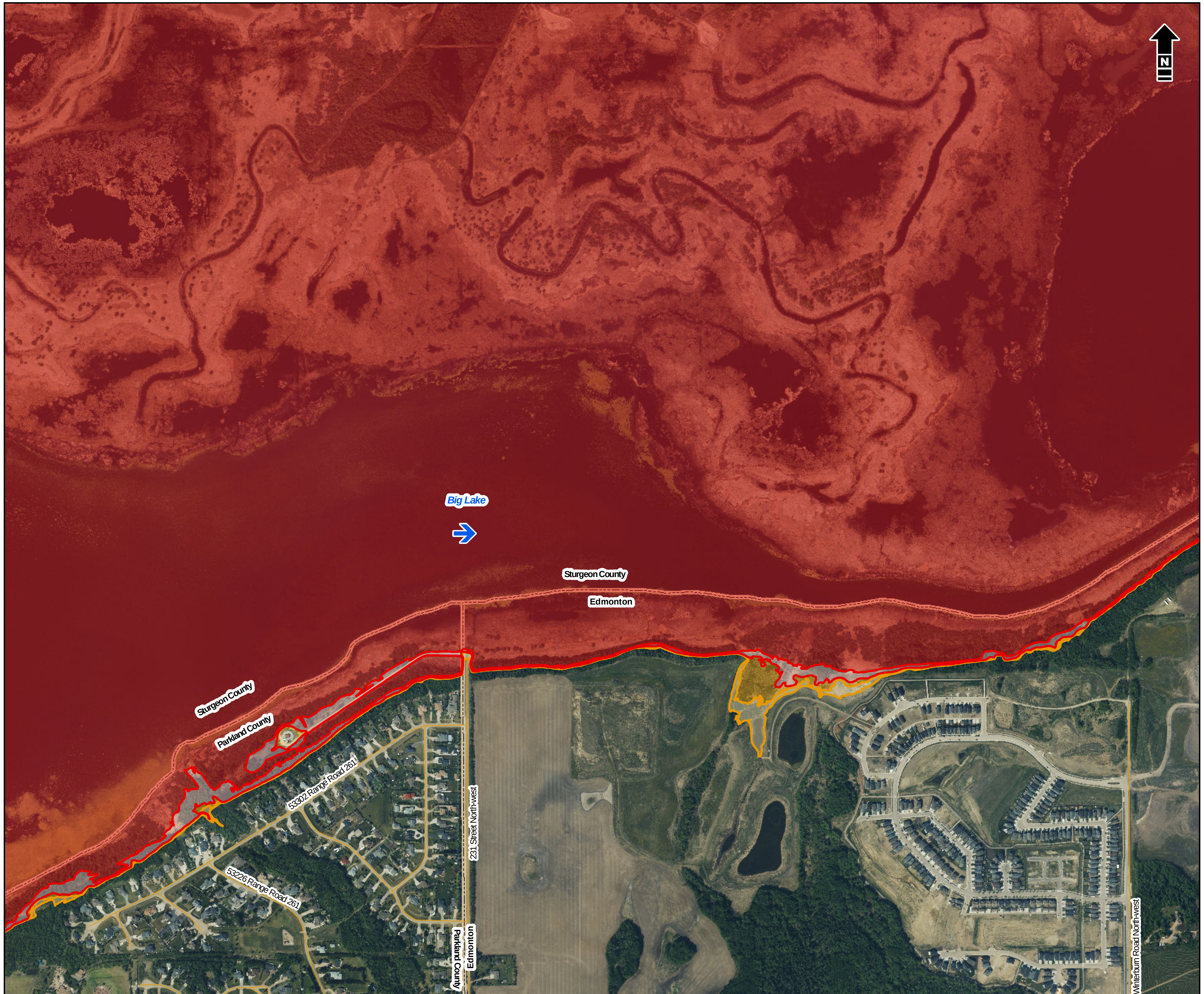

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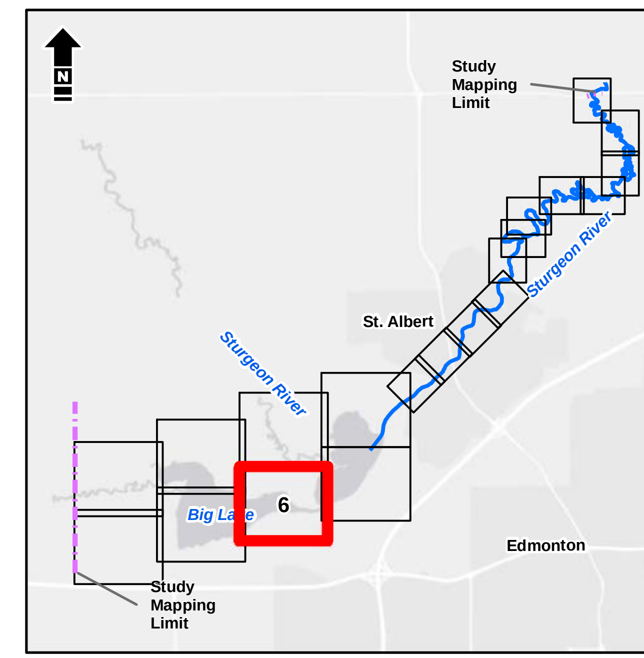

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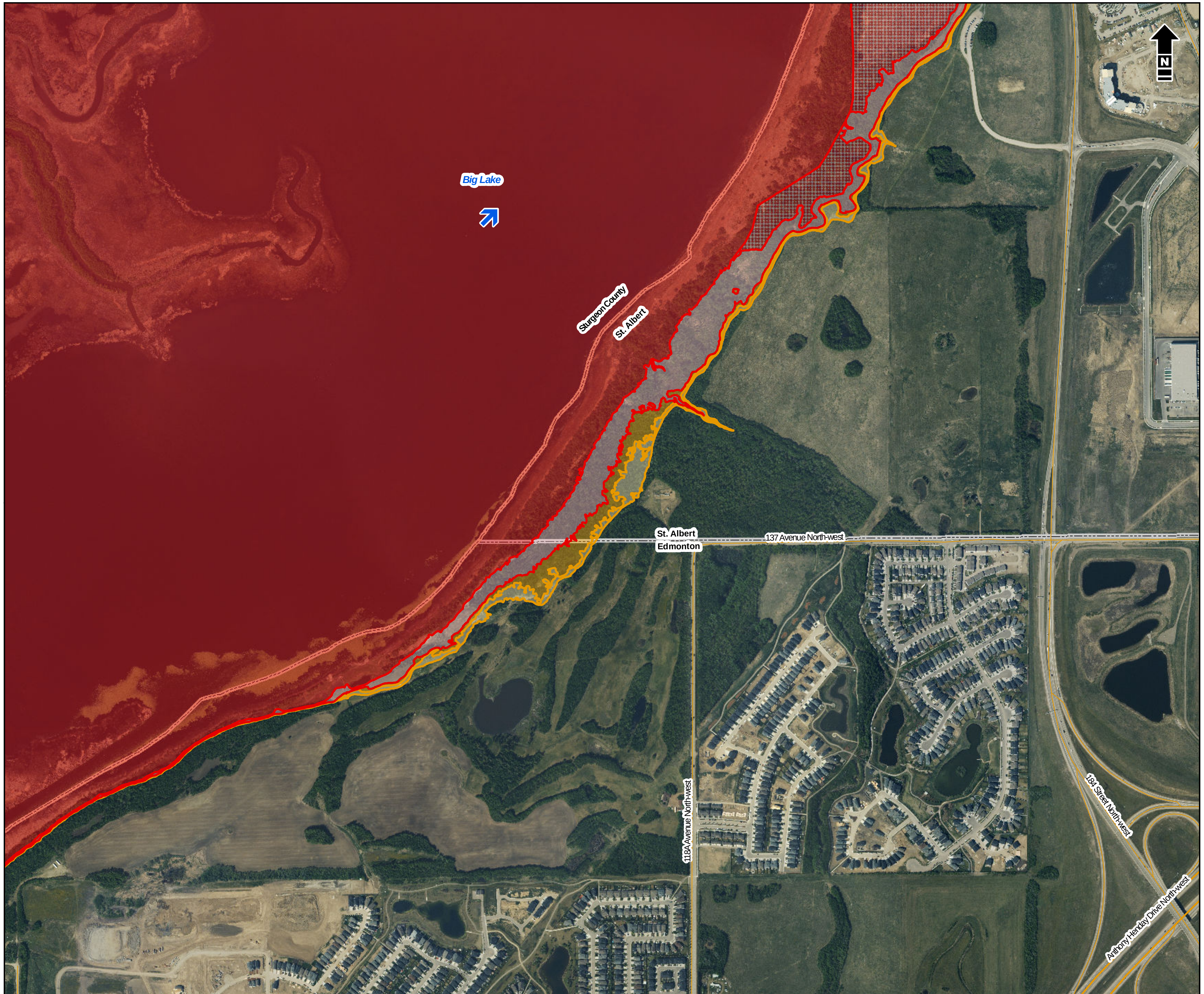

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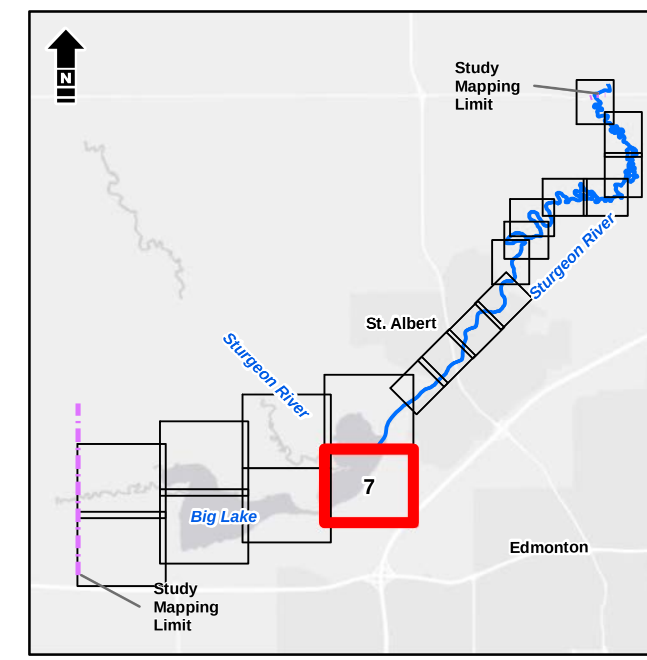

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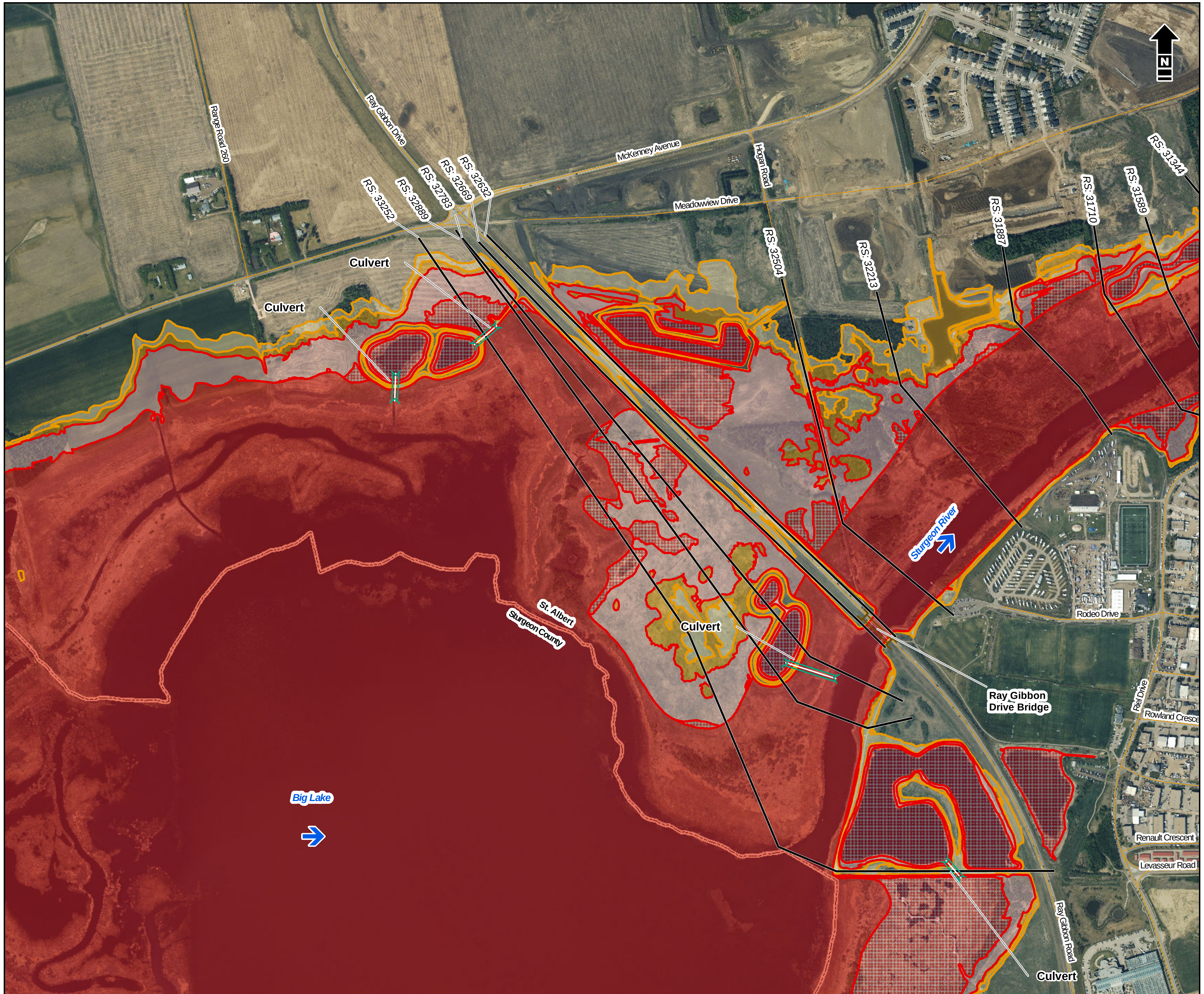

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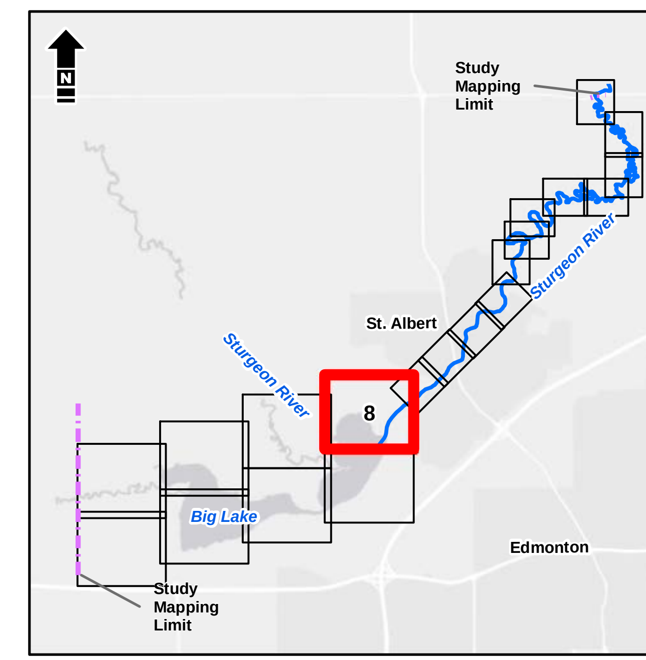

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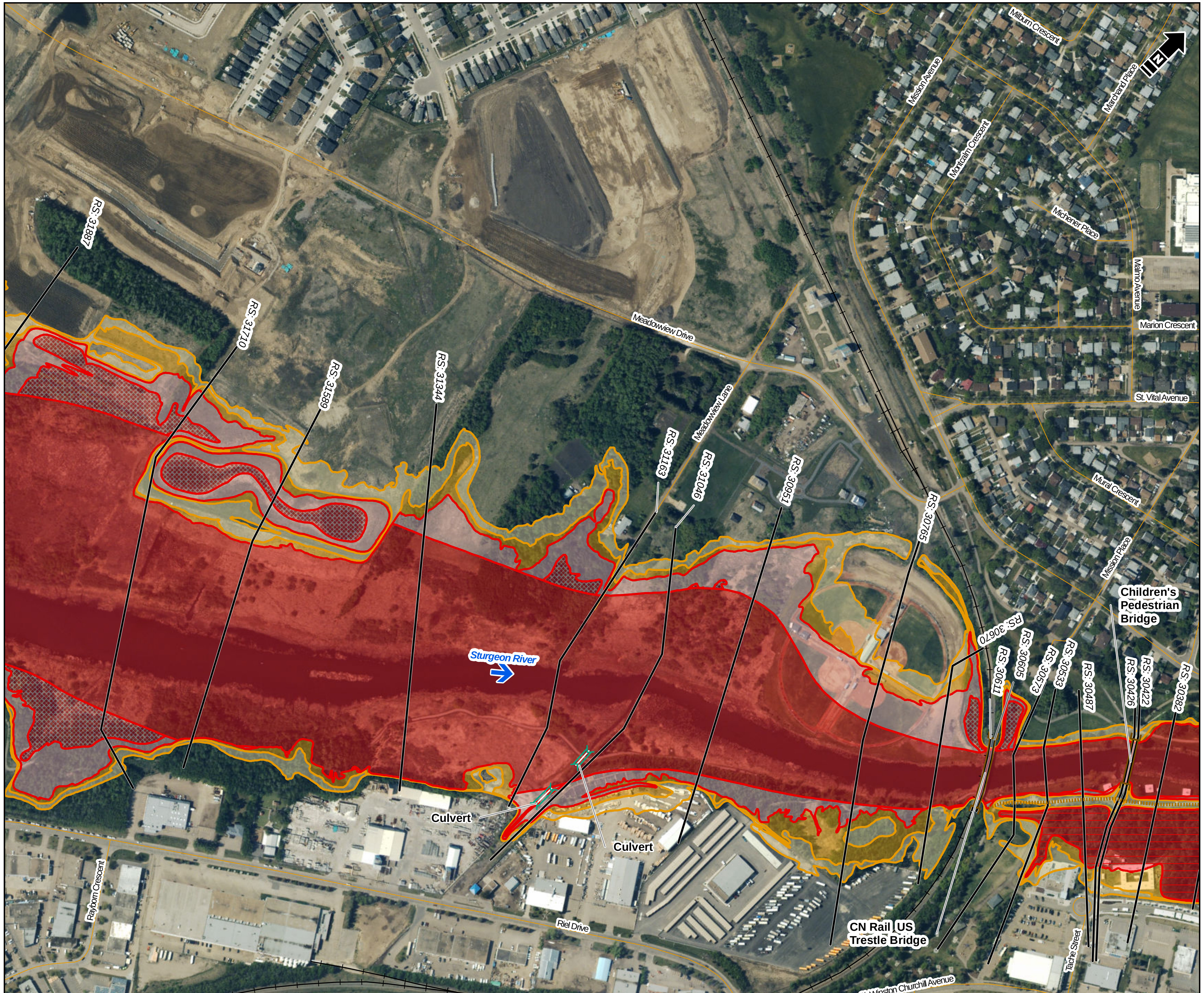

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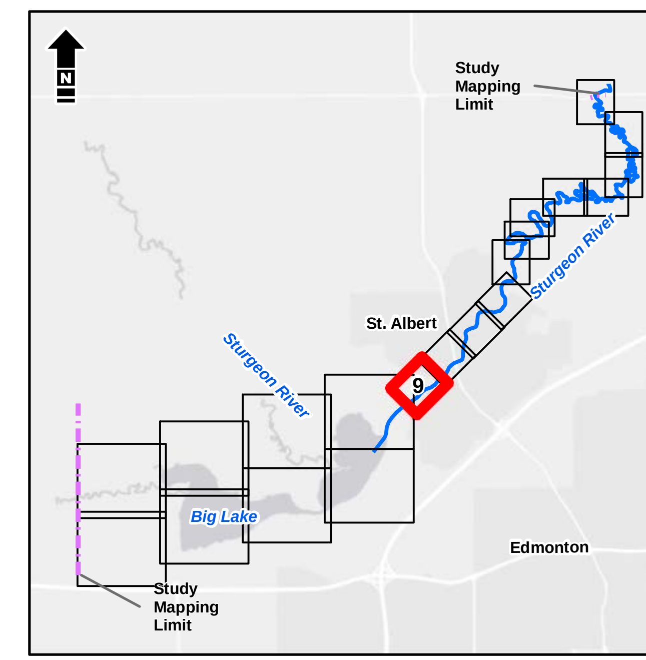

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NAD 1983 CRSS 3TM 114

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Governing Design Flood Hazard Map

Date:	Project:	Submitter:	Reviewer:
May 2022	28312	B. Coates	M. Shome

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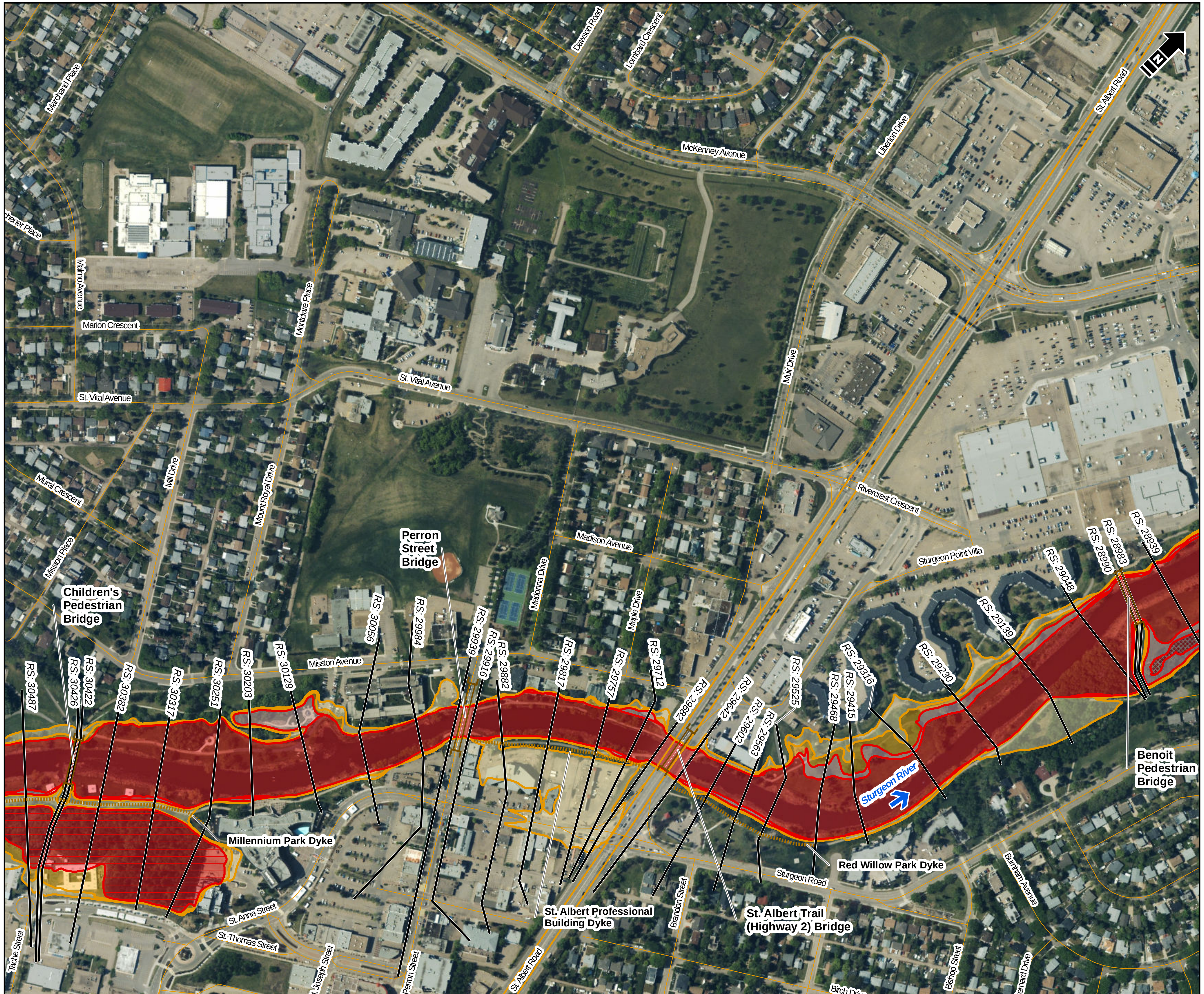

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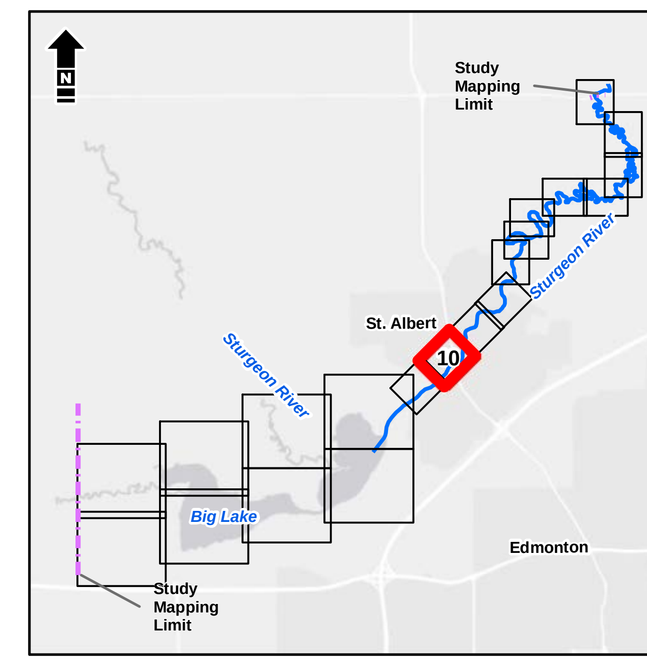

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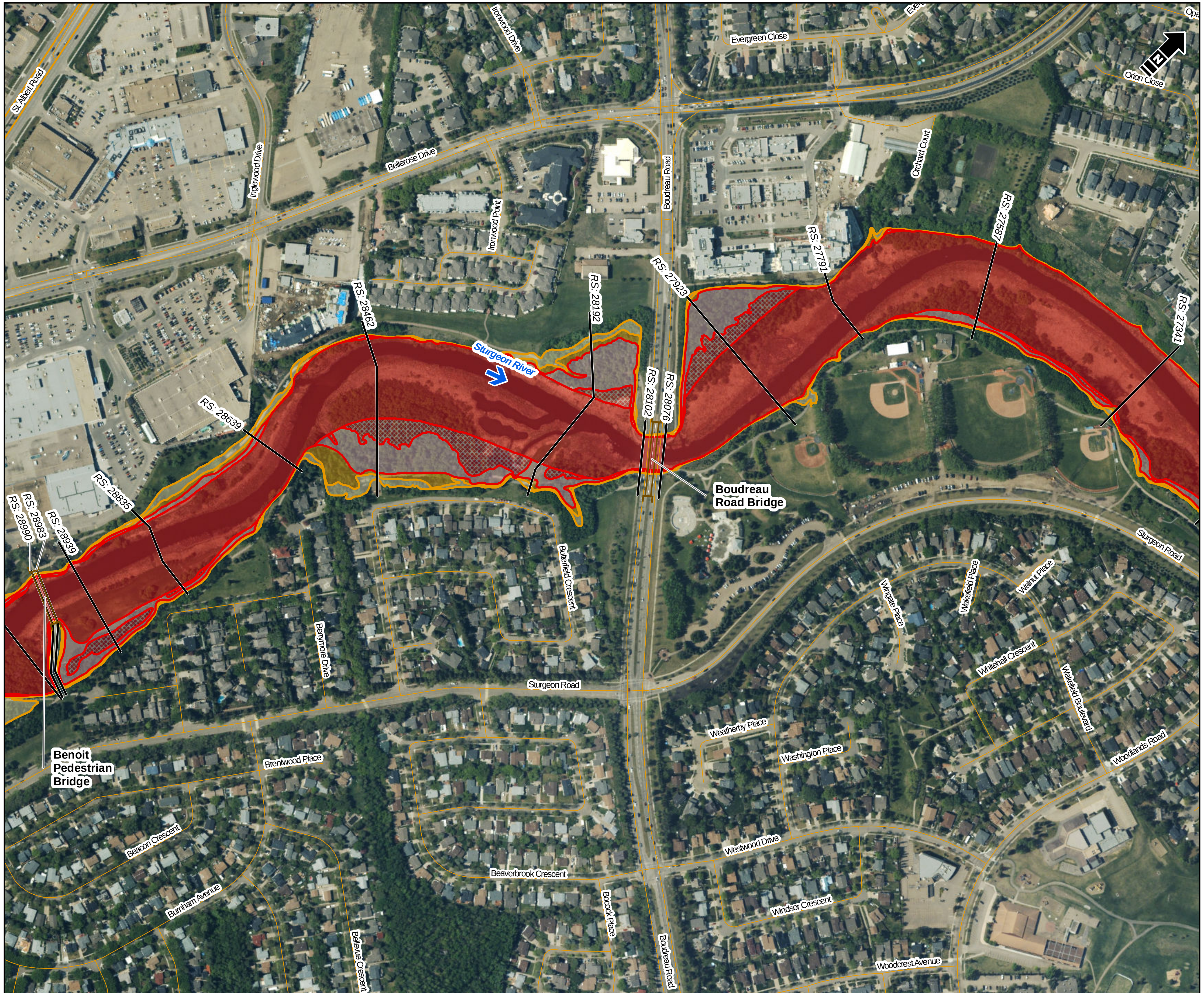

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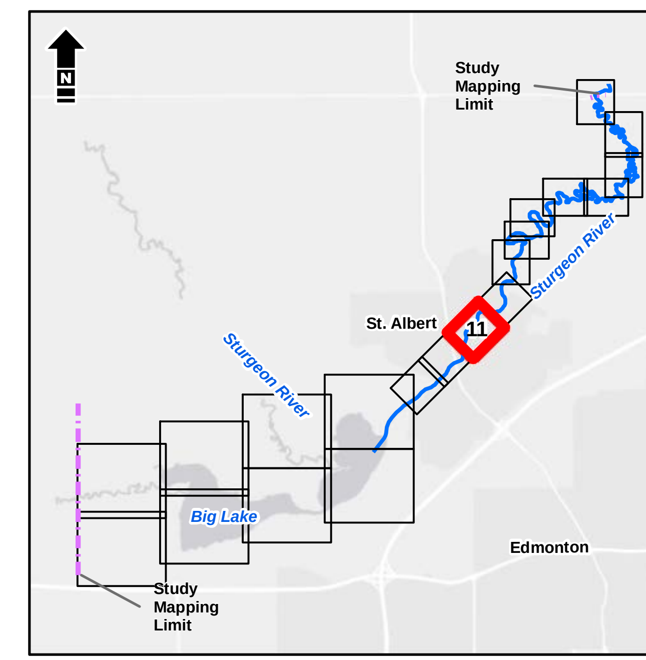

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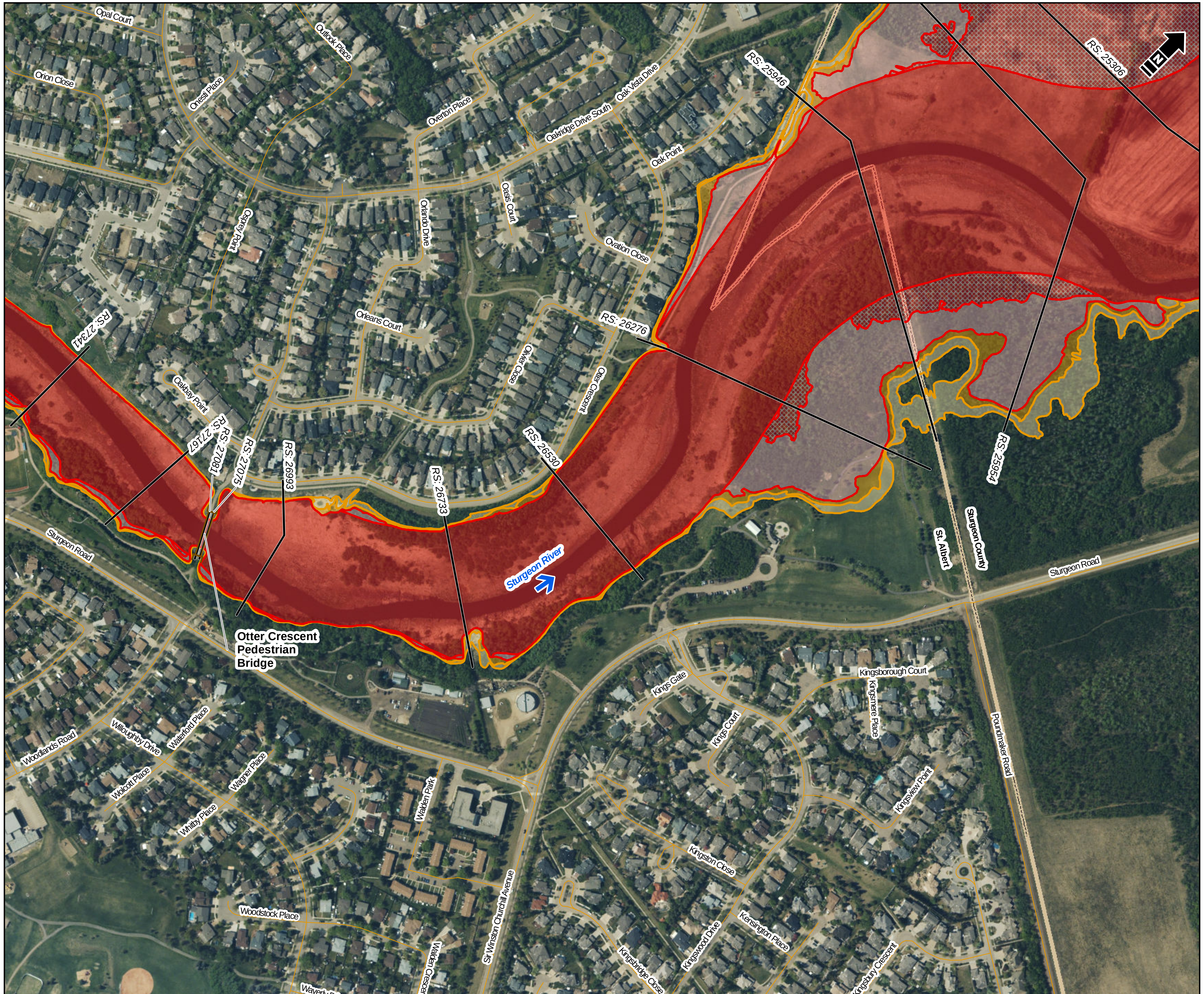

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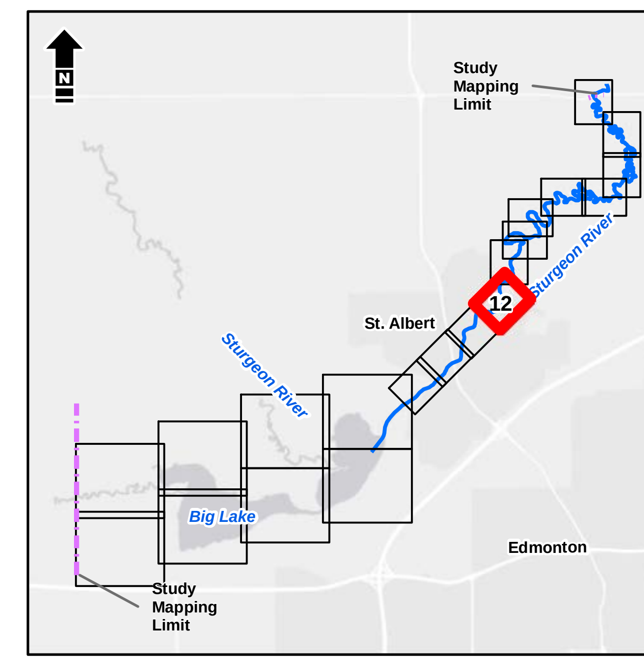

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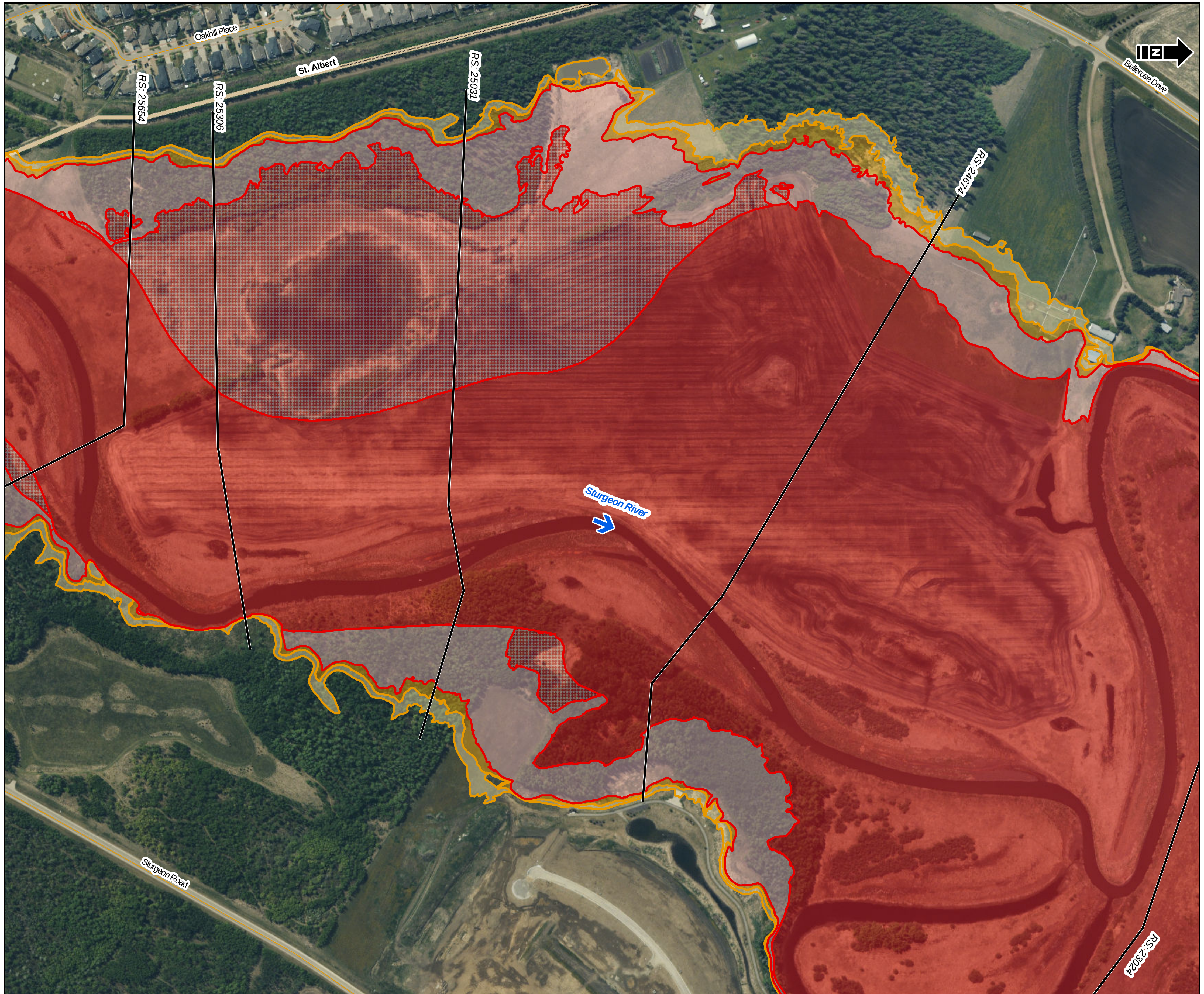

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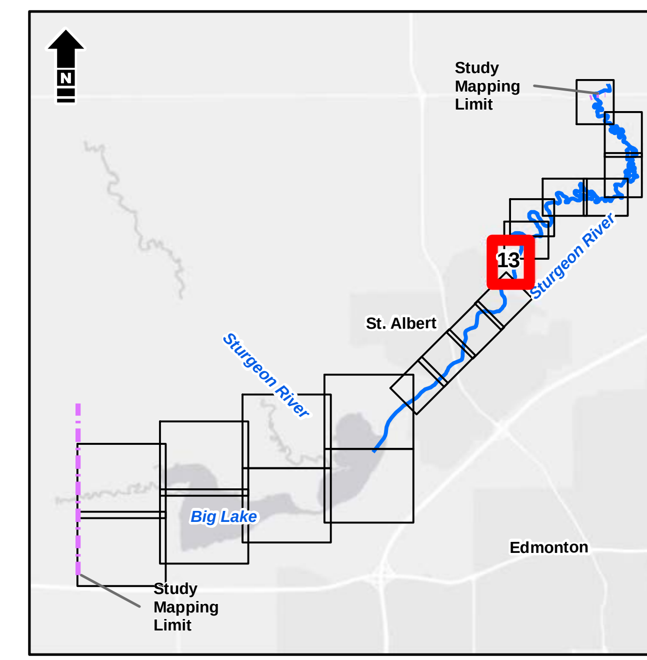

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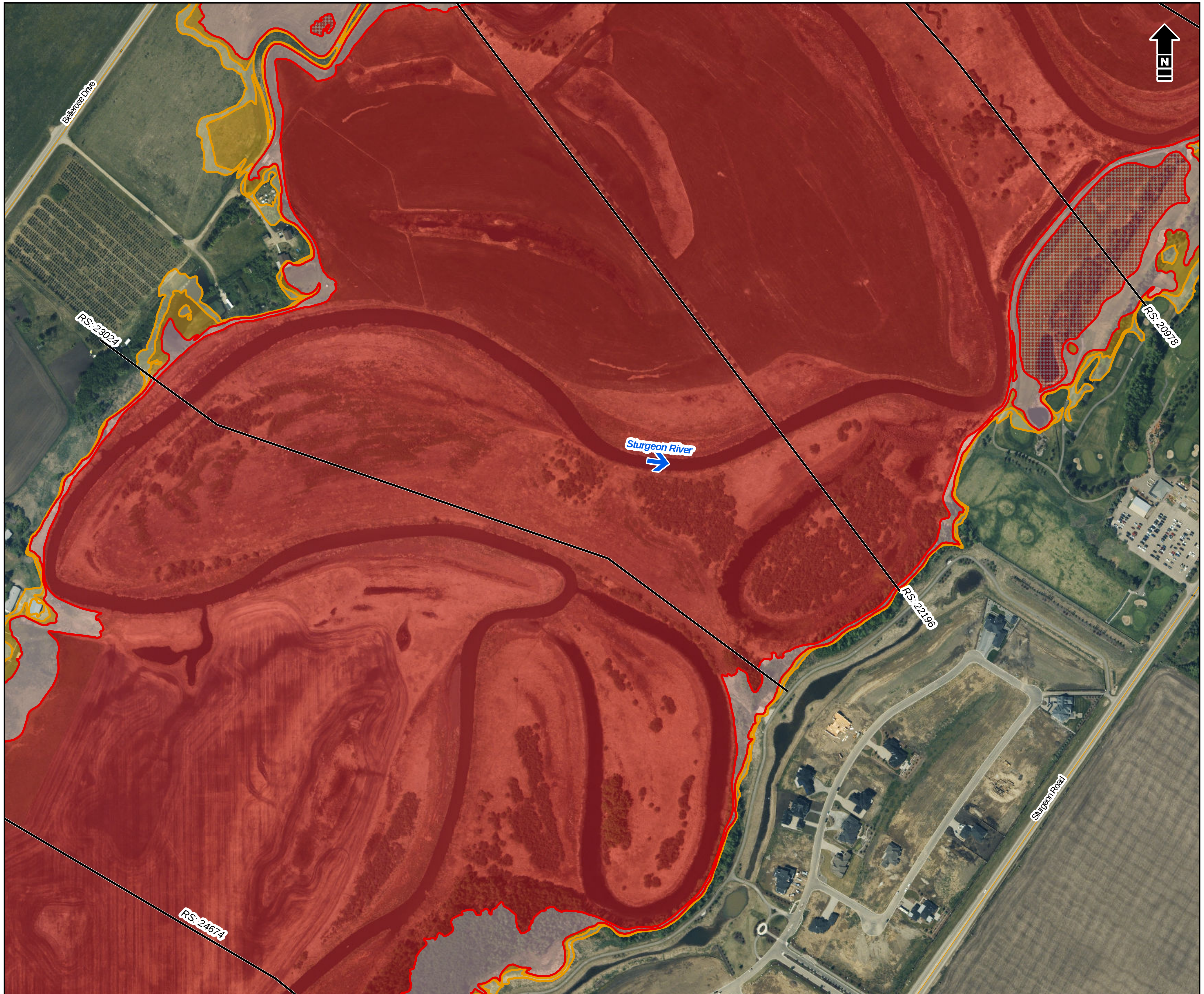
Date: May 2022	Project: 28312	Submitter: B. Coates	Reviewer: M. Shome



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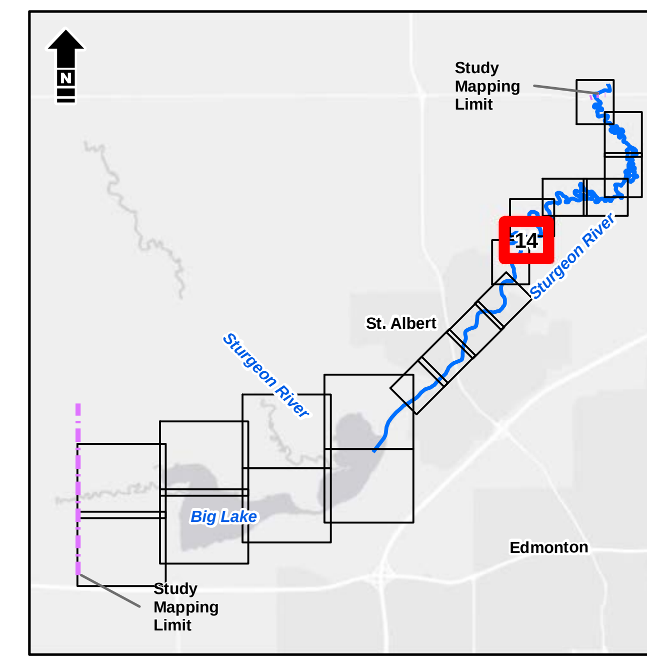

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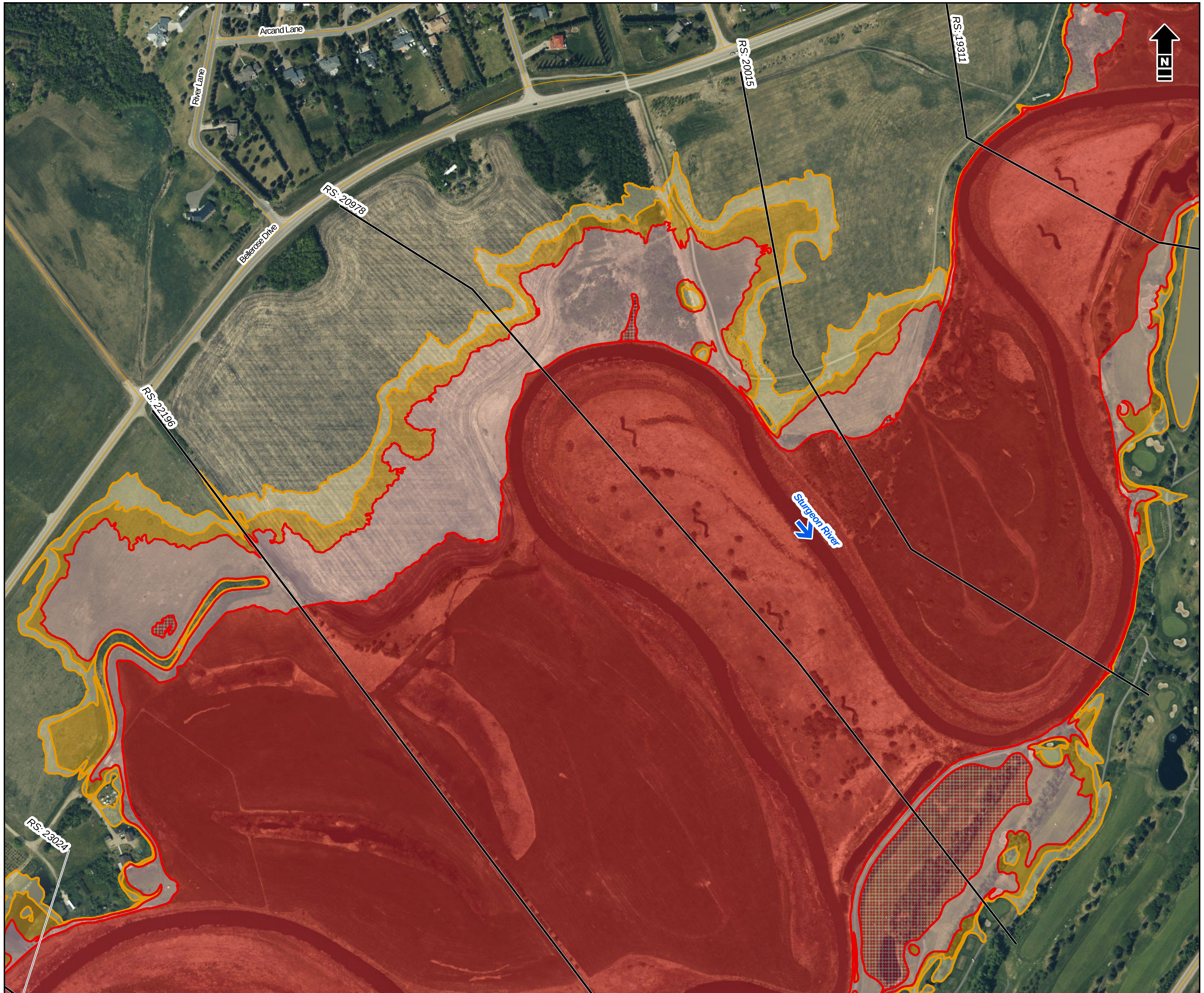
Date: May 2022	Project: 28312	Submitter: B. Coates	Reviewer: M. Shome



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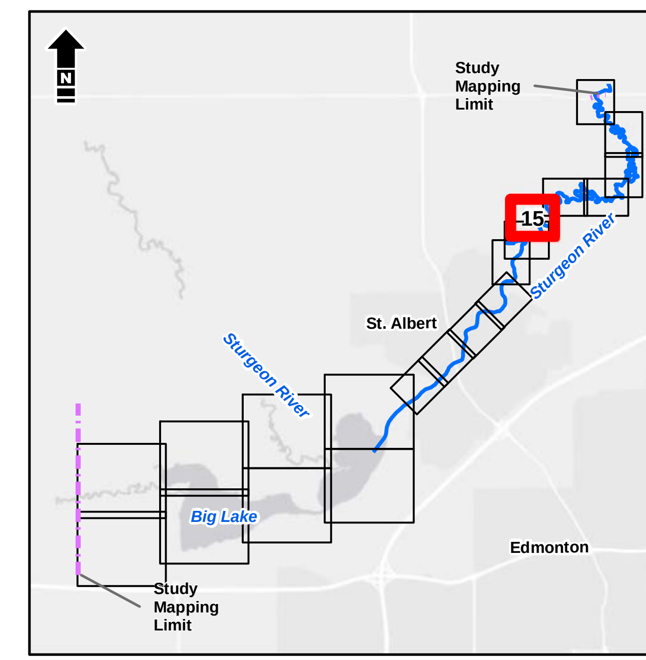

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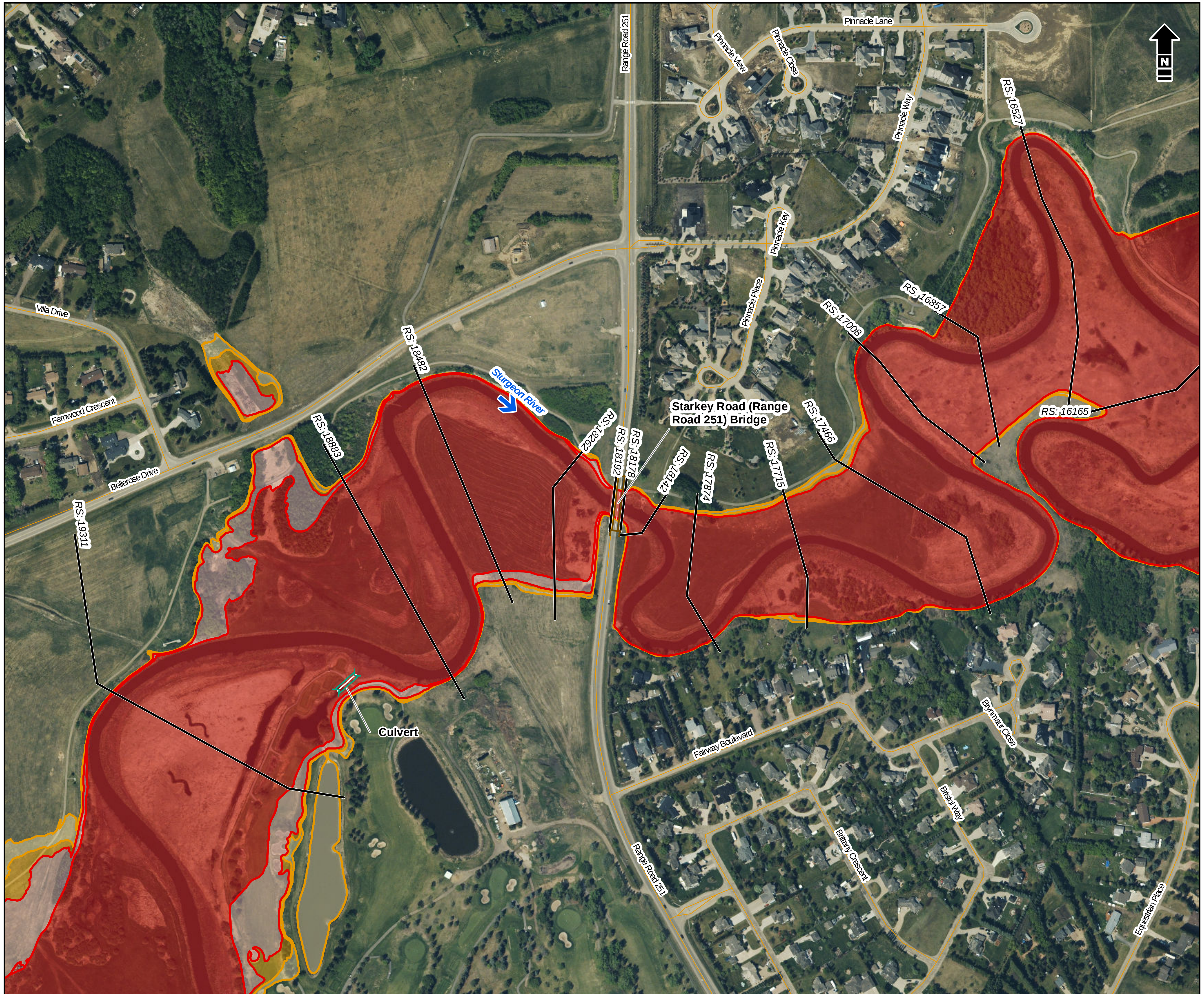

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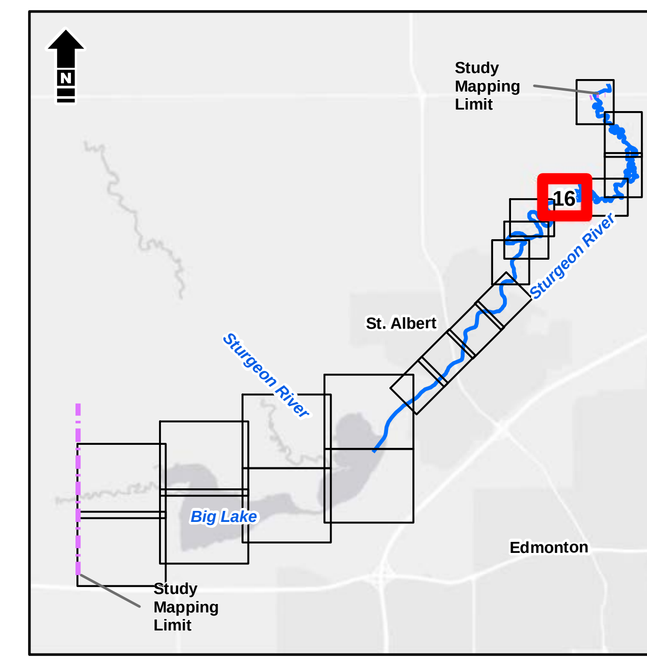

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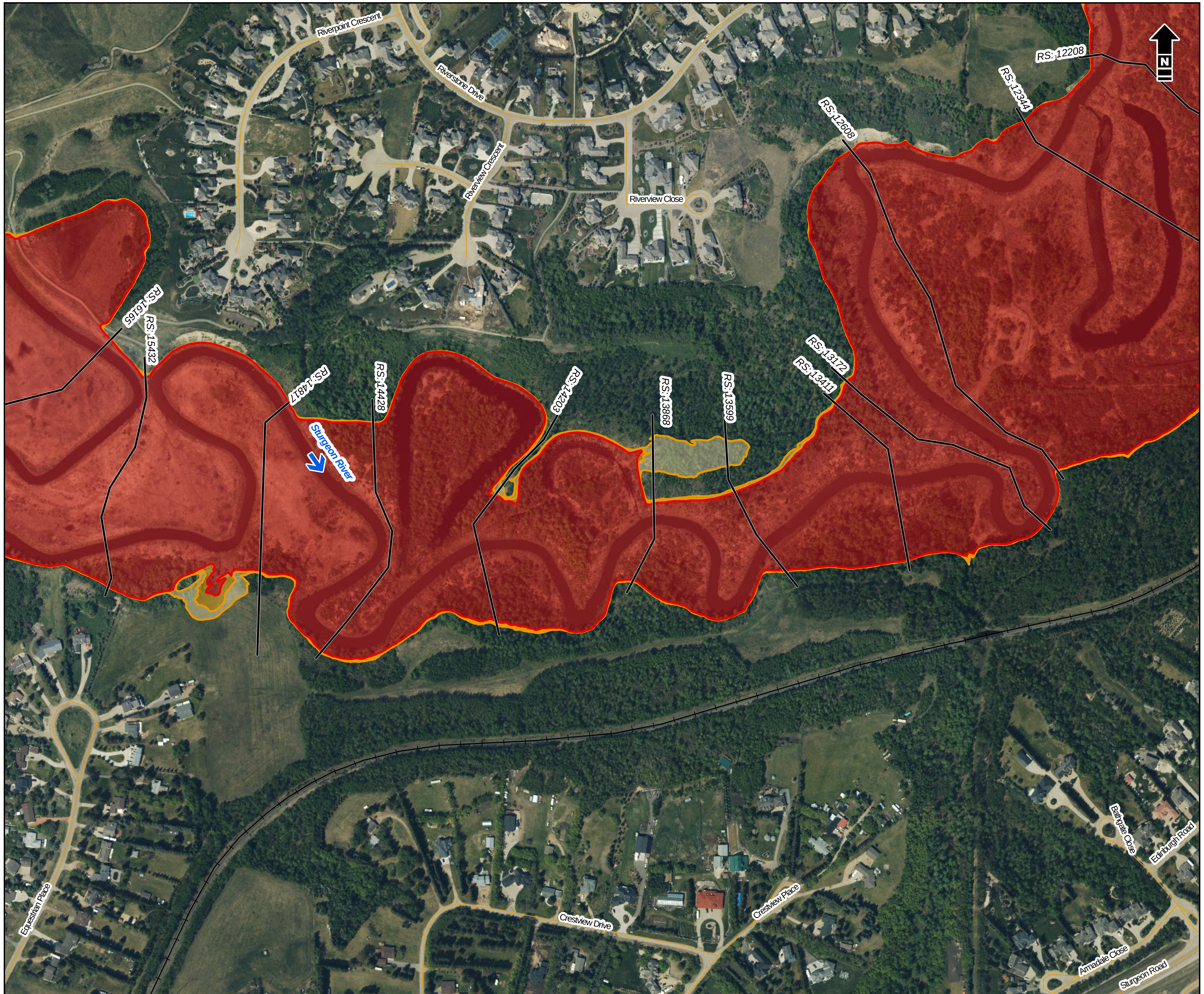

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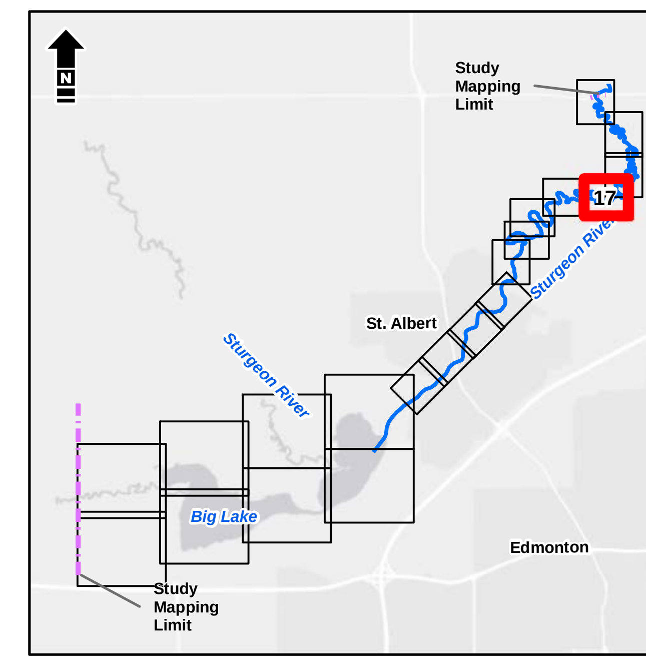

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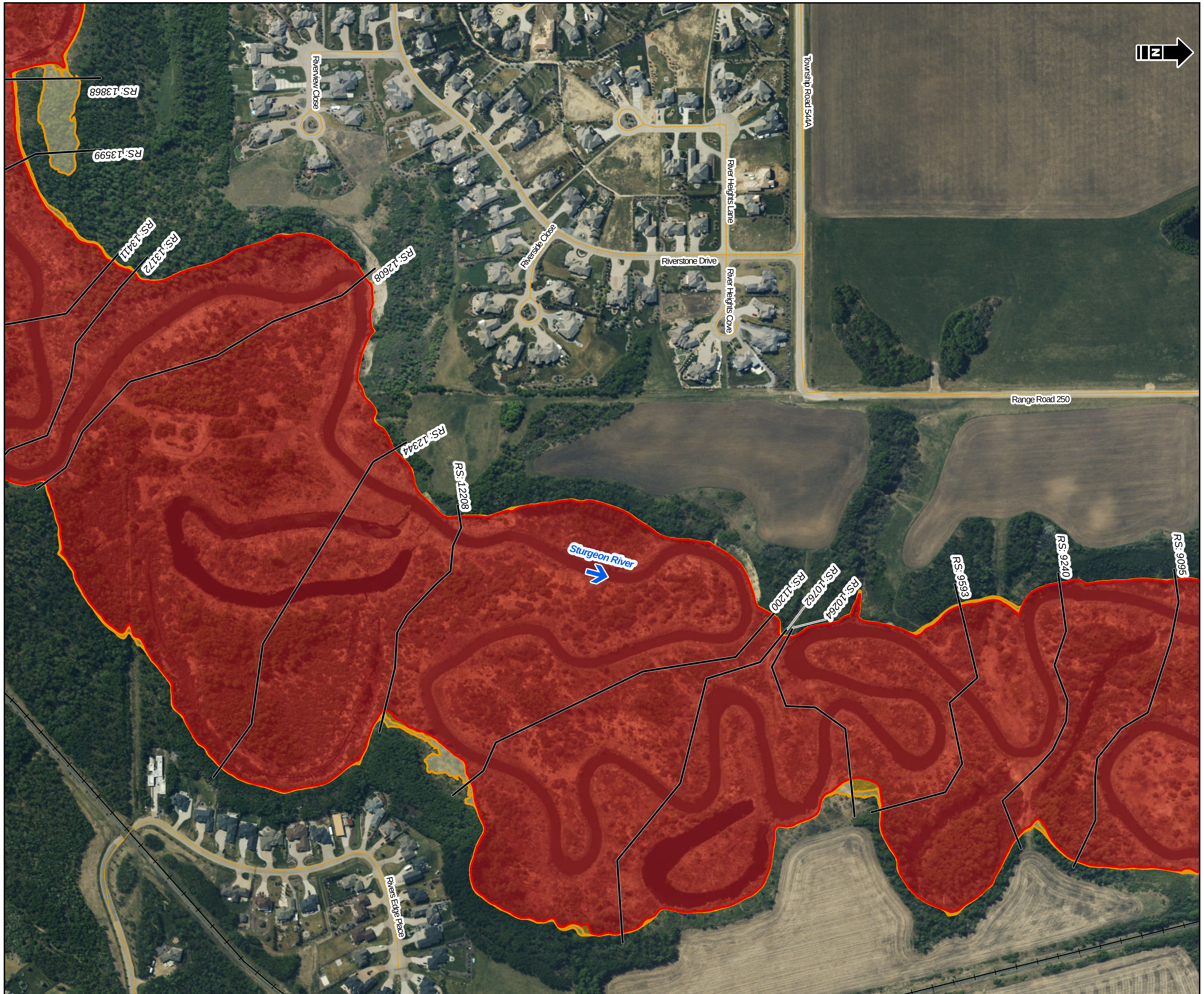

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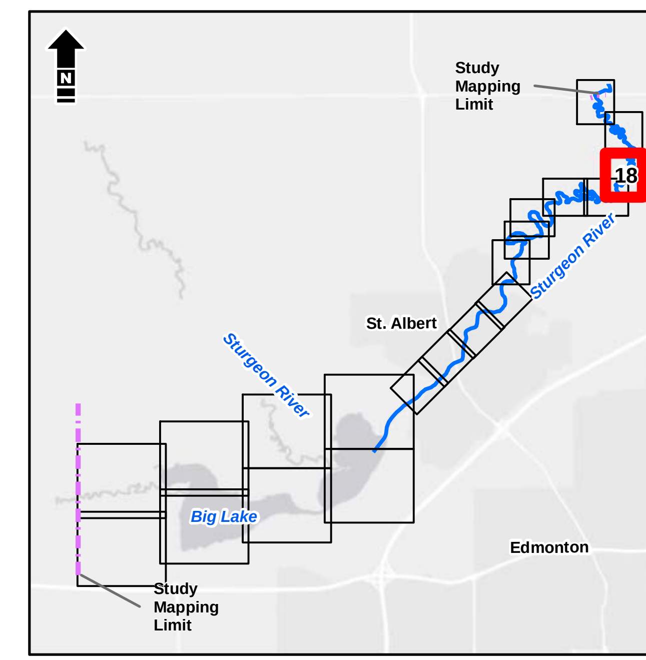

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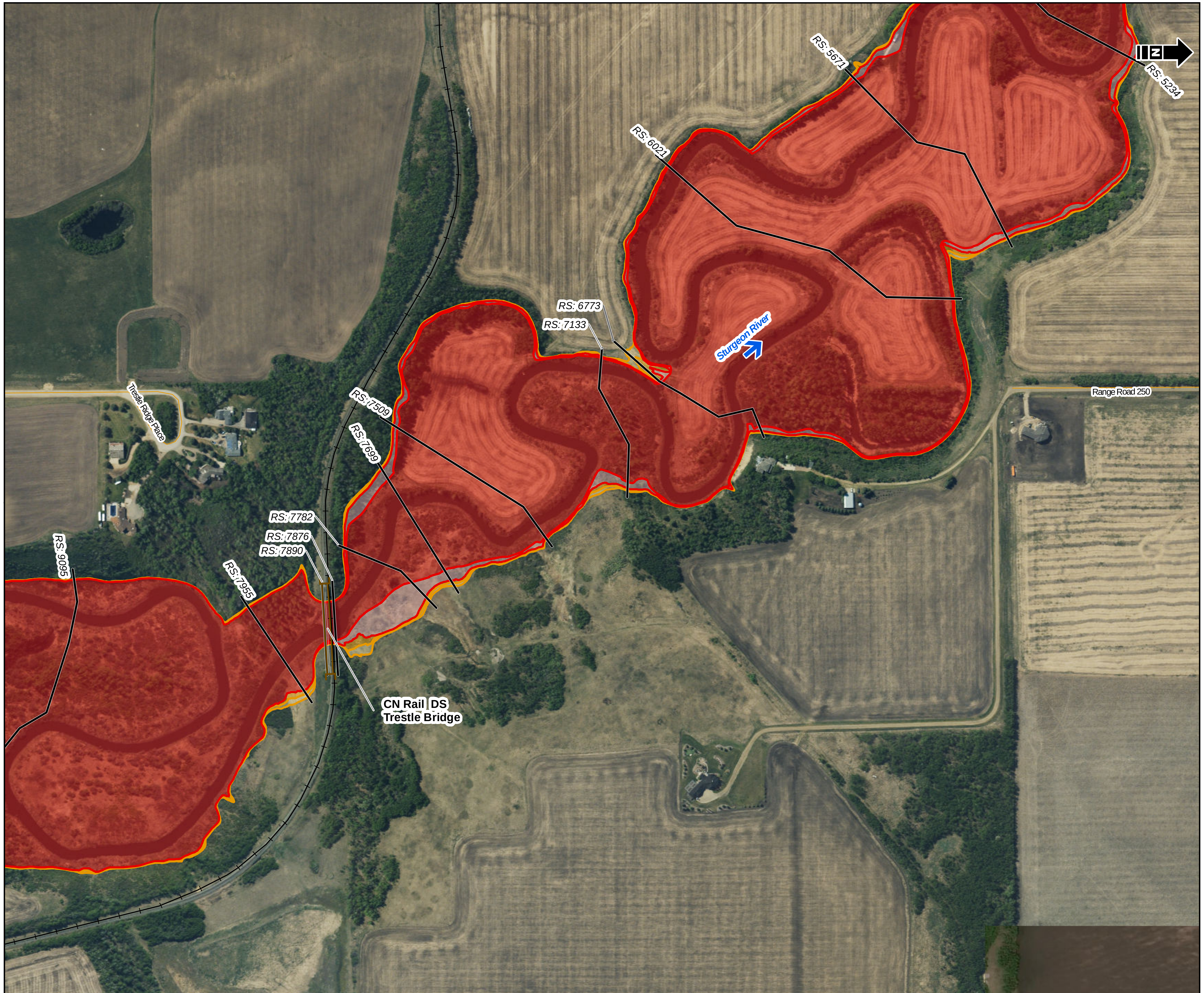

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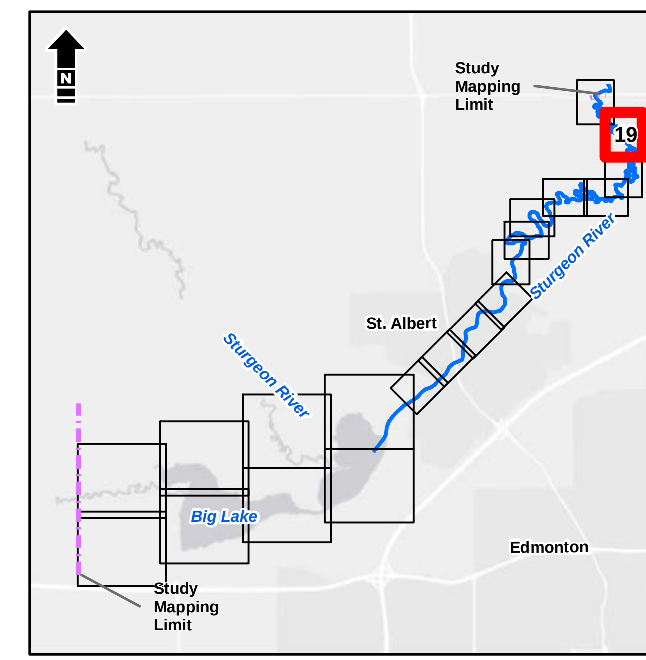

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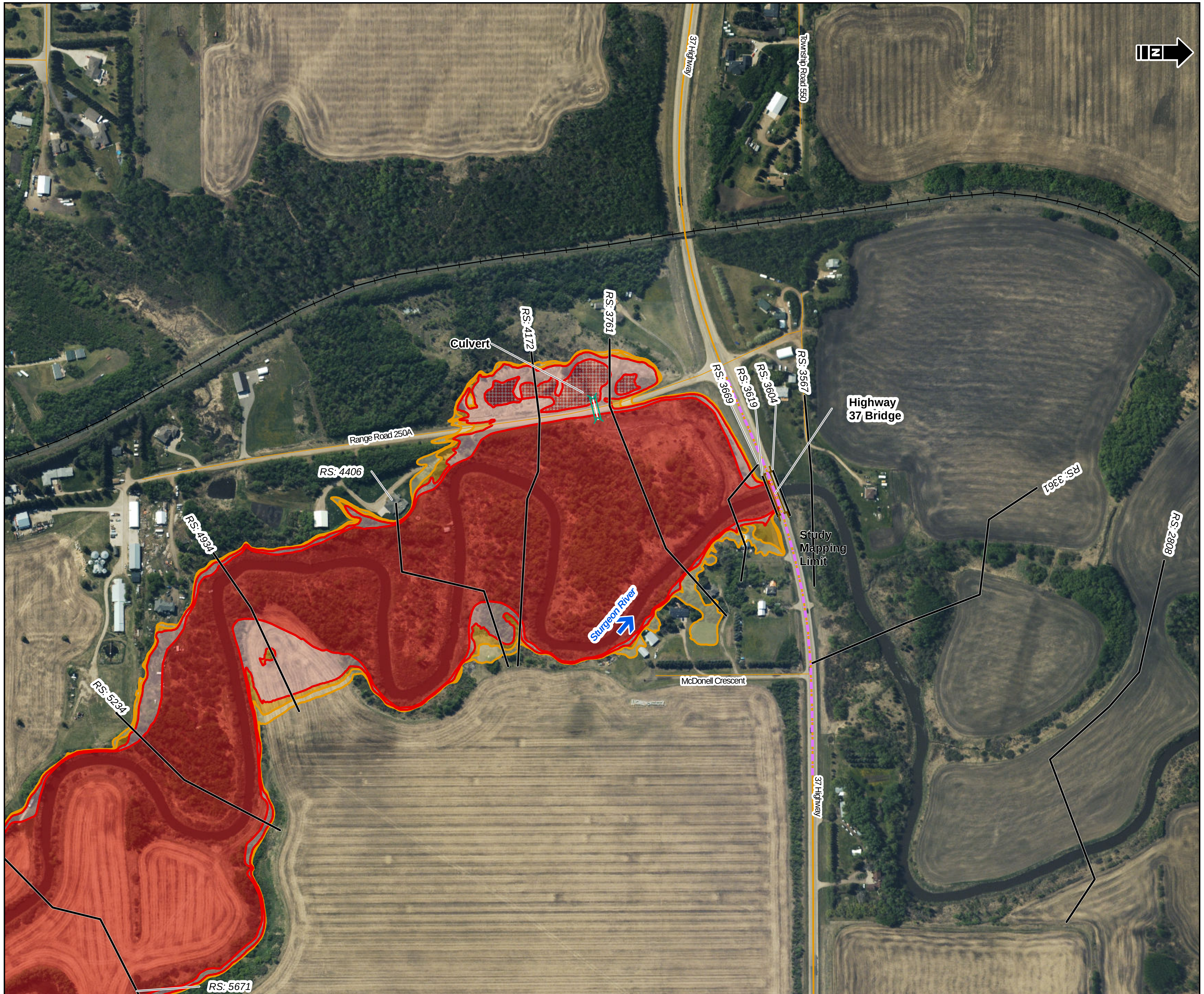

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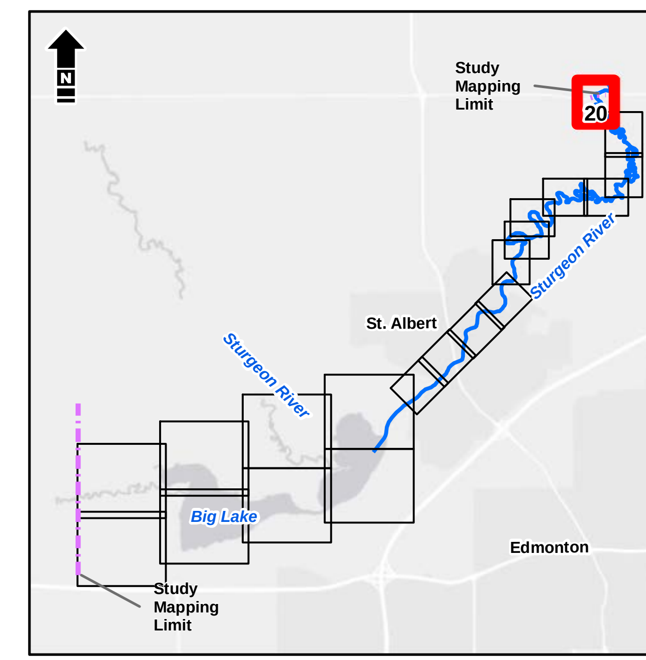

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