AER/AGS Special Report 125

Alberta Energy Regulator

Evaluation of Critical Mineral Potential in Alberta: Regional Till Geochemistry and a Catchment Basin Analysis of Stream Sediment Geochemistry

AGS
ALBERTA GEOLOGICAL SURVEY

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Evaluation of Critical Mineral Potential in Alberta: Regional Till Geochemistry and a Catchment Basin Analysis of Stream Sediment Geochemistry

C. Knox, B. Elder, D. Sacco and R. Adams

Palmer, part of SLR Consulting (Canada) Ltd.

September 2025

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ISBN 978-1-4601-5729-9

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Knox, C., Elder, B., Sacco, D. and Adams, R. (2025): Evaluation of critical mineral potential in Alberta: regional till geochemistry and a catchment basin analysis of stream sediment geochemistry; Alberta Energy Regulator / Alberta Geological Survey, AER/AGS Special Report 125, 98 p.

Publications in this series have undergone only limited review and are released essentially as submitted by the author.

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Published September 2025 by:
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Appendices

Digital Appendix A – Till and stream sediment analytical results
The appendix consists of two zip files (A1_Till_Data.zip and A2_Stream_Sediment_Data.zip), located in the download zip file.
Digital Appendix B – Till and stream sediment analytical certificates
The appendix consists of three zip files (B1_Till_Geochemistry_Lab_Certificates.zip, B2_Till_Grain_Size Analysis_Lab_Reports.zip, and B3_Stream_Sed_Geochemistry_Lab_Certificates.zip), located in the download zip file.

Foreword

The Alberta Geological Survey (AGS) outsourced a till and stream sediment sampling program in southwestern, northwestern, and north-central Alberta to provide a better understanding of the province's critical mineral potential. This project delivers information useful in the exploration of critical mineral potential in Alberta through geochemical and grain-size analyses in areas where data gaps exist. All planning, logistics, fieldwork execution, sample collection, submission of samples for geochemical and textural analysis, data compilation, and reporting was completed by Palmer (now SLR Consulting (Canada) Ltd.), with oversight and approval by the Alberta Energy Regulator (AER) and the AGS.

The results of the first phase of the project were reported in AER/AGS Special Report 115. The second phase of the project builds on that work and the new details are provided herein. The report includes a description of the methods used and results from a multiphase drill-supported till sampling survey designed to extend sampling coverage in northwestern Alberta where standard surface till sampling efforts were impeded by the glaciolacustrine material that overlies the till. A total of 32 new till samples were collected in this area to improve data coverage. This report outlines preliminary data treatment, regional till geochemistry, and a catchment basin analysis of stream sediment geochemistry for the evaluation of critical mineral potential in Alberta. The new till sample descriptions and geochemical analysis results are appended to the original results from AER/AGS Special Report 115 and included with this publication.

This work was completed under the Mineral Grant provided by the Government of Alberta dated June 22, 2021.

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Evaluation of Critical Mineral Potential in Alberta: Regional Till Geochemistry and a Catchment Basin Analysis of Stream Sediment Geochemistry

Project #
2207802

Prepared For
Alberta Energy Regulator

December 19, 2024

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1. Introduction

The Government of Alberta has outlined a Minerals Strategy and Action Plan with a critical objective to increase the availability of public geoscience information (Alberta Energy, 2021). This information equips exploration companies, property owners, and Indigenous Peoples with the knowledge necessary to make informed decisions about Alberta's resources. As the provincial geoscience experts, the Alberta Geological Survey (AGS), a branch of the Alberta Energy Regulator (AER) has initiated a Mineral Mapping Program, funded by the Alberta Minerals Grant (Alberta Energy, 2021). As part of this program, AER and AGS recognize that high-quality and comparable regional-scale geochemical and mineralogical data form an important foundation for successful mineral exploration and are integral to attracting exploration investment to the province.

To provide these critical data, AER and AGS contracted Palmer to oversee and complete regional till and stream sediment sampling surveys in three areas of interest (AOIs) (Figure 1). The ambitious program extends over 142,000 km^2, reaching the northern and southern borders of the province. The three AOIs include: the foothills of the Rocky Mountains (AOI-1); an area surrounding High Level (AOI-2), and an area between Fort McMurray and Lesser Slave Lake (AOI-3). These areas were chosen because of their prospective geology and the low density of geochemical and mineralogical data that was previously available to inform mineral exploration and resource development initiatives and decisions. The program was initiated in 2022 and has three main objectives:

- to systematically sample till throughout the three AOIs for geochemical and mineralogical analysis;
- to systematically sample stream sediment throughout suitable parts of the three AOIs for geochemical and mineralogical analysis; and
- to gather field-based observations of the properties and genesis of Quaternary sedimentary deposits that will be used for the correlation of units and remote sensing data elsewhere in the province.

The majority of till and stream sediment sampling was completed in 2022. The sampling coverage achieved throughout AOI-1 and AOI-3 was adequate, but till sampling in AOI-2 was impeded by poor access and a mantle of glaciolacustrine material that overlies the till. A pilot program was completed in January 2023 to determine how new lightweight drilling technology could be used to improve data coverage where standard surface till sampling approaches are ineffective. The results from these first two programs are detailed in Sacco *et al.* (2023).

This report includes the methods and results of the recent multi-phase drill-supported till sampling survey designed to extend sampling coverage in the northern portion of AOI-2. Phase 1 was completed in October 2023, and Phase 2 was completed in March 2024, both based on the protocols established during the pilot drill program. All sampling was conducted to standards established by the AGS and Geological Survey of Canada (GSC) to provide high-quality field and analytical results that are consistent with, and comparable to, the existing provincial geochemical data. The till geochemistry is presented herein with a preliminary catchment basin analysis of the stream sediment geochemistry. New till geochemistry and sample descriptions are appended to the original results from Sacco *et al.* (2023) and provided in Appendix A with the stream sediment geochemistry and catchment basins. Processing of till and stream sediment mineralogy is pending, and the results will be provided in a subsequent AGS data release.

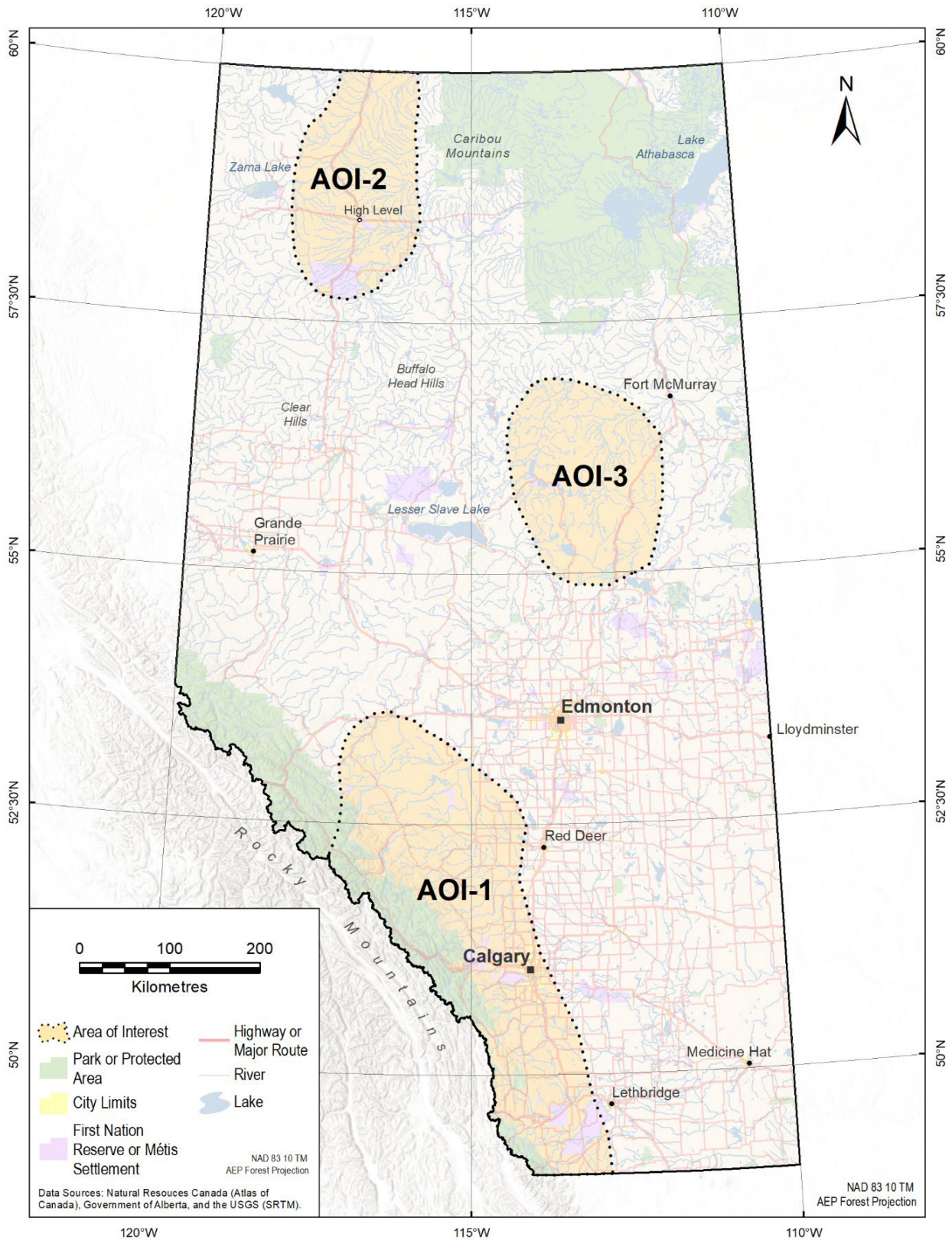


Figure 1. Project areas of interest (AOIs). AOI-1 encompasses part of the Rocky Mountain Foothills and extends east into the plains region. AOI-2 encompasses the town of High Level. AOI-3 is between Fort McMurray and Lesser Slave Lake.

1.1 Regional Quaternary Geology

Quaternary deposits are extensive across much of Alberta with sediment packages up to 445 m in thickness, the thickest of which are in the northern and eastern regions of the province (Atkinson and Lyster, 2010). Extensive subglacial till deposits are found throughout AOI-1, with ablation till commonly occurring in the east part of the AOI (Fenton *et al.*, 2013) (Figure 2). The Laurentide Ice Sheet (LIS) flowed south to southwestward into this region, while the Cordilleran Ice Sheet (CIS) advanced eastward out of the Rocky Mountains (Holme *et al.*, 2002; Atkinson *et al.*, 2014, Atkinson and Utting, 2021). The coalescence of these ice sheets within AOI-1 created a dynamic glacial environment producing numerous different ice flow directions throughout glaciation (Figure 2). During deglaciation, the LIS retreated northward and eastward, and the CIS retreated westward (Holme *et al.,* 2002; Atkinson and Utting*,* 2021). Glacial lakes developed in many low-lying areas and fine-grained glaciolacustrine sediments were deposited within them. These deposits are most common in the plains portion of AOI-1 and were locally incised by glacial meltwater that also deposited glaciofluvial material (Holme *et al.*, 2002; Fenton *et al.*, 2013).

In northern Alberta, AOI-2 was mainly affected by southwestward flow of the LIS, with regions near the centre of the AOI affected by westward and northwestward flow (Atkinson *et al.,* 2014; Fenton *et al.,* 2003). Till occurs extensively throughout AOI-2 within the sediment stratigraphy and is commonly overlain by various thicknesses of glaciolacustrine sediments (Figure 3). Glaciofluvial material comprises a small portion of the surficial deposits, typically peripheral to modern drainages (Figure 3). Eolian deposits occur in association with the glaciolacustrine and glaciofluvial deposits and are extensive in the southeastern parts of AOI-2 adjacent to the Peace River (Fenton *et al.*, 2013; Wolfe *et al.*, 2004).

The LIS flowed dominantly southward to southwestward throughout AOI-3 (Atkinson *et al.,* 2014; Atkinson and Utting*.,* 2021; Fenton *et al.*, 2003). Streamlined landforms with a south to southeastward orientation were identified in the regional mapping and it is unknown if these represent advance- or retreat-phase conditions. Subglacial till is particularly abundant along the east and southwest borders of AOI-3, while thick accumulations of ablation till occur in the southwest (Figure 4). Glaciofluvial deposits are common in low-lying areas within glacial meltwater channels, such as along the Athabasca River (Fenton *et al.,* 2013). Glaciolacustrine deposits appear to increase in abundance to the north and are likely present under the organic deposits throughout the middle of the AOI (Figure 4). Eolian deposits are identified in association with glaciofluvial deposits adjacent to the Athabasca River (Figure 4).

Postglacial Holocene deposits are present throughout all three AOI's. Organic deposits occur in low-lying areas, particularly within the northern part of AOI-2 and the central part of AOI-3 in association with fine grained till and glaciolacustrine materials. Colluvial deposits make up a small proportion of the plains but are commonly found on the slopes of river valleys, such as along the Athabasca River in AOI-3. Colluvium dominates the more mountainous western half of AOI-1 (Fenton *et al.,* 2013). The remaining surficial deposits consist of minor fluvial and lacustrine deposits.

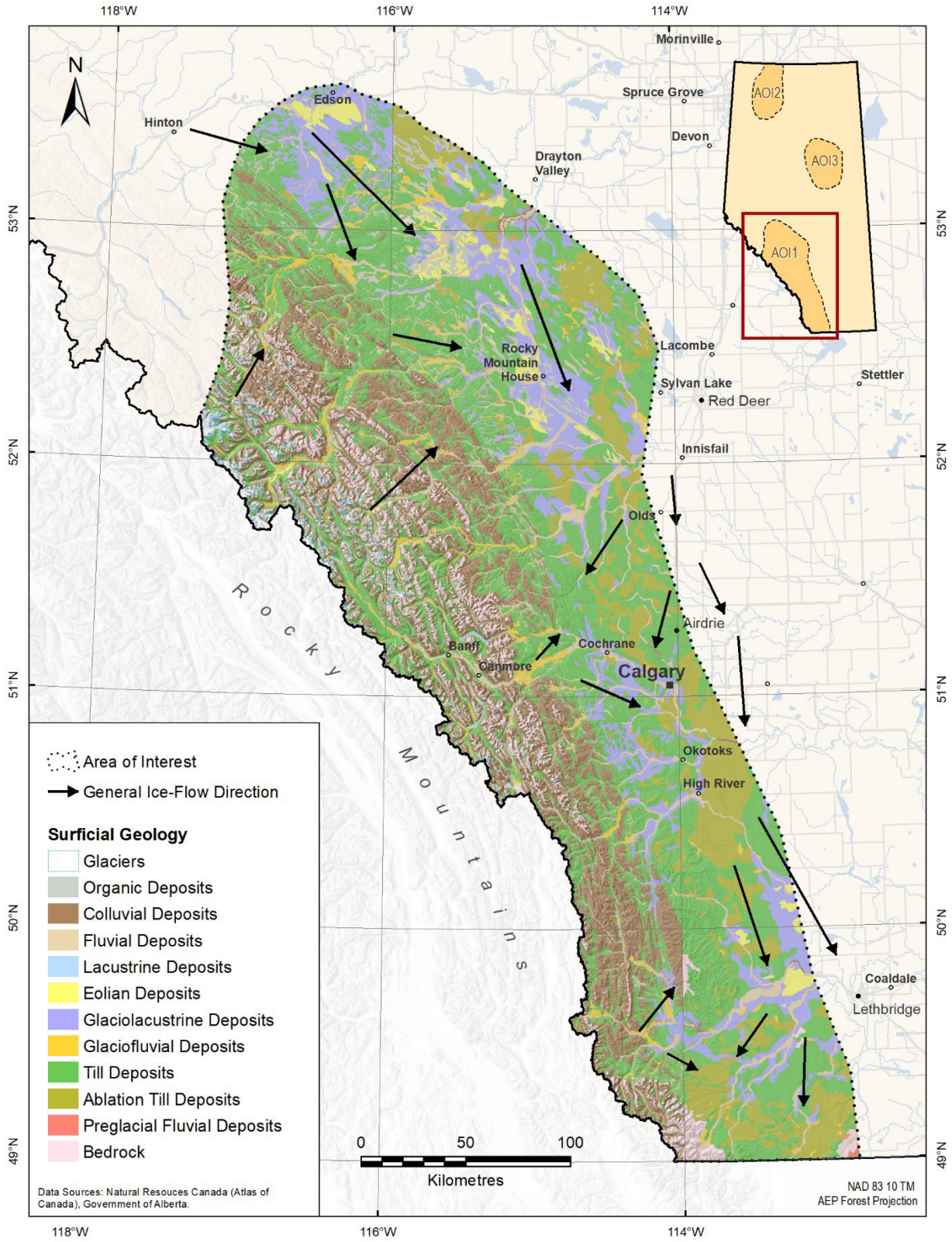
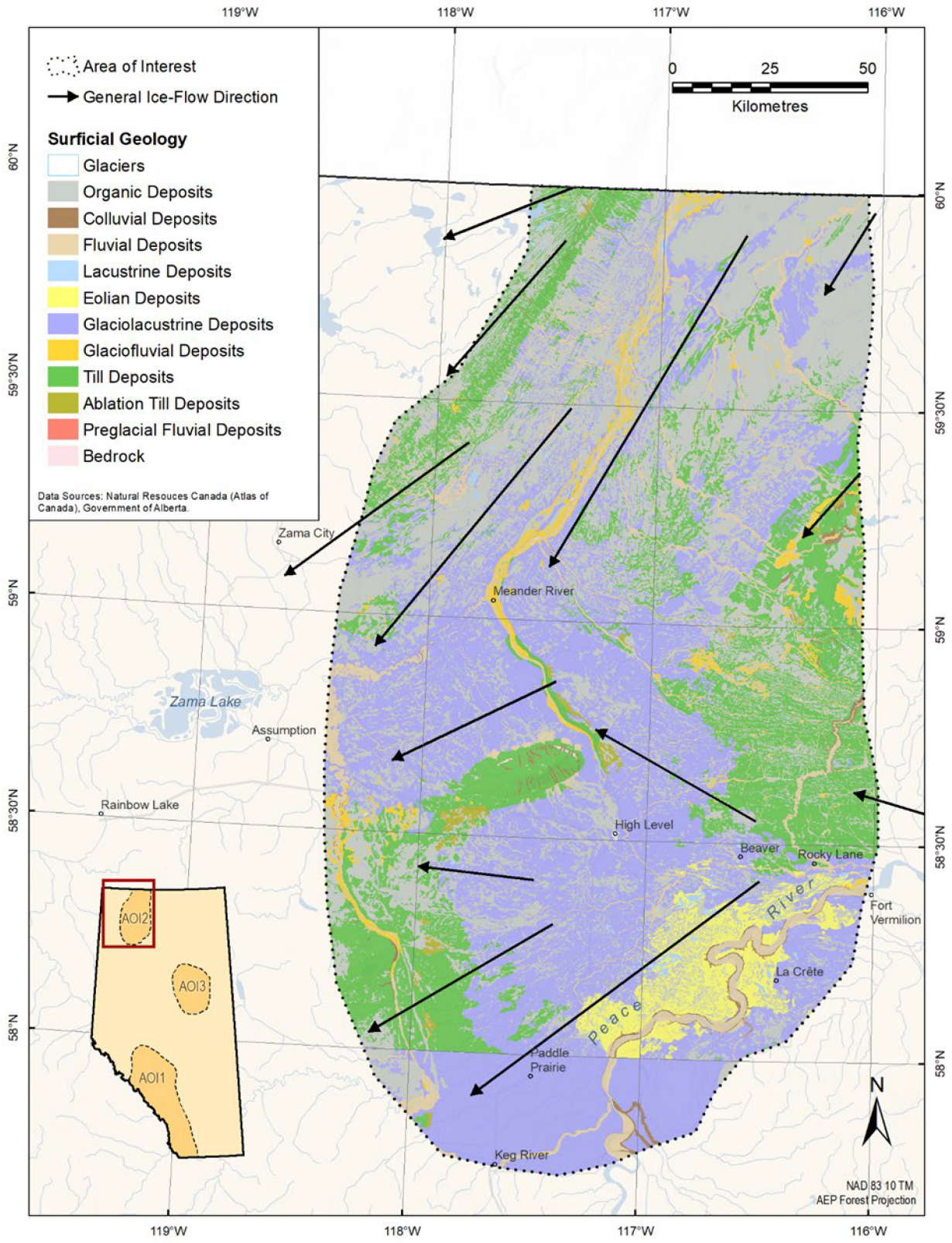


Figure 2. Generalized surficial geology and dominant ice flow directions in AOI-1 (https://open.alberta.ca/opendata/gda-dig_2014_0022).



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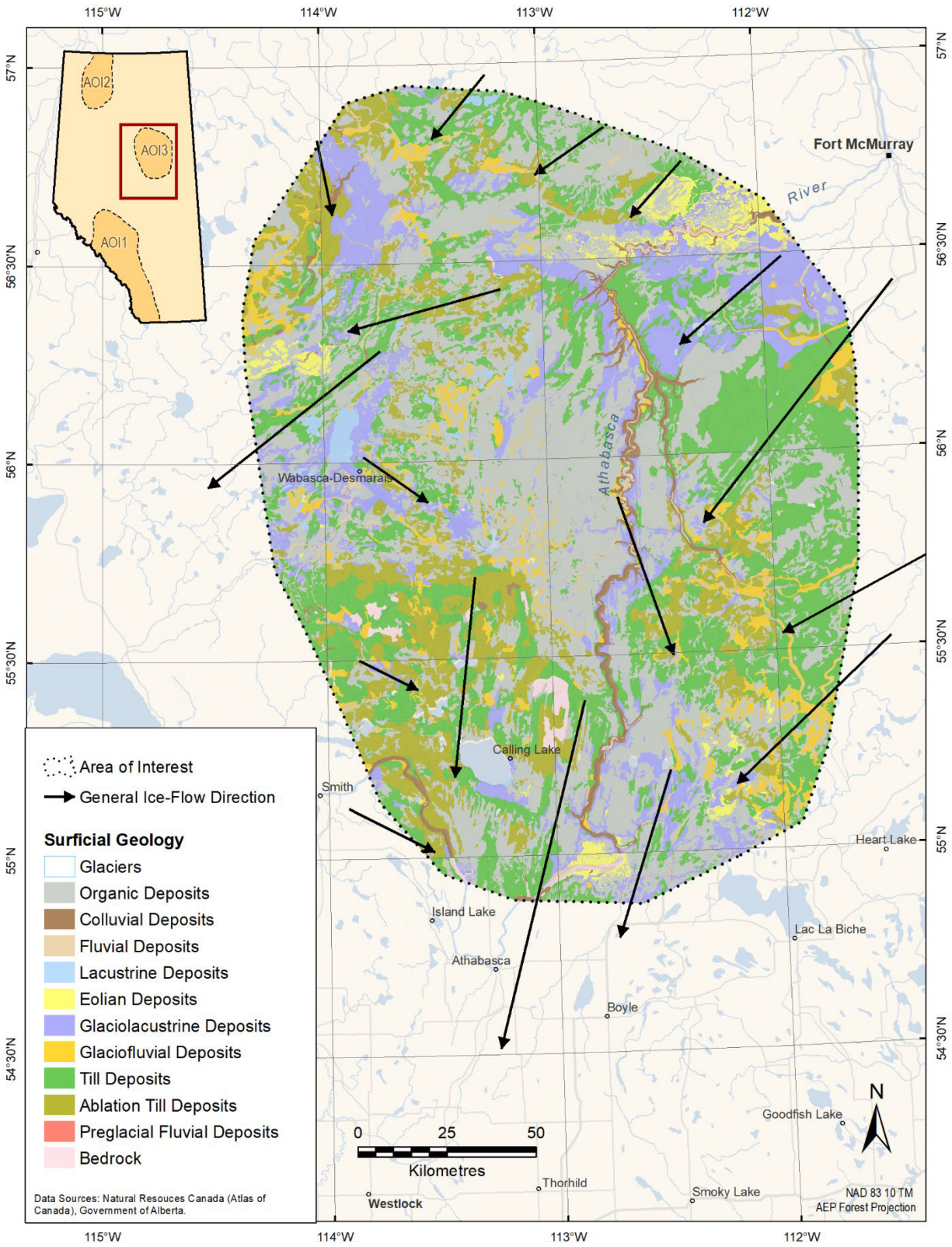

Figure 4. Generalized surficial geology and dominant ice flow directions in AOI-3 (https://open.alberta.ca/opendata/gda-dig_2014_0022).

1.2 Summary of Previous Program Activities

The initial till and stream sediment sampling program was completed in 2022, and the geochemistry analytical results were released in 2023 (Sacco *et al.,* 2023). Till and stream sediment sampling was completed by nine field crews using standard pick-and-shovel sampling techniques over a five-week period spanning September to October 2022. The pilot drill-supported till sampling program was completed over a 10-day period in January 2023 by one field crew using a ShockAuger shallow-drilling system. Surface and drill-supported till sampling was primarily truck-supported with a few days of helicopter-supported sampling in AOI-2. The stream sediment sampling was dominantly helicopter-supported, although one crew was able to access a number of sites by truck in AOI-1. The field crews used local accommodations, moving as required to minimize travel distances from the accommodations to the sampling areas. Details of these field programs and a description of sampling and analytical methods is presented in Sacco *et al.* (2023).

Over 1350 new till and stream sediment samples were collected and analysed using methods that conform to strict quality control specifications outlined in Geological Survey of Canada (2017). Till samples were collected from 211 sites in AOI-1, 66 sites in AOI-2, and 81 sites in AOI-3; stream sediment samples were collected from 176 sites in AOI-1, 121 sites in AOI-2, and 106 sites in AOI-3 (Sacco *et al,* 2023) (Figure 5). Most large data gaps were a result of till being buried beneath another material or the avoidance of national and provincial parks, First Nations Reserves, urban areas and associated infrastructure, and existing mineral exploration leases. Gaps in till sampling coverage west of Red Deer in AOI-1 are due to the presence of extensive glaciofluvial deposits. Extensive glaciolacustrine mantles further reduce sampling opportunities in portions of all AOIs. Prior to the drill-supported sampling, most till samples collected in the areas of AOI-2 covered with glaciolacustrine material were acquired from deeply incised stream cuts near roads. Public road access in AOI-2 and AOI-3 is moderate to poor, reducing truck-supported till sampling opportunities in those area. Some proposed sample sites were not reached because they were on private land, behind gates, or because buried utilities were present.

The pilot drill-supported till sampling program demonstrated that purpose-built, shallow-drilling technology can be used to efficiently collect till samples in areas where standard pick-and-shovel approaches are inadequate (*e.g.,* under glaciolacustrine cover). This technology paired with the extensive seismic line networks provide an opportunity to fill data gaps in areas where access and/or glaciolacustrine material at surface previously hindered till sampling efforts.

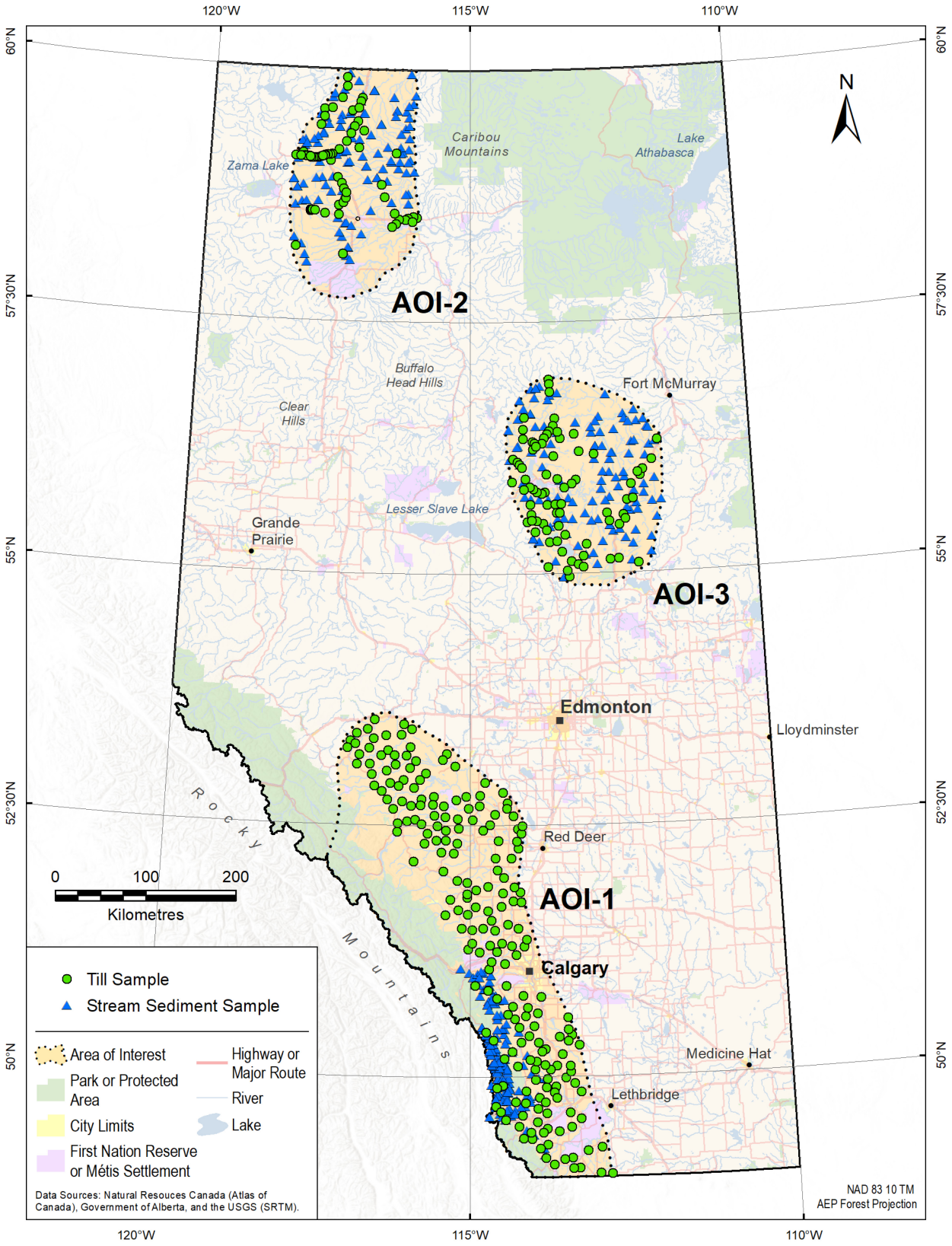

Figure 5. Till and stream sediment sample locations from previous program surveys (Sacco et al., 2023).

2. Fall-Winter 2023 and 2024 Drill-supported Till Survey

A multi-phase drill-supported till survey was completed within AOI-2 to begin filling data gaps remaining from the initial till surveys. The north central portion of AOI-2 was targeted for both surveys because opportunities for standard pick-and-shovel sampling were limited by the mantle of glaciolacustrine material overlying till and poor road access. Additionally, the Great Slave Lake Shear Zone is associated with a sphalerite-in-till anomaly and was highlighted as an area of interest for follow-up work in previously completed regional-scale till surveys (Plouffe *et al.,* 2006). Phase 1 was completed in October of 2023 and Phase 2 was completed in March of 2024.

2.1 Survey Design

Sampling locations were predetermined to help optimize sample distributions and streamline the field programs. Sampling was restricted to Crown land, avoiding private property, national and provincial parks, First Nations Reserves and existing mineral exploration leases. Sampling sites were planned along existing unvegetated to sparsely vegetated seismic lines that are oriented roughly perpendicular to ice flow direction. The target sample spacing along the transects was 3-5 km, but the actual sample spacing varied depending on the ground conditions. A line-locate request was submitted through the Alberta One Call system for each planned site to ensure the absence of underground utilities. Only sites that were cleared by all registered utility companies were included in the final program design.

2.2 Drilling and Sampling Methods

Phase 1 of the survey utilized Argo all-terrain vehicles to transport personnel and gear between sites, while an AS350-B3 helicopter was used to complete drill moves in one sling load. Reconnaissance of the seismic lines and drilling sites was completed prior to drilling, during which time brush and deadfall were cleared. Phase 2 was completed when there was snow on the ground and both crew and equipment were moved by helicopter. Pads were cleared by a dedicated prep crew prior to the arrival of the sampling crew and drill.

Drill-supported sampling was completed using a ShockAuger shallow-drilling system, which is a recently developed, rotary percussion drilling system specifically tooled and engineered for till sampling (Figure 6). The system was configured to operate to a maximum depth of 15 m. This configuration allows for rapid collection of till samples below thick covers of glaciolacustrine material. A custom, reinforced 60-mm-diametre flow-through style sampler was used to collect *in situ* material from the boreholes. Boreholes were twinned when collecting minerology samples to acquire enough sample volume, while maintaining a consistent sampling depth. Till was sampled using protocols consistent with Sacco *et al.* (2023), and the sediment stratigraphy of the borehole was described at each location.



Figure 6. ShockAuger lightweight shallow-drilling system, configured without tracks and used to sample till in remote areas beneath glaciolacustrine sediments.

2.3 Survey Results

A total of 32 new till samples and two field duplicates were collected for analysis during the drill-supported till survey. Four days of line prep were completed prior to Phase 1 sampling. Sampling during Phase-1 was focused on the west side of Highway 35 and completed over seven days; however, several of these days had delayed starts due to weather. In addition, there was over a day of total standby time related to helicopter issues. Aside from weather and helicopter standby time, the sampling was effective, and the largest challenges were related to access along the seismic lines. There were several areas where brush or fallen trees created a barrier that could not be efficiently cleared. In addition, some steep riverbanks and excessive swampy locations could not be traversed, even with the amphibious vehicles. As a result, some proposed lines and sample locations were necessarily abandoned. Overall, the combined ground and air-support program was effective, but either a larger ground support vehicle or a separate, preliminary ground preparation and reconnaissance program would be advantageous to avoid disruptions to the survey strategy. The final day of Phase-1 was completed with full helicopter support, and the crew reported a significant increase in efficiency.

Phase-2 was completed during the winter with full helicopter support, focussing east of Highway 35. Moves were efficient and the snowpack simplified moves and ground activities. The winter program introduced unique weather complications. When temperatures are below -20°C, there is increased likelihood of equipment failure and weather-related injuries. There were several delays due to weather either being too

cold or visibility being too poor to operate the drill and helicopter safely. Completing this type of program with full helicopter support in the winter is ideal, provided there is sufficient flexibility for weather delays.

In total, 390 geochemical till samples have now been systematically collected across the three AOIs as part of the AER's Mineral Mapping Program (Table 1). The recent drill-supported sampling increases the total number of geochemical till samples collected in AOI-2 to 98 (Figure 7). There were only four sites drilled where till was not intersected due to the thickness of the glaciolacustrine mantle. The efficacy of the drill-supported sampling is evident in the consistent, tightly spaced sample distribution along the Zama City Highway and the collection of till samples buried beneath glaciolacustrine materials in the north central part of AOI-2. The program demonstrates that till sampling can be completed in remote areas with poor access and that full helicopter support is ideal. Moving people and some equipment on the ground with amphibious vehicles can be accomplished with suitable preparation, but there are likely some conditions that will still inhibit ground movement (*e.g.,* steep riverbanks).

Table 1. Summary of geochemical till sample results for the three AOIs.

AOI	Geochemical Samples	Field Duplicate Samples	Reference Standards	Total Samples
AOI-1	211	13	13	237
AOI-2	98	8	8	114
AOI-3	81	5	5	91
Total	**390**	**26**	**26**	**442**

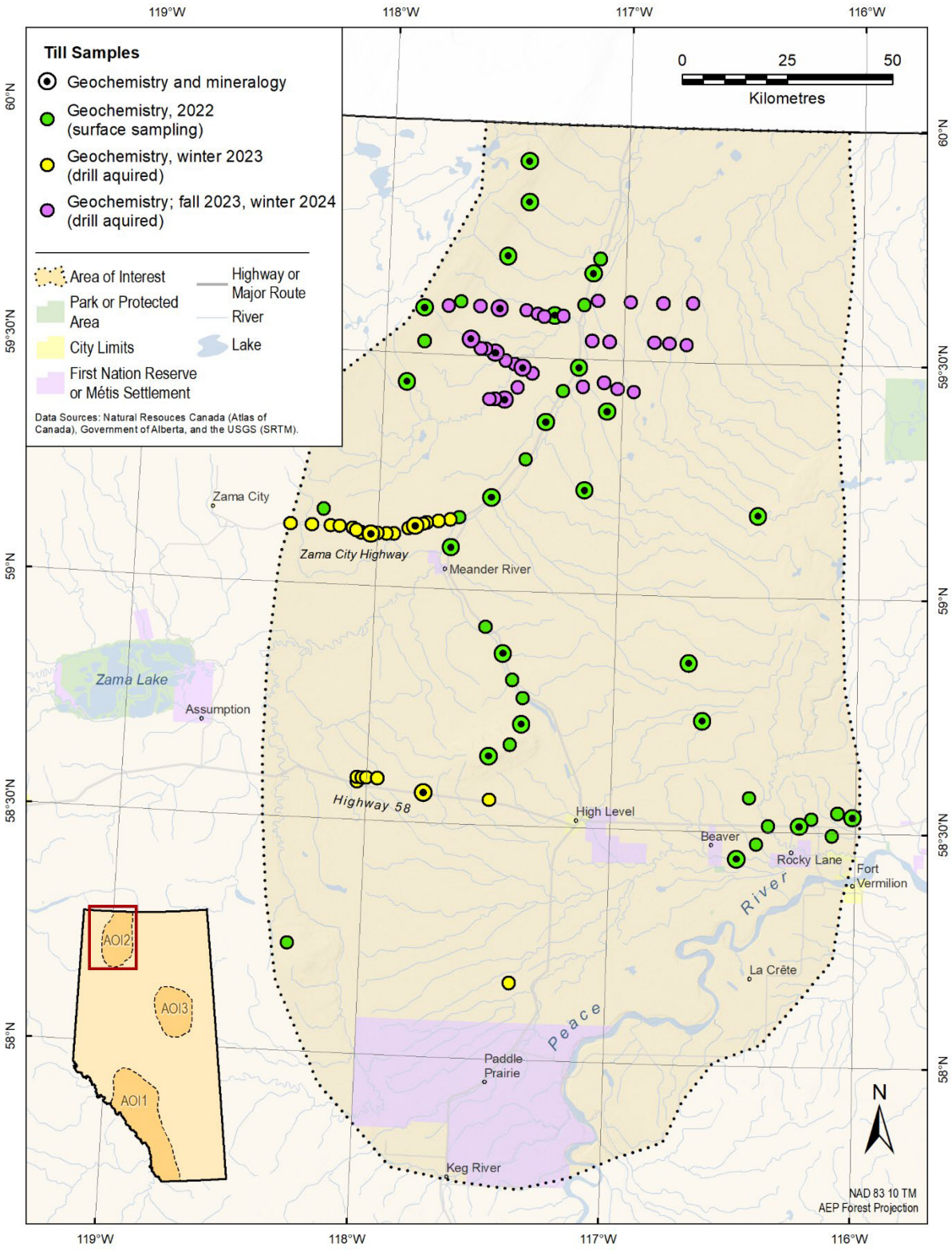

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Figure 7. Updated till sample coverage in AOI-2 following the conclusion of drill-supported sampling.

3. Geochemical Analysis and Evaluation

3.1 Laboratory Analytical Methods

Geochemical analysis for all samples was completed at Bureau Veritas (BV) Laboratories in Vancouver, BC. Till and stream sediment samples were oven-dried at 60°C and sieved to produce a silt+clay (<0.063 mm) size-fraction split. A 15 g aliquot of the silt+clay underwent a modified aqua-regia digestion (1:1:1 ratio of HNO_3:HCl:H_2O) and was analyzed by inductively coupled plasma mass spectrometry (ICP-MS) for 65 elements (53 elements + REE; lab method code AQ251-EXT+REE). Analytes, their detection limits and the reported concentrations of certified reference material (CRM) OREAS47 for AQ251-EXT+REE are provided in Table 2. Another aliquot was subjected to lithium borate fusion followed by nitric acid digestion. Eighteen major oxides and elements were determined using inductively coupled plasma-emission spectrometry (ICP-ES) and loss-on-ignition was completed by weight difference after ignition at 1000°C (lab method code LF300). In addition, 45 trace elements, including 14 precious and base metal elements, were determined by ICP-MS following the lithium borate fusion dissolution (lab method code LF100-EXT). Analytes, their detection limits, and the reported concentrations of CRM OREAS-47 for LF300 and LF100-EXT are provided in Table 3.

In addition to the geochemical analysis, a 300-g split of the till matrix was sent to Saskatchewan Research Council (SRC) Geoanalytical Laboratories in Saskatoon, SK for grain-size analysis. The material was collected in a separate bag and shipped directly to SRC for analysis. This is the only protocol changed during the program; previous samples for grain size analysis were split from the master sample at BV before shipment to SRC.

The moisture content of the samples was determined by weighing them as received, drying them at 60°C, and reweighing them. The samples were disaggregated using a rolling pin and sieved to ±2 mm. Sand fractions were determined by sieving using 2 mm, 1 mm, 250 µm, 125 µm, and 63 µm sieve sizes. Determination of the sand, silt and clay size-fractions was completed using the hydrometer method. Ten grams of the <2 mm size-fraction was transferred to a flask and deflocculated with Calgon® and deionized water. The flask was then shaken until the contents were thoroughly mixed, and the mixture was sieved through a screen into a graduated cylinder. After a certain period, dependent on ambient room temperature, an aliquot of clay was removed from the cylinder, while the sieved sand and aliquots of sample material were dried and weighed again. The calculations to determine the percentage of sand, silt, and clay size fractions were based on the total dry weight. Quality control for this analysis involved testing an in-house sand, silt, and clay standard that was inserted every 12 samples. Replicate samples were also inserted after every 40 samples or at the end of a smaller group. The reported detection limit of the analysis 0.01%.

Table 2. Elements, units of measurement, lower detection limit (LDL) and upper detection limit (UDL) for analytical package AQ251-EXT+REE (aqua-regia digestion and ICP-MS).

Element	Unit	LDL	UDL	OREAS47 certified value
Ag	ppb	2	100000	107
Al	pct	0.01	10	0.81
As	ppm	0.1	10000	9.53
Au	ppb	0.2	100000	32.4
B	ppm	1	2000	-
Ba	ppm	0.5	10000	62
Be	ppm	0.1	1000	0.19
Bi	ppm	0.02	2000	0.15
Ca	pct	0.01	40	0.547
Cd	ppm	0.01	2000	0.5
Ce	ppm	0.1	2000	44.7
Co	ppm	0.1	2000	49.9
Cr	ppm	0.5	10000	30.4
Cs	ppm	0.02	2000	1.19
Cu	ppm	0.01	10000	160
Dy	ppm	0.02	2000	1.26
Er	ppm	0.02	2000	0.58
Eu	ppm	0.02	2000	0.6
Fe	pct	0.01	40	1.65
Ga	ppm	0.1	1000	3.28
Gd	ppm	0.02	2000	1.92
Ge	ppm	0.1	100	0.075
Hf	ppm	0.02	1000	0.2
Hg	ppb	5	50000	140
Ho	ppm	0.02	2000	0.21
In	ppm	0.02	1000	0.037
K	pct	0.01	10	0.116
La	ppm	0.5	10000	25.2
Li	ppm	0.1	2000	8.83
Lu	ppm	0.02	2000	0.07
Mg	pct	0.01	30	0.484
Mn	ppm	1	10000	270
Mo	ppm	0.01	2000	12.7

Element	Unit	LDL	UDL	OREAS47 certified value
Na	pct	0.001	5	0.091
Nb	ppm	0.02	2000	0.92
Nd	ppm	0.02	2000	17.8
Ni	ppm	0.1	10000	80
P	pct	0.001	5	0.055
Pb	ppm	0.01	10000	284
Pd	ppb	10	100000	43.1
Pr	ppm	0.02	2000	5.3
Pt	ppb	2	100000	25.7
Rb	ppm	0.1	2000	7.15
Re	ppb	1	100000	-
S	pct	0.02	10	0.046
Sb	ppm	0.02	2000	0.2
Sc	ppm	0.1	100	3.17
Se	ppm	0.1	100	-
Sm	ppm	0.02	2000	2.66
Sn	ppm	0.1	100	2.54
Sr	ppm	0.5	2000	31.4
Ta	ppm	0.05	2000	-
Tb	ppm	0.02	2000	0.23
Te	ppm	0.02	1000	0.016
Th	ppm	0.1	2000	3.25
Ti	pct	0.001	5	0.07
Tl	ppm	0.02	1000	0.083
Tm	ppm	0.02	2000	0.084
U	ppm	0.1	2000	0.47
V	ppm	1	10000	24.7
W	ppm	0.1	100	0.11
Y	ppm	0.01	2000	5.75
Yb	ppm	0.02	2000	0.5
Zn	ppm	0.1	10000	213
Zr	ppm	0.1	2000	6.7

Table 3. Elements, units of measurement, lower detection limit (LDL) and upper detection limit (UDL) for analytical packages LF300 and LF100-EXT (lithium borate fusion followed by ICP-ES/MS).

Analyte	Method	Unit	LDL	UDL	OREAS47 certified value
SiO_2	LF300	pct	0.01	100	72.78
Al_2O_3	LF300	pct	0.01	100	11.96
Cr_2O_3	LF300	pct	0.002	10	165
CaO	LF300	pct	0.01	100	3.27
Fe_2O_3	LF300	pct	0.04	100	3.97
K_2O	LF300	pct	0.01	100	1.42
MgO	LF300	pct	0.01	100	1.67
MnO	LF300	pct	0.01	30	0.064
Na_2O	LF300	pct	0.01	100	3.47
P_2O_5	LF300	pct	0.01	100	0.129
TiO_2	LF300	pct	0.01	10	0.379
Ba	LF300	ppm	5	5	473
Nb	LF300	ppm	5	1000	17.9
Ni	LF300	ppm	20	10000	91
Sc	LF300	ppm	1	10000	9.27
Sr	LF300	ppm	2	50000	402
Y	LF300	ppm	3	50000	11.6
Zr	LF300	ppm	5	50000	161
LOI	LF300	pct	0.1	100	1.02
Sum	LF300	pct	0.01	100	-
Ag	LF100-EXT	ppm	0.1	100	-
As	LF100-EXT	ppm	1	10000	9.67
Au	LF100-EXT	ppm	0.5	100000	-
Ba	LF100-EXT	ppm	1	50000	473
Be	LF100-EXT	ppm	1	10000	0.97
Bi	LF100-EXT	ppm	0.5	2000	-
Cd	LF100-EXT	ppm	0.1	2000	-
Ce	LF100-EXT	ppm	0.1	50000	56
Co	LF100-EXT	ppm	0.2	10000	52
Cs	LF100-EXT	ppm	0.1	1000	2.01
Cu	LF100-EXT	ppm	0.1	10000	149
Dy	LF100-EXT	ppm	0.05	10000	2.11
Er	LF100-EXT	ppm	0.03	10000	1.16

Analyte	Method	Unit	LDL	UDL	OREAS47 certified value
Eu	LF100-EXT	ppm	0.02	10000	1.01
Ga	LF100-EXT	ppm	0.5	10000	14.1
Gd	LF100-EXT	ppm	0.05	10000	2.83
Hg	LF100-EXT	ppm	0.01	50	-
Hf	LF100-EXT	ppm	0.1	10000	4.1
Ho	LF100-EXT	ppm	0.02	10000	0.42
La	LF100-EXT	ppm	0.1	50000	30.9
Lu	LF100-EXT	ppm	0.01	10000	0.16
Mo	LF100-EXT	ppm	0.1	2000	12.7
Nb	LF100-EXT	ppm	0.1	1000	17.9
Nd	LF100-EXT	ppm	0.3	10000	24
Ni	LF100-EXT	ppm	0.1	10000	91
Pb	LF100-EXT	ppm	0.1	10000	-
Pr	LF100-EXT	ppm	0.02	10000	6.58
Rb	LF100-EXT	ppm	0.1	1000	37.6
Sb	LF100-EXT	ppm	0.1	2000	-
Se	LF100-EXT	ppm	0.5	100	-
Sm	LF100-EXT	ppm	0.05	10000	4.01
Sn	LF100-EXT	ppm	1	10000	6.14
Sr	LF100-EXT	ppm	0.5	50000	402
Ta	LF100-EXT	ppm	0.1	1000	0.46
Tb	LF100-EXT	ppm	0.01	10000	0.39
Th	LF100-EXT	ppm	0.2	10000	3.84
Tl	LF100-EXT	ppm	0.1	1000	-
Tm	LF100-EXT	ppm	0.01	10000	0.17
U	LF100-EXT	ppm	0.1	10000	0.79
V	LF100-EXT	ppm	8	10000	61
W	LF100-EXT	ppm	0.5	10000	-
Y	LF100-EXT	ppm	0.1	50000	11.6
Yb	LF100-EXT	ppm	0.05	10000	1.08
Zn	LF100-EXT	ppm	5	10000	217
Zr	LF100-EXT	ppm	0.1	50000	161

Carbon content was determined by LECO analysis (lab method code TCCRB), which determines total carbon, graphite carbon, organic carbon, and inorganic carbon present in the sample. All forms of carbon were converted into CO_2 through combustion in an induction furnace, and the concentration was measured by adsorption in an infrared spectrometric cell. To determine graphitic carbon, the samples were leached with dilute HCl, followed by ignition at 500°C and analysis of the residue. Inorganic carbon was directly measured by analyzing the CO_2 evolved from a sample split leached with perchloric acid. Organic carbon was calculated by subtracting the inorganic and graphitic carbon from the total carbon. Analytes and their detection limits for TCCRB are provided in Table 4.

Table 4. Elements, units of measurement, lower detection limit (LDL) and upper detection limit (ULD) for analytical package TCCRB (carbon analysis by LECO).

Analyte	Unit	LDL	UDL
Total C	pct	0.02	100
Organic C	pct	0.02	100
Inorganic C	pct	0.08	100
Graphite C	pct	0.02	20

3.2 Quality Control of Geochemical Data

Verification of the accuracy and precision of geochemical analyses is necessary to ensure their reliability. Each block of 20 samples submitted for geochemical analysis included a field duplicate (FDUP), an analytical duplicate (ADUP), and an aliquot of CRM. The field duplicates were randomly selected and collected from the same site (*i.e.,* drill hole) as the routine field sample to test sample site variability. The analytical duplicate is a split of the field duplicate, which was completed in the lab after the initial sieving sample preparation. The CRM (OREAS47) is an augmented Canadian subglacial till from a source location near Chibougamau, Quebec. It was used as the reference standard to measure the accuracy of the laboratory results, by providing a comparison between the analytical results and known values. Reliability of the results was measured by statistical evaluation of analytical results from the CRM, field duplicate samples, and analytical duplicate samples. Quality control calculations are completed on the entire geochemical dataset.

To estimate the analytical accuracy of the analyses, 26 aliquots of OREAS47 were analysed with the till samples and 24 with the stream sediment samples. Results for the OREAS47 standard are compared to the recommended values provided by OREAS using percentage recovery values. Percentage recovery, which represents a measure of accuracy, is defined by the following equation (*cf.* Ziegler and Combs, 1997):

$$Percentage\ Recovery = 100 \times \frac{C_m}{C_A}$$

where:
C_m = the measured concentration of the standard sample
C_A = the actual concentration of the standard sample (recommended or provisional value)

Percentage recovery values near 100% indicate a high degree of accuracy. If 50% or less of the results for an element were below the lower detection limit (LDL), the <LDL values were set to one half of the LDL for the percentage recovery calculation. If more than 50% of the results for an element were below the LDL, the percentage recovery was not calculated. In addition, the OREAS47 standard is not adequately characterized for some elements, thereby precluding percentage recovery calculations.

The percent relative standard deviation (%RSD) of repeated analyses of OREAS47 provides a measure of precision. Low %RSD values indicate a high degree of precision. The %RSD is defined by the following equation:

$$\%\ Relative\ Standard\ Deviation = 100 \times \frac{s}{x}$$

where:
s = standard deviation
x = mean of replicate determinations

If 50% or less of the results for an element were below the lower detection limit (LDL), the <LDL values were set to one half of the LDL for the %RSD calculation. If more than 50% of the results for an element were below the LDL, the RSD was not calculated.

The till and stream sediment sample batches submitted to BV each included 26 and 24 field duplicates, respectively. An analytical duplicate was created from each field duplicate, resulting in the same number of analytical duplicate pairs for each sample type. The average of the relative percentage difference (RPD) for each analyte represents a measure of precision (*cf.* Ziegler and Combs, 1997; Zimmerman et al., 2001). The RPD for a set of duplicate pair results is defined by the following equation:

$$Relative\ Percent\ Difference = 100 \times \frac{|C_1 - C_2|}{C_x}$$

where:
C_1 = concentration of the analyte in duplicate 1
C_2 = concentration of the analyte in duplicate 2
C_X = mean of the concentration in the duplicates

If values below the lower detection limit (LDL) were returned for an element in both samples of a duplicate pair, that pair was removed from the RPD calculation for that element. If a given duplicate pair returned one value below the LDL and one measurable value, then the <LDL value was set to half of the LDL for the purpose of the RPD calculation.

Analytical differences between the field and analytical duplicate pairs should reflect the homogeneity of the sample pairs and the analytical precision (low values indicating a high level of homogeneity and analytical precision).

3.3 Catchment Basin Delineation

Catchment basins were delineated for the 398 stream sediment samples collected in 2022 as a basis for the catchment basin analysis. Catchment basins were delineated with GIS software (QGIS v 3.28, 2024), using the Alberta ArcHydro Phase 2 Catchments polygon dataset (Alberta Environment and Parks, 2018) as a framework, and refined where necessary by topographical analysis of a 90-metre resolution digital elevation model (DEM) (NASA Shuttle Radar Topography Mission (SRTM), 2013).

Some sample locations have more than one upstream catchment. QGIS's Flow Trace plugin (QGIS v 3.28, 2024) was used in conjunction with the Alberta ArcHydro vector drainage lines to determine which contributing catchments should be merged to indicate potential stream sediment source areas. Many samples were collected upstream of the existing catchment endpoints (*i.e.,* transition to next catchment). Where this occurred, the downstream end of the catchment was clipped to provide a more accurate representation of the potential sediment source area. The clipping was completed using a topographic upslope area delineation (Conrad *et al.,* 2015) from a hydrologically conditioned version of the SRTM-DEM.

A nesting order was assigned for catchment polygons that overlap. Catchment polygon overlap occurs when there are several samples collected along the same stream network. Non-nested catchments were attributed with a 1st order rank, with increased rankings for catchments associated with downstream samples. This allows for greater flexibility in symbolizing the dataset and isolating results from nested basins

for analysis. Each catchment polygon includes the unique sample ID from the corresponding stream sediment sample location, excluding field and analytical duplicates, so that geochemical results or field notes can be joined to the polygon data.

The catchment basin delineation process assumes the SRTM-DEM and watercourse datasets reliably model the terrain features within the study area, and therefore, the outputs are limited to their resolution and positional accuracy.

3.4 Geochemical Data Standardization and Treatment

Elements of interest highlighted in the presentation of data below were selected based on their association with mineralization in Alberta. Rare earth element (REE) concentrations determined by ICP-MS following the lithium borate fusion dissolution were summed to create a multivariate signature representing total REEs, light rare earth elements (LREEs), and heavy rare earth elements (HREEs). For this evaluation, La, Ce, Pr, Nd, and Sm were used for the LREE signature and Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu were used for the HREE signature.

Analytical results from the stream sediment and till were separated based on AOI and treated as separate datasets to account for geographic differences in background concentrations. To improve suitability for statistical evaluation, censored data was substituted. Censored data distributions are artificially skewed due to data points that occur below detection limits. Data points below the detection limit were substituted with half of the lower detection limit for elements with less than 1% censored data. Data points below the detection limit were substituted with predicted values based on linear regression coefficients for elements with greater than 1% censored data.

For stream sediment data in AOI-1, censored Au and W values in till samples and censored Au, As, and W values in stream sediment samples were substituted with half of the lower detection limit. In AOI-3, no censored values were present in the till data; however, censored Au values in stream sediment samples were substituted with predicted values based on linear regression coefficients (Figure 8). Prior to this substitution, the Au data distribution was de-skewed through a log-10 transformation to improve normality. No censored data was present in AOI-2 for the elements of interest.

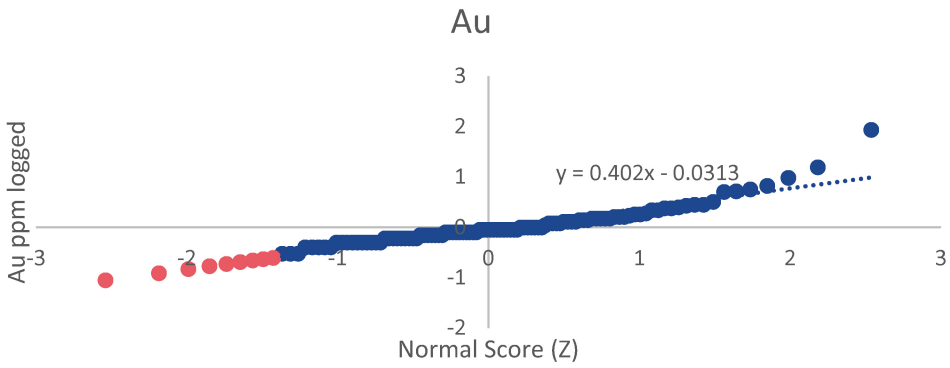

Figure 8. Example of substitution for Au data below the lower detection limit in the stream sediment data from AOI-3. Red symbols represent the substituted data.

4. Geochemical Results and Discussion

4.1 Geochemistry Quality Control Evaluation

Average percent recovery (APR) values for determinations by lithium-borate fusion ICP-ES/MS are generally above 90%. APR values for determination by aqua-regia ICP-MS are generally 85% (Table 5). The low APR value for Ga (<85%) and high APR values (<115%) for Au by aqua-regia ICP-MS and Be by lithium-borate fusion ICP-ES/MS fall outside of the accepted two times the relative standard deviation of the CRM certified values limit and indicate potential issues with accuracy. Blank APR values in Table 5 represent the undefined concentrations of select elements in the certified reference material (CRM). Blank %RSD values occur when more than 50% of the results for an element are below the LDL.

Relative percent differences for the field and analytical duplicates of major oxide determinations by lithium-borate fusion ICP-ES are mostly less than 10%. RPD values for field and analytical duplicates of trace element, precious and base metal determinations by lithium-borate fusion ICP-MS, are generally less than 5%. RPD values for elemental determinations by aqua-regia ICP-MS have a greater range, typically from <5% to <20%. Typically, elements with RPD values of >20% (B, W, Sn, Se, Te, S, Au, Pt, Ni) have several measured values near or below the LDL. Elements with RPD values >50% (Be, Re, Pt) have mostly measured values near or below the LDL. Blank RPD values in Table 5 indicate all analytical results for that element were below the LDL.

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Table 5. Quality control results for analytical precision by percent relative standard deviation (%RSD), and accuracy by average percent recovery (APR) for OREAS47 certified reference material. Average relative percent differences (RPD) for field and analytical duplicates (FDUP; ADUP). %RSD and RPD values in blue are between 15% and 30%, values in orange are between 30% and 50%, and values in red are >50%. APR values in orange are within 5 to 15% of 100%, and values in red are within 15 to 25% of 100%.

		Till				Stream sediments			
Element	Analytical method	%RSD (OREAS47)	APR (OREAS47)	Average RPD value (FDUP)	Average RPD value (ADUP)	%RSD (OREAS47)	APR (OREAS47)	Average RPD value (FDUP)	Average RPD value (ADUP)
Ag	AQ251-EXT+REE	7.1	99.2	11.0	9.6	4.6	100.1	10.3	4.9
Al	AQ251-EXT+REE	6.9	98.4	5.1	5.9	4.6	102.8	6.1	3.5
As	AQ251-EXT+REE	7.0	96.9	9.0	6.5	4.2	99.2	9.3	4.1
Au	AQ251-EXT+REE	5.9	116.5	13.4	17.5	6.9	117.6	38.6	40.0
B	AQ251-EXT+REE	32.8	-	16.5	21.0	26.7	-	16.0	9.9
Ba	AQ251-EXT+REE	8.2	95.3	13.8	8.1	4.9	96.5	10.3	8.8
Be	AQ251-EXT+REE	14.7	105.3	9.0	13.4	14.9	109.3	16.5	14.6
Bi	AQ251-EXT+REE	7.7	94.5	5.3	6.1	5.8	93.9	7.6	5.1
Ca	AQ251-EXT+REE	7.3	104.4	14.4	10.2	4.8	109.0	10.7	3.1
Cd	AQ251-EXT+REE	9.1	97.0	16.1	13.4	6.1	99.5	10.5	6.4
Ce	AQ251-EXT+REE	7.4	93.2	4.9	6.4	3.8	93.2	6.0	4.3
Co	AQ251-EXT+REE	6.7	96.2	7.4	4.9	2.0	98.6	6.6	4.0
Cr	AQ251-EXT+REE	7.6	101.4	4.5	5.0	4.0	104.6	6.2	5.9
Cs	AQ251-EXT+REE	8.3	93.9	5.7	8.1	4.2	94.3	8.8	8.6
Cu	AQ251-EXT+REE	6.7	94.2	7.4	6.6	2.6	95.7	9.2	4.4
Dy	AQ251-EXT+REE	7.1	-	5.3	7.5	5.7	-	7.1	4.7
Er	AQ251-EXT+REE	7.9	-	4.8	8.8	5.2	-	6.5	4.0
Eu	AQ251-EXT+REE	9.8	-	5.5	7.2	6.4	-	6.7	5.2
Fe	AQ251-EXT+REE	6.8	95.3	3.6	4.1	2.2	97.7	5.9	2.3
Ga	AQ251-EXT+REE	9.5	80.3	4.1	5.5	7.7	84.2	7.0	4.5
Gd	AQ251-EXT+REE	10.2	89.4	4.9	7.7	6.0	88.4	6.5	4.1
Ge	AQ251-EXT+REE	-	-	-	-	0.0	-	-	-
Hf	AQ251-EXT+REE	9.4	-	12.5	11.0	7.8	-	17.6	8.1
Hg	AQ251-EXT+REE	23.0	-	10.2	8.3	12.7	-	11.9	10.9
Ho	AQ251-EXT+REE	7.9	90.1	5.4	8.5	6.7	91.2	6.9	5.6
In	AQ251-EXT+REE	14.2	95.2	14.8	10.5	14.6	99.8	21.2	17.8
K	AQ251-EXT+REE	8.1	97.8	6.2	7.0	6.4	101.5	7.0	4.8
La	AQ251-EXT+REE	7.2	96.7	4.4	5.6	4.2	96.3	5.5	4.4
Li	AQ251-EXT+REE	9.3	94.9	5.5	6.4	5.6	99.1	6.5	4.7

		Till				Stream sediments			
Element	*Analytical method*	*%RSD (OREAS47)*	*APR (OREAS47)*	*Average RPD value (FDUP)*	*Average RPD value (ADUP)*	*%RSD (OREAS47)*	*APR (OREAS47)*	*Average RPD value (FDUP)*	*Average RPD value (ADUP)*
Lu	AQ251-EXT+REE	7.8	85.1	5.4	8.3	8.3	87.4	8.8	6.1
Mg	AQ251-EXT+REE	7.6	96.9	6.0	4.3	3.3	101.5	8.6	2.6
Mn	AQ251-EXT+REE	7.2	99.7	10.7	6.0	3.2	102.9	13.6	2.4
Mo	AQ251-EXT+REE	6.6	93.6	13.3	10.5	2.2	95.7	8.3	4.3
Na	AQ251-EXT+REE	10.2	100.9	8.5	9.5	11.4	106.8	6.5	3.7
Nb	AQ251-EXT+REE	15.3	-	12.1	14.8	16.1	-	13.4	11.2
Nd	AQ251-EXT+REE	8.2	96.6	4.3	6.7	4.6	96.3	4.9	4.5
Ni	AQ251-EXT+REE	6.6	96.2	6.6	6.3	2.5	98.1	6.8	4.6
P	AQ251-EXT+REE	6.7	95.1	4.3	4.1	3.4	96.2	5.4	3.2
Pb	AQ251-EXT+REE	6.8	93.4	4.7	4.6	3.4	94.1	7.1	4.1
Pd	AQ251-EXT+REE	9.0	101.6	-	-	8.0	101.4	-	-
Pr	AQ251-EXT+REE	8.8	94.8	-	6.9	4.6	94.9	5.8	4.9
Pt	AQ251-EXT+REE	7.7	96.5	-	-	6.3	97.5	66.7	-
Rb	AQ251-EXT+REE	7.7	95.7	4.4	5.9	3.8	99.0	6.6	6.5
Re	AQ251-EXT+REE	-	-	-	-	-	-	42.1	29.9
S	AQ251-EXT+REE	24.6	85.0	-	13.2	6.5	88.6	13.7	3.5
Sb	AQ251-EXT+REE	6.4	96.7	11.4	14.7	6.1	94.4	12.7	14.1
Sc	AQ251-EXT+REE	9.0	91.9	5.0	5.6	7.1	96.7	6.4	4.0
Se	AQ251-EXT+REE	59.5		27.3	23.1	66.45	-	15.6	13.8
Sm	AQ251-EXT+REE	8.5	95.6	4.8	7.3	5.2	95.5	6.6	6.4
Sn	AQ251-EXT+REE	9.0	89.9	15.0	8.4	7.1	92.2	14.6	6.3
Sr	AQ251-EXT+REE	8.0	102.7	7.1	6.3	5.4	107.1	6.4	3.8
Ta	AQ251-EXT+REE	-	-	-	-	-	-	-	-
Tb	AQ251-EXT+REE	8.6	87.0	5.2	7.2	6.3	85.5	6.2	4.9
Te	AQ251-EXT+REE	-	-	23.5	21.3	14.1	-	24.3	25.6
Th	AQ251-EXT+REE	9.0	93.1	5.7	5.6	6.6	95.2	4.9	5.5
Ti	AQ251-EXT+REE	9.4	101.6	7.5	13.2	5.3	103.0	9.2	7.7
Tl	AQ251-EXT+REE	9.5	93.2	7.9	8.3	4.1	95.0	6.9	6.7
Tm	AQ251-EXT+REE	11.1	-	5.8	8.6	5.6	-	7.1	5.2
U	AQ251-EXT+REE	8.9	86.0	7.0	6.6	7.8	87.6	7.0	4.1
V	AQ251-EXT+REE	8.1	95.9	5.4	6.2	5.6	100.1	5.6	4.2
W	AQ251-EXT+REE	-	-	-	-	-	-	-	-
Y	AQ251-EXT+REE	8.3	94.9	5.4	7.4	4.1	96.7	6.4	3.8

		Till				Stream sediments			
Element	*Analytical method*	*%RSD (OREAS47)*	*APR (OREAS47)*	*Average RPD value (FDUP)*	*Average RPD value (ADUP)*	*%RSD (OREAS47)*	*APR (OREAS47)*	*Average RPD value (FDUP)*	*Average RPD value (ADUP)*
Yb	AQ251-EXT+REE	10.4	89.2	5.6	8.7	6.6	90.4	6.4	5.6
Zn	AQ251-EXT+REE	6.3	96.6	6.2	4.7	1.8	98.1	5.1	3.5
Zr	AQ251-EXT+REE	9.6	88.7	10.0	7.9	6.5	87.7	13.5	7.5
SiO_2	LF300	0.3	98.7	2.3	0.9	0.2	98.7	1.9	0.8
Al_2O_3	LF300	0.8	101.1	1.8	2.0	0.9	101.0	3.7	1.2
Cr_2O_3	LF300	6.5	89.9	7.8	7.8	4.1	91.4	6.6	10.7
CaO	LF300	0.9	100.6	12.9	8.8	0.9	101.0	11.1	2.6
Fe_2O_3	LF300	1.2	101.3	2.9	2.7	1.1	101.3	5.4	2.3
K_2O	LF300	1.5	101.4	2.4	2.4	1.7	101.0	3.5	1.8
MgO	LF300	1.0	102.7	5.3	2.4	0.8	103.0	6.9	1.7
MnO	LF300	7.6	102.6	11.0	5.0	5.3	107.0	15.6	0.6
Na_2O	LF300	1.2	99.0	6.8	5.6	0.9	98.9	4.8	1.6
P_2O_5	LF300	4.0	96.7	5.3	3.9	6.0	98.7	6.4	3.2
TiO_2	LF300	1.2	99.9	2.3	2.0	1.3	100.8	2.1	1.1
Ba	LF300	1.5	98.2	7.2	2.5	1.6	99.8	4.3	2.4
Nb	LF300	12.4	99.3	16.3	18.1	13.9	105.9	19.1	19.8
Ni	LF300	3.2	95.9	10.8	17.4	4.5	96.3	27.2	23.5
Sc	LF300	0.0	97.1	2.8	2.8	0.0	97.1	5.3	3.2
Sr	LF300	1.0	99.1	2.8	3.7	1.0	99.2	4.1	1.3
Y	LF300	4.5	95.6	3.7	4.7	4.4	94.8	6.2	2.6
Zr	LF300	2.8	100.5	6.0	5.1	3.1	101.0	14.1	5.6
Ag	LF100-EXT	0.0	-	17.7	13.7	9.8	-	13.4	4.6
As	LF100-EXT	3.1	-	10.2	7.1	4.9	-	10.4	5.0
Au	LF100-EXT	6.8	-	16.2	27.2	6.9	-	39.8	47.73
Ba	LF100-EXT	4.6	96.6	7.8	4.8	3.6	98.5	4.2	3.3
Be	LF100-EXT	85.8	150.2	89.5	87.3	75.3	150.7	74.2	83.0
Bi	LF100-EXT	0.0	-	9.0	8.9	28.6	-	17.4	14.5
Cd	LF100-EXT	4.1	-	14.1	12.0	12.7	-	11.5	10.9
Ce	LF100-EXT	5.5	98.1	3.7	5.6	5.6	98.1	5.7	6.8
Co	LF100-EXT	5.9	97.6	7.5	7.0	4.0	97.8	7.7	5.6
Cs	LF100-EXT	7.3	94.1	4.1	9.0	8.1	96.6	9.6	6.5
Cu	LF100-EXT	2.2	-	7.4	6.6	3.1	-	8.8	4.4
Dy	LF100-EXT	5.7	95.8	4.3	5.3	5.9	99.5	4.7	6.3

		Till				Stream sediments			
Element	*Analytical method*	*%RSD (OREAS47)*	*APR (OREAS47)*	*Average RPD value (FDUP)*	*Average RPD value (ADUP)*	*%RSD (OREAS47)*	*APR (OREAS47)*	*Average RPD value (FDUP)*	*Average RPD value (ADUP)*
Er	LF100-EXT	5.1	97.1	5.3	5.9	5.7	98.8	7.0	5.8
Eu	LF100-EXT	5.0	96.9	4.5	5.5	4.4	96.9	6.8	6.6
Ga	LF100-EXT	6.9	90.7	4.0	7.2	4.9	94.2	6.3	5.7
Gd	LF100-EXT	3.9	101.1	4.0	4.7	4.8	100.6	5.7	4.2
Hg	LF100-EXT	4.5	95.5	7.7	6.0	5.0	97.6	12.6	5.2
Hf	LF100-EXT	37.1	-	11.2	9.6	34.2	-	14.1	18.3
Ho	LF100-EXT	4.7	92.0	4.4	5.8	6.3	95.8	5.8	5.9
La	LF100-EXT	5.0	100.3	4.1	4.9	5.8	99.9	4.6	5.6
Lu	LF100-EXT	7.2	97.8	5.2	6.4	7.2	100.0	6.4	4.7
Mo	LF100-EXT	3.2	95.9	15.7	12.1	3.6	97.9	11.8	9.0
Nb	LF100-EXT	5.3	89.5	3.4	5.3	3.4	90.8	4.2	4.7
Nd	LF100-EXT	4.5	98.8	3.4	5.3	4.9	99.0	5.1	5.7
Ni	LF100-EXT	2.2	88.7	6.5	6.4	3.3	88.0	7.9	3.6
Pb	LF100-EXT	4.7	-	4.6	5.1	4.4	-	7.2	5.1
Pr	LF100-EXT	4.4	99.0	2.6	4.0	3.9	99.7	4.9	4.7
Rb	LF100-EXT	4.7	97.6	3.0	5.1	3.1	98.4	4.8	3.1
Sb	LF100-EXT	0.0	-	12.6	11.4	13.9	-	12.8	12.3
Se	LF100-EXT	-	-	42.2	27.6	-	-	18.8	14.1
Sm	LF100-EXT	4.5	93.7	3.6	5.6	5.2	93.8	5.3	5.0
Sn	LF100-EXT	9.7	102.0	27.2	26.2	22.3	102.7	34.6	45.3
Sr	LF100-EXT	6.0	97.4	3.1	5.5	5.3	99.0	4.8	3.9
Ta	LF100-EXT	14.6	94.5	11.8	10.6	17.0	89.5	16.9	10.7
Tb	LF100-EXT	4.3	95.2	3.5	5.6	4.7	96.7	5.5	4.5
Th	LF100-EXT	5.4	99.5	4.3	5.2	4.0	101.8	7.0	7.1
Tl	LF100-EXT	-	-	5.9	7.5	-	-	11.6	14.1
Tm	LF100-EXT	5.5	92.1	5.0	7.2	7.0	94.3	6.0	5.3
U	LF100-EXT	10.1	96.3	7.4	8.0	11.0	99.3	9.5	6.5
V	LF100-EXT	6.1	94.4	5.2	7.5	7.6	96.9	6.4	4.8
W	LF100-EXT	-	-	22.3	24.2	-	-	29.3	28.1
Y	LF100-EXT	5.1	96.7	4.3	7.2	3.6	96.0	5.7	4.5
Yb	LF100-EXT	4.7	99.0	4.1	5.6	5.3	98.0	6.6	5.6
Zn	LF100-EXT	2.5	97.4	6.9	5.4	3.4	98.3	6.1	4.1
Zr	LF100-EXT	5.0	95.9	6.4	6.5	4.6	98.5	11.6	5.3

4.2 Catchment Basin and Till Geochemistry

Using both stream sediment and till geochemistry is an effective way to determine prospectivity because both materials can be a first derivative of bedrock. Alternatively, the stream sediments may be derived from the till as a second derivative of bedrock and still provide a predictable relationship to bedrock. Areas with anomalous till and/or stream sediments are considered prospective, especially if the results of the two materials correlate spatially. All till and stream sediment geochemical analytical results are provided in Appendix A in spreadsheet (*i.e.,* MS Excel) and tab-delimited formats. Catchment basins are also provided in shapefile format in Appendix A. Lab certificates are provided in Appendix B.

A total of 398 catchment basins were delineated for the stream sediment samples, including 176 in the southern part of AOI-1 (Figure 9), 121 in AOI-2 (Figure 10), and 224 in AOI-3 (Figure 11). Analytical results from the geochemical stream sediment samples were attributed to the resulting catchments. Catchments were symbolized by colour based on their respective anomaly classes for a suite of elements related to mineralization in Alberta (Figures 12-75). Included in figures 12-75 are proportional-dot plots representing the till geochemistry. Anomaly classes are based on standard progressive percentiles that are calculated separately for each material type and AOI to reduce the influence of geographic variation on the data presentation.

Figures 12-75 provide a basic symbolization of the data, and additional evaluation can be completed to refine the results. For example, the catchment basins are intended to delineate the potential bedrock source area of the stream sediments; however, they do not indicate how reliably the stream sediments represent bedrock composition. There are several factors that can be considered when evaluating the reliability of catchment data to represent bedrock composition and indicate mineralization. In large catchments, geochemical concentrations can become diluted, and it may be difficult to recognize anomalies representing mineralization (Hawkes, 1976). Where sediments are thick, the streams may not interface with the bedrock, and as a result, the stream sediments will be composed of remobilized surficial material that may have been derived from beyond the catchment basin. When the sediment is dominantly composed of till, the transport vectors of till can be used to estimate potential source areas beyond the catchment basin. Glaciofluvial or glaciolacustrine deposits, however, may have more complex transport histories and are less likely to represent local bedrock. Provided herein are the treated data attributed to the catchments without any consideration for these factors, and therefore, there may still be mineral potential within catchments related to stream sediment samples that do not appear anomalous.

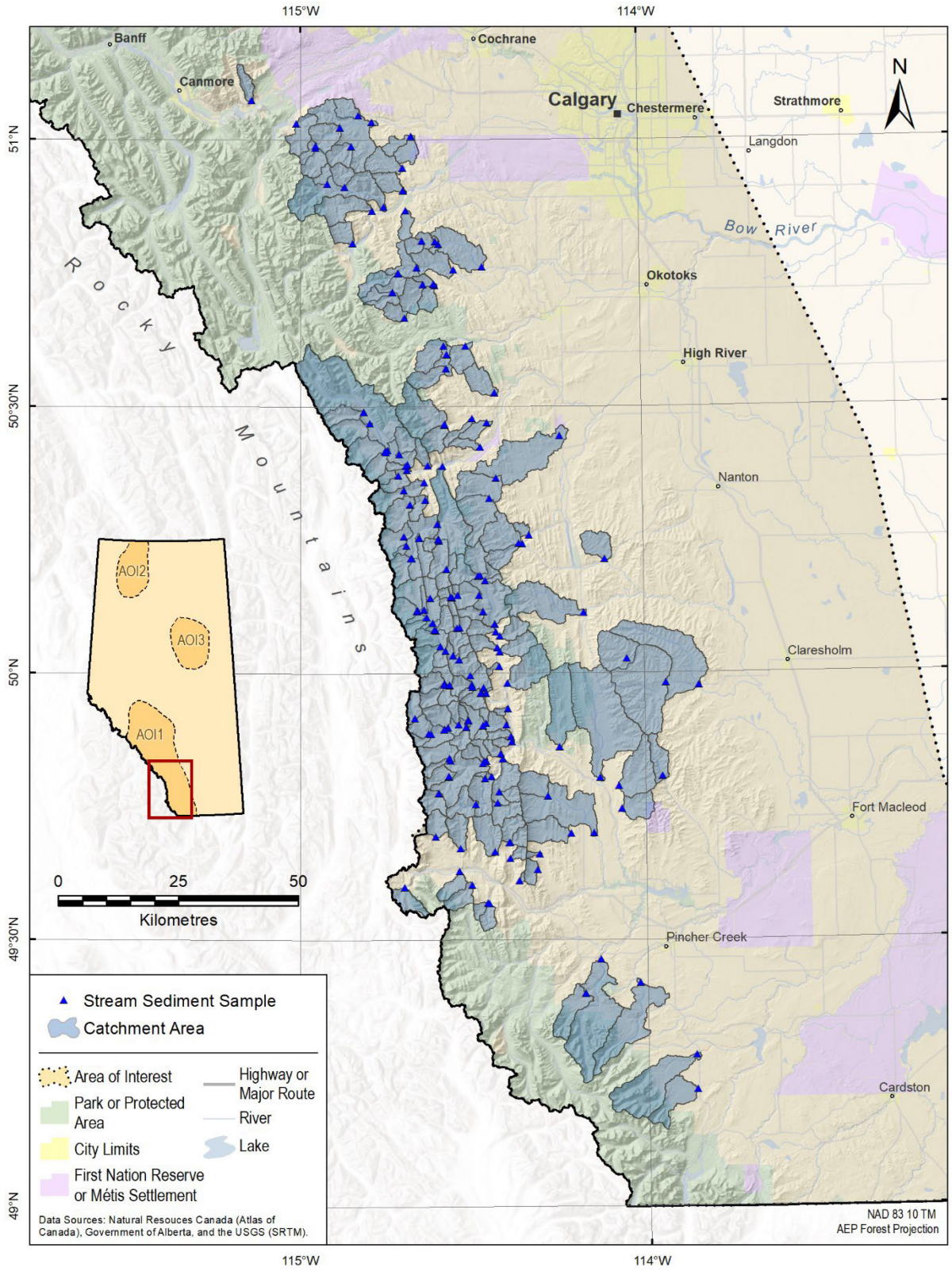

Figure 9. Stream sediment sample locations and their associated catchments in AOI-1. Stream sediment samples were not collected from the northern portion of AOI-1.

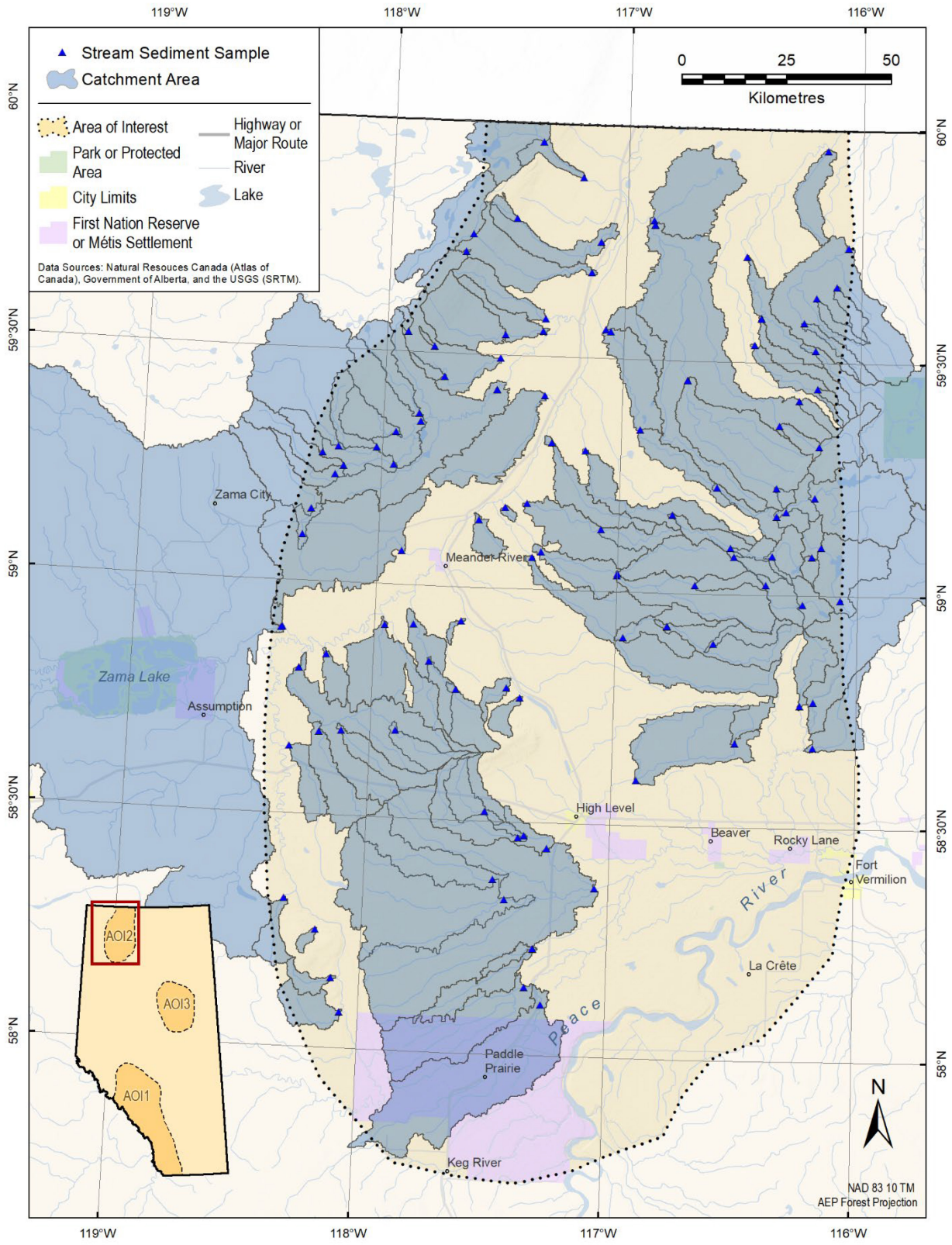

Figure 10. Stream sediment sample locations and their associated catchments in AOI-2.

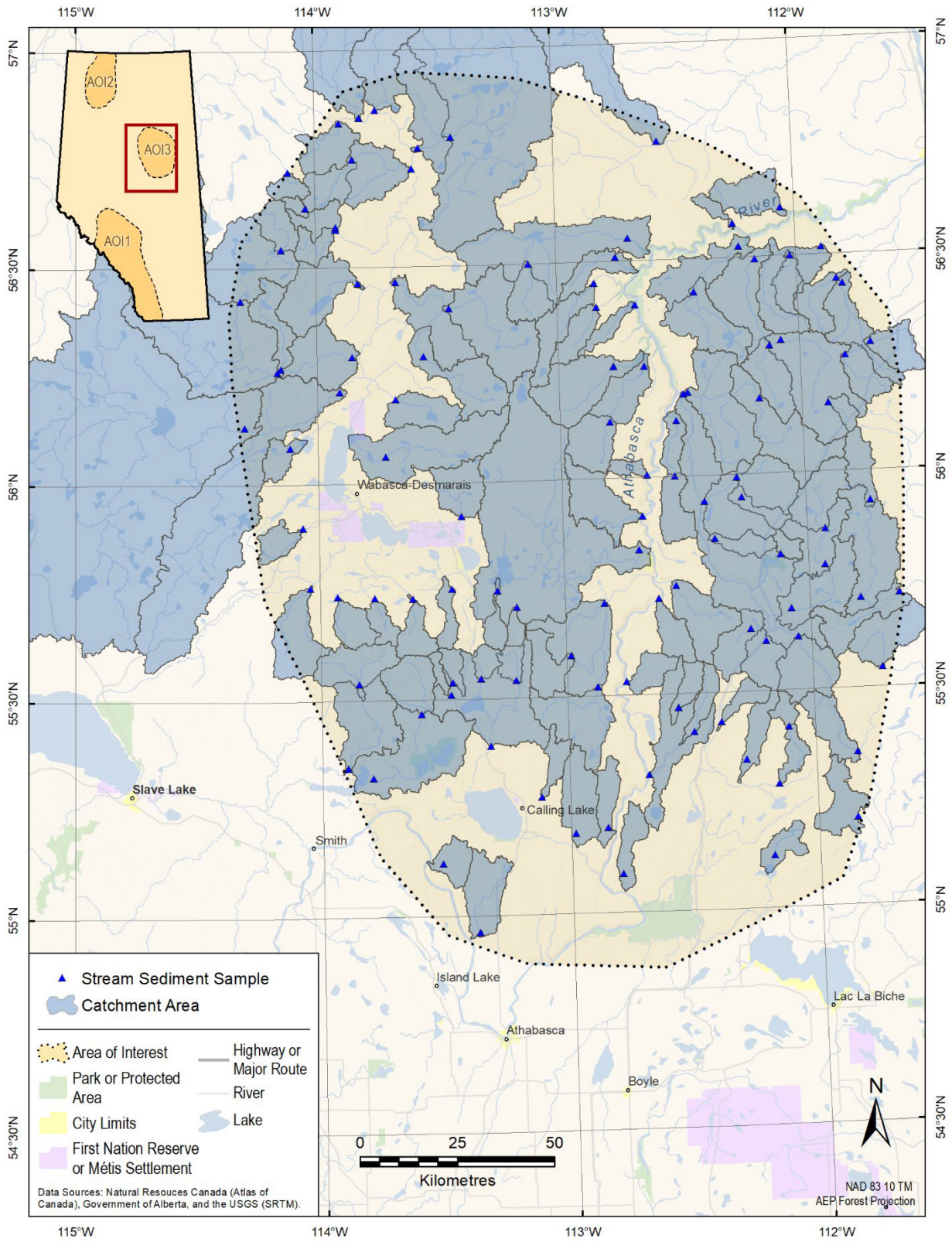

Figure 11. Stream sediment sample locations and their associated catchments in AOI-3.

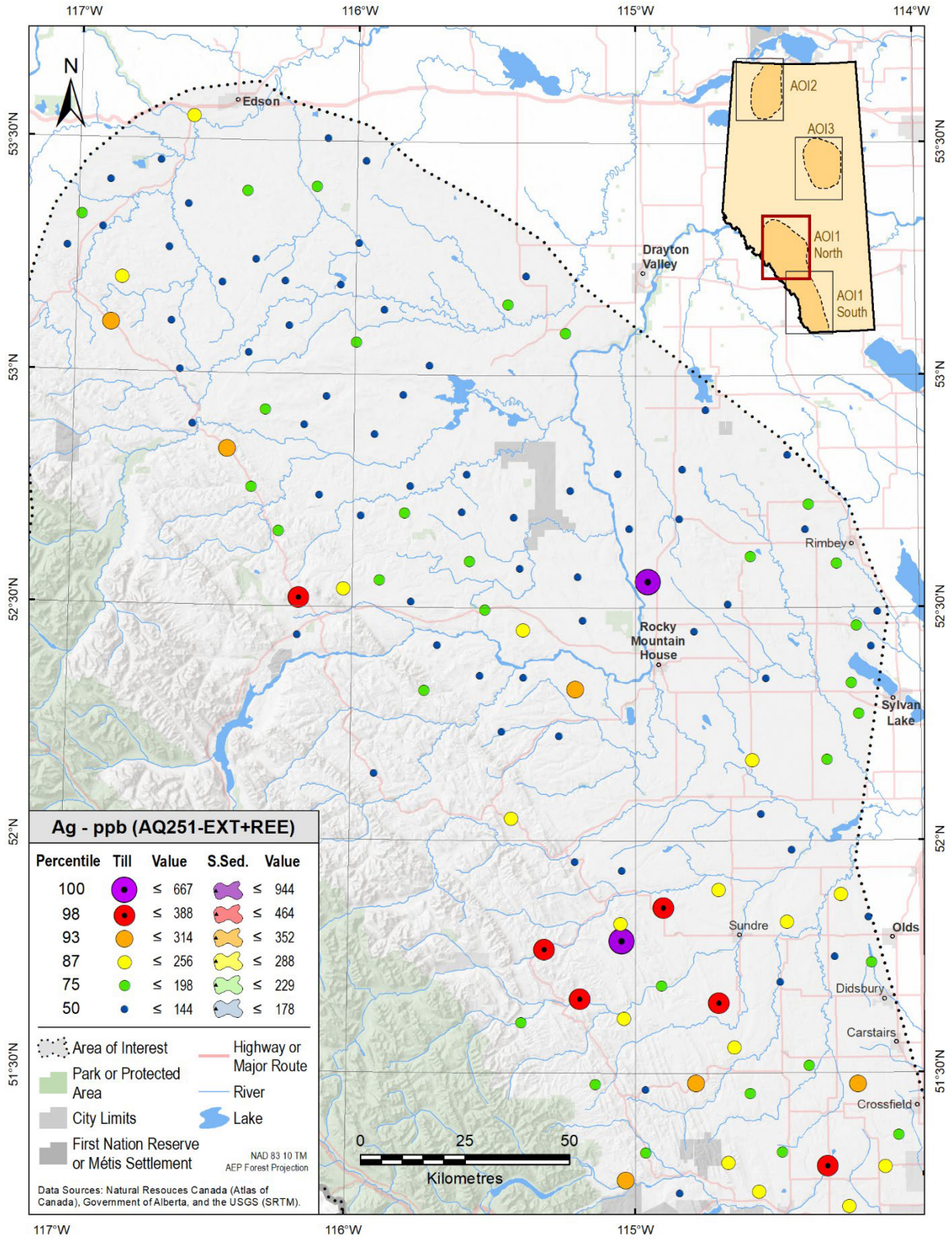

Figure 12. Silver (Ag) concentrations in till in the northern half of AOI-1.

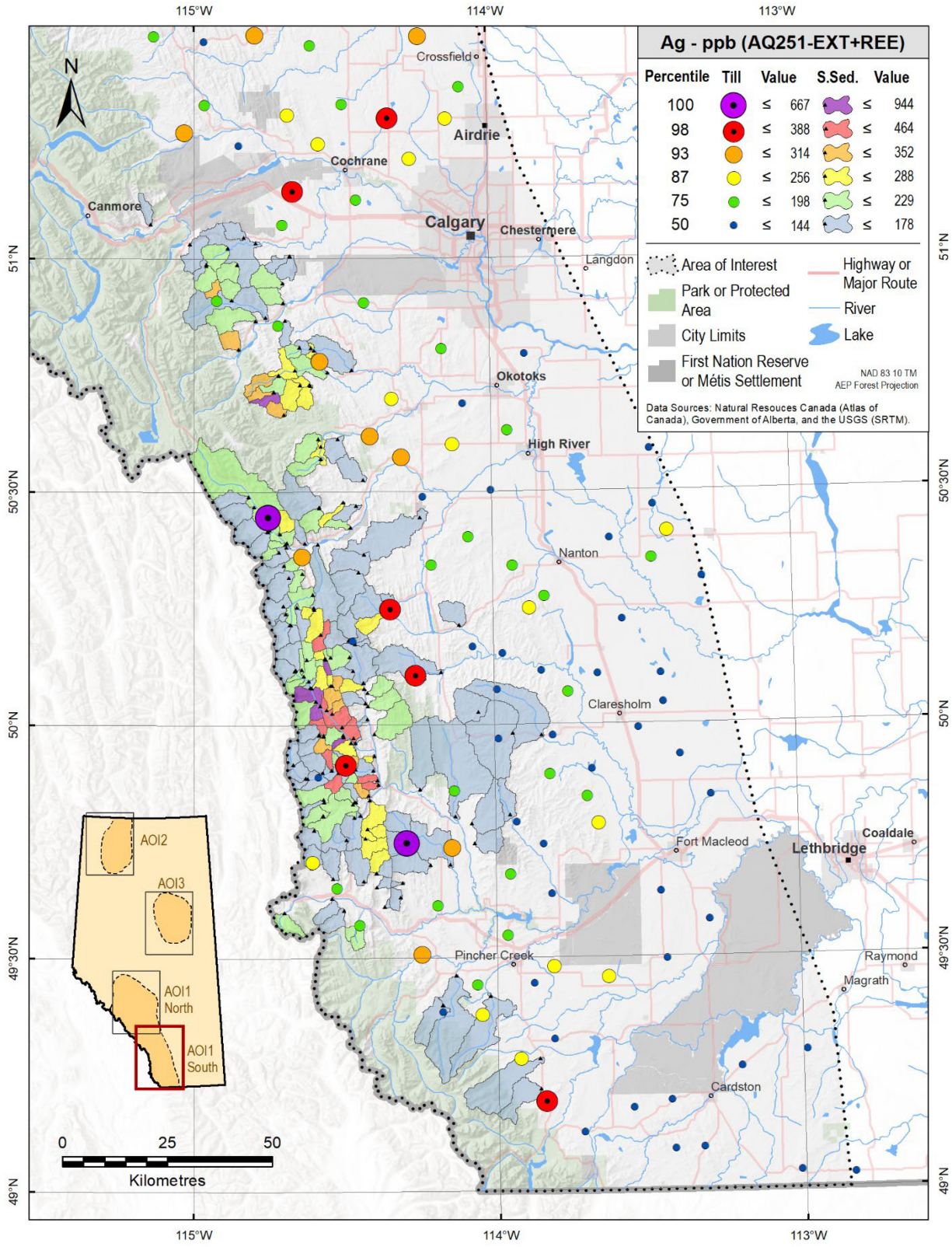

Figure 13. Silver (Ag) concentrations in till and stream sediments in the southern half of AOI-1.

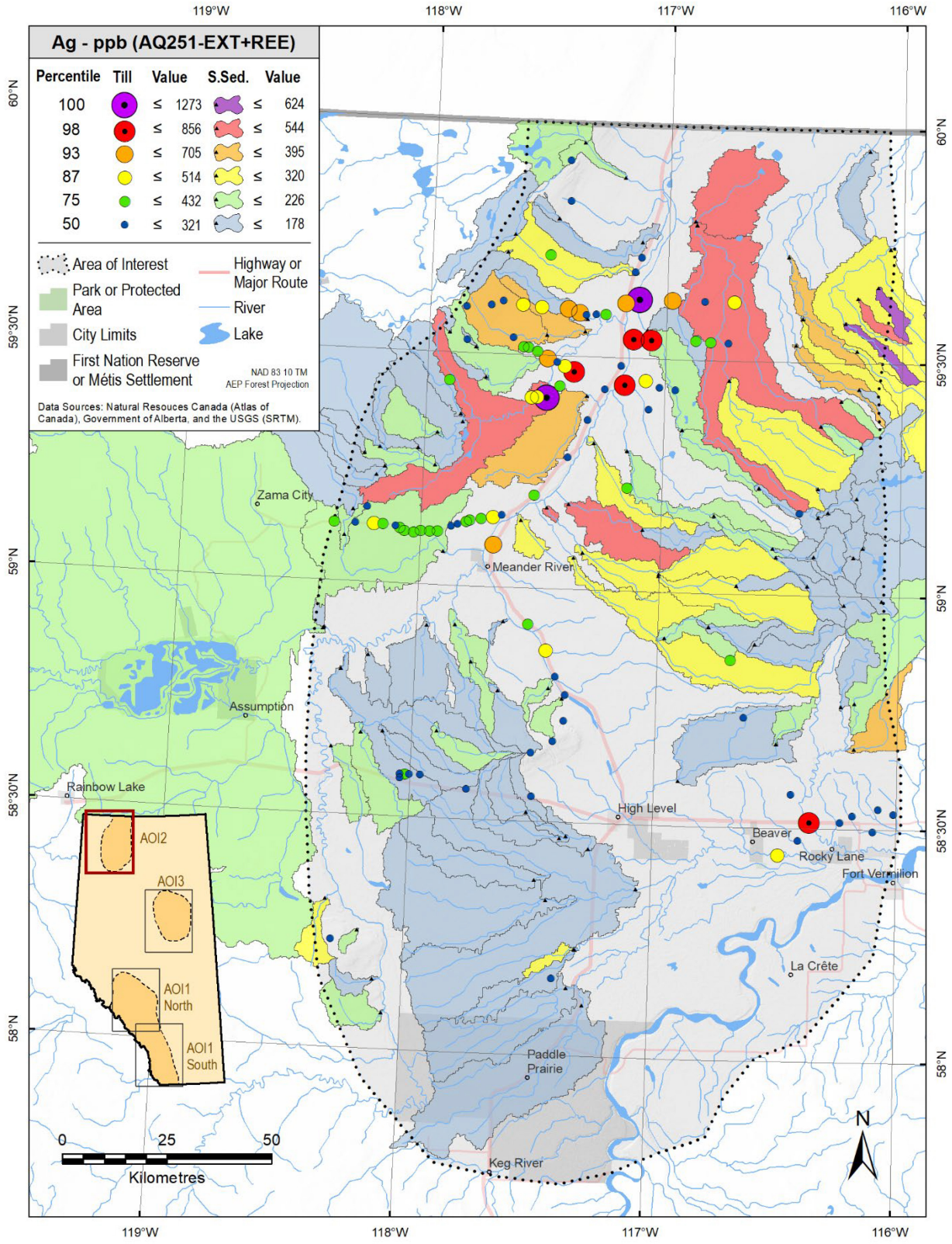

Figure 14. Silver (Ag) concentrations in till and stream sediments in AOI-2.

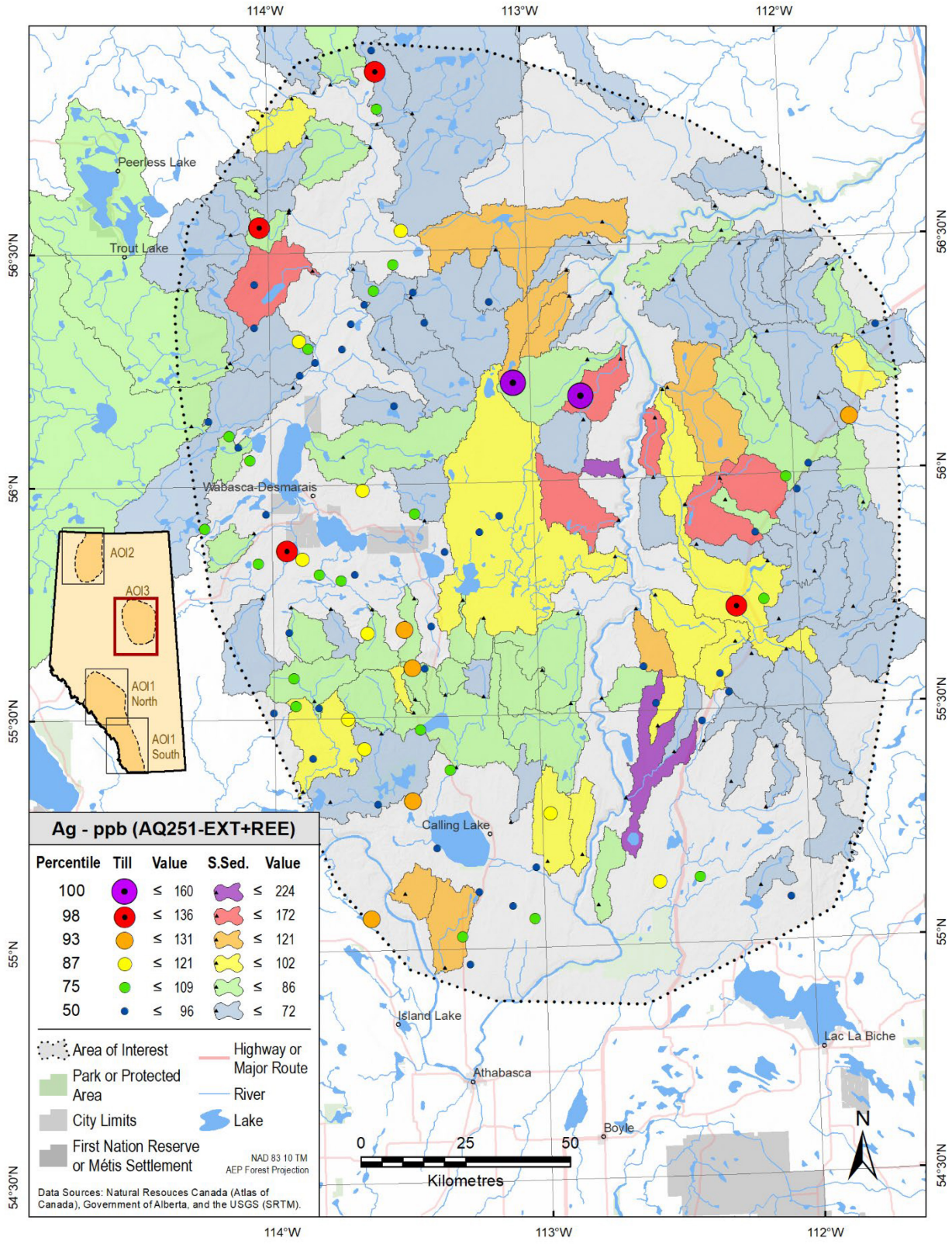

Figure 15. Silver (Ag) concentrations in till and stream sediments in AOI-3.

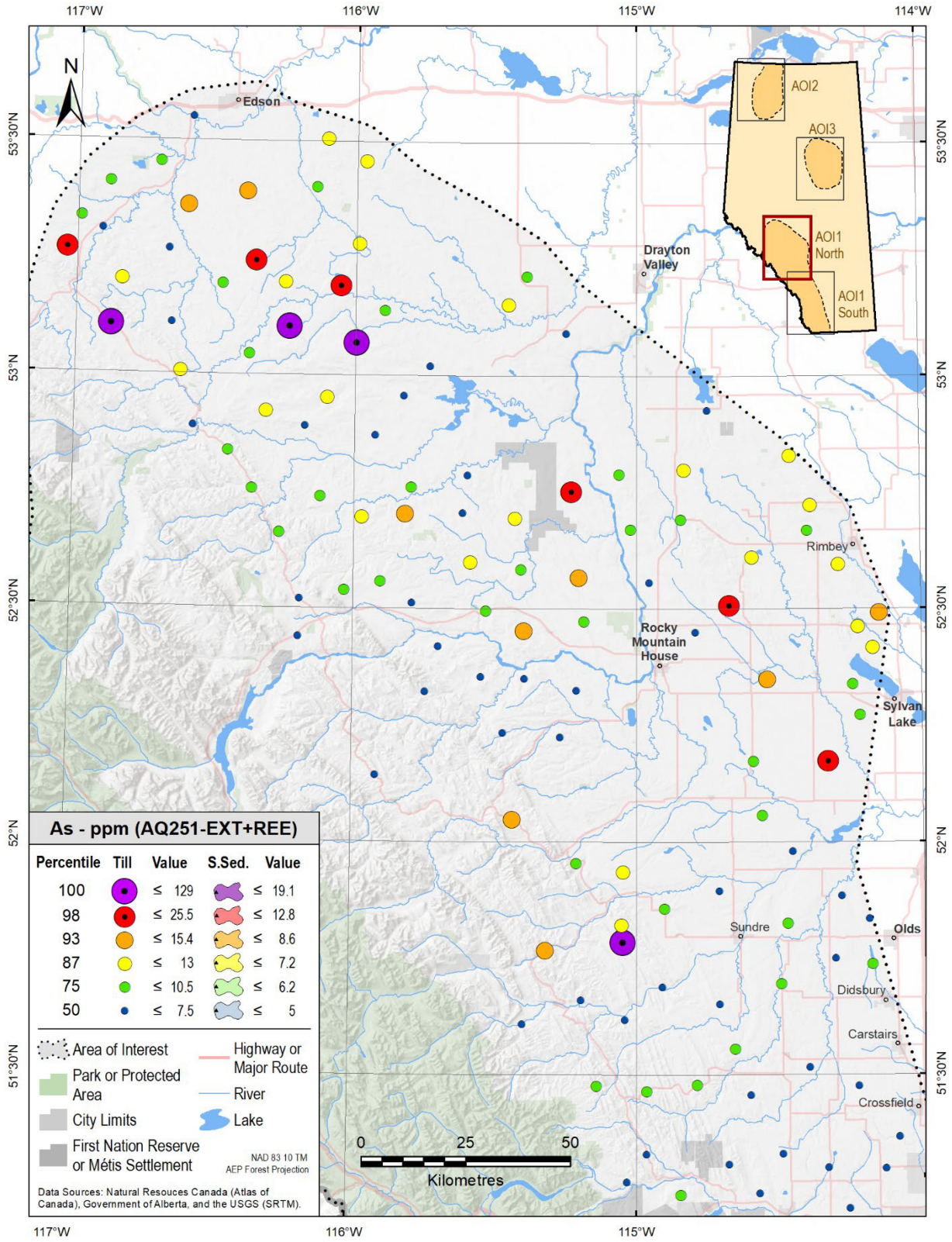

Figure 16. Arsenic (As) concentrations in till in the northern half of AOI-1.

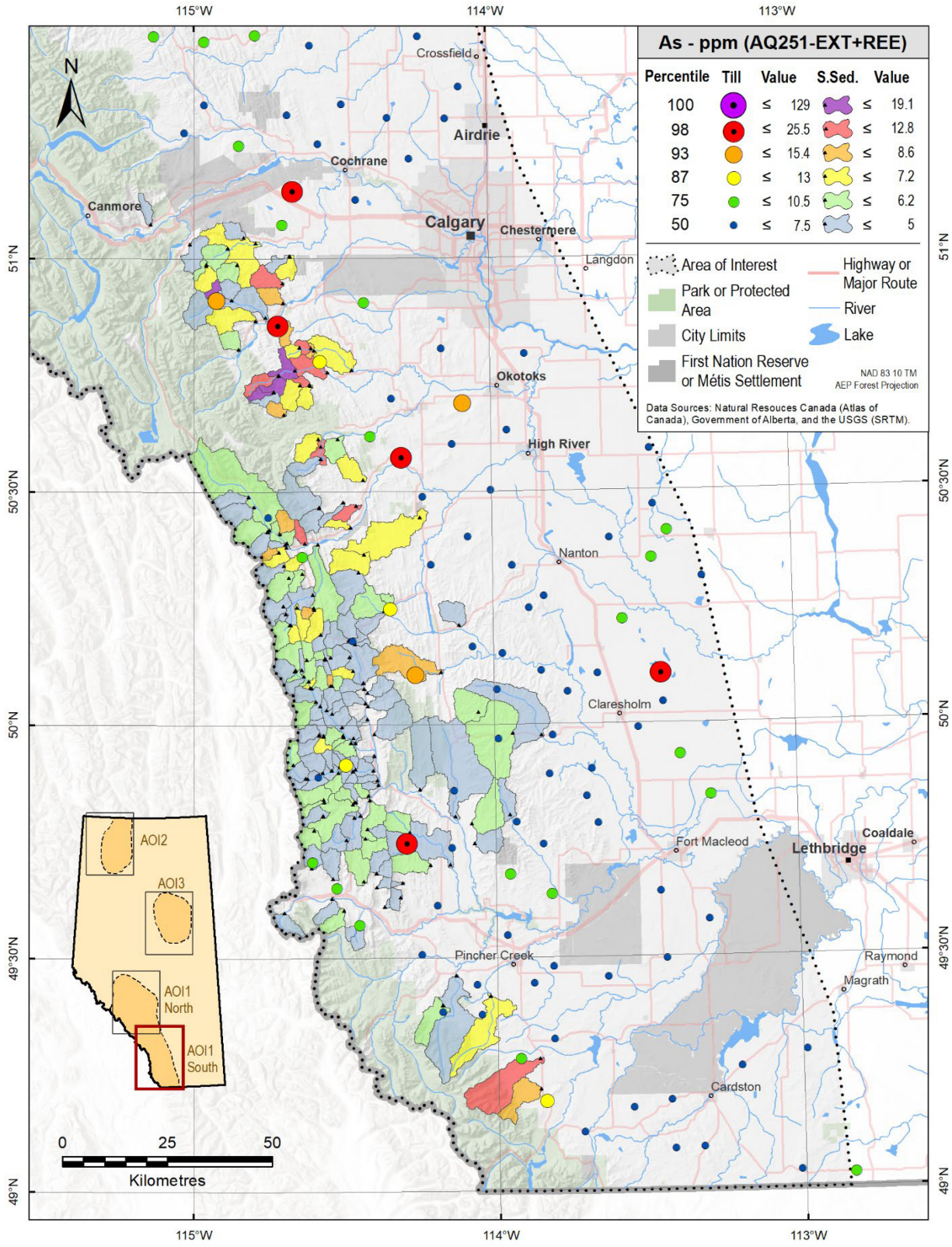

Figure 17. Arsenic (As) concentrations in till and stream sediments in the southern half of AOI-1.

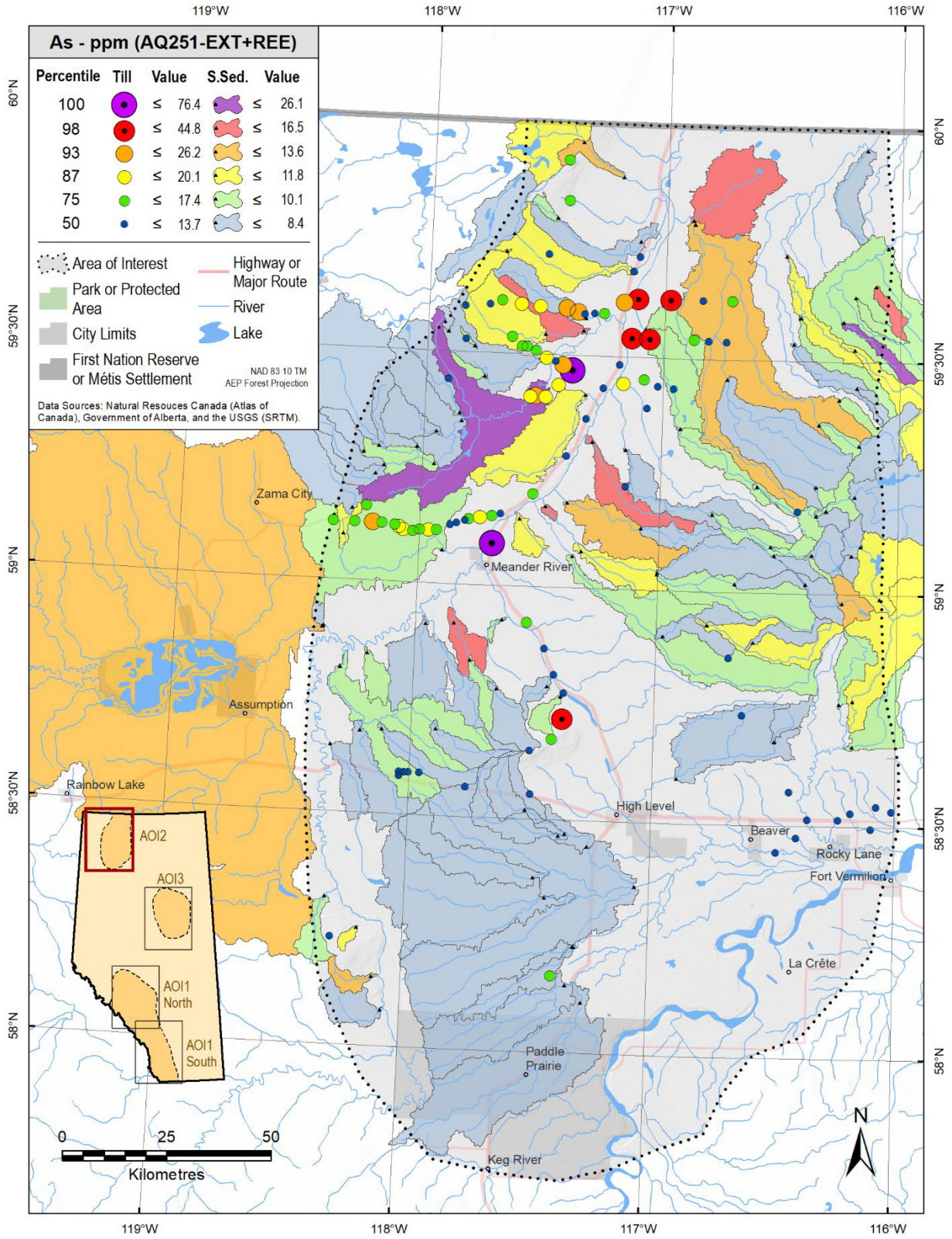

Figure 18. Arsenic (As) concentrations in till and stream sediments in AOI-2.

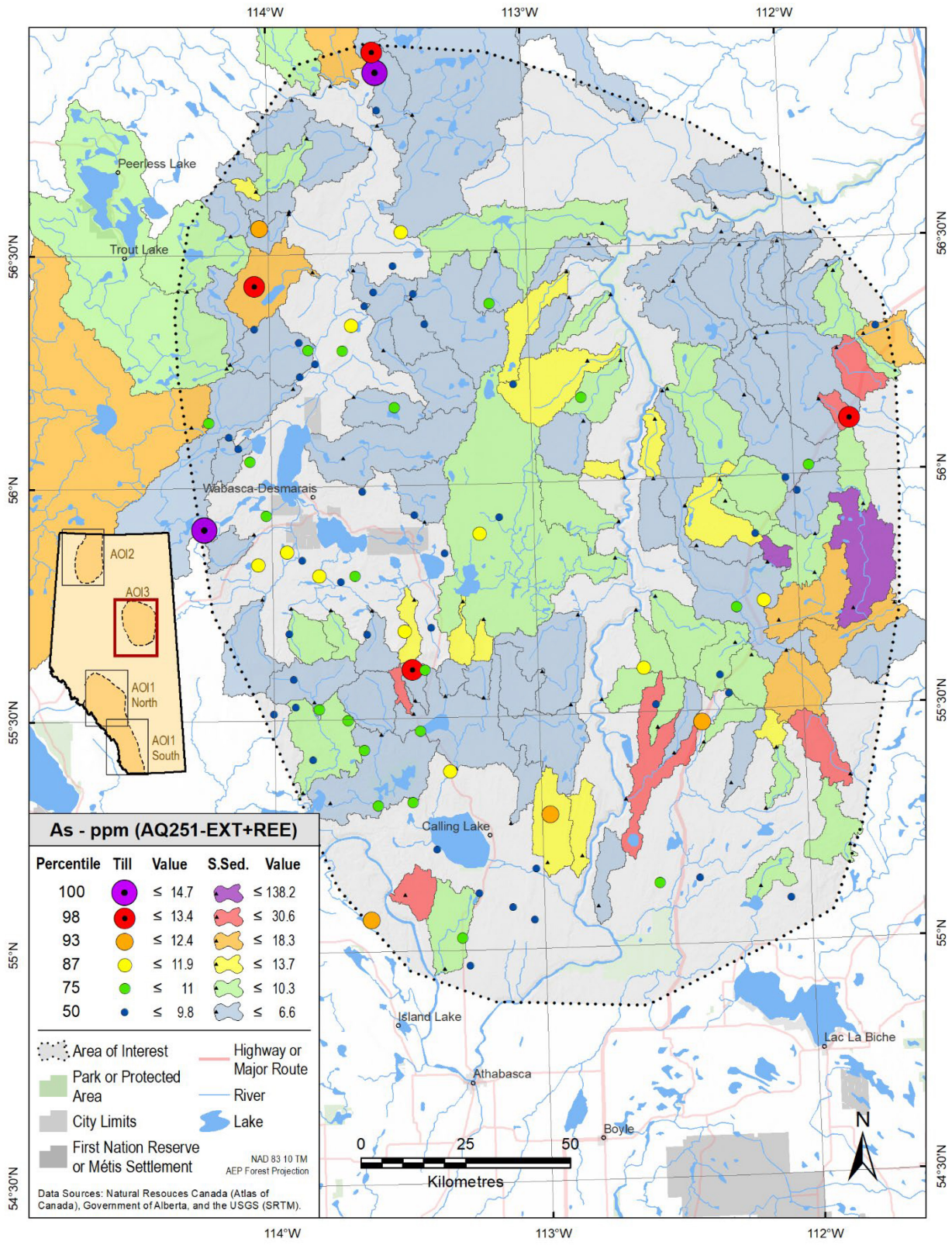

Figure 19. Arsenic (As) concentrations in till and stream sediments in AOI-3.

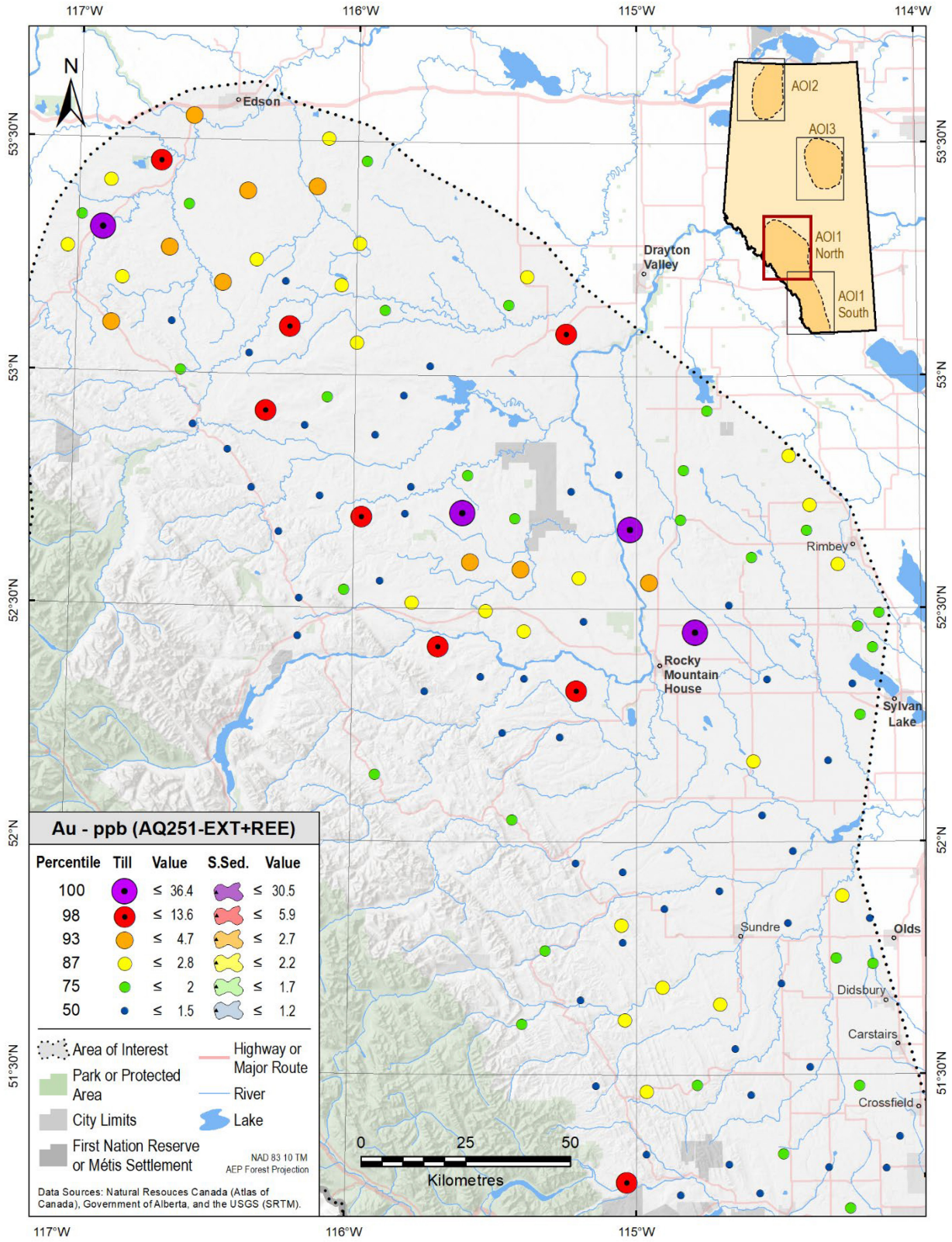

Figure 20. Gold (Au) concentrations in till in the northern half of AOI-1.

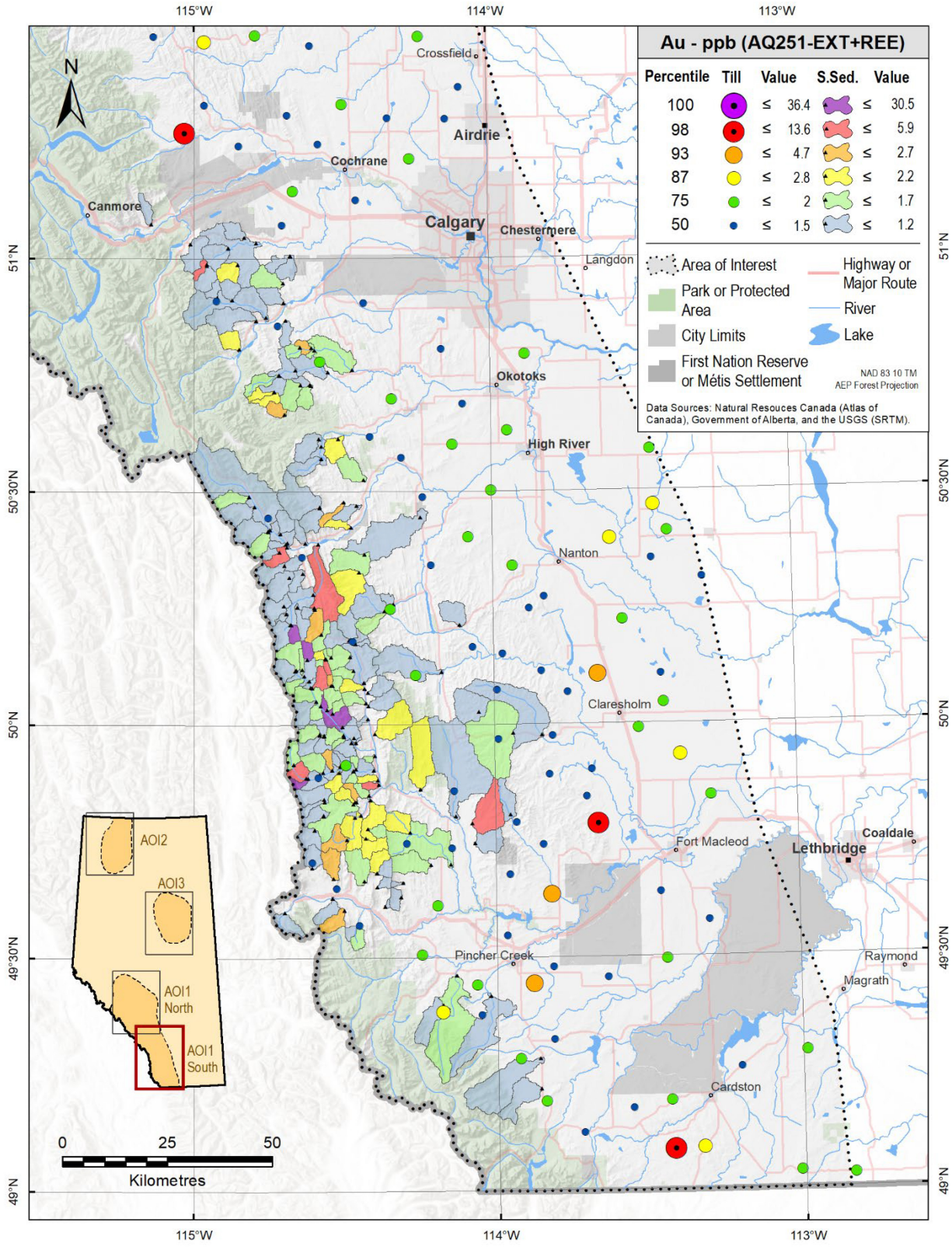

Figure 21. Gold (Au) concentrations in till and stream sediments in the southern half of AOI-1.

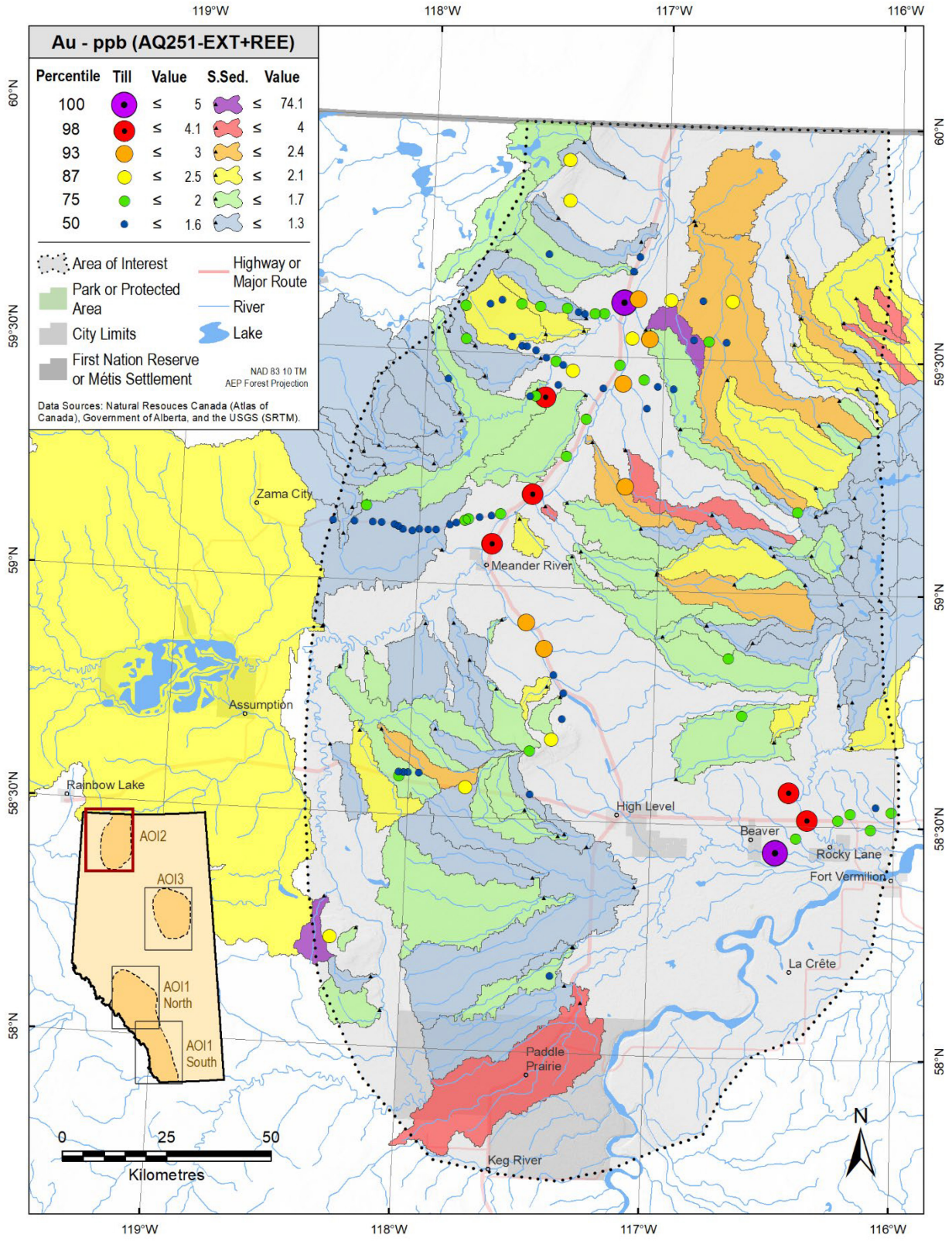

Figure 22. Gold (Au) concentrations in till and stream sediments in AOI-2.

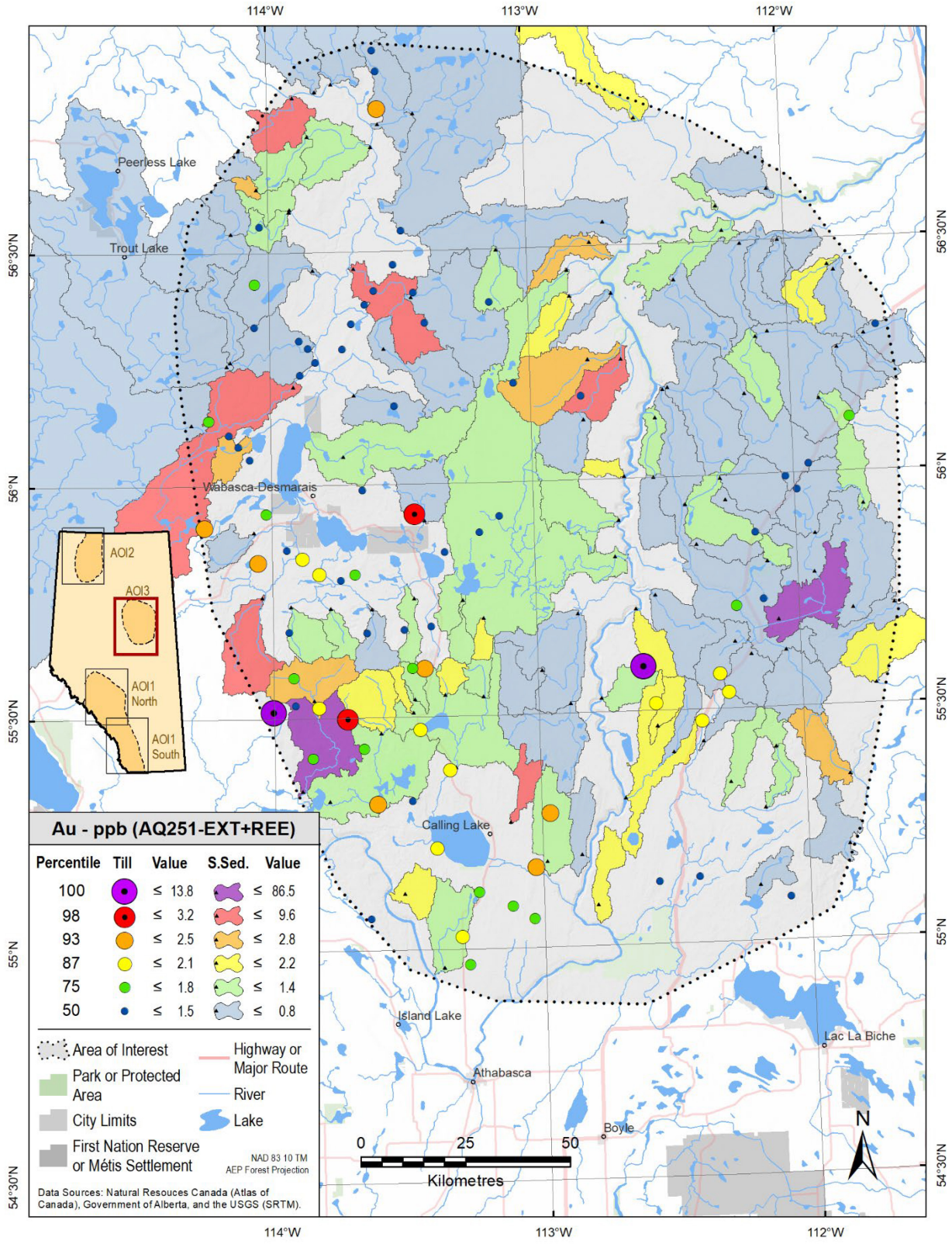

Figure 23. Gold (Au) concentrations in till and stream sediments in AOI-3.

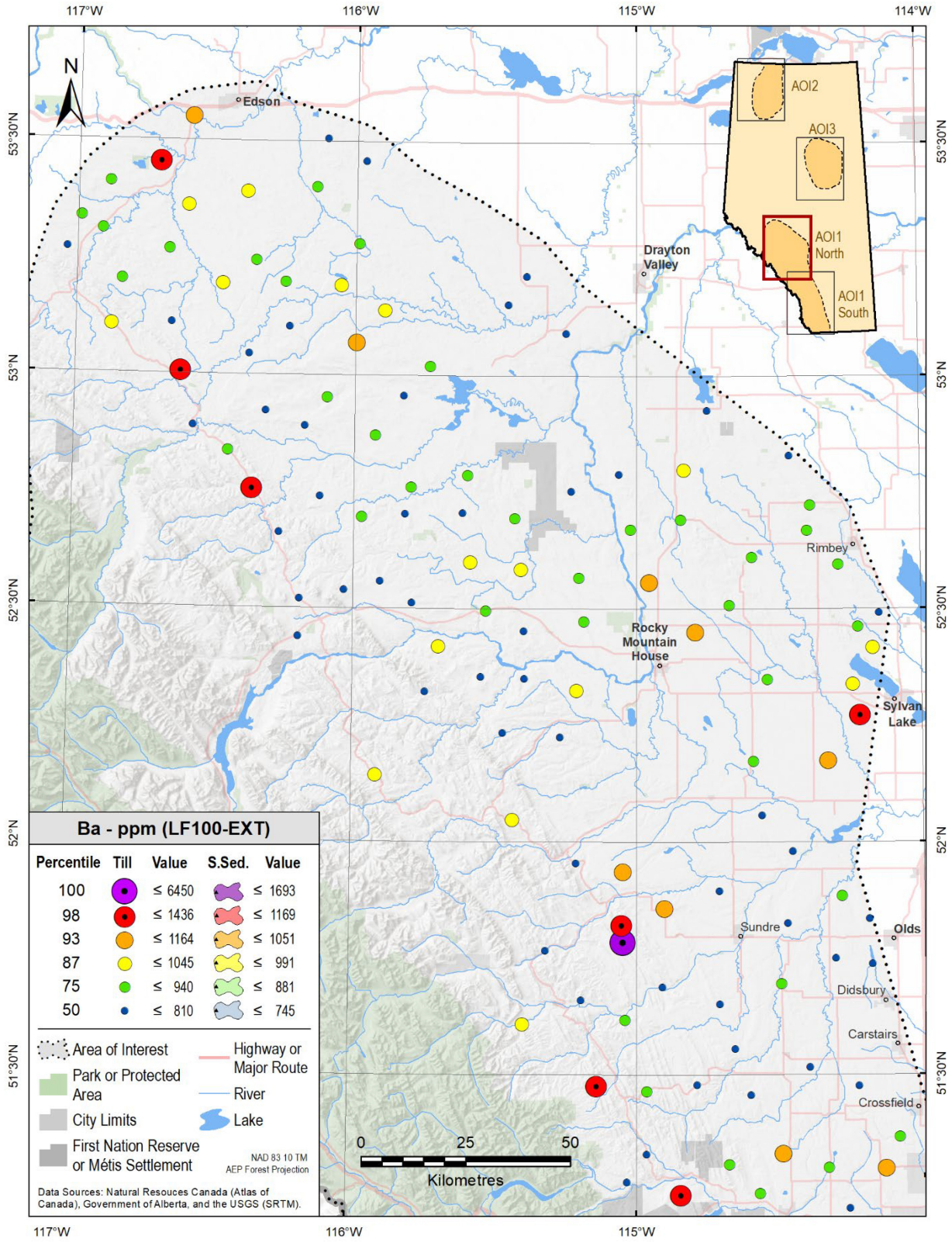

Figure 24. Barium (Ba) concentrations in till in the northern half of AOI-1.

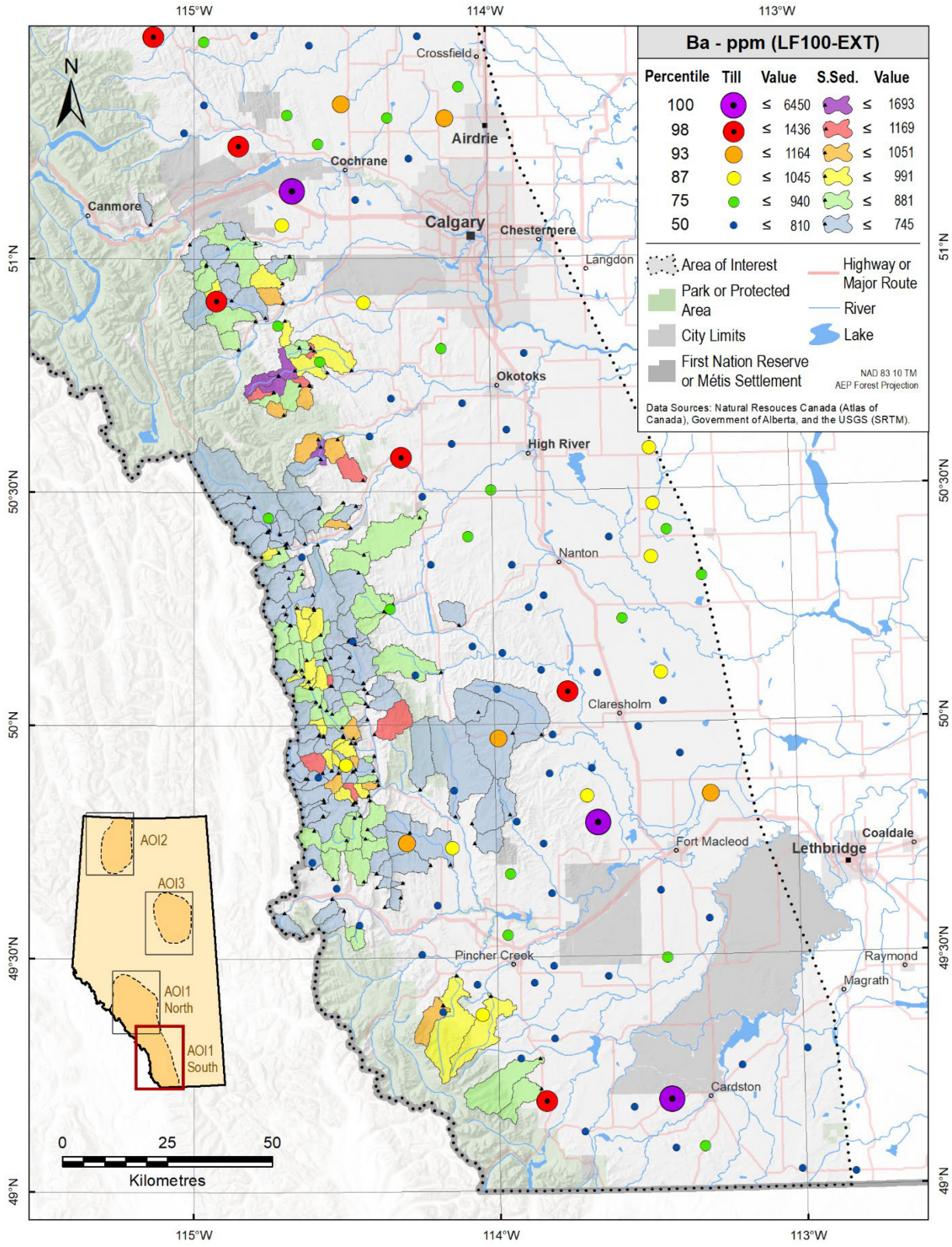

Figure 25. Barium (Ba) concentrations in till and stream sediments in the southern half of AOI-1.

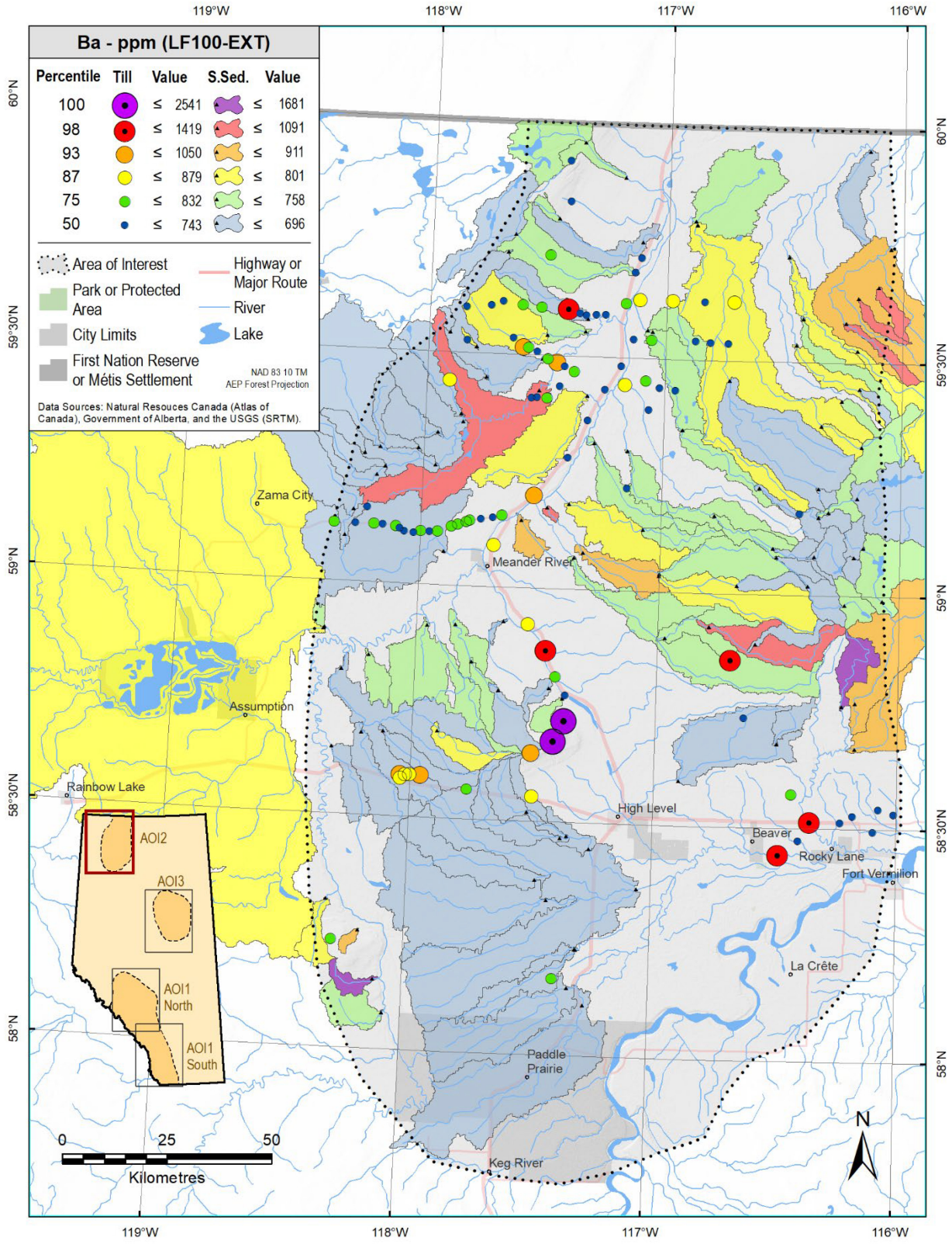

Figure 26. Barium (Ba) concentrations in till and stream sediments in AOI-2.

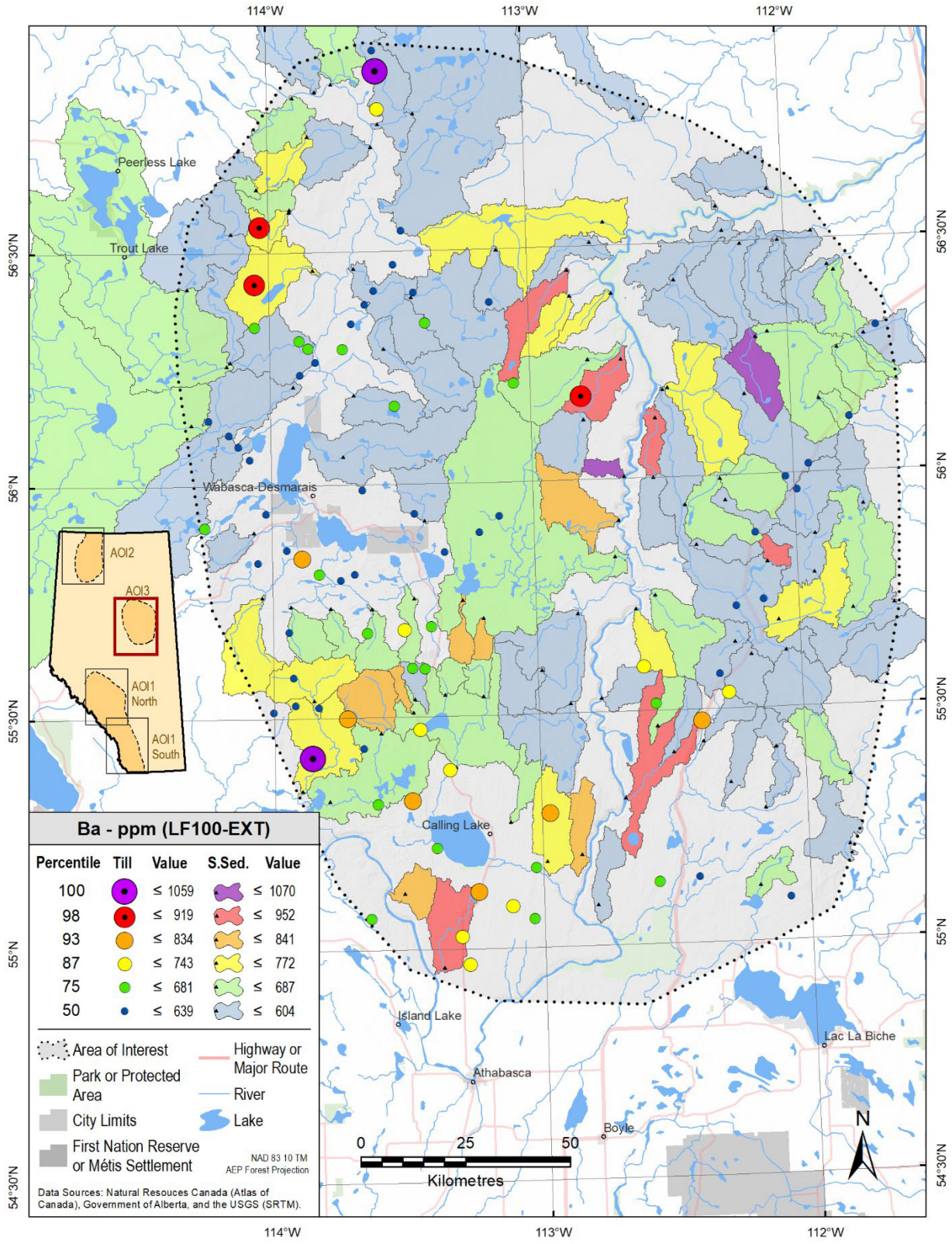

Figure 27. Barium (Ba) concentrations in till and stream sediments in AOI-3.

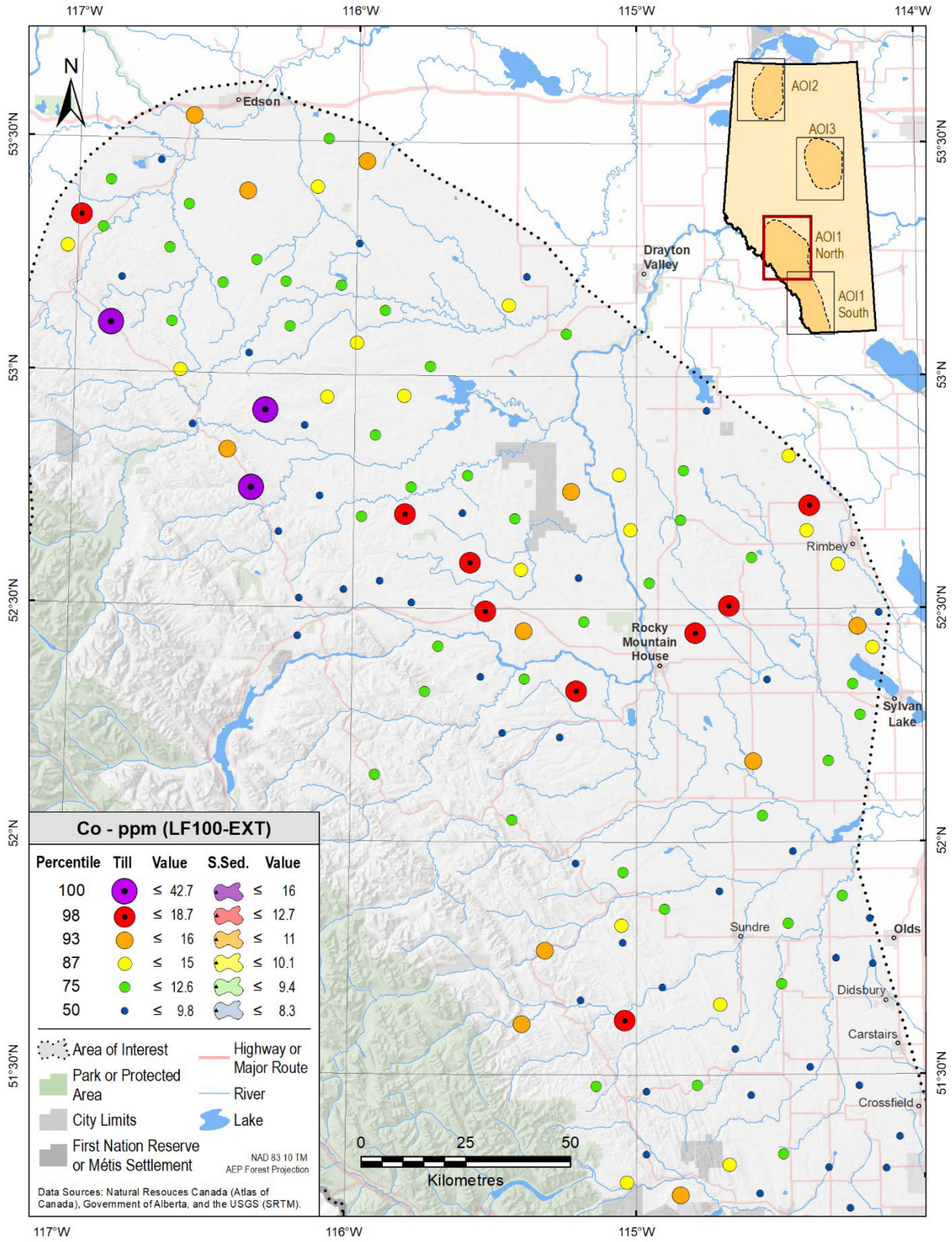

Figure 28. Cobalt (Co) concentrations in till in the northern half of AOI-1.

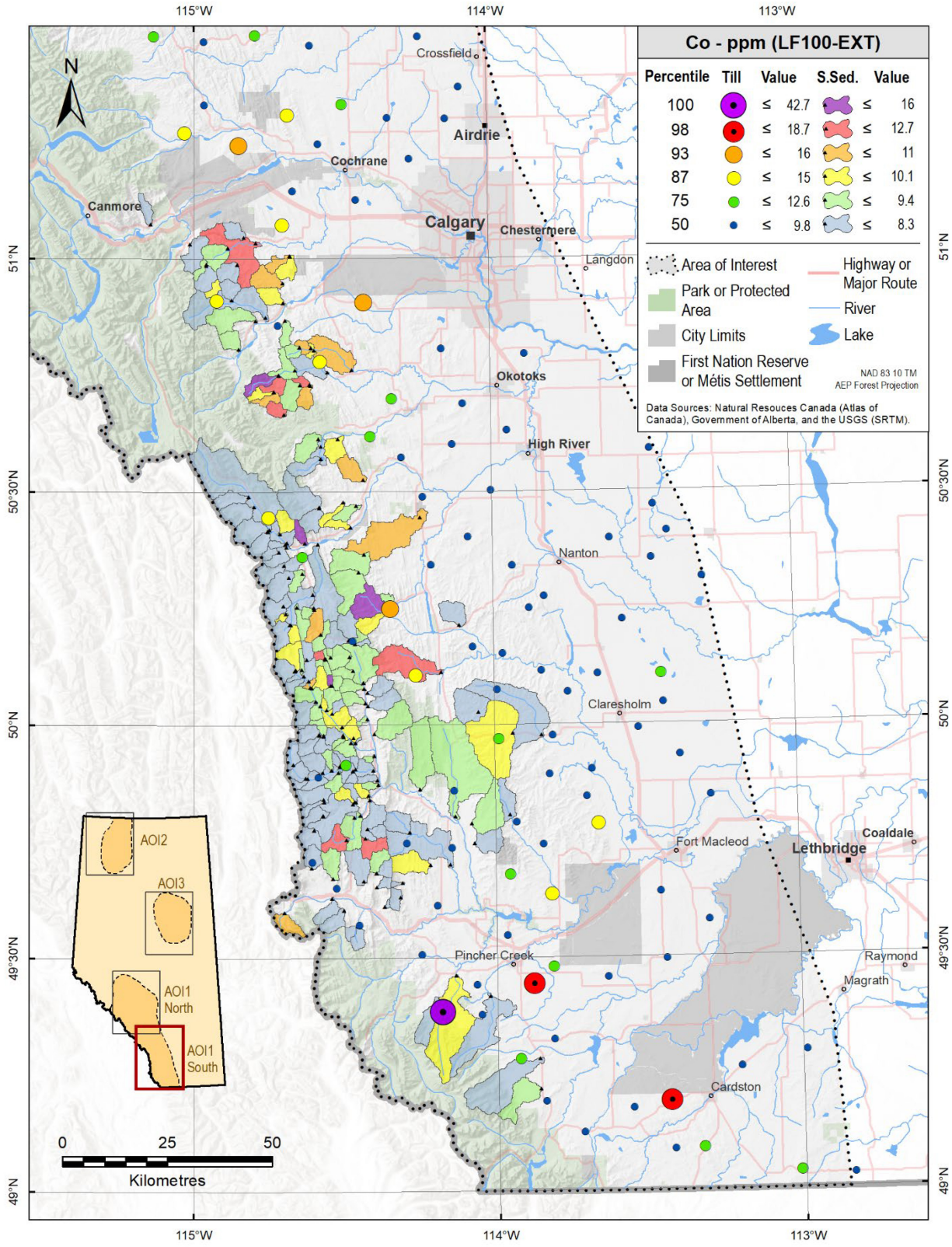

Figure 29. Cobalt (Co) concentrations in till and stream sediments in the southern half of AOI-1.

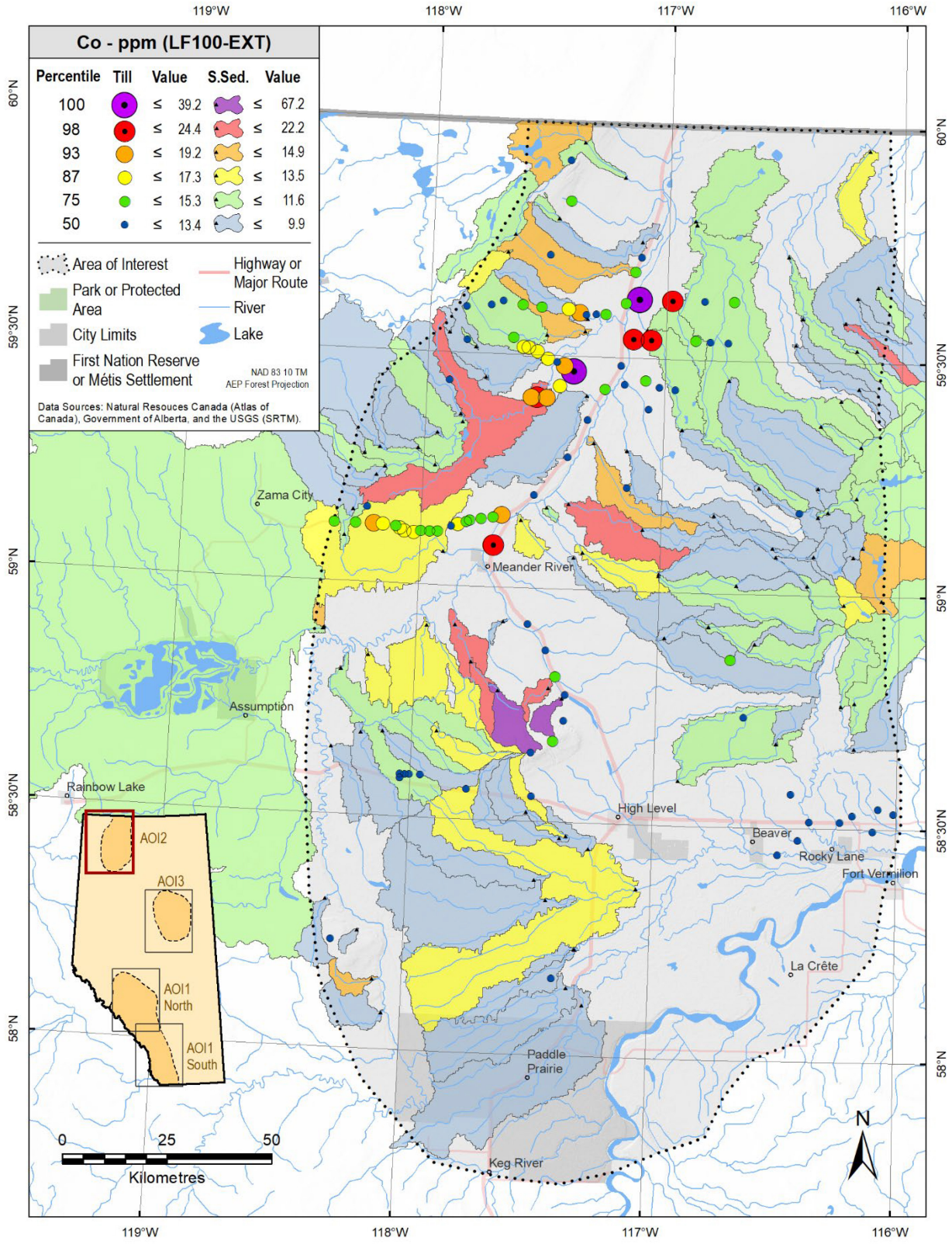

Figure 30. Cobalt (Co) concentrations in till and stream sediments in AOI-2.

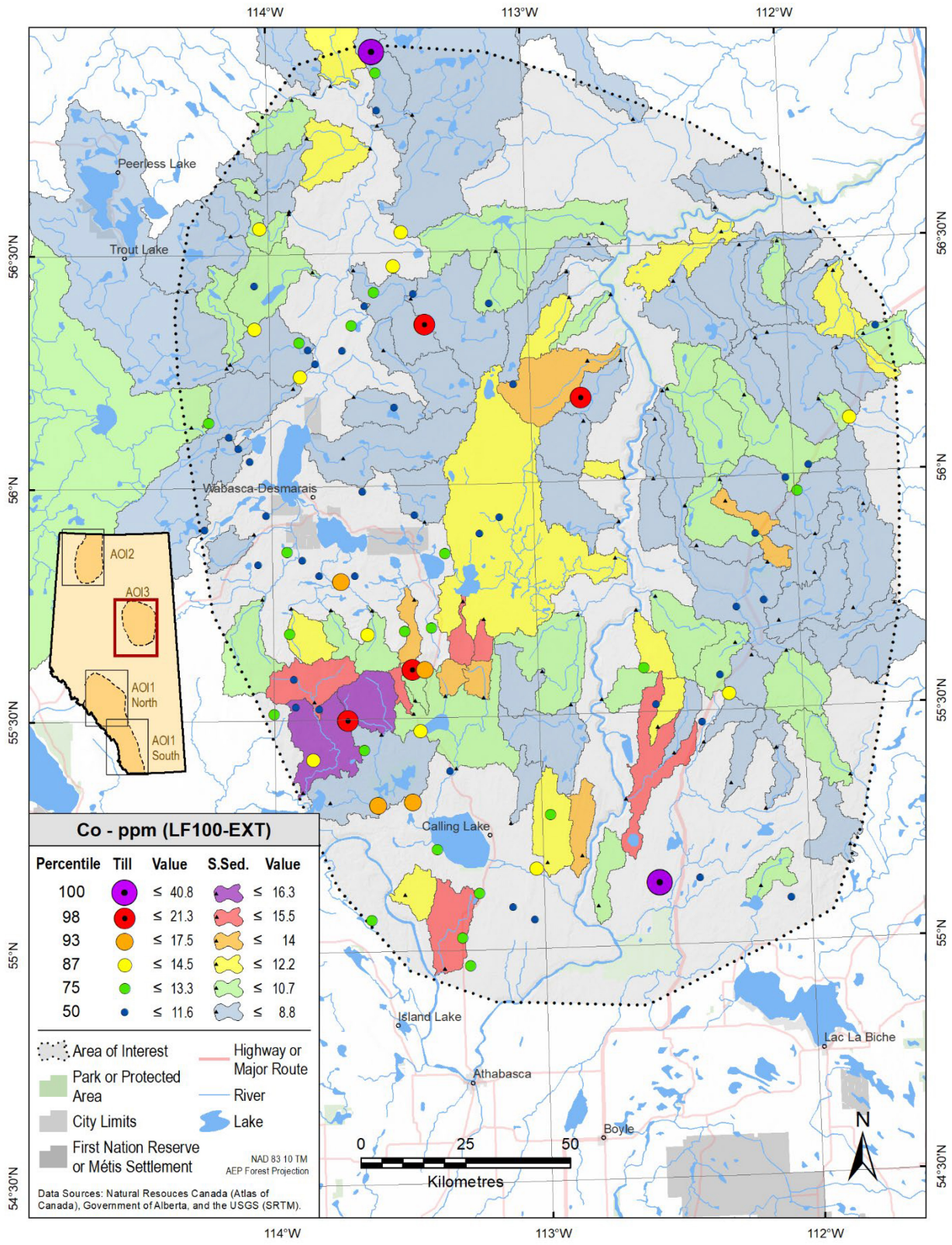

Figure 31. Cobalt (Co) concentrations in till and stream sediments in AOI-3.

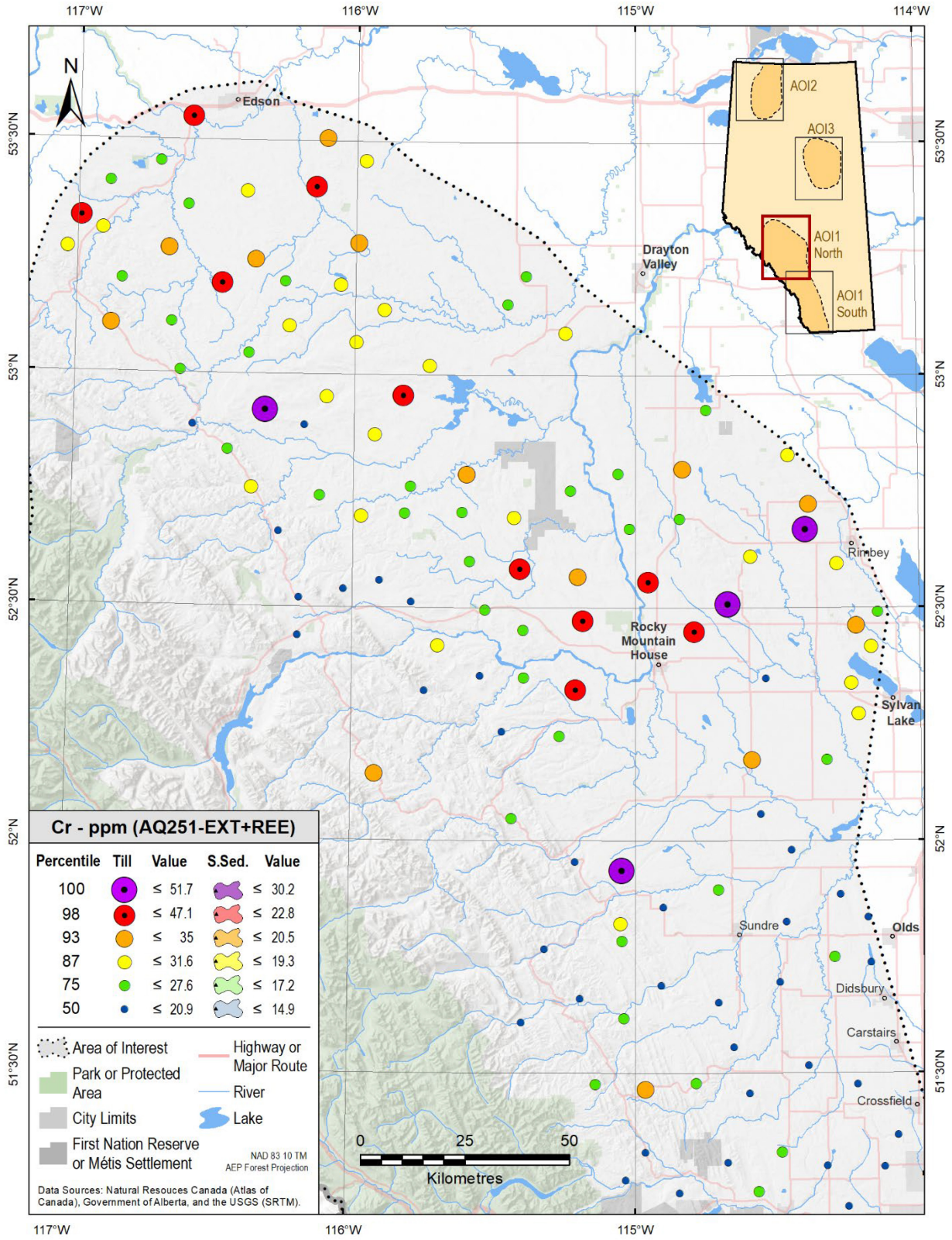

Figure 32. Chromium (Cr) concentrations in till in the northern half of AOI-1.

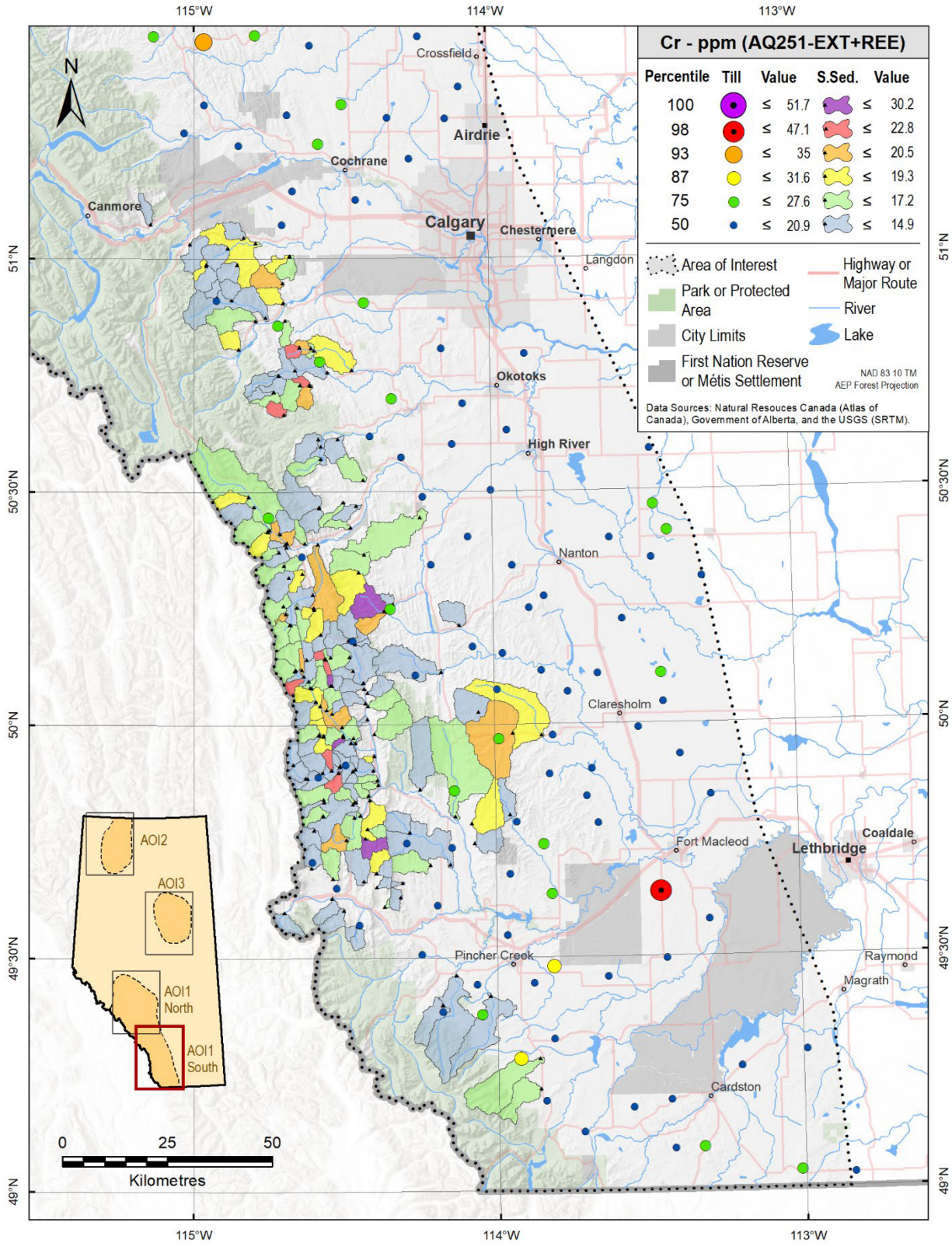

Figure 33. Chromium (Cr) concentrations in till and stream sediments in the southern half of AOI-1.

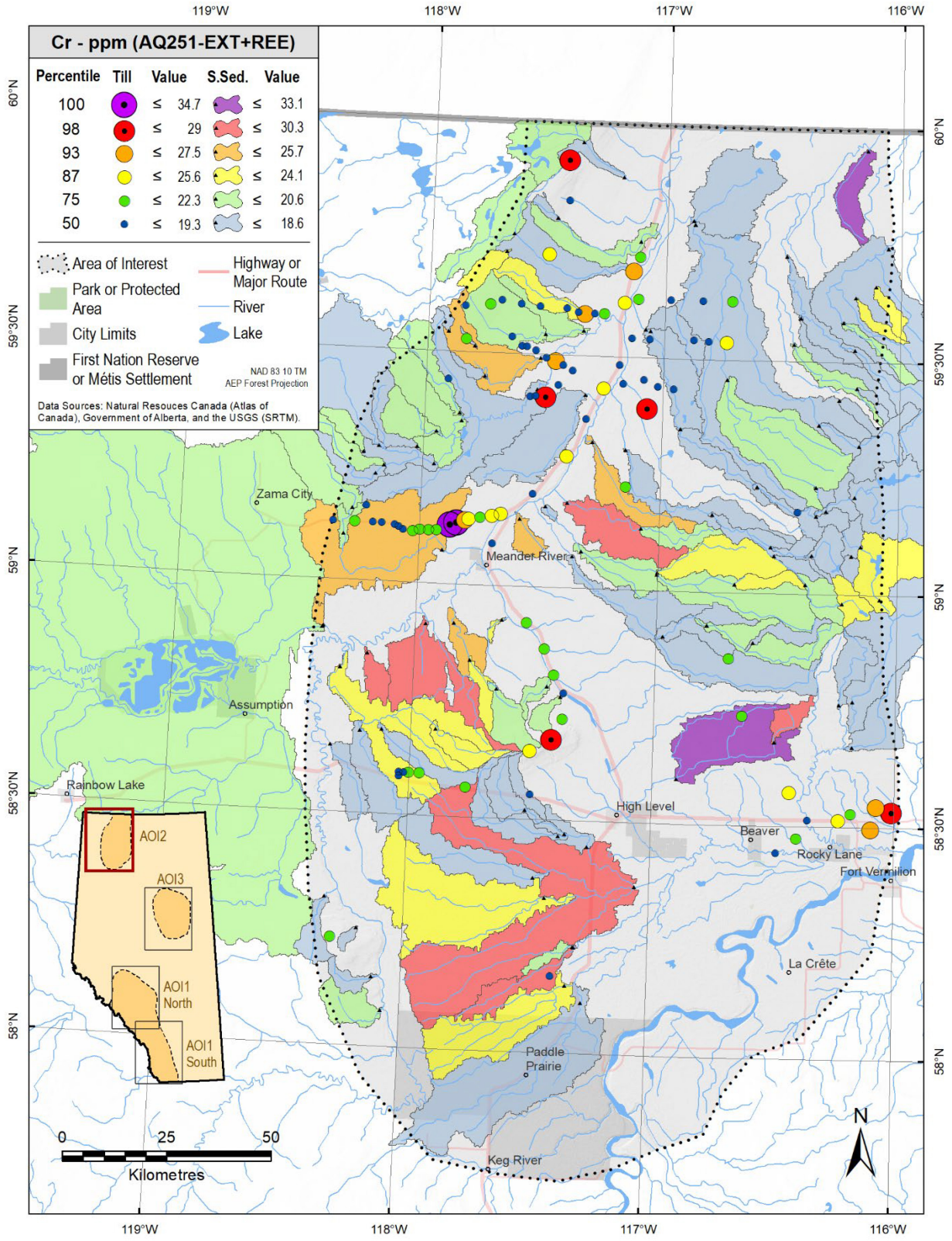

Figure 34. Chromium (Cr) concentrations in till and stream sediments in AOI-2.

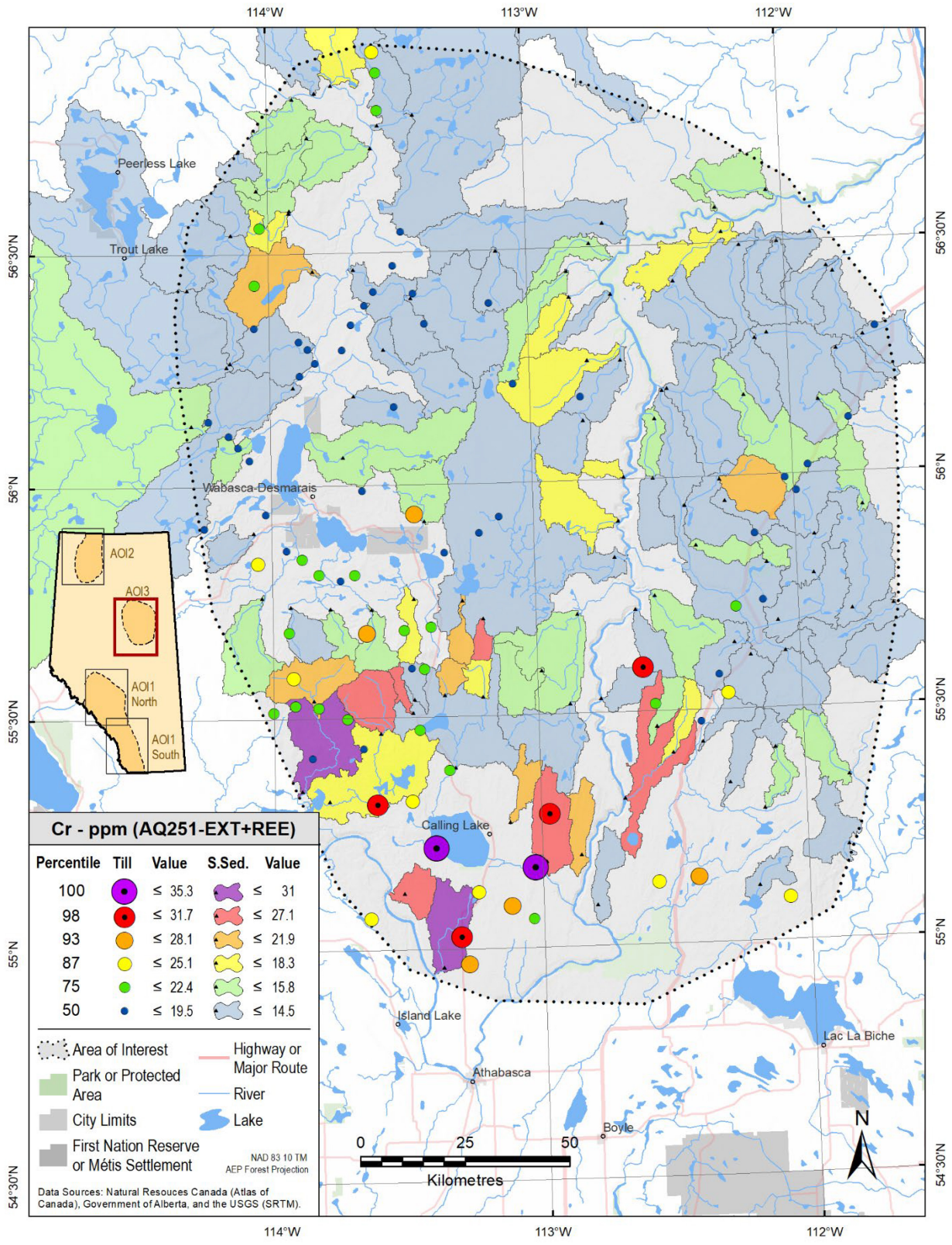

Figure 35. Chromium (Cr) concentrations in till and stream sediments in AOI-3.

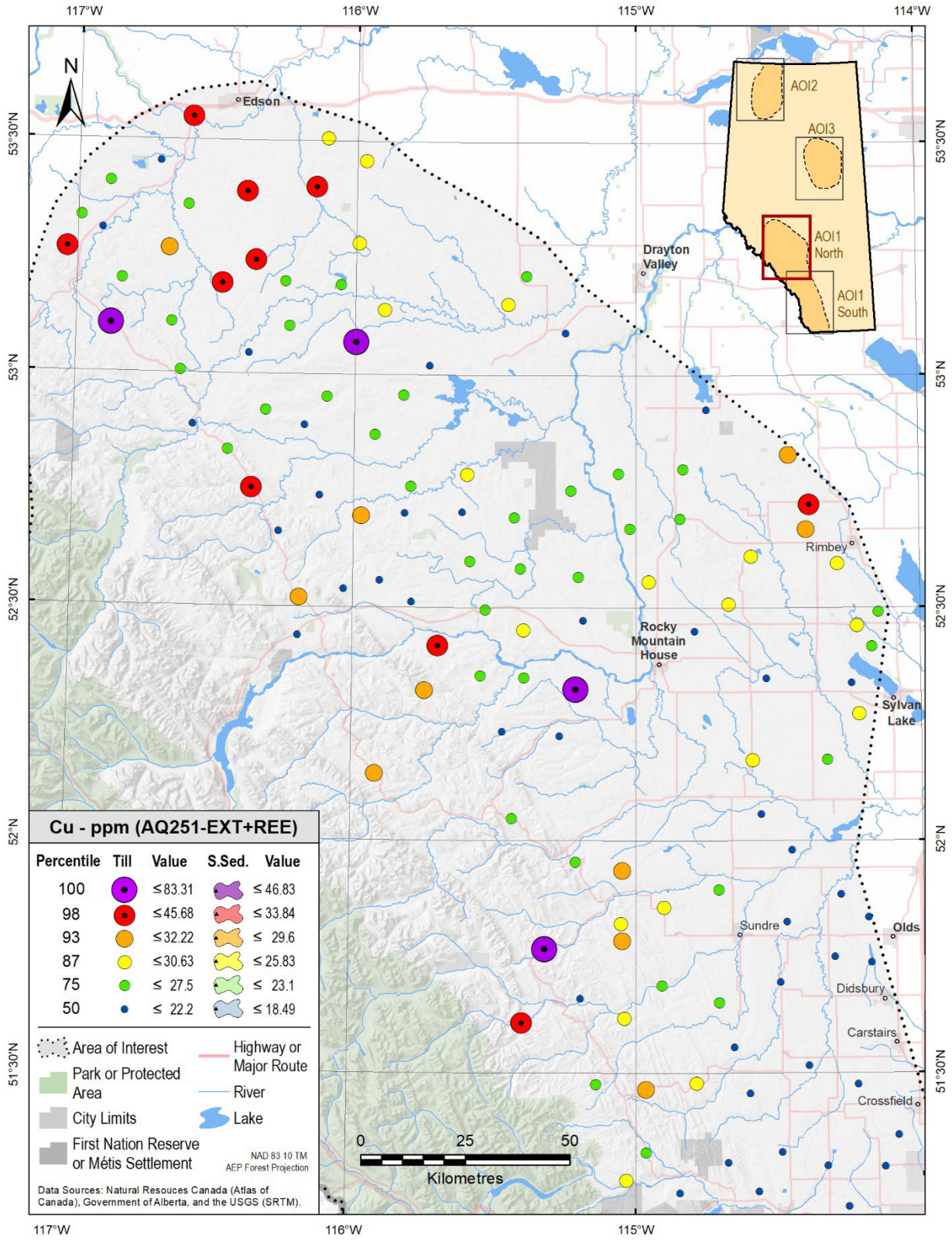

Figure 36. Copper (Cu) concentrations in till in the northern half of AOI-1.

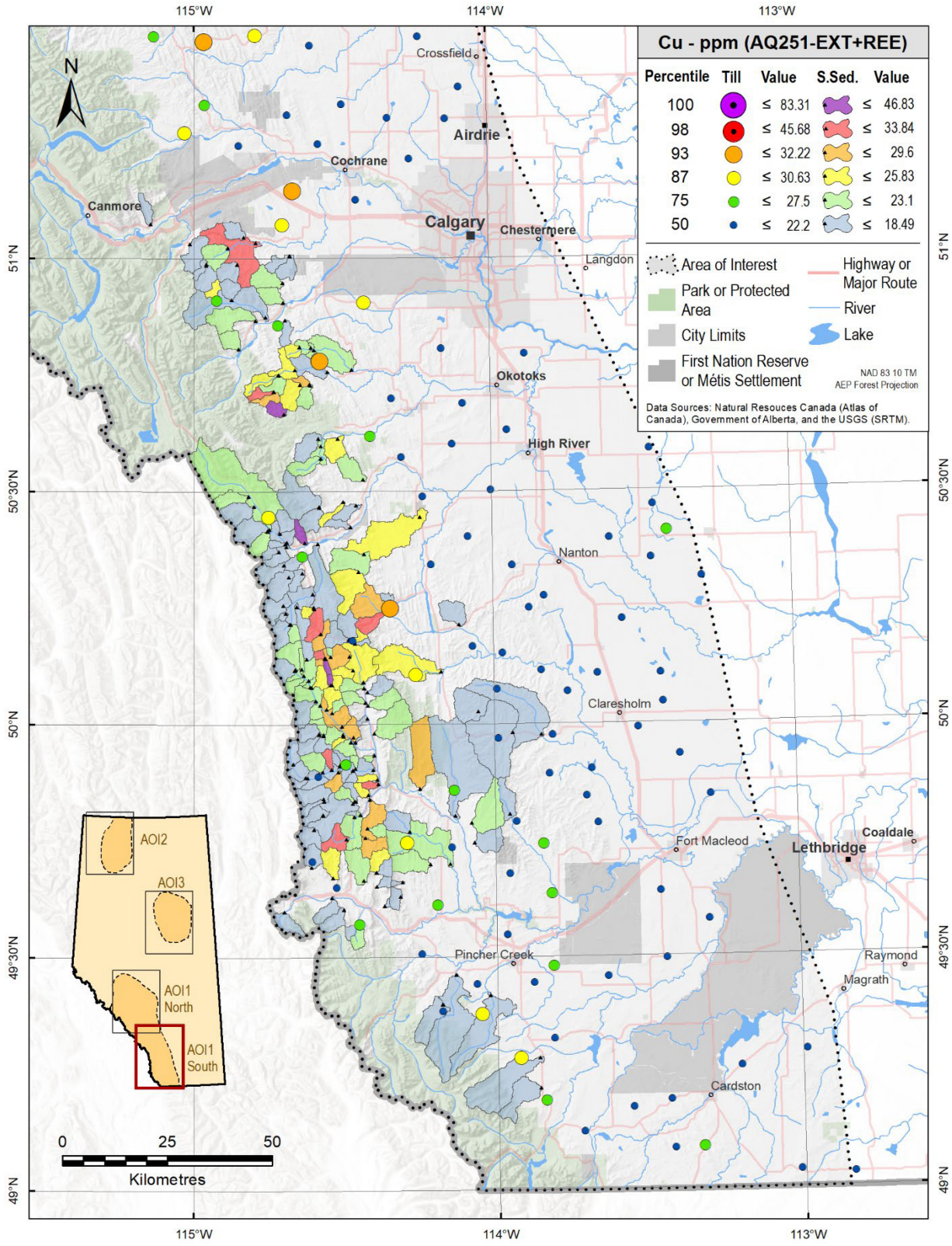

Figure 37. Copper (Cu) concentrations in till and stream sediments in the southern half of AOI-1.

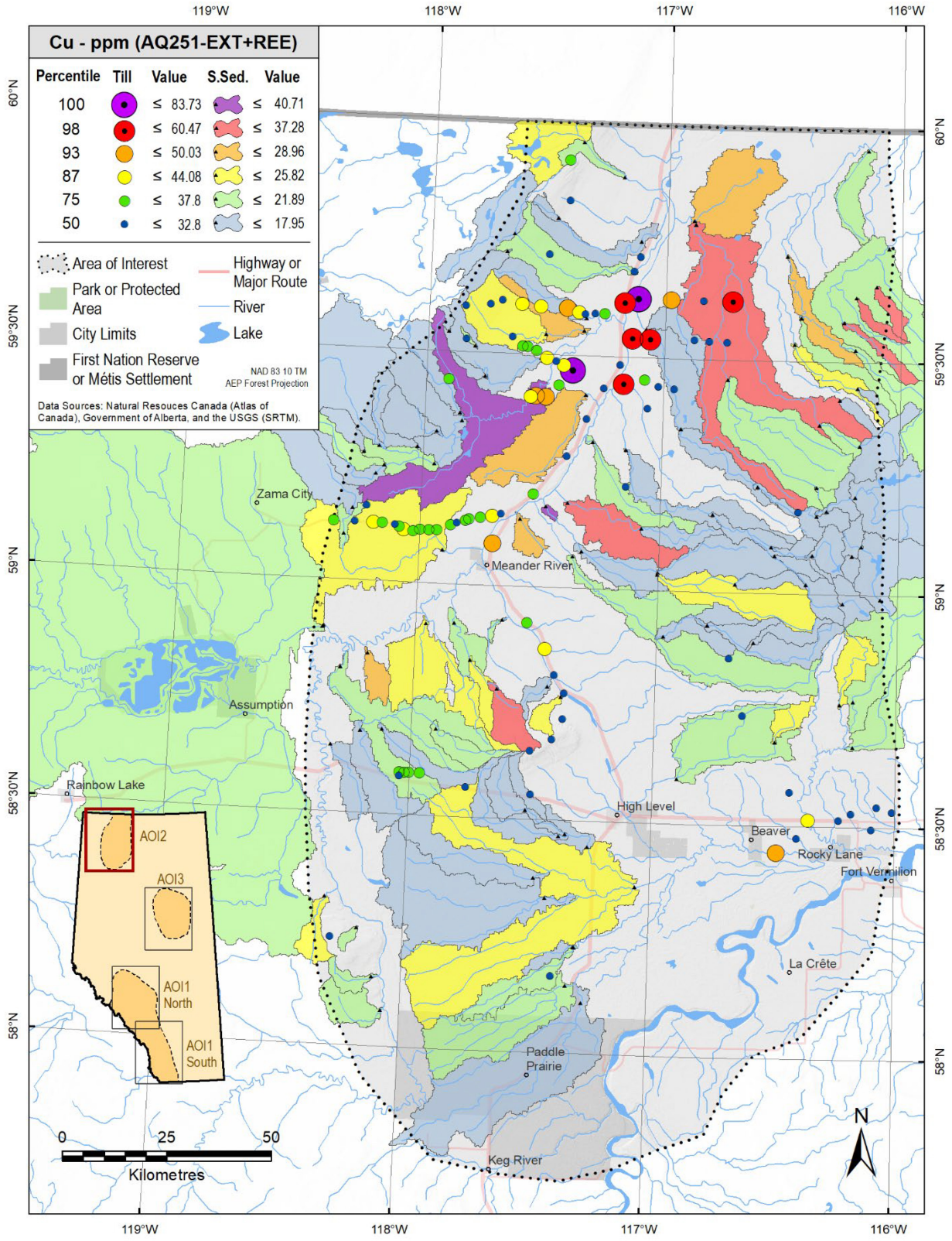

Figure 38. Copper (Cu) concentrations in till and stream sediments in AOI-2.

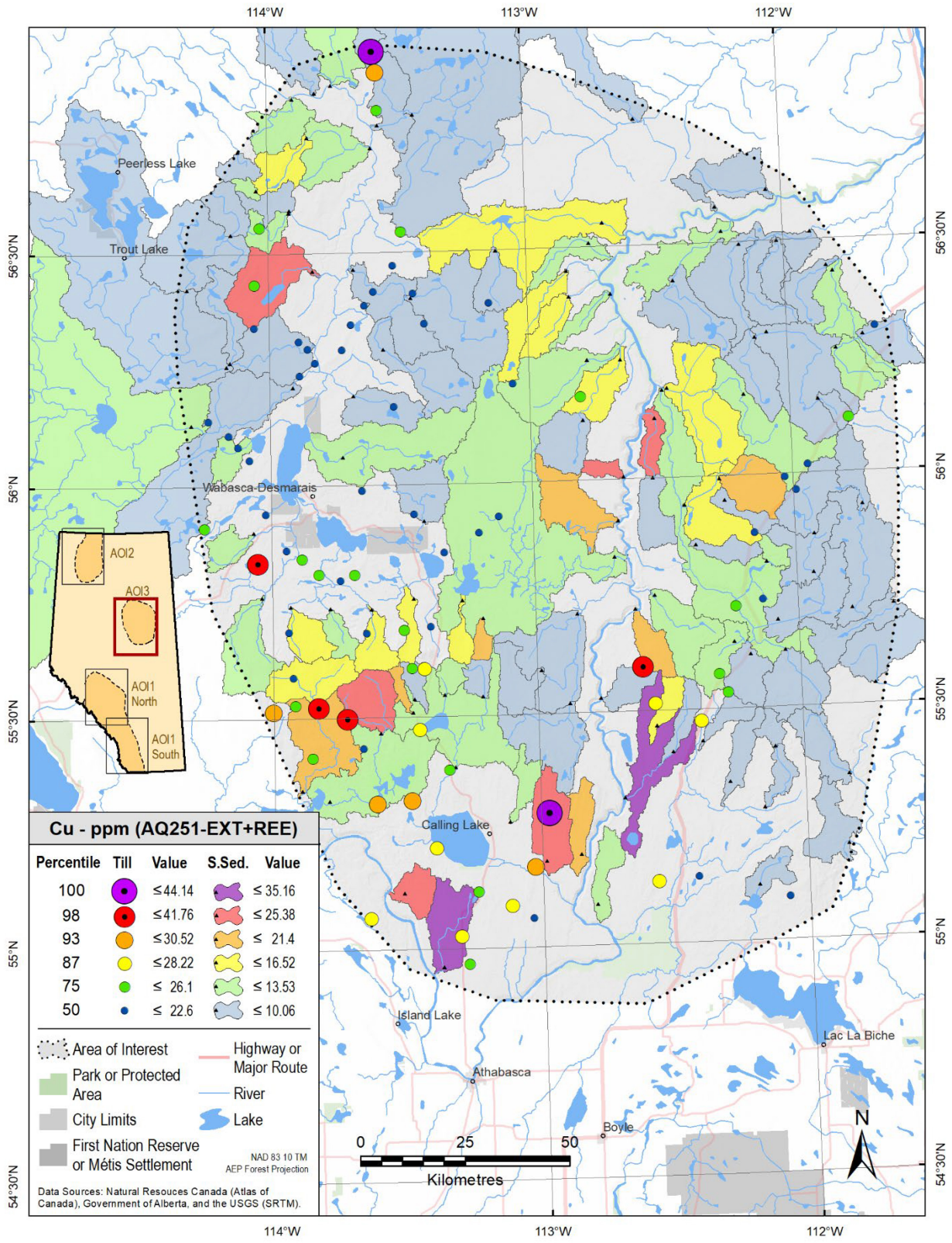

Figure 39. Copper (Cu) concentrations in till and stream sediments in AOI-3.

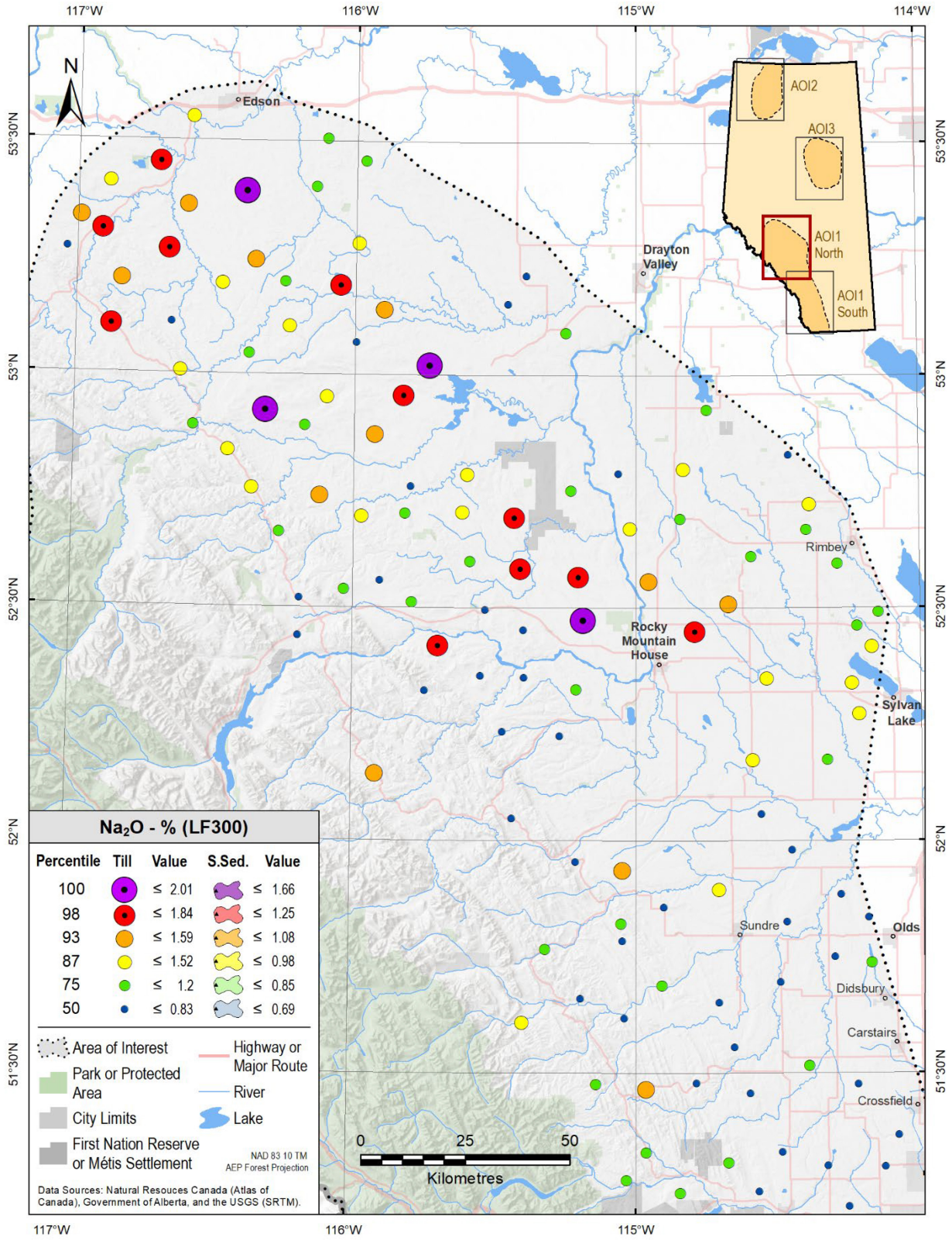

Figure 40. Sodium (Na_2O) concentrations in till in the northern half of AOI-1.

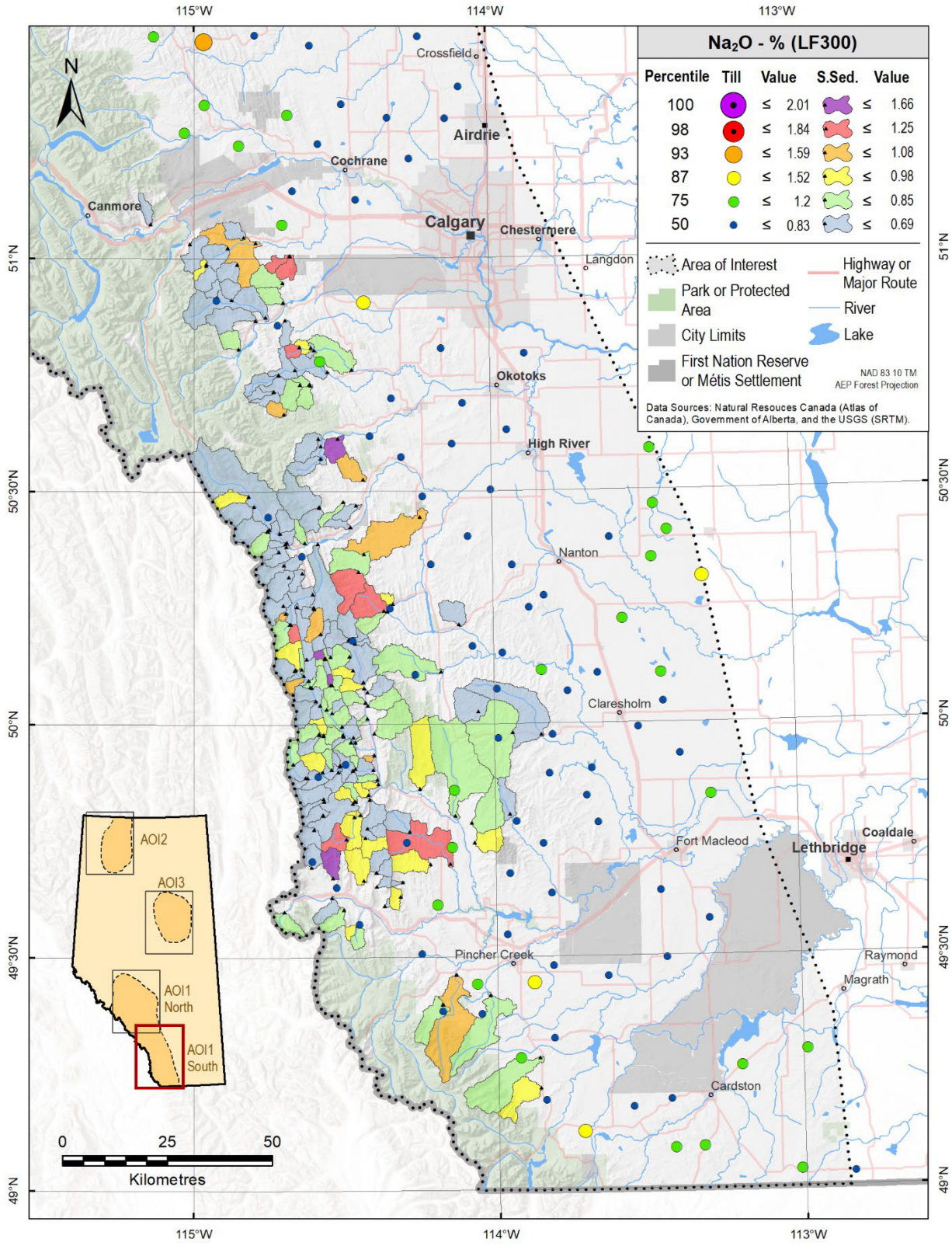

Figure 41. Sodium (Na_2O) concentrations in till and stream sediments in the southern half of AOI-1.

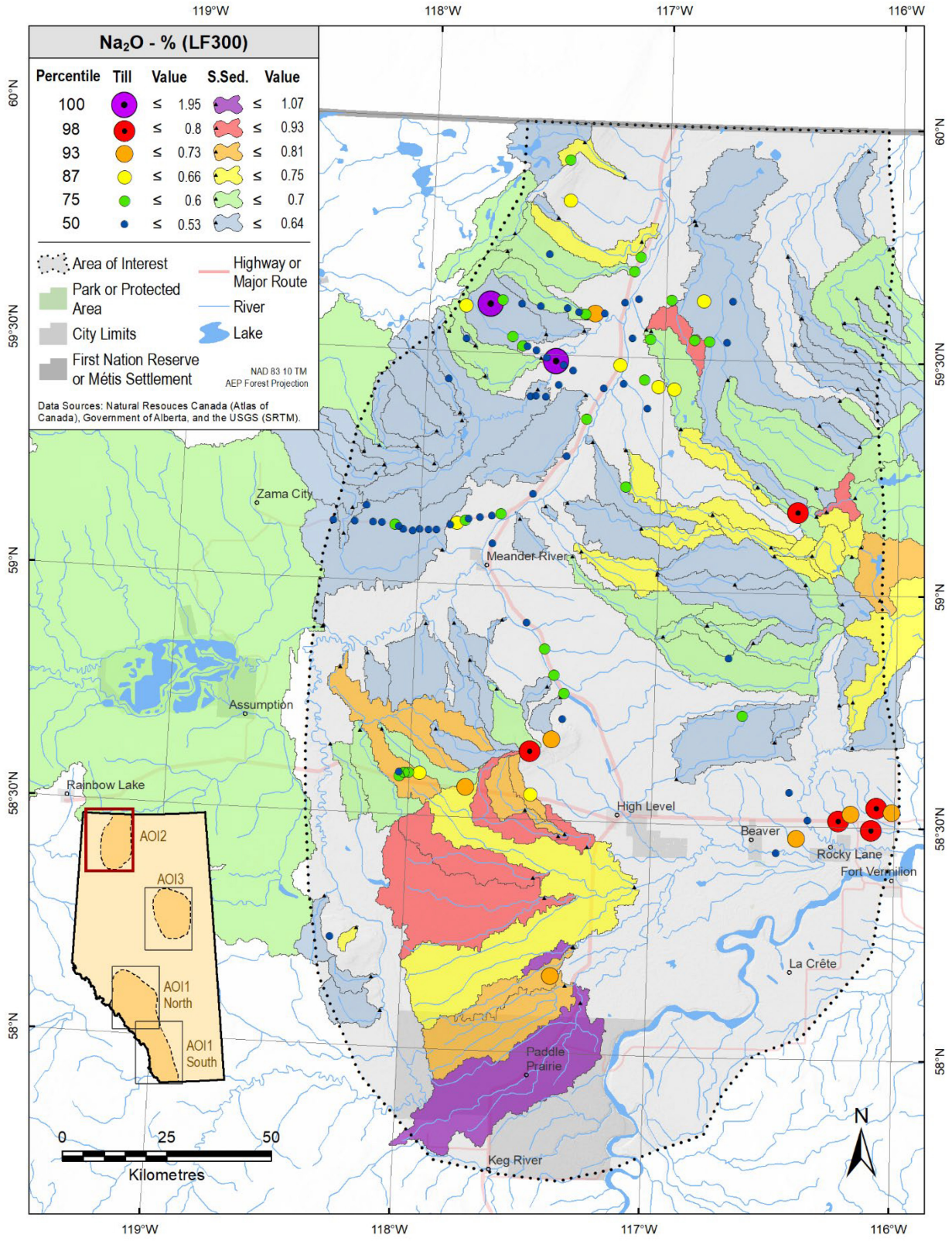

Figure 42. Sodium (Na_2O) concentrations in till and stream sediments in AOI-2.

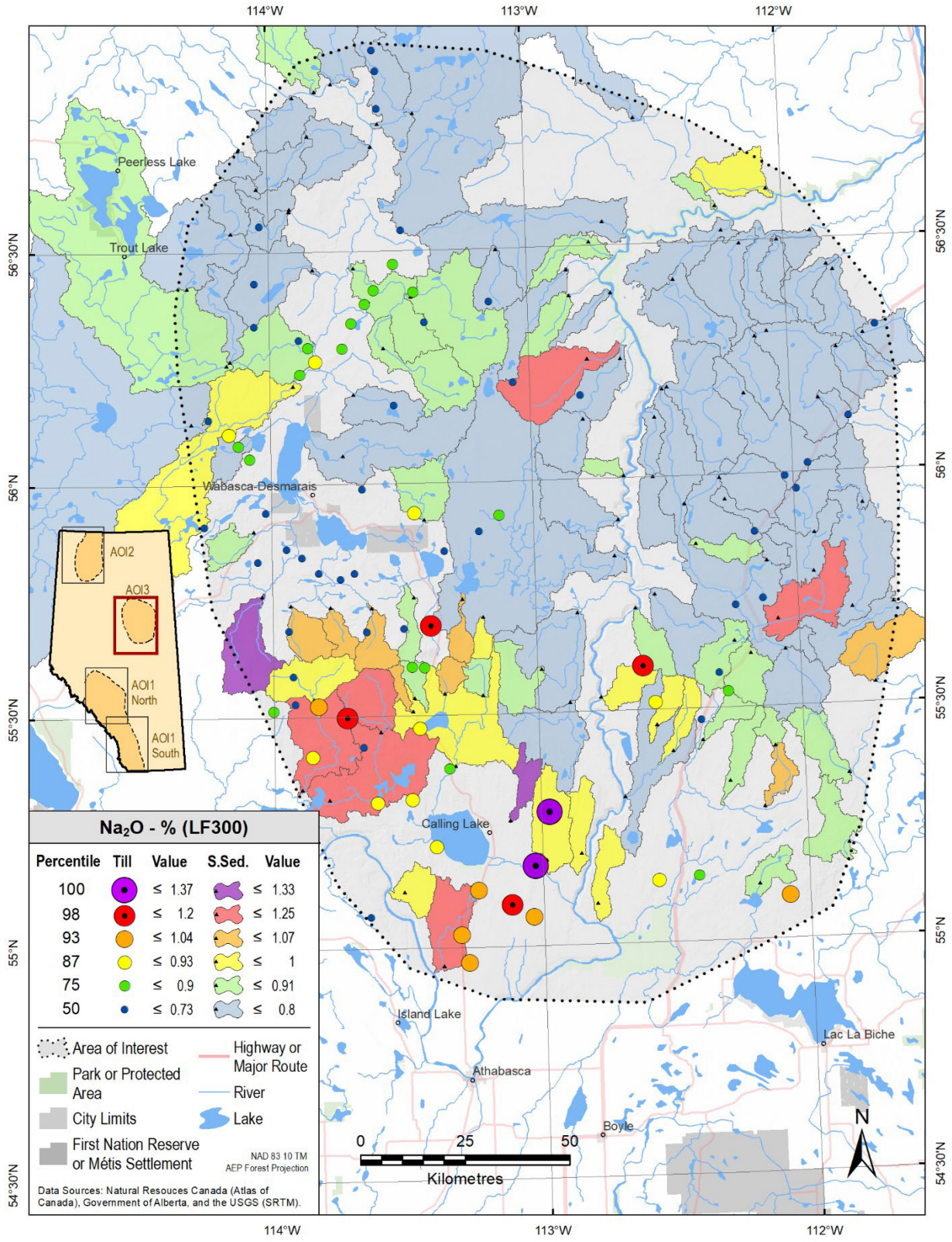

Figure 43. Sodium (Na_2O) concentrations in till and stream sediments in AOI-3.

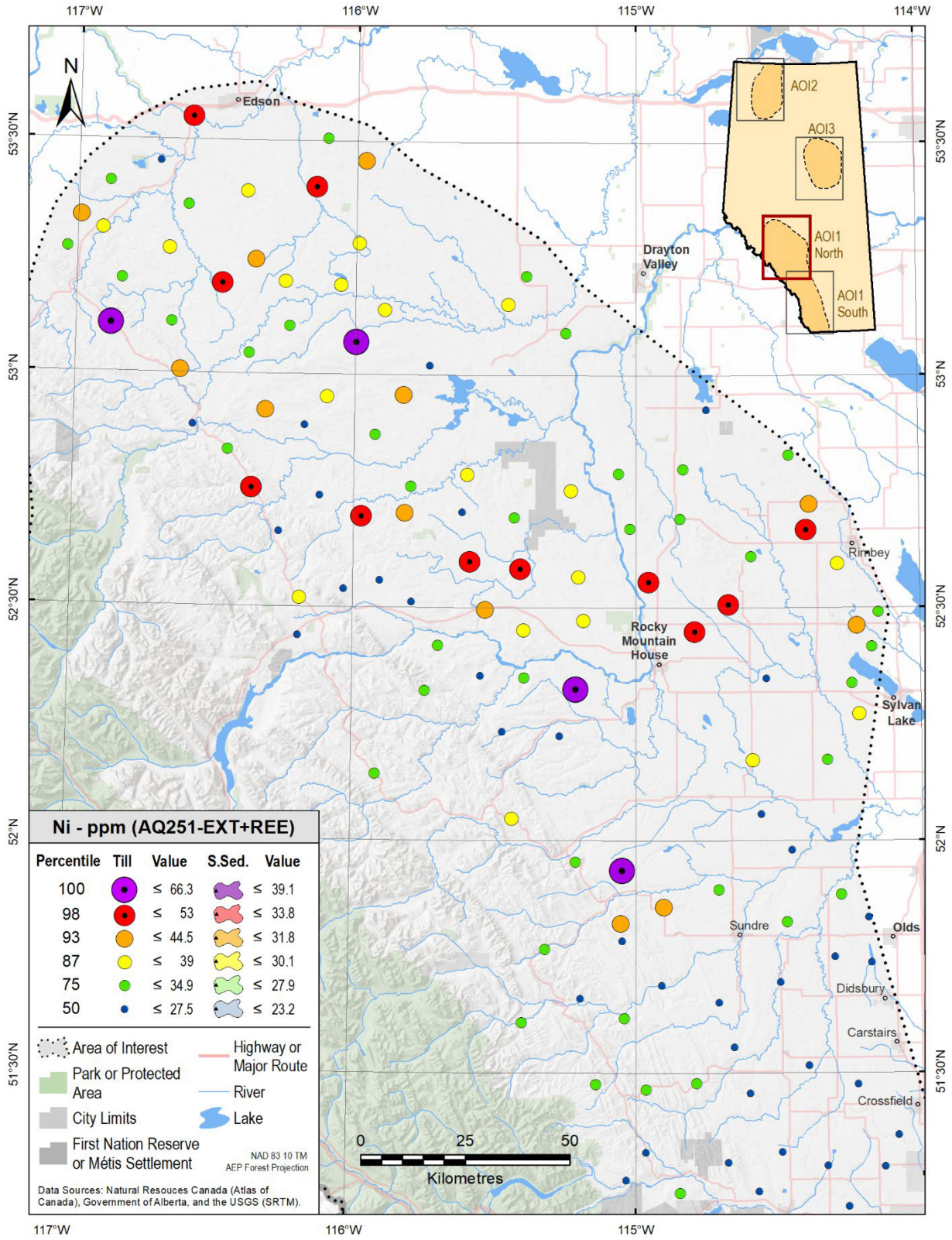

Figure 44. Nickel (Ni) concentrations in till in the northern half of AOI-1.

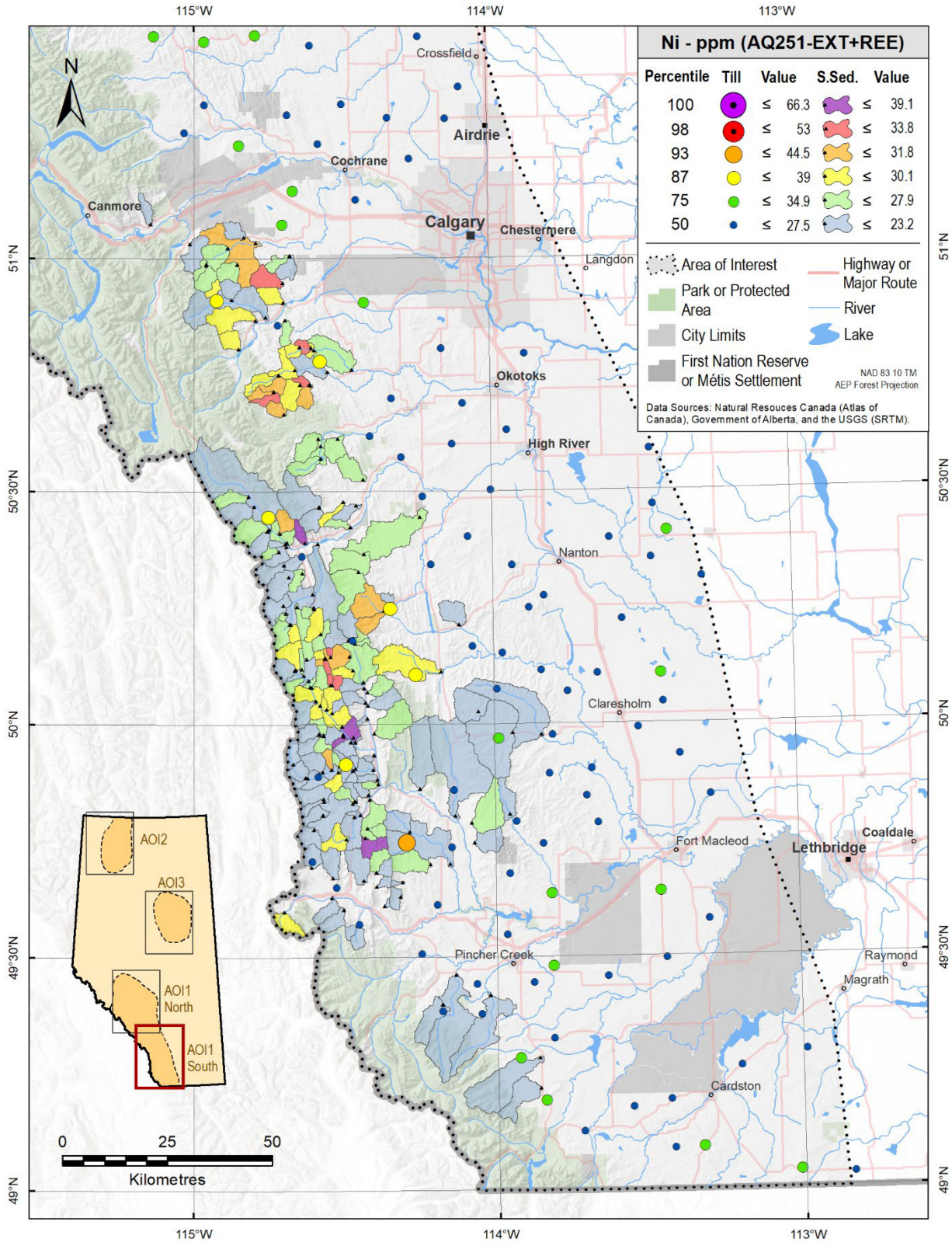

Figure 45. Nickel (Ni) concentrations in till and stream sediments in the southern half of AOI-1.

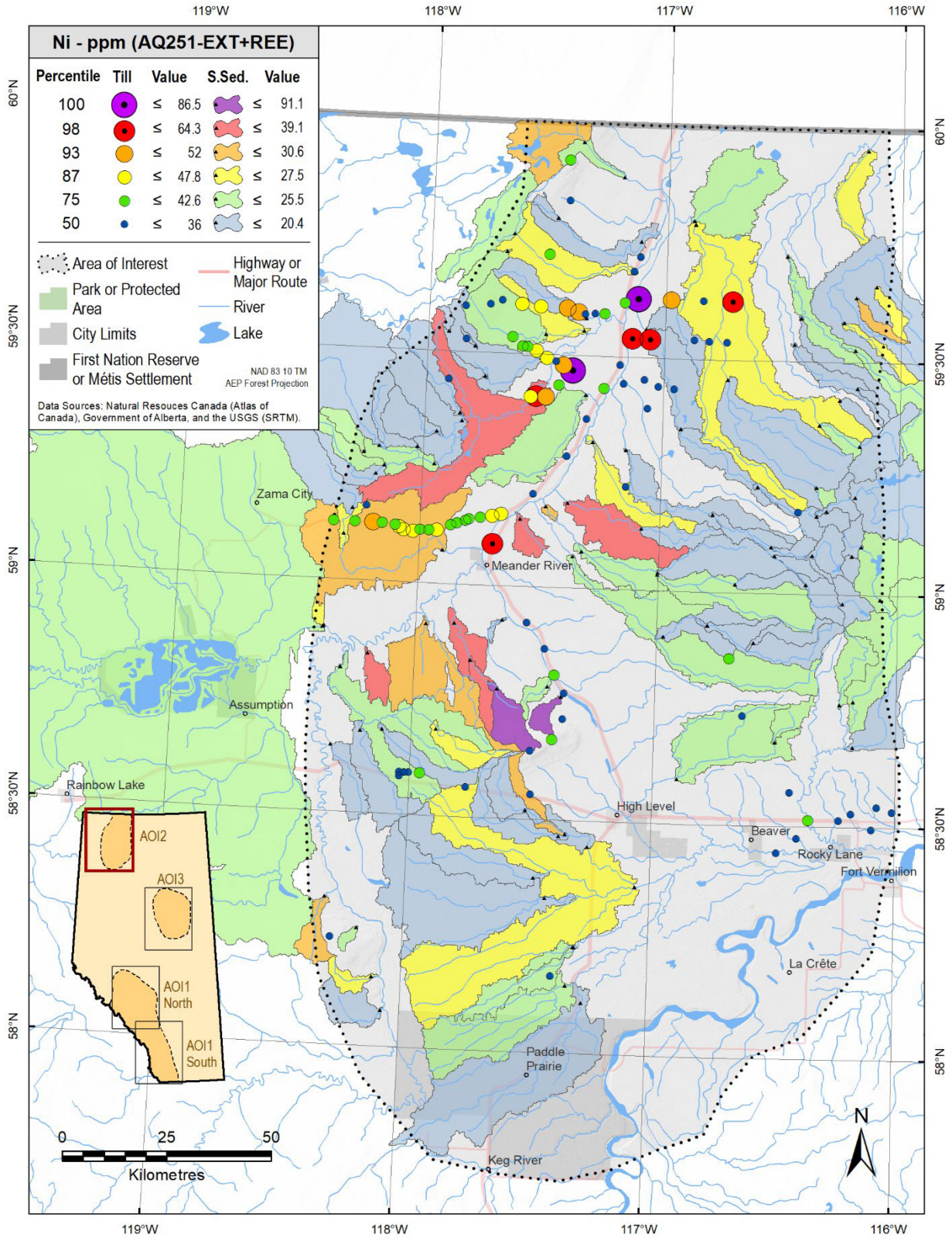

Figure 46. Nickel (Ni) concentrations in till and stream sediments in AOI-2.

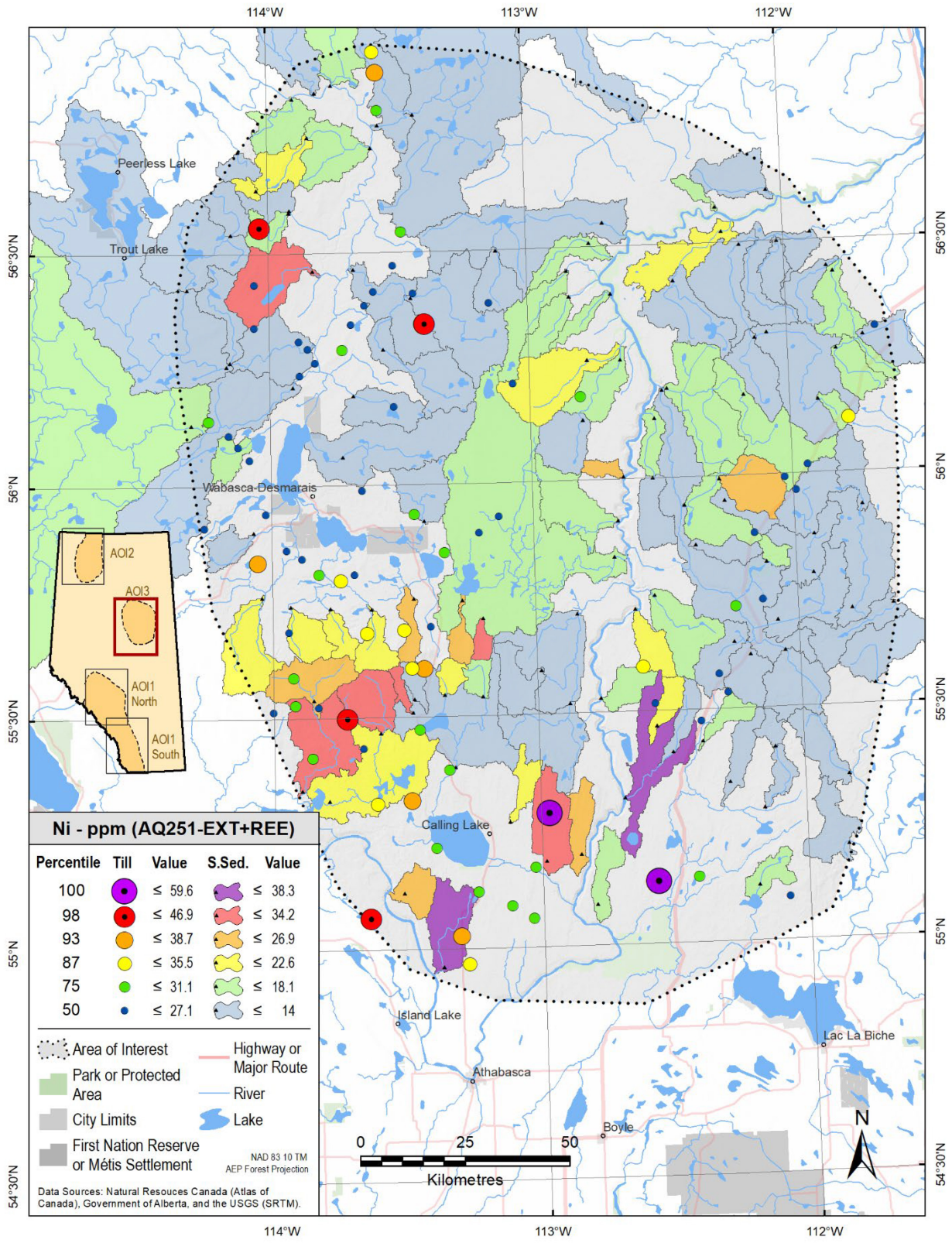

Figure 47. Nickel (Ni) concentrations in till and stream sediments in AOI-3.

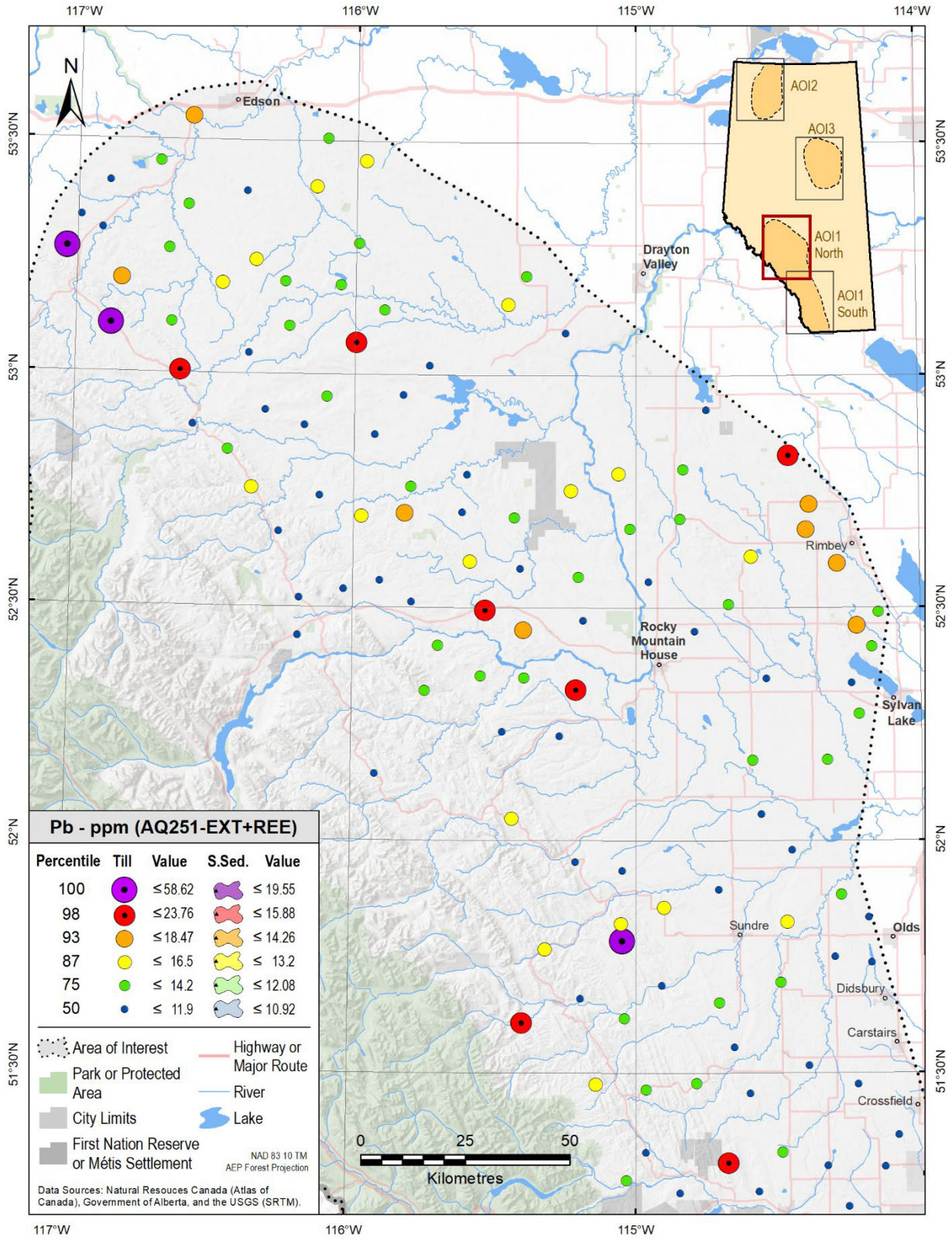

Figure 48. Lead (Pb) concentrations in till in the northern half of AOI-1.

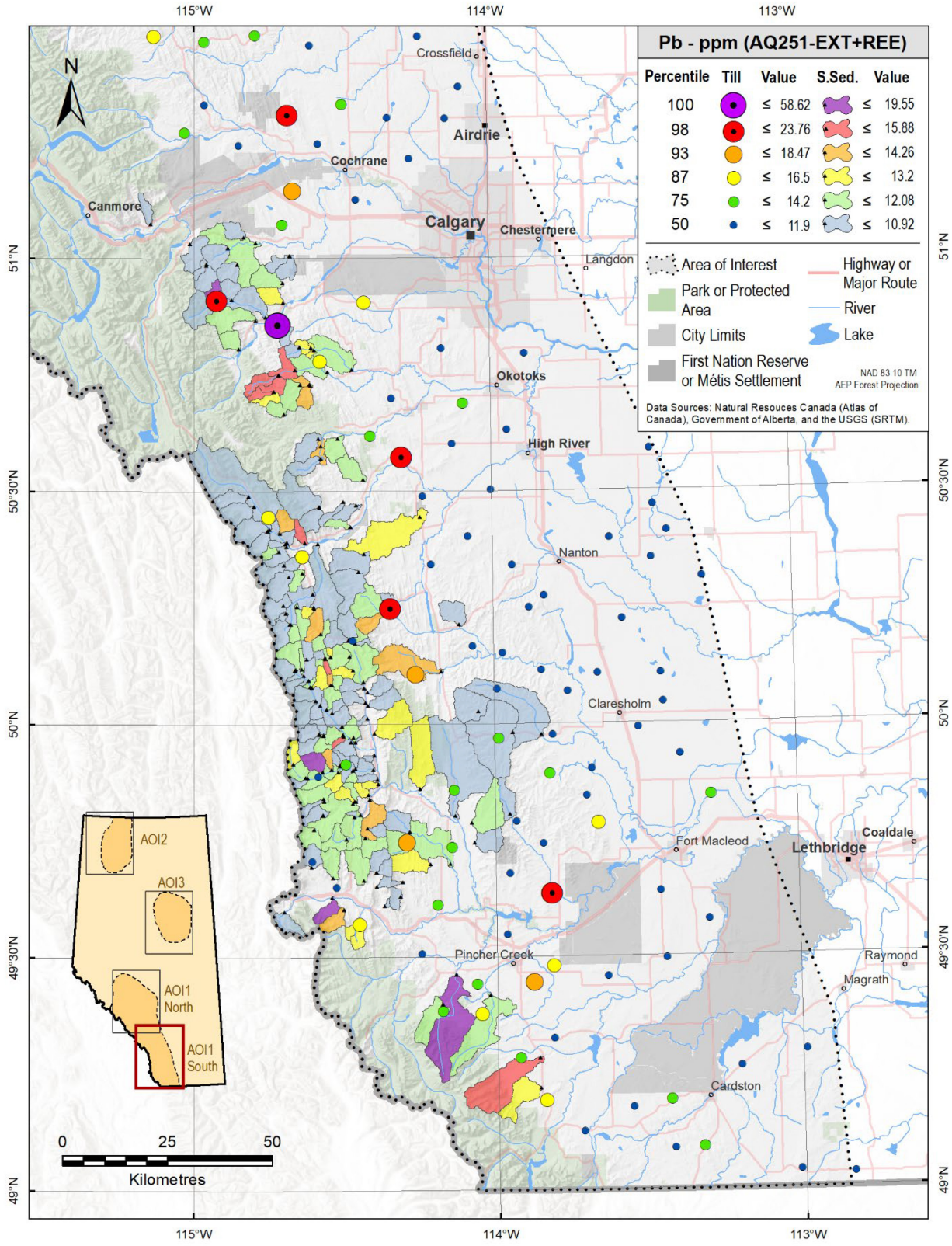

Figure 49. Lead (Pb) concentrations in till and stream sediments in the southern half of AOI-1.

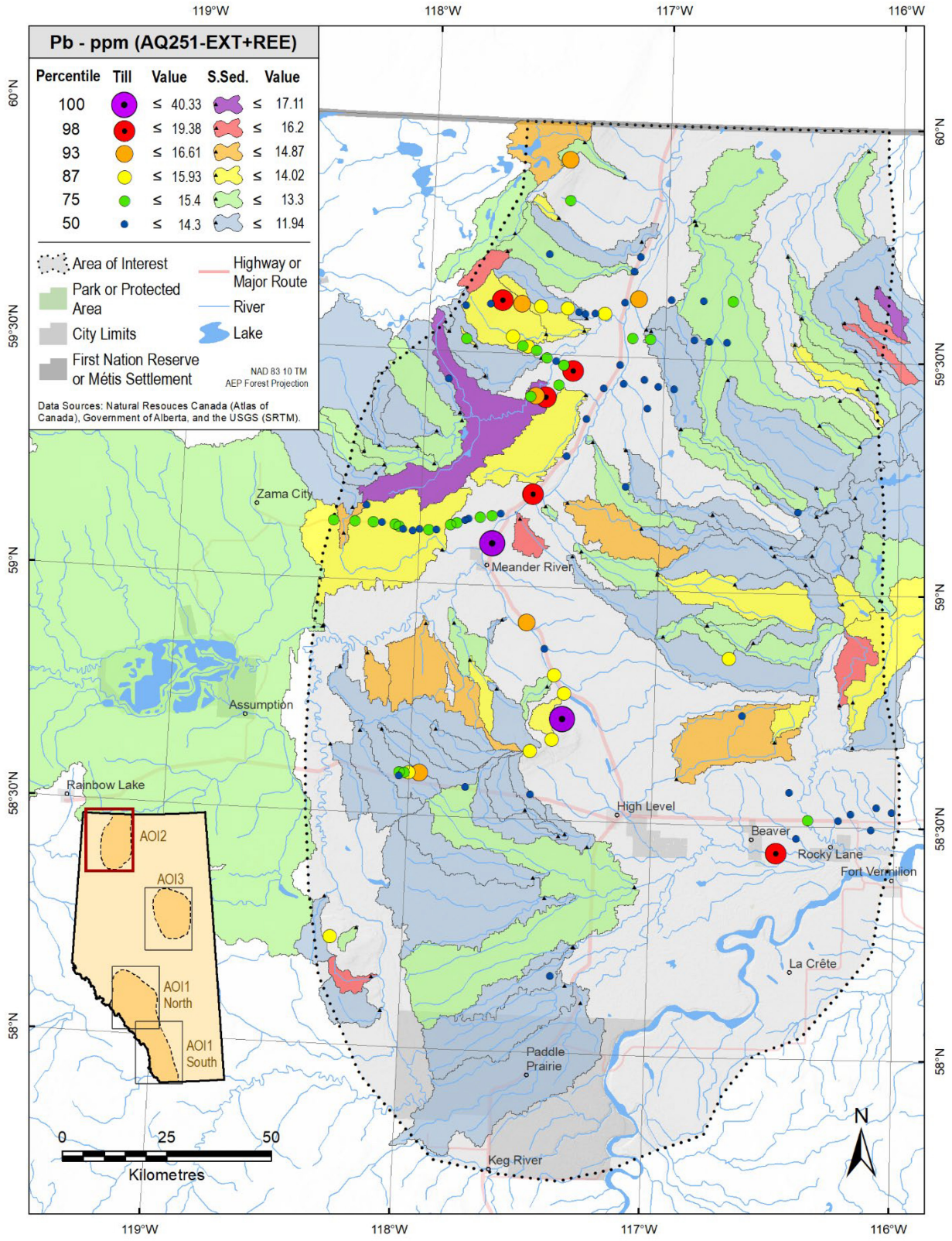

Figure 50. Lead (Pb) concentrations in till and stream sediments in AOI-2.

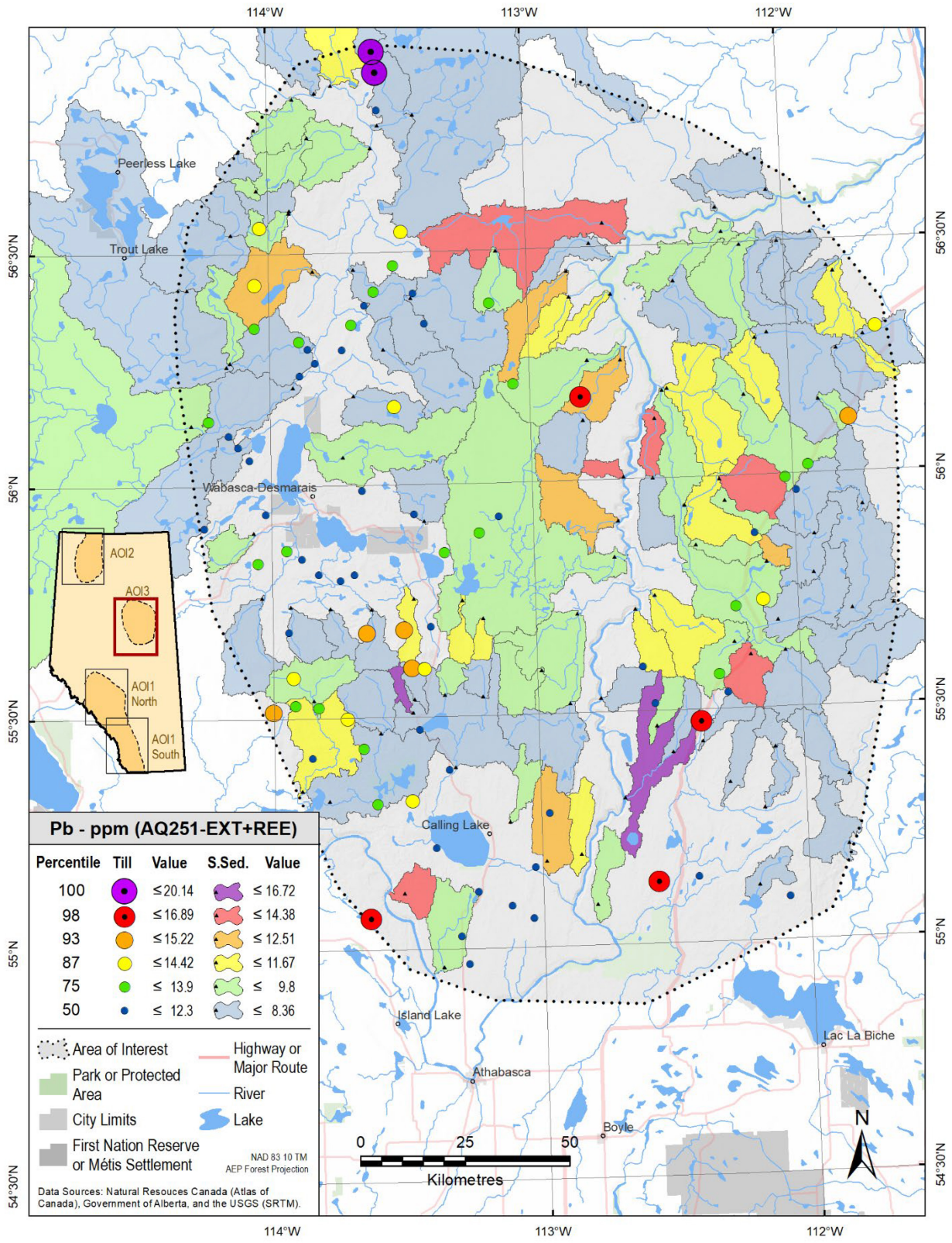

Figure 51. Lead (Pb) concentrations in till and stream sediments in AOI-3.

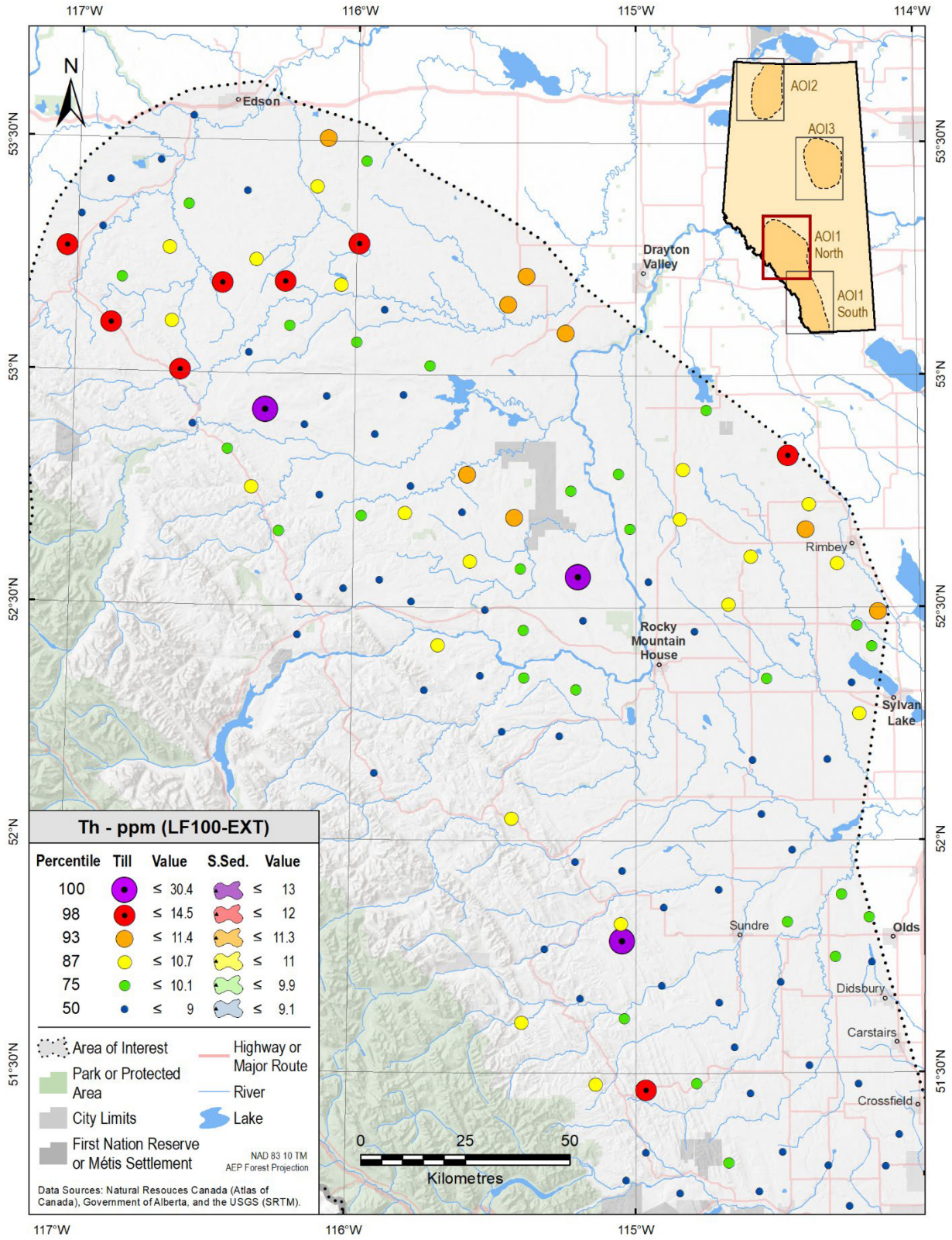

Figure 52. Thorium (Th) concentrations in till in the northern half of AOI-1.

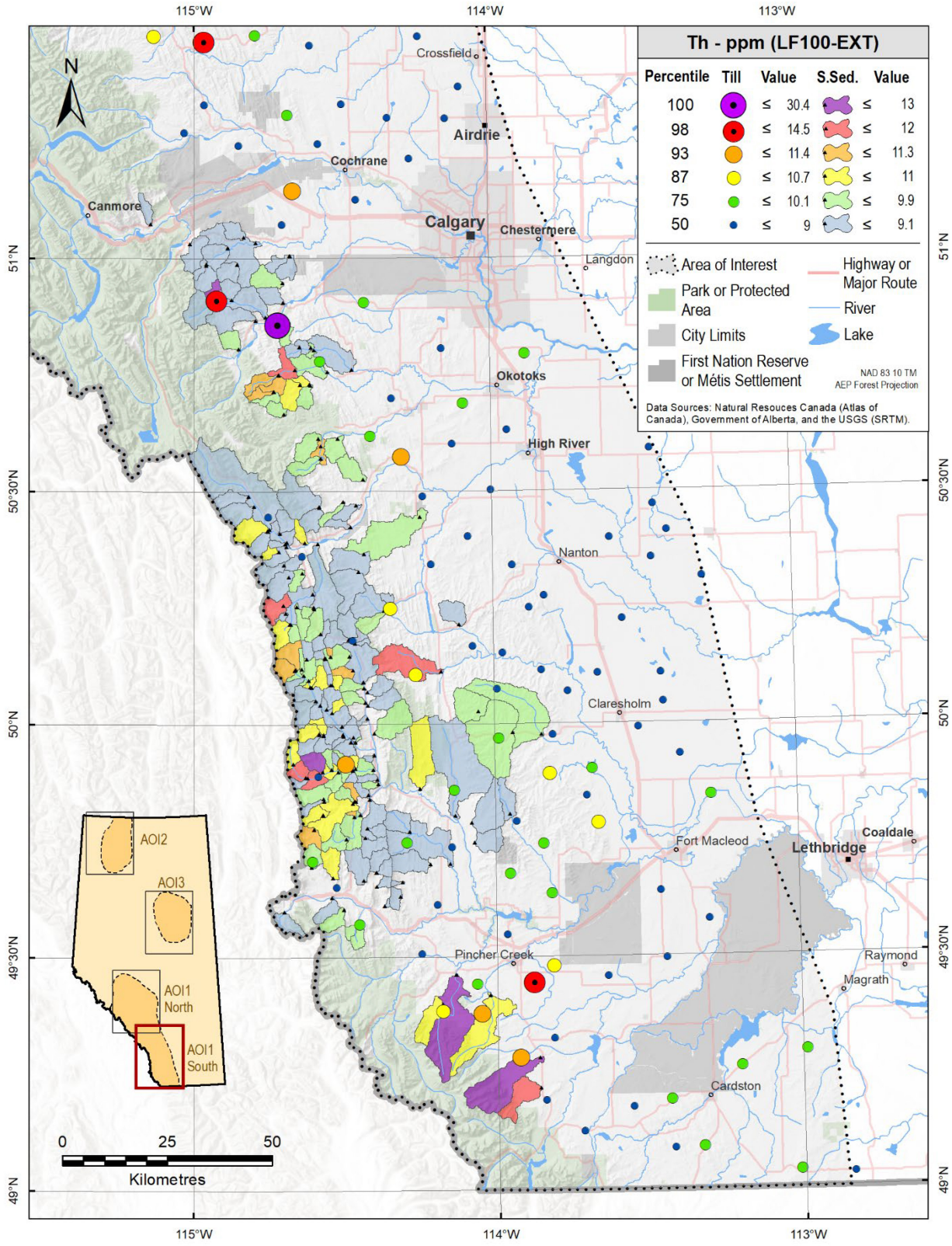

Figure 53. Thorium (Th) concentrations in till and stream sediments in the southern half of AOI-1.

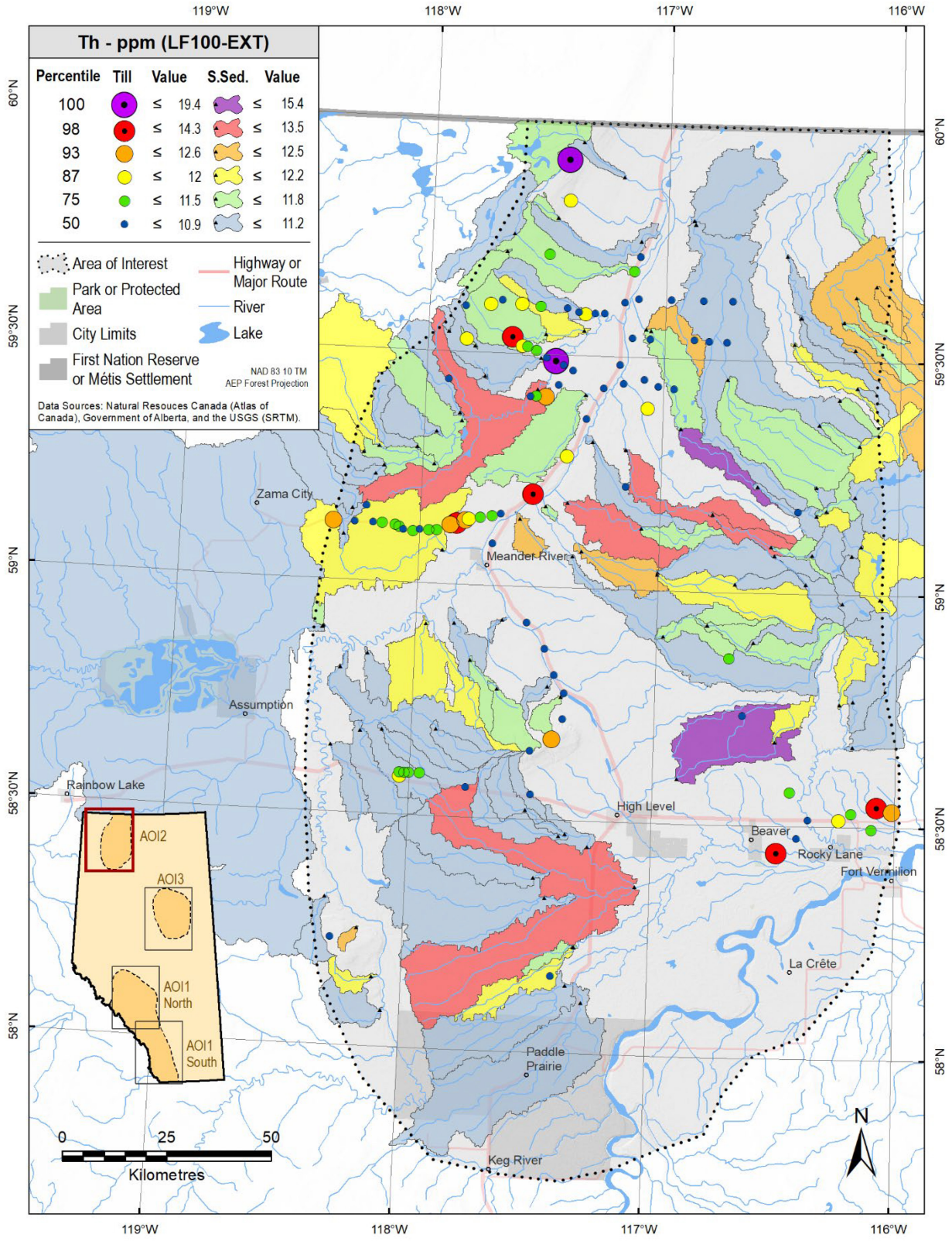

Figure 54. Thorium (Th) concentrations in till and stream sediments in AOI-2.

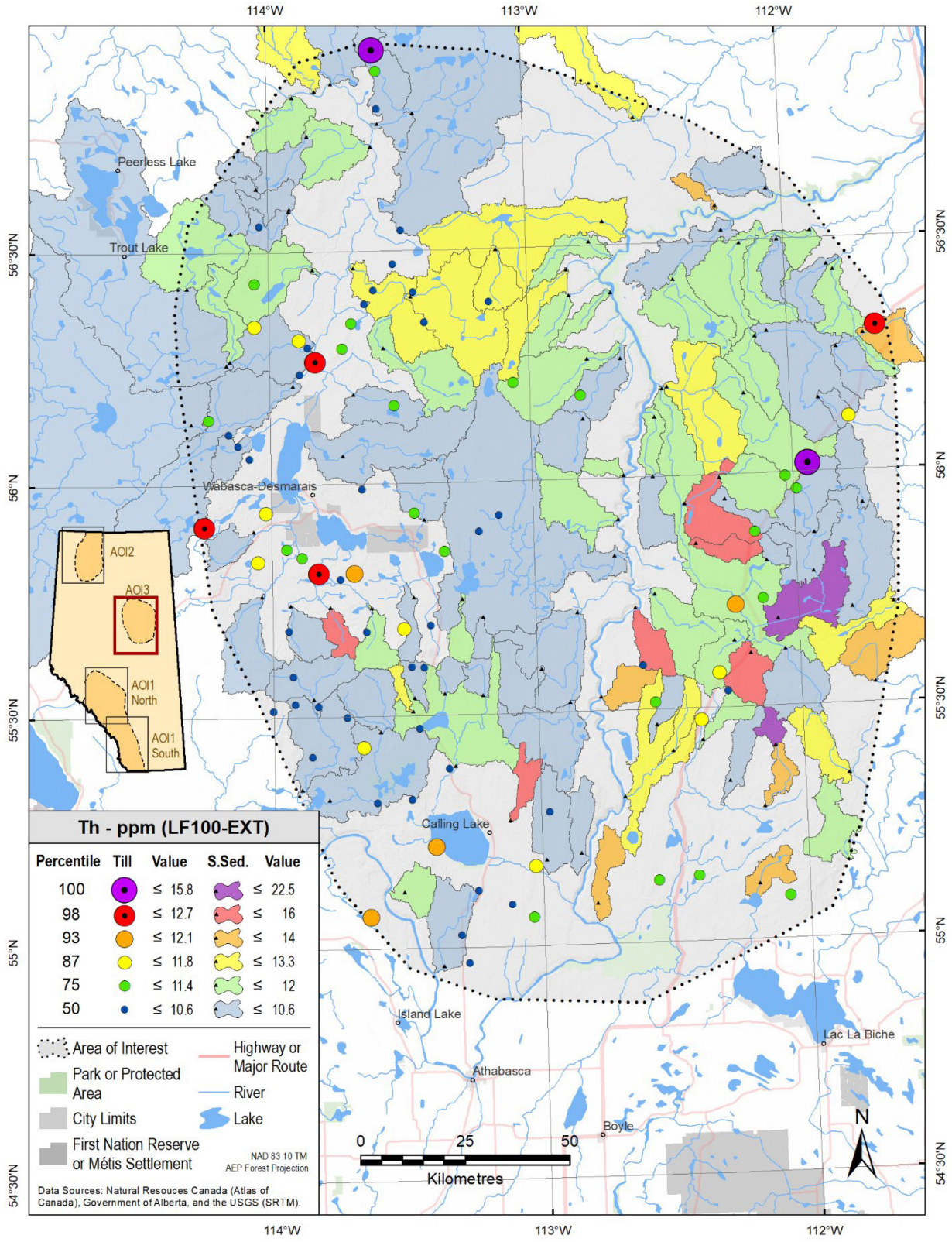

Figure 55. Thorium (Th) concentrations in till and stream sediments in AOI-3.

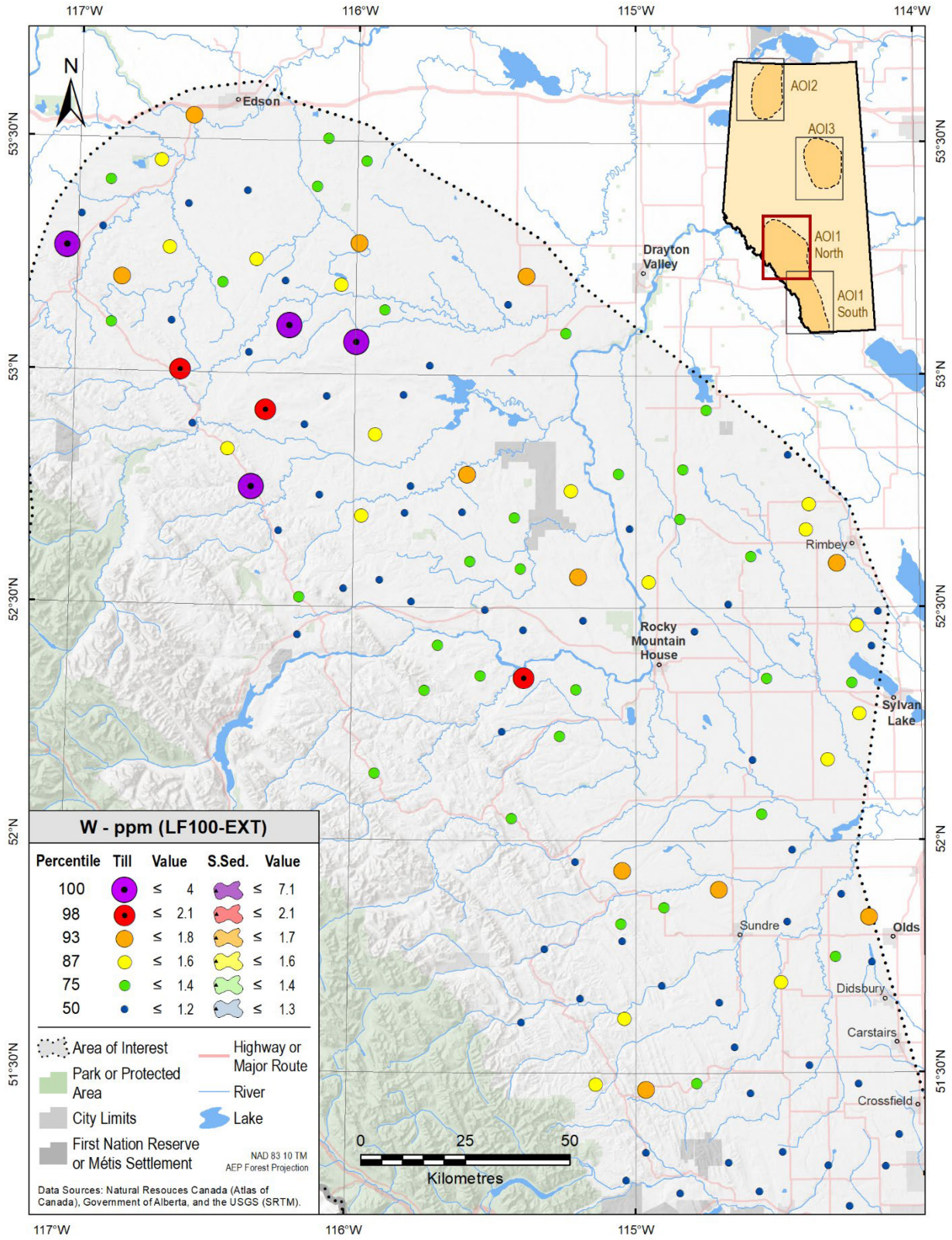

Figure 56. Tungsten (W) concentrations in till in the northern half of AOI-1.

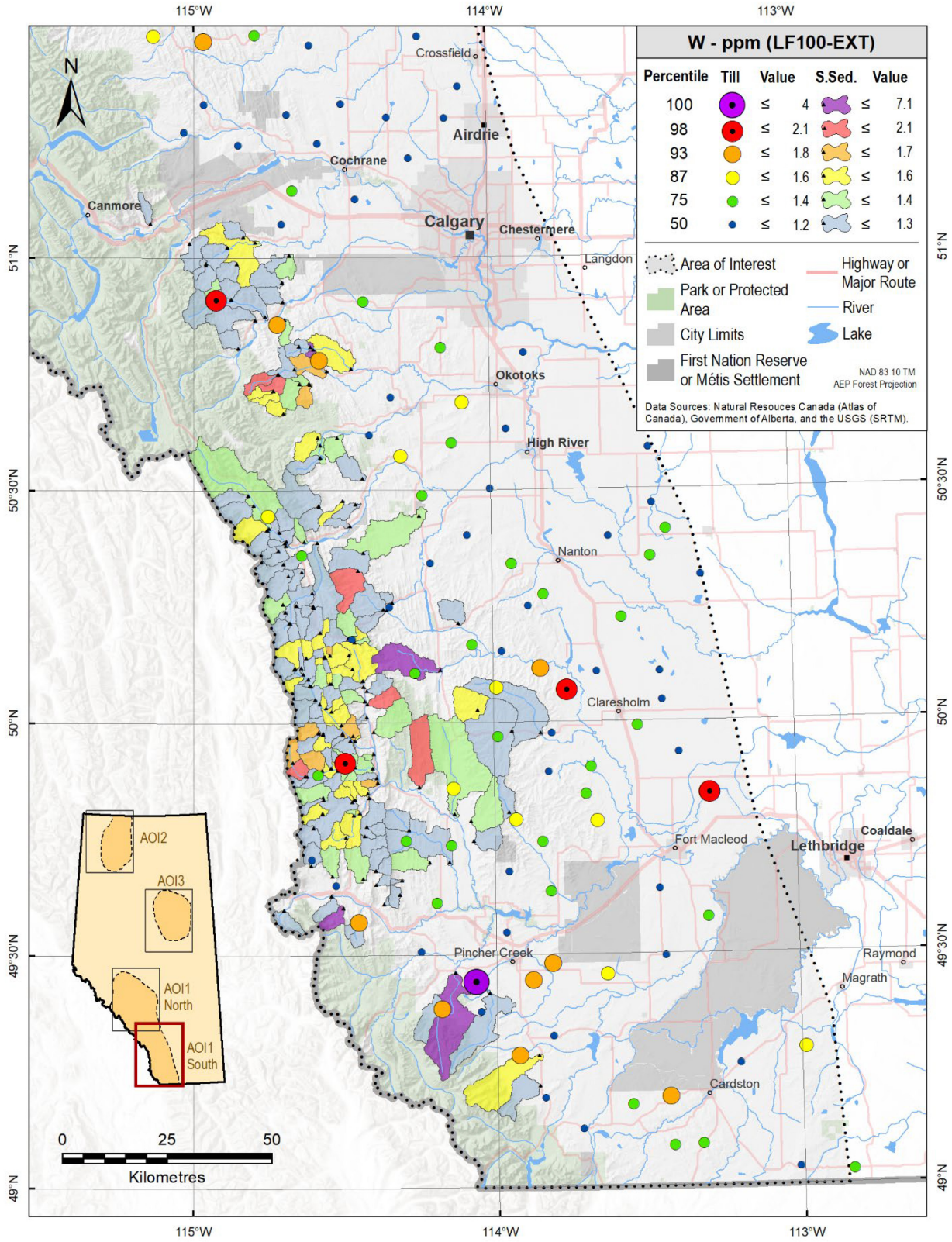

Figure 57. Tungsten (W) concentrations in till and stream sediments in the southern half of AOI-1.

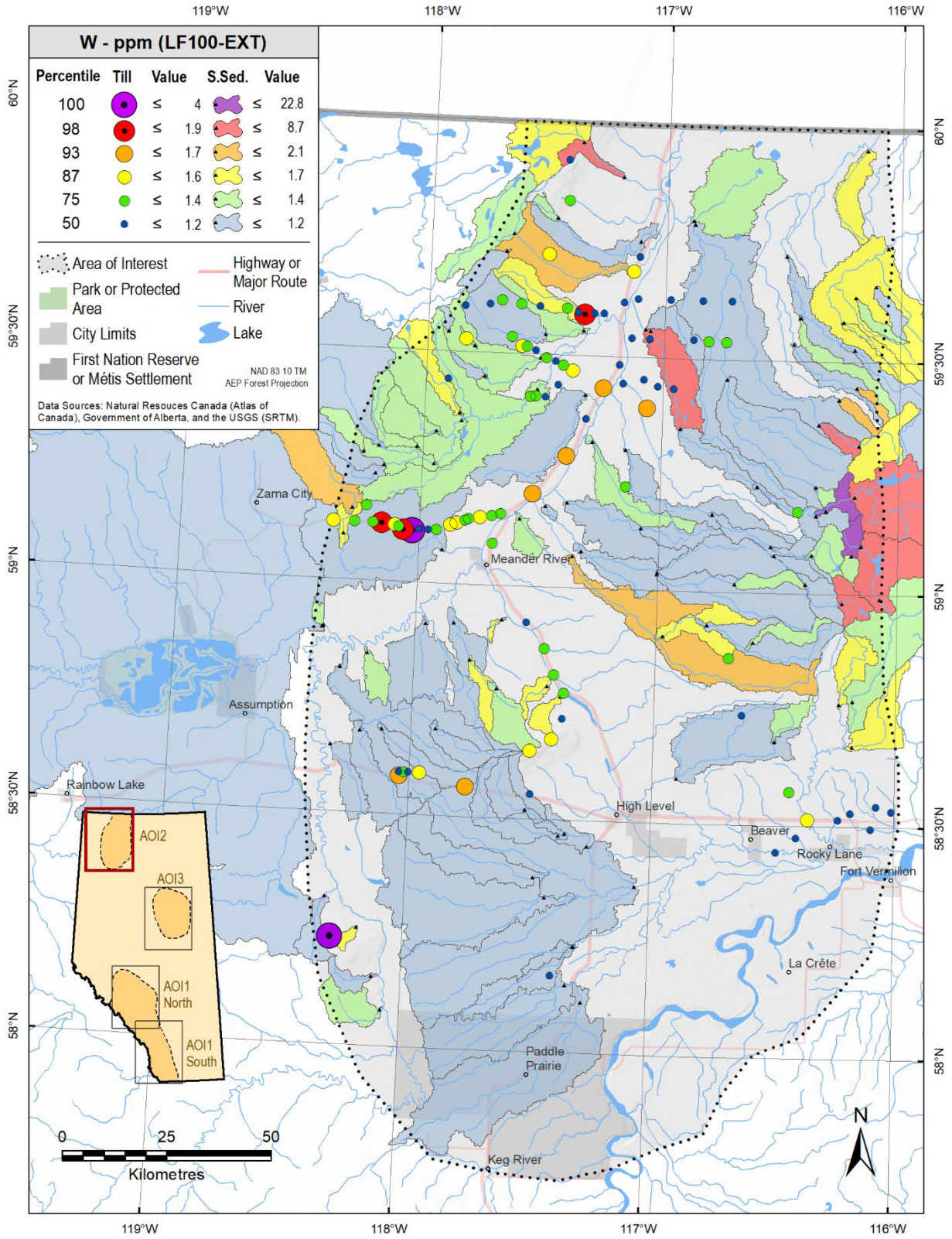

Figure 58. Tungsten (W) concentrations in till and stream sediments in AOI-2.

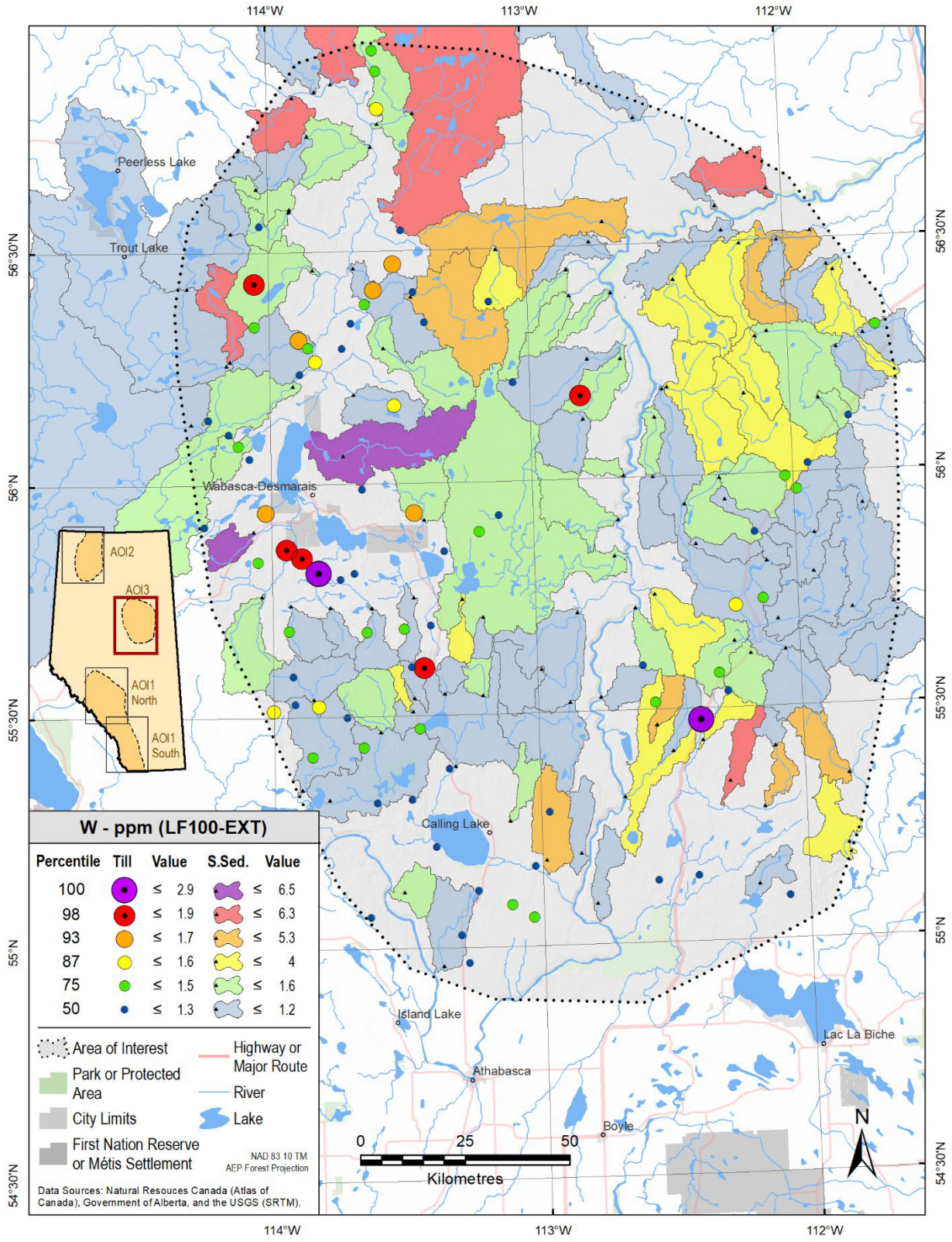

Figure 59. Tungsten (W) concentrations in till and stream sediments in AOI-3.

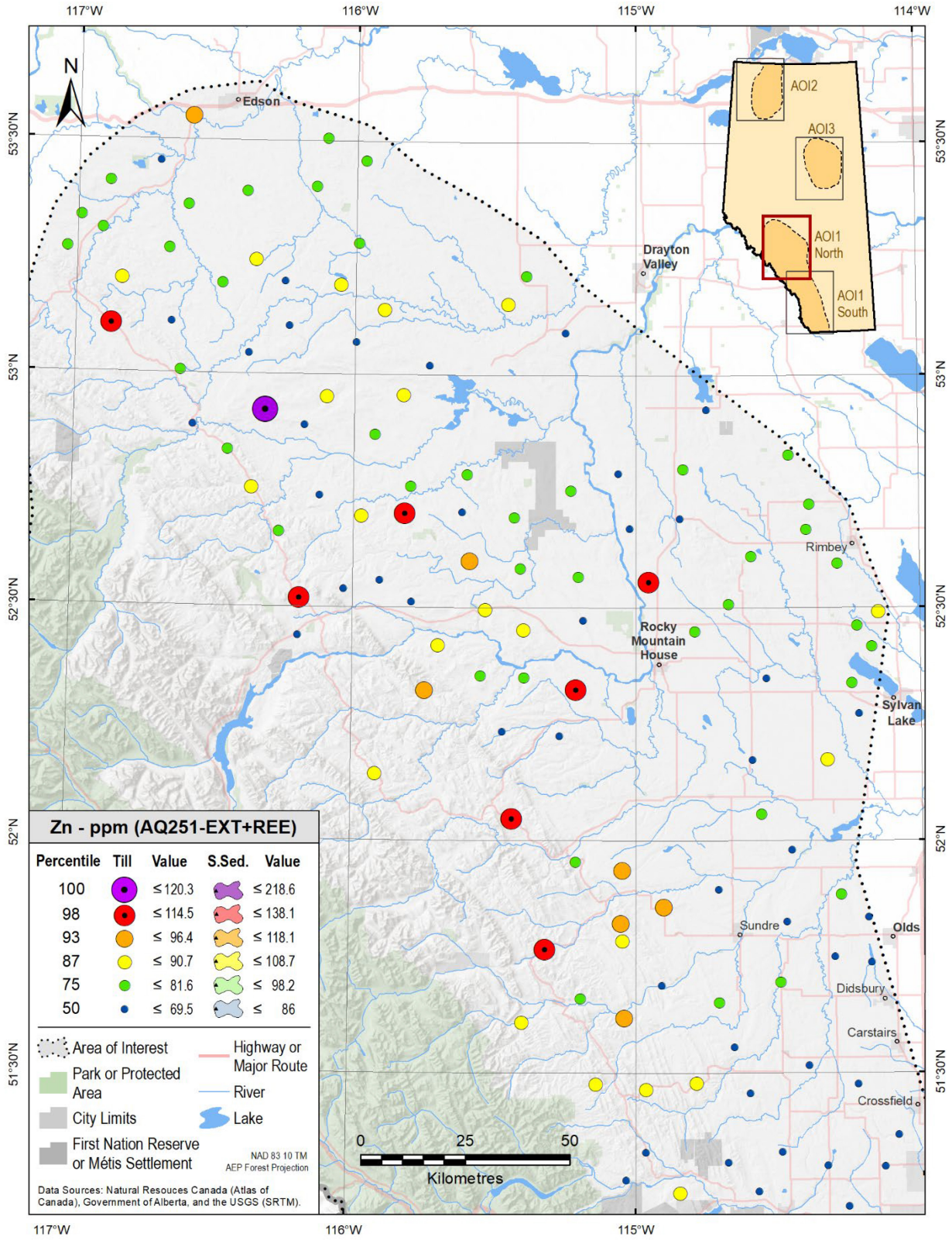

Figure 60. Zinc (Zn) concentrations in till in the northern half of AOI-1.

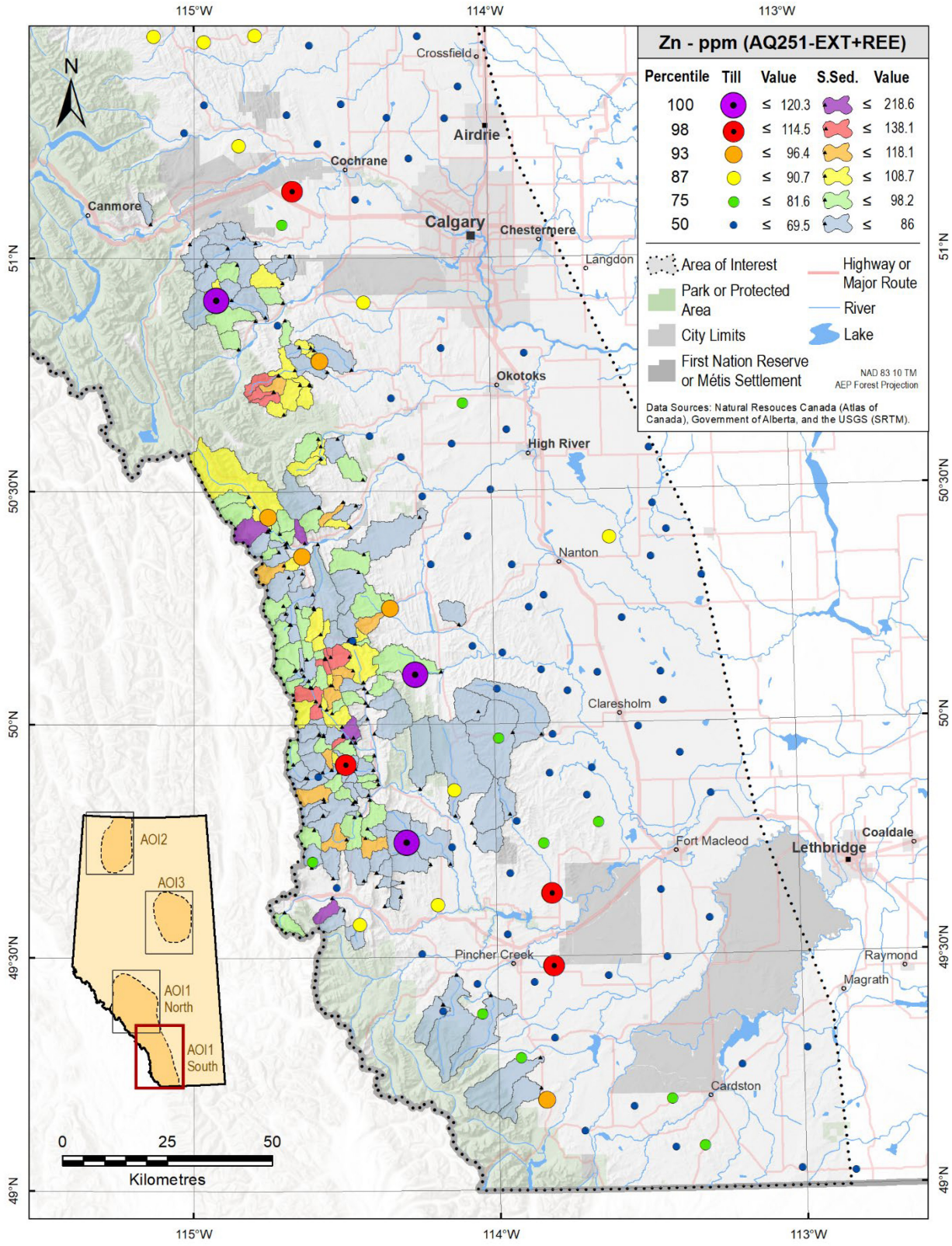

Figure 61. Zinc (Zn) concentrations in till and stream sediments in the southern half of AOI-1.

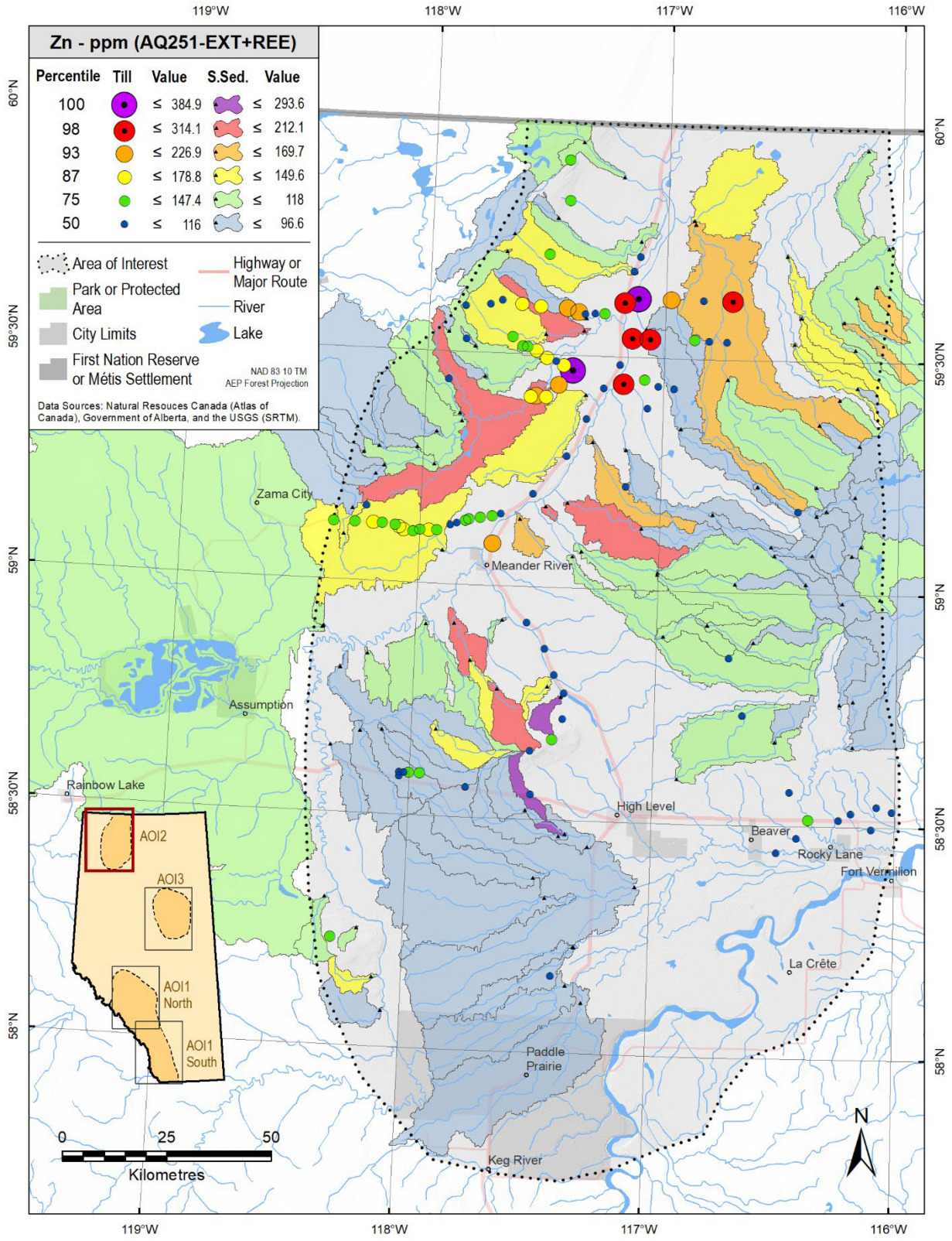

Figure 62. Zinc (Zn) concentrations in till and stream sediments in AOI-2.

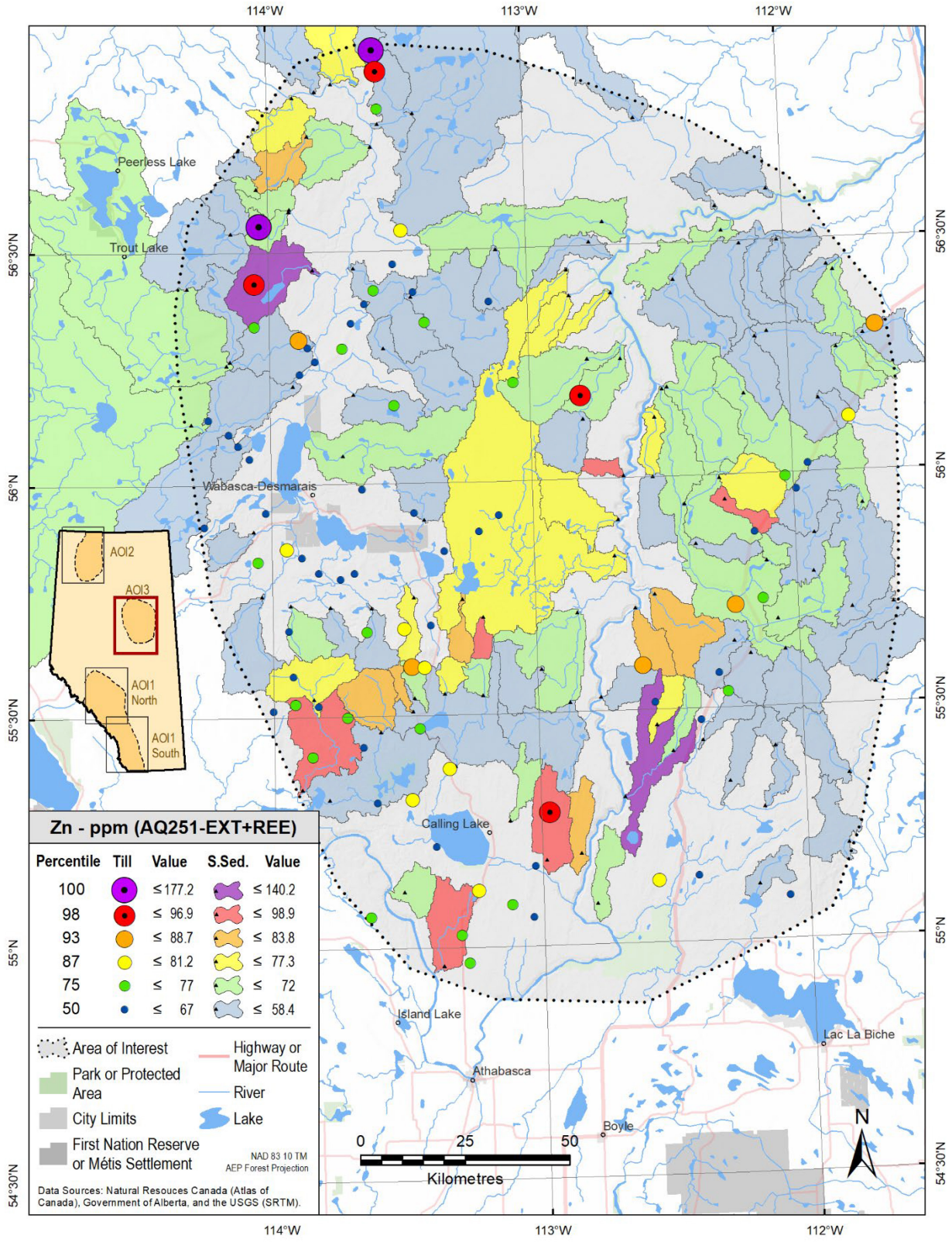

Figure 63. Zinc (Zn) concentrations in till and stream sediments in AOI-3.

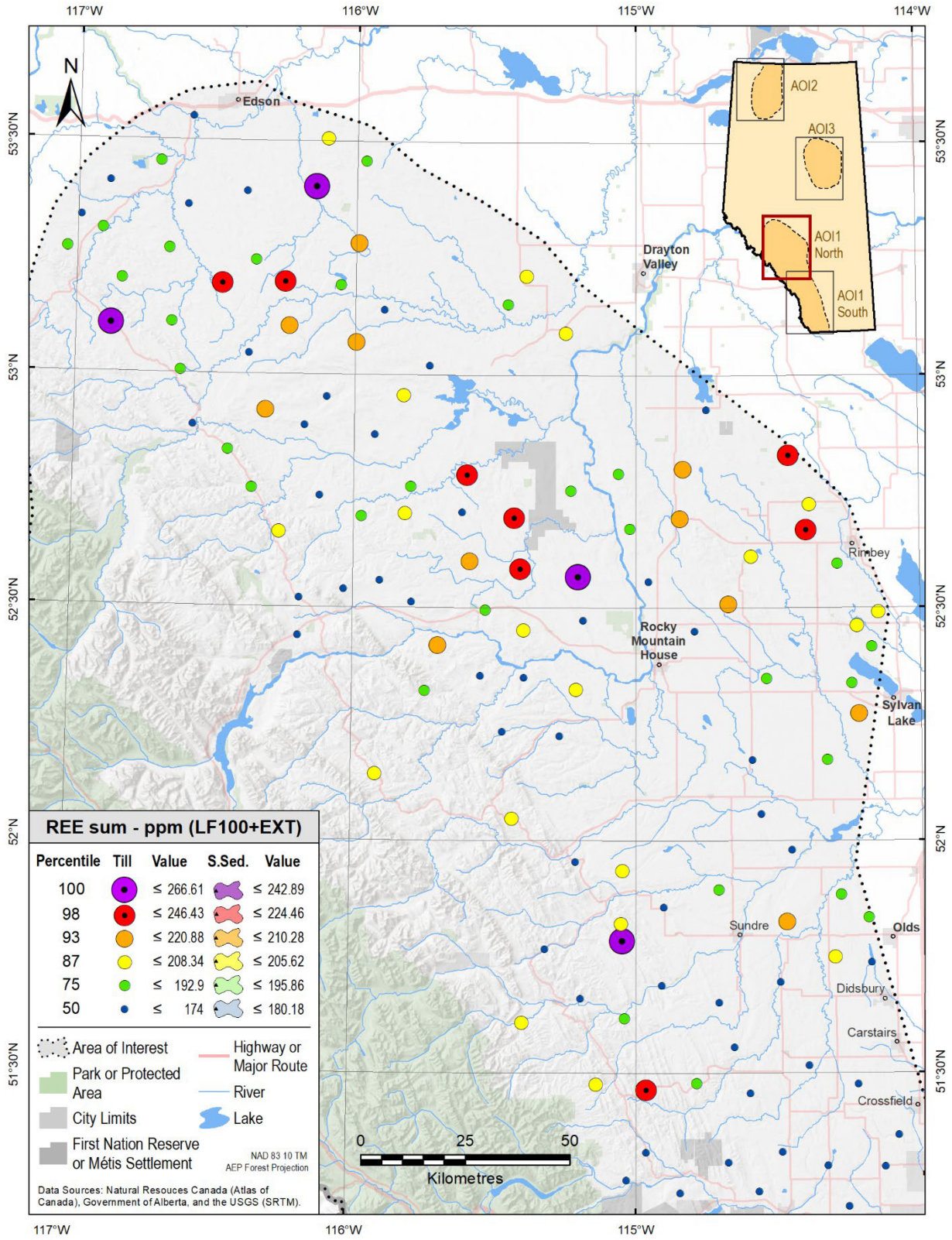

Figure 64. Total REE (La, Ce, Pr, Nd, Sm, Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till in the northern half of AOI-1.

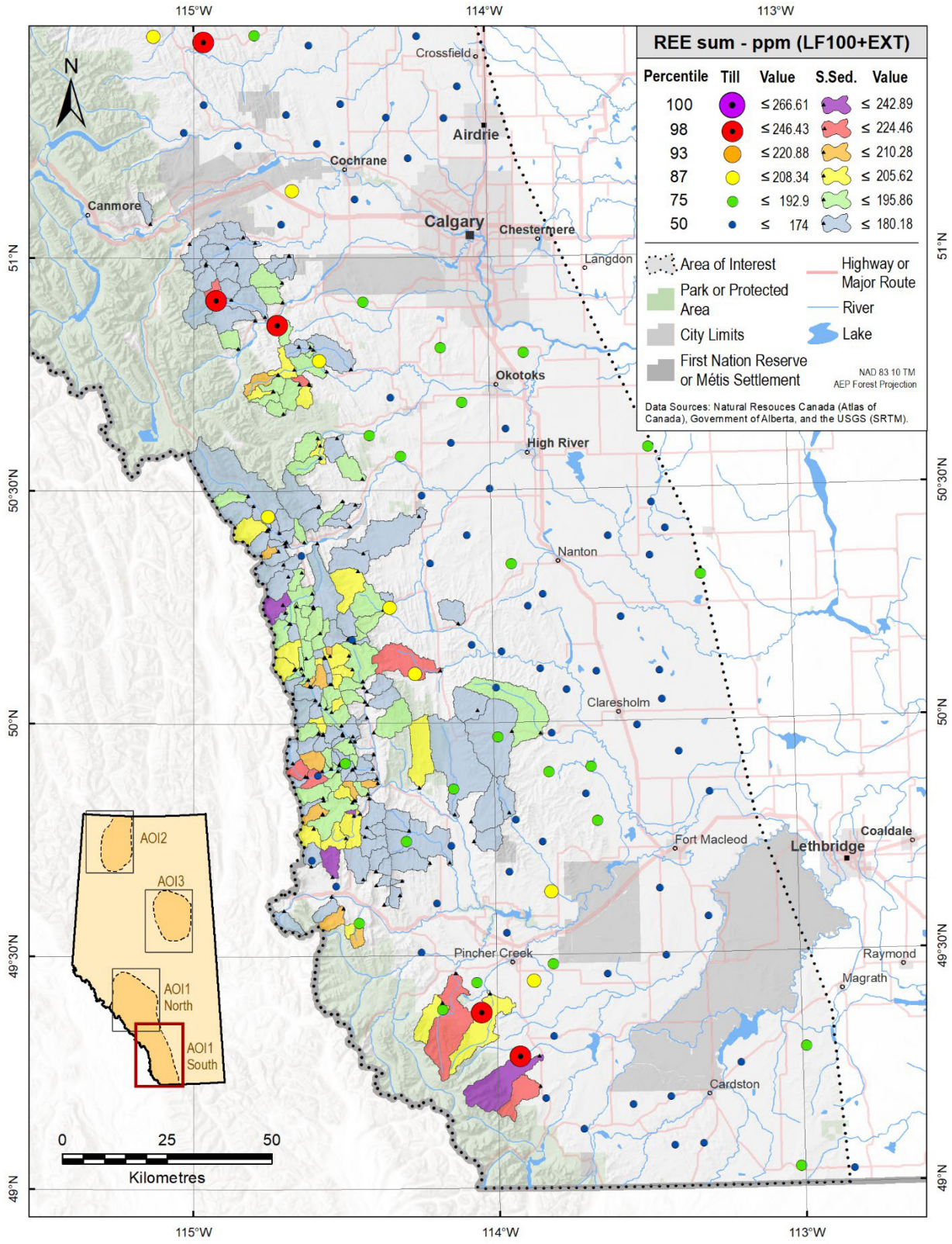

Figure 65. Total REE (La, Ce, Pr, Nd, Sm, Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till and stream sediments in the southern half of AOI-1.

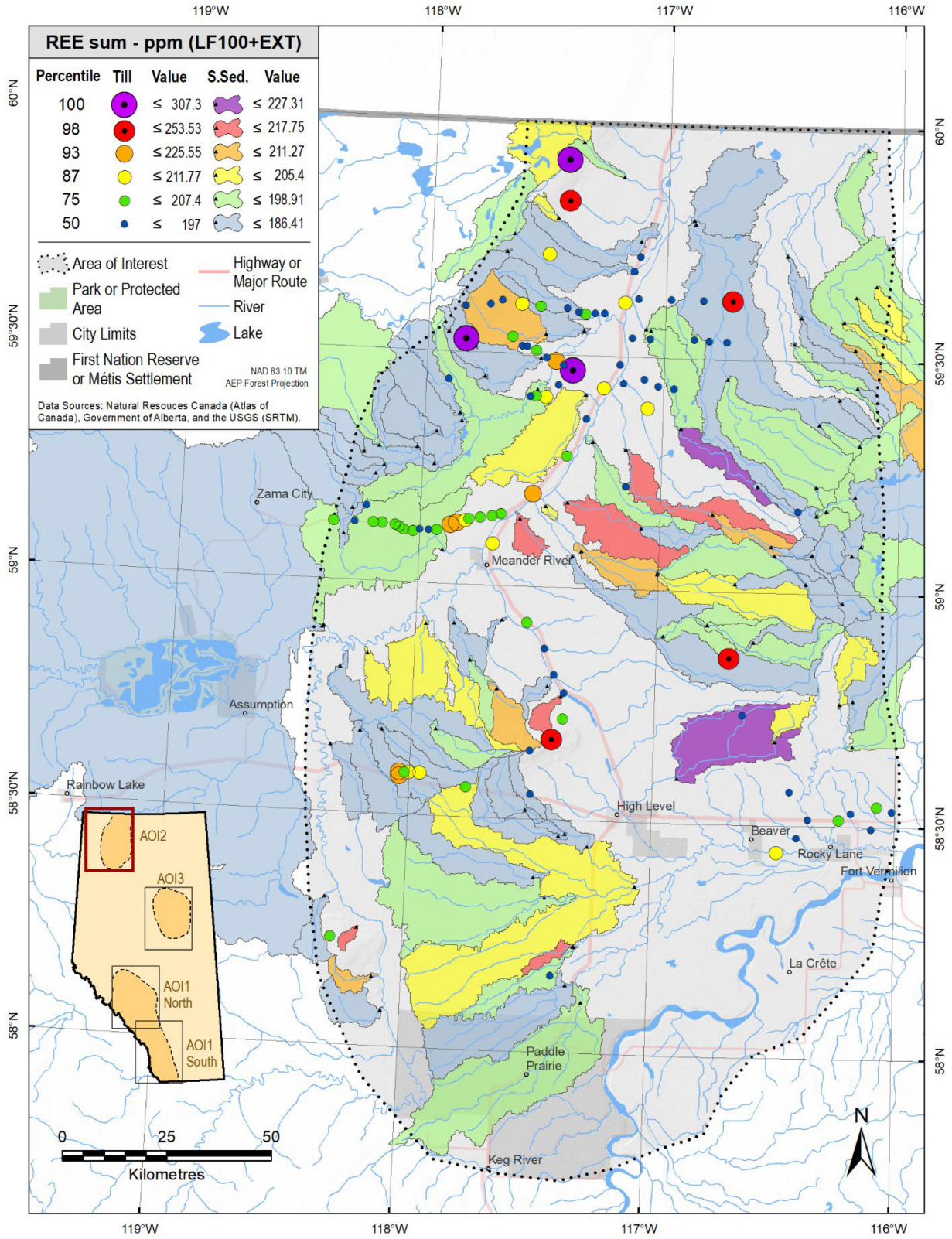

Figure 66. Total REE (La, Ce, Pr, Nd, Sm, Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till and stream sediments in AOI-2.

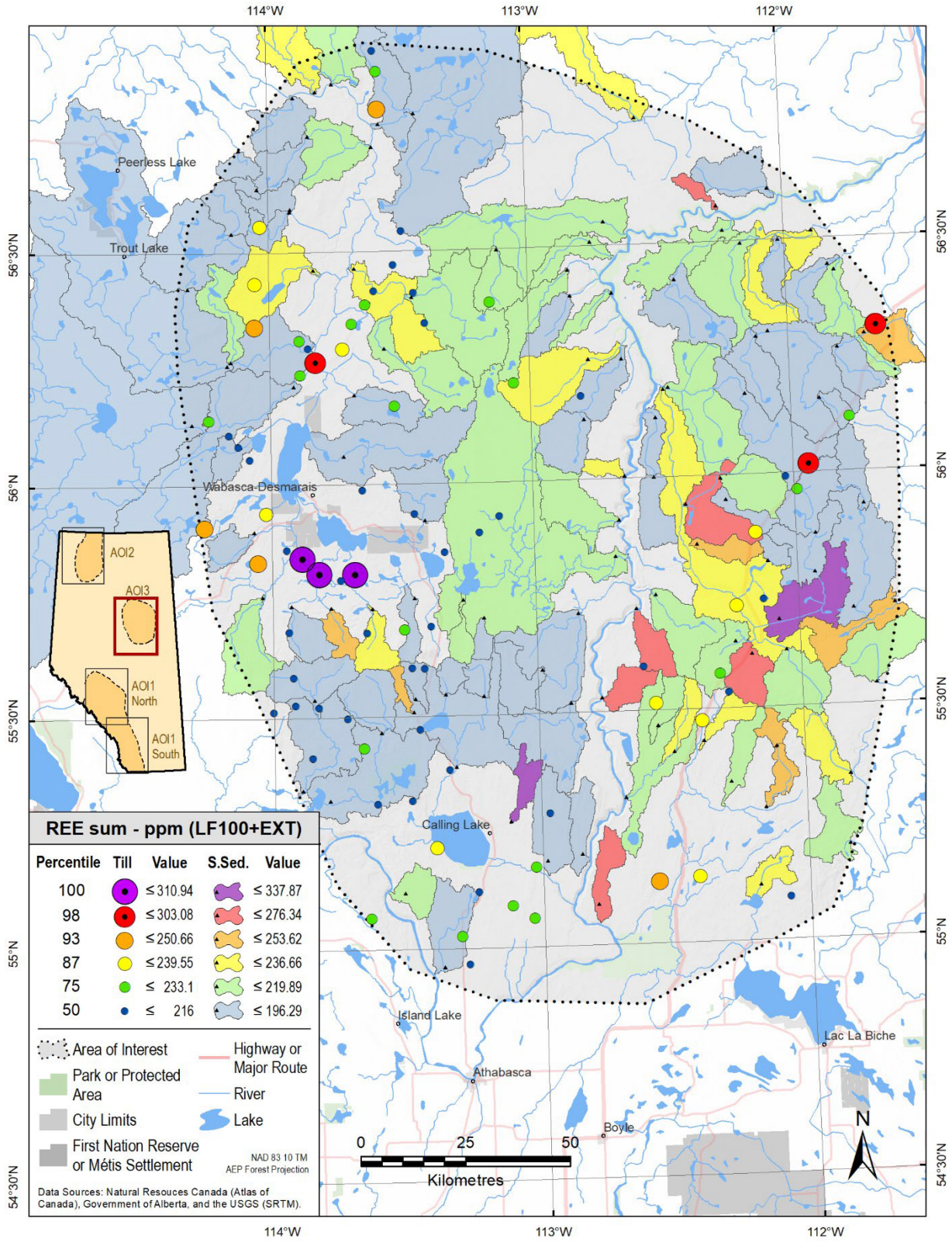

Figure 67. Total REE (La, Ce, Pr, Nd, Sm, Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till and stream sediments in AOI-3.

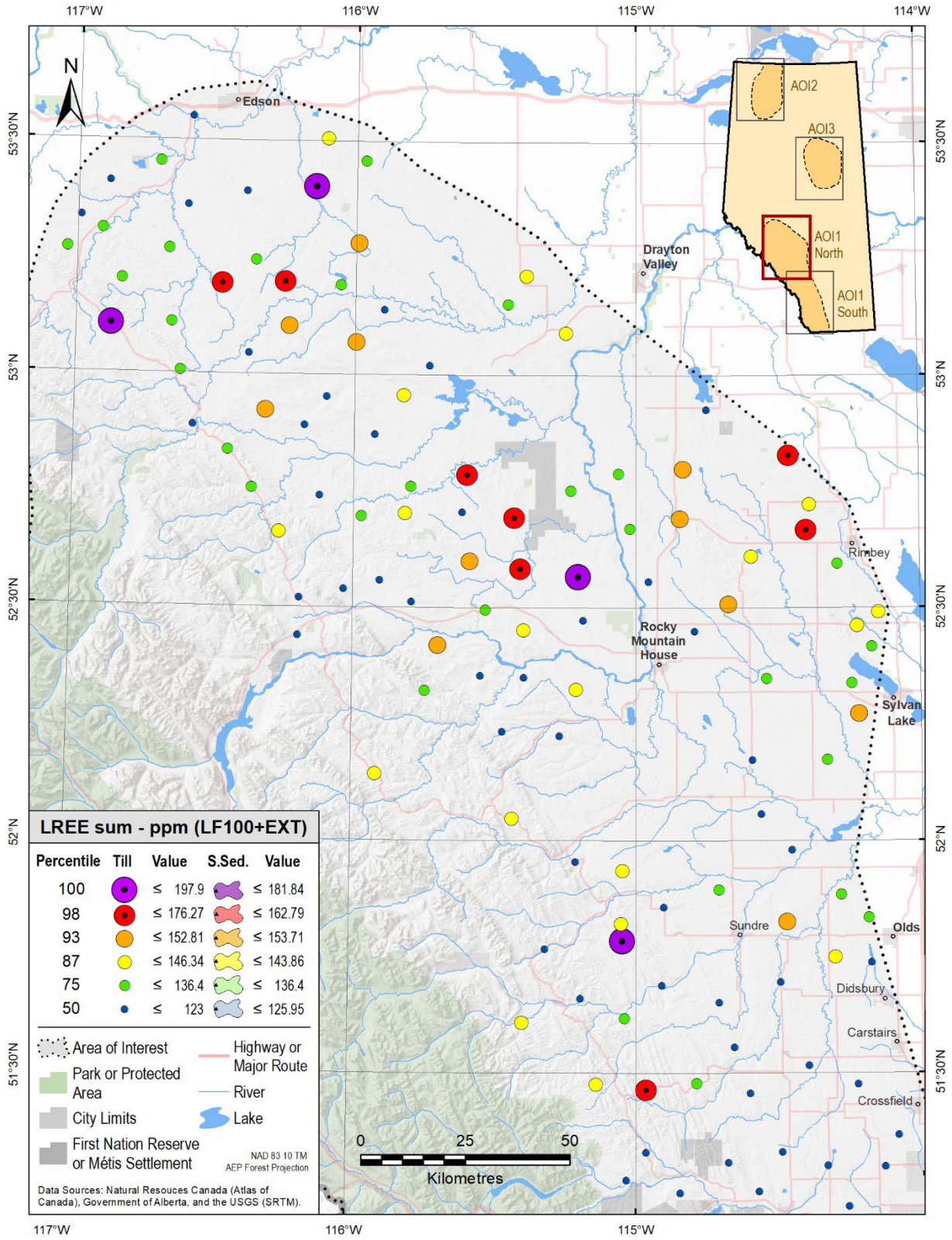

Figure 68. Total LREE (La, Ce, Pr, Nd, and Sm) concentrations in till in the northern half of AOI-1.

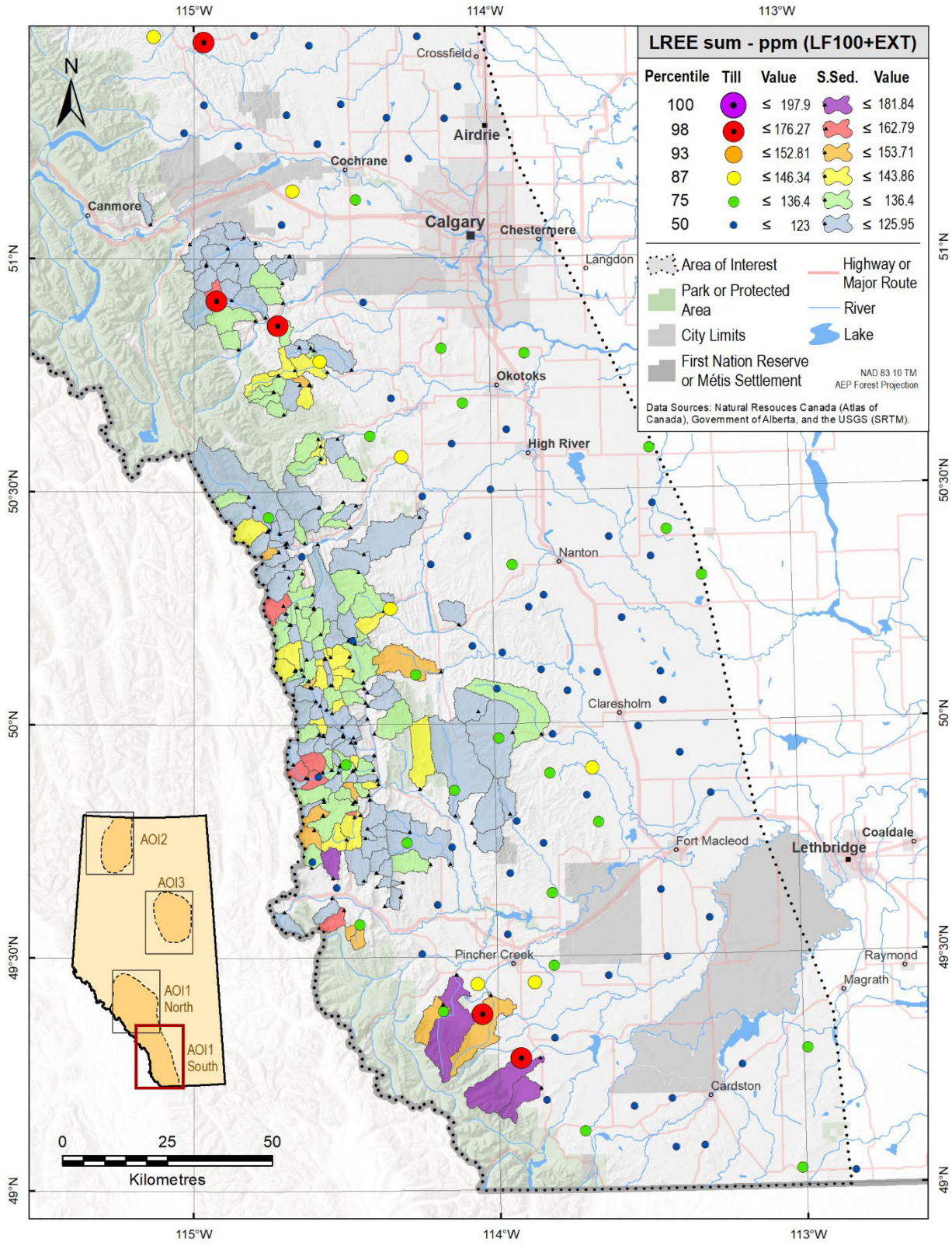

Figure 69. Total LREE (La, Ce, Pr, Nd, and Sm) concentrations in till and stream sediments in the southern half of AOI-1.

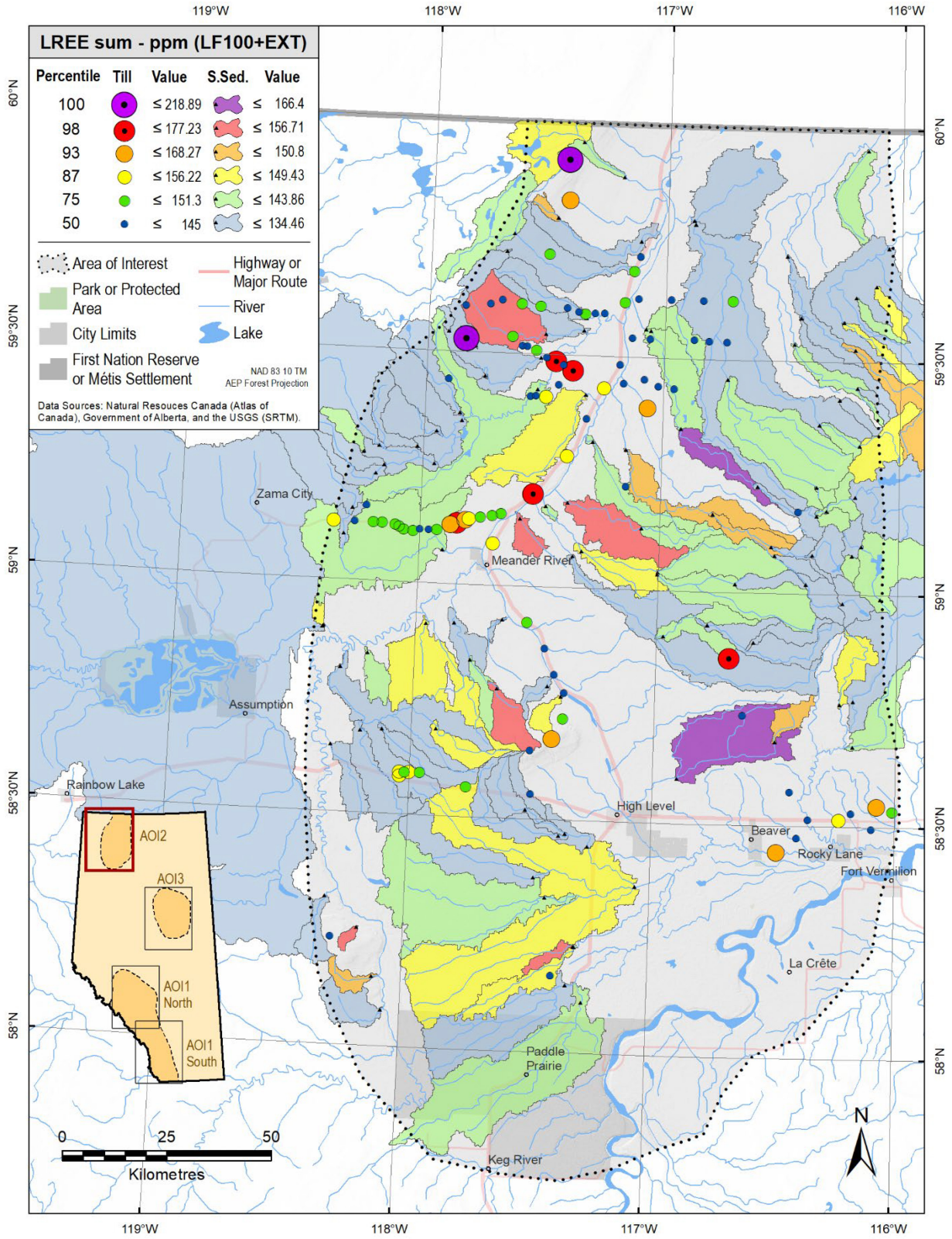

Figure 70. Total LREE (La, Ce, Pr, Nd, and Sm) concentrations in till and stream sediments in AOI-2.

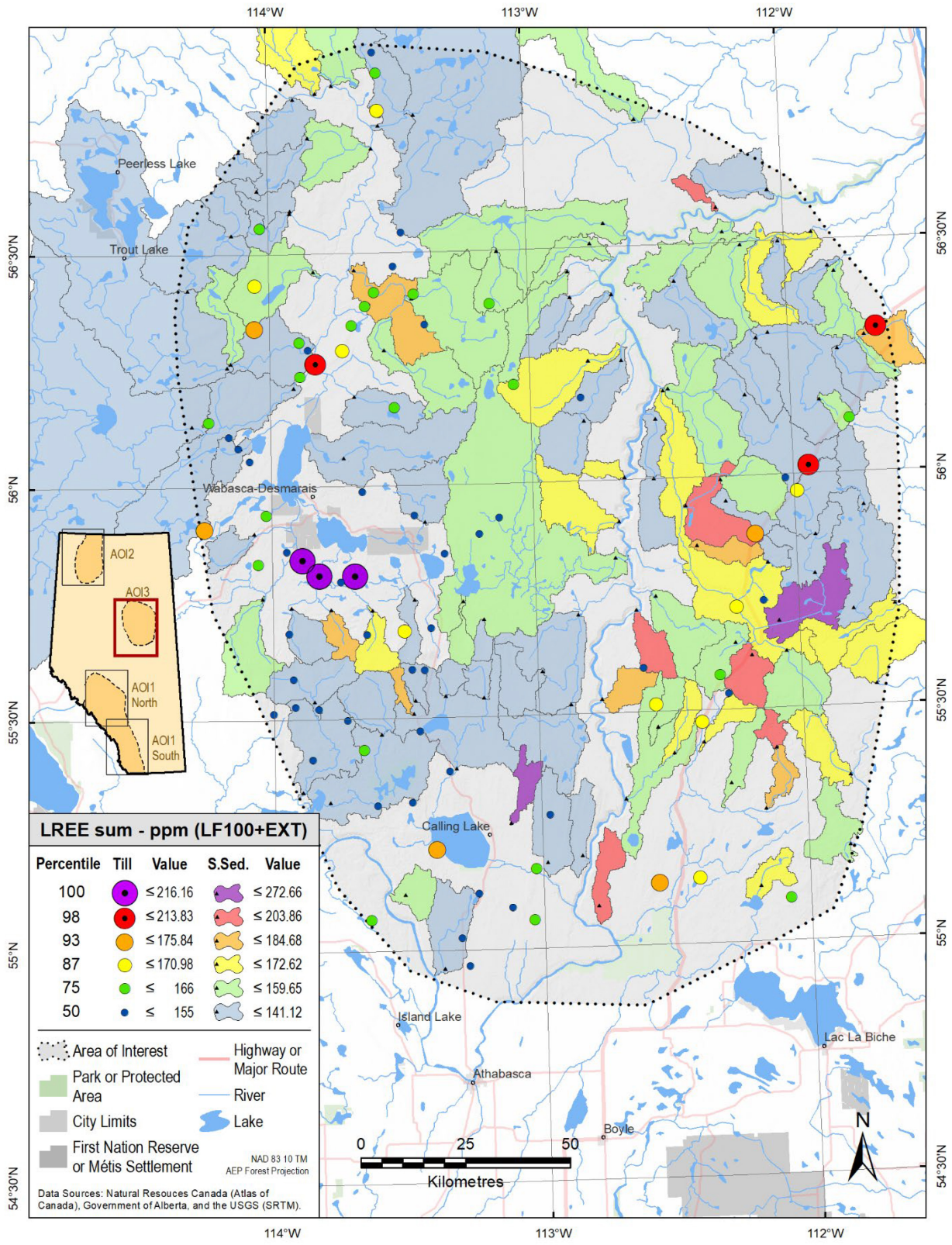

Figure 71. Total LREE (La, Ce, Pr, Nd, and Sm) concentrations in till and stream sediments in AOI-3.

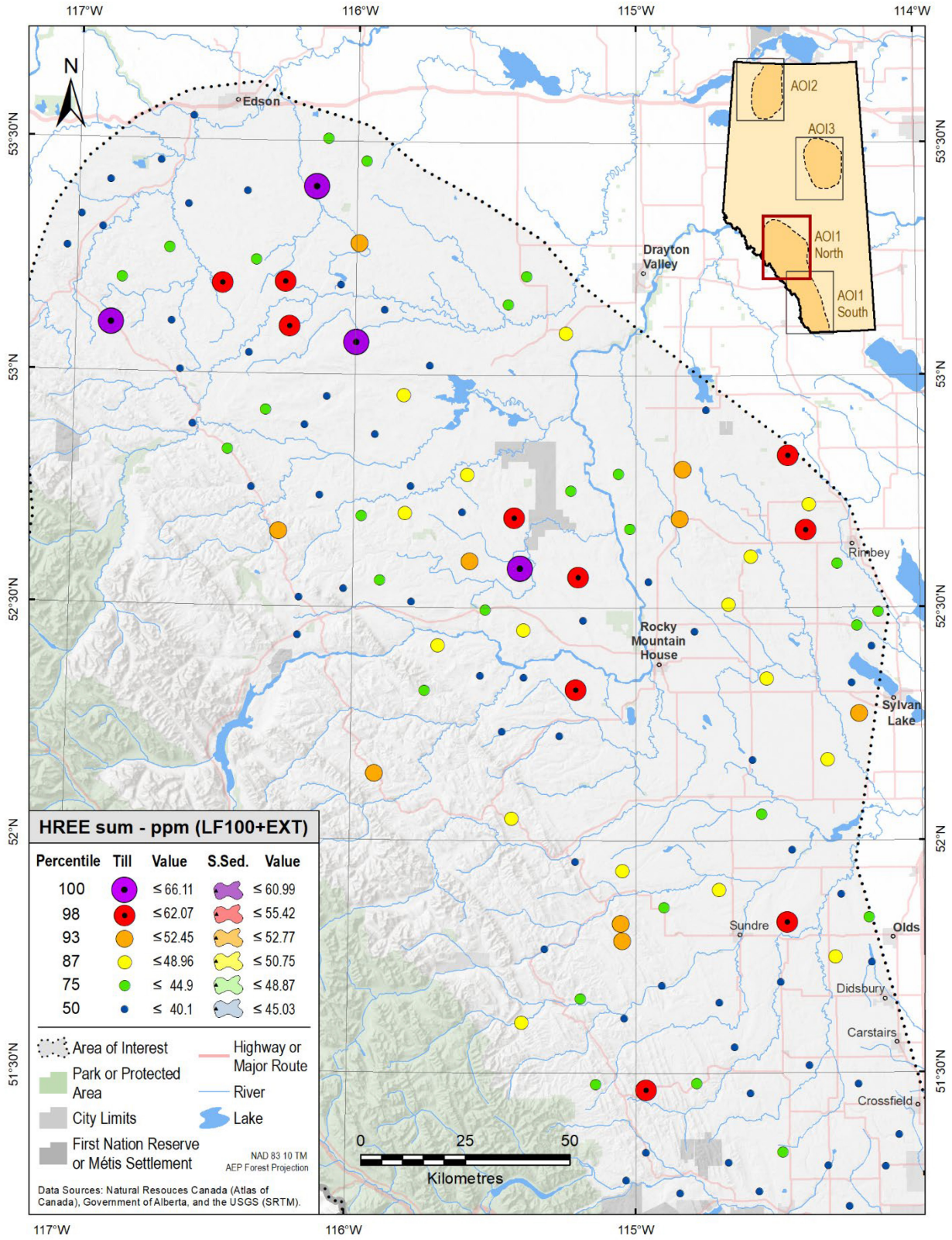

Figure 72. Total HREE (Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till in the northern half of AOI-1.

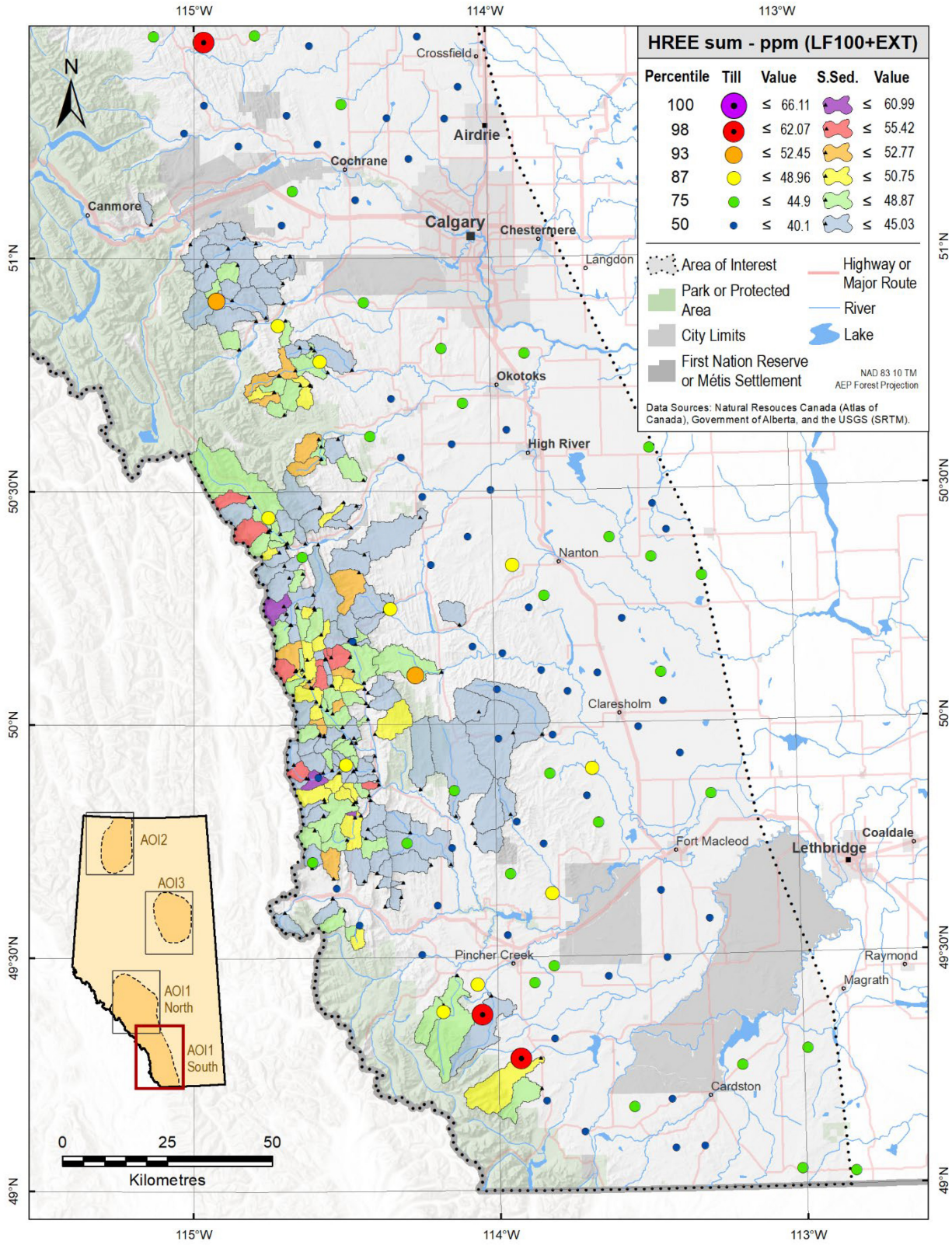

Figure 73. Total HREE (Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till and stream sediments in the southern half of AOI-1.

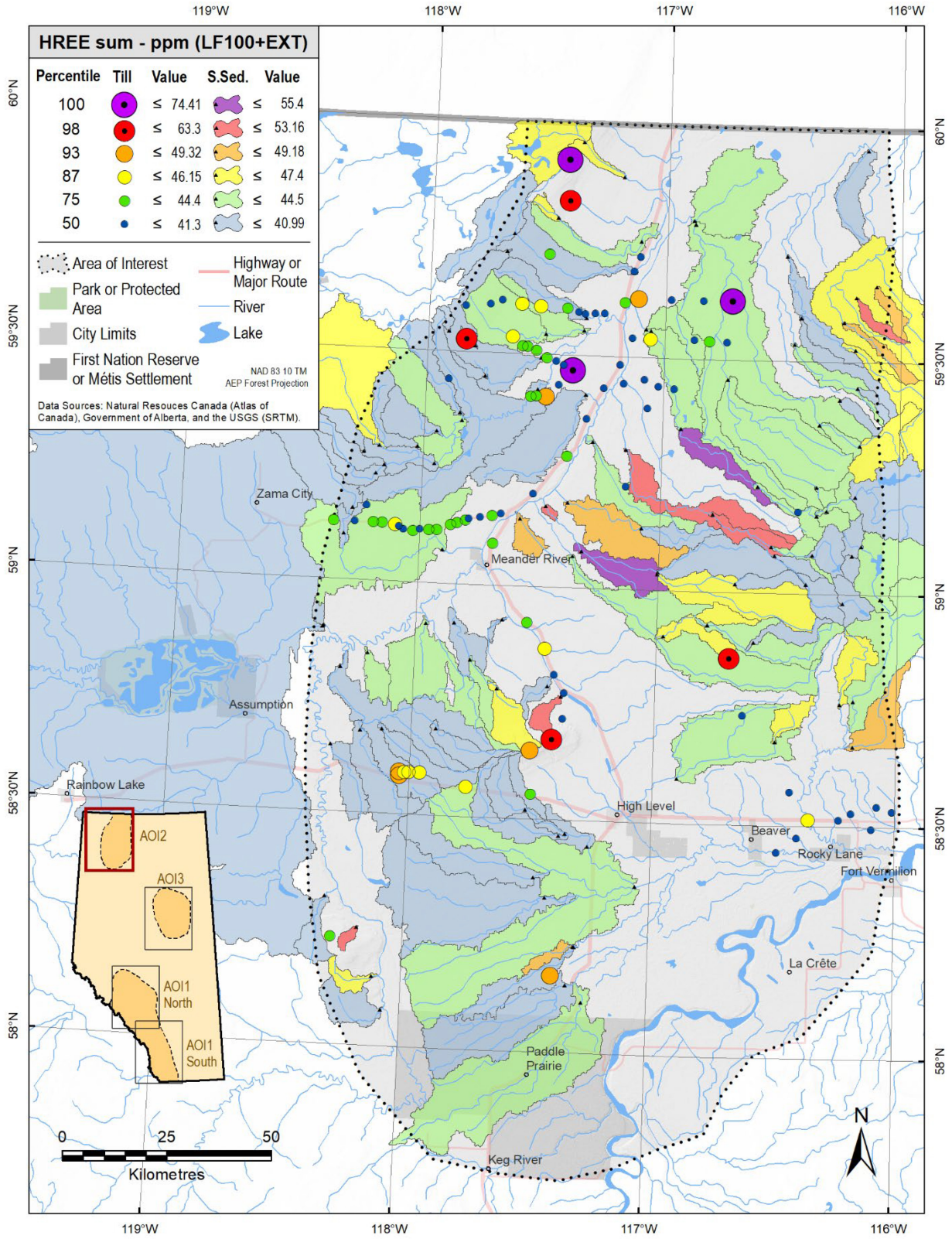

Figure 74. Total HREE (Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till and stream sediments in AOI-2.

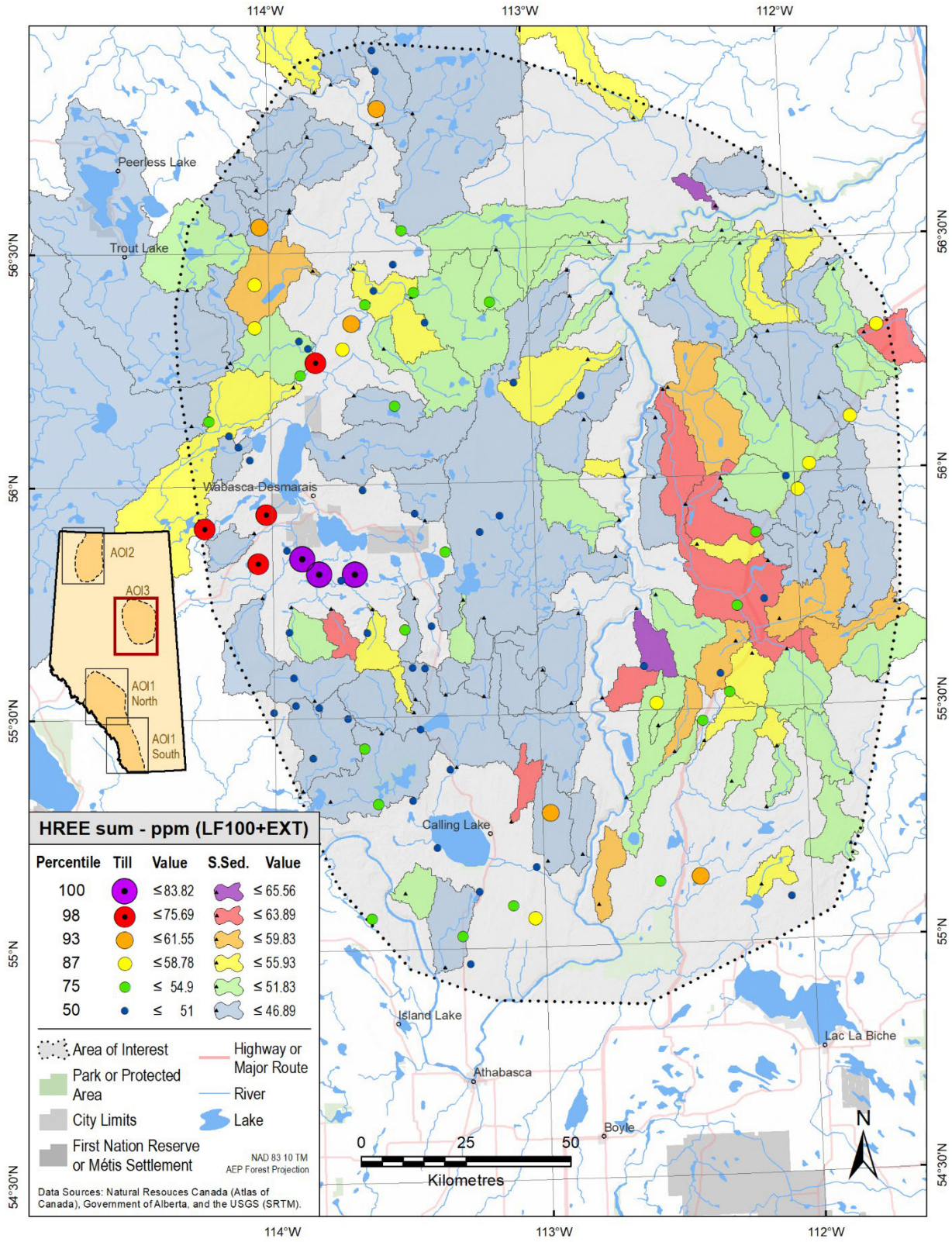

Figure 75. Total HREE (Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations in till and stream sediments in AOI-3.

4.3 Grain-Size Analysis (Till Samples Only)

The results of the grain-size analysis exhibit three groupings that appear to be related to the specific characteristics of each AOI (Figure 76). AOI-1 shows the largest spread in matrix composition, which likely reflects the various sediment source areas. Sandier samples are likely derived from the Rocky Mountains and were probably transported by the Cordilleran Ice Sheet, while siltier samples are more likely associated with sedimentary packages in the plains regions of Alberta that were transported by the Laurentide Ice Sheet. Samples from AOI-2 have a dominantly sandy-mud composition, likely reflective of the numerous fine-grained sedimentary lithologies present in the central plains. The grain size composition of these samples may also be affected by the integration of pre-existing silt and clay deposits (*i.e.,* glaciolacustrine) into the subglacial bedload. Fenton *et al.* (2006) observed silt and clay below till in drill core near AOI-2 that could have been entrained during a glacial readvance. The newly collected till samples have comparable granulometry to the rest of the samples previously collected in AOI-2, although a few samples in the northeast have noticeably higher sand contents. Samples from AOI-3 show the tightest grouping, straddling the sandy-mud and muddy-sand categories. Again, these results are most likely a reflection of relatively consistent ice-flow deriving sediment from fine-grained sedimentary rocks.

A number of samples from AOI-1 and AOI-3 have sand concentrations near 80%, which are likely a function of local bedrock lithology, but could also indicate that the material has been slightly reworked by post-depositional processes resulting in the winnowing of the silt and clay component. On the other end of the spectrum, some samples in AOI-1 and AOI-2 have very high concentrations of silt and clay with less than 10% sand. Again, this may be a function of the local bedrock, but these tills could be associated with glaciolacustrine sediments, potentially being sampled from a gradational contact between till and the overlying glaciolacustrine mantle, or the till may be a product of an ice readvance that overran glaciolacustrine material diluting the subglacial bedload with silt and clay. Regardless of the mechanism causing these compositional outliers, analytical results from samples that have heavily skewed grain size concentrations may not be directly comparable to the rest of the dataset.

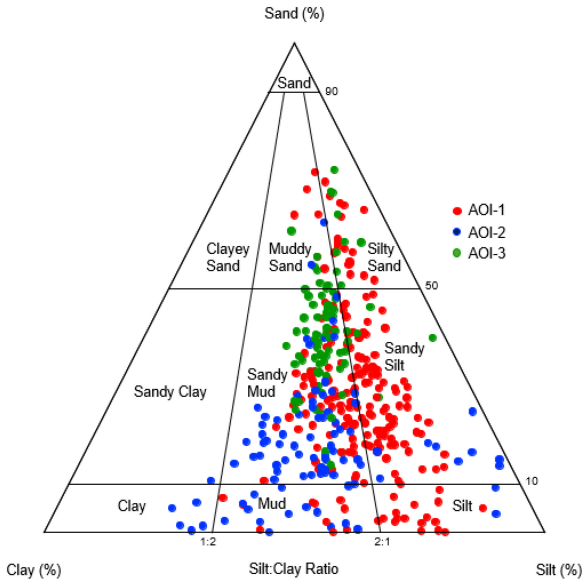

Figure 76. Ternary diagram showing the percentage of sand, silt, and clay in the till matrix, following Folk's (1954) classification.

5. Conclusions

A critical component of Alberta's Minerals Strategy and Action Plan is to increase the availability of public geoscience information to equip explorers, property owners, and Indigenous Peoples with the information necessary to make informed decisions about Alberta's resources. AER is contributing to this plan through their Mineral Mapping Program, which amongst other initiatives, aims to generate high-quality and comparable regional-scale geochemical and mineralogical data that builds upon existing provincial exploration data.

The drill-supported till survey in AOI-2 was completed in two phases in October of 2023 and March of 2024. The results from this survey expand the coverage of till data into areas where standard till sampling approaches would not be possible. This recent program has demonstrated how lightweight drilling technology can be used to effectively extend till sampling surveys into areas with little to no access and areas where till is buried by a mantle of glaciolacustrine material. During this program, protocols for sampling and movement of staff and equipment were refined, providing a means to continue extending the coverage of reliable regional-scale geochemistry and to follow up existing anomalies. There are significant opportunities for addition sampling in northern Alberta using these methods considering the vast areas with poor access and the extensive mantles of glaciolacustrine sediment.

As part of AERs mineral Mapping Program, this regional till and stream sediment sampling survey has provided new data from nearly 800 locations across the three AOIs. All geochemical samples were analysed using methods that conform to strict quality control specifications and have resulted in the production of a comprehensive geochemical data set (Appendix A). Catchments have been delineated for all stream sediment samples. These catchment basins provide a relatively accurate understanding of the area tested by the stream sediment samples (*i.e.*, are covered by a catchment basin), and a general indication of the potential source area for anomalous samples. Paired with the till geochemistry, the two datasets provide a robust means to identify areas of prospectivity suitable for more detailed surveys through government or private initiatives. The lessons learned can be leveraged to fill remaining data gaps throughout Alberta, continuing to stimulate interest in Alberta's mineral potential, and achieving the goals set out in the province's Minerals Strategy and Action Plan.

6. Acknowledgments

This program was funded entirely by AER through the Alberta Minerals Grant (Alberta Energy, 2021). We would like to thank Delta Helicopters for their provision of air support and North Point Rentals for supplying the Argos. A special thank you to Mark Kelland at Woodsmen Contracting for exceptional support with pad clearing and who's local knowledge contributed to the success of the program. And lastly, we appreciate the assistance provided by the team at AER and AGS, who were always available to provide support, guidance, and useful information throughout the program.

7. Statement of Limitations

This report has been prepared by Palmer, a part of SLR Consulting (Canada) Ltd. (SLR) for AER (Client) in accordance with the scope of work and all other terms and conditions of the agreement between such parties. This report is not to be used for any purpose other than as intended.

Any findings, conclusions, recommendations, or designs provided in this report are based on conditions and criteria that existed at the time work was completed and the assumptions and qualifications set forth herein.

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8. Certification

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Appendix A

Till and stream sediment analytical results

Provided separately as:
A1 Till Data.zip
A2 StreamSed Data.zip

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Appendix B

Till and stream sediment analytical certificates

Provided separately as:
B1 Till Geochemistry Lab Certificates.zip
B2 Till Grain Size Analysis Lab Reports.zip
B3 Stream Sed Geochemistry Lab Certificates.zip