



# Compilation of geochemical data between Lillooet and French Bar Creek, south-central British Columbia

R.E. Lett



Ministry of  
Energy, Mines and  
Petroleum Resources



British Columbia Geological Survey GeoFile 2018-4

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**Front cover:** The Fraser River valley north of Lillooet. **Photo by R.E. Lett.**

Appendices for this paper can be downloaded from

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R.E. Lett<sup>1a</sup>

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## Abstract

Results of two multi-media geochemical surveys along the west side of the Fraser River between Lillooet and French Bar Creek were originally published in British Columbia Geological Survey Fieldwork papers in 2006 and 2007, but the digital data for the surveys were not released. A compilation of the results from the two surveys, the raw data of which are released herein as readily accessible spreadsheets, reveals a strong geochemical expression of epithermal gold mineralization from occurrences in the 'Watson Bar gold belt' as anomalous Au, As, Cu, and Hg in stream sediments. The highest Au, As, Cu, and Pb concentrations are in bedrock at the Watson Bar developed prospect. Gold mineralization is also reflected by elevated As in stream water. Several other Au anomalies in stream sediment and bedrock lack a clear source of Au mineralization. Sediment and water from Boiler Creek near the northern limit of the project area have anomalous REE levels. The sediment and water also have elevated Al and Fe values suggesting that the source for the REEs may be clay minerals weathered from volcanic rocks.

**Keywords:** Canada, British Columbia, Lillooet, geochemistry, water, sediment, rock

## 1. Introduction

In 2003, prospector E. Balon, traced the source of a British Columbia Regional Geochemical Survey stream-sediment gold anomaly (29 ppb), to gold-mineralized quartz veins near the headwaters of Skoonka Creek, west of Spences Bridge (Balon, 2005). The mineralized veins are in andesites of the Pimainus Formation (Lower Cretaceous, Spences Bridge Group). Although this discovery stimulated extensive exploration of the area underlain by Spences Bridge Group rocks towards Lillooet, no economic gold deposits were found. Nonetheless, the exploration prompted the British Columbia Geological Survey to carry out detailed stream-sediment, moss mat-sediment, stream water, and bedrock geochemical sampling along a 800 km<sup>2</sup> belt north of Lillooet and west of the Fraser River in 2005 and 2006 (Fig. 1).

Survey results for the Lillooet area were reported by Lett (2006) and for the McLeod Lake area by Lett and Blumel (2007). This GeoFile releases the original raw data of these surveys as readily usable spreadsheets (Appendices 1-6) and provides a summary linking the two areas. Since the initial fieldwork, Jackaman (2010) re-analyzed some samples taken from the belt during the British Columbia Regional Geochemical Survey (RGS) conducted in 1992 and 1993

(Jackaman et al., 1992a,b; Jackaman and Matysek, 1994), and Arnie and Bluemel (2011) provided an analysis of the catchment basin geochemistry. Results from these studies have not been included in Appendices 1 to 6.

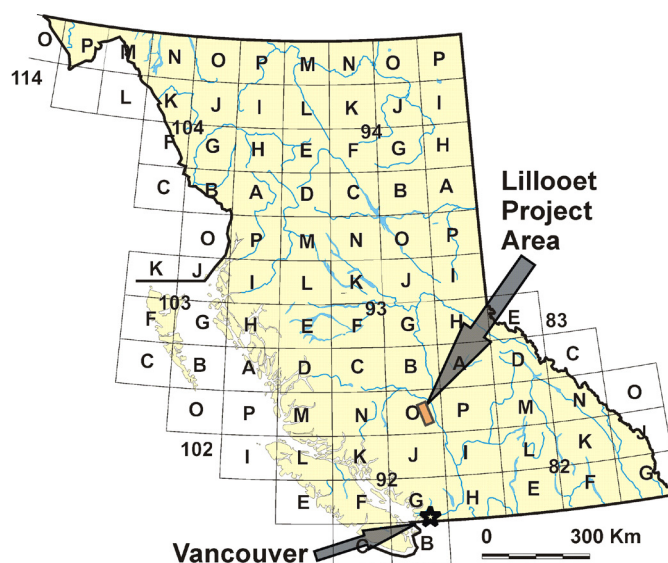


Fig. 1. Project location.

## 2. Survey area description

### 2.1. Landforms, drainage, access, climate, and vegetation

The multi-media geochemical sampling in 2005 and 2006 covered about 800 km<sup>2</sup> along the west side of the Fraser River (Fig. 1). Landforms are typical of the Camelsfoot Ranges, a physiographic subdivision of the Coast Mountains, with rugged mountains (up to 2,445 m) in the southeast, and the deeply incised Fraser River canyon to the northwest (Fig. 2; Holland, 1976). Along the west side of the Fraser River, from Lillooet to Watson Bar Creek 70 km to the north, are a series of small plateaus formed on flat-lying basalt and alluvial benches close to the river. The plateaus and benches are incised by large creeks that flow from the uplands into the Fraser River, such as Slok Creek, McKay Creek, Leon Creek, Watson Bar Creek, Ward creek, South French Bar Creek (Fig. 3). North of Watson Bar Creek the land surface is less rugged (Fig. 3). Access to the area is along the West Pavilion Road, an unpaved road that traverses the west side of the Fraser River from Lillooet to the Big Bar Ferry. Branches of the West Pavilion Road allow access to the uplands west of the Fraser River.



b)



**Fig. 2.** Physiography of project area. **a)** The Fraser River valley north of Lillooet. **b)** Terrain near French Bar Creek.

Climate and vegetation are typical of the Coast Ranges and the Fraser Plateau. Annual rainfall is less than 280 mm and temperatures range from -6°C in winter to 40°C in summer. In late summer the larger creeks have a diminished water flow and many of the smaller drainages are completely dry. Vegetation at lower elevations in the Fraser Canyon is an understory of bunchgrass prairie with sagebrush and a canopy of scattered Ponderosa pine or Douglas fir. Douglas fir, White spruce, and Engelmann spruce stands are common on the uplands west of the Fraser Canyon. Much of the mature timber has been harvested, and the stands remaining in 2005 were damaged by the mountain pine beetle infestation.

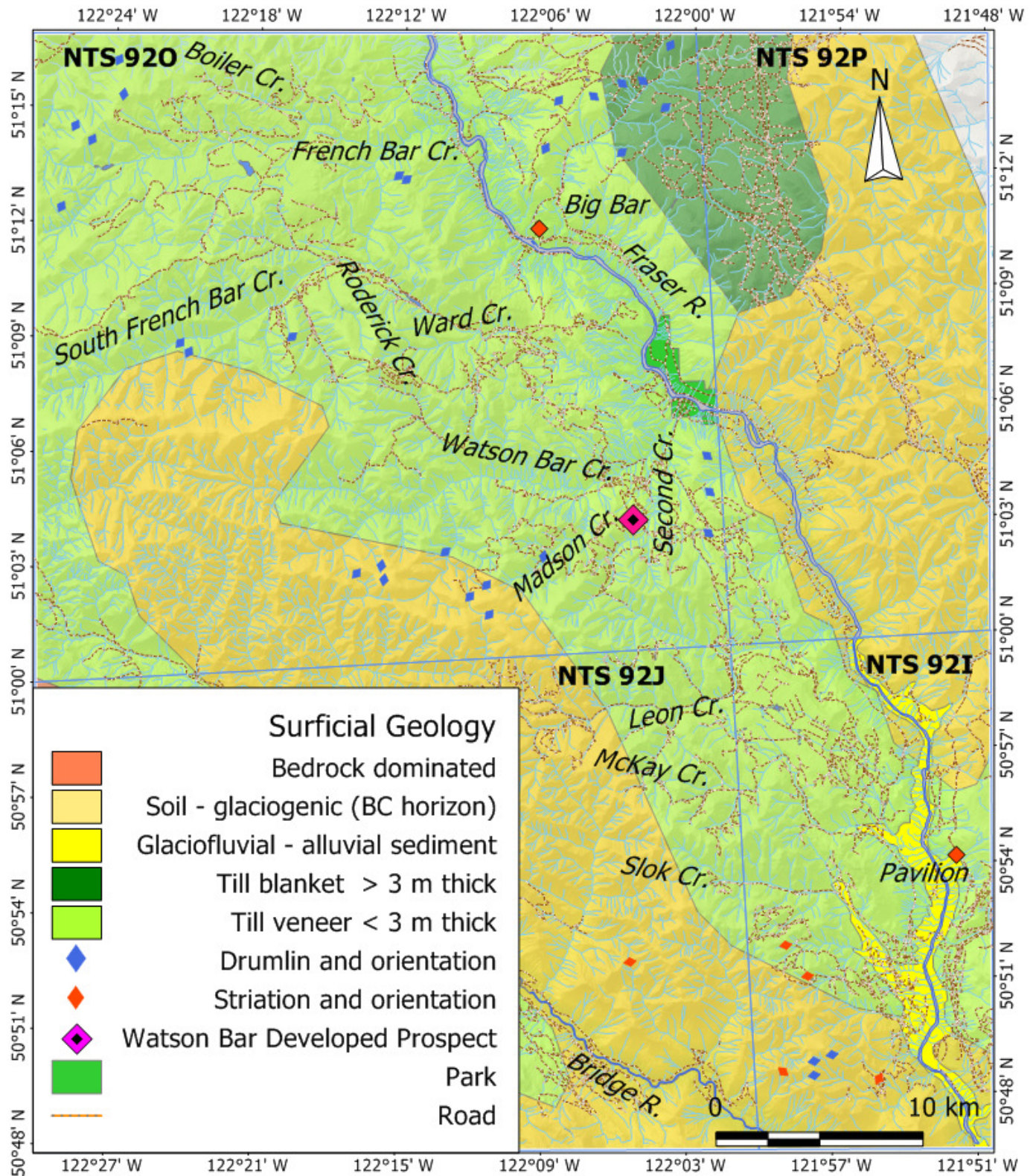
### 2.2. Surficial geology

As alpine glaciers expanded during the early stages of the Fraser Glaciation, ice flowed northeast and southwest from a center in the Camelsfoot Range (Fig 3). These glaciers filled the major northeast- and east-trending valleys and deposited a varying till thickness. Eventually the valley glaciers coalesced to block the Fraser River, forming a large, proglacial lake. Tretin (1961), suggested that by the late Pleistocene the Fraser River valley contained more than 300 m of sediment deposited in alluvial fan, braided stream, deltaic, and lacustrine environments (Figs. 4a,b). Holocene erosion, in places to bedrock, formed the present day Fraser River valley.

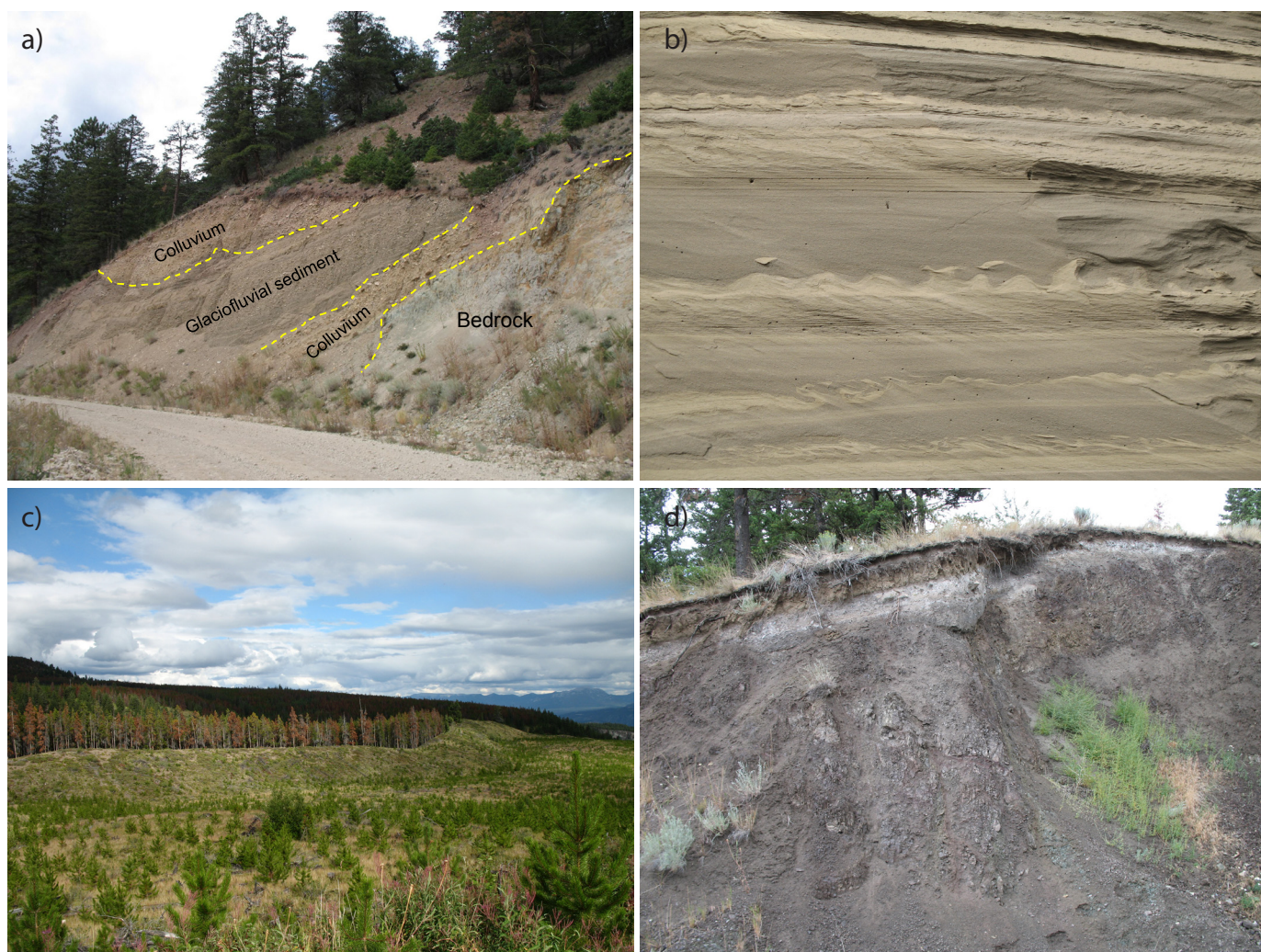
From the orientation of cirques in the Camelsfoot Range, Broster and Huntley (1992) suggested that an ice divide separated north- and south-flowing ice near Ward Creek and French Bar Creek. Broster and Huntley (1992) identified massive matrix supported, massive clast supported and stratified diamicts in the area. Striations and flutings suggest ice-flowed to the north and northeast, parallel to the Fraser River valley. Locally, surficial sediments range from a sandy till on the uplands to colluvium covering steeper hill slopes. Ice melt-out landforms and glaciofluvial deposits include eskers (Fig. 4c) and terraces along valley sides. Soil formed on the glacial sediment is predominantly a Dystric Brunisol with an intermittent layer of the Bridge River volcanic ash at the base of the B horizon soil (Fig. 4d).

### 2.3. Bedrock geology

Middle to Upper Cretaceous (Albion) rocks of Spences Bridge Group are the oldest rocks in the project area (Fig. 5). They consist of a lower unit of volcanic arenite, conglomerate, minor siltstone, phyllitic argillite, and rare carbonaceous shale, and an upper unit of plagioclase-phyric dacite, andesite, and minor basalt. Spences Bridge Group rocks in the study area are overlain by Middle to Lower Cretaceous volcanoclastic rocks of the Jackass Mountain Group (Cathro et al., 1998), which are in turn overlain by Eocene volcanic, shale, rhyodacite flows, and tuffaceous wacke of the Ward Creek assemblage, and Miocene to Pliocene vesicular and amygdaloidal basalt with minor conglomerate and sandstone of the Chilcotin Group (Read, 1988). Slices of the Spences Bridge and Jackass Mountain groups are exposed in the Fraser fault zone, a major northwest-



**Fig. 3.** Locations, surficial geology, and ice-flow indicators (from Fulton, 1995; Arnold, et al., 2016).



**Fig. 4.** Surficial geology. **a)** Glaciofluvial sediment, colluvium, bedrock complex north of Watson Bar Creek. **b)** Glaciofluvial sands, with parallel-stratification, ripple-drift cross stratification and climbing ripples; road cut west of the Big Bar ferry. **c)** Winding east-trending esker near French Bar Creek. **d)** A typical soil formed on weathered bedrock with a Bridge River ash deposit.

trending, Eocene dextral wrench fault system that includes the Fraser, Slok Creek, the Hungry Valley faults and the Watson Bar thrust (Trettin, 1961, Read, 1988). Displacement along the Fraser Fault zone north of Lilloett is estimated to be 130 km (Monger and Journeay, 1994).

## 2.4. Mineral deposits

Several epithermal gold mineral occurrences are in the project area, and Cathro et al. (1998) identified five styles hosted by Jackass Mountain Group rocks in what he termed the 'Watson Bar gold belt': 1) iron carbonate-silica alteration zones with elevated Au, As, Sb, and Hg; 2) thrust-hosted quartz sulphide mineralization; 3) quartz-sulphide veins related to quartz-feldspar porphyry sills intruding the Jackass Mountain Group; 4) high-angle quartz-sulphide veins and stockworks; and 5) gold-rich conformable zones in the sedimentary rocks.

The largest gold deposit in the area is the Watson Bar developed prospect (MINFILE 092O 051). The MINFILE report reads as follows: "A north-northwest trending splay of the Fraser fault

system crosses the property bringing Lower Cretaceous Jackass Mountain Group arkose, greywacke and minor siltstone, on the west, into contact with Eocene volcanic rocks, on the east. Sedimentary rocks are intruded by a granodiorite stock and feldspar porphyry dikes of Late Cretaceous to Early Tertiary age. Six zones of intense silicification have been identified on the property. In two instances, silicic zones are parallel to the greywacke-intrusive contacts. Quartz-carbonate-(barite) veins are drusy, banded and commonly chalcedonic and trend both northwest and northeast. Pyrite typically occurs as disseminations in the wallrock while chalcopryite, stibnite and galena are restricted to quartz veins and fractures". Sphalerite, arsenopyrite, cinnabar, realgar, native gold, and scorodite also occur. Diamond drilling in 2009 established a shallow southwest-dipping thrust (Zone V) containing an estimated 942 tonnes grading 19.55 g/tonne Au (Fig. 5). Other, smaller epithermal Au mineralized occurrences in the Watson Bar Gold belt include the MAD (MINFILE 092O 092), Buster (MINFILE 092O 055) and Astonisher (MINFILE 092O 054).

### 3. Survey methods

#### 3.1. Sampling and sample preparation

The samples collected in 2005 and in 2006 included stream sediment (including heavy mineral concentrates), stream water, moss mat sediment, and bedrock (Figs. 6, 7; Table 1). Outcrop was sampled along roads and at the Watson Bar developed prospect (Zone V).

Sediment and water were collected from first- and second-order drainages where accessible from road, and sample site characteristics such as the sediment texture, stream size, and water flow were recorded. Water was analysed for pH and conductivity at each site with a calibrated Hatch pH meter, and

**Table 1.** Types of geochemical samples collected.

| Sample type               | Number |
|---------------------------|--------|
| Stream water              | 50     |
| Stream sediment           | 59     |
| Moss mat sediment         | 19     |
| Heavy mineral concentrate | 7      |
| Bedrock                   | 36     |

a water sample for trace element analysis was filtered through a 0.45 micron filter and acidified with Seastar Baseline 6M HNO<sub>3</sub>.

Stream-sediment and moss mat-sediment samples were air dried at the British Columbia Geological Survey Laboratory in Victoria, and the -18 mesh (< 1 mm) fraction was recovered by gently disaggregating the sediment or by pounding moss mats before dry sieving through a 1 mm stainless steel screen. One sample of the 1 mm fraction was then screened to -80 ASTM mesh (<0.177 mm) and a second sample screened to -230 (< 0.063 mm) mesh. Control reference material and analytical duplicate samples were included with each analytical block of twenty.

In 2005 and 2006, the -80 and -230 mesh fractions of stream-sediment and moss mat-sediment samples, the -150 mesh steel mill pulverized rock samples, and the quality control replicate and standard reference material samples were analysed at ACME Analytical, Vancouver (now Bureau Veritas) for 37 trace and minor elements by a combination of inductively coupled mass spectroscopy (ICP-MS) and inductively coupled plasma emission spectroscopy (ICP-ES) following HNO<sub>3</sub>-HCl-H<sub>2</sub>O (1:1:1 v/v) acid (modified aqua regia) dissolution. Selected -80 mesh fraction samples were also analyzed for Au and 32 trace elements at ActLabs (Ancaster, Ontario) by instrumental neutron activation analysis (INAA). In 2005, the filtered, acidified water samples, standards and blanks were analyzed for major and trace elements by ICP-MS at ACME Analytical, and in 2006 at the Environmental Geochemistry Laboratory of the Geological Survey of Canada (GSC), in Ottawa. Elements determined and analytical techniques are as follows.

- Filtered (0.45 micron) acidified (6 M HNO<sub>3</sub>) stream-water samples analyzed for Al, B, Ag, As, Ba, Be, Ca, Cd, Ce,

Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Ho, In, K, La, Li, Lu, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Pr, Rb, Re, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Ti, Tl, Tm, U, V, Y, W, Zn and Zr, by ICP-MS and for Ca, K and Na by ICP-ES. Detection limits for the elements determined in 2005 by Acme Analytical and the GSC are listed in Table 2.

- The -80 mesh (<0.177 mm) fraction of the stream- and moss mat- sediment analyzed for Ag, Al, As, Au, B, Ba, Bi, Ca, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Te, Th, Ti, Tl, U, V, W and Zn by HNO<sub>3</sub>-HCl-H<sub>2</sub>O acids (1:1:1 v/v) dissolution - ICP-MS; for Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, Hg, Ir, La, Lu, Mo, Na, Nd, Ni, Rb, Sb, Sc, Sm, Sn, Sr, Ta, Tb, Th, U, W, Yb and Zn by INAA and for loss on ignition (LOI) at 500°C Detection limits for ICP-MS and INAA are listed in Table 3.
- The -200 mesh (<0.070 mm) fraction of rock samples collected from outcrop for Ag, Al, As, Au, B, Ba, Bi, Ca, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Te, Th, Ti, Tl, U, V, W and Zn by HNO<sub>3</sub>-HCl-H<sub>2</sub>O acids (1:1:1 v/v) dissolution - ICP-MS; for Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, Hg, Ir, La, Lu, Mo, Na, Nd, Ni, Rb, Sb, Sc, Sm, Sn, Sr, Ta, Tb, Th, U, W, Yb and Zn by INAA by HNO<sub>3</sub>-HCl-H<sub>2</sub>O acids (1:1:1 v/v) - ICP-MS and INAA.
- Ten bulk stream-sediment samples were panned, heavy minerals recovered with a Morpheus spiral concentrator and the gold grains counted.

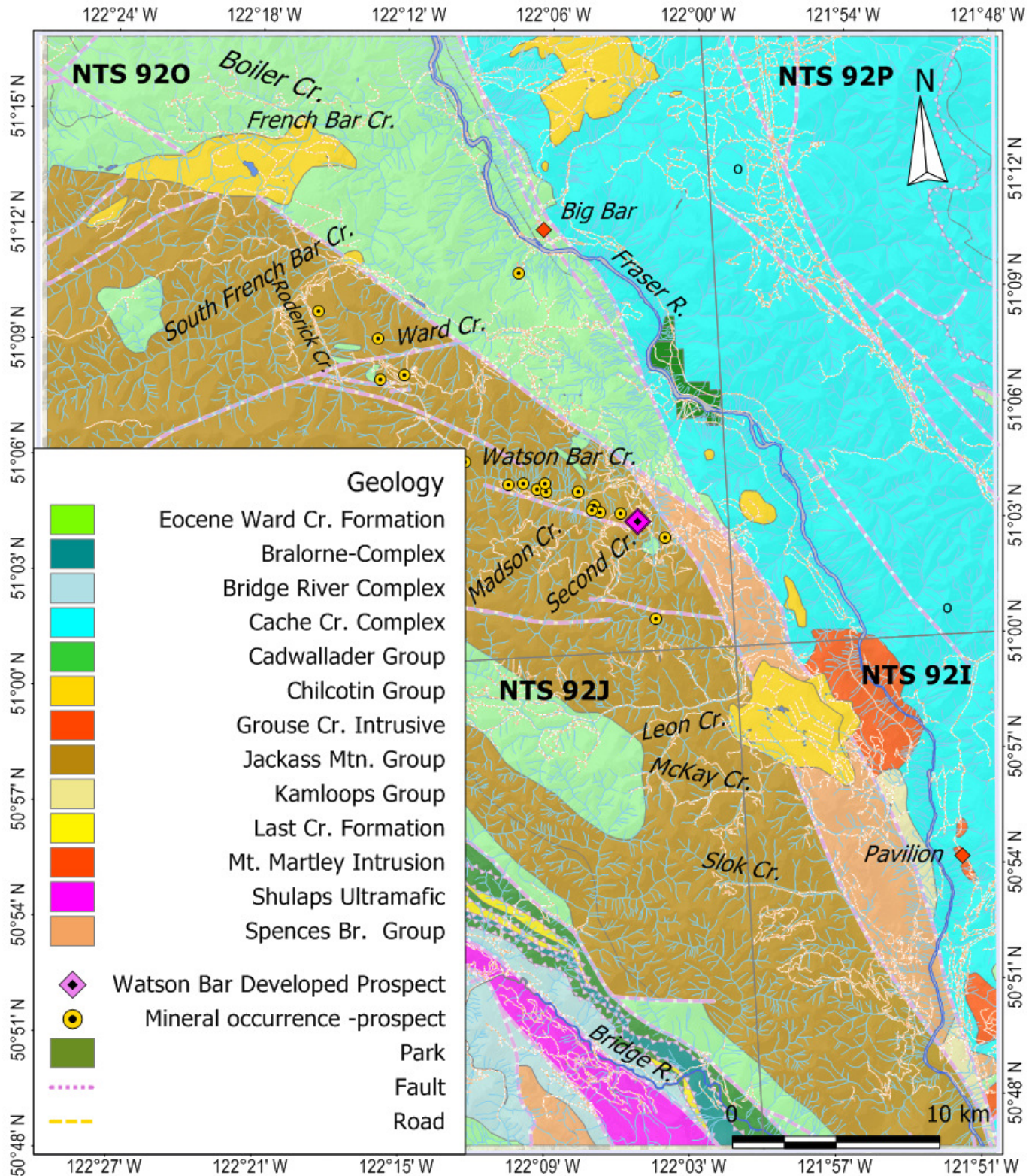


Fig. 5. Project area geology and mineral occurrences.

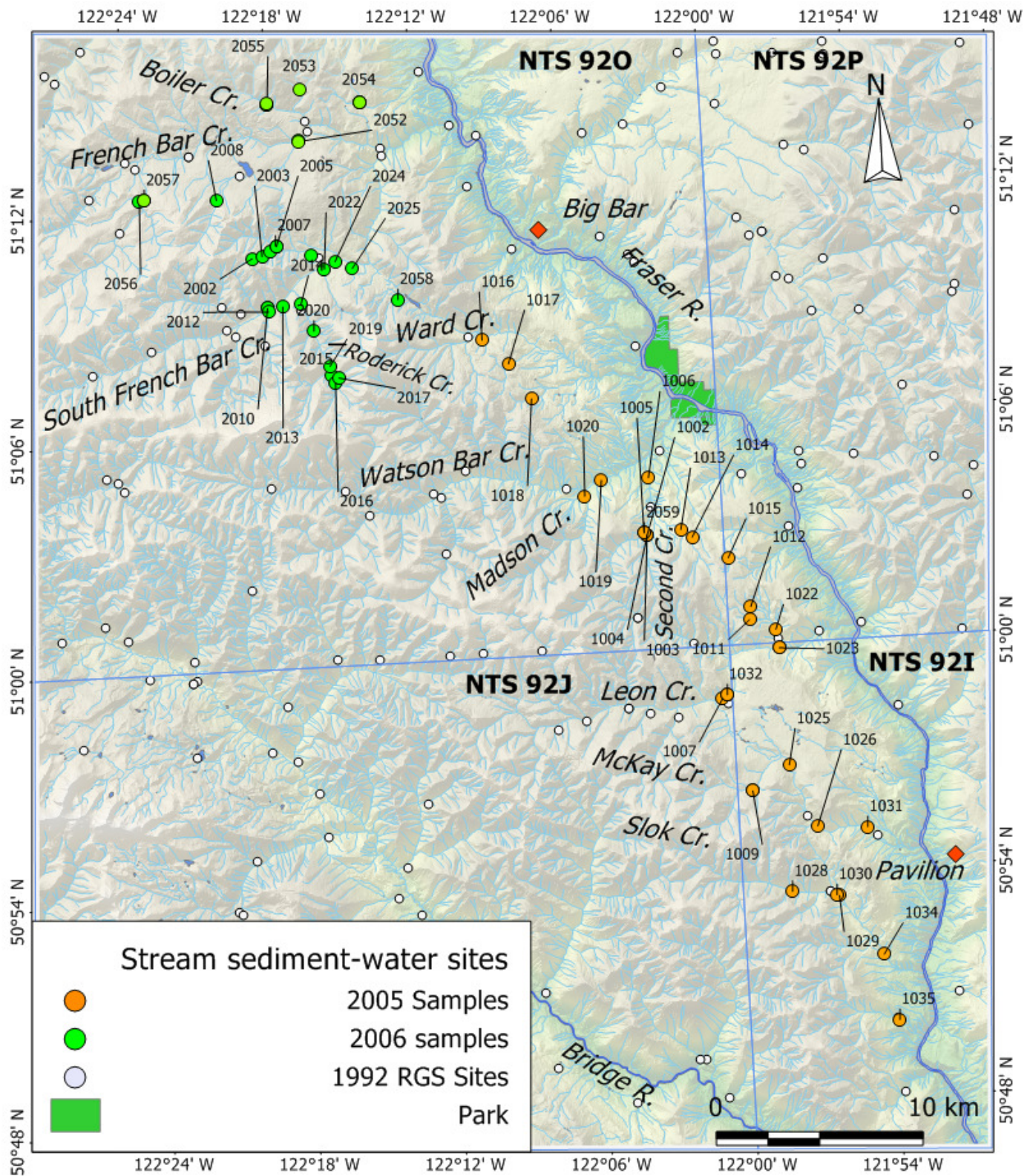


Fig. 6. Stream-sediment and water sample locations.



**Table 2.** Detection limits for water analyzed by Acme Analytical and the Geological Survey of Canada.

| Element | Acme 2005 | GSC 2006 | Element | Acme 2005 | GSC 2006 |
|---------|-----------|----------|---------|-----------|----------|
| Ag ppb  | 0.05      | 0.005    | Mo ppb  | 0.1       | 0.05     |
| Al ppb  | 1         | 2        | Na ppm  | 0.05      | 0.05     |
| As ppb  | 0.5       | 0.1      | Nb ppb  | 0.01      | 0.01     |
| B ppb   | 20        | 0.5      | Nd ppb  | 0.01      | 0.005    |
| Ba ppb  | 0.05      | 0.2      | Ni ppb  | 0.2       | 0.2      |
| Be ppb  | 0.05      | 0.005    | P ppb   | 20        | 0.05     |
| Br ppb  | 5         |          | Pb ppb  | 0.1       | 0.01     |
| Ca ppm  | 0.05      | 0.02     | Pr ppb  | 0.01      | 0.005    |
| Cd ppb  | 0.05      | 0.02     | Rb ppb  | 0.01      | 0.05     |
| Ce ppb  | 0.01      | 0.01     | Re ppb  | 0.01      | 0.005    |
| Cl ppm  | 7         |          | S ppb   | 1         | 0.05     |
| Co ppb  | 0.02      | 0.05     | Sb ppb  | 0.05      | 0.01     |
| Cr ppb  | 0.5       | 0.1      | Sc ppb  | 1         | 0.001    |
| Cs ppb  | 0.01      | 0.01     | Se ppb  | 0.5       | 1        |
| Cu ppb  | 0.1       | 0.1      | Si ppb  | 6         | 0.02     |
| Dy ppb  | 0.01      | 0.005    | Sm ppb  | 0.02      | 0.005    |
| Er ppb  | 0.01      | 0.005    | Sn ppb  | 0.05      | 0.01     |
| Eu ppb  | 0.01      | 0.005    | Sr ppb  | 0.01      | 0.5      |
| Fe ppb  | 12        | 0.005    | Ta ppb  | 0.02      | 0.01     |
| Ga ppb  | 0.05      | 0.01     | Tb ppb  | 0.01      | 0.005    |
| Gd ppb  | 0.01      | 0.005    | Te ppb  | 0.05      | 0.02     |
| Ge ppb  | 0.05      | 0.02     | Ti ppb  | 10        | 0.5      |
| Hf ppb  | 0.02      | 0.01     | Tl ppb  | 0.01      | 0.005    |
| Ho ppb  | 0.01      | 0.005    | Tm ppb  | 0.01      | 0.005    |
| In ppb  | 0.01      | 0.01     | U ppb   | 0.02      | 0.005    |
| K ppm   | 50        | 0.05     | V ppb   | 0.2       | 0.1      |
| La ppb  | 0.01      | 0.01     | W ppb   | 0.02      | 0.02     |
| Li ppb  | 0.1       | 0.02     | Y ppb   | 0.01      | 0.01     |
| Lu ppb  | 0.01      | 0.005    | Yb ppb  | 0.01      | 0.005    |
| Mg ppm  | 0.05      | 0.005    | Zn ppb  | 0.5       | 0.5      |
| Mn ppb  | 0.05      | 0.1      | Zr ppb  | 0.02      | 0.05     |

**Table 3.** Detection limits for elements determined by HNO<sub>3</sub>-HCl-H<sub>2</sub>O (1:1:1 v/v) dissolution - ICP-MS and by INAA in drainage sediment, soil, till, and rock samples.

| Element       | Detection Limit | Element       | Detection Limit | Element     | Detection Limit |
|---------------|-----------------|---------------|-----------------|-------------|-----------------|
| Ag ppb ICP-MS | 2               | Rb ppm ICP-MS | 0.1             | Ag ppm INAA | 5               |
| Al pct ICP-MS | 0.01            | Re ppb ICP-MS | 1               | As ppm INAA | 0.5             |
| As ppm ICP-MS | 0.1             | S pct ICP-MS  | 0.02            | Au ppb INAA | 2               |
| Au ppb ICP-MS | 0.2             | Sb ppm ICP-MS | 0.02            | Ba ppm INAA | 50              |
| B ppm ICP-MS  | 1               | Sc ppm ICP-MS | 0.1             | Br ppm INAA | 0.5             |
| Ba ppm ICP-MS | 0.5             | Se ppm ICP-MS | 0.1             | Ca pct INAA | 1               |
| Be ppm ICP-MS | 0.1             | Sn ppm ICP-MS | 0.1             | Ce ppm INAA | 3               |
| Bi ppm ICP-MS | 0.02            | Sr ppm ICP-MS | 0.5             | Co ppm INAA | 1               |
| Ca pct ICP-MS | 0.01            | Ta ppm ICP-MS | 0.05            | Cr ppm INAA | 5               |
| Cd ppm ICP-MS | 0.01            | Te ppm ICP-MS | 0.02            | Cs ppm INAA | 1               |
| Ce ppm ICP-MS | 0.1             | Th ppm ICP-MS | 0.1             | Eu ppm INAA | 0.2             |
| Co ppm ICP-MS | 0.1             | Ti ppm ICP-MS | 0.001           | Fe pct INAA | 0.01            |
| Cr ppm ICP-MS | 0.5             | Tl pct ICP-MS | 0.02            | Hf ppm INAA | 1               |
| Cs ppm ICP-MS | 0.1             | U ppm ICP-MS  | 0.1             | Hg ppm INAA | 1               |
| Cu ppm ICP-MS | 0.01            | V ppm ICP-MS  | 2               | Ir ppm INAA | 5               |
| Fe pct ICP-MS | 0.01            | W ppm ICP-MS  | 0.1             | La ppm INAA | 0.5             |
| Ga ppm ICP-MS | 0.1             | Y ppm ICP-MS  | 0.01            | Lu ppm INAA | 0.05            |
| Ge ppm ICP-MS | 0.1             | Zn ppm ICP-MS | 0.1             | Mo ppm INAA | 1               |
| Hf ppm ICP-MS | 0.02            | Zr ppm ICP-MS | 0.1             | Na pct INAA | 0.01            |
| Hg ppb ICP-MS | 5               |               |                 | Nd ppm INAA | 5               |
| In ppm ICP-MS | 0.02            |               |                 | Ni ppm INAA | 20              |
| K pct ICP-MS  | 0.01            |               |                 | Rb ppm INAA | 15              |
| La ppm ICP-MS | 0.5             |               |                 | Sb ppm INAA | 0.1             |
| Li ppm ICP-MS | 0.1             |               |                 | Sc ppm INAA | 0.1             |
| LOI_pct GRAV  | 0.01            |               |                 | Se ppm INAA | 3               |
| Mg pct ICP-MS | 0.01            |               |                 | Sm ppm INAA | 0.1             |
| Mn ppm ICP-MS | 1               |               |                 | Sn pct INAA | 0.02            |
| Mo ppm ICP-MS | 0.01            |               |                 | Sr pct INAA | 0.05            |
| Na pct ICP-MS | 0.001           |               |                 | Ta ppm INAA | 0.5             |
| Nb ppm ICP-MS | 0.02            |               |                 | Tb ppm INAA | 0.5             |
| Ni ppm ICP-MS | 0.1             |               |                 | Th ppm INAA | 0.2             |
| P pct ICP-MS  | 0.001           |               |                 | U ppm INAA  | 0.5             |
| Pb ppm ICP-MS | 0.01            |               |                 | W ppm INAA  | 1               |
| Pd ppb ICP-MS | 2               |               |                 | Yb ppm INAA | 0.2             |
| Pt ppb ICP-MS | 10              |               |                 | Zn ppm INAA | 50              |

#### 4. Quality control measures

Reliable interpretations of geochemical data cannot be made unless the variability introduced by the sampling method and the sample analysis is known. Sampling and sample analysis variability, measured in terms of accuracy and precision, are determined by a statistical analysis of the data from samples that were duplicated in the field, analytical duplicates, and randomly inserted standard reference materials.

Filtered water blank and duplicate stream-water samples and the NRC River water standard SLRS 3 were included randomly with the project generated samples (Table 4). Boron, Cu, and Sr are the only elements with a concentration detected in the filtered blank samples that are more five times the detection limit. A maximum Cu value in the blank water of 1.1 ppb suggests that the credibility of values below 1 ppb should be considered with caution because of possible contamination. Table 4 lists the precision for elements in water expressed as a percent relative standard deviation (% RSD) calculated from five SLRS 3 analyses. The table reveals that of all the elements, only Cl, Co, and V have a % RSD greater than 12%.

#### 4.1. Drainage sediment data precision

Drainage sediment control measures for the Lillooet project followed the National Geochemical Reconnaissance (NGR) - Regional Geochemical Survey (RGS) scheme whereby a field duplicate sample, an analytical duplicate sample, and a geochemical standard are randomly imbedded in each block of 20 samples analyzed. In Table 4 the results of analyzing the CANMET sediment standards STSD 1 and 4 and a British Columbia Geological Survey sediment standard (RD 2001) by HNO<sub>3</sub>-HCl-H<sub>2</sub>O - ICP-MS and by INAA reveal that for most elements the reported values are within +/- 10% of the CANMET recommended values. Precision for many of the INAA determined elements (e.g., Au, As) calculated from four repeated analyses of RD 2001 is > 17% RSD (> 35% at the 95% confidence level) suggesting that the sediment INAA data should be interpreted with caution. However, the precision is < 17% RSD for most elements (except for Au) determined by HNO<sub>3</sub>-HCl-H<sub>2</sub>O - ICP-MS indicating that there is less variation by this method despite a smaller sample weight (0.5 g) used for the analysis (Table 5).

**Table 4.** Filtered water blank, precision (% RSD) and NRC standard SLRS 3 recommended values.

| Element | Mean 2005 | %RSD 2005 | Mean 2006 | %RSD 2006 | SLRS 3 |
|---------|-----------|-----------|-----------|-----------|--------|
| Ag ppb  | 0.05      | 0         | 0.005     | 0         |        |
| Al ppb  | 33.5      | 6.33      | 32.667    | 1.79      | 31     |
| As ppb  | 0.7       | 0.00      | 0.693     | 0.83      | 0.72   |
| B ppb   | 20        | 0.00      | 4.120     | 9.47      |        |
| Ba ppb  | 12.81     | 1.21      | 13.043    | 0.99      | 13.4   |
| Be ppb  | 0.05      | 0.00      | 0.006     | 12.30     | 0.005  |
| Br ppb  | 19        | 0.00      |           |           |        |
| Ca ppm  | 5.8045    | 2.59      | 5.866     | 2.97      | 6      |
| Cd ppb  | 0.05      | 0.00      | 0.020     | 0.00      | 0.13   |
| Ce ppb  | 0.27      | 0.00      | 0.263     | 1.32      |        |
| Cl ppm  | 3.5       | 20.20     |           |           |        |
| Co ppb  | 0.025     | 28.28     | 0.050     | 0.00      | 0.027  |
| Cr ppb  | 0.5       | 0.00      | 0.247     | 2.34      | 0.3    |
| Cs ppb  | 0.01      | 0.00      | 0.010     | 0.00      |        |
| Cu ppb  | 1.55      | 4.56      | 1.290     | 0.78      | 1.35   |
| Dy ppb  | 0.01      | 0.00      | 0.020     | 2.69      |        |
| Er ppb  | 0         | 0.00      | 0.012     | 6.95      |        |
| Eu ppb  | 0.01      | 0.00      | 0.006     | 0.00      |        |
| Fe ppb  | 107.5     | 0.66      | 99.367    | 2.47      | 100    |
| Ga ppb  | 0.05      | 0.00      | 0.010     | 0.00      |        |
| Gd ppb  | 0.03      | 0.00      | 0.030     | 8.31      |        |
| Ge ppb  | 0.05      | 0.00      | 0.020     | 0.00      |        |
| Hf ppb  | 0.02      | 0.00      | 0.005     | 264.58    |        |
| Ho ppb  | 0.01      | 0.00      | 0.005     | 0.00      |        |
| K ppm   | 0.6135    | 3.80      | 0.680     | 6.79      | 0.7    |
| La ppb  | 0.22      | 6.43      | 0.220     | 2.14      |        |
| Li ppb  | 0.55      | 12.86     | 0.504     | 0.52      |        |
| Lu ppb  | 0.01      | 0.00      | 0.005     | 0.00      |        |
| Mg ppm  | 1.6985    | 3.29      | 1.625     | 2.66      | 1.6    |
| Mn ppb  | 4.055     | 1.22      | 3.573     | 4.98      | 3.9    |
| Mo ppb  | 0.2       | 0.00      | 0.185     | 5.26      | 0.19   |
| Na ppm  | 2.479     | 0.00      | 2.399     | 2.09      | 2.3    |
| Nd ppb  | 0.235     | 3.01      | 0.214     | 3.92      |        |
| Ni ppb  | 0.65      | 10.88     | 0.740     | 1.35      | 0.83   |
| P ppb   | 20        | 0.00      | 0.050     | 0.00      |        |
| Pb ppb  | 0.1       | 0.00      | 0.063     | 4.76      | 0.68   |
| Pr ppb  | 0.05      | 0.00      | 0.055     | 1.21      |        |
| Rb ppb  | 1.665     | 3.82      | 1.556     | 1.51      |        |
| Re ppb  | 0.01      | 0.00      | 0.005     | 0.00      |        |
| S ppb   | 4         | 0.00      | 3.041     | 3.73      |        |
| Sb ppb  | 0.145     | 4.88      | 0.119     | 5.05      | 0.12   |
| Sc ppb  | 1         | 0.00      | 0.001     | 0.00      |        |
| Se ppb  | 0.5       | 0.00      | 1.000     | 0.00      |        |
| Si ppb  | 1.573     | 1.35      | 1.718     | 3.59      |        |
| Sm ppb  | 0.04      | 0.00      | 0.043     | 0.84      |        |
| Sn ppb  | 0.05      | 0.00      | 0.010     | 0.00      |        |
| Sr ppb  | 32.33     | 2.41      | 30.070    | 1.34      | 0.028  |
| Tb ppb  | 0.01      | 0.00      | 0.005     | 0.00      |        |
| Te ppb  | 0.05      | 0.00      | 0.020     | 0.00      |        |
| Ti ppb  | 10        | 0.00      | 0.720     | 1.39      |        |
| Tl ppb  | 0.01      | 0.00      | 0.007     | 9.91      |        |
| Tm ppb  | 0.01      | 0.00      | 0.005     | 0.00      |        |
| U ppb   | 0.04      | 0.00      | 0.041     | 5.56      | 0.045  |
| V ppb   | 0.3       | 47.14     | 0.273     | 2.11      | 0.3    |
| Y ppb   | 0.115     | 6.15      | 0.113     | 0.00      |        |
| Yb ppb  | 0.01      | 0.00      | 0.011     | 9.09      |        |
| Zn ppb  | 1.05      | 6.73      | 1.000     | 1.00      | 1.04   |
| Zr ppb  | 0.08      | 0.00      | 0.071     | 4.97      |        |

The average coefficient of variation, or  $CV_{AVR}$  (%) calculated from formula proposed by Abzalov, (2008) provides an estimate of sampling precision from the field duplicate data. In the formula the terms a and b represent the analyses of the first and second of the duplicate sample pair and N is the number of duplicate pairs. Values can range from 0%, when duplicate pairs have identical concentrations, to an upper value above 141.21% (i.e. the square root of 2) when duplicate results exhibit maximum differences.

$$CV_{AVR}(\%) = 100 \times \sqrt{\frac{2}{N} \sum_{i=1}^N \left( \frac{(a_i - b_i)^2}{(a_i + b_i)^2} \right)}$$

**Table 5.** CANMET STSD 1; four analyses and recommended values for comparison. Percent RSD from four repeat analyses of BCGS RD standard by  $\text{HNO}_3$ -HCl- $\text{H}_2\text{O}$  (1:1:1 v/v) dissolution - ICP-MS and/or INAA

| Element - Method | Detection Limit | STSD 1<br>2005 1008 | STSD 1<br>CANMET | STSD 4<br>20061009SS | STSD 4<br>CANMET | Mean<br>RD 2001 | % RSD<br>RD 2001 |
|------------------|-----------------|---------------------|------------------|----------------------|------------------|-----------------|------------------|
| Ag ppb ICP-MS    | 2               | 274                 | 300              | 304                  | 300              | 73.00           | 16.51            |
| Al pct ICP-MS    | 0.01            | 1.08                |                  | 1.11                 |                  | 1.99            | 1.32             |
| As ppm ICP-MS    | 0.1             | 17.9                | 17               | 10.8                 | 11               | 5.63            | 4.20             |
| As ppm INAA      | 0.5             | 23.8                | 23               | 16.2                 | 15               | 6.48            | 32.28            |
| Au ppb ICP-MS    | 1               | 8.7                 | 8                | 1.4                  | 4                | 71.00           | 105.31           |
| Au ppb INAA      | 2               | 23                  | 8                | 14                   | 4                | 46.50           | 34.43            |
| Ba ppm ICP-MS    | 0.5             | 252.4               |                  | 948.2                |                  | 51.55           | 2.62             |
| Ba ppm INAA      | 50              | 780                 | 630              | 1900                 | 2000             | 462.50          | 14.27            |
| Bi ppm ICP-MS    | 0.02            | 0.44                |                  | 0.2                  |                  | 0.53            | 4.79             |
| Br ppm INAA      | 0.5             | 42.6                | 40               | 12.9                 | 13               | 4.53            | 37.56            |
| Ca pct ICP-MS    | 0.01            | 1.53                |                  | 1.1                  |                  | 0.74            | 2.02             |
| Cd ppm ICP-MS    | 0.01            | 0.9                 | 0.8              | 0.41                 | 0.6              | 0.24            | 10.31            |
| Ce ppm INAA      | 3               | 56                  | 51               | 44                   | 44               | 23.00           | 12.30            |
| Co ppm ICP-MS    | 0.1             | 13.9                | 14               | 10.7                 | 11               | 12.15           | 1.06             |
| Co ppm INAA      | 1               | 18                  | 17               | 14                   | 13               | 11.75           | 22.38            |
| Cr ppm ICP-MS    | 0.5             | 27.7                | 28               | 30.6                 | 30               | 20.75           | 5.60             |
| Cr ppm INAA      | 5               | 58                  | 67               | 98                   | 93               | 45.00           | 20.61            |
| Cs ppm INAA      | 1               | 2                   | 1.8              | 1.9                  |                  |                 |                  |
| Cu ppm ICP-MS    | 0.01            | 34.22               | 36               | 68.97                | 66               | 175.56          | 2.23             |
| Eu ppm INAA      | 0.2             | 1.8                 | 1.6              | 1.3                  | 1.2              | 0.83            | 15.25            |
| Fe pct ICP-MS    | 0.01            | 3.18                | 3.5              | 2.66                 | 2.6              | 4.40            | 4.22             |
| Fe pct INAA      | 0.01            | 4.73                | 4.7              | 4.11                 | 4.1              | 4.49            | 23.49            |
| Ga ppm ICP-MS    | 0.02            | 3.8                 |                  | 3.9                  |                  | 6.13            | 1.56             |
| Hf ppm INAA      | 1               | 6                   | 3.1              | 6                    | 5.5              | 2.50            | 23.09            |
| Hg ppb ICP-MS    | 5               | 100                 | 110              | 768                  | 930              | 18.00           | 17.57            |
| K pct ICP-MS     | 0.01            | 0.07                |                  | 0.1                  |                  | 0.04            | 0.00             |
| La ppm ICP-MS    | 0.5             | 21.7                |                  | 13.2                 |                  | 4.53            | 7.52             |
| La ppm INAA      | 0.5             | -0.5                | 30               | 23.6                 | 24               | 12.23           | 22.92            |
| Lu ppm INAA      | 0.05            | 0.76                | 0.8              | 0.49                 | 0.5              | 0.28            | 9.48             |
| Mg pct ICP-MS    | 0.01            | 0.72                |                  | 0.69                 |                  | 0.71            | 1.34             |
| Mn ppm ICP-MS    | 1               | 3568                | 3740             | 1184                 | 1200             | 442.00          | 4.34             |
| Mo ppm ICP-MS    | 0.01            | 1.06                | 2                | 1.21                 | 2                | 13.46           | 8.50             |
| Na pct ICP-MS    | 0.001           | 0.023               |                  | 0.042                |                  | 0.03            | 3.14             |
| Na pct INAA      | 0.01            | 1.47                | 1.34             | 2.09                 | 2                | 1.34            | 19.35            |
| Nd ppm INAA      | 5               | 29                  | 28               | -5                   | 21               | 6.25            | 120.71           |
| Ni ppm ICP-MS    | 0.1             | 19.5                | 18               | 25.3                 | 23               | 12.93           | 5.45             |
| P pct ICP-MS     | 0.001           | 0.142               |                  | 0.086                |                  | 0.06            | 2.98             |
| Pb ppm ICP-MS    | 0.01            | 33.11               | 34               | 13.39                | 13               | 6.96            | 1.74             |
| S pct ICP-MS     | 0.02            | 0.19                |                  | 0.09                 |                  | 0.57            | 4.21             |
| Sb ppm ICP-MS    | 0.02            | 2.3                 | 2                | 5.09                 | 3.6              | 0.17            | 17.15            |
| Sb ppm INAA      | 0.1             | 4.7                 | 3.3              | 8.1                  | 7.3              | 0.68            | 22.22            |
| Sc ppm ICP-MS    |                 | 3.5                 |                  | 3.2                  |                  | 5.00            | 5.16             |
| Sc ppm INAA      | 0.1             | 13.9                | 14               | 13.3                 | 14               | 16.43           | 23.12            |
| Se ppm ICP-MS    | 0.1             | 1.9                 |                  | 0.8                  |                  | 3.35            | 3.85             |
| Sm ppm INAA      | 0.1             | 6.5                 | 6                | 4.3                  | 5                | 2.40            | 15.21            |
| Sr ppm ICP-MS    | 0.5             | 28.4                |                  | 61.5                 |                  | 50.70           | 2.42             |
| Te ppm ICP-MS    | 0.02            | 0.04                |                  | -0.02                |                  | 0.42            | 10.11            |
| Th ppm ICP-MS    | 0.1             | 0.8                 |                  | 1.3                  |                  | 1.03            | 9.34             |
| Th ppm INAA      | 0.2             | 4.2                 | 3.7              | 3.8                  | 4.3              | 2.08            | 16.40            |
| Ti pct ICP-MS    | 0.001           | 0.031               |                  | 0.069                |                  | 0.14            | 2.75             |
| Tl ppm ICP-MS    | 0.02            | 0.22                |                  | 0.12                 |                  | 0.03            | 0.00             |
| U ppm ICP-MS     | 0.1             | 6.4                 | 8                | 2                    | 3                | 0.40            | 0.00             |
| U ppm INAA       | 0.5             | 8.1                 | 8                | 5                    | 3                | 1.03            | 109.62           |
| V ppm ICP-MS     | 2               | 46                  | 47               | 55                   | 51               | 97.25           | 4.23             |
| Yb ppm INAA      | 0.2             | 4.5                 | 4                | 3                    | 2.6              | 1.95            | 18.96            |

In Table 6 the  $CV_{AVR}$  (%) values for each element in the field duplicate samples analyzed by  $\text{HNO}_3$ -HCl- $\text{H}_2\text{O}$  - ICP-MS and by INAA are sorted in order of increasing field duplicate  $CV_{AVG}$  (%) value (i.e. good to poor precision). For sediments, values of below  $CV_{AVG}$  (%) 15% (green) indicate good data quality, values between 15 and 30% (blue) acceptable quality, those from 30 and 50% (purple) marginal quality, and those over 50%, (red) poor quality. Eighty two percent of the elements by  $\text{HNO}_3$ -HCl- $\text{H}_2\text{O}$  - ICP-MS have good to acceptable precision whereas only 54% of the INAA determined elements are in this category. More elements in bedrock and till sample duplicates have  $CV_{AVG}$  (%) values < 15% compared to  $CV_{AVG}$  sediment samples, which may reflect the smaller grain size of the samples. Typically, the highest  $CV_{AVG}$  (%), or greatest variability, is for Au in sediment and bedrock duplicates (Table 7).

**Table 6.** Average coefficient of variation ( $CV_{AVG}$  %) calculated from element data for five field duplicate sediment samples (0.177 mm fraction) analyzed by  $HNO_3$ -HCl- $H_2O$  (1:1:1 v/v) dissolution - ICP-MS and INAA.

| Element AR ICPMS | $CV_{AVR}$ (%) | Element INAA | $CV_{AVR}$ (%) |
|------------------|----------------|--------------|----------------|
| K pct            | 0.00           | Hf ppm       | 10.10          |
| In ppm           | 0.00           | Ba ppm       | 11.24          |
| Ce ppm           | 1.38           | Sm ppm       | 14.61          |
| Rb ppm           | 1.88           | Sc ppm       | 14.87          |
| Li ppm           | 2.89           | Fe pct       | 15.32          |
| Cs ppm           | 3.05           | Yb ppm       | 15.36          |
| Co ppm           | 3.45           | Co ppm       | 17.01          |
| Al pct           | 3.45           | Na pct       | 17.26          |
| Fe pct           | 3.73           | Eu ppm       | 19.66          |
| Zn ppm           | 4.71           | Ce ppm       | 19.68          |
| Y ppm            | 4.80           | Th ppm       | 22.56          |
| Zr ppm           | 4.84           | Cr ppm       | 23.15          |
| Hf ppm           | 5.84           | Lu ppm       | 25.42          |
| V ppm            | 7.59           | Br ppm       | 36.35          |
| Tl ppm           | 7.86           | As ppm       | 42.22          |
| Bi ppm           | 9.56           | Au ppb       | 53.51          |
| Sc ppm           | 9.90           | Zn ppm       | 57.07          |
| P pct            | 10.68          | La ppm       | 68.59          |
| Cd ppm           | 11.37          | Cs ppm       | 70.05          |
| Pb ppm           | 11.95          | U ppm        | 79.21          |
| Ag ppb           | 12.03          | Ca pct       | 93.42          |
| As ppm           | 12.07          | Sb ppm       | 103.46         |
| Mg pct           | 12.19          | Ta ppm       | 208.65         |
| Mo ppm           | 12.45          | Nd ppm       | 341.48         |
| Sn ppm           | 12.83          |              |                |
| Be ppm           | 12.83          |              |                |
| La ppm           | 12.86          |              |                |
| U ppm            | 13.02          |              |                |
| Ga ppm           | 13.04          |              |                |
| Ca pct           | 13.15          |              |                |
| Sr ppm           | 16.62          |              |                |
| Cr ppm           | 16.78          |              |                |
| Cu ppm           | 17.76          |              |                |
| Ni ppm           | 19.30          |              |                |
| Th ppm           | 21.77          |              |                |
| Hg ppb           | 22.03          |              |                |
| Ti pct           | 24.23          |              |                |
| Sb ppm           | 27.22          |              |                |
| Ba ppm           | 30.90          |              |                |
| Na pct           | 32.73          |              |                |
| Nb ppm           | 34.67          |              |                |
| LOI pct Grav     | 37.25          |              |                |
| Mn ppm           | 40.92          |              |                |
| Au ppb           | 44.82          |              |                |
| B ppm            | 44.91          |              |                |
| Se ppm           | 46.27          |              |                |

## 5. Results

### 5.1. Stream-water chemistry

Before a reliable statistical analysis of the filtered, acidified stream-water data is possible, the results need correction for elements where many values are below the lower detection limit and for the differences in the lower detection limit for data

**Table 7.** Average coefficient of variation ( $CV_{AVG}$  %) calculated from element data for five duplicate rock pulp samples analysed by  $HNO_3$ -HCl- $H_2O$  (1:1:1 v/v) dissolution and INAA.

| Element _Method | $CV_{AVR}$ (%) | Element -Methc | $CV_{AVR}$ (%) |
|-----------------|----------------|----------------|----------------|
| Fe pct ICP-MS   | 4.22           | Hf ppm INA     | 0.00           |
| Co ppm ICP-MS   | 5.08           | Eu ppm INA     | 1.91           |
| Ga ppm ICP-MS   | 5.12           | Sb ppm INA     | 1.97           |
| Sc ppm ICP-MS   | 5.16           | Na % INA       | 2.24           |
| Ti pct ICP-MS   | 5.42           | Fe % INA       | 2.71           |
| La ppm ICP-MS   | 5.54           | Nd ppm INA     | 3.47           |
| Pb ppm ICP-MS   | 5.95           | Sm ppm INA     | 3.97           |
| Mn ppm ICP-MS   | 5.99           | La ppm INA     | 4.01           |
| Ni ppm ICP-MS   | 6.09           | Cr ppm INA     | 4.03           |
| Cu ppm ICP-MS   | 6.38           | Co ppm INA     | 5.35           |
| Na pct ICP-MS   | 6.41           | Ba ppm INA     | 5.70           |
| Sr ppm ICP-MS   | 6.44           | Sc ppm INA     | 5.70           |
| Zn ppm ICP-MS   | 6.79           | Th ppm INA     | 5.84           |
| P pct ICP-MS    | 7.07           | Ce ppm INA     | 5.90           |
| V ppm ICP-MS    | 7.17           | As ppm INA     | 10.28          |
| Ca pct ICP-MS   | 7.81           | U ppm INA      | 13.94          |
| Al pct ICP-MS   | 7.84           | Cs ppm INA     | 14.14          |
| Cr ppm ICP-MS   | 7.98           | Zn ppm INA     | 15.58          |
| Th ppm ICP-MS   | 8.14           | Ca % INA       | 20.00          |
| Mo ppm ICP-MS   | 9.12           | Au ppb INAA    | 42.92          |
| Ag ppb ICP-MS   | 9.13           | Br ppm INA     | 125.58         |
| Cd ppm ICP-MS   | 9.16           |                |                |
| Ba ppm ICP-MS   | 10.04          |                |                |
| U ppm ICP-MS    | 10.17          |                |                |
| Bi ppm ICP-MS   | 10.96          |                |                |
| K pct ICP-MS    | 13.59          |                |                |
| Hg ppb ICP-MS   | 15.24          |                |                |
| Mg pct ICP-MS   | 18.34          |                |                |
| B ppm ICP-MS    | 18.78          |                |                |
| Sb ppm ICP-MS   | 19.48          |                |                |
| Tl ppm ICP-MS   | 19.51          |                |                |
| As ppm ICP-MS   | 23.90          |                |                |
| Au ppb ICP-MS   | 33.46          |                |                |
| Se ppm ICP-MS   | 42.08          |                |                |

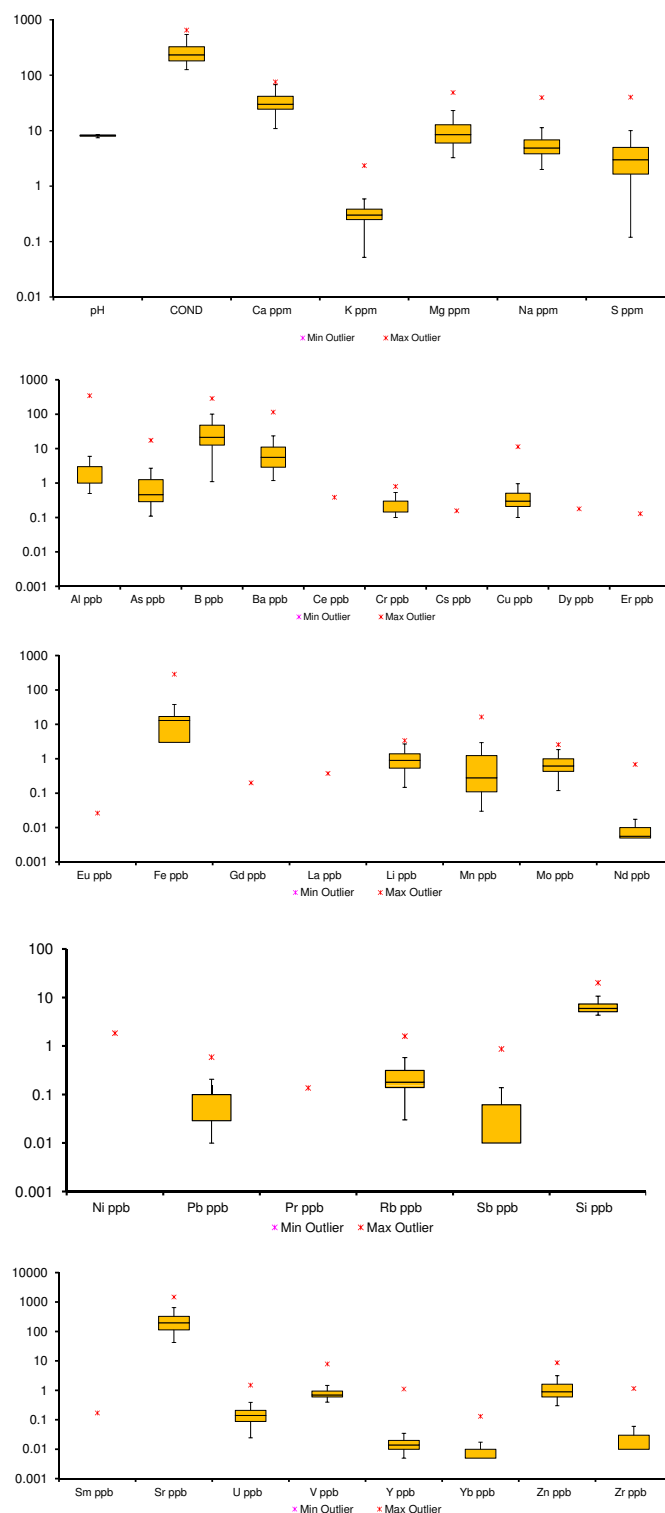
reported by ACME and by the GSC. For some of the elements, the lower detection limit remained the same, so a value of one half the lower detection limit was substituted for any value below the detection limit. Where the detection limit values reported by the two laboratories differed, the data with a higher detection limit were assigned a value of one half the detection limit, whereas element values from the laboratory with a lower detection limit were unchanged except for removal of the negative sign. Only one or two of the Ag, Be, Br, Cd, Ga, Ge, Hf, In, Nb, P, Hg, Re, Sc, Se, Ta, Tb, Ti, Tl, Tm and W values were above the lower detection limit reported by the two laboratories and these elements were not included in the statistical analysis (these values are reported in Appendix 2). Table 8 lists mean, median, minimum, maximum, 1<sup>st</sup> quartile, 3<sup>rd</sup> quartile, 3<sup>rd</sup> quartile + 1.5 inter quartile range, 95<sup>th</sup> percentile, and the number of outliers beyond the 3<sup>rd</sup> quartile + 1.5 inter quartile range for pH, conductivity, and element data from the analysis of 47 stream-water samples.

**Table 8.** Summary statistics for stream water samples. Min.-Minimum value; Max.- Maximum values; 1 Q - 1<sup>st</sup> Quartile; 3 Q - 3<sup>rd</sup> Quartile; 3Q + (IGR\*1.5) - 3<sup>rd</sup> Quartile + (Interquartile range x 1.5); Outliers - Number of values above the 3Q + (IGR\*1.5).

| Element | Mean   | Median | Min.  | Max.    | 1 Q    | 3 Q    | 3Q+(IGR*1.5) | 95 <sup>th</sup> % tile | Outliers |
|---------|--------|--------|-------|---------|--------|--------|--------------|-------------------------|----------|
| pH      | 8.12   | 8.20   | 7.45  | 8.55    | 7.97   | 8.33   | 8.88         | 8.42                    | 0        |
| COND    | 248.84 | 224.50 | 0.00  | 653.00  | 172.70 | 314.75 | 527.83       | 449.25                  | 2        |
| Al ppb  | 11.58  | 1.00   | 0.50  | 345.70  | 1.00   | 3.00   | 6.00         | 30.25                   | 4        |
| As ppb  | 1.23   | 0.45   | 0.11  | 17.50   | 0.29   | 1.10   | 2.32         | 4.03                    | 5        |
| B ppb   | 51.64  | 21.27  | 1.10  | 287.00  | 12.23  | 48.59  | 103.14       | 252.25                  | 6        |
| Ba ppb  | 11.43  | 5.43   | 1.18  | 115.62  | 2.89   | 10.08  | 20.85        | 27.24                   | 6        |
| Ca ppm  | 33.95  | 30.42  | 10.94 | 75.88   | 24.69  | 42.40  | 68.97        | 58.33                   | 2        |
| Ce ppb  | 0.02   | 0.01   | 0.01  | 0.39    | 0.01   | 0.01   | 0.01         | 0.04                    | 8        |
| Cr ppb  | 0.26   | 0.30   | 0.10  | 0.80    | 0.14   | 0.30   | 0.54         | 0.50                    | 2        |
| Cs ppb  | 0.01   | 0.01   | 0.01  | 0.16    | 0.01   | 0.01   | 0.01         | 0.02                    | 4        |
| Cu ppb  | 0.43   | 0.30   | 0.10  | 3.30    | 0.21   | 0.50   | 0.94         | 0.70                    | 2        |
| Dy ppb  | 0.01   | 0.01   | 0.01  | 0.18    | 0.01   | 0.01   | 0.01         | 0.01                    | 2        |
| Er ppb  | 0.01   | 0.01   | 0.01  | 0.13    | 0.01   | 0.01   | 0.01         | 0.01                    | 2        |
| Eu ppb  | 0.01   | 0.01   | 0.01  | 0.03    | 0.01   | 0.01   | 0.01         | 0.01                    | 1        |
| Fe ppb  | 21.35  | 13.00  | 3.00  | 287.50  | 3.00   | 17.08  | 38.19        | 59.48                   | 5        |
| Gd ppb  | 0.01   | 0.01   | 0.01  | 0.20    | 0.01   | 0.01   | 0.01         | 0.01                    | 2        |
| K ppm   | 0.42   | 0.30   | 0.05  | 2.35    | 0.25   | 0.39   | 0.60         | 1.02                    | 9        |
| La ppb  | 0.02   | 0.01   | 0.01  | 0.38    | 0.01   | 0.01   | 0.01         | 0.03                    | 7        |
| Li ppb  | 1.05   | 0.90   | 0.15  | 3.40    | 0.51   | 1.38   | 2.67         | 2.43                    | 2        |
| Mg ppm  | 11.27  | 8.65   | 3.25  | 48.84   | 6.10   | 12.91  | 23.12        | 23.47                   | 3        |
| Mn ppb  | 1.38   | 0.28   | 0.03  | 16.48   | 0.11   | 1.25   | 2.95         | 5.69                    | 5        |
| Mo ppb  | 0.68   | 0.61   | 0.12  | 1.30    | 0.42   | 0.98   | 1.81         | 1.20                    | 0        |
| Na ppm  | 8.13   | 4.94   | 2.00  | 39.57   | 3.85   | 6.85   | 11.36        | 29.43                   | 6        |
| Nd ppb  | 0.03   | 0.01   | 0.01  | 0.69    | 0.01   | 0.01   | 0.02         | 0.05                    | 7        |
| Ni ppb  | 0.21   | 0.10   | 0.10  | 1.84    | 0.10   | 0.10   | 0.10         | 0.75                    | 11       |
| Pb ppb  | 0.07   | 0.10   | 0.01  | 0.10    | 0.03   | 0.10   | 0.21         | 0.10                    | 1        |
| Pr ppb  | 0.01   | 0.01   | 0.01  | 0.14    | 0.01   | 0.01   | 0.01         | 0.01                    | 4        |
| Rb ppb  | 0.26   | 0.18   | 0.03  | 1.59    | 0.14   | 0.29   | 0.51         | 0.57                    | 4        |
| S ppm   | 3.74   | 3.00   | 0.12  | 16.00   | 1.62   | 4.87   | 9.75         | 10.75                   | 4        |
| Sb ppb  | 0.07   | 0.01   | 0.01  | 0.87    | 0.01   | 0.04   | 0.09         | 0.30                    | 7        |
| Si ppb  | 6.83   | 5.97   | 4.34  | 20.14   | 5.11   | 7.44   | 10.94        | 11.12                   | 3        |
| Sm ppb  | 0.01   | 0.01   | 0.01  | 0.17    | 0.01   | 0.01   | 0.01         | 0.01                    | 4        |
| Sr ppb  | 254.54 | 191.96 | 42.51 | 1483.94 | 113.01 | 319.40 | 628.97       | 471.55                  | 3        |
| U ppb   | 0.21   | 0.14   | 0.02  | 1.51    | 0.09   | 0.22   | 0.40         | 0.48                    | 5        |
| V ppb   | 1.21   | 0.70   | 0.40  | 7.90    | 0.60   | 0.98   | 1.53         | 3.74                    | 7        |
| Y ppb   | 0.04   | 0.01   | 0.01  | 1.11    | 0.01   | 0.02   | 0.04         | 0.07                    | 5        |
| Yb ppb  | 0.01   | 0.01   | 0.01  | 0.13    | 0.01   | 0.01   | 0.01         | 0.01                    | 2        |
| Zn ppb  | 1.55   | 0.90   | 0.30  | 8.68    | 0.60   | 1.64   | 3.19         | 6.25                    | 4        |
| Zr ppb  | 0.06   | 0.02   | 0.02  | 1.16    | 0.02   | 0.03   | 0.04         | 0.11                    | 7        |

Element, pH, and conductivity box and whisker plots (Fig. 8) were generated from the data used to create Table 8. Strontium, Al, Fe, and B concentrations exceed 100 ppb in several samples and the water pH ranges from 7.45 to 8.55. The concentration of sulphide mineralization pathfinders are lower, with the maximum As value of 17.5 ppb, Mo to 1.3 ppb and Cu to 11.42 ppb. Although the Cu lower detection limit is 0.1 ppb, an analysis of the blank water samples suggests possible Cu contamination may be present at levels below 1.1 ppm. Copper above 1.1 ppb was detected in only one water sample from a stream near Ward Creek.

Figure 9 identifies the different types drainage samples collected at each site; sediment site and sample descriptions are reported in Appendix 1. The water is alkaline, and the streams south of Ward Creek have a pH greater than 8.18 (Fig. 10, Appendix 2). In the northern part of the project area, the stream water is less alkaline and several streams near French Bar Creek have a pH between 7.55 and 7.45. The highest Cu measured (3.3 ppb) is in the water from a stream flowing into Ward Creek (Fig. 11) and the highest As (17.1 ppb) is in the water from Second Creek, a tributary of Watson Bar Creek (area A, Fig. 12). Two km downstream from the sample site where Second Creek crosses the West Pavilion Road, As concentration in the water decreases from 17.1 ppb to less than 5 ppb. Elevated As levels (up to 10 ppb) are in a water sample from Roderick Creek (area B, Fig. 12). This creek drains a ridge with several gold mineral occurrences (e.g. Astonisher, Buster), the most likely source of As in the water. The highest Fe concentrations



**Fig. 8.** Box and whisker plots for elements, pH, and conductivity in stream water samples.

(up to 288 ppb) are in water samples from Boiler and French Bar Creeks (area A, Fig. 13) and Fe is also elevated in water from Roderick Creek (area B, Fig. 13). The S detected by ICP-MS in the water is likely as  $\text{SO}_4$  and the equivalent  $\text{SO}_4$  to 16 ppm S (maximum detected) is 48 ppm. Three streams including

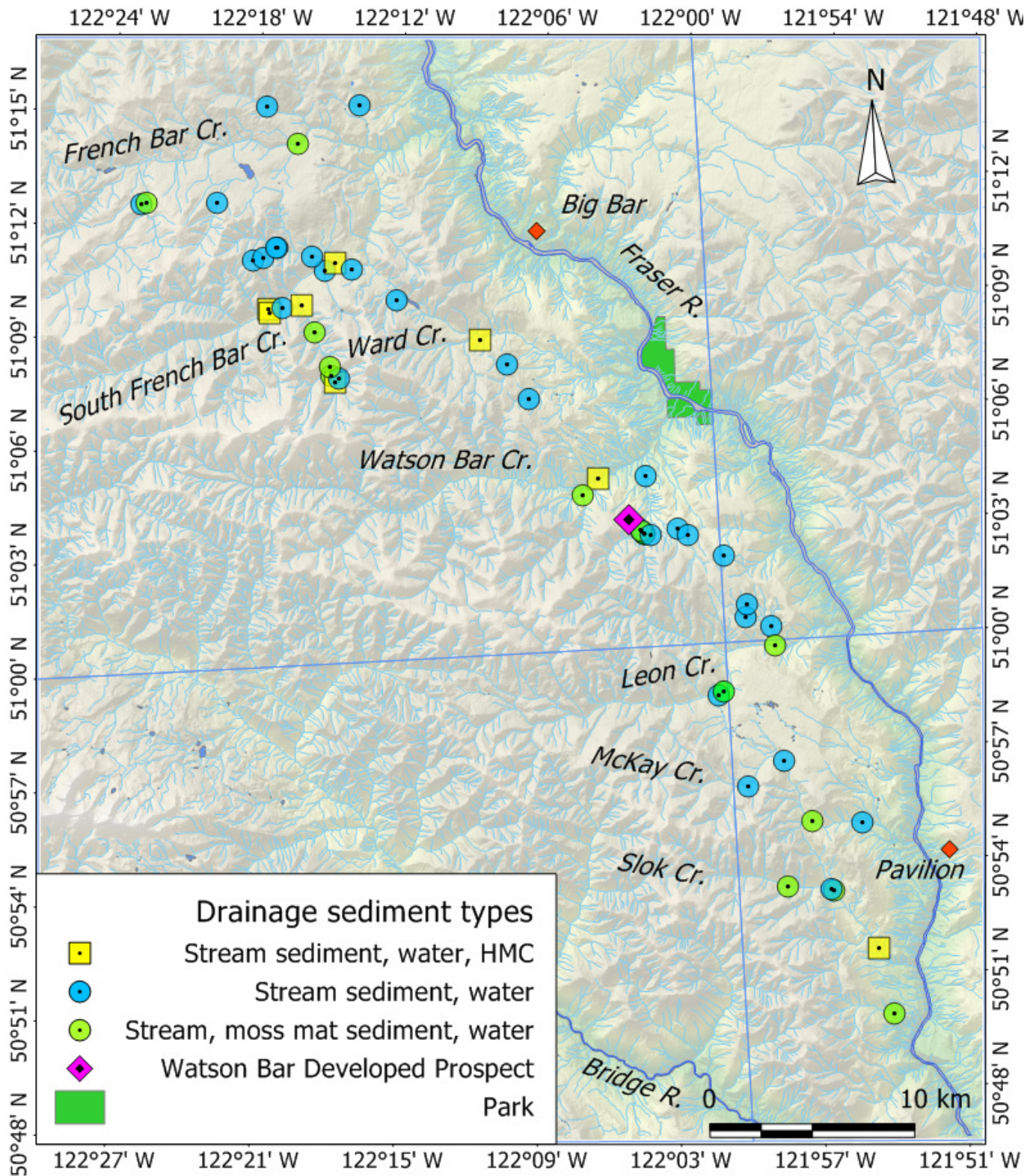


Fig. 9. Drainage sample types.

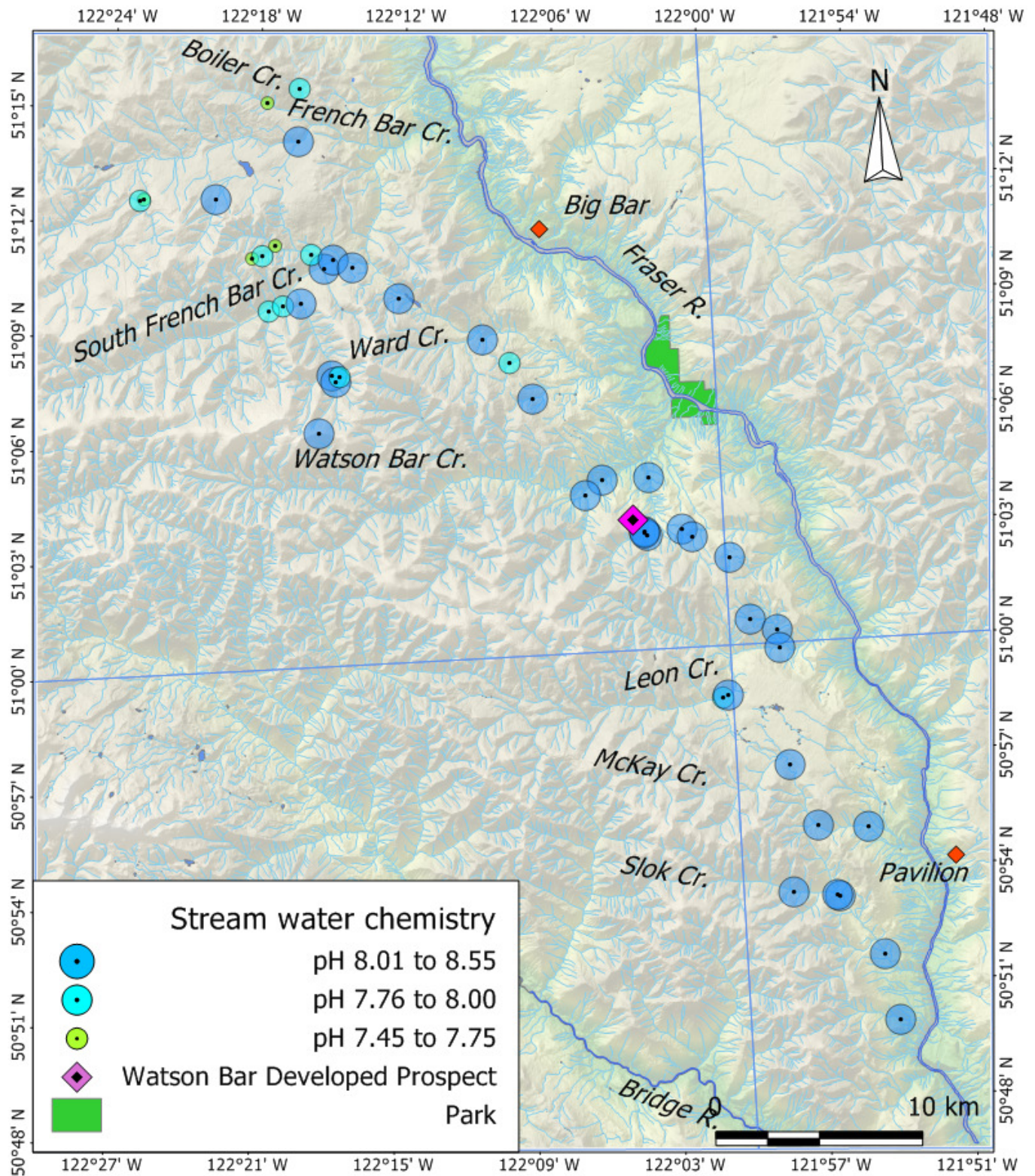


Fig. 10. Stream water pH.

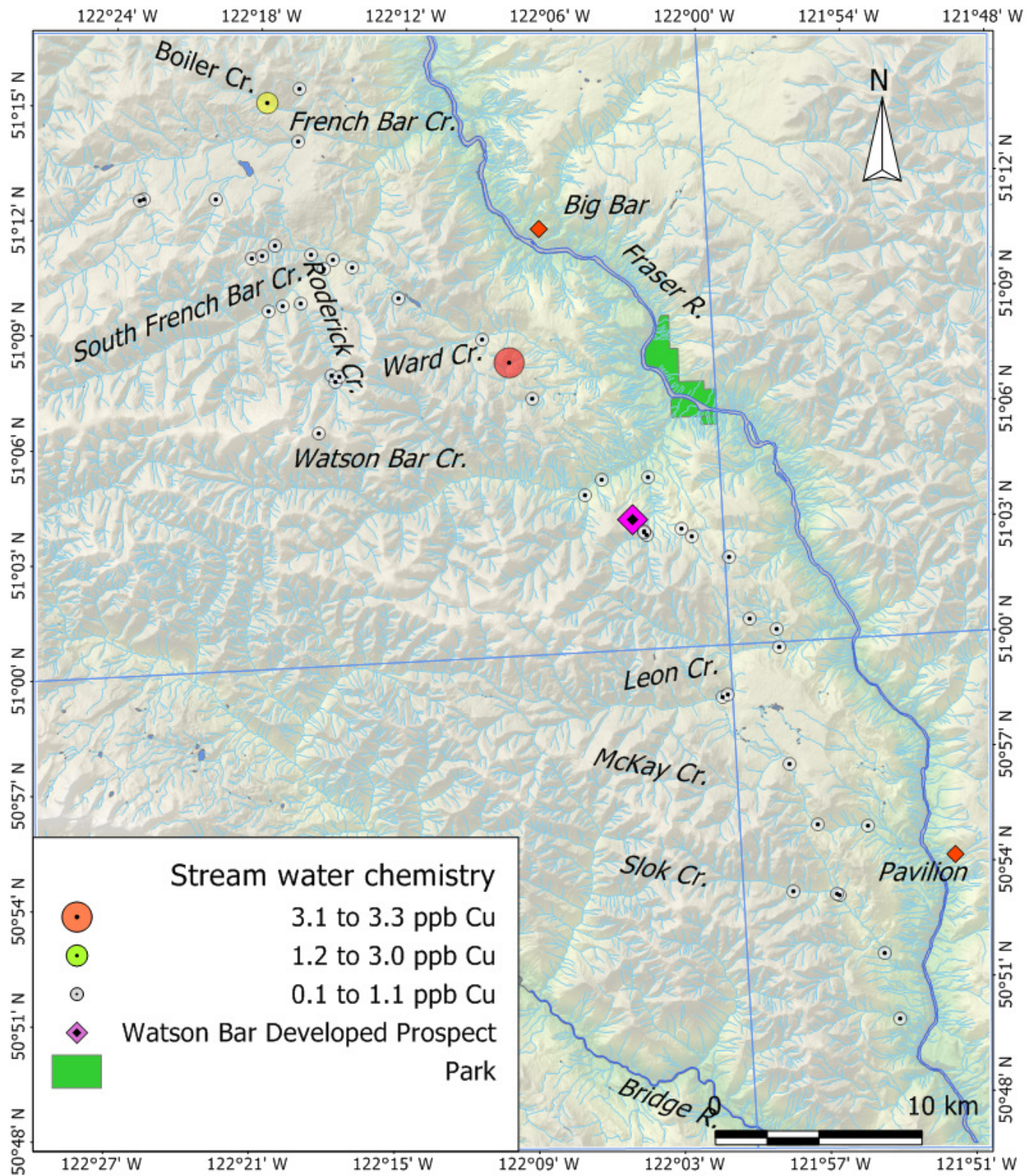


Fig. 11. Copper in stream water.

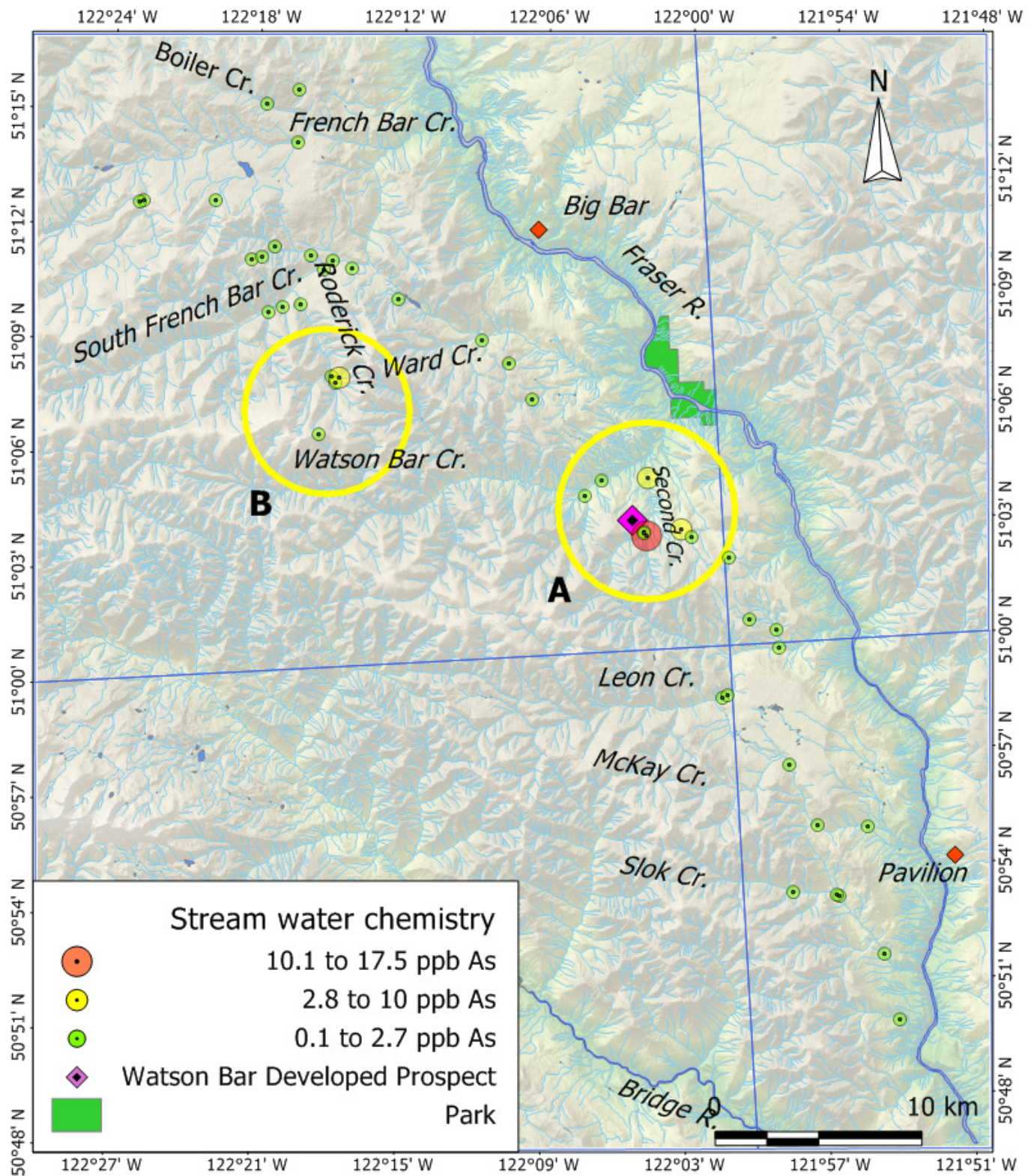


Fig. 12. Arsenic in stream water.

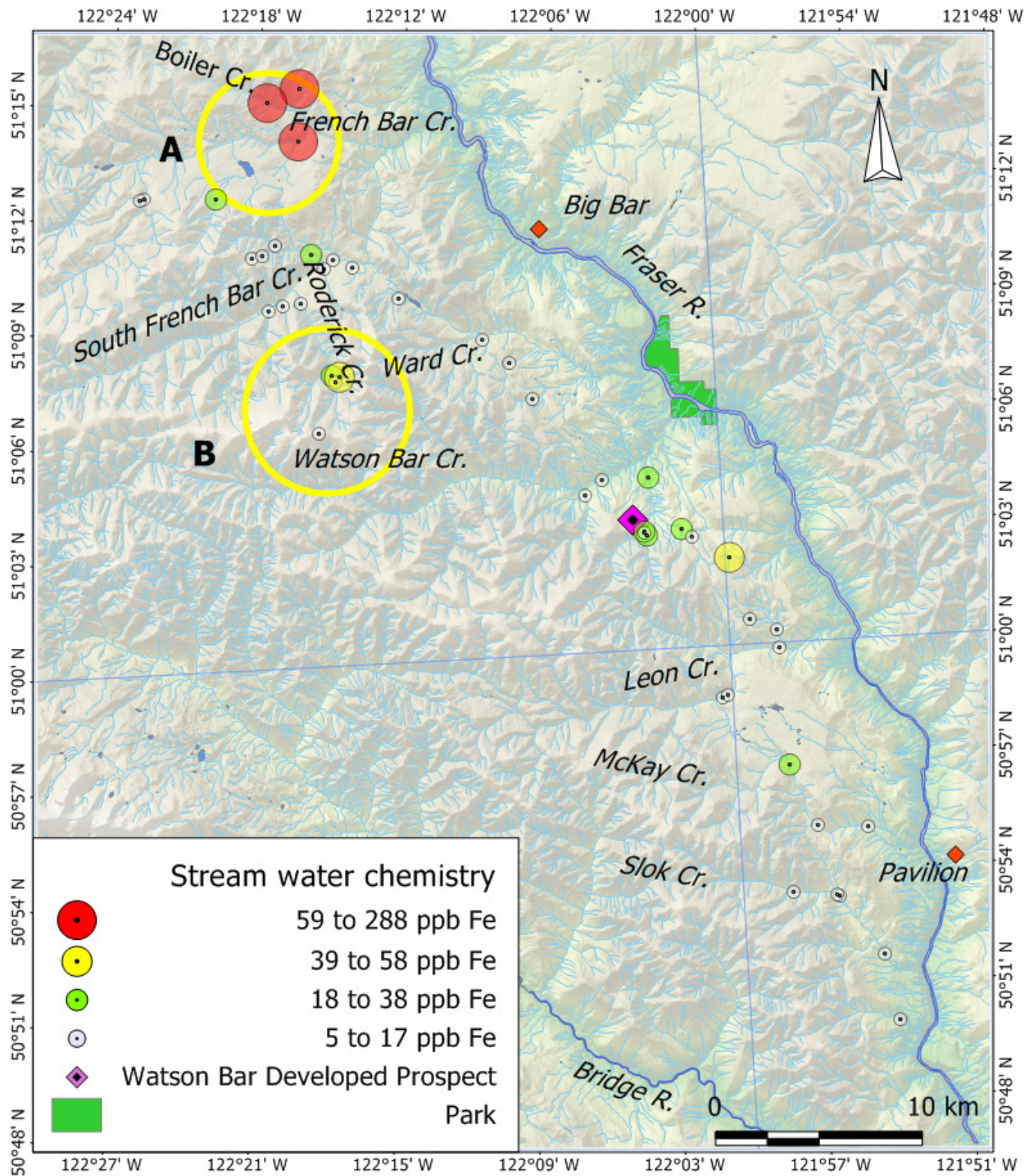


Fig. 13. Iron in stream water.

Second Creek (area A, Fig. 14) have elevated  $\text{SO}_4$ , suggesting an oxidizing sulphide source. Boiler and Watson Bar Creeks (areas A and B, Fig. 15) have up to 288 ppb Al (Fig. 15) and elevated Si (Fig. 17) suggesting weathering products of rock or surficial sediment. Three creeks including Second Creek have more than 58 ppm Ca in the water (areas A, B and C, in Fig. 16) and the higher Ca levels are associated with the more alkaline stream water.

Only Boiler Creek and an unnamed creek to the northeast have detectable REE contents (e.g., Yb, Fig. 18). The REE contents in the Boiler Creek sediment and water (Fig. 19), normalized to a North American shale REE chemistry, increase from La to Yb. There are Ce and Eu negative peaks, and the REE pattern is similar to that observed for seawater (see Rollinson, 1993). The anomalous REE concentrations are associated with high Fe and Al in the Boiler Creek water and sediment, suggesting that the chemistry reflects clay minerals weathered from volcanic rocks.

### 5.2. Stream sediment and moss mat sediment comparison

Figure 20 compares the median and range values for Ag, As, Au, Ba, Cu, Hg, Mo, Ni, Pb, V and Zn in 104 stream-sediment samples (Appendix 3) and 74 moss mat-sediment samples (Appendix 4). Previous studies by Matysek et al. (1988) revealed elevated Au levels in moss mat sediment compared to stream sediment. However, the concentration of most elements in the present study is higher in the stream sediment (carried as bedload) compared to moss mat sediment (Fig. 20). This pattern likely reflects that streams in the project area lack the energy to transport Au in suspension for trapping by moss mats.

### 5.3. Stream-sediment geochemistry and grain size comparison

Figure 21 shows the median and range values for Ag, As, Au, Ba, Cu, Hg, Mo, Ni, Pb, V, and Zn in the -80 mesh (< 0.177 mm) and - 230 mesh (< 0.063 mm) size fractions recovered from four sediment samples (Appendix 5). The partitioning of elements in the two size fractions is inconsistent. For example, Ag, Au and Ba are higher in the - 230 mesh fraction, but Hg, Mo and Sb are higher in the - 80 mesh fraction. The differences likely reflect the chemistry of different minerals partitioned into the two grain size fractions.

### 5.4. Stream-sediment geochemistry and stream-sediment and moss mat-sediment patterns

A statistical summary of elements in the -80 mesh (< 0.177 mm) stream-sediment fraction analysed by  $\text{HNO}_3$ -HCl- $\text{H}_2\text{O}$  (1:1:1 v/v) dissolution ICP-MS and by INAA is given in Table 9. The highest Au (420 ppb by  $\text{HNO}_3$ -HCl- $\text{H}_2\text{O}$  - ICP-MS is in the sediment from a tributary of Boiler Creek draining an area beyond the northern boundary of the project area (area A, Fig. 22). Three creeks also have INAA Au contents of above 40 ppb and up to 365 ppb (areas A, B and C, Fig. 23), but only Madson Creek has gold in the moss mat sediment above 100 ppb and up to 430 ppb (area A, Fig. 24). The heavy mineral fraction from

seven streams in the South French Bar area were examined for indicator minerals, but only three contained gold grains and the - 80 mesh (< 0.177 mm) sediment fraction contained less than 5 ppb Au.

Madson and Second Creeks have Cu levels in the sediment that are above 58 ppm (area A, Fig. 25). These creeks also have the highest levels of As (to 289 ppm, area A, Fig. 26) and Hg (to 3282 ppb, area A, Fig. 27). Lower, but still elevated As concentrations are in sediment from two other Creeks (areas B and C, Fig. 26). Samarium is an example of REEs elevated in sediment from Boiler Creek (area A, Fig. 28). Although most sediments have less than 30% LOI, one sample from a stream draining east into the Fraser River has more than 70% LOI (Fig. 29). The high organic content of the sediment may be responsible for the elevated As levels. Two other samples from streams draining into South French Bar Creek have between 50 to 70% LOI (Fig. 29).

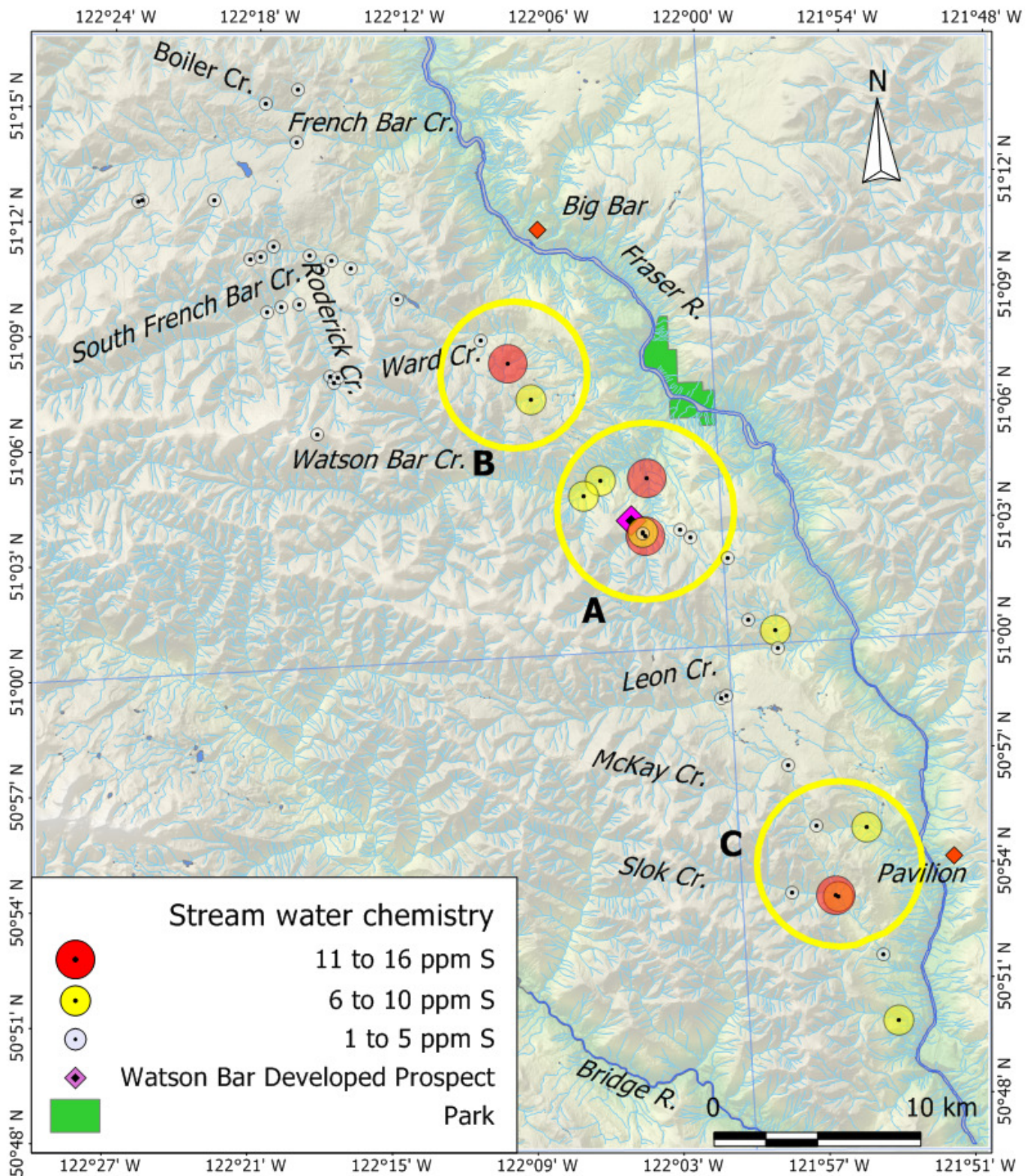


Fig. 14. Sulphur in stream water.

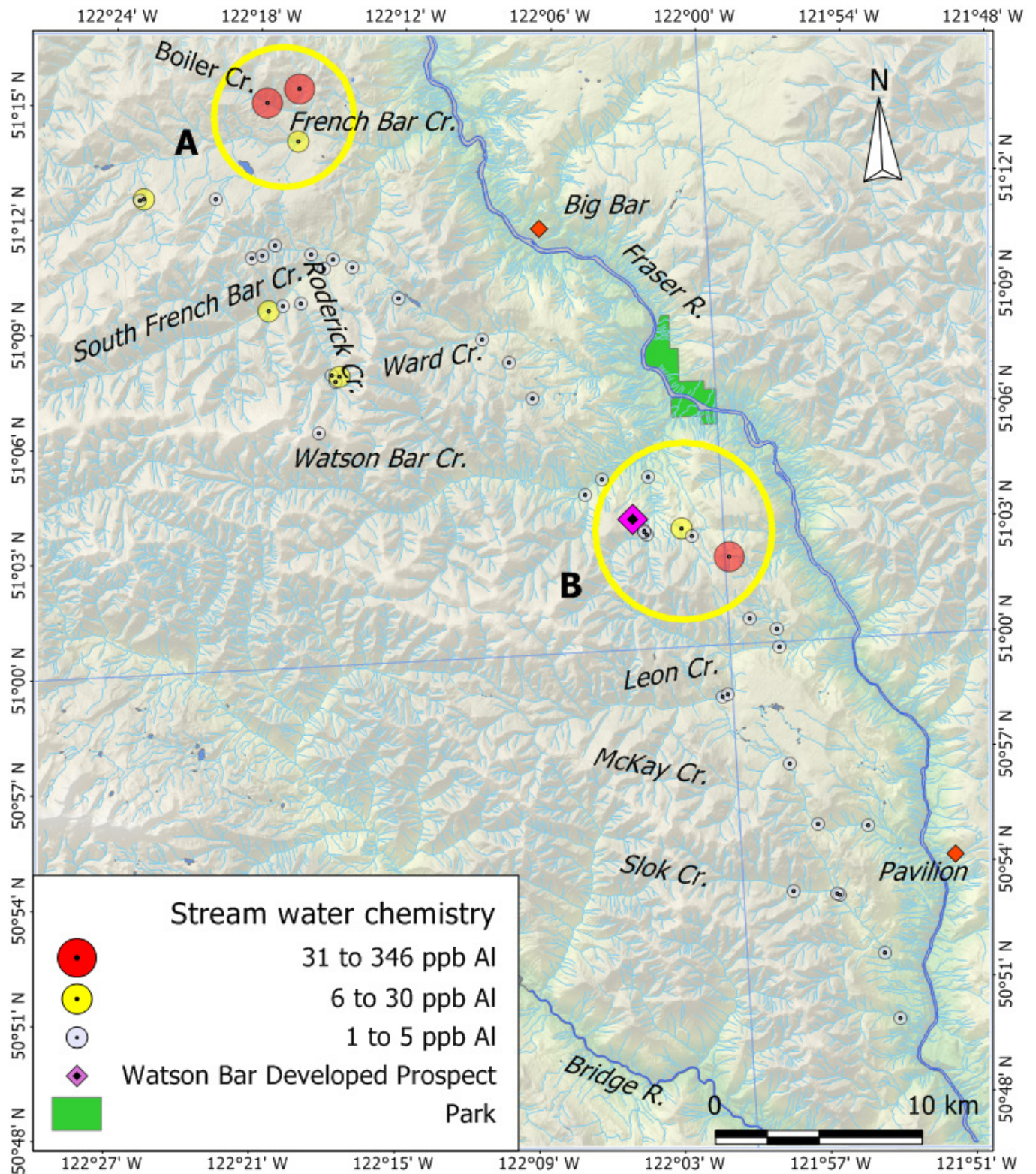


Fig. 15. Aluminum in stream water.

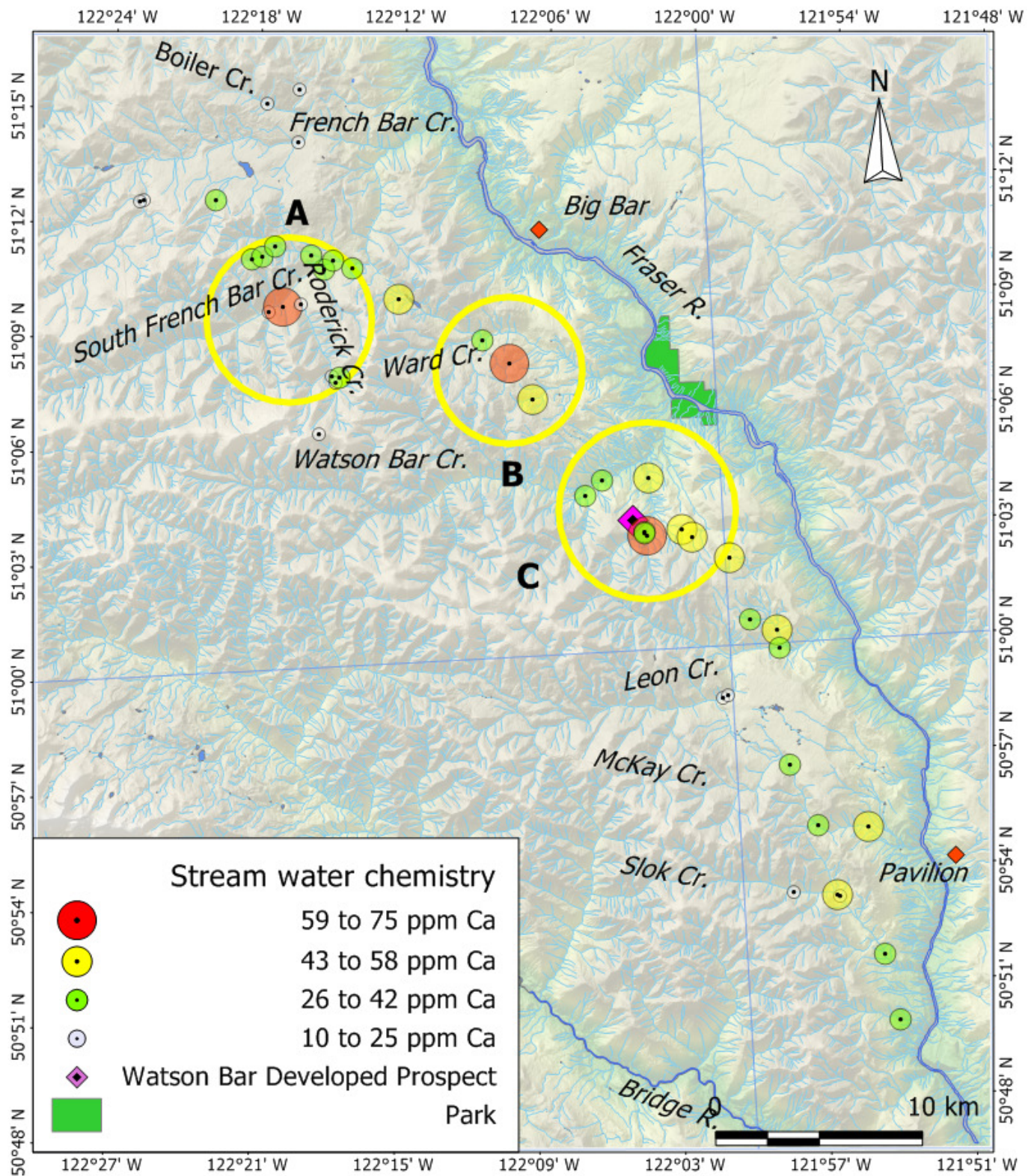


Fig. 16. Calcium in stream water.

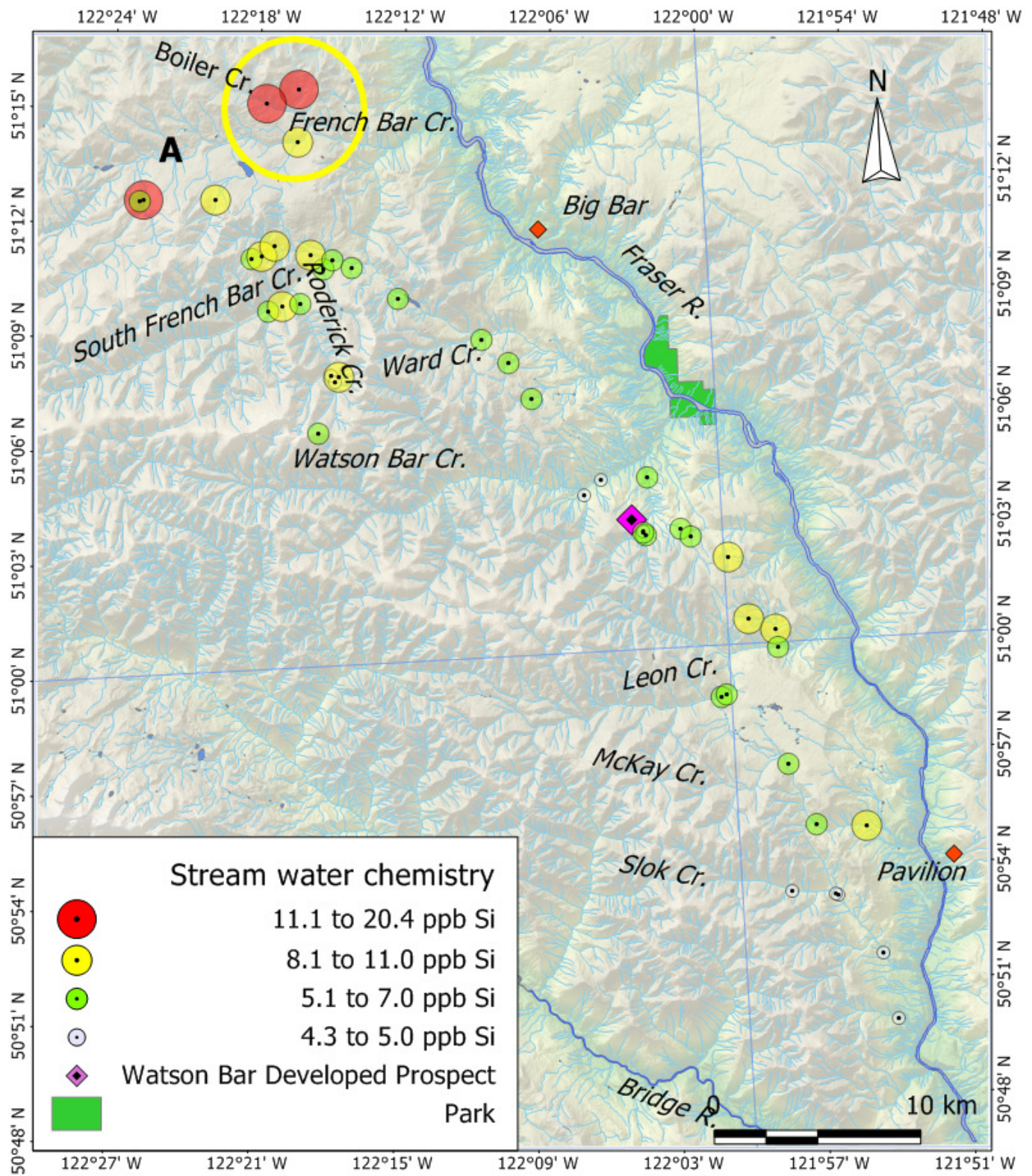


Fig. 17. Silicon in stream water.

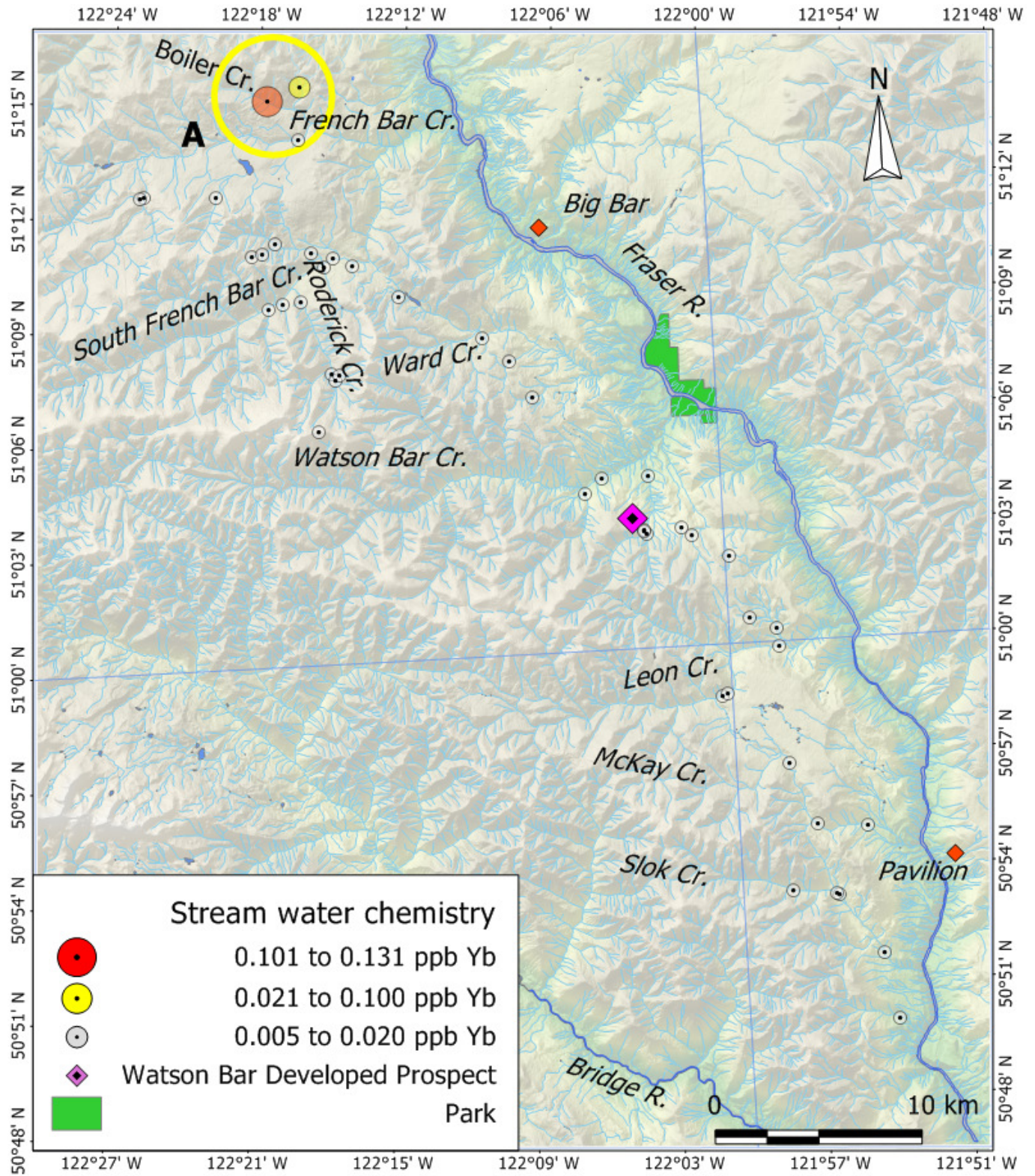
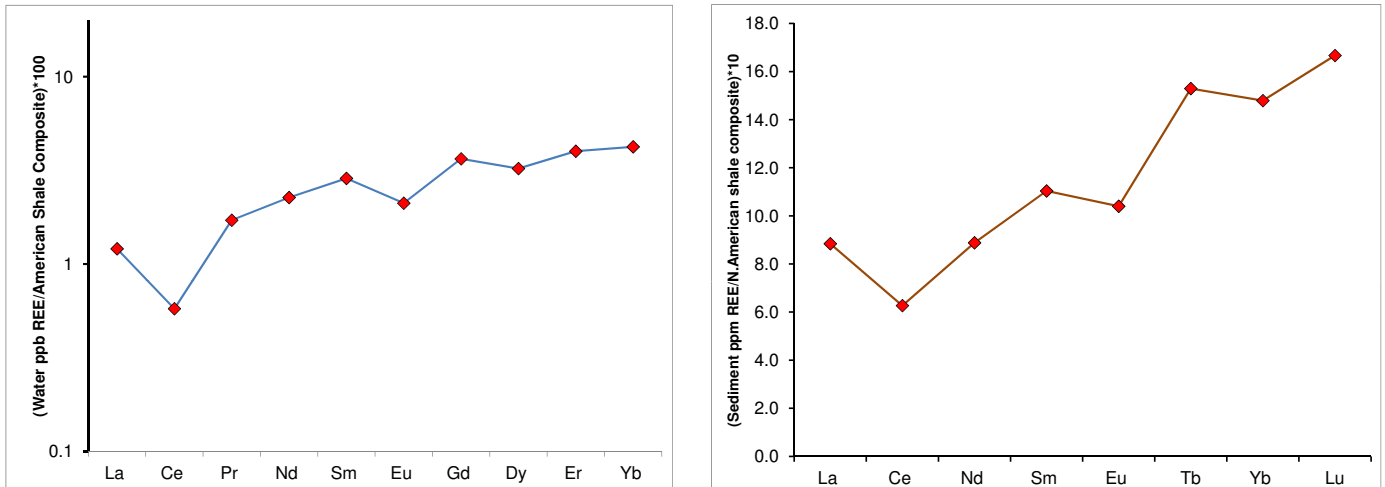
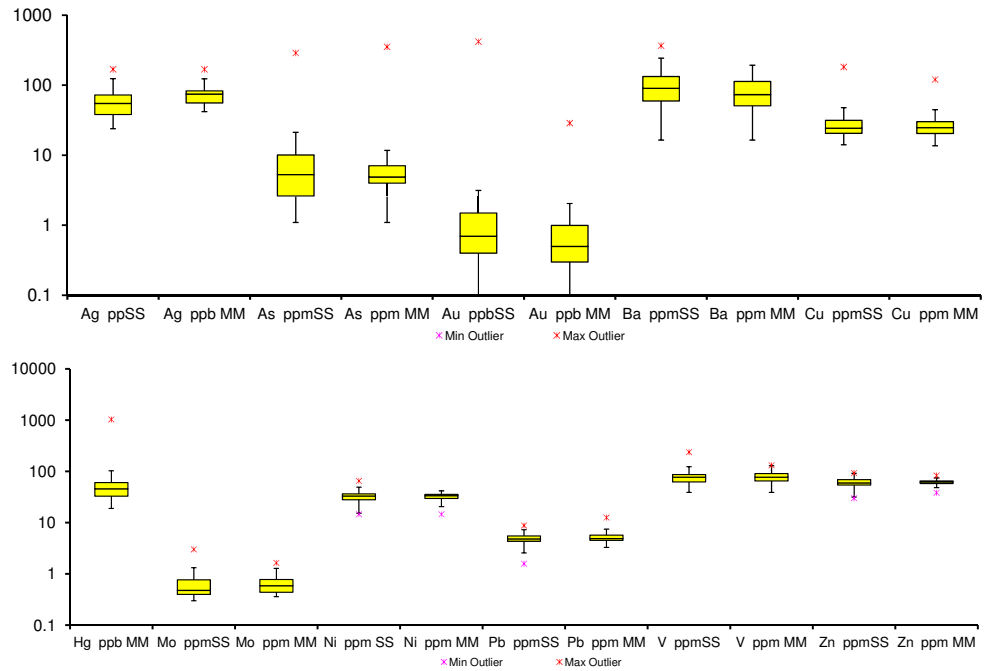


Fig. 18. Ytterbium in stream water.

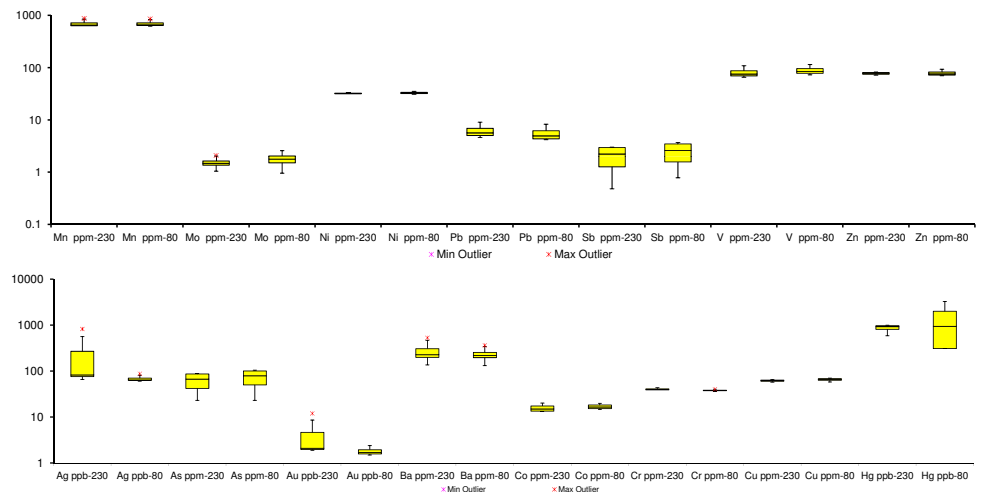


**Fig. 19.** Rare earth elements (REE) in Boiler Creek water sample and stream-sediment samples (92O-2006-1055). The REE values are normalized to a North American shale composite (Gromet et al., 1984).

**Fig. 20.** Comparison of moss mat sediment (MM) and stream sediment (SS) chemistry.



**Fig. 21.** Comparison of elements in - 80 mesh (< 0.177 mm) and - 230 mesh (< 0.063 mm) of stream sediments analysed by  $\text{HNO}_3\text{-HCl-H}_2\text{O}$  (1:1:1 v/v) dissolution - ICP-MS.

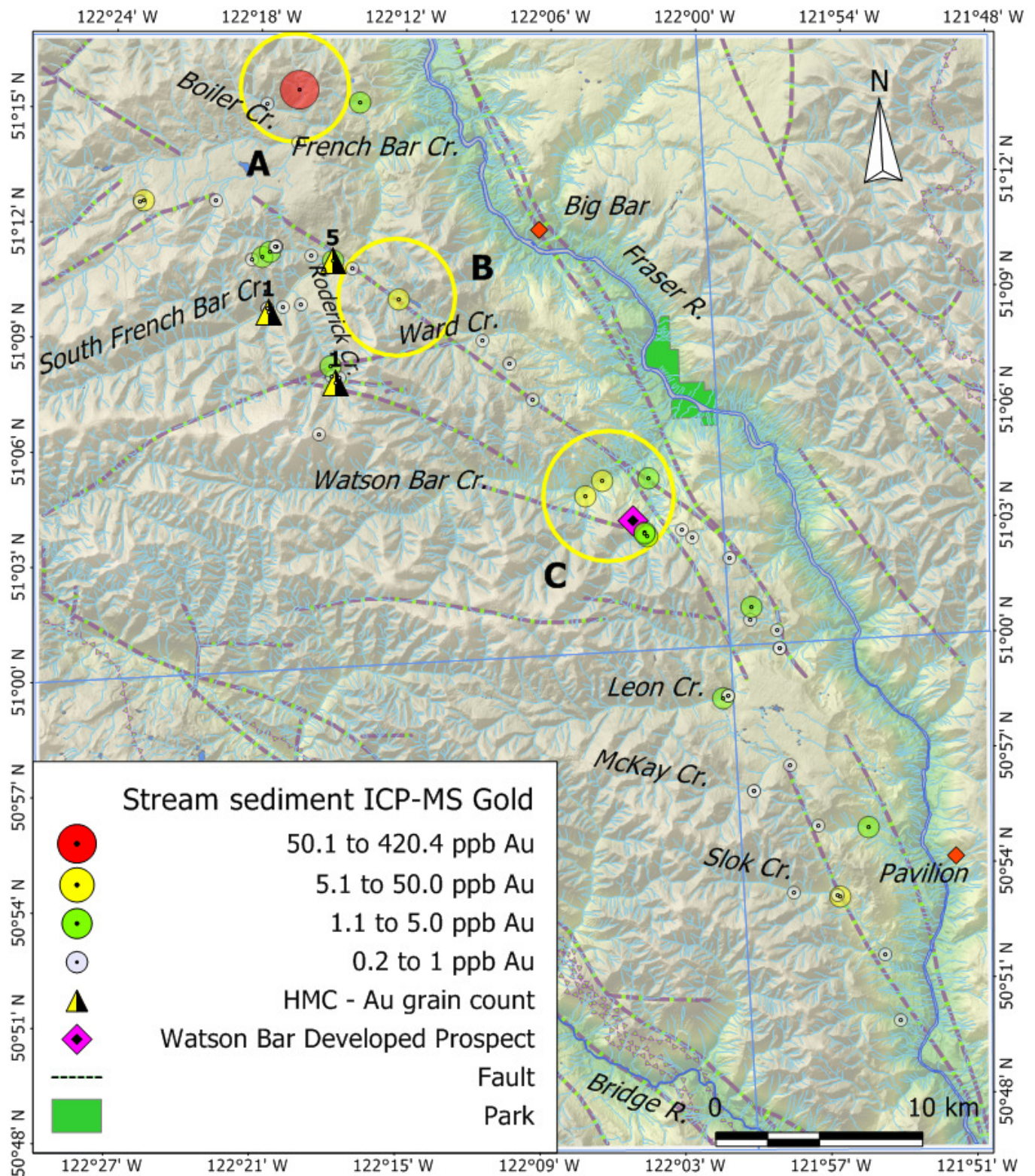


**Table 9.** Stream sediment statistics for Ag to Lu.

| Element- Method | Mean  | Median | Minimum | Maximum | 3 <sup>rd</sup> Quartile | 80 Percentile | 90 Percentile | 95 Percentile | Count |
|-----------------|-------|--------|---------|---------|--------------------------|---------------|---------------|---------------|-------|
| Ag ppb ICP-MS   | 60    | 55     | 18      | 169     | 71                       | 73            | 92            | 126           | 59    |
| Al pct ICP-MS   | 1.77  | 1.81   | 0.10    | 2.81    | 2.10                     | 2.16          | 2.25          | 2.49          | 59    |
| As ppm ICP-MS   | 20.8  | 4.8    | 1.1     | 289.2   | 8.5                      | 17.9          | 54.0          | 100.8         | 59    |
| As ppm INAA     | 18.4  | 7.7    | 0.3     | 188.0   | 11.5                     | 11.8          | 43.5          | 95.1          | 56    |
| Au ppb ICP-MS   | 9.3   | 0.7    | 0.1     | 420.4   | 1.5                      | 1.6           | 4.5           | 11.8          | 59    |
| Au ppb INAA     | 16.3  | 1      | 1       | 367     | 1                        | 1             | 8             | 44            | 56    |
| B ppm ICP-MS    | 8     | 6      | 1       | 45      | 9                        | 10            | 17            | 34            | 59    |
| Ba ppm ICP-MS   | 113.3 | 85.3   | 16.5    | 449.0   | 132.9                    | 141.0         | 204.7         | 258.1         | 59    |
| Ba ppm INAA     | 482   | 485    | 25      | 780     | 590                      | 610           | 670           | 685           | 56    |
| Be ppm ICP-MS   | 0.4   | 0.4    | 0.1     | 0.8     | 0.5                      | 0.5           | 0.6           | 0.7           | 26    |
| Bi ppm ICP-MS   | 0.06  | 0.06   | 0.02    | 0.26    | 0.07                     | 0.07          | 0.08          | 0.12          | 59    |
| Br ppm INAA     | 14.2  | 6.9    | 0.3     | 92.3    | 16.3                     | 19.6          | 34.4          | 50.7          | 56    |
| Ca pct ICP-MS   | 2.15  | 1.30   | 0.65    | 27.74   | 1.77                     | 2.04          | 2.97          | 6.24          | 59    |
| Ca pct INAA     | 2.3   | 2.0    | 0.5     | 13.0    | 3.0                      | 3.0           | 4.0           | 4.5           | 56    |
| Cd ppm ICP-MS   | 0.13  | 0.11   | 0.07    | 0.60    | 0.14                     | 0.16          | 0.18          | 0.22          | 59    |
| Ce ppm ICP-MS   | 15.2  | 14.9   | 3.6     | 25.5    | 17.5                     | 17.9          | 18.3          | 19.3          | 26    |
| Ce ppm INAA     | 25    | 25     | 4       | 48      | 28                       | 29            | 33            | 37            | 56    |
| Co ppm ICP-MS   | 12.9  | 12.4   | 2.5     | 29.5    | 14.5                     | 15.1          | 16.0          | 20.2          | 59    |
| Co ppm INAA     | 13    | 13     | 2       | 25      | 16                       | 16            | 18            | 19            | 56    |
| Cr ppm ICP-MS   | 37.7  | 38.3   | 3.1     | 76.0    | 44.7                     | 46.2          | 49.5          | 53.7          | 59    |
| Cr ppm INAA     | 98    | 88     | 3       | 220     | 124                      | 126           | 156           | 203           | 56    |
| Cs ppm ICP-MS   | 0.96  | 0.55   | 0.26    | 4.37    | 1.24                     | 1.48          | 2.02          | 2.28          | 26    |
| Cs ppm INAA     | 1.6   | 2.0    | 0.5     | 6.0     | 2.0                      | 2.0           | 3.0           | 4.0           | 56    |
| Cu ppm ICP-MS   | 32.09 | 24.32  | 14.11   | 182.63  | 31.23                    | 36.62         | 58.43         | 68.02         | 59    |
| Eu ppm INAA     | 0.7   | 0.7    | 0.1     | 1.7     | 0.8                      | 0.9           | 1.0           | 1.0           | 56    |
| Fe pct ICP-MS   | 2.93  | 2.85   | 0.58    | 5.61    | 3.33                     | 3.38          | 3.62          | 4.18          | 59    |
| Fe pct INAA     | 3.26  | 3.24   | 0.41    | 5.46    | 3.88                     | 3.90          | 4.32          | 4.88          | 56    |
| Ga ppm ICP-MS   | 6.2   | 6.3    | 0.6     | 9.7     | 7.8                      | 7.9           | 8.2           | 8.9           | 59    |
| Hf ppm ICP-MS   | 0.23  | 0.24   | 0.02    | 0.41    | 0.30                     | 0.33          | 0.37          | 0.40          | 26    |
| Hf ppm INAA     | 3     | 3      | 1       | 8       | 4                        | 4             | 5             | 5             | 56    |
| Hg ppb ICP-MS   | 141   | 36     | 10      | 3282    | 51                       | 59            | 217           | 330           | 59    |
| K pct ICP-MS    | 0.07  | 0.06   | 0.03    | 0.18    | 0.08                     | 0.08          | 0.10          | 0.12          | 59    |
| La ppm ICP-MS   | 7.7   | 7.4    | 1.0     | 18.0    | 8.5                      | 8.7           | 9.5           | 10.8          | 59    |
| La ppm INAA     | 11.3  | 13.1   | 0.3     | 27.5    | 14.8                     | 15.0          | 15.8          | 17.3          | 56    |
| Li ppm ICP-MS   | 13.9  | 13.2   | 1.9     | 23.5    | 20.0                     | 20.4          | 22.1          | 23            | 26    |
| LOI pct Grav    | 13.7  | 9.7    | 3.8     | 71.8    | 17.9                     | 18.7          | 25.6          | 31.1          | 55    |
| Lu ppm INAA     | 0.24  | 0.22   | 0.01    | 0.76    | 0.26                     | 0.27          | 0.34          | 0.37          | 56    |

**Table 9.** (continued) Stream sediment statistics for Mg to Zr.

| Element- Method | Mean  | Median | Minimum | Maximum | 3 <sup>rd</sup> Quartile | 80 Percentile | 90 Percentile | 95 Percentile | Count |
|-----------------|-------|--------|---------|---------|--------------------------|---------------|---------------|---------------|-------|
| Mg pct ICP-MS   | 0.86  | 0.89   | 0.32    | 1.27    | 1.03                     | 1.08          | 1.20          | 1.23          | 59    |
| Mn ppm ICP-MS   | 841   | 584    | 114     | 4102    | 808                      | 885           | 1514          | 2823          | 59    |
| Mo ppm ICP-MS   | 0.70  | 0.47   | 0.26    | 3.02    | 0.65                     | 0.83          | 1.66          | 2.10          | 59    |
| Na pct ICP-MS   | 0.04  | 0.03   | 0.01    | 0.11    | 0.05                     | 0.06          | 0.08          | 0.08          | 59    |
| Na pct INAA     | 1.67  | 1.68   | 0.09    | 2.59    | 2.10                     | 2.15          | 2.25          | 2.30          | 56    |
| Nb ppm ICP-MS   | 0.76  | 0.76   | 0.05    | 1.60    | 1.05                     | 1.09          | 1.28          | 1.43          | 26    |
| Nd ppm INAA     | 9     | 9      | 3       | 27      | 11                       | 11            | 14            | 16            | 56    |
| Ni ppm ICP-MS   | 32.2  | 32.9   | 6.4     | 65.6    | 36.0                     | 37.4          | 41.3          | 43.2          | 59    |
| P pct ICP-MS    | 0.075 | 0.065  | 0.032   | 0.460   | 0.081                    | 0.082         | 0.088         | 0.100         | 59    |
| Pb ppm ICP-MS   | 4.97  | 4.84   | 1.48    | 8.84    | 5.49                     | 5.67          | 6.14          | 8.03          | 59    |
| Pd ppb ICP-MS   | 5     | 5      | 5       | 14      | 5                        | 5             | 5             | 5             | 26    |
| Rb ppm ICP-MS   | 4.1   | 3.8    | 1.5     | 9.7     | 4.5                      | 4.6           | 5.4           | 6.0           | 26    |
| Rb ppm INAA     | 13    | 7      | 7       | 65      | 7                        | 7             | 35            | 41            | 56    |
| Re ppm ICP-MS   | 0.7   | 0.5    | 0.5     | 3.0     | 0.5                      | 1.0           | 1.0           | 1.0           | 26    |
| S pct ICP-MS    | 0.05  | 0.02   | 0.01    | 0.34    | 0.08                     | 0.09          | 0.11          | 0.14          | 59    |
| Sb ppm ICP-MS   | 0.63  | 0.23   | 0.08    | 7.79    | 0.49                     | 0.61          | 1.21          | 2.66          | 59    |
| Sb ppm INAA     | 1.2   | 0.7    | 0.1     | 8.4     | 1.1                      | 1.3           | 2.0           | 4.0           | 56    |
| Sc ppm ICP-MS   | 5.3   | 5.5    | 0.5     | 11.6    | 6.4                      | 6.6           | 7.5           | 7.6           | 59    |
| Sc ppm INAA     | 11.7  | 11.6   | 0.7     | 17.8    | 14.3                     | 14.8          | 15.5          | 16.5          | 56    |
| Se ppm ICP-MS   | 0.9   | 0.6    | 0.1     | 3.8     | 1.2                      | 1.2           | 1.9           | 2.8           | 59    |
| Sm ppm INAA     | 2.4   | 2.5    | 0.1     | 6.6     | 2.8                      | 2.8           | 3.0           | 3.2           | 56    |
| Sn ppm ICP-MS   | 0.5   | 0.5    | 0.1     | 1.2     | 0.6                      | 0.6           | 0.7           | 0.9           | 26    |
| Sr pct INAA     | 0.04  | 0.03   | 0.03    | 0.12    | 0.03                     | 0.03          | 0.08          | 0.10          | 56    |
| Sr ppm ICP-MS   | 191.6 | 135.0  | 58.2    | 2391.9  | 174.3                    | 184.9         | 238.9         | 317.2         | 59    |
| Ta ppm INAA     | 0.4   | 0.3    | 0.3     | 2.3     | 0.3                      | 0.3           | 0.3           | 1.2           | 56    |
| Tb ppm INAA     | 0.3   | 0.3    | 0.3     | 1.3     | 0.3                      | 0.3           | 0.3           | 0.4           | 56    |
| Te ppm ICP-MS   | 0.02  | 0.01   | 0.01    | 0.19    | 0.02                     | 0.03          | 0.04          | 0.07          | 59    |
| Th ppm ICP-MS   | 1.0   | 1.0    | 0.1     | 2.5     | 1.1                      | 1.2           | 1.4           | 1.8           | 59    |
| Th ppm INAA     | 2.1   | 2.2    | 0.1     | 4.8     | 2.7                      | 2.7           | 3.0           | 3.3           | 56    |
| Ti pct ICP-MS   | 0.116 | 0.120  | 0.007   | 0.195   | 0.155                    | 0.168         | 0.181         | 0.191         | 59    |
| Tl ppm ICP-MS   | 0.05  | 0.04   | 0.02    | 0.27    | 0.05                     | 0.06          | 0.10          | 0.13          | 59    |
| U ppm ICP-MS    | 0.9   | 0.6    | 0.2     | 5.4     | 0.8                      | 0.9           | 1.6           | 2.7           | 59    |
| U ppm INAA      | 1.3   | 0.9    | 0.3     | 5.1     | 2.0                      | 2.3           | 3.4           | 4.1           | 56    |
| V ppm ICP-MS    | 78    | 77     | 15      | 238     | 88                       | 89            | 98            | 112           | 59    |
| W ppm ICP-MS    | 0.07  | 0.05   | 0.05    | 0.20    | 0.05                     | 0.05          | 0.10          | 0.20          | 59    |
| Y ppm ICP-MS    | 6.96  | 6.96   | 2.03    | 10.56   | 7.86                     | 8.02          | 8.66          | 112.83        | 26    |
| Yb ppm INAA     | 1.5   | 1.5    | 0.1     | 4.6     | 1.8                      | 1.8           | 2.1           | 2.3           | 56    |
| Zn ppm ICP-MS   | 59.9  | 59.8   | 17.9    | 93.6    | 67.2                     | 70.1          | 75.0          | 79.3          | 59    |
| Zn ppm INAA     | 52    | 25     | 25      | 200     | 63                       | 90            | 135           | 180           | 56    |
| Zr ppm ICP-MS   | 8.3   | 7.9    | 1.0     | 15.4    | 11.0                     | 11.6          | 12.8          | 14.0          | 26    |



**Fig. 22.** Gold by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution - ICP-MS in - 80 mesh (< 0.177 mm) stream sediment. Gold grain count in three HMC samples shown for comparison.

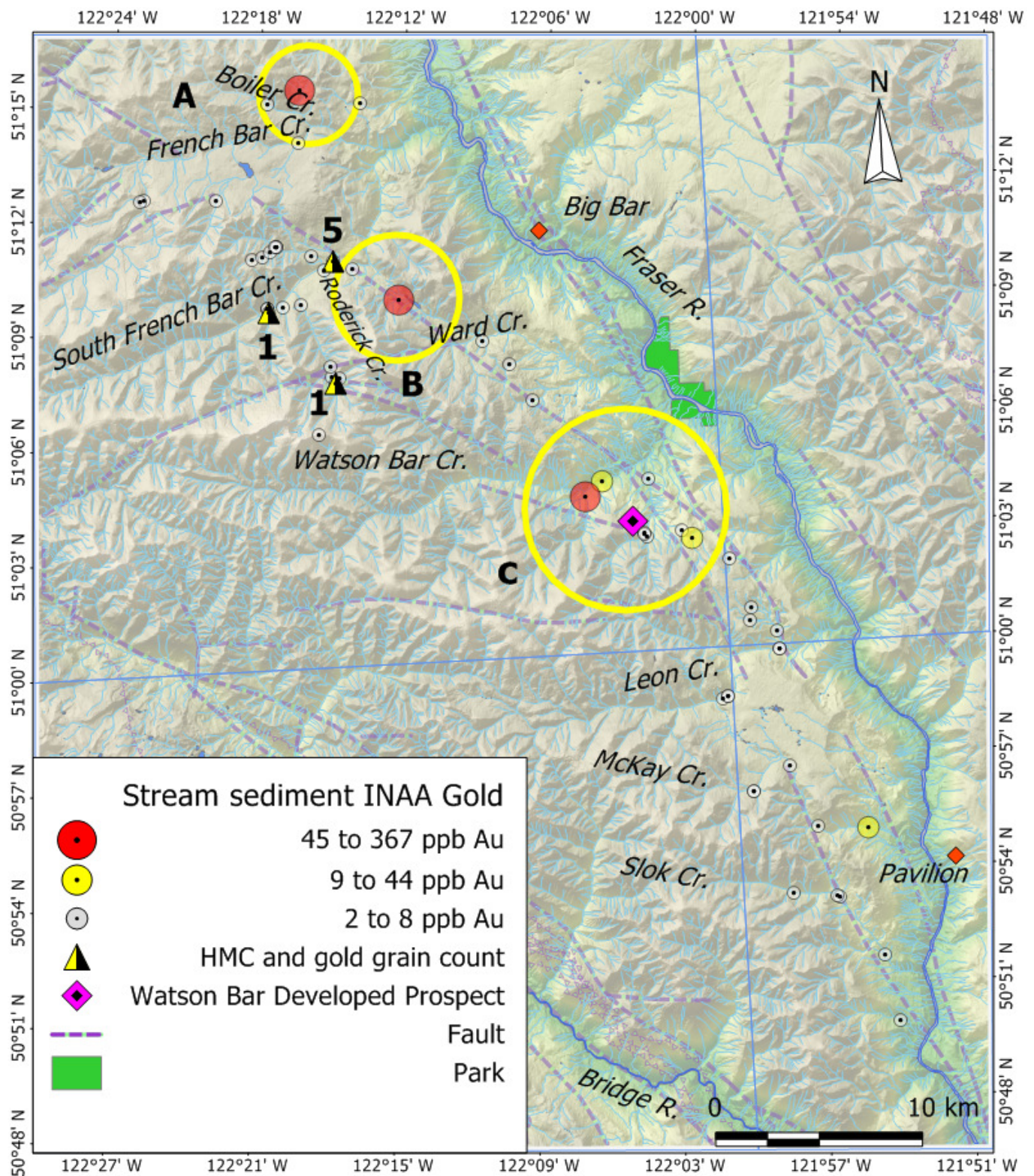


Fig. 23. Gold by INAA in - 80 mesh (< 0.177 mm) stream sediment. Gold grain count in three HMC samples shown for comparison.

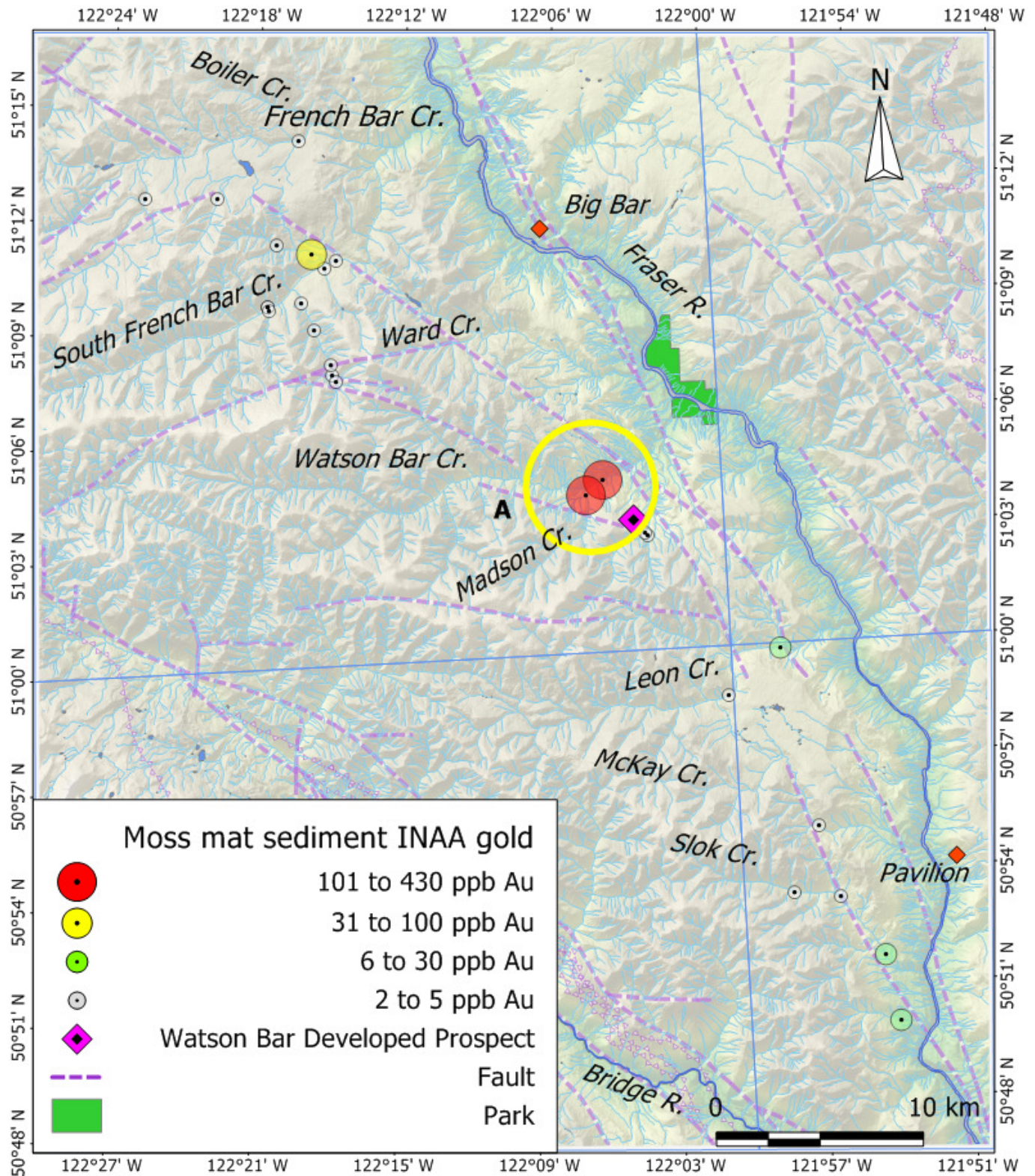


Fig. 24. Gold by INAA in - 80 mesh (< 0.177 mm) moss mat sediment.

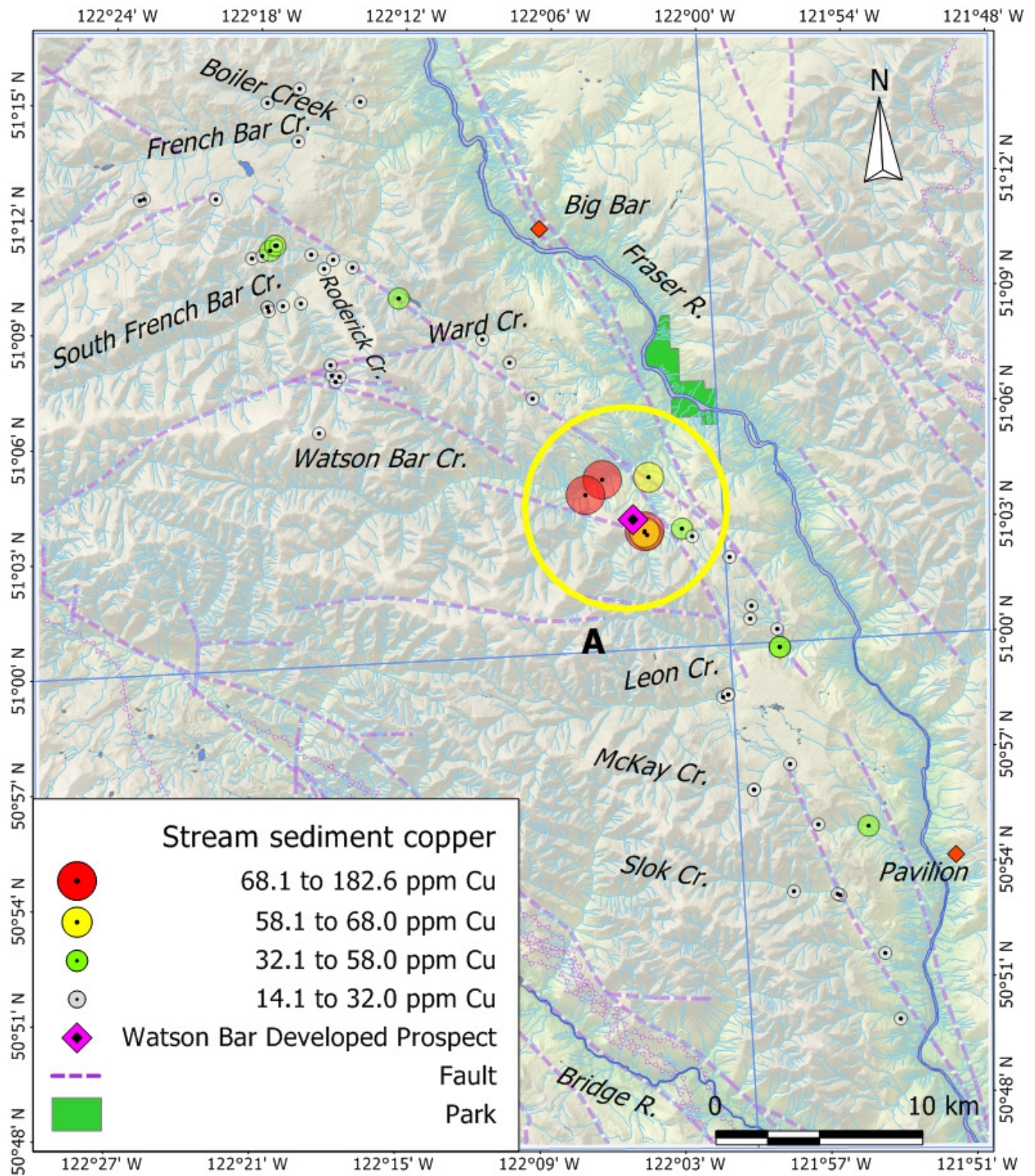


Fig. 25. Copper by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution - ICP-MS in - 80 mesh (< 0.177 mm) stream sediment.

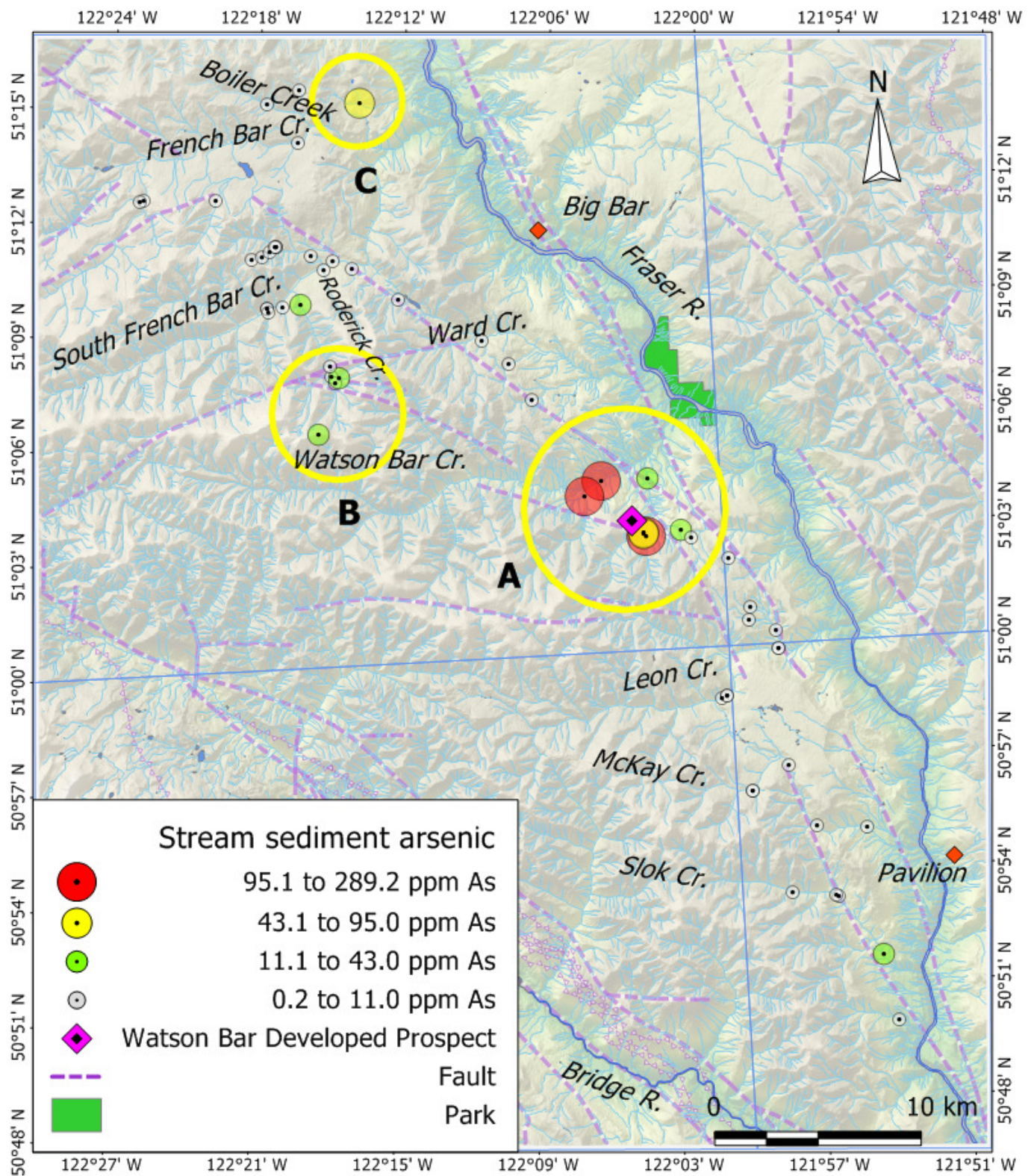


Fig. 26. Arsenic by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution - ICP-MS in - 80 mesh (< 0.177 mm) stream sediment.

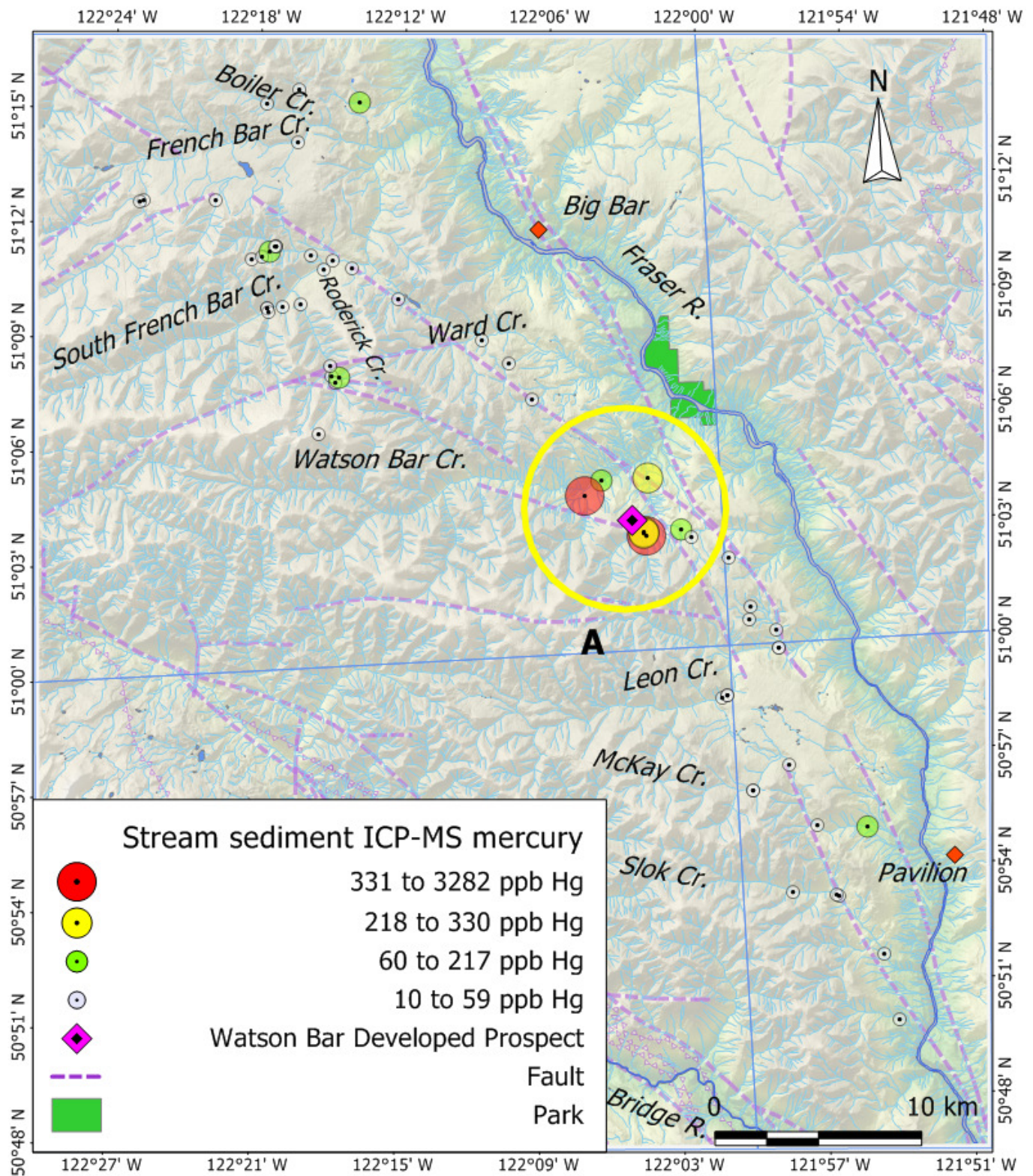


Fig. 27. Mercury by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution - ICP-MS in - 80 mesh (< 0.177 mm) stream sediment.

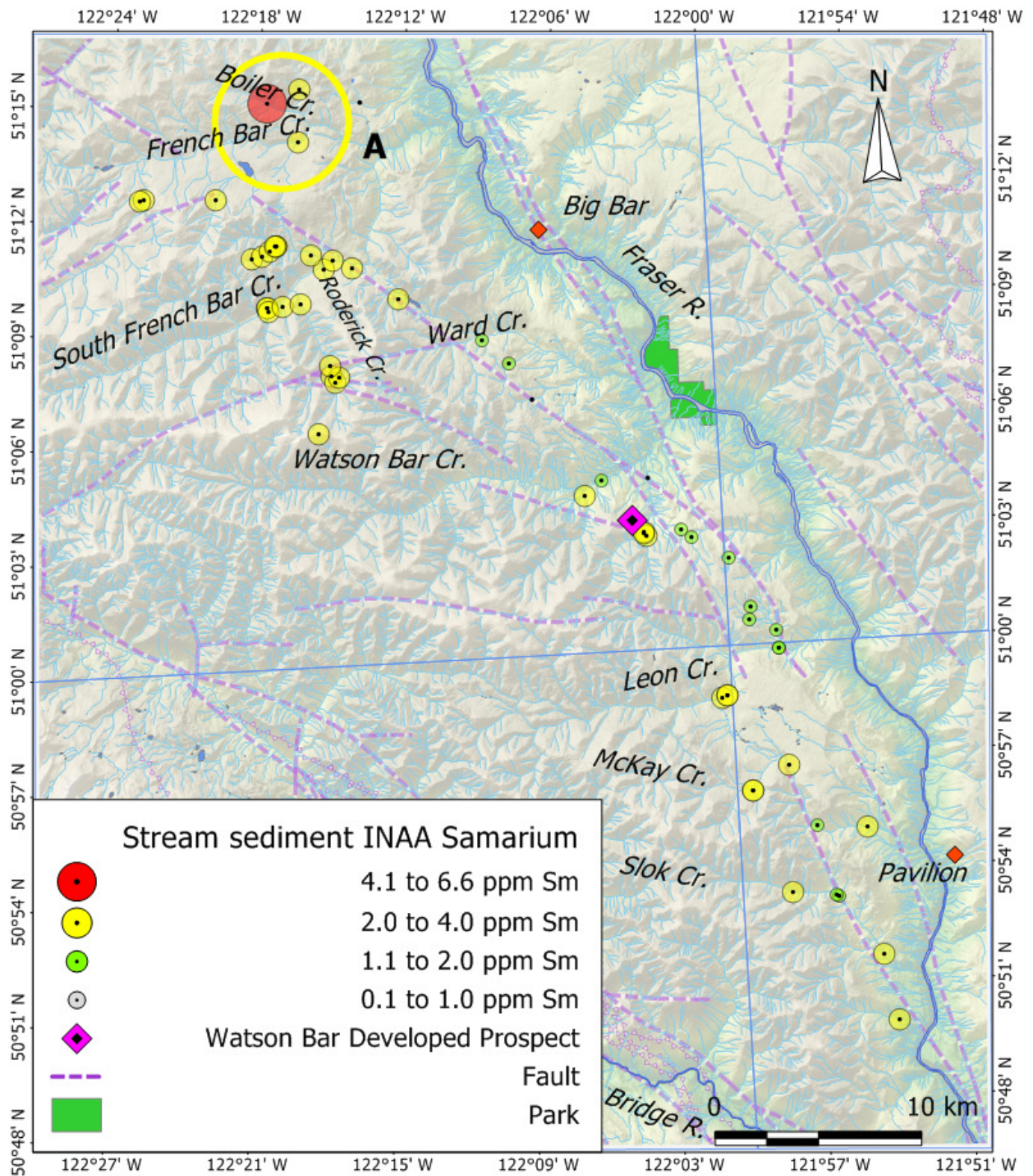


Fig. 28. Samarium by INAA in - 80 mesh ( $< 0.177$  mm) stream sediment.

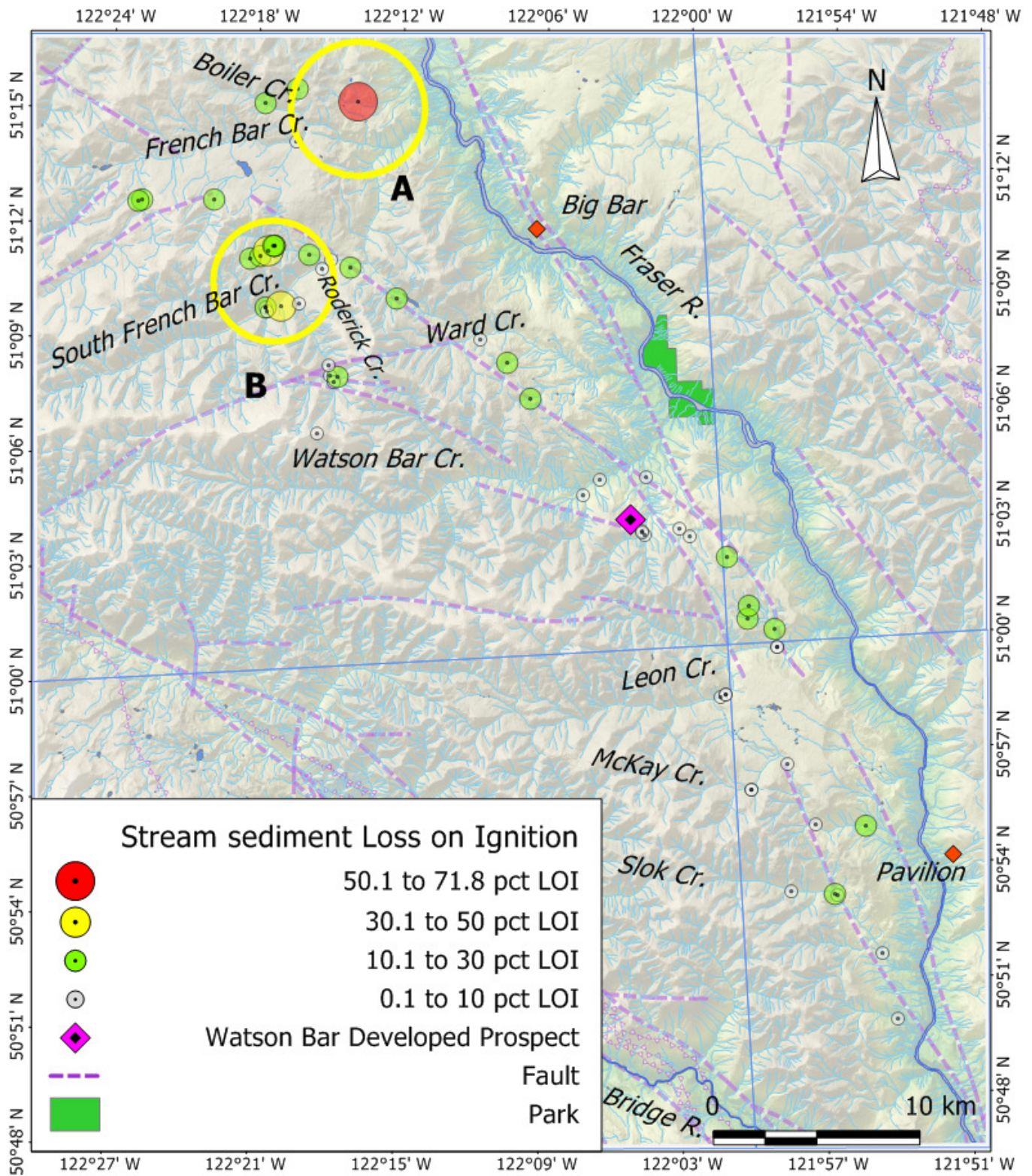


Fig. 29. Loss on ignition (LOI) in - 80 mesh (< 0.177 mm) stream sediment.

## 5.6. Bedrock geochemistry

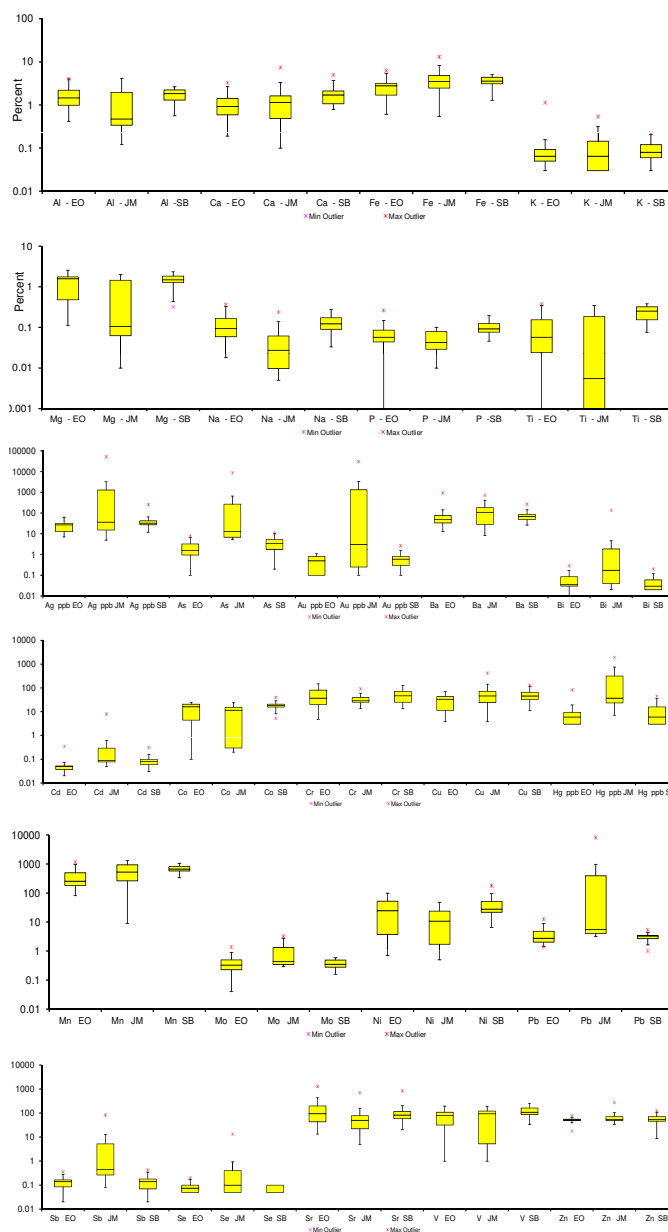
Table 10 lists element statistics for in 36 bedrock samples and Figure 30 compares median, quartile and range values for major and trace elements in Eocene, Jackass Mountain Group and Spences Bridge Group rock samples. Jackass Mountain Group rocks have higher Fe, Ca, K, but lower Mg and Na contents compared to the Eocene and Spences Bridge Group rocks. The Jackass Mountain rocks also have higher Ag, As, Au, Bi, Cd, Cu, Hg, Mo, Pb, Sb, Se and Zn, whereas the Eocene rocks have higher Cr, Co, Ni and Sr. The concomitant Ag, As, Au, Bi, Cd, Cu, Hg, Mo, Pb, Sb, Se and Zn values reflects the gold-mineralized Jackass Mountain rocks at the Watson Bar (Zone V) developed prospect.

**Table 10.** Bedrock geochemistry statistics.

| Element-Method | Mean   | Median | Minimum | Maximum | 3 quartile | 80 Percentile | 90 Percentile | 95 Percentile | Count |
|----------------|--------|--------|---------|---------|------------|---------------|---------------|---------------|-------|
| Ag ppb ICP-MS  | 37.14  | 30     | 5       | 259     | 38.5       | 42            | 56            | 73.75         | 36    |
| Al pct ICP-MS  | 1.77   | 1.7    | 0.39    | 4.14    | 2.37       | 2.52          | 2.735         | 3.5375        | 36    |
| As ppm ICP-MS  | 6.73   | 3.6    | 0.1     | 72.9    | 6.85       | 7.4           | 9.95          | 20.375        | 36    |
| As ppm INAA    | 5.12   | 1.95   | 0.2     | 28.8    | 4.875      | 5.96          | 15.34         | 22.43         | 14    |
| Au ppb ICP-MS  | 25.02  | 0.6    | 0.1     | 872.4   | 0.825      | 1.1           | 2.4           | 3.25          | 36    |
| Au ppb INAA    | 21.79  | 1      | 1       | 270     | 1          | 3.4           | 14            | 105.55        | 14    |
| B ppm ICP-MS   | 4.10   | 3.5    | 0.5     | 12      | 5.25       | 6             | 8             | 10.5          | 36    |
| Ba ppm ICP-MS  | 127.08 | 69.15  | 13      | 932     | 125.2      | 130           | 241.3         | 382.625       | 36    |
| Ba ppm INAA    | 768.79 | 755    | 30      | 1600    | 1022.5     | 1100          | 1274.3        | 1436.85       | 14    |
| Bi ppm ICP-MS  | 0.07   | 0.035  | 0.01    | 0.29    | 0.07       | 0.08          | 0.165         | 0.28          | 36    |
| Br ppm INAA    | 0.39   | 0.3    | 0.3     | 1.5     | 0.3        | 0.3           | 0.3           | 0.72          | 14    |
| Ca % INAA      | 2.89   | 3      | 0.5     | 7       | 4          | 4.8           | 6             | 6.35          | 14    |
| Ca pct ICP-MS  | 1.65   | 1.285  | 0.19    | 7.48    | 2.0825     | 2.13          | 3.045         | 4.1125        | 36    |
| Cd ppm ICP-MS  | 0.09   | 0.07   | 0.02    | 0.35    | 0.0925     | 0.1           | 0.155         | 0.2725        | 36    |
| Ce ppm INAA    | 28.43  | 27.5   | 16      | 51      | 31.5       | 35.2          | 42.8          | 46.45         | 14    |
| Co ppm ICP-MS  | 16.35  | 17.3   | 0.1     | 39.9    | 20.675     | 21.2          | 23.9          | 27.075        | 36    |
| Co ppm INAA    | 16.71  | 16     | 3       | 36      | 23.25      | 24.4          | 28.5          | 32.1          | 14    |
| Cr ppm ICP-MS  | 52.89  | 37.55  | 4.7     | 148.6   | 73.65      | 79.4          | 115.7         | 133.35        | 36    |
| Cr ppm INAA    | 105.93 | 62     | 18      | 291     | 161        | 184.6         | 211.5         | 240.3         | 14    |
| Cs ppm INAA    | 1.89   | 1.25   | 0.5     | 6       | 2.75       | 3.4           | 4             | 4.7           | 14    |
| Cu ppm ICP-MS  | 41.58  | 37.55  | 3.8     | 129.61  | 60.9425    | 64.32         | 69.64         | 82.915        | 36    |
| Eu ppm INAA    | 0.82   | 0.8    | 0.1     | 1.5     | 1.15       | 1.24          | 1.3           | 1.37          | 14    |
| Fe % INAA      | 4.09   | 3.585  | 1.62    | 8.04    | 4.7225     | 4.942         | 7.05          | 7.9035        | 14    |
| Fe pct ICP-MS  | 3.31   | 3.39   | 0.54    | 6.27    | 4.2425     | 4.62          | 4.87          | 5.13          | 36    |
| Ga ppm ICP-MS  | 6.62   | 6.75   | 1       | 15.4    | 8.075      | 9.6           | 10.65         | 12.25         | 36    |
| Hf ppm INAA    | 3.14   | 3      | 2       | 6       | 4          | 4             | 4             | 4.7           | 14    |
| Hg ppb ICP-MS  | 24.11  | 7      | 3       | 195     | 24.25      | 27            | 45            | 108.5         | 36    |
| K pct ICP-MS   | 0.13   | 0.07   | 0.03    | 1.14    | 0.12       | 0.13          | 0.195         | 0.5025        | 36    |
| La ppm ICP-MS  | 10.93  | 9.95   | 2.6     | 21.4    | 13.325     | 14.8          | 18.85         | 19.95         | 36    |
| La ppm INAA    | 14.37  | 13.35  | 7       | 28.7    | 16.075     | 18.06         | 22.36         | 25.125        | 14    |
| Lu ppm INAA    | 0.28   | 0.295  | 0.14    | 0.48    | 0.35       | 0.376         | 0.428         | 0.454         | 14    |
| Mass g Bal     | 30.47  | 27.05  | 21.2    | 44.54   | 38.6875    | 39.676        | 40.812        | 42.226        | 14    |
| Mg pct ICP-MS  | 1.29   | 1.47   | 0.04    | 2.57    | 1.775      | 1.9           | 2.05          | 2.3725        | 36    |
| Mn ppm ICP-MS  | 616.14 | 607    | 81      | 1335    | 828.75     | 876           | 1031.5        | 1175.25       | 36    |
| Mo ppm ICP-MS  | 0.44   | 0.36   | 0.04    | 1.48    | 0.51       | 0.56          | 0.64          | 1.05          | 36    |
| Na % INAA      | 2.81   | 2.675  | 0.73    | 5.51    | 3.4875     | 3.63          | 3.991         | 4.6065        | 14    |
| Nb ppm ICP-MS  | 0.12   | 0.098  | 0.009   | 0.367   | 0.16325    | 0.173         | 0.252         | 0.2715        | 36    |
| Nd ppm INAA    | 11.07  | 11.5   | 3       | 21      | 15         | 16.2          | 18.7          | 19.7          | 14    |
| Ni ppm ICP-MS  | 38.08  | 26.85  | 0.6     | 180.7   | 48.125     | 51.3          | 94.75         | 106.225       | 36    |
| P pct ICP-MS   | 0.09   | 0.079  | 0.001   | 0.263   | 0.10275    | 0.108         | 0.1445        | 0.18975       | 36    |
| Pb ppm ICP-MS  | 3.89   | 3.345  | 1.02    | 12.63   | 4.6575     | 4.75          | 5.875         | 8.865         | 36    |
| Rb ppm INAA    | 32.46  | 0.55   | 0.55    | 116     | 64.25      | 69.4          | 90            | 103           | 14    |
| S pct ICP-MS   | 0.01   | 0.005  | 0.005   | 0.04    | 0.005      | 0.005         | 0.01          | 0.02          | 36    |
| Sb ppm ICP-MS  | 0.47   | 0.145  | -0.02   | 10.35   | 0.24       | 0.28          | 0.41          | 0.565         | 36    |
| Sb ppm INAA    | 2.18   | 0.25   | 0.05    | 16.3    | 1          | 1.32          | 6.98          | 11.685        | 14    |
| Sc ppm ICP-MS  | 8.42   | 8.7    | 0.4     | 18      | 11.15      | 11.4          | 12.85         | 14.15         | 36    |
| Sc ppm INAA    | 15.35  | 13.2   | 4       | 32.7    | 17.275     | 19.14         | 27.57         | 30.945        | 14    |
| Se ppm ICP-MS  | 0.08   | 0.05   | 0.05    | 0.2     | 0.1        | 0.1           | 0.1           | 0.125         | 36    |
| Sm ppm INAA    | 2.98   | 3      | 1.6     | 5.3     | 3.4        | 3.64          | 4.42          | 4.845         | 14    |
| Sr ppm ICP-MS  | 179.06 | 80.2   | 10.4    | 1289.6  | 156.4      | 227.5         | 488.8         | 742.35        | 36    |
| Tb ppm INAA    | 0.32   | 0.3    | 0.3     | 0.6     | 0.3        | 0.3           | 0.3           | 0.405         | 14    |
| Te ppm ICP-MS  | 0.01   | 0.01   | 0.01    | 0.04    | 0.01       | 0.02          | 0.03          | 0.0325        | 36    |
| Th ppm ICP-MS  | 1.74   | 1.35   | 0.4     | 8.4     | 1.725      | 2             | 2.8           | 4.575         | 36    |
| Th ppm INAA    | 3.28   | 2.4    | 1.3     | 7.7     | 3.4        | 4.48          | 6.87          | 7.375         | 14    |
| Ti pct ICP-MS  | 0.17   | 0.151  | -0.001  | 0.381   | 0.27225    | 0.322         | 0.3405        | 0.37575       | 36    |
| Ti ppm ICP-MS  | 0.05   | 0.02   | 0.01    | 0.52    | 0.03       | 0.03          | 0.07          | 0.1775        | 36    |
| U ppm ICP-MS   | 0.67   | 0.4    | 0.1     | 2.9     | 0.9        | 0.9           | 1.2           | 2.225         | 36    |
| U ppm INAA     | 1.40   | 0.3    | 0.3     | 4.2     | 2.1        | 2.5           | 3.73          | 4.07          | 14    |
| V ppm ICP-MS   | 108.86 | 103    | 1       | 252     | 122.25     | 163           | 206           | 220.5         | 36    |
| W ppm ICP-MS   | 0.08   | 0.05   | 0.05    | 0.3     | 0.05       | 0.05          | 0.15          | 0.225         | 36    |
| W ppm INAA     | 0.50   | 0.5    | 0.5     | 0.5     | 0.5        | 0.5           | 0.5           | 0.5           | 14    |
| Yb ppm INAA    | 1.62   | 1.5    | 0.7     | 2.9     | 2.075      | 2.18          | 2.44          | 2.64          | 14    |
| Zn ppm ICP-MS  | 58.15  | 54.45  | 8.8     | 125.3   | 70.55      | 73.2          | 77.05         | 91.475        | 36    |
| Zn ppm INAA    | 64.64  | 30     | 30      | 221     | 100.75     | 111.8         | 117.9         | 155.35        | 14    |

Figures 31 to 35 show the variation of Ag, As, Au, Cu and Hg in rock samples across the project area. The Watson Bar Zone V developed prospect gold-mineralized samples have the highest Au, Ag, As, Cu and Hg values (area A, Figs. 31 to

35). A talus boulder sample from Roderick Creek of a grey to brown weathering, fine grained sediment containing graphitic-carbonaceous grains has 872 ppb Au (ICP-MS) and 79 ppb Ag; other rock samples from the same area have elevated As and Hg (area B, Figs. 31, 32, 33, 35). The source for the anomalous rock samples along Roderick Creek is gold mineralization in Jackass Mountain Group sedimentary rocks that are intruded by hornblende biotite grandodiorite to hornblende biotite quartz monzonite on the Roderick claims (Durfeld, 2013). Several other samples of Spences Bridge Group volcanic rocks near Leon Creek and Slok Creek have anomalous As, Cu, and Ag contents (areas B and C, Figs 32, to 34). Their location near faults suggests that there may be minor Ag-Cu mineralization in rocks associated with these structures.



**Fig. 30.** Box and whisker plots for major and trace elements in bedrock. All trace elements are in ppm unless stated. EO: Eocene rocks; JM: Jackass Mountain Group; SB: Spences Bridge Group.

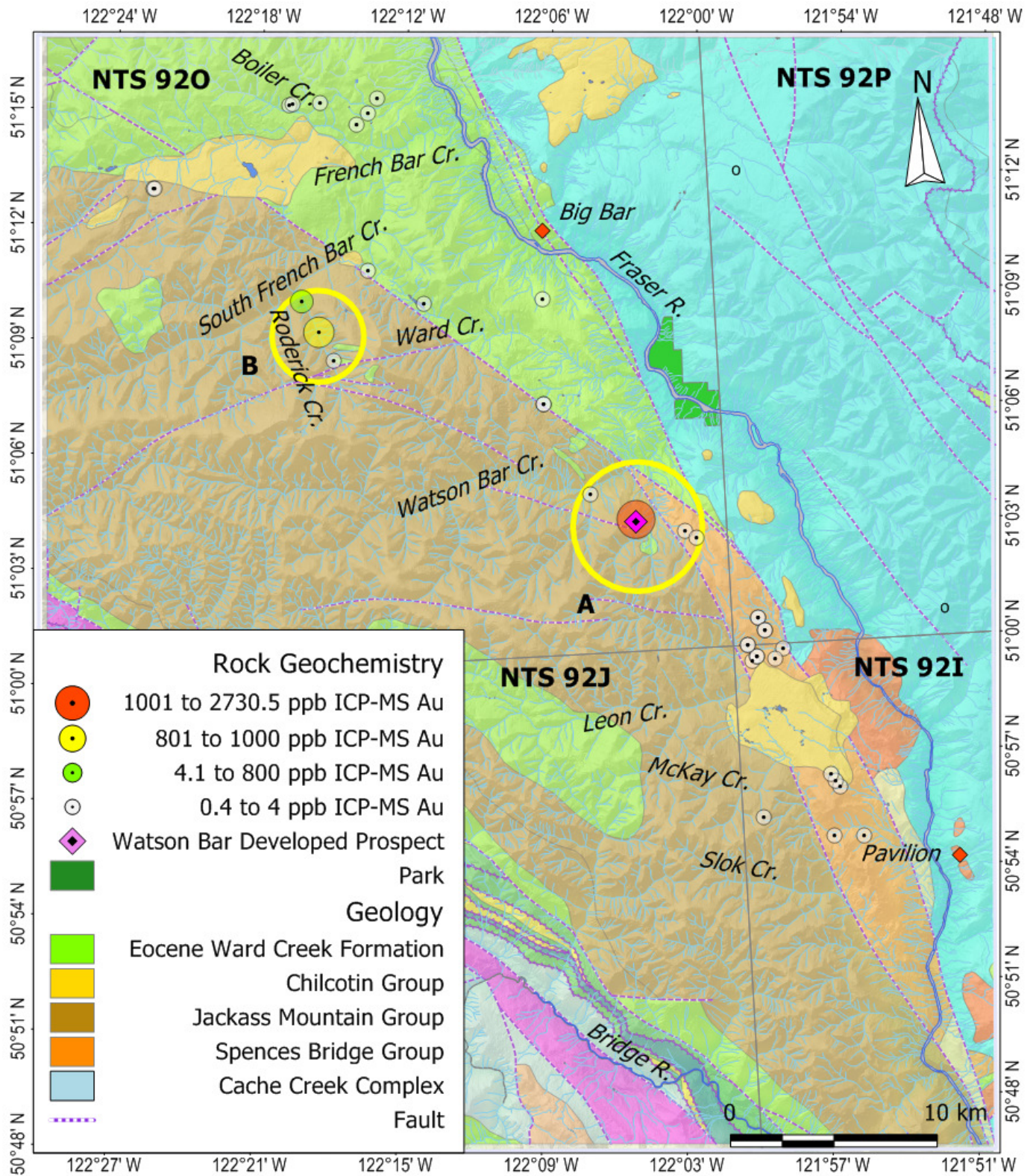


Fig 31. Gold by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution ICP-MS in bedrock samples.

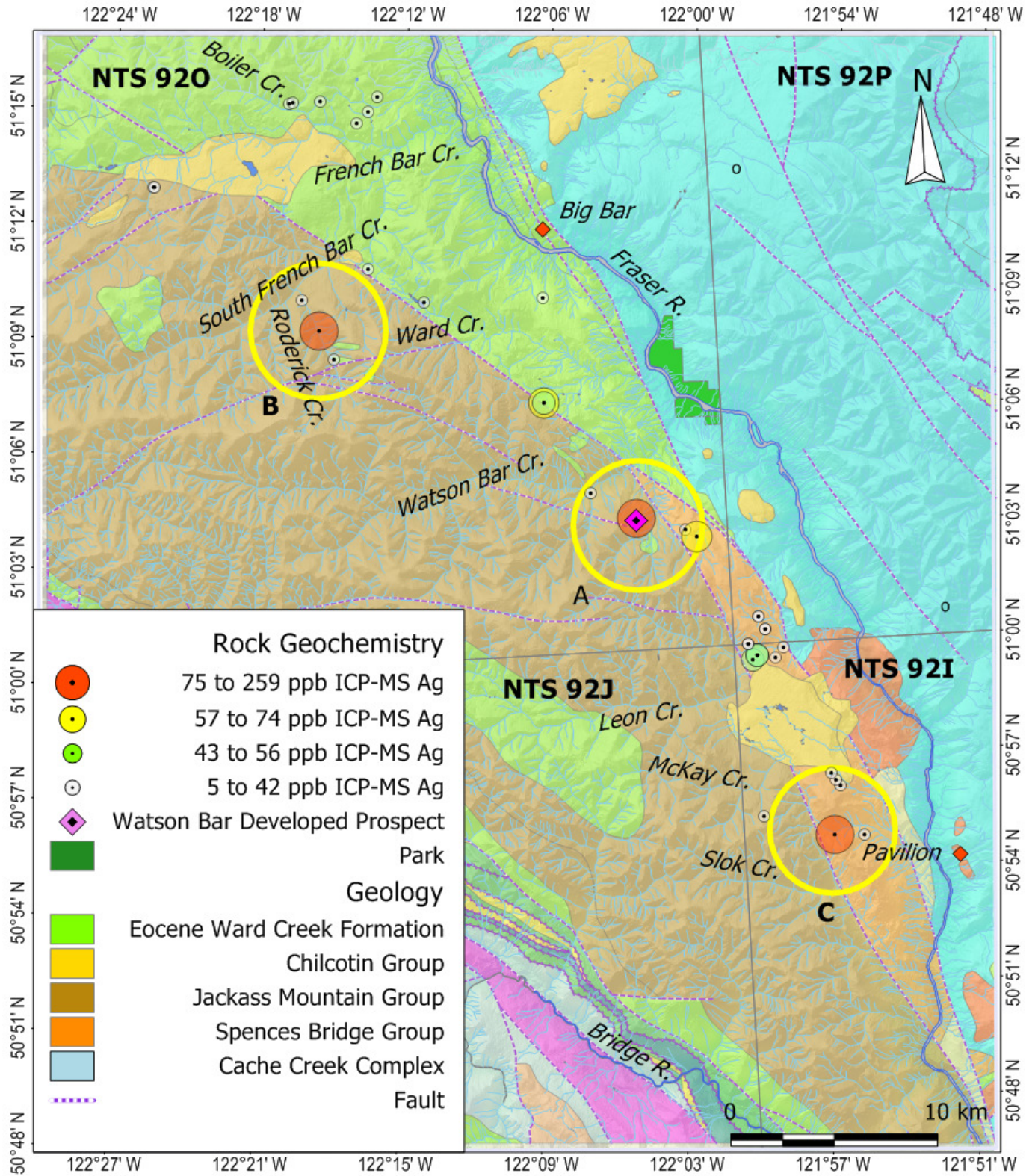


Fig. 32. Silver by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution ICP-MS in bedrock samples.

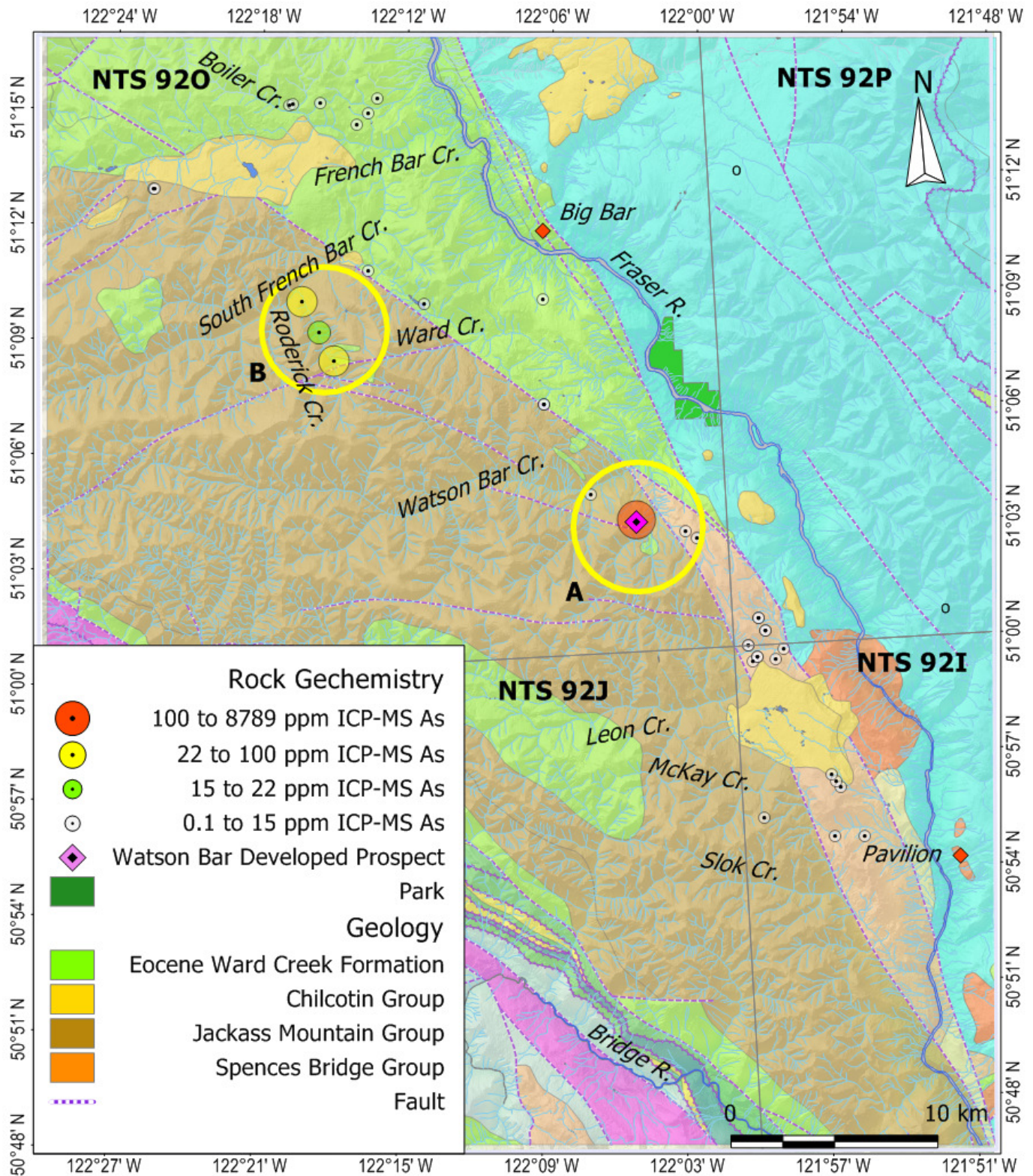


Fig. 33. Arsenic by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution ICP-MS in bedrock samples.

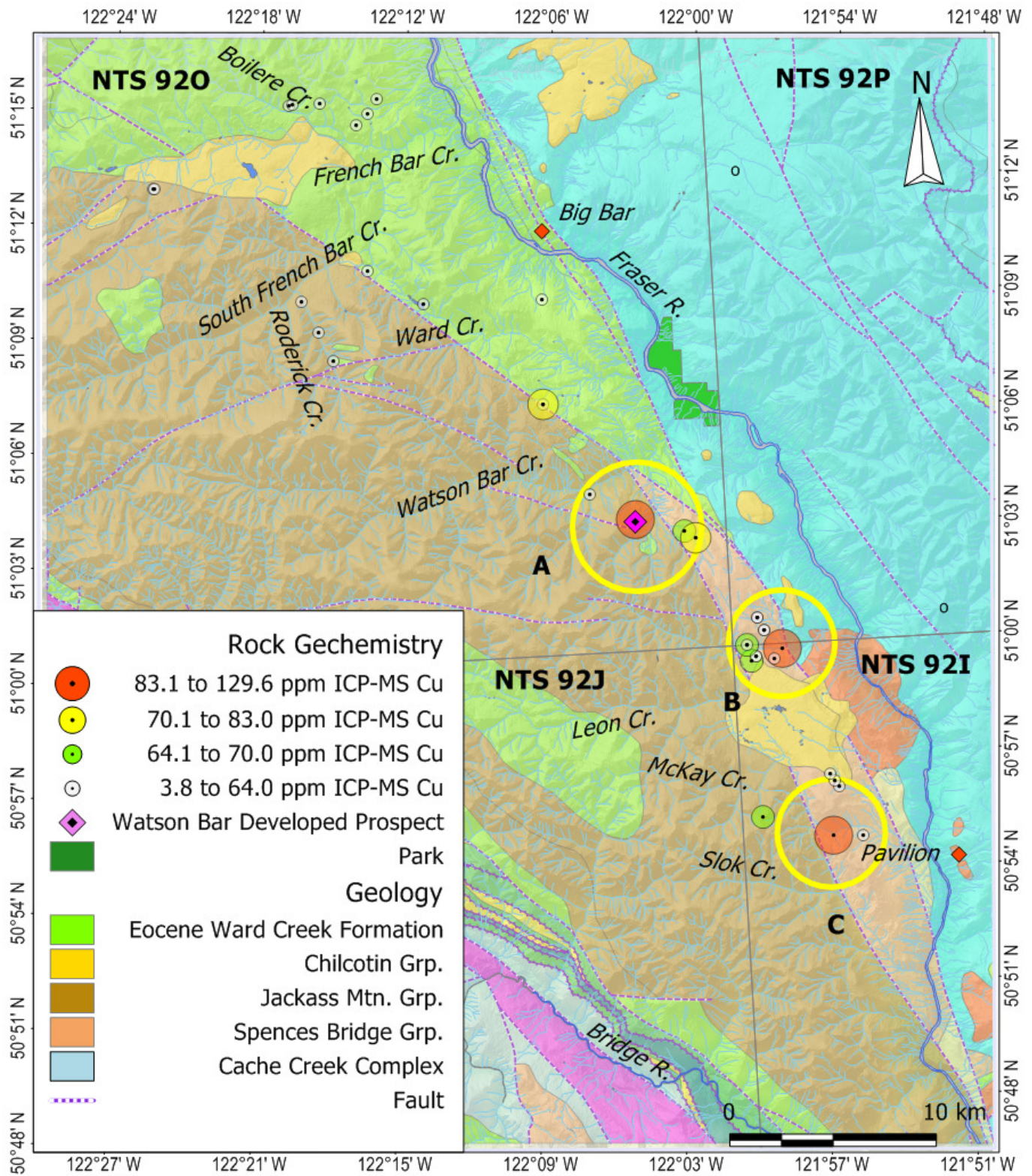


Fig. 34. Copper by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution ICP-MS in bedrock samples.

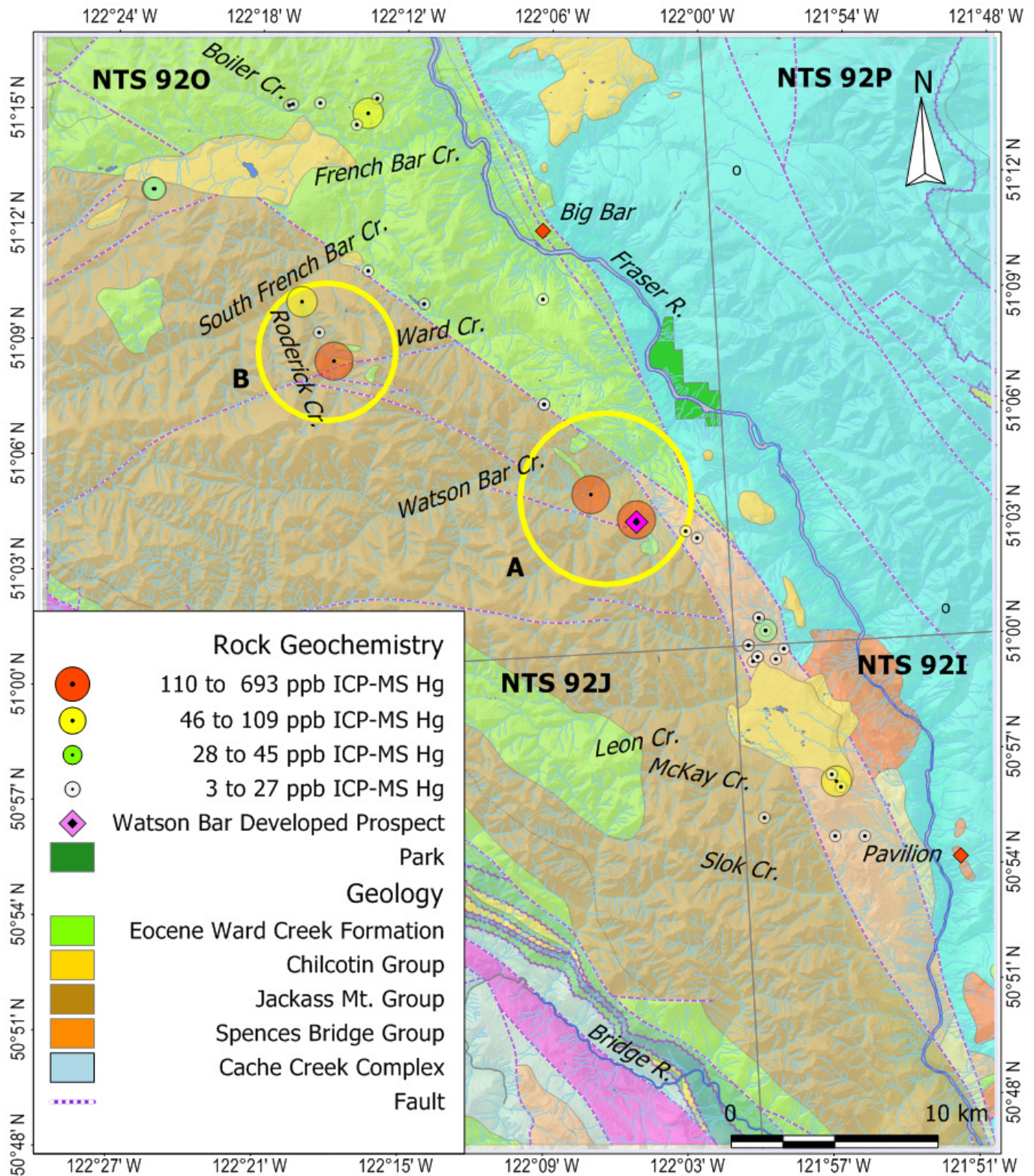


Fig. 35. Mercury by HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution ICP-MS in bedrock samples.

## 6. Summary

- Anomalous Au, Ag, As and Hg in stream sediments are geochemical indicators for epithermal Au mineralization in the 'Watson Bar gold belt'. Elevated As in stream water is also an indicator for Au mineralization, but values are only detectable close to peak concentrations.
- In most streams, the moss mat sediment gold content is less than that in stream sediments. Only Madson Creek near the Watson Bar developed prospect has a higher moss mat sediment Au content compared to stream sediment values. The low energy of most streams in the project area is the probable cause for limited capture of suspended gold grains in the stream water by the moss. One creek in the South French Bar Creek area has five gold grains in a HMC, the - 80 mesh ( $> 0.177$  mm) fraction of the stream sediment contains less the 5 ppb Au.
- Gold anomalies detected in stream sediment near Ward and Boiler Creeks cannot be traced to a known gold-mineralized bedrock source. For example, the highest Au in sediment detected during the sampling, by both HCl-HNO<sub>3</sub>-H<sub>2</sub>O dissolution ICP-MS and INAA, is from a tributary of Boiler Creek draining an area north of the project area. However, the gold in this sediment is not associated with other typical gold mineralization pathfinders (e.g., arsenic).
- A talus boulder sampled adjacent to Roderick Creek has high Au and Ag. Other rock samples from the same area have elevated As and Hg and the source for these metals is gold mineralization reported on the Roderick property to the east of the creek.
- Elevated REE, Al and Fe concentrations are present in stream water and sediment from Boiler Creek, which drains a region north of the project area. The association of REE with Fe and Al in the water and sediment suggests weathering of clay minerals in the volcanic bedrock.

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