KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND ANALYSIS

PREPARED FOR:

ELSA RECLAMATION AND DEVELOPMENT COMPANY LTD.

APRIL 2012

ACCESS

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April 2012

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ELSA RECLAMATION AND DEVELOPMENT COMPANY LTD. (ERDC)

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1 INTRODUCTION

The soil and vegetation baseline study is a component of several ongoing investigations designed to examine the degree, extent and pathways of metal contamination originating from abandoned mines and waste material scattered throughout the United Keno Hill Mine (UKHM) site (Figure 1-1). Heavy metal elements have been and continue to be dispersed around the site and into adjacent environs via abiotic (water and air transport) and biotic (absorption into trophic systems) processes. As the region is highly mineralized, control plots were sampled to characterise the background concentration levels to discern natural from anthropogenic contamination. By understanding the sources and transport pathways of heavy metals into local ecosystems, future remediation and closure efforts can be better planned and more effective.

Several constituents of potential concern (COPC) exist in the UKHM district and are available for plant uptake. These metals are: antimony (Sb), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), silver (Ag), selenium (Se) and zinc (Zn). Of particular interest, for the purpose of this study, are Cd and Zn which are preferentially accumulated by certain species of plants. This study is an investigation into the transmission of COPC from soils to vegetation and how different sources of contamination (points of discharge, tailings impoundments and waste rock dumps) convey COPC into the local ecosystems.

This report has five main sections which are briefly described:

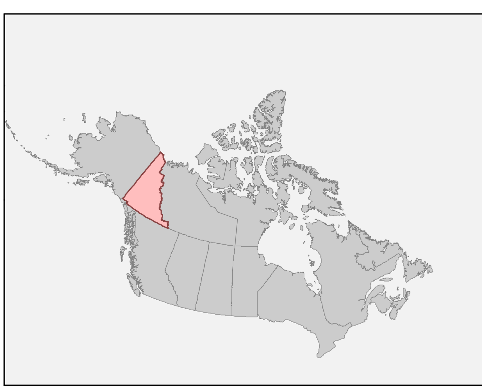
1) The beginning section gives a concise background of preceding related studies, objectives for the current investigation, the scope of work, a biophysical overview of the study area and information on each of the COPC under investigation in this study.

2) The second section presents the methodology and results. The metal analysis results for soil and plant tissues for each specific study within the UKHM district are presented in tables and the levels of Cd and Zn are highlighted in bar graphs. Maps were developed to show Cd and Zn concentration distribution patterns for soil, willow and *Ledum* species. The maps help illustrate pattern of distribution of Cd and Zn in sample soil and plant sites, and also show the geographical locations of "hotspots".

3) Within the results section is a compilation of soil and vegetation metal analysis for Keno City. This is a subcomponent of the UKHM district-wide soil and vegetation baseline study; the results are briefly discussed in this report. This data was also given to SENES Consulting to be used in their 2012 Human Health and Ecological Risk Assessment for the Historic Keno Hill Mine Site report.

4) The last section includes a discussion of results, recommendations and conclusion.

5) Includes supporting material: references, photographs



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PROJECT PROPOSAL &
WATER LICENCE APPLICATION

FIGURE 1-1
PROJECT LOCATION

APRIL 2012

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1.1 PROJECT BACKGROUND

Due to historic mining activities the environment within and around the United Keno Hill Mine site (UKHM) continues to be impacted by metal contaminants. Scattered throughout the UKHM claims properties are numerous abandoned adits, rock waste dumps, pits, trenches and tailings impoundments. From these anthropogenic points of disturbance heavy metals left over from mineral extraction are exposed to erosion and dissipation. Chemical weathering releases metal ions that are dissolved in water then carried downhill by streams. These waterways are conduits that further disperse metal contamination into riparian zones and terrestrial receiving areas. Contaminants can also be transported as windblown particles that are deposited along the path of prevalent winds. Metal contamination then extends beyond the footprint of direct disturbance as the heavy metals become integrated into the chemical cycling of biotic and abiotic processes that constitute the local ecosystems.

While the anthropogenic sources of metals are clearly recognized there are numerous natural sources that contribute COPC to the surface streams, such as water eroded native ore veins or seeps in highly mineralized zones. Many of these natural sources have not been located and the amount of contamination they contribute has not been quantified.

The point sources and associated riparian zones that have been previously sampled and were included in this study are: Silver King, Husky (Southwest), No Cash Creek and Sadie Ladue. The two tailings impoundments, Elsa (Valley) and MacKeno, were included in the study. Sampling in these two areas was done in and around the tailings to determine levels of contamination impoundment, plus identify plants that exhibit tolerance to high heavy metal soil content.

The accumulation of certain heavy metals in plants is a health concern for animals that consume these plants and for humans that hunt and gather wild food. The UKHM site is within the traditional territory of Na-Cho Nyak Dun First Nation (NNDFN) who have harvested fish, mammals and plants in this area over the millennia, and still do. The South McQuesten River lowlands and uplands are a popular moose hunting area for local people as well as hunters from other communities. A study involving the collection and analysis of moose muscle, kidneys and livers was conducted in 2004. The results showed that the liver and kidneys from moose had high concentrations of Cd, but that muscle tissue was not accumulating Cd so the muscle tissue is safe to eat (Gamberg, Palmer and Roach, 2005).

Several previous studies have been conducted in UKHM which have explored pathways by which contaminants are being absorbed into plant tissues. The Phase 1 Terrestrial Effects Sampling Program was initiated in 2007 by EDI Environmental Dynamics Ltd. (EDI, 2008). The 2007 investigations evaluated contaminant levels in lichens, which receive contaminants from airborne particulates and identified the pattern of dispersal around the Valley Tailings where lichens showed elevated metal levels, especially around the eastern portion of the tailings. This study concluded that airborne contaminant transport was occurring, and the heaviest deposits were along a southeastern trajectory, in the direction of the prevalent wind and immediate to the source.

In Phase 2 of the Terrestrial Effects Sampling Program (EDI, 2009), the main objective was to provide information on metal levels in plants traditionally harvested and consumed by members of the Na-Cho Nyak Dun First Nations (NNDFN) for medicinal purposes. It was found that plants collected by the tailings impoundments had higher concentration of COPC when compared to control plant sample results.

The objectives in Phase 3 Terrestrial Effects Sampling Program were twofold: 1) determine the source of the elevated metal levels found in the plant samples taken and analyzed, 2) to find out if natural background metal concentration in soils and plants differ from concentrations found at sites that have been altered by mining. This study compared elevated metal concentrations in soils and a variety of plants from different source types: tailings, point source and natural occurrence, to determine if metal accumulation in plants was directly associated from the mineral soil via their root systems or through airborne deposition.

1.2 OBJECTIVES

The main objective for implementing a soil and vegetation sampling program is to ensure that the health and function of the local ecosystems is monitored and distressed areas are identified for remediation efforts. Where historical mining disturbance has degraded the soil and plant quality the Soil and Vegetation Sampling Study will assist in defining particular "hotspots" so reclamation efforts are more focused. As natural systems can tolerate and metabolize certain types and levels of contamination, the potential for phytoremediation is examined as a possible closure option component. The main objectives for conducting the 2011 UKHM District Soil and Vegetation baseline studies are:

- Continuation of soil and vegetation metal concentration data collection through revisiting previous sites and expanding the study into other areas;
- Develop a databank on metal concentrations in soil and vegetation samples by location;
- Locate and sample control plots to determine natural mineral background concentration levels to clarify the extent of anthropogenic contaminant contribution;
- Determine the relationship between concentration of metals in plant tissues and the concentration of metals in the soils that the plants are rooted in;
- To understand the attenuation potential of local vegetation and dispersal pathways for heavy metals released from historic mining sites;
- To help monitor the effectiveness of future reclamation measures by establishing a current profile of metal contamination levels by location;
- Produce a "quick study" map atlas that show relative concentration of Zn and Cd in soils, willows and Ledum species per specific study area, that can be easily updated;
- Provide recommendations to improve future soil and vegetation data collection process;
- Develop a list of native plants that could be candidates for reclamation trials.

1.2.1 The Keno City Soil and Vegetation Sampling Program

Keno City soil and vegetation sampling program was undertaken as a separate component to the overall UKHM District baseline study. The methodology for collecting soils and plant samples was the same, the one exception being that the sampling sites were randomly selected by imposing a grid pattern onto an aerial map of Keno City, the interstices of the grid lines were the sampling sites (Figure 1-2). The main premise for this program was to provide SENES Consultants Ltd. information for their 2012 Human Health Risk Assessment for the Residents of Keno City report. The SENES study was conducted to determine if a particular chemical constituent poses a significant risk to human health. This component of the study is addressed in more detail in section 2.9.

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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 1-2
KENO CITY SAMPLE SITES

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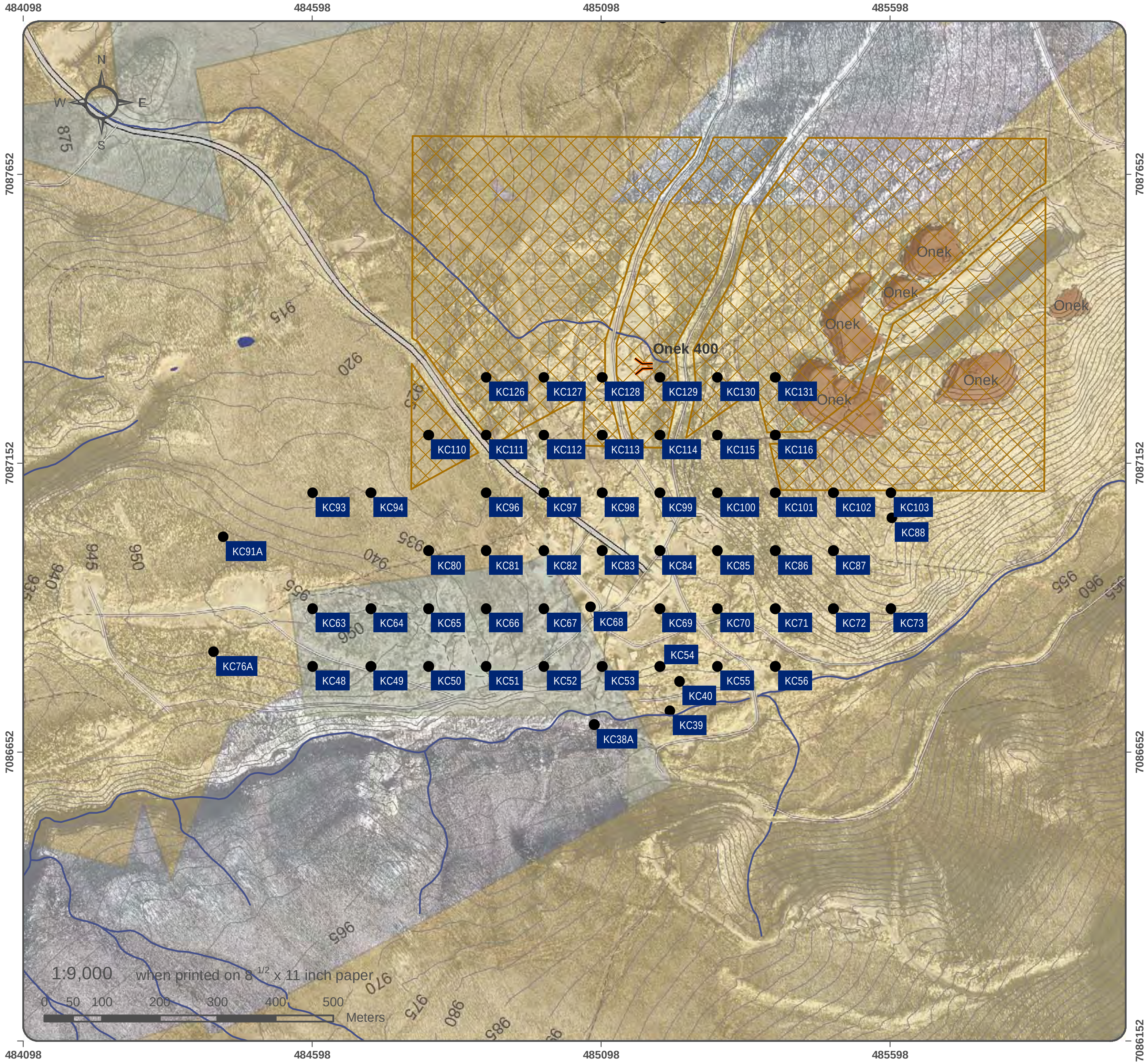

Sample Site
Adit
Silver Trail Highway
Secondary/Local Road
Trails/Track
Watercourse
Waterbody
ERDC Owned Quartz Claims
Other Alexco Owned Quartz Claims
Lot 960

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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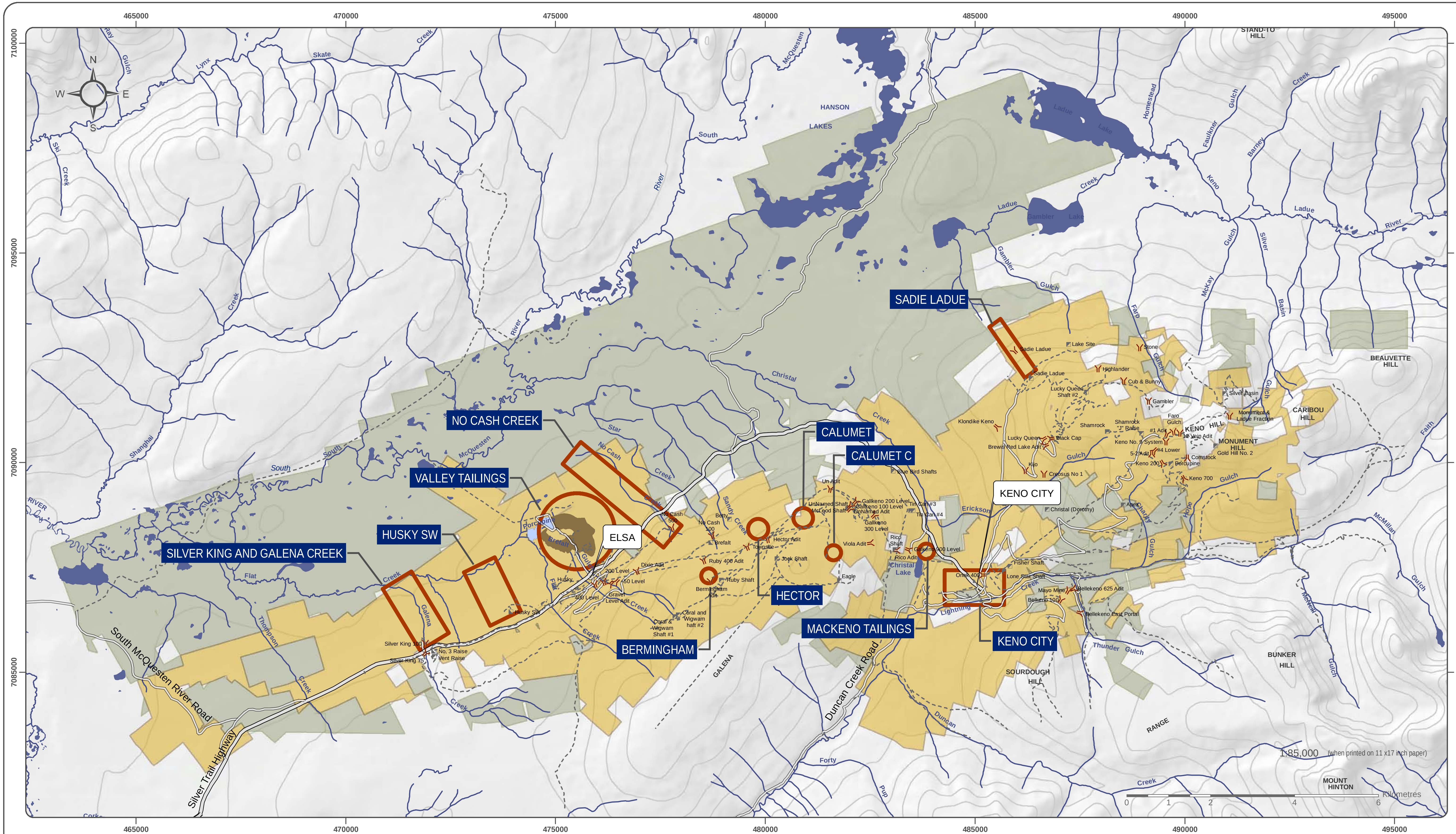
1.3 GENERAL BIOPHYSICAL DESCRIPTION

The Keno Hill Silver District is approximately 45km northeast of the town of Mayo in the Yukon Territory and 340km northeast from Whitehorse. The UKHM property consists of 827 mining claims and leases and is situated along the south side of the MacQuesten River valley, the entire property covers a total area of 232km^2 (Figure 1-3). Most of the adits and sites of historic mine workings overlap three nearby mountains: Galena Hill, Keno Hill and Sourdough Hill which are have peak elevations of 1400m, 1825m and 1370m respectively.

The study area is located in the North Yukon Plateau ecoregion, which is a climatic and biophysical subset of the Boreal Cordillera ecozone. Snowfall is minimal during the long cold winters with mean temperature of -20^{0}C, extreme lows down to -50^{0}C. The summers are usually dry and warm with maximum temperatures reaching 32^{0}C. The growing season is short, but vigorous because of the extended daylight hours in the summer. The average annual precipitation ranges from 300mm in the valleys to 600mm on mountaintops. The maximum precipitation is in August and minimum precipitation occurs in April. The study area is within the Extensive Discontinuous Permafrost Zone. Permafrost is commonly encountered under thick organic layers that cover the South McQuesten River valley and north facing slopes.

The landscape in this area was been formed by past glacial activity, large deposits of glaciofluvial and glaciolacustrine material blanket the valley floor. Morainal till covers the lower to mid mountain slopes, but only a thin veneer of soil remains in the alpine, here often bedrock and talus is exposed. Since soil is limited, only low growing plants exist at higher elevations such as sedges, grasses and creeping shrubs. Sub-alpine firs and larger shrubs become more dominant in the subalpine and upper boreal zones. The primary tree species along the mid and lower slopes are white spruce *(Picea glauca)*, trembling aspen (*Populus tremuloides*), Alaskan birch (*Betula neoalaskana*), and the occasional balsam poplar *(Populus balsamifera)*. There is a matrix of scrub birch (*Betula glandulosa*), willow (*Salix sp.*) and ericaceous shrubs with sparse to open black spruce cover. Streams web among the tussocks of sedges and hummocks of moss eventually joining the South MacQuesten River that flows to the Stewart River a tributary of the Yukon watershed.

An overview map of the study areas sampled during the 2011 soil and vegetation baseline program is provided below.



National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced underlicense from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

Datum: NAD 83; Map Projection: UTM Zone 8N

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- Adit
- Shaft
- Contour (100 m)
- Highway
- Local
- Track
- Watercourse
- Waterbody
- Sampling Areas
- Valley Tailings Pond
- Valley Tailings
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims

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KENO DISTRICT SOIL AND VEGETATION BASELINE AND HEAVY METAL STUDY

FIGURE 1-3
STUDY AREA AND GENERAL SAMPLING LOCATIONS

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1.4 SCOPE OF WORK

The key tasks that were undertaken for the Baseline Soil and Vegetation Study are summarized below:

1. Review 2007 to 2010 data from several sources and integrate information into a workable data base, including information gathered from current study;
2. Note data gaps to be addressed, formulate sampling plan;
3. Selection of plant species to sample, that could be key intermediates in pathways to higher trophic levels;
4. Selection and testing of control plots that were near study area, but had not experienced mining disturbance or other industrial impacts;
5. Expand vegetation and soil sampling into areas not previously sampled: Hector, Calumet and below Calumet C rock waste piles;
6. Develop a sampling system for Keno City to further understand the degree and dispersal patterns of COPC within and around village;
7. Interpret soil and plant tissue metal analysis using CCME guidelines, for all study areas, point discharge, tailings impoundments and Keno City;
8. Describe metal analysis results in table, graph and map forms for easy transmission of information;
9. Discuss findings and make recommendations to improve future soil and vegetation baseline studies and remediation strategies for closure plans.

1.5 CONSTITUENTS OF POTENTIAL CONCERN

The Constituents of Potential Concern were selected based on criteria developed by SENES for soils that have elevated concentrations of a metal as compared to back ground metal concentrations from control plots. Those metals identified as being overabundant in mine disturbed areas, also had to be identified by the Canadian Council of Ministers of the Environment (CCME) as having toxicity level thresholds that when exceeded could compromise the health of biological receptors.

If no concentration CCME guideline is indicated in data tables presented in this report, means that based on current understanding constituents are not considered harmful. No CCME guideline values are available for aluminum, bismuth, calcium, iron, magnesium, phosphorus, potassium, titanium and zirconium, therefore they were not considered to be COPC. Iron (Fe) however is included in the tables, not because it is a COPC, but it is often involved in binding with other COPC creating precipitates and taking more harmful heavy metals out of solution, thereby reducing their availability for plant uptake. So Fe is presented in the following tables to show fluctuations in concentrations relative to other elements such as manganese (Mn) that may be mitigating the toxicity of metals that are considered COPC by binding to them.

Other metals are sometimes added to data tables if soil concentrations are near or over CCME guidelines in a particular study area, for example selenium (Se) was often detected at low levels in most areas sampled, but was higher in MacKeno Tailings so was included in the data tables the MacKeno Tailings findings.

Below is a list of COPC that were found in soil and plant samples taken at UKHM. The descriptions of each metal explain why they are of concern. It should be noted that toxic effects usually require persistent exposure to high concentrations.

Antimony (Sb) uptake by plants is in proportion to the concentration Sb in soils that the plant is rooted in; however, very little is known about the mechanisms of Sb uptake by plants. Its toxicity highly depends upon chemical form and oxidation state with +3 compounds exerting greater toxicity than +5 compounds. For humans and animals, antimony compounds show toxic properties similar to those of arsenic. This depends on how much antimony a person has been exposed to, for how long, and current state of health. Exposure to high levels of antimony can result in a variety of adverse health effects (Tashin, 2009).

Arsenic (As) can be toxic to humans in low persistent doses. However, arsenic does not accumulate in most plants to the extent the Cd and Zn can. Background concentrations in soil samples range from 1 to 40 mg/kg, with mean values around 5 mg/kg. Arsenopyrite (FeAsS) is a common mineral in the area and is at elevated levels even in the control soil samples. Naturally elevated levels of arsenic in soils may be associated with geological substrata such as sulfide ores. Arsenic was found to exceed the CCME guideline thresholds for industry (12mg/Kg) in the majority of soil samples (Meharg, 2001).

Cadmium (Cd) is an accumulative poison so low exposure over time can result in lethal levels of this metal concentrating in the kidneys and liver of animals. It is also considered a carcinogenic substance if inhaled. Some species of fish are sensitive to Cd and sub lethal levels can affect growth, behavior and cause physiological problems. Cadmium and its compounds may travel through soil, but its mobility depends on several factors such as pH and amount of organic matter, which will vary depending on the local environment. Generally, cadmium binds strongly to organic matter where it will be rendered immobile in soil. Cd can hyperaccumalate in plants such as willows which is a browse food for moose (Smolders, 2001).

Copper (Cu) is more toxic to aquatic organisms and ecosystems than terrestrial life forms. Copper compounds are usually soluble in water, and solubility increases as water hardness and pH decreases. Copper strongly attaches to organic matter and minerals, so it becomes relatively immobile when it comes in contact with these substrates. When there is overabundant concentrations of Cu, the activity of soil microorganisms can be interrupted impeding nutrient cycling. Also, Cu can accumulate in plants and animals especially if not bound within the soil matrix (Kabata-Pendias, 2011).

Iron (Fe) Iron is a common constituent in soils and groundwater and was found to be abundant in many of the soil samples taken. Fe readily undergoes reduction or oxidation, depending upon surrounding conditions. As a consequence there are many microbiological metabolic pathways that utilize ferrous and ferric iron (Kabata-Pendias, 2011). Fe is a necessary nutrient for both plants and animals, and is not considered a toxic substance unless absorbed at very high dosage and then it causes damage to the brain and the liver.

Lead (Pb) forms various complexes with soil components, and only a small fraction of the lead present as these complexes in the soil solution are phyto available. Despite its lack of essential function in plants, the Pb ions left in the soil solution is absorbed through the plant's root network and accumulates in the root tissue. Lead is more toxic to freshwater fish and invertebrates than terrestrial life forms. In humans it is dangerous to young children interfering with brain development and adults at higher concentrations cause reproductive problems. Lead is also a known carcinogenic, prolonged exposure should be avoided.

Manganese (Mn) Manganese is the 10th most abundant metal in soils, where it occurs as oxide and hydroxide compounds as it cycles through its various oxidation states depending on local conditions. Similar to iron, Mn is an essential trace nutrient in all life forms, involved the functioning of enzymes. Manganese compounds are less toxic than those of other metals, such as nickel and copper. Fe and Mn often occur naturally together and can utilize the same membrane transport mechanisms. Manganese poisoning has been linked to impaired motor skills and cognitive disorders in mammals.

Silver (Ag) ions and compounds are toxic to some bacteria, algae and fungi, and could cause damage to symbiotic interchanges between bacteria, fungus and root systems of plants. It has been demonstrated that silver inhibits enzymes for the nitrogen cycles of nitrifying bacteria in soil at very high concentrations (>540 mg /kg). In general, accumulation of silver by terrestrial plants from soils is low; when silver accumulates it does so mainly in the root systems of plants. In solution, ionic silver is extremely toxic to aquatic plants and animals and aqueous concentrations of 1–5 µg/litre killed sensitive species of aquatic organisms. Most of the silver in the KHSD is not likely to occur in an ionic form.

Selenium (Se) will complex with organics quite easily thus reducing its solubility and restricting its movement through the ecosystem. There is evidence that in areas where soils contain high Se concentrations, Se can accumulate in plant tissues and can then be passed up through the food chain. Water can carry carrying soil particulate or dissolved Se into aquatic environments where it is absorbed by aquatic organisms. When animals absorb or accumulate extremely high concentrations of selenium it can cause reproductive failure and birth defects.

Zinc (Zn) is an essential micronutrient in plants and animals; it can be a potential hazard when ingested in high dosages. At elevated concentrations Zn can cause copper deficiencies and affect iron metabolism. Zinc is particularly toxic to certain species of algae, crustaceans and salmonids. Solubility of zinc is generally controlled by hydroxide and/or carbonate levels. However, in the presence of high concentrations of iron and manganese, co-precipitation and sorption of zinc is a key solubility control.

2 METHODOLOGY

Most of the soil sampling sites in the UKHM district were established in the fall of 2009 by EDI, except along the NC system which was sampled by Access in the same year. These soil pits were excavated to a depth below the rooting zone; 60cm to 1m and where possible, both A and B horizons were sampled. Soil was collected by scraping away a few centimeters from the side of the pit to expose soil that was not disturbed during excavation. Using a clean stainless steel spoon and clean latex gloves, soil samples were taken and transferred to a clean glass jar. Prior to and between sampling the spoon was cleaned using distilled water. The soil samples collected in 2009 were shipped to CANTEST Ltd. for testing. Analysis provided a profile of 30 elements, pH and soil texture for each soil sample submitted. In the following year, 2010, EDI revisited these sites to obtain additional vegetation samples for their Terrestrial Effects Phase 3 study.

In July and August of 2011 the sampling sites were again revisited by Access using the GPS coordinates from the previously established soil and vegetation plots. Plot locations were marked by flagging tape and/or evidence of a soil pit excavation; however some plots were difficult to find during the 2011 summer survey. Where it was not possible to relocate an old site, a new soil sampling pit was excavated and soil sample was taken from the rooting zone of the plants that were also being collected. Clean disposable latex gloves were used for each different plant and soil sample collected. Approximately 50g to 100g of leaves were collect per sample. Plant tissue samples were then placed into zip-lock freezer bags kept cool and shipped to Maxxam Analytics Inc. (Maxxam) within five days of sampling. At the lab the plant leaves were washed prior to metal content analysis using CRC-ICPMS.

The same procedure was followed at the control sites; in addition soil samples were taken to ensure that the plants sampled were rooted in close proximity to the soil pit. The collection protocol for soils was the same as described above.

During the 2011 Soil and Vegetation Baseline Study: 211 plant leaf samples were taken, including those taken in the Keno City area. In addition, 96 new soil samples, (including 48 from Keno City) and four Bog blueberry (*Vaccinium uliginosum*) fruit samples were collected and analyzed.

2.1 VEGETATION SAMPLES

The types of plants chosen to be sampled were based on the following criteria:

- Plants that are consumed by wildlife that in turn are hunted and consumed by humans e.g. moose. Or plants used for traditional medicinal purposes e.g. both willow and Ledum;
- Plants that were common and well distributed over the district, so they are easy to find within the selected study areas and proximal to soil sampling sites;
- Plant species known to tolerate certain levels of heavy metal contamination in soils, so they are present in impacted areas.

The three plants and the tissue types selected to collected and analyzed are described below:

Willow (*Salix sp*)

Willows are known to be accumulators of heavy metals (Kosvakinka and Quigley, 2005), this shrub is a preferred food source for moose and occasionally harvested as a medicinal plant by humans. Willow is ubiquitous in the study area so was an ideal specimen to use for examining the relationship between soil contamination and flora attenuation of heavy minerals in the Keno District. To reduce genetic variation Grey willow (*Salix glauca*) was the preferred species of willow leaves collected at the UKHM district and Keno City sites. Grey willow is also the most common willow species found within the study area. At sites where Grey willow was not available, leaves of other willows were collected from shrubs rooted closest to the soil pit. Other *Salix* species included in sampling were: *alaxensis, arbusculoides, bebbiana, pseudomonticola and scouleriana*. All leaf samples were considered composites and identified as "Willow" when shipped to the lab.

Labrador Tea Leaves (*Ledum*)

Labrador Tea is the common name for *Ledum groenlandicum*; an ericaceous shrub that grows extensively in peat lands and moss covered lower slopes of the UKHM district. In the same type of habitat grows another species, *Ledum decumbens*, a very similar looking, but smaller shrub. The leaves of both shrubs were collected as a composite sample and labelled "*Ledum*". Ledum species typically grow in moist to wet, acidic, nutrient-poor organics and only occasionally root in mineral soils. Uptake of minerals would be from ions available in the organic substrate where this shrub's root system is established.

Blueberries

Only four bog blueberry (*Vaccinium uliginosum*) samples were collected and submitted for testing, as it was a cold wet summer and blueberries were scarce at the time of sampling. Two samples came from the Valley Tailings area, one from Silver King and one from No Cash Creek. Labarge and Can-nic-a-nick Environmental Consulting firms included bog blueberry sampling and analysis in their 2010 Aquatic Resources Assessment of the Keno Valley study. In this study they compared the metal concentration derived from samples collected around Christal Creek to commercial available fruit drink concentrates as controls.

"The arsenic values documented in Christal Creek are below but close to the mean in the fruit juice concentrates. Cadmium concentrations recorded in blueberries from Christal Creek were significantly higher than the maximum concentration in the tested fruit juice concentrates. The sample size (2) from Christal Creek is much too small and further testing should be undertaken to confirm these high levels. Lead levels in the Christal Creek blueberries were similar to the mean of the juice concentrates. Zinc concentrations were about three times higher in the Christal Creek blueberries than the maximum recorded in the fruit juice concentrate however, higher concentrations were found in blueberries from other areas of the Yukon (Labarge and Can-nic-a-nick, 2010)."

The Christal Creek area was not included in this study and there are no control metal values for bog blueberries from selected control sites. The four samples taken this year, although inconclusive, did show that the concentrations of COPC in berries are lower than those found in leaf tissues at the same plot site. It is recommended that a more focused attempt be made at sampling berries at the areas known to have high levels of COPC in soils, and to find control samples near UKHM site.

Leaves

There are no CCME guidelines on metal content in vegetation regarding consumption by wildlife or humans. In attempts to put the current data into perspective, comparisons have been made with the metal content of vegetation samples taken at the control sites. All leave samples were washed at the lab before metal analysis was preformed, so air borne contamination on leaf surfaces did not influence results.

Soil Samples

As described in the methodology the soil samples extracted this year, were taken at rooting depth, usually around 10 to 25cm deep. This depth corresponds to the B horizon in the type of mineral soils commonly encounter in this ecoregion, Eutric Brunisols.

In the 2009 Elsa Tailings Terrestrial Effects Study conducted by EDI, soil was collected from two mineral horizons (A and B) at each soil pit. As the A horizons are usually not well developed and shallow (<10cm), the 2009 data from the B horizons were used with plant sample data derived from this study. Where old soil pits could not be located, a new soil pit was excavated and sampled, to ensure that the plant samples were from shrubs rooted near where the soil was collected. Often soils were disturbed and horizons mixed, so it was not reasonable to identify a specific soil horizon (nor necessary), it was more important to confirm that the soil tested was from the rooting zone of the plants sampled to ascertain if there was a relationship between metal uptake in plants and soil metal concentrations.

Many plant samples came from shrubs growing in organic substrate, not mineral soil especially *Ledum*. No organic soils samples were taken, so metal levels in plant leaves were used as a proxy to compare metal levels between sampling points. The metal concentration in plants was particularly important when tracing point source systems, such as NCC, Silver King, and Husky, where the changes in metal levels may relate to the distance from contamination source.

2.1.1 Results

In this section the results are presented for each specific study area within the UKHM district and the data is presented in tables, graphs and on aerial maps. The tables show the actual numeric value of COPC concentrations in soil and vegetation samples. The CCME industry guidelines for specific metals are in parenthesis beside each element symbol. In the case of the Keno City study area the CCME residential guideline levels are used. The COPCs soil values that exceed CCME guidelines are denoted in red. For metals Fe and Mn there is no guideline values, as these metals have a relatively low toxicity compared to others, but are included as they bind with other COPCs creating precipitates, or plant uptake tracers.

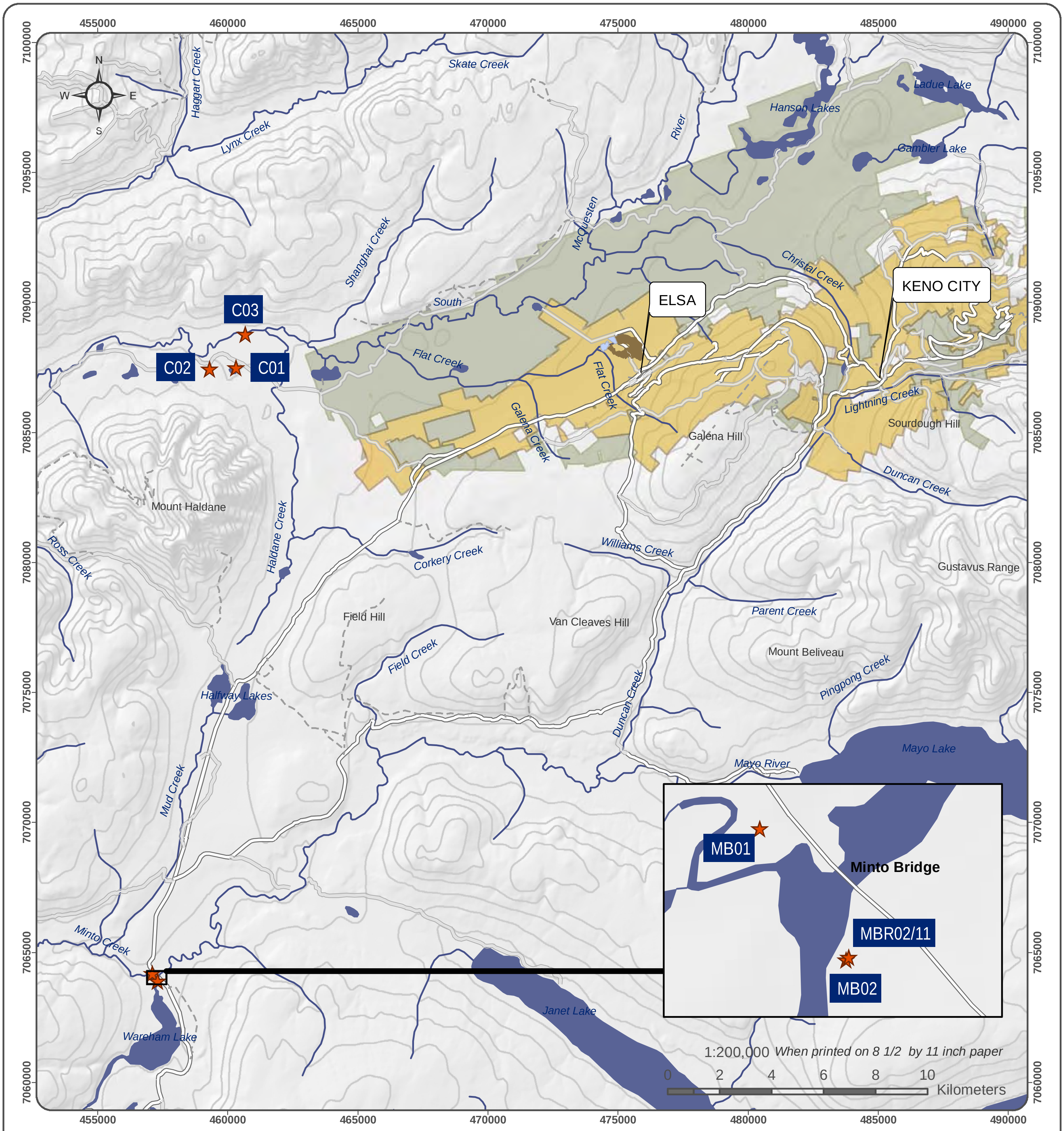
In the following data tables the highest concentration value for each metal detedted at specific study areas have been highlighted in yellow regardless if they exceed CCME values or not. The maps are focused on the amount of Zn and Cd that exist in soils, and vegetation at sample plots. The graphs present three metals; Mn, Cd and Zn, Cd and Zn are of greater interest in regards to environmental impact. Mn is included since it is easily absorbed by plants and transported to leaf tissue by similar mechanisms as Zn and Cd are (Kabata-Pendias, 2011). So Mn is treated as tracer element to compare its soil concentration with vegetation leaf tissue concentrations.

There are no threshold values for heavy metal concentration in plants, as uptake varies widely between different species, type of plant tissue and growth conditions. Instead average metal concentrations found in control plant samples are used as a comparison to plant samples taken in study areas to show whether there is a difference in accumulation of contaminants by plants between the two areas.

2.1.2 Controls

Five control plots were selected near the Keno Hill Mining District, that were undisturbed by mining activities to reflect natural background metal concentration that occur in local soils and vegetation. Three control plots were located approximately 13 km west of Elsa near Haldane Mountain and the South McQuesten River and two control plots were situated above the Mayo River Bridge which is 25km southwest of Elsa (Figure 2-1).

All five control plots had mineral soils, willow and *Ledum* leaves collected and analyzed for metal content. The controls are representative of the ambient metal content in soils that have not been disturbed or contaminated by past mining activities.



Control Plot
Secondary Road
Limited-used road
Trail
Watercourse
Waterbody
Valley Tailings Pond
Valley Tailings
ERDC Owned Quartz Claims
Other Alexco Owned Quartz Claims

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Datum: NAD 83; Projection: UTM Zone 8N

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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-1
LOCATION OF CONTROL PLOTS

APRIL 2012

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(*Last edited by: jlindeman; 30/04/2012/14:26 PM*)

Table 2-1 presents the concentrations of the metals in soils extracted from these control plots.

Table 2-1 Control Soil Samples Metal Concentrations, Access 2011

Metals (mg/Kg) CCME Industrial Limit (mg/Kg)	C01	C02	C03	MB01	MB02	Average Value
Sb (40)	0.7	0.9	0.8	4	2.8	1.8
Ag (40)	<0.05	0.13	0.07	0.3	0.39	0.19
As (12)	5	13.4	20	76.7	29.1	28.8
Cd (22)	0.25	0.48	0.18	0.25	0.88	0.41
Cu (91)	9.4	26.5	12.6	20.3	57.1	25.2
Fe	16000	19400	24800	17400	42400	24000
Pb (600)	7.5	11.8	11	44.9	27.2	20.5
Mn	1590	308	330	254	762	648.8
Ni (50)	14	22.6	19.3	18.2	51	25.0
Se (2.9)	<0.5	0.6	0.5	<0.5	0.7	0.56
Zn (360)	79	76	83	64	156	91.6

The CCME guidelines for metal contaminants concentrations in soils are included in parentheses in the left column. The concentrations highlighted in red are metal concentrations in soil above the CCME thresholds for industrial lands.

The above table shows As values are elevated and exceed the CCME thresholds in four of the five control samples. This indicates that there is high level of naturally occurring As in the soil environment near the KHSD. More control samples must be established to confirm this is a well distributed characteristic and not just localized., It appears the Mayo Bridge area controls (MB01 and MB02) are more mineralized than the control samples at the South McQuesten sites (C01,C02 and C03), which will raise the average of each metal concentration. If a background-based comparison of metals-in-soils concentrations becomes critical to justify not remediating sites in the KHSD based on an elevated regional metals signature, there may be a need to select and test more control plots to develop a more accurate idea of background metal concentrations for the region.

The average concentration of each COPC is calculated below to determine the background profile for metal content in willow leaves.

Table 2-2 Metal Concentrations from Willow at Control Sites, 2011

Metals (mg/Kg)	C01 Willow	C02 Willow	C03 Willow	MB01 Willow	MB02 Willow	Average Control Value
Sb	0.003	0.001	0.003	0.018	0.006	0.006
As	0.01	0.01	0.01	0.12	0.04	0.04
Ag	0.004	0.004	0.004	0.014	0.004	0.006
Cd	1.52	0.912	1.04	0.811	0.807	1.02
Cu	1.31	1.1	1.72	1.3	1.15	1.32
Fe	22	13	14	32	20	20.2
Pb	0.069	0.035	0.07	0.633	0.17	0.20
Mn	43.5	58.5	82.7	100	29.8	62.9
Ni	3.04	0.35	1.62	4.58	0.98	2.1
Zn	20.9	46.1	66.6	24.1	26.1	36.8

Both willow and Ledum shrubs at the control plots were rooted in mineral soil.

Table 2-3 Metal Concentrations from Ledum at Control Sites, 2011

Metals (mg/Kg)	C01 Ledum	C02 Ledum	C03 Ledum	MB01 Ledum	MB02 Ledum	Average Control Value
Sb	0.001	0.003	0.001	0.011	0.009	0.005
Ag	0.004*	0.004	0.004	0.006	0.005	0.005*
As	0.01	0.02	<0.01	0.08	0.05	0.03
Cd	<0.002	0.003	<0.002	0.017	0.017	0.008
Cu	1.43	1.5	2.01	1.68	1.28	1.58
Fe	13	26	16	24	19	19.6
Pb	0.047	0.074	0.04	0.282	0.228	0.134
Mn	91.3	81.3	747	196	89	241
Ni	0.2	0.05	0.49	0.38	0.14	0.252
Zn	10.2	7.4	9.05	8.67	9.06	8.88

*The 0.004 is the limit of detection for Ag, so values could be lower.

From the limited data set shown in the two tables above, *Ledum* leaves appear to accumulate Mn more than willow, as where willow appear to have a higher preference for Zn, Cd and Ni.

2.4 POINT SOURCES OF METAL CONTAMINATION

The discharge from old mine adits in the Keno Hill Mine District are point sources for metal contamination to the receiving water and potentially the adjacent soils/vegetation environment. Zn is the primary COPC that drains from the adits; however, low quantities of cadmium, manganese, iron and other associated elements are also discharged. Mine discharge enters the surface drainage systems and carries these substances further downhill. Natural sources may also be contributing to metal loading, but these systems are harder to discern. A variety of reactions can occur to the metal ions along the way: oxidation, reduction, acidification, solubilisation and the presence of chelating agents affect heavy metal mobility and availability to the plants (Mathe-Gasper and Attila, 2005).

The point sources and their downstream environs that were sampled in this study include:

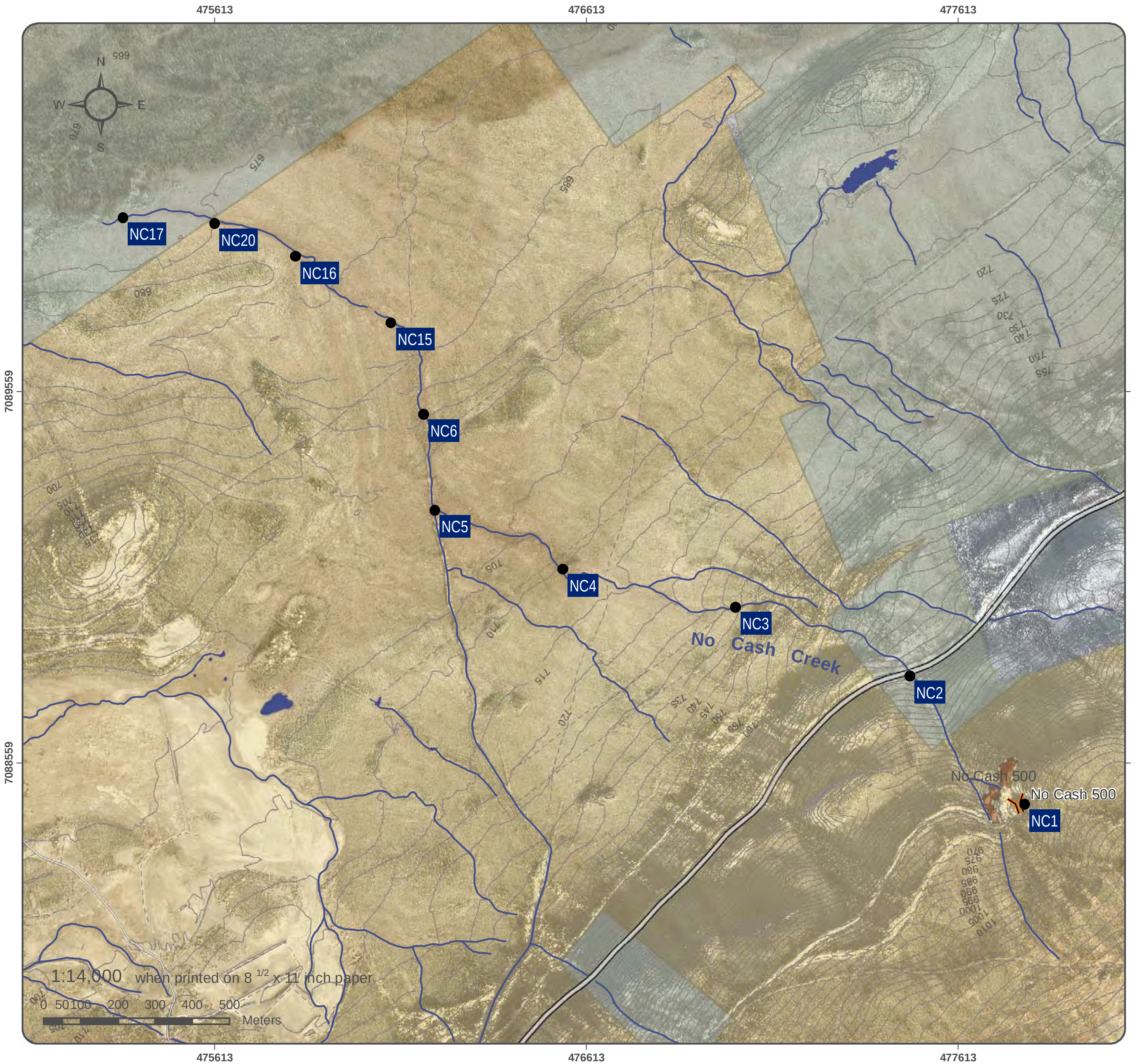
- No Cash 500 adit (also includes discharges from the Bermingham and Ruby adits which are upslope from No Cash adit
- Husky SW shaft
- Silver King 100 adit
- Sadie Ladue 600 adit

2.4.1 No Cash Creek

The No Cash (NC) 500 adit has been identified as the second highest point source for Zinc loading in the District (InTerraLogic, ITL, 2011). High concentrations of Zn and Cd are observed at NC1, the first sampling station near the adit (Figure 2-2). At sampling station NC2, 500m downstream, the Zn and Cd content in the water decreases substantially due to natural attenuation processes. Geochemical analysis has confirmed that manganese (Mn) and Zn are precipitating out of the water column together in oxy-hydroxide mineral forms (Sheriff, 2011). The oxidation of these metals is augmented by the highly aerated water that flows along the steep gradient reach between NC1 and NC2. At the lower creek reaches, NC 4 and beyond, the slope gradient lessens and water enters a large fen. In this environment two other biogeochemical mechanisms that may be involved in the attenuation of metals are:

- Sorption onto organic complexes associated with peat, which is plentiful in the lower reaches of NCC as the water disperses into the valley bog. (AEG, 2011)
- Sulphide precipitation caused by sulphate reducing bacteria that reside in the oxygen poor reducing environment of the valley bog. (AEG, 2011)

Based on past (Kwong, 97) and current (ITL, 2011) natural attenuation studies undertaken in this area, a conceptual model of the pathways for metals uptake of select COCPs is being developed. One component of this model is the role that vegetation has in the uptake of Cd, Zn and other minerals in the NC system.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-2
NO CASH CREEK SAMPLE SITES

MAY 2012

- Sample Site
- Adit
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Soils

The metal concentrations displayed in Table 2-4 are from soil samples taken in 2009. The NC1 plot is at the No Cash 500 adit where there is very little vegetation and mine waste is exposed. Subsequent stations progress further downstream spaced approximately 400 to 500m apart. NC6 was the last site where mineral soil samples were taken. Further down the No Cash (NC) system the organic ground cover thickens and shrubs are mainly rooting in peat not mineral soil, eventually the creek empties into a terminal pond.

Table 2-4 Soil Metal Concentrations at No Cash, Access 2009

Metals (mg/Kg) CCME Industry Limit (mg/Kg)	NC 1	NC2	NC3	NC4	NC5	NC6	Average Control Value
As (12)	86.4	150	62.9	72.7	49.3	34.6	28.8
Cd (22)	248	111	33.8	63.2	93.1	23.7	0.41
Cu (91)	144	78.3	35.2	81.3	61.3	54.9	25.2
Fe	31700	37500	22200	27700	32600	23800	24000
Pb (600)	167	1250	269	492	94.3	61	20.5
Mn	35400	11600	5600	8670	23300	6710	648.8
Ni (50)	89.8	54.4	33.4	50.2	76.4	37.1	25.0
Zn (360)	14800	8870	2790	5430	8220	2680	91.6

In this data set As, Cd and Zn are the three COPC that occur persistently over the CCME industry thresholds and Zn is one to two orders of magnitude over its guideline limit, at all NC sampling sites. Although there is overall decrease in the concentrations of metals from NC1 to NC6, this decline is not constant as metal levels fluctuate from one sampling site to the next. At NC4 and NC5 most of the above metals concentrations increase from NC3, and then at NC6 metal concentrations level off. This pattern can be more easily seen in Figure 2-3 which focuses on the concentrations of Zn, Mn, and Cd from the above data table.

The elements Fe and Mn are essential nutrients for plant growth and metabolism. Fe toxicity is rare in animals digesting plants in iron rich soil, as the uptake of Fe ions is well regulated by plants (Ohlson and Staaland, 2001). In the wet acidic peat lands metal ions are available to bind with other metals and organic substances, in essence absorbing these metals out of solution, so they are not available for uptake by vegetation.

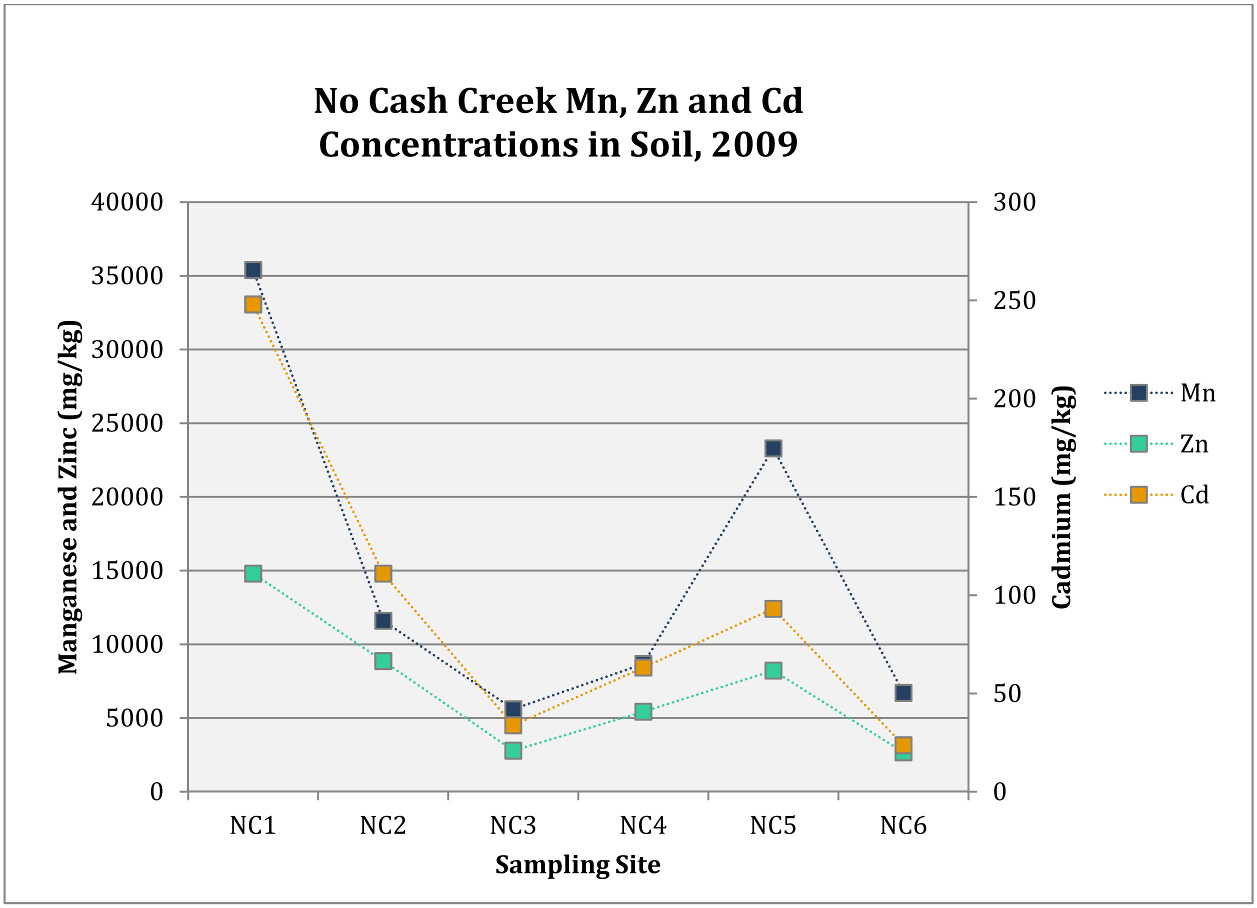
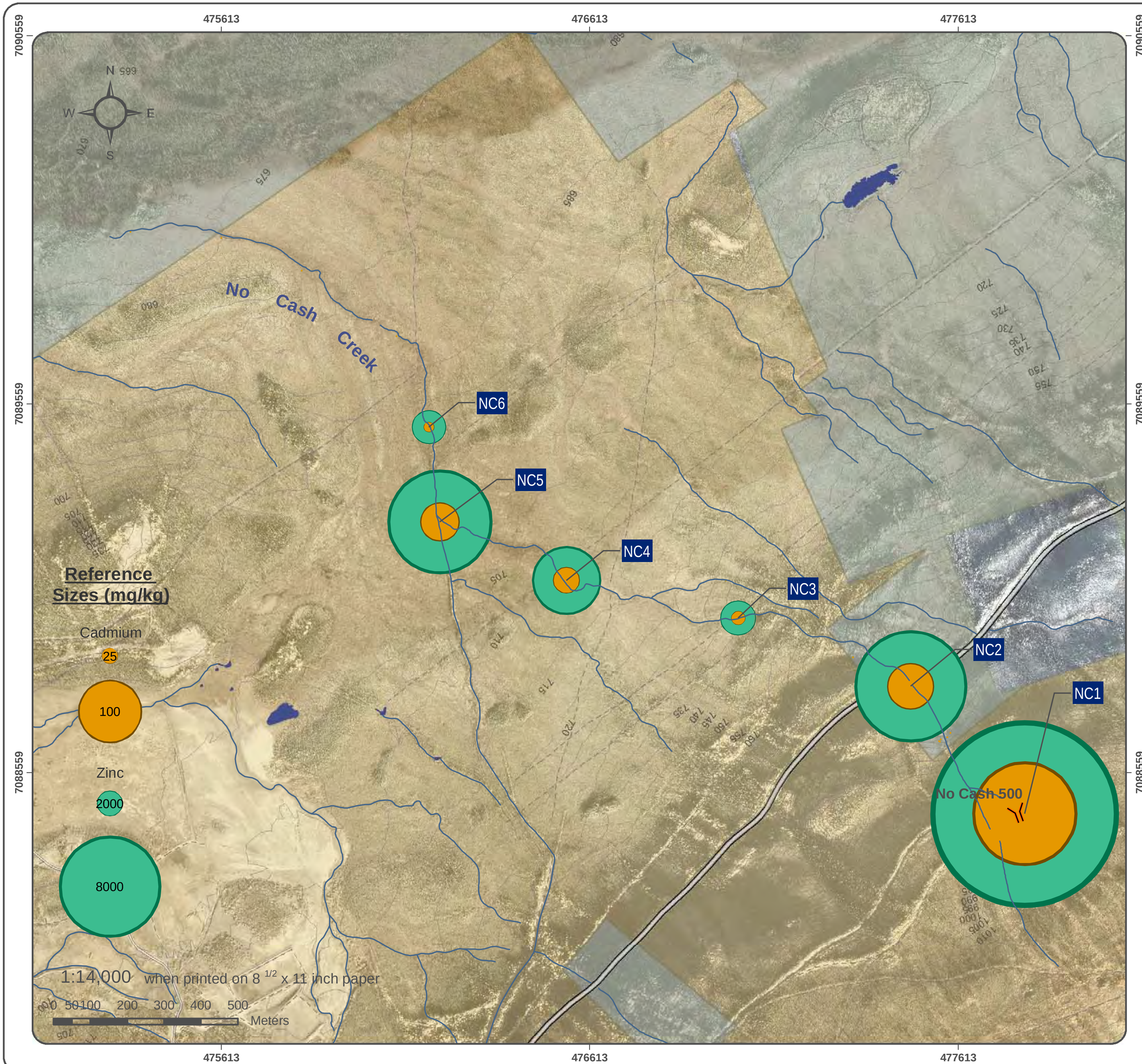


Figure 2-3 Graph of No Cash Creek Mn, Zn and Cd Concentrations in Soil, 2009

Note in the above figure, the concentration scale differs for Cd, right end scale, than Zn and Mn, left end scale. A similar pattern of concentration change occurs for most metals as samples are taken further away from adit source. This pattern is more apparent in Figure 2-4 below, where the Zn and Cd "hotspots" can be viewed in relation to the landscape and relative position to each sampling site. Note that in the map below, that the same circle size represents different concentrations for Cd compared to Zn. The Cd and Zn concentrations are at different magnitudes so to fit them on the same map, Cd concentration are factored by three and Zn was factored by a hundred.

In general, there appears to be a decrease in metal levels with an increase in distance from the No Cash 500 level adit. At NC4 and NC5 there is an increase in concentrations of all metals, the reason for this increase is not fully understood. It could be that another source (perhaps Valley Tailings) has or is contributing to contamination further downstream or oxidation/reduction reactions that precipitate metals are curtailed or a combination of these factors in addition to other unknown factors is occurring.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-4
NO CASH CREEK ZN AND CD CONCENTRATIONS IN SOIL, 2009

APRIL 2012

- Soil Cadmium (mg/kg) / 3
- Soil Zinc (mg/kg) / 100
- Adit
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Vegetation

Willow and *Ledum* leaves were collected in late July of 2011, from sampling sites below the Silver Trail road, NC4 to NC20. Both willow and *Ledum* leaves were collected at the NC4 and NC5 soil pits excavated in 2009. Beyond the NC6 sampling site the shrubs are rooting in organics which was often more than 1 m deep in the valley bottom, samples of organic soils were taken by ITL, but have yet to be correlated to plant sample locations.

Willow

Table 2-5 No Cash Creek Metal Concentrations Willow Leave Tissue, 2011

Metals (mg/Kg)	NC4	NC5	NC6	NC 15	NC16	NC20	NC17	Avg Control Value
As	0.04	0.07	0.06	0.06	0.06	0.04	0.04	0.04
Cd	3.8	0.478	0.781	1.94	2.17	0.869	1.07	1.02
Cu	1.29	2.04	0.58	1.02	2.06	0.92	1.66	1.32
Fe	13	16	35	14	22	19	15	20.2
Pb	0.195	0.279	0.344	0.383	0.455	0.135	0.295	0.20
Mn	49.9	39.9	43.7	27.3	44.3	300	63.3	62.9
Ni	0.17	0.86	0.06	0.14	0.31	0.1	0.37	2.1
Zn	376	61.7	92.9	219	380	74.7	272	36.8

In order to put the data in Table 2-5 into perspective, comparisons need to be made with willow samples taken at the control sites, provided in the far right column.

The willow leaves from the NC area contain higher concentration of metals. Noticeably, Zn is present in the NC willows at higher levels than controls; other metals are also markedly higher, except for Ni and Mn. There is a noticeable increase in Zn and Cd at sites NC16 and NC 17, which are at the bottom of the NC system. At the time of sampling the ground was submerged, these lower plots may be receiving water, and therefore also potentially contaminants from other sources that feed into the valley flood plain. See photos 1, 2 and 3 in Appendix A.

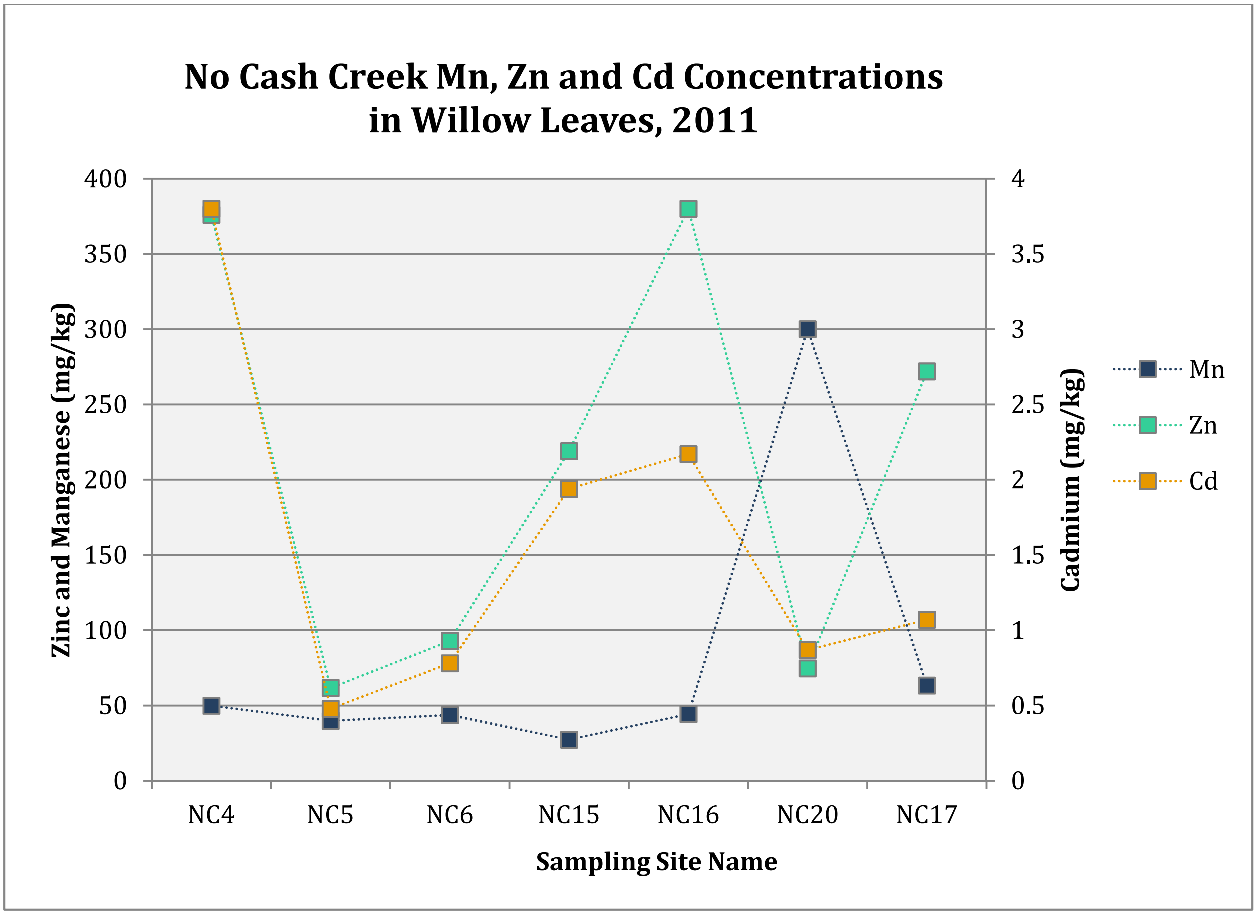
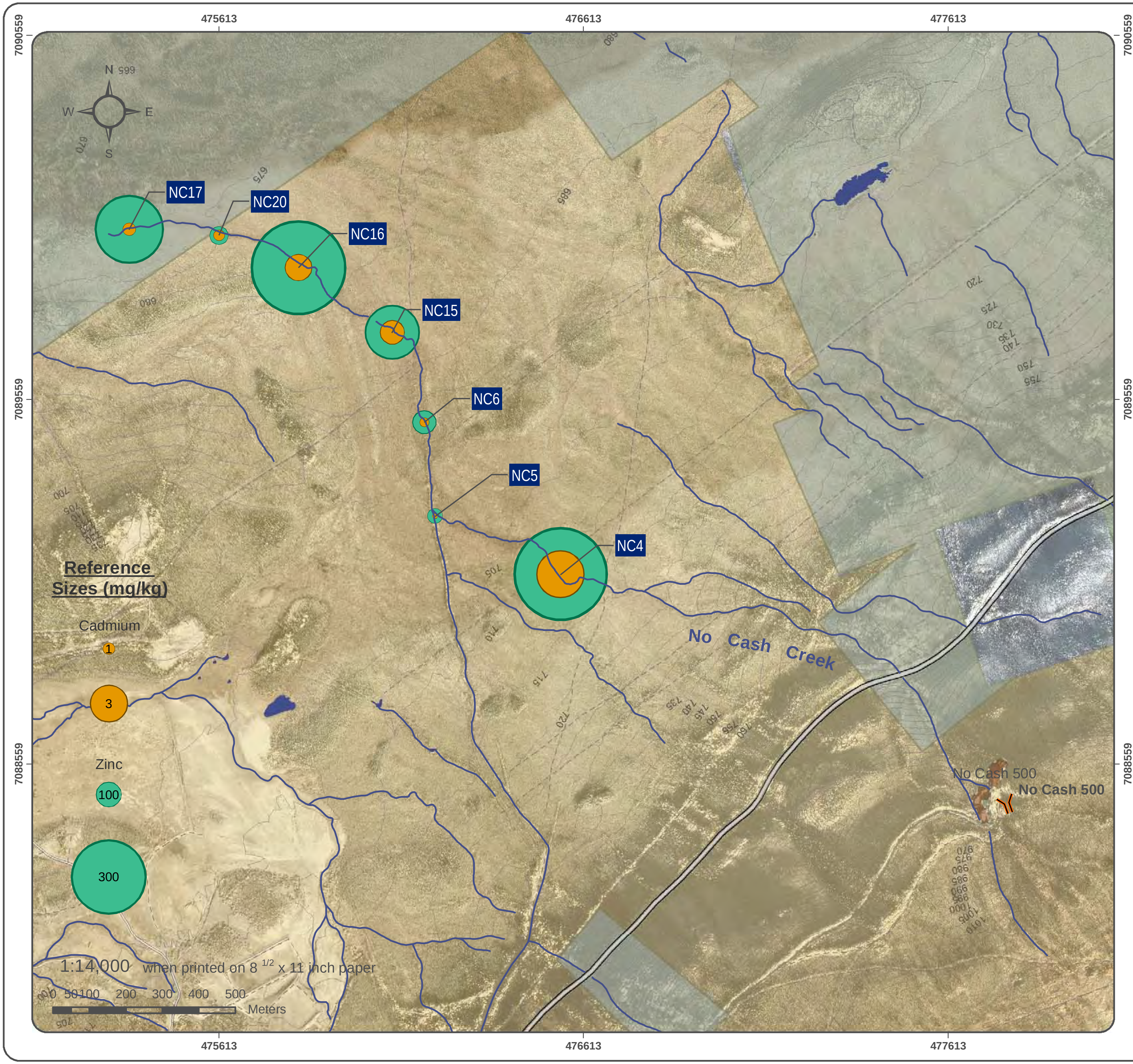


Figure 2-5 Graph of No Cash Creek Mn, Zn and Cd Concentrations in Willow Leaves, 2011

The sites NC4, NC5 and NC6 had both soil and willow leaf samples taken, when the two were compared, no direct relationship between leaf tissue concentration of Zn, Cd and Mn and the soil concentrations was apparent. This is illustrated in the maps (Figure 2-4 and 2-6), at NC5 the soils are high in Zn and Cd, but this is not reflected in the willow leave tissue. This of course is a small sample number, more paired soil/ willow samples will be needed to properly investigate this relationship.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-6
NO CASH CREEK ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

APRIL 2012

- Willow Cadmium (mg/kg) x 10
- Willow Zinc (mg/kg) / 5
- Adit
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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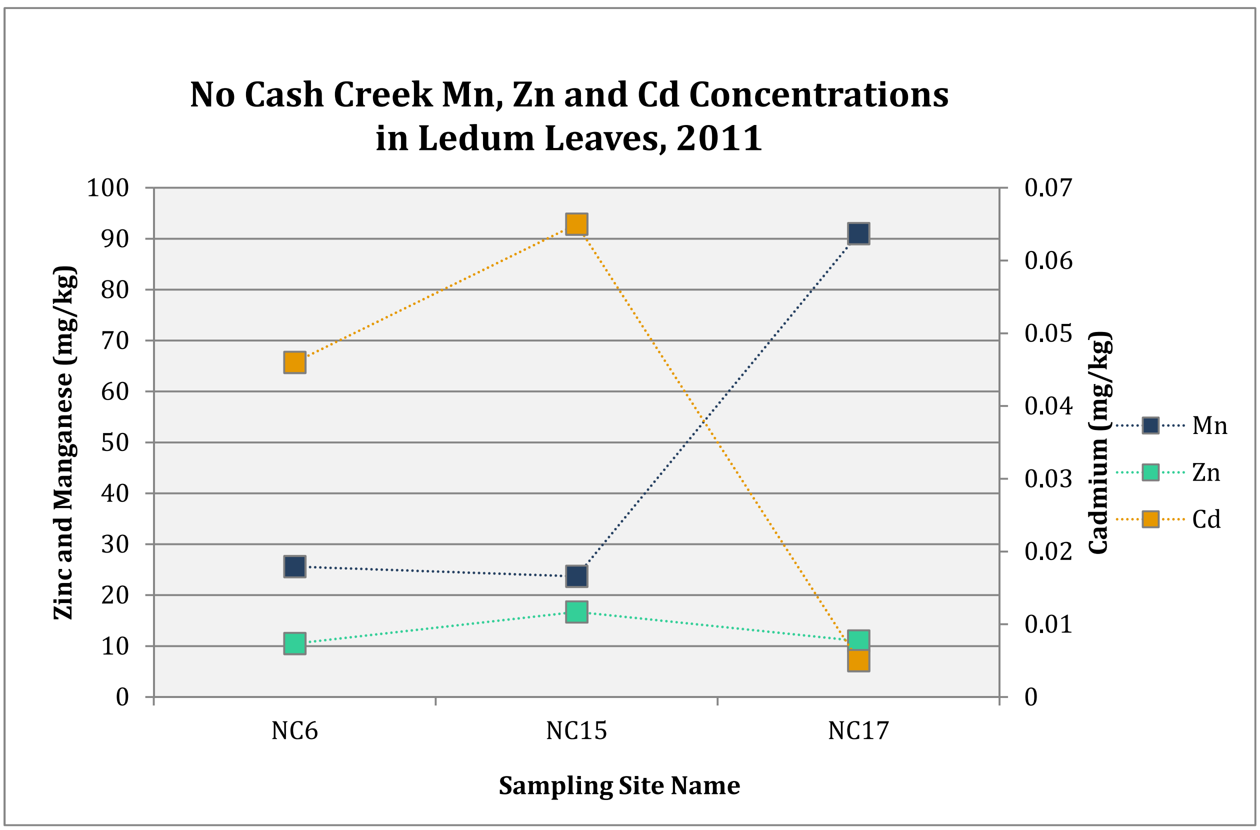
Ledum Species and Blueberries

Table 2-6 Metal Concentration in Ledum Sp. Leaves in Comparison to Control Values

Metals (mg/Kg)	NC6	NC 15	NC17	Average Control Value for Ledum Sp.	NC 16Blueberries
As	0.14	0.1	0.02	0.04	0.01
Cd	0.046	0.065	0.005	1.02	0.076
Cu	1.51	1.46	0.55	1.32	0.55
Fe	46	31	13	20.2	3
Pb	0.92	0.74	0.121	0.20	0.017
Mn	25.6	23.7	91	62.9	3.07
Ni	0.1	0.09	0.04	2.1	0.04
Zn	10.5	16.7	11	36.8	2.98

The COPCs in Ledum leave tissue collected at No Cash Creek sampling sites are near or below concentrations determined for Ledum leave samples at control locations. As seen in the graph below (Figure 2-7) Cd and Mn concentrations trend in opposite direction between plot NC15 and NC17. The Cd leaf concentrations drops and the Mn raises by a similar factor. Only one sample of blueberries was collected and metal concentrations are presented for comparison. The COPC concentrations are lower in the blueberries than both willow and Ledum leave samples in the NC sites and controls.



Note difference in concentration scales for Mn and Zn compared to Cd.

Figure 2-7 Graph of No Cash Creek Mn, Zn and Cd Concentrations in Ledum Leaves, 2011

A map of Zn, Cd and Mn concentrations in Ledum leaf tissue is not presented as there is not enough data plots to find patterns of metal uptake by Ledum species. In general metal levels in Ledum leaves are lower than willow leaves and are less of a concern as a vector for entering the food web.

Discussion

General Points:

- No Cash soil samples have elevated levels of Zn, Cd and As, when compared to CCME standards.
- No Cash soil samples have the highest Zn and Cd soil deposits of all the point sources examined in this study.
- There is an overall decrease in metals levels as distance increases from the No Cash adit, but a noticeable increase at soil sampling sites NC4 and NC5.
- There may be other seeps and surface streams that are contributing to metal loading of the lower NC system, for example the diversion ditch from the Valley Tailings headwaters area to the south west that joins No Cash Creek at NC5. Another possibility is sediments and metals in solution are deposited in low lying terrestrial areas during flooding events, when water breaches the creek channel.
- Willow leaves contain higher concentrations of Zn and Cd than Labrador tea.
- A direct relationship between Zn, Cd and Mn concentrations in willow leave tissues and corresponding soils is not apparent in this limited sampling set.

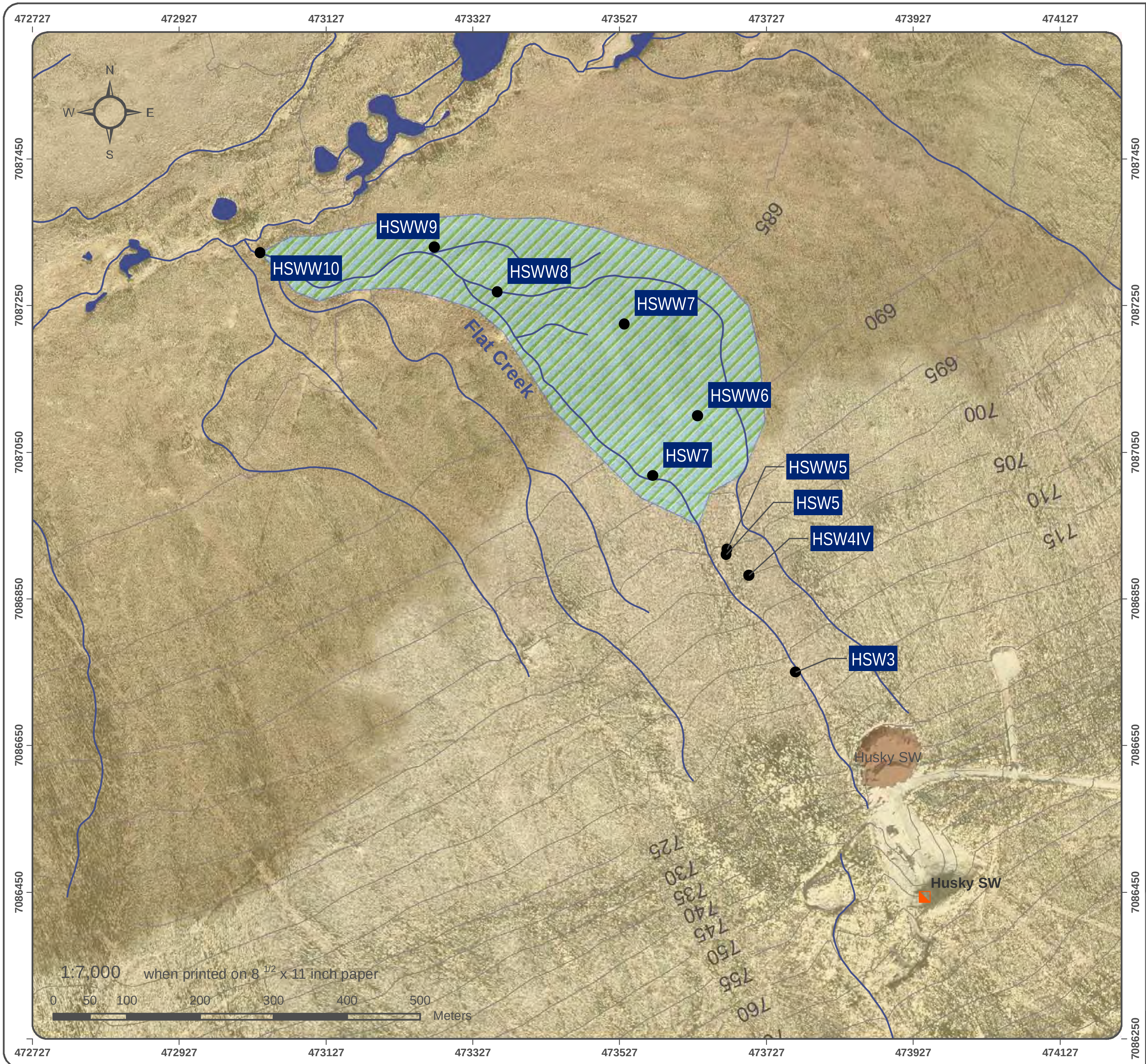
2.4.2 Husky Adit – Flat Creek

Flat Creek originates on the northwest face of Galena Hill; the upper reaches of this creek are steep and flow through a gulch before entering a culvert at the Silver Trail road. The creek is still in a confined channel below the road until just west and north of the Husky adit, where the slope declines significantly (Figure 2-8). Flat Creek then enters a peat land fen, and there it joins several tributaries that originate from seeps and /or surface run off, that flow and braid into numerous streams. The substrate that the willows and Ledum species grew from is primarily organic, so no mineral soil samples were taken along this drainage in 2009. One sample of soil was collected at HSW7 this summer and was a mix of mineral and organics. A summary of the metals concentrations in this one sample are shown in the table below.

Table 2-7 Soil Metal Concentrations at Husky SW Adit, HSW7, 2011

Metals (mg/Kg) CCME Industry Limit (mg/Kg)	Sb (40)	Ag (40)	As (12)	Cd (22)	Cu (91)	Fe	Pb (600)	Ni (50)	Zn (360)
HSW7	2.4	3.14	34.4	0.99	40.1	17100	38.2	27.1	108
Average Control Values	1.8	0.19	28.8	0.41	25.2	24000	20.5	25	91.6

Arsenic is almost three times over its CCME guideline threshold, but within range of the control concentration. The other metals occur at slightly elevated levels in comparison to control values, except Fe which is below, and are well beneath the CCME guideline thresholds. Many of the plant species that are growing in the valley lowlands are rooting in organics, not mineral soil. In order to determine to what degree plant mineral uptake is associated with mineral content in organic substrates, the peat would need to be analysed for metal content and compared to plant samples taken from the same site. Heavy metals tend to complex with organics reducing the metals availability for plant uptake, so a relationship between organic substrate and plant leaf concentrations would be a complex and not so direct.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-8
HUSKY SW SAMPLE SITES

MAY 2012

- Sample Site
- Shaft
- Watercourse
- Unconfined Waterways
- Waterbody
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-8 Husky SW Adit, Metal Concentrations Willow Leave Tissue, 2011

Metals mg/Kg	HSW3 Willow	HSW4 Willow	HSW4ii Willow	HSW4iv Willow	HSW5 Willow	HSW7 Willow	HSWW5 Willow	HSWW6 Willow	HSWW7 Willow	HSWW8 Willow	HSWW9 Willows	HSWW10 Willow	Average Control Value
As	.02	0.02	0.03	0.05	0.03	0.03	0.06	0.05	0.05	0.07	0.06	0.46	0.04
Cd	3.79	0.174	0.176	0.512	0.175	0.204	0.238	0.657	0.33	0.137	0.11	4.75	1.02
Cu	1.27	1.37	0.83	1.23	0.96	0.72	0.8	1.56	0.79	0.77	0.61	1.33	1.32
Fe	29	20	28	19	21	19	30	19	25	47	45	67	20.2
Pb	0.048	0.049	0.045	0.21	0.104	0.048	0.075	0.62	0.07	0.075	0.186	3.1	0.20
Mn	416	46.3	48.1	101	160	120	190	56	76.1	294	103	280	62.9
Ni	1.04	0.14	0.33	0.25	0.39	0.27	0.18	0.38	0.43	0.07	0.13	0.37	2.1
Zn	152	56.9	41.2	125	26.9	28.2	31.4	79.3	34.9	16.3	24.8	221	36.8

At HSW3 site, Cd concentrations in willow leaves are more than three times the background average and Zn is approximately five times higher. Elevated levels of these two metals are to be expected as this sampling site is the closest to the Husky adit, a point source for contaminants. The levels of Cd in leaf tissue drop off sharply in the next site HSW4 and range from 0.11 g/kg to 0.657 g/kg in subsequent down gradient sampling sites (Figure 2-9). The Zn concentrations in willow leaves also decrease after HSW3 and fluctuate at lower values in the sampling sites HSW4 to HSWW9. Site HSWW10 the lowest sampled point in the drainage and the furthest from the point source, is at the confluence of many streams coming off the lower slope of Galena Hill and the drainage from the Valley Tailings settling ponds. The convergence of multiple waterways bearing metal loads is likely the reason HSWW10 shows the highest concentrations of As, Cd, Fe, Pb and Zn in willow leaves sampled, or may be affected by tailings deposition from a high water event eroding tailings from the Valley Tailings area. Unfortunately Ledum leaves were not collected at HSW3 or HSWW10 to see if a similar pattern of metal uptake occurs for both shrubs.

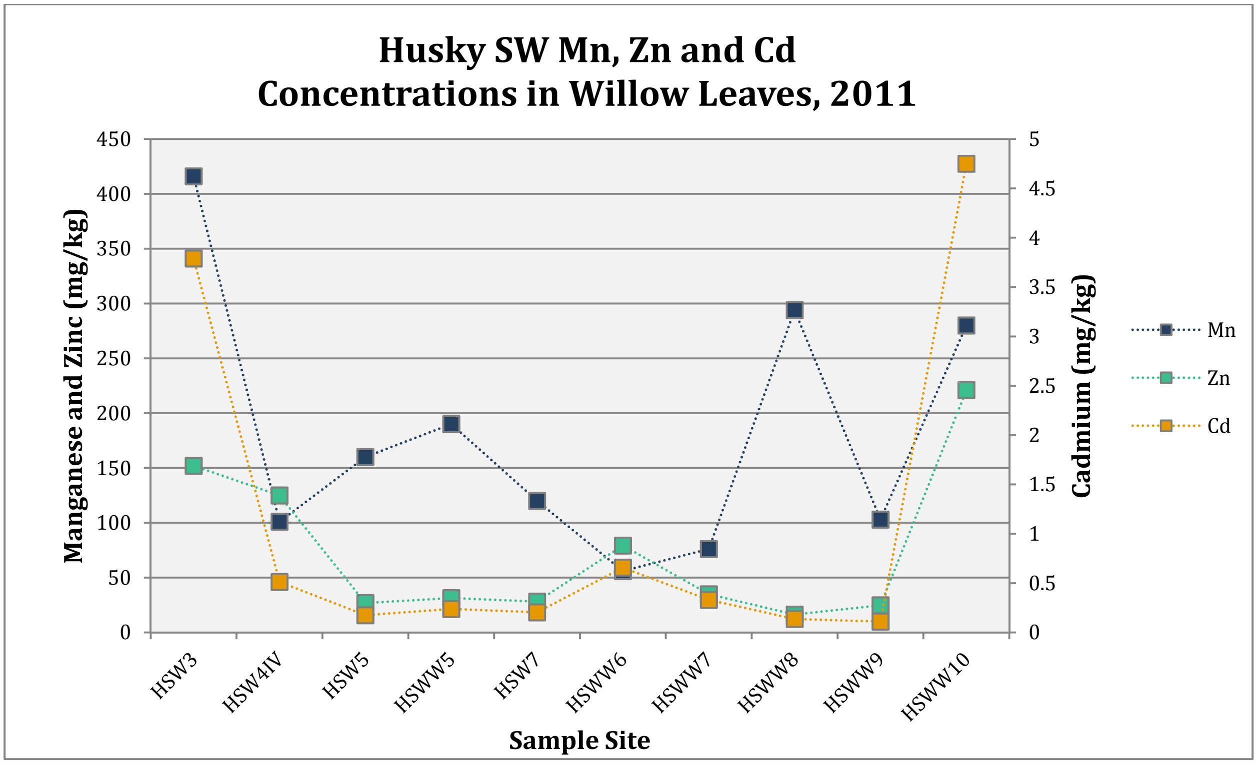
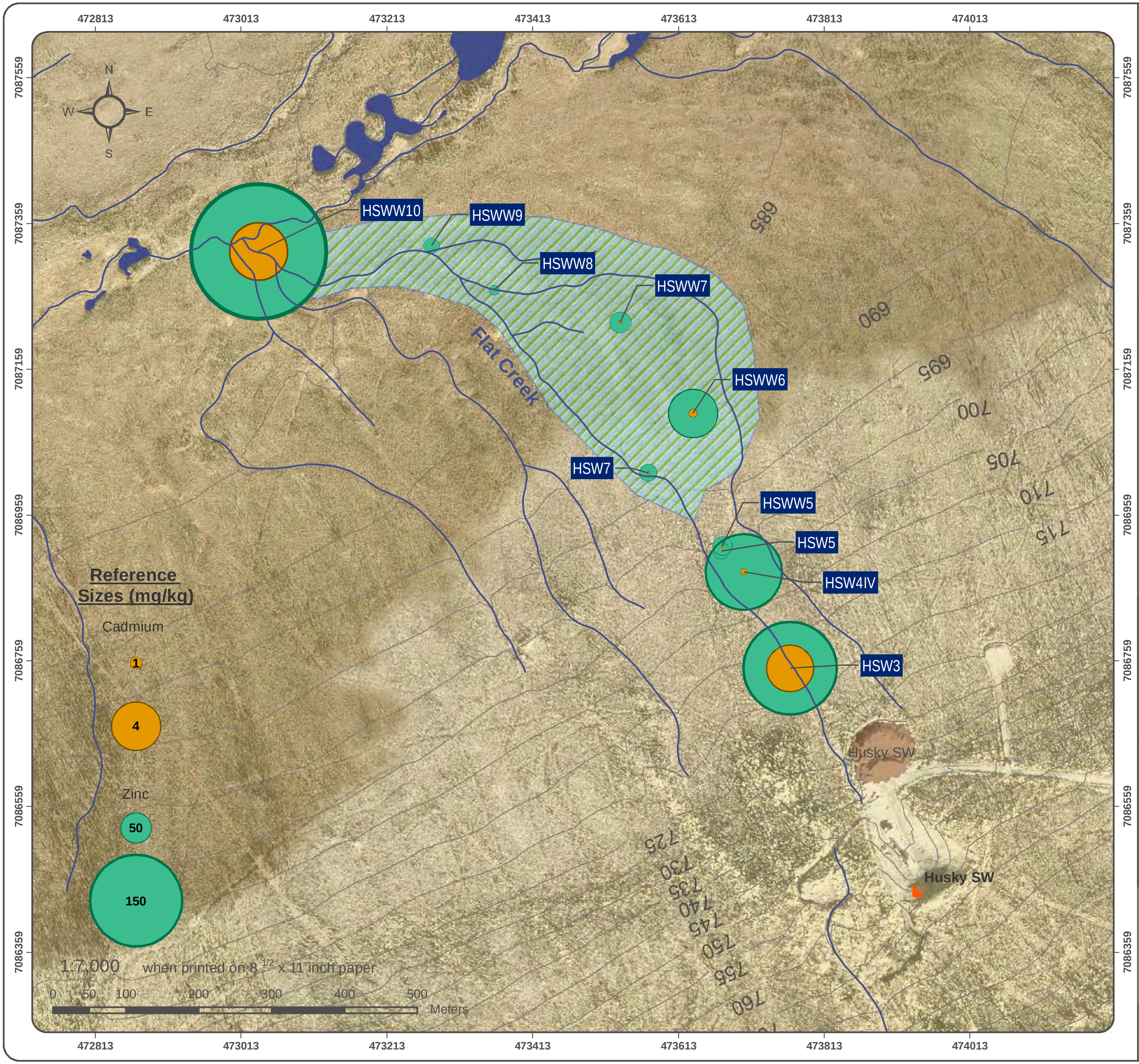


Figure 2-9 Graph of Husky SW Mn, Zn and Cd Concentrations in Willow Leaves, 2011



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-10
HUSKY SW
ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012

- Willow Cadmium (mg/kg) x 10
- Willow Zinc (mg/kg) / 2
- Shaft
- Watercourse
- Unconfined Waterways
- Waterbody
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-9 Husky SW, Metal Concentrations Ledum Leaves, 2011

Metals mg/Kg	HSW4 Ledum	HSW5 Ledum	HSW7 Ledum	HSWW5 Ledum	HSWW6 Ledum	HSWW7 Ledum	HSWW8 Ledum	Control Average
As	0.02	0.13	0.59	0.06	0.09	0.04	0.09	0.04
Cd	0.004	0.007	0.052	0.004	0.004	0.006	0.016	1.02
Cu	1.72	1.63	2.57	1.69	1.96	2.05	1.9	1.32
Fe	19	70	386	43	44	29	59	20.2
Pb	0.01	0.213	0.356	0.204	0.065	0.086	0.165	0.20
Mn	27.3	53.1	52.6	23.6	49.9	53.7	119	62.9
Ni	0.04	0.21	0.56	0.29	0.21	0.32	0.22	2.1
Zn	8.88	11.1	10.8	8.14	8.7	12.3	12.7	36.8

Ledum does not accumulate Cd and Zn to the same extent as willow species do and leaf concentration are comparatively lower than control values for Cd. However As, Cu, Fe, Pb and Ni are at slightly higher concentrations in Ledum than for willow at this study area, again these values are near average control values. When looking at the map (Fig 2-10) and the above table, there is a small increase in Cd concentrations at HSW7 and again at HSWW8 in Ledum leaves.

In Figure 2-11 below the graph shows Zn and Cd concentration levels in Ledum leaves parallel each other, till sample site HSW7 where there is a significant peak in Cd. Both Zn and Cd concentrations in Ledum leaves, across the sampling set, are lower than the control averages.

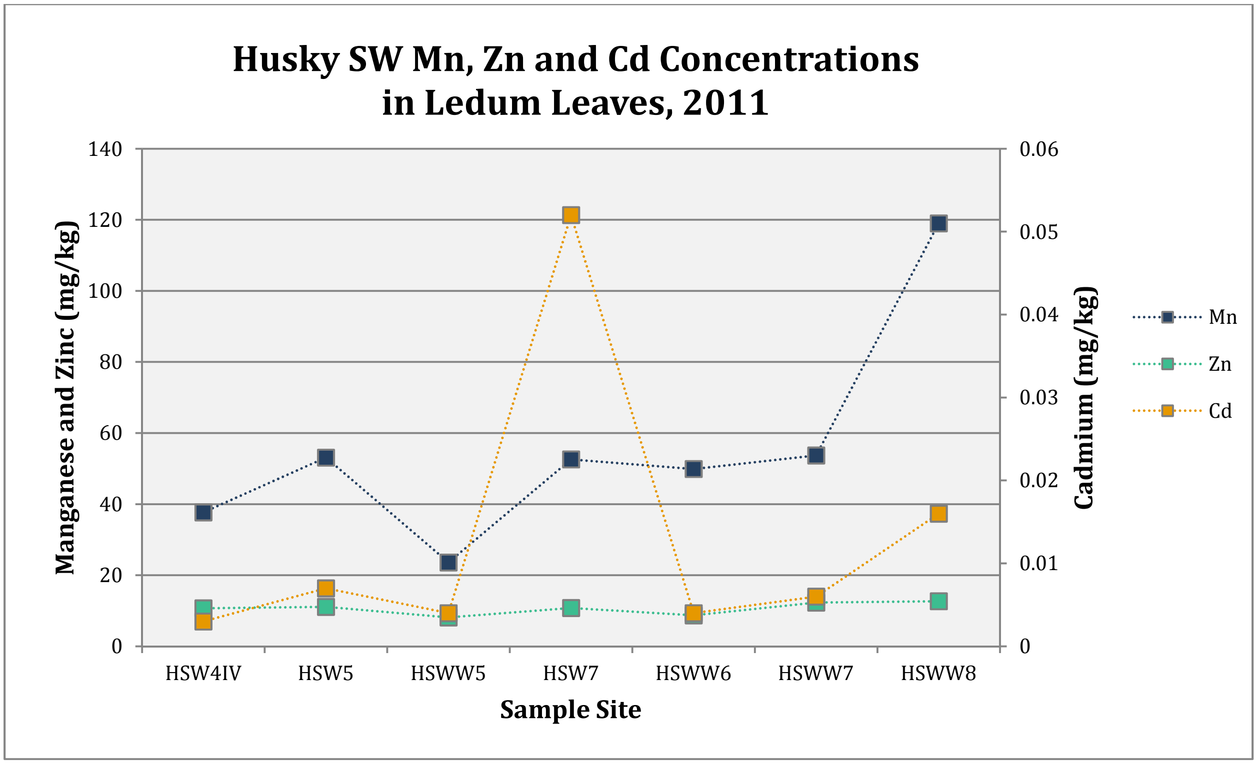
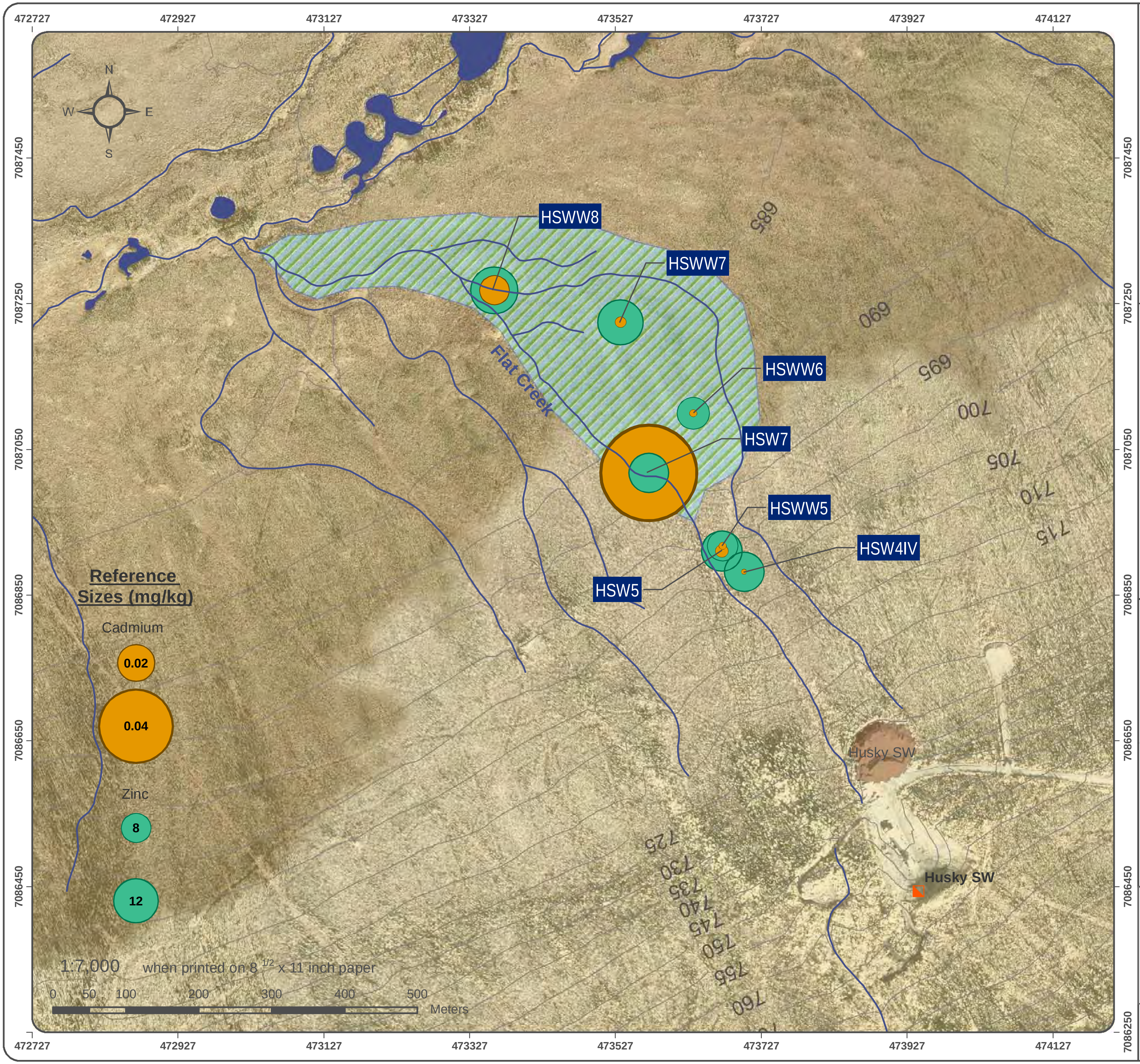


Figure 2-11 Graph of Husky SW Mn, Zn and Cd Concentrations in Ledum Leaves, 2011



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-12
HUSKY SW
ZN AND CD CONCENTRATIONS IN LEDUM SPECIES, 2011

MAY 2012

- Ledum Cadmium (mg/kg) x 1500
- Ledum Zinc (mg/kg) x 3
- Shaft
- Watercourse
- Unconfined Waterways
- Waterbody
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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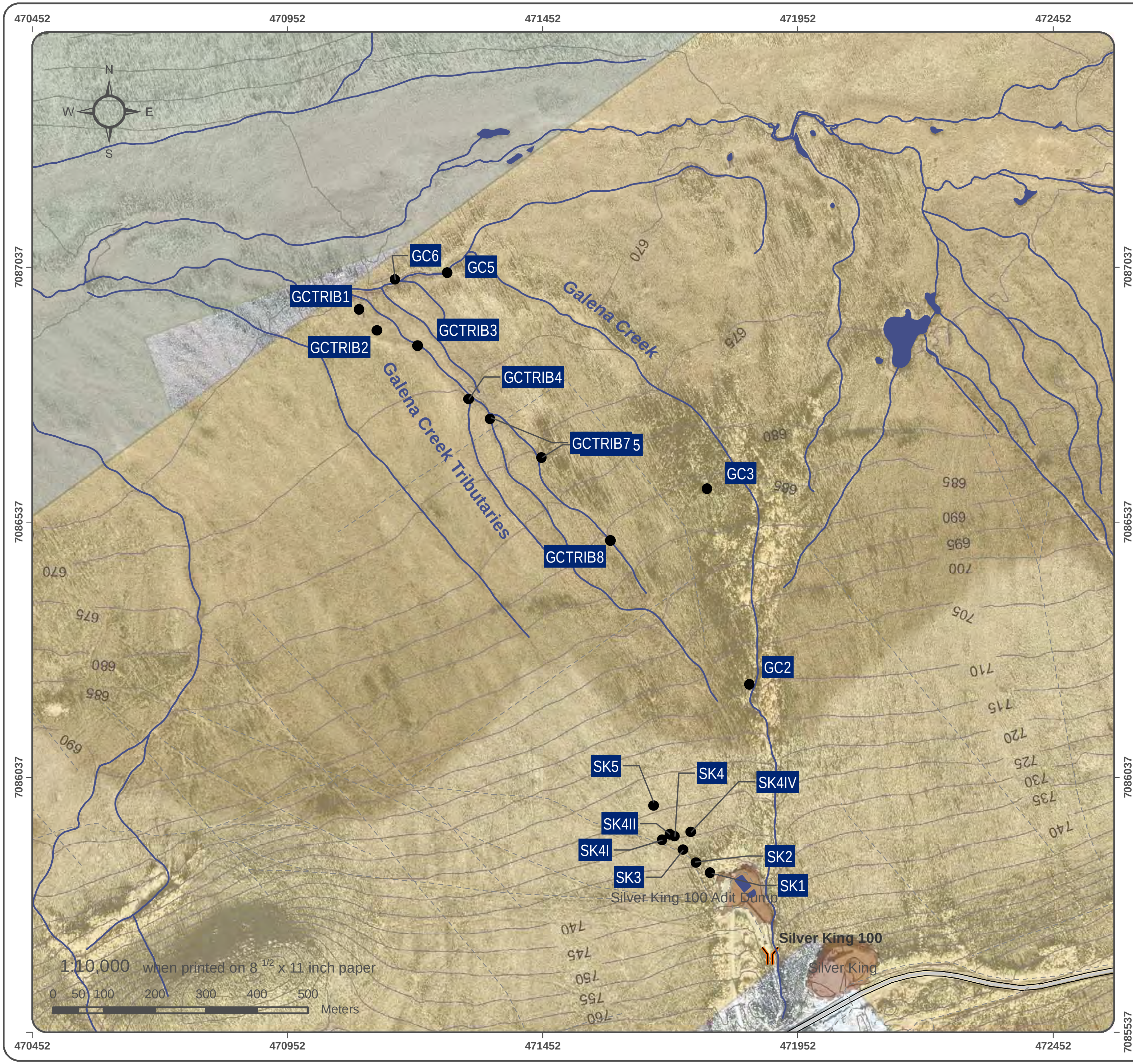
2.5 SILVER KING –POINT SOURCE

The Silver King study area is composed of three vegetation sampling sections (Figure 2-13). In the most eastern section are six plots along and close to the main stem of Galena Creek, referred to by the initials GC (e.g. GC1, GC2…etc.). The Silver King (SK) plot series begins just below the outlet for the SK100 treatment pond. The discharged water is directed to the northwest of the treatment pond via a culvert onto the forest floor near the sampling plot SK1. At the time of the study water was on the surface of the forest floor at the point of release and was still on the surface for approximately 60m downhill of culvert (see photo 6). By plot SK4, the organic layer is greater than 50cm thick and effluent had been absorbed and no collecting on the surface.

The GC sample sites follow the lower Galena Creek; the sample sites are situated along the west side bank of the creek. This creek is confined in a deep channel that passes through upland forests consisting of spruce, aspen and scattered cottonwood. It looks like a portion of the creek has been trenched and tailings are revealed along the cut banks of the channel. This waterway enters a fen type ecosystem about 1 km below the adit, where the creek becomes more diffuse and braided.

To the west of Galena creek runs a tributary labelled GCTrib, it starts at elevation 695m and joins the main stem of Galena creek at 670m; there are six plots along edge of this tributary. This tributary is not very confined, especially in the lower reaches, so in high water events the flood waters cover low lying areas, thereby dispersing sediment over a wider area.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-13 SILVER KING AND GALENA CREEK SAMPLE SITES

MAY 2012

- Sample Site
- Adit
- Silver Trail Highway
- Trails/Track
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

The location of SK-5 was approximated from LK field notes.

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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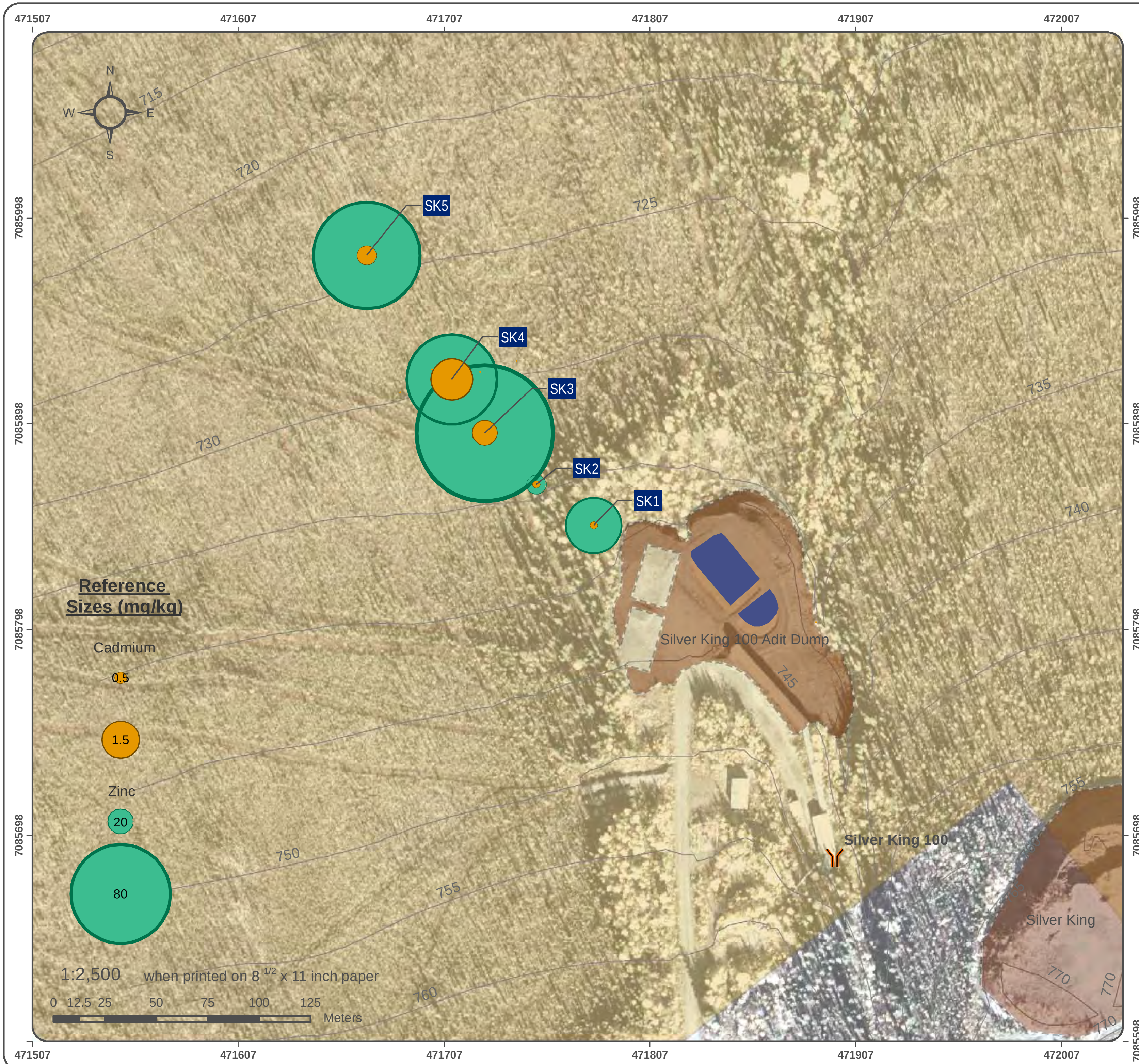
Table 2-10 Silver King, Soil Metal Concentrations, 2009

Metals (mg/Kg) CCME Industry Limit (mg/Kg)	SK01	SK02	SK3	SK4	SK05	Average Control Value
As (12)	13.4	28.4	29.8	14.3	37.4	28.8
Cd (22)	0.3	0.3	1	0.7	0.8	0.41
Cu (91)	18	22	26	17	40	25.2
Fe	14400	31500	23800	9300	19500	24000
Pb (600)	4.2	3.6	9.5	1.3	29.5	20.5
Mn	2770	793	5620	283	2130	648.8
Ni (50)	11	16	29	14	29	25.0
Zn (360)	45	16	110	127	86	91.6

The soil data comes from the 2009 sampling program, the soil pits were revisited, so the vegetation collected were at or near the soil sampled.

Arsenic (As) is consistently over the CCME soil guidelines for industry guidelines, but similar to control average value. The Zn and Cd concentrations in soil samples are below CCME guidelines and average background values at the sample points, except Zn at SK4 where it is above the control average (Figure 2-14). The plot SK5 has the most elevated levels of COPC however they are all below CCME recommended thresholds.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-14
SILVER KING
ZN AND CD
CONCENTRATIONS IN SOIL, 2009

MAY 2012

- A Horizon Cadmium (mg/kg) * 20
- A Horizon Zinc (mg/kg)
- Adit
- Waterbody
- ERDC Owned Quartz Claims
- Waste Rock Dump

The location of SK-5 was approximated from LK field notes.

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-11 Silver King, Metal Concentrations in Willow Leaves, 2011

Metals (mg/Kg)	SK1	SK3	SK4	SK4i	Average Control Value
As	0.02	0.02	0.02	0.01	0.04
Cd	4.26	0.302	0.119	0.205	1.02
Cu	2.09	0.74	0.93	1.27	1.32
Fe	18	15	26	17	20.2
Pb	0.178	0.086	0.073	0.101	0.20
Mn	69.3	40.2	220	191	62.9
Ni	3.7	0.38	0.1	0.92	2.1
Zn	206	65.2	59.4	103	36.8

The highest values for Zn and Cd in willow leaf tissue are at SK1, the plot closest to the treatment pond discharge, further downhill these concentrations are significantly reduced by plot SK3 (Figure 2-15 and 2-16). The changes in willow leaf Zn and Cd concentrations parallel each other, as where Mn concentrations spike at plot SK04 then decline. The Cd levels are higher in the leaf tissue than in the soil (see Table 2-14 and 2-16) as willow hyperaccumulates Cd and accumulate Zn (Kabata-Pendias, 2011). Most of the COPC concentration values are close to the control values, except for Zn which was over the control values at all SK samples.

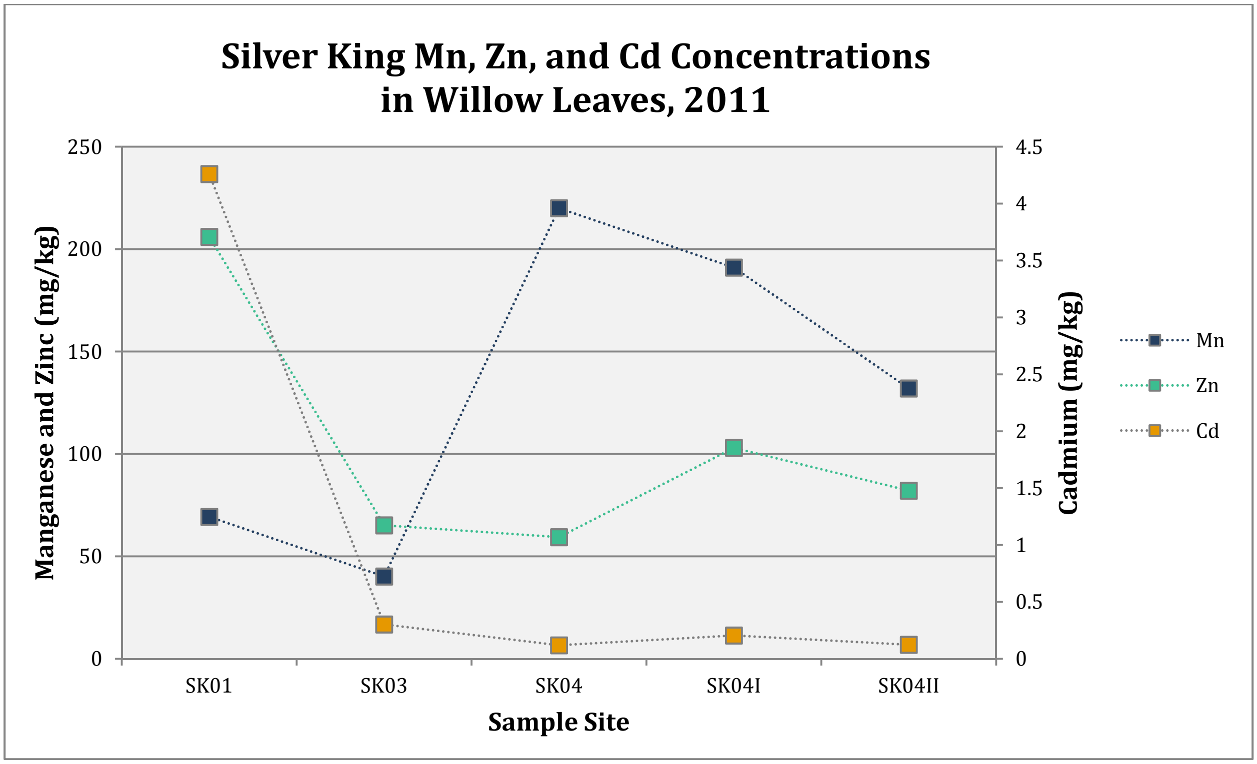

Figure 2-15 Graph of Silver King Mn, Zn and Cd in Willow Leaves, 2011

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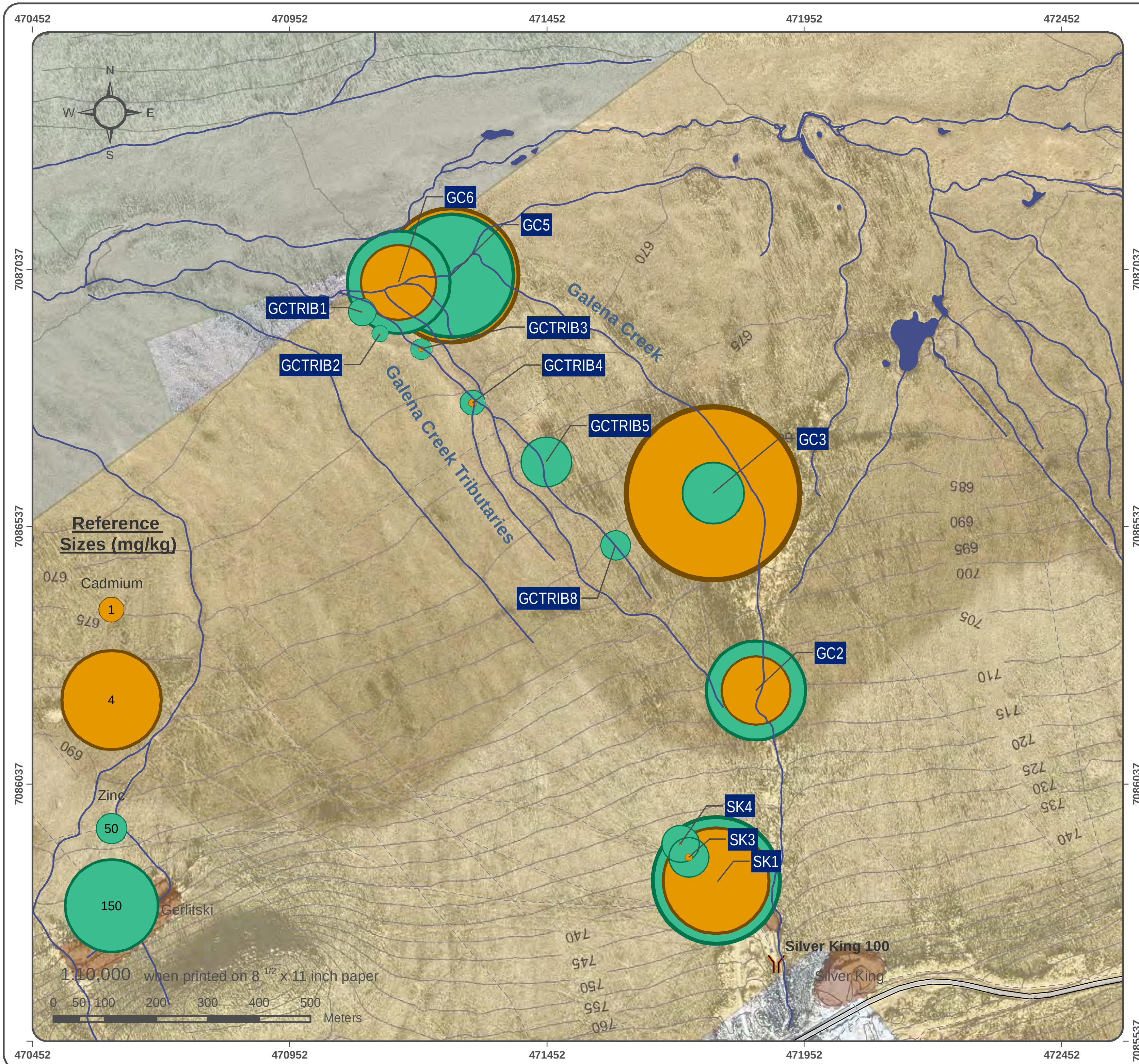
FIGURE 2-16 SILVER KING & GALENA ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012



Willow Cadmium (mg/kg) x 20

Willow Zinc (mg/kg) / 2

Adit

Silver Trail Highway

Trails/Track

Watercourse

Waterbody

ERDC Owned Quartz Claims

Other Alexco Owned Quartz Claims

Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-12 Silver King, Metal Concentrations in Ledum Leaves, 2011

Metals mg/Kg	SK1	SK3	SK4	SK4iv	Control Average
As	0.03	0.05	0.029	0.008	0.04
Cd	0.009	0.007	0.005	0.004	1.02
Cu	1.28	0.92	1.27	1.48	1.32
Fe	18	17	15	13	20.2
Pb	0.215	0.055	0.125	0.07	0.20
Mn	58.2	54.5	269	109	62.9
Ni	0.18	0.16	0.05	0.09	2.1
Zn	7.73	9.19	13.8	11.7	36.8

It appears that the level of Cd in Ledum leaves progressively declines as the distance increases from contaminant point source. The Cd concentrations detected in the SK plots are very low, so this relationship is tenuous. Again there is a spike in Mn Ledum leaf concentrations at SK04 that also occurs in willow leaves. The highest soil Mn concentration is upslope at SK3, 5620 mg/kg, but the immediate soils concentrations at SK4 is only 283 mg/kg.

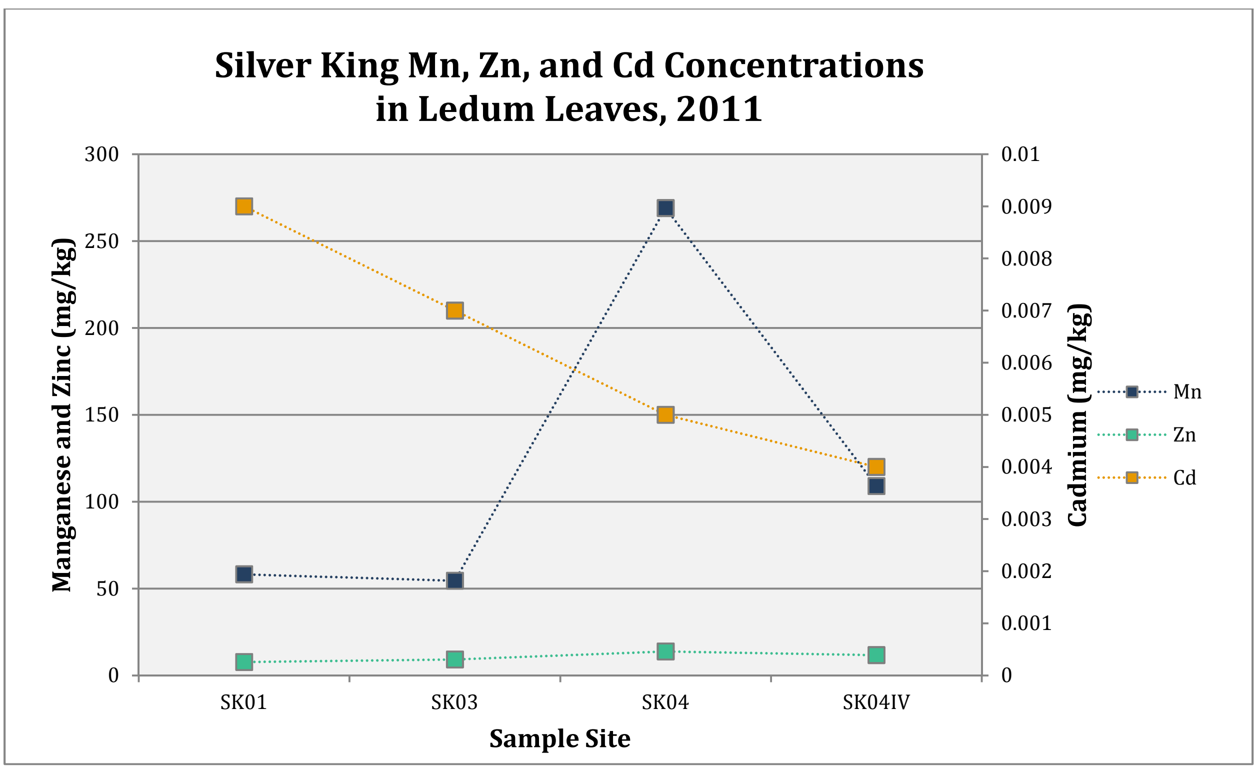

Figure 2-17 Graph of Silver King Mn, Zn and Cd Concentrations in Ledum Leaves, 2011

General Observations:

- The Silver King Zn and Cd concentrations in soils are below CCME thresholds and are close to control values.
- Pattern of Cd and Zn uptake into willow leaves appears to parallel each other.
- SK1 plot was found to have high Zn and Cd concentrations in willow leaf tissue, higher than soils taken at plot.

2.5.1 Galena Creek and Tributary

The main Galena Creek (GC) is confined in a steep sided ravine that cuts through an upland forest, composed of spruce and aspen. It appears that the Galena Creek had been trenched in the past as the banks and slopes of the ravine looked disturbed and early successional shrub growth was regenerating along the creek. There is also evidence of old roads and trails along this creek. No soil samples were taken along the Galena Creek or its western tributary only vegetation was collected and analyzed. The tributary (GCTrib) is situated in a thick moss fen, so mineral soil would be hard to extract and not the rooting medium for the plants collected. The maps indicating COPC concentrations for willow tissues along Galena Creek and its tributary can be found above in the Silver King section of the report (Figure 2-15).

The table below summarizes the concentrations of COPCs in willow leave tissue samples for Galena Creek and its western tributary.

Table 2-13 Galena Creek, Willow Leaves Tissue Metal Concentrations, 2011

Metals (mg/Kg)	GC1	GC2	GC3	GC4	GC5	GC6	GC TRIB1	GC TRIB3	GC TRIB4	GC TRIB5	GC TRIB7iii	GC TRIB8	Avg Control Value
As	0.04	0.02	0.03	0.03	0.07	0.1	0.06	0.18	0.05	0.02	0.02	0.02	0.04
Cd	2.65	2.76	7.01	2.16	5.45	3.02	0.03	0.209	0.329	0.092	0.05	0.043	1.02
Cu	1.62	2.48	2.12	1.84	1.41	1.3	1.31	1.31	1.14	0.75	1.55	1.02	1.32
Fe	18	24	25	16	37	58	45	120	19	14	20	13	20.2
Pb	0.53	0.092	0.223	0.087	0.049	0.108	0.043	0.146	0.023	0.063	0.029	0.047	0.20
Mn	73.7	20.5	8.92	37.8	272	68.6	39.9	62.3	108	42.4	53.2	41.7	62.9
Ni	1.94	0.37	0.33	0.13	0.13	0.17	0.22	0.46	0.83	1.17	0.74	0.38	2.1
Zn	134	160	99.7	11	200	166	44.9	34.8	40.5	80.3	30.5	48.2	36.8

In the GC sampling area the highest Cd levels in willow leaves were found at plot GC3, which is located midway between Silver King 100 and the valley bottom. The highest Zn concentrations were at plot GC5 located at the confluence of Galena Creek and a tributary that flows from the northeast. In the willow leaves samples from the Silver King and Galena area, Cd and Zn concentrations are approximately seven times higher than the control values. Figure 2-15 shows that the Galena Creek sampling plots had higher Zn and Cd values in willow leaves than the GCTrib series of sampling plots. Note the relatively higher concentrations of Zn and Cd in willow leaves in the valley bottom at the confluences of Galena Creek and tributaries (plots GC5 and GC6). Some contamination may be coming from Flat Creek which runs below the Valley Tailings impoundment and joins Galena Creek and its tributaries near Plots GC6 and GC5. The valley bottom floods often in the spring when run off is high, but ice lenses in the peat prevent water absorption, so metal loading of these lower plots could deposited during periodic flooding of Flat Creek in addition to increased runoff.

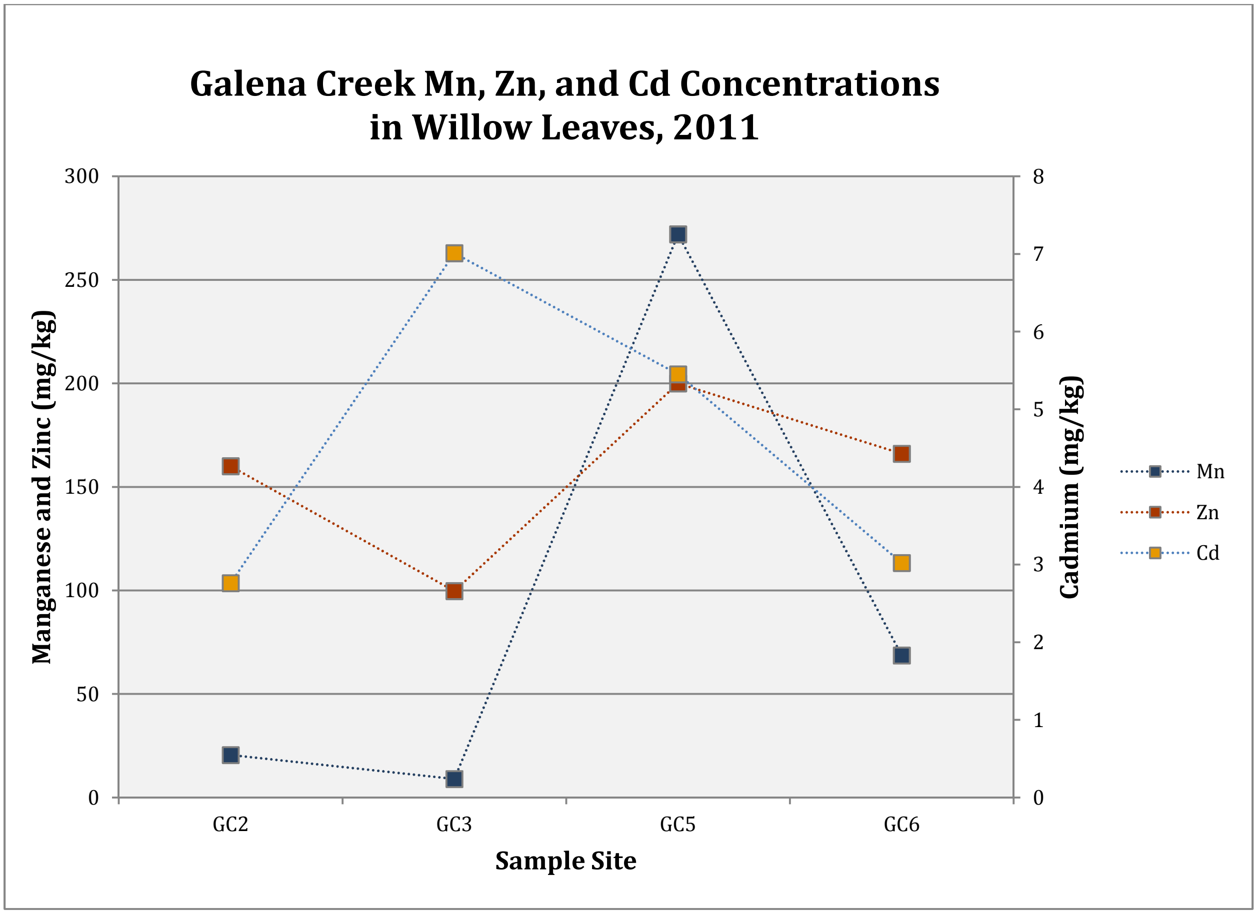

Figure 2-18 Graph of Galena Creek Mn, Zn and Cd Concentrations in Willow Leaves, 2011

Table 2-14 Galena Creek Ledum Sp. Leaves Tissue Metal Concentrations, 2011

Metals mg/Kg	GC4	GCTRIB5	GCTRIB7	Control Average
As	0.03	0.03	0.06	0.03
Cd	0.009	0.006	0.011	0.008
Cu	1.84	2.05	1.65	1.58
Fe	16	14	50	19.6
Pb	0.087	0.085	0.069	0.134
Mn	37.8	40.1	89.8	241
Ni	0.13	0.03	0.05	0.252
Zn	11	11.9	12.8	8.88

The three *Ledum* samples in the above table are near or below the control values, the highest values in this sample set were from plot GCTrib7, which is mid way between the Silver King adit and Flat Creek.

There is no graph or map depicting *Ledum* leaf tissue concentrations, as there were only three samples taken, not enough to illustrate a pattern of COPC depositions.

General Observations:

- Higher concentrations of Zn and Cd are found along Galena Creek than its western tributary.
- The lower sample sites, GC5 and GC6, could be receiving additional metal loads from several other streams and occasional flooding of Flat Creek.

2.6 SADIE LADUE

Sadie Ladue site is on the northwest side of Keno Hill at an elevation of 1260m. buildings and exposed mine waste, especially tailings, deposited downhill into a broad gully. There is a noticeable vegetation kill zone along the swath of waste. The gully narrows and deepens; some surface runoff collects in the gully then is joined by water coming from an adit drainage pipe just east of the Sadie Ladue Adit 600 and continues to flow to a lake approximately 3km below adit. Both soil and vegetation samples were taken at seven sites, SLV07 is at a small wetland which is just outside of the UKHM claim boundary (Figure 2-19)

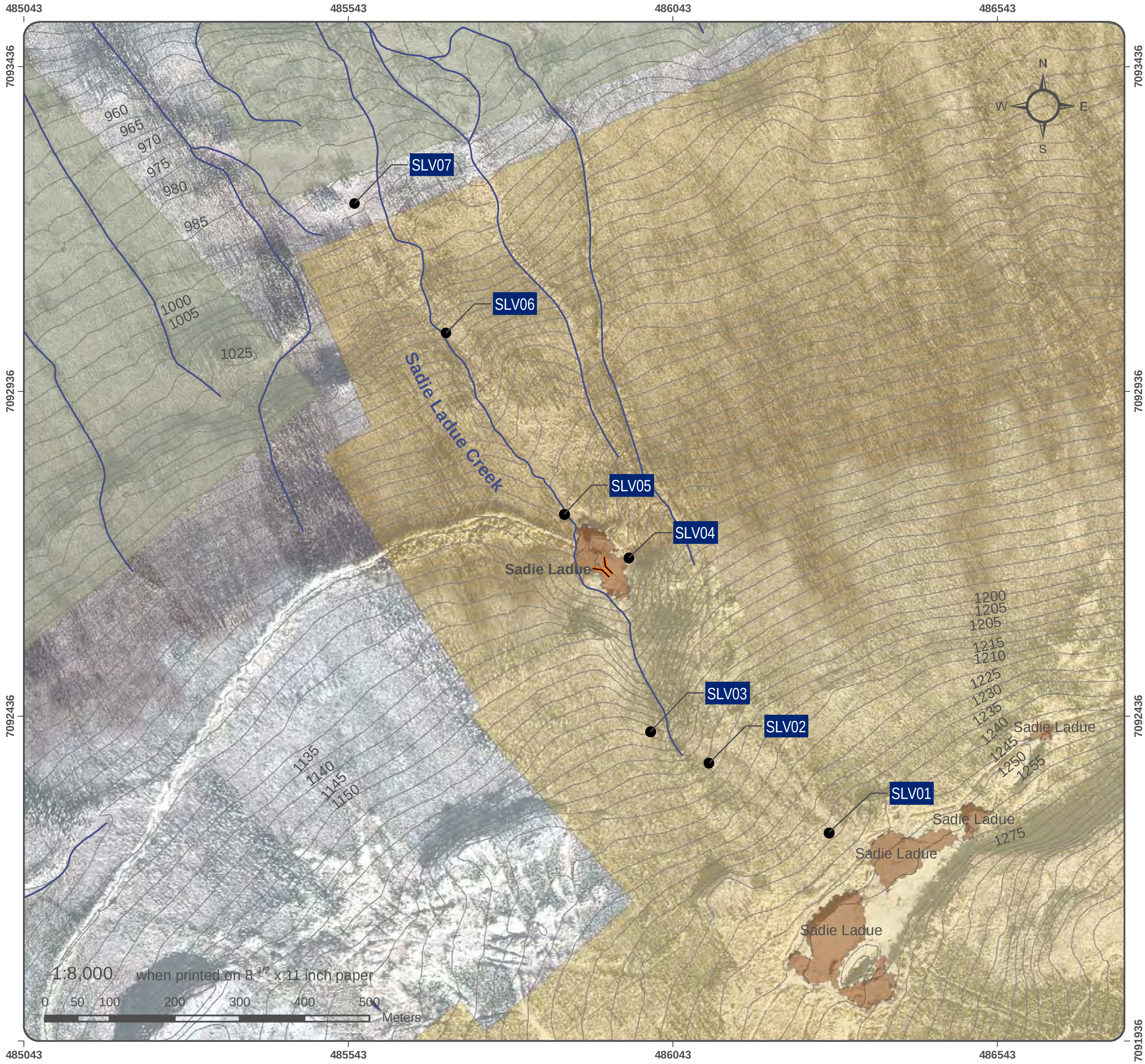

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FIGURE 2-19
SADIE LADUE SAMPLE SITES

MAY 2012

- Sample Site
- Adit
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-15 Sadie Ladue Metal Concentration in Soil Samples, 2011

Metals (mg/Kg) CCME Industry Limit (mg/Kg)	SLV02	SLV03	SLV05	SLV06	SLV07	Average Control Value
Sb (40)	98.4	2.2	49.4	46.8	34.2	1.8
As (12)	220	15.6	116	83.6	79.5	28.8
Ag (40)	84.6	0.59	63.3	82.7	44.7	0.19
Cd (22)	345	1.26	40.3	31.6	86.1	0.41
Cu (91)	82.9	32.8	58.3	56.2	47.3	25.2
Fe	2E+05	24000	1E+05	1E+05	77400	24000
Pb (600)	2420	25.2	1610	1510	1120	20.5
Mn	65400	718	29800	29900	20200	648.8
Ni (50)	11.1	27.9	22.4	21.7	24.8	25.0
Zn (360)	283	140	4550	2590	6960	91.6

The site SLV02 has very high concentrations of the COPC: Sb, As, Ag, Cd, Pb, Mn, and Fe. Plot SLV02 is approximately 300m below the Sadie Ladue shaft (Figure 2-19), and just above where the gully narrows at 1205 m elevation. Mine waste material has accumulated at this location; many trees and shrubs have died or are stressed around this site (see Photo 8 and 9). Another soil "hotspot" is plot SLV07 where Cd and Zn are at high concentrations. The Plot SLV07 is on a bench where the stream runoff pools into a small wetland and sediments drop out. This wetland is well vegetated with sedges (*Carex*), grasses and numerous shrubs, that could have developed a tolerance to the presences of heavy metals.

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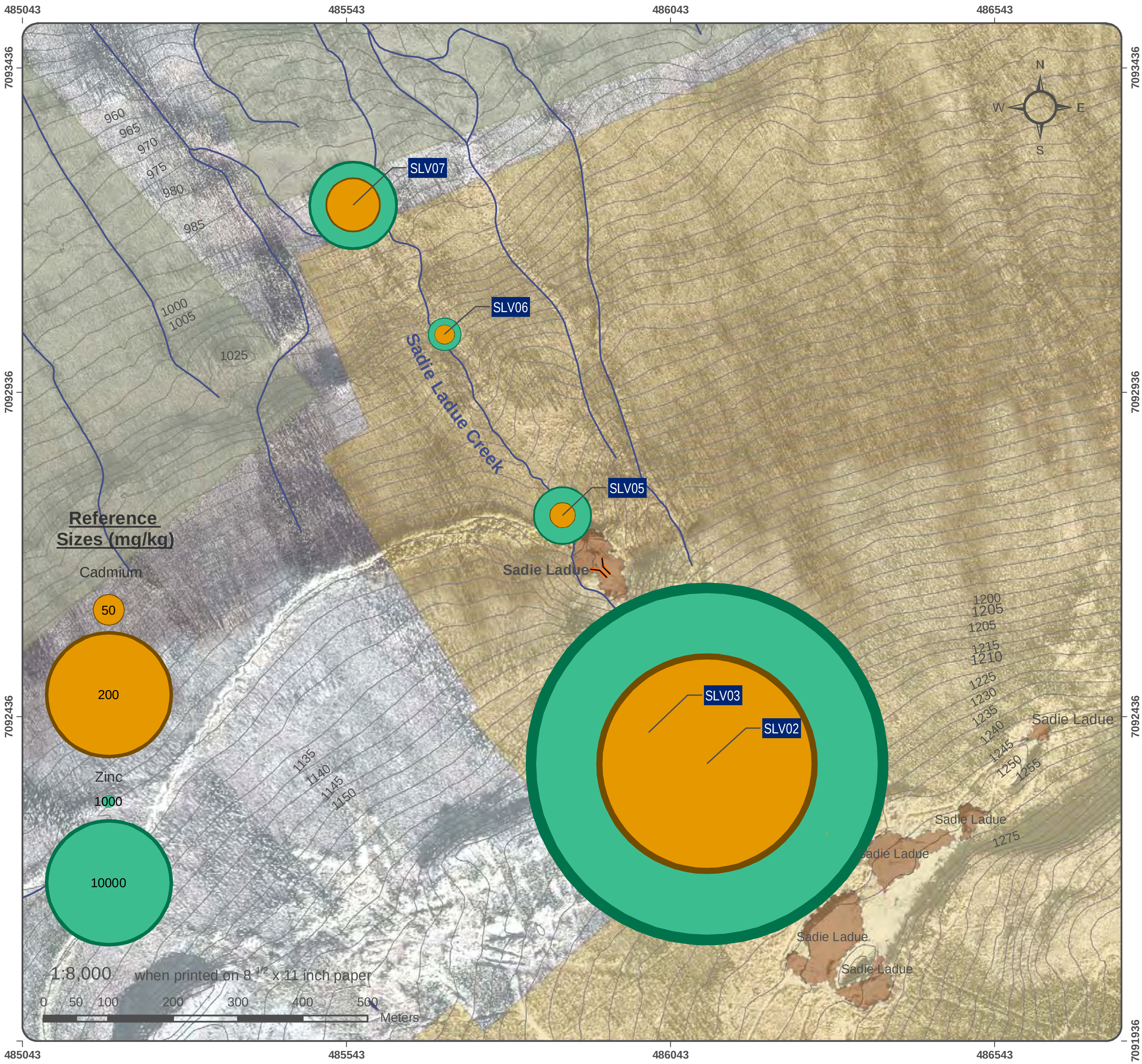
KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-20 SADIE LADUE ZN AND CD CONCENTRATIONS IN SOIL, 2011

MAY 2012



- Soil Cadmium (mg/kg) / 2
- Soil Zinc (mg/kg) / 100
- Adit
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-16 Sadie Ladue Metal Concentrations in Willow Samples

Metals mg/Kg	SLV01 Willow	SLV02 Willow	SLV03 Willow	SLV04 Willow	SLV05 Willow	SLV06 Willow	SLV07 Willow	Avg Control Value
Sb	0.01	0.035	0.008	0.015	0.021	0.026	0.048	0.006
Ag	0.024	0.041	0.006	0.007	0.016	0.009	0.04	0.006
As	0.02	0.09	0.01	0.02	0.04	0.02	0.09	0.04
Cd	11.9	3.49	1.07	9	18.9	15.1	10.7	1.02
Cu	2.08	1.18	1.19	1.47	1.27	1.04	0.61	1.32
Fe	17	111	14	14	43	18	98	20.2
Pb	0.652	1.81	0.115	0.089	0.589	0.148	1.45	0.20
Mn	32.7	137	56.9	28.8	58.9	19.3	78	62.9
Ni	0.89	3.54	0.25	0.54	0.42	0.42	0.24	2.1
Zn	608	605	129	365	609	563	643	36.8

The most elevated concentrations for Sb, As, Ag, Cd, Pb, Mn, and Fe occur in the soil sample from SLV02, but only Fe, Mn and Ni were elevated the willow leaf tissue collected at SL02. Some of these metals, such as Pb do not accumulate in leaf tissues, but are stored in the root system. Both Zn and Cd do accumulate in leaves (Mathe-Gaspar and Attila, 2005) both metals are seen at high concentrations in willow leaf samples in all the Sadie Ladue samples, especially at SLV07. The Zn concentration is relatively high in the willow leaves in all samples, as are Cd levels when compared to control values. The willow leaf concentrations of Cd and Zn change in tandem from site to site, and then diverge at SLV07 (Figure 2-21). Mn levels in leaf tissue are low compared to soil concentrations

No Ledum leaves were collected at along the Sadie Ladue as the growth conditions were poor for this shrub so specimens were scarce at plot sites.

Die back of plants in the swath of tailings are likely being caused by Zn toxicity and other heavy metals(see Photos 8 and 9).

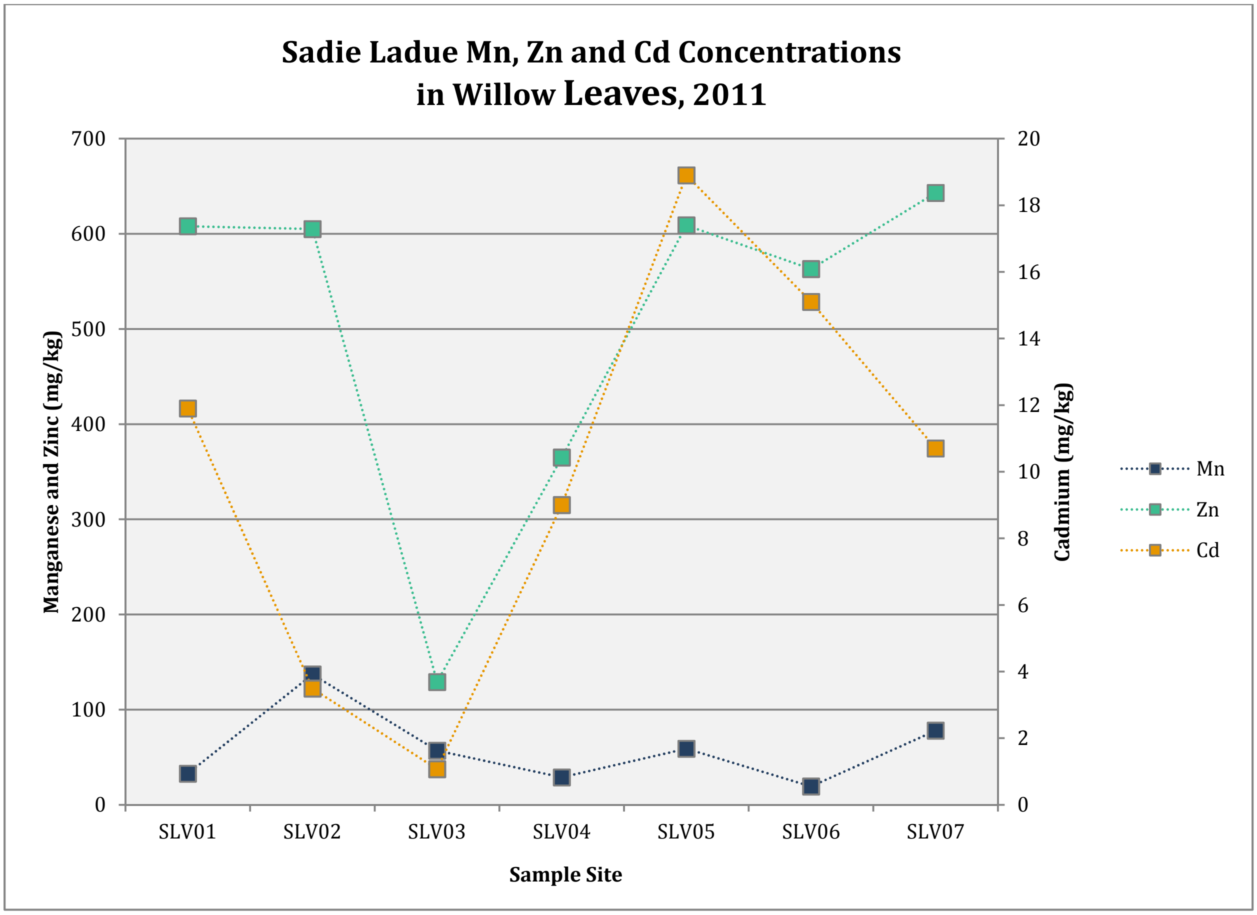

Figure 2-21 Graph of Sadie Ladue Mn, Zn and Cd Concentrations in Willow Leaves, 2011

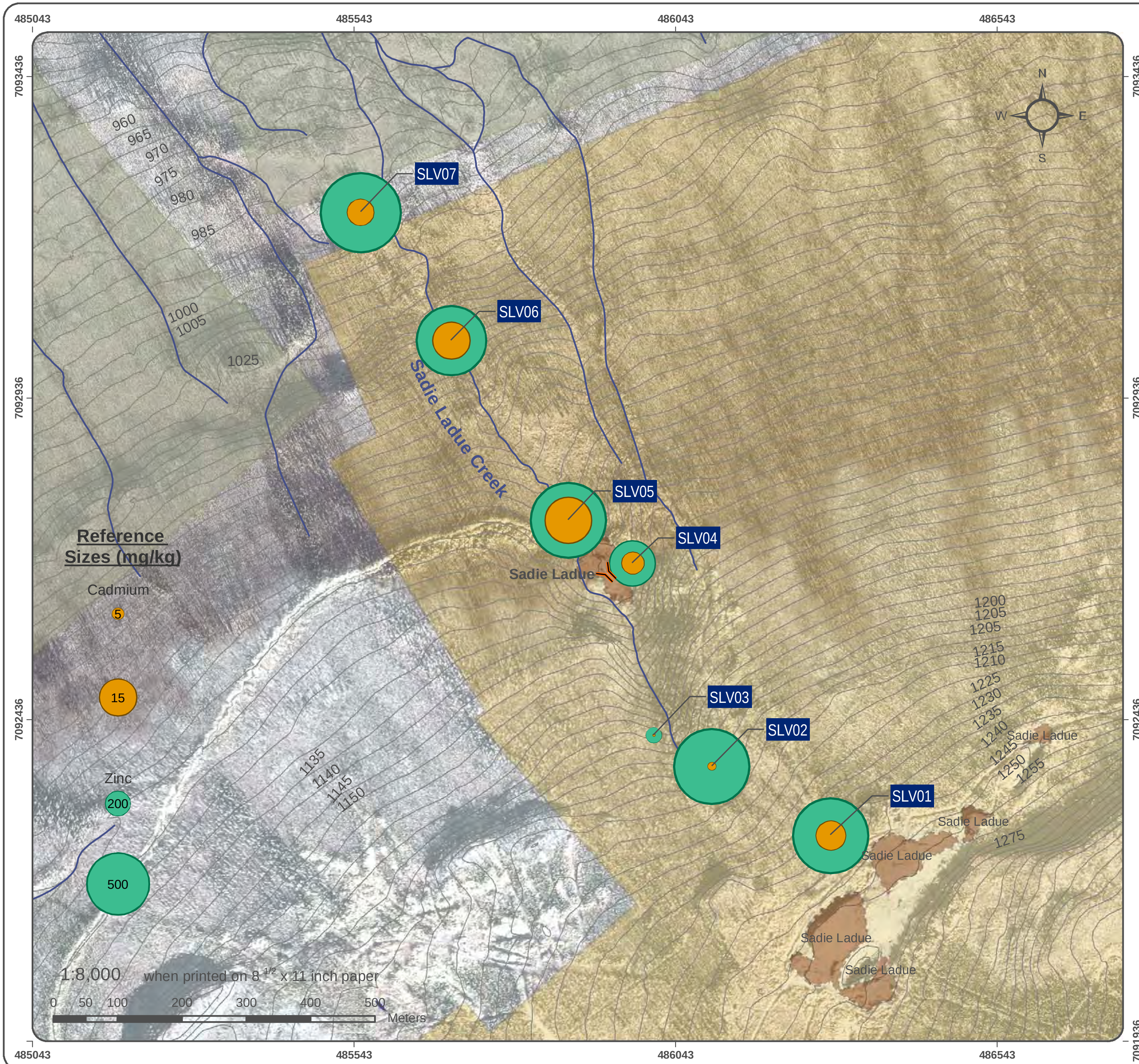

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FIGURE 2-22 SADIE LADUE ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012

- Willow Cadmium (mg/kg) * 2
- Willow Zinc (mg/kg) / 10
- Adit
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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General Observations:

- The plot SLV02, closest to Sadie Ladue mine portal, has very high soil concentrations of Sb, Cd, Pb, As and Ag, levels are above the CCME industrial thresholds.
- The Zn concentration in willow leaves are very high throughout the sampling series.
- Cd and Zn concentrations in willow leaves follow a parallel pattern till SLV07, where Cd levels decrease and Zn is at its maximum for the sampling sites.
- Sadie Ladue drainage has some of the highest Pb deposits than other point sources.
- Wetland plants located near SL07 could be heavy metal tolerant, useful cultivars for future reclamation efforts.

2.7 MINE TAILING SITES

Two mine tailings deposit sites were visited for soil and vegetation collection: MacKeno Tailings and Valley Tailings. Historically tailings were deposited in the MacKeno area predominantly in the 1950s, and in the Elsa area beginning in the 1930s and in a much larger way beginning in the late 1950s through the 1980s. As would be expected high concentrations of COPCs were detected in soil samples taken from both areas,

2.7.1 MacKeno Tailings

The MacKeno Tailings impoundment is 1.5km northwest of Keno City on the east side of Christal Lake. The surface of the tailings had been recently graded and was left bare. The tailings area is approximately 7500m^2 surrounded on three sides by mature white spruce forest, on the west side is the Christal Lake shoreline. A thin margin of sedges and grass are between the exposed tailings and the water (see photos 16 and 17). Seven plot locations were revisited and new soil and vegetation samples were collected, the data is presented in the following tables and figures.

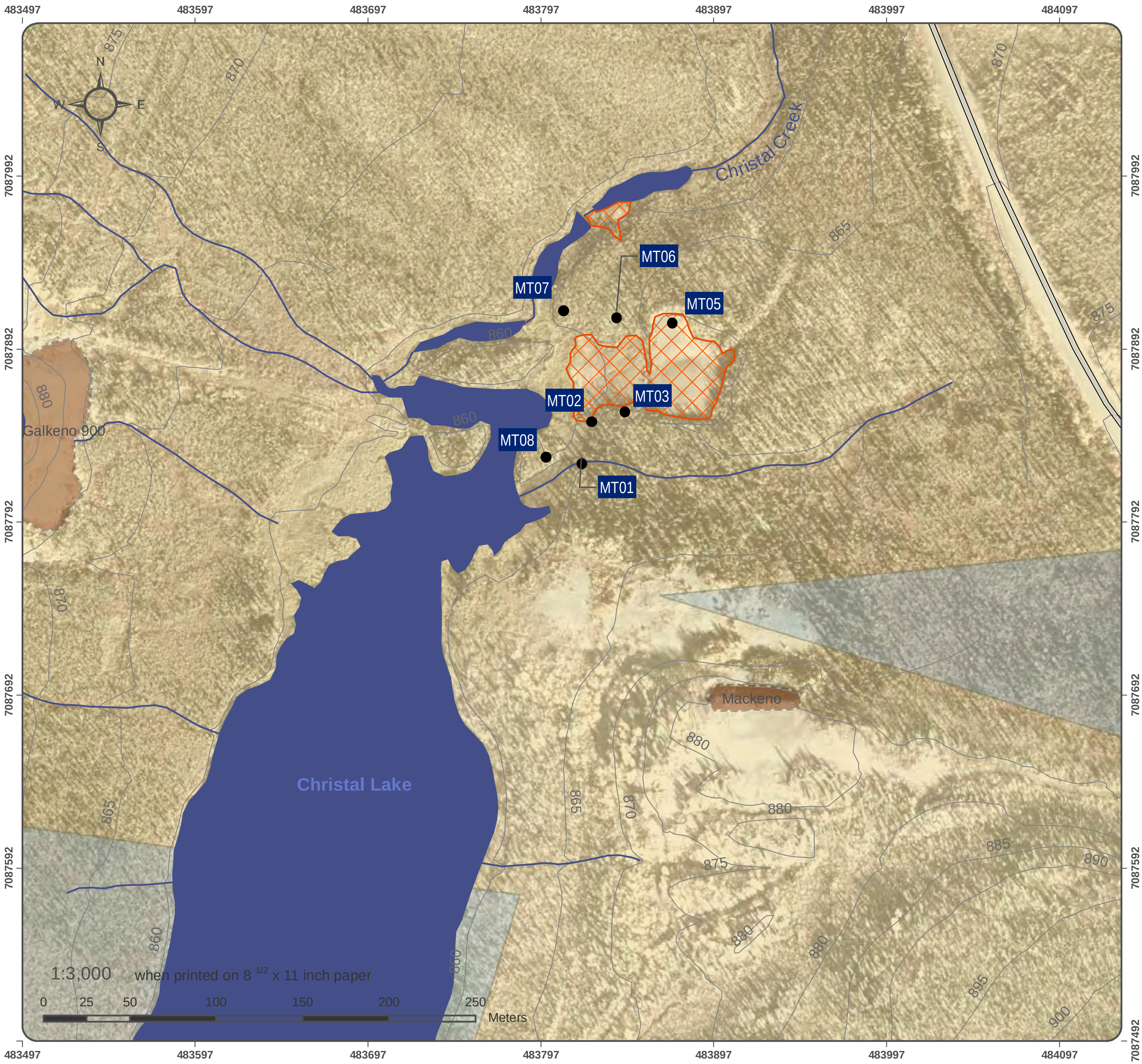

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FIGURE 2-23 MACKENO TAILINGS SAMPLE SITES

MAY 2012

- Sample Site
- Silver Trail Highway
- MacKeno Tailings
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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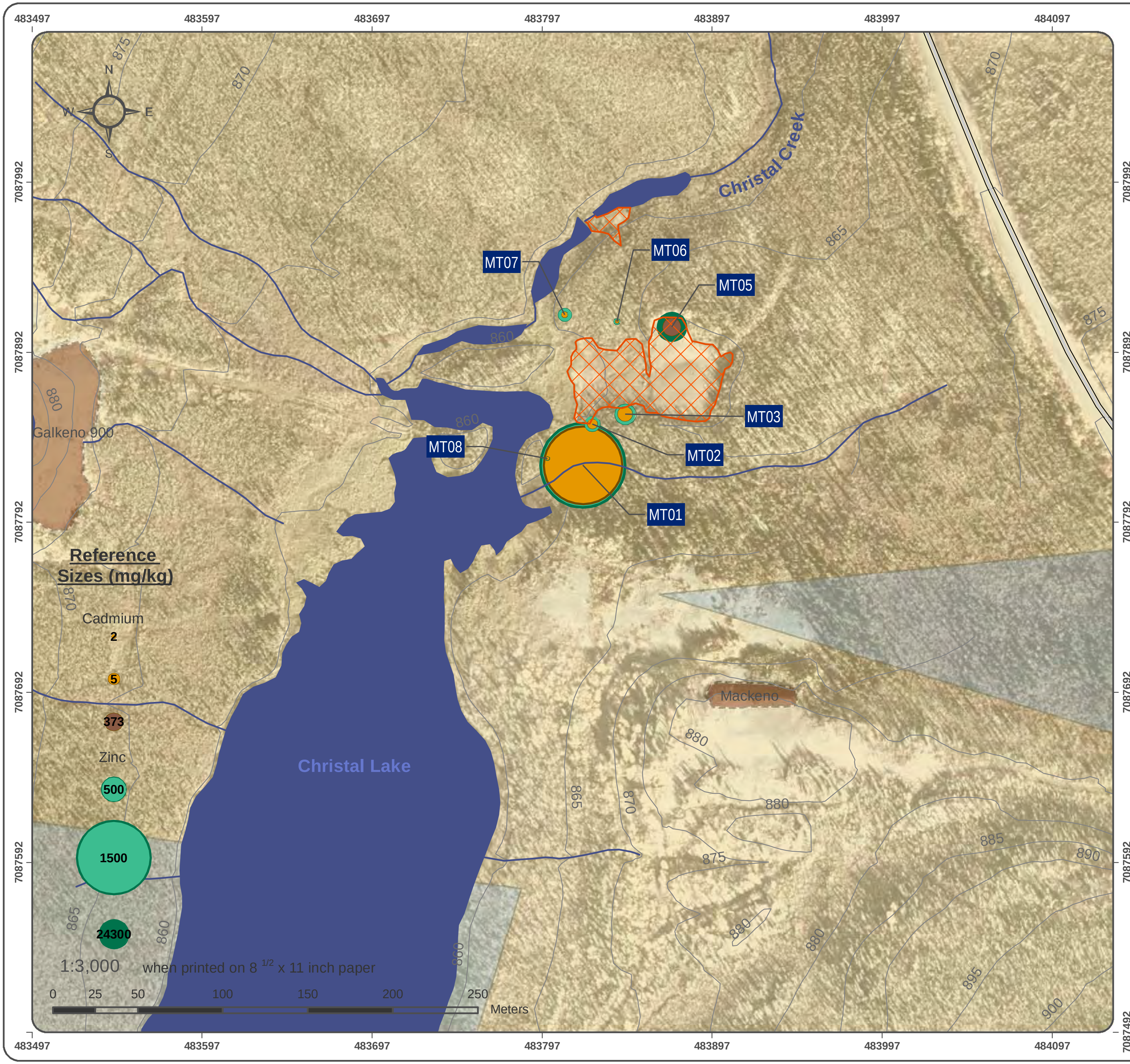
Table 2-17 MacKeno Tailings Metal Concentrations in Soil Samples

Metals (mg/Kg) CCME Industry Limit (mg/Kg)	MT01	MT02	MT03	MT05	MT06	MT07	MT08	Average Control Value
Sb (40)	11.5	2.5	1.9	256	2.1	3.8	1.4	1.8
As (12)	252	40.9	39.9	1840	21.3	154	32.7	28.8
Ag (40)	2.59	0.65	0.5	87	0.48	1.15	0.39	0.19
Cd (22)	64	4	6.06	373	1.63	2.78	1.44	0.41
Cu (91)	47.3	37.9	76.9	133	38.7	47.4	40.3	25.2
Fe	22200	19300	27100	70100	18000	26300	15700	24000
Ni (50)	35.1	25.4	72.1	20	25	33.3	16.4	25.0
Pb (600)	166	40.1	32.4	6620	41.7	92.1	26.3	20.5
Se (2.9)	2.4	2.1	1	1.4	1.4	2.7	2.8	0.56
Zn (360)	1720	318	433	24300	140	288	97	91.6

The sample site MT05 (Figure 2-24) is located in the non-vegetated area of tailings, the soil analysis of this plot show that the concentrations of COCPs were well over the guideline thresholds and control values, Zn and Cd were at particularly elevated concentrations. The MT01 site was also high in As, Zn and Cd, this soil sample was taken on the north side of a small stream that drains into Christal Lake, approximately 50m away. The MT01 site was disturbed and partially vegetated, but the plants in this location appeared stressed.

Antimony (Sb) is presented in this table as it is approximately six times above the CCME industrial guidelines and was only found in low concentrations at the other sites included in this baseline study. Also, Se is shown in the above table, although not over its CCME guideline threshold of 2.9 mg/kg, there is possibility that it may occur at higher levels in the area.

Note that the plot MT04 was not sampled, as this location is in exposed tailings the same as MT05. So, taking two samples seemed like a duplication of effort. MT08 was on a small forested peninsula and did not appear to have tailings deposited on its surface as the soil profile was undisturbed and ground cover was intact and had a high percent cover of lichens.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-24 MACKENO TAILINGS ZN AND CD CONCENTRATIONS IN SOIL, 2011

MAY 2012

- Soil Cadmium (mg/kg) * 2
- Soil Cadmium (mg/kg) / 25
- Soil Zinc (mg/kg) / 25
- Soil Zinc (mg/kg) / 1000
- Silver Trail Highway
- Watercourse
- Waterbody
- MacKeno Tailings
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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As illustrated on the map, aside from the high concentration of Cd and Zn at MT05, the MT01 soil sample also has elevated Cd and Zn. The MT05 sample was taken near a small stream that flowed through a forested area. The stream does run through a disturbed area where heavy equipment had pushed through a rough access route and the soil profile showed that the horizons were mixed with tailings. MT02 and MT02 sites were also taken from locations that were disturbed and near the edge of the tailings. The sample sites in the northern part of the study area are vegetated and do not appear to have been disturbed.

There are signs that Christal Lake has fluctuating water levels, when in flood the lake water will be in contact with the tailings impoundment and there is likely contaminants reaching the lake through runoff.

Table 2-18 MacKeno Tailings Metal Concentrations in Willow Samples

Metals (mg/Kg)	MT01	MT02	MT03	MT06	Avg Control Value
Sb	0.398	0.081	0.063	0.096	0.006
Ag	0.098	0.058	0.054	0.067	0.006
As	2.06	0.63	0.33	0.64	0.04
Cd	12.8	11.1	6.8	11.8	1.02
Cu	1.67	1.6	2.31	2.28	1.32
Fe	79	41	39	44	20.2
Pb	6.34	2.82	2.78	3.79	0.20
Mn	140	156	125	93.3	62.9
Ni	0.39	3.97	5.05	6.1	2.1
Zn	458	391	391	187	36.8

The willow leaf samples from plot MT01 contain the highest overall levels for COPCs in the MacKeno area, except for Mn, Ni and Cu. The willow leaves also had the highest concentrations of Cd and Zn, which corresponds to the elevated concentrations of these two metals in the soil at that location. A direct relationship cannot be confirmed with such a small sample, more sampling would need to be undertaken to determine that correlation.

In Figure 2-25 the plots with the higher Zn and Cd concentrations in willow leave tissue are MT01, MT02 and MT03, which are in close proximity to each other and in the southern part of the MacKeno tailings.

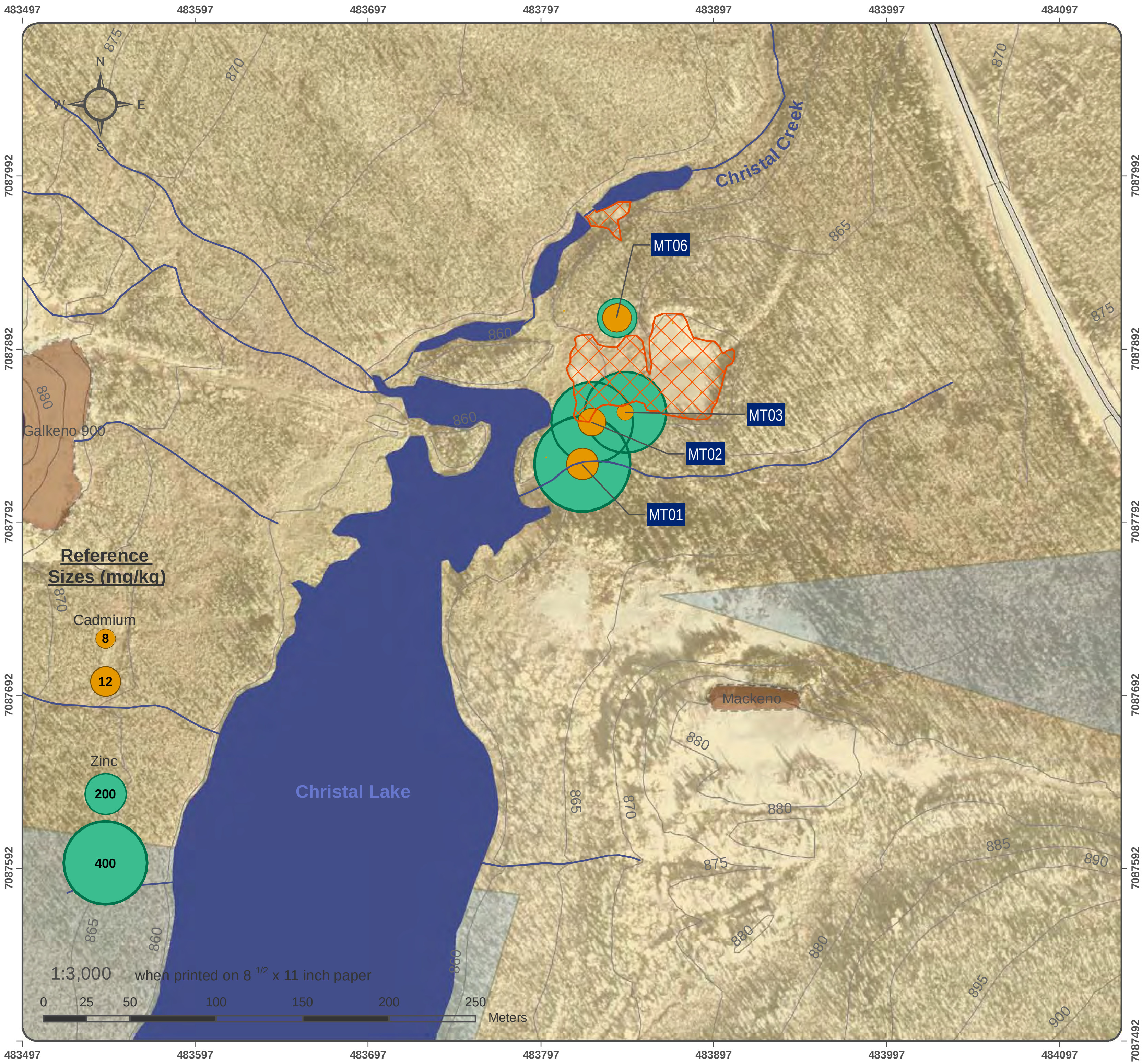

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FIGURE 2-25 MACKENO TAILINGS ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012

- Willow Cadmium (mg/kg) * 2
- Willow Zinc (mg/kg) / 6
- Silver Trail Highway
- Watercourse
- Waterbody
- MacKeno Tailings
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-19 MacKeno Tailings Metal Concentrations in Ledum Samples

Metals (mg/Kg)	MT01	MT03	MT07	MT08	Avg Control Values
Sb	0.089	0.069	0.24	0.038	0.005
Ag	0.054	0.063	0.157	0.031	0.005
As	0.64	0.48	1.28	0.24	0.03
Cd	0.131	0.098	0.199	0.041	0.008
Cu	2.46	2.8	2.5	2.44	1.58
Fe	31	31	46	23	19.6
Pb	3.24	4.28	8.97	1.86	0.134
Mn	203	452	627	266	241
Ni	0.21	0.42	0.25	0.39	0.252
Zn	23.2	30.5	26.2	16.3	8.88

The Ledum leave tissues with the higher metal concentrations come from site MT07, which is a shrub and grass covered slope, with no recent disturbances apparent. At MT03 the Ledum sample had higher values for Cu, Ni and Zn which was also the case for willow leaves collected at this site (Figure 2-26).

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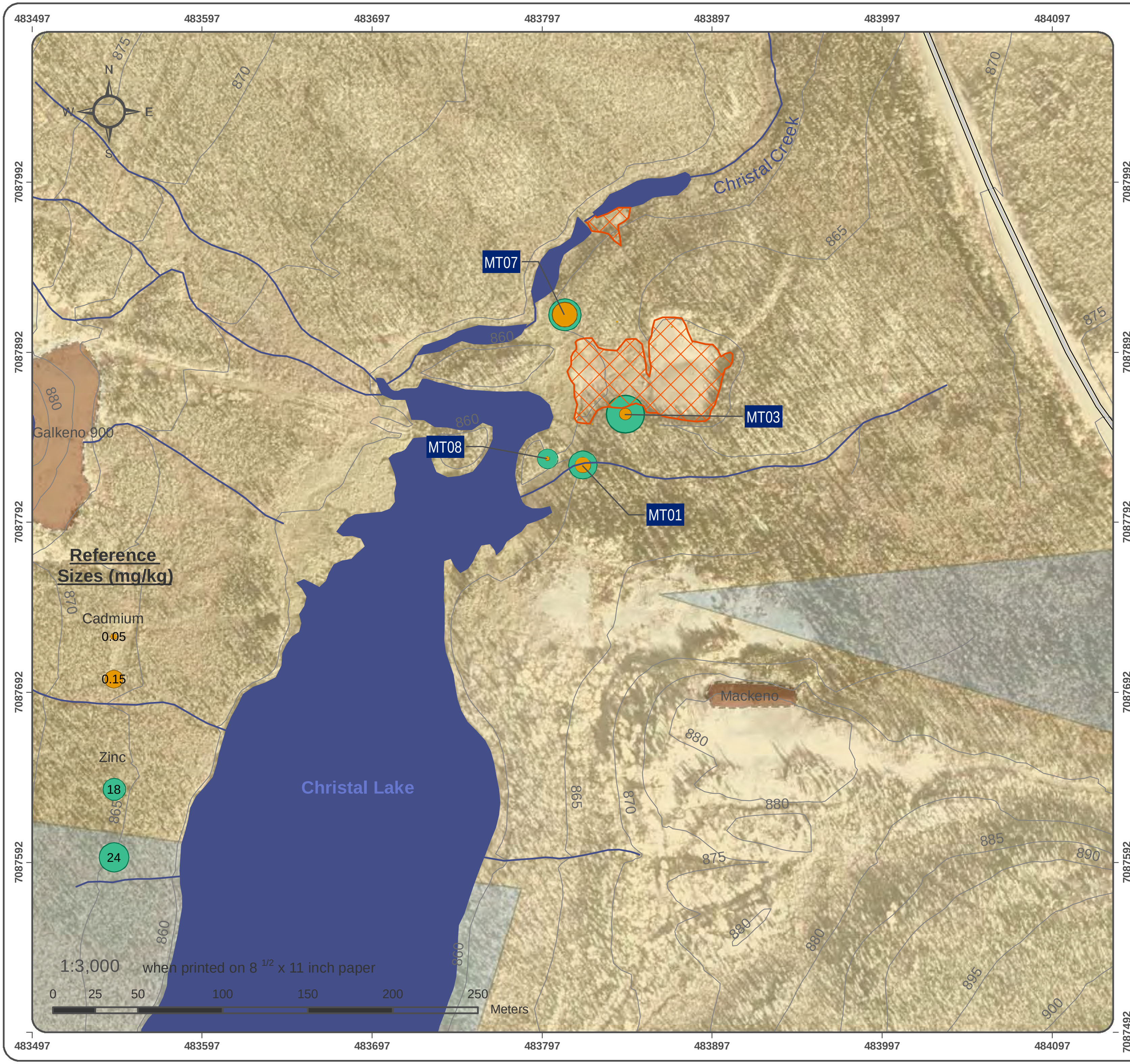
FIGURE 2-26 MACKENO TAILINGS ZN AND CD CONCENTRATIONS IN LEDUM LEAVES, 2011

MAY 2012



- Ledum Zinc (mg/kg)
- Ledum Cadmium (mg/kg) * 100
- Silver Trail Highway
- Watercourse
- Waterbody
- MacKeno Tailings
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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General Observations:

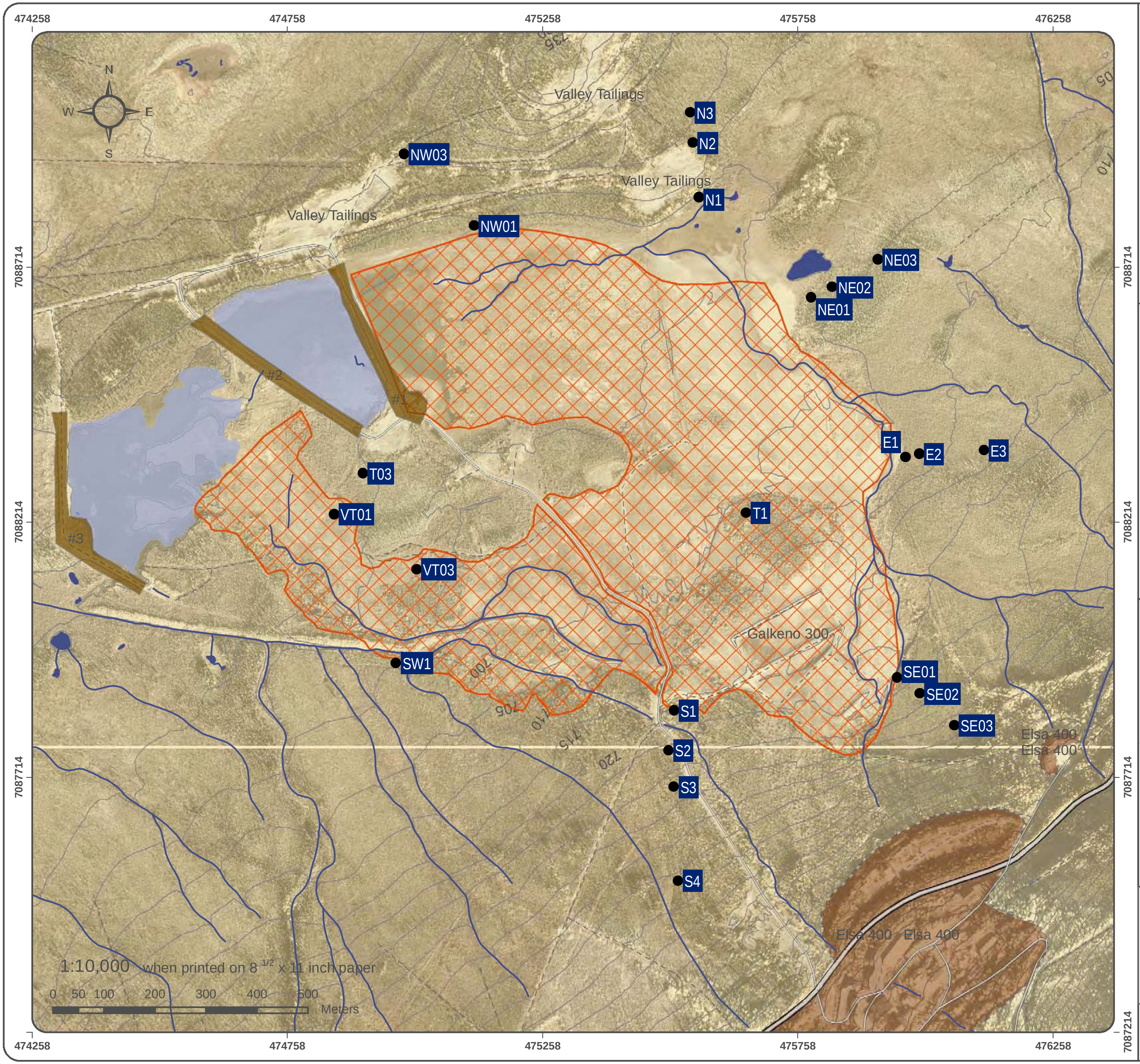
- MT05 had the highest COPC concentrations; this soil sample was of tailings material and had no vegetation growth nearby to show corresponding vegetation uptake levels.

- The plot with the next highest COPC levels in soils was at MT01, where both willow and Ledum were sampled. The willow leaf tissue exhibited corresponding high levels of Zn and Cd as well as the other elevated soil constituents e.g. Pb, Fe and As.

- Ledum collected from MT01 did not show high concentrations relative to the soil COPC profile, instead Ledum had high concentration of Zn at MT03 and high Cd concentrations at MT07.

2.7.2 Valley Tailings

The valley tailings are below the town of Elsa in the valley flats of the McQuesten River. Plots radiate from the tailings impoundment in seven directions: N, NE, E, SE, S and SW. The sampling plot layout (Figure 2-27) is based on EDI Terrestrial Effects Study-Phase 1 the purpose of which was to determine the extent of windborne contamination of lichens. The prevalent winds caused deposits of contamination to be heaviest in the E-SE direction. That trend is confirmed in the following table where the highest level of COPC is in the centre of the tailings impoundment at VT01, VT02 and VT03. These sites are exposed tailings, where very little or no vegetation has regenerated.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-27 VALLEY TAILINGS SAMPLE SITES

MAY 2012

- Sample Sites
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- Valley Tailings Pond
- Valley Tailings
- Dam
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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Table 2-20 Valley Tailings Metal Concentrations in Soil Samples

	Metals Concentrations (mg/Kg)								
Plot #	Sb (40)	As (12)	Ag (40)	Cd (22)	Cu (91)	Fe	Pb (600)	Ni (50)	Zn (360)
E01	671	1100	159	54.3	498	87800	183	9.8	3350
E02	4.8	24.4	0.92	1.07	66.4	20900	33.9	29.8	148
N01	1.3	15.7	0.2	0.48	31.3	21000	12.7	25.1	79
N02	1.5	15.1	0.2	0.36	31.6	21000	17.3	24.8	77
N03	1	12.8	0.16	0.63	35	19600	11.2	24.6	86
NE01	193	520	84.5	65.1	117	64000	18.9	8.8	2850
NE02	2.2	19.4	0.29	0.57	35.1	20700	14.6	23.4	87
NE03	1	16.8	0.27	0.6	36.8	20800	16.2	26.6	109
NW02	1.3	15.5	0.15	0.11	31.4	24100	15.9	26.8	57
S1	32.8	246	18.1	13.5	63.3	36200	1220	30.7	787
S2	257	1100	128	81.5	221	83100	15200	18.3	6040
SE1	254	1940	94.8	109	307	108000	8150	14.6	6780
SE2	1	22.4	0.42	109	48.1	17300	28.7	20.2	67
T01	0.168	0.49	0.074	0.056	2.12	44	6.3	0.14	25
T03	0.8	14.5	0.19	0.34	29.8	21300	14	23.9	72
VT01	204	1660	88.7	81.8	114	138000	6170	12.4	5670
VT02	272	2030	82.2	141	177	140000	9580	12.1	9510
VT03	439	7750	58.6	119	253	239000	23400	32.4	8160
Average Control Values	1.8	28.8	0.19	0.41	25.2	24000	25	20.5	91.6

Arsenic (As) concentrations in eight of the plots exceeds the control background level of 28.8 mg/kg. Those plots are located on the tailing or close to the edge of the tailings. The plots VT01, VT02 and VT03 have high COPC concentrations as the soil samples were taken directly from the tailings material. At these three plots all the COPC listed were over their CCME thresholds for industrial areas, except for Ni. Two other plots with relatively high metal concentration for the area are: E01 is at the edge of a white spruce forest that borders the east side of Valley Tailings, the soil sampled was taken from a disturbed area by the tailings edge, the soil analysis showed a high concentration of Sb at this location. The S2 plot just west of the access road and less than a kilometer downhill from Elsa, it is vegetated but has been disturbed by road building and earlier clearing (Figure 2-27).

The map (Figure 2-28) shows the location of the contamination “hotspots” within the limits of the sampling effort. As would be expected, the plots located directly on the tailings have the highest concentrations of Cd and Zn. The other areas that are highlighted on the map are the southern and eastern plots that are in the vegetated areas surrounding tailings impoundment but closest to the impoundments edges.

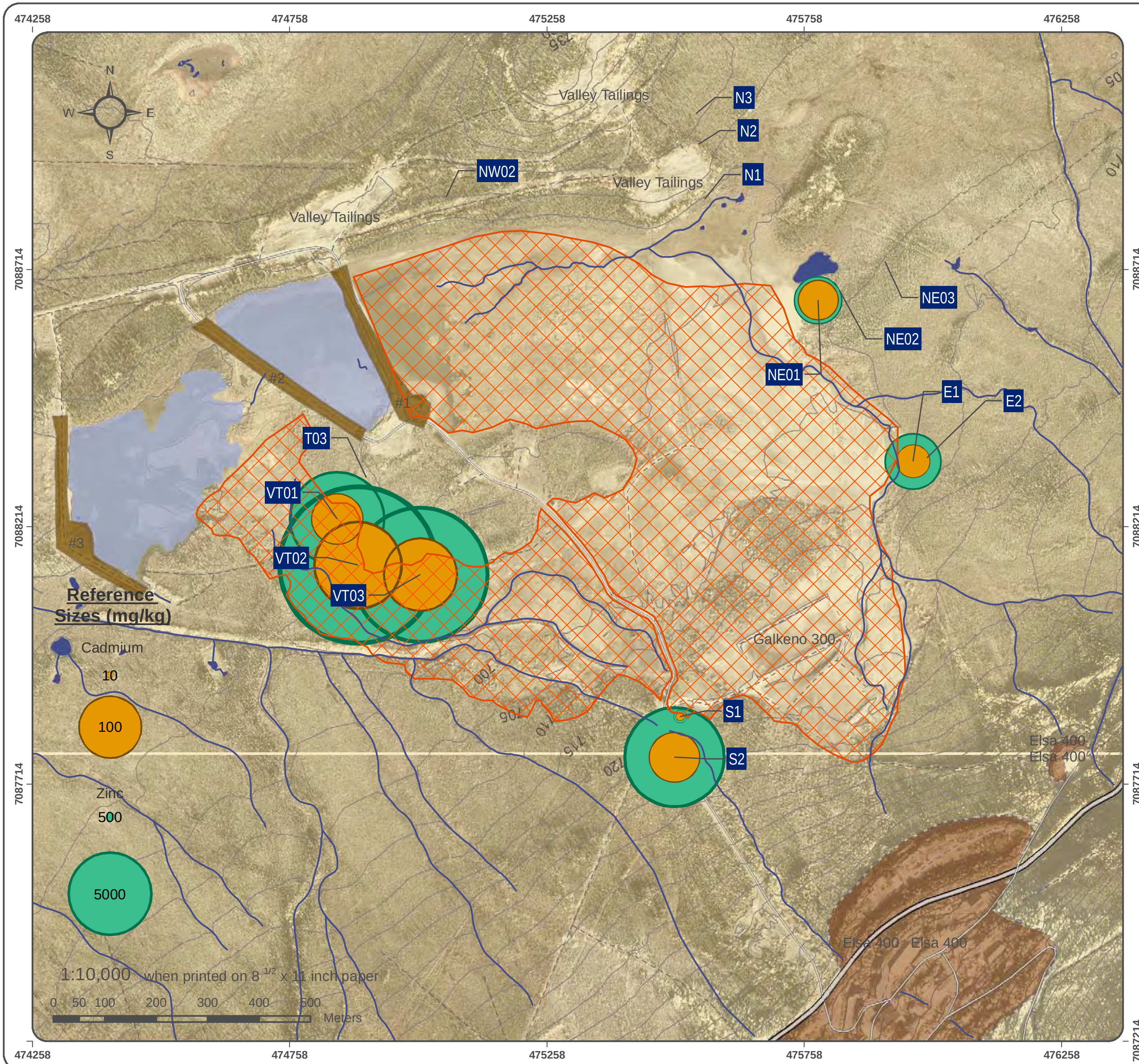

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FIGURE 2-28
VALLEY TAILINGS ZN AND CD CONCENTRATIONS IN SOIL, 2011

MAY 2012

- Soil Cadmium (mg/kg) / 2
- Soil Zinc (mg/kg) / 75
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- Valley Tailings Pond
- Valley Tailings
- Dam
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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The maps of Zn and Cd concentrations in willow and Ledum leaf tissues show that the higher metal content came from the plots in the southern and eastern sections (Figures 2-29 and 2-30). There is a trend of decreasing metal concentrations the further the sample is taken from the tailings. Wind borne dispersal of contaminants from the Valley Tailings was found to follow the path of the prevailing winds and settle out in the southeastern portion of the area and beyond the tailings area (EDI, 2008). The southern plots S1,S2, S3, S4 plus SE01,SE02,SE03 may also be receiving metal loads by water transport as these plots are downhill of Elsa and old mine workings.

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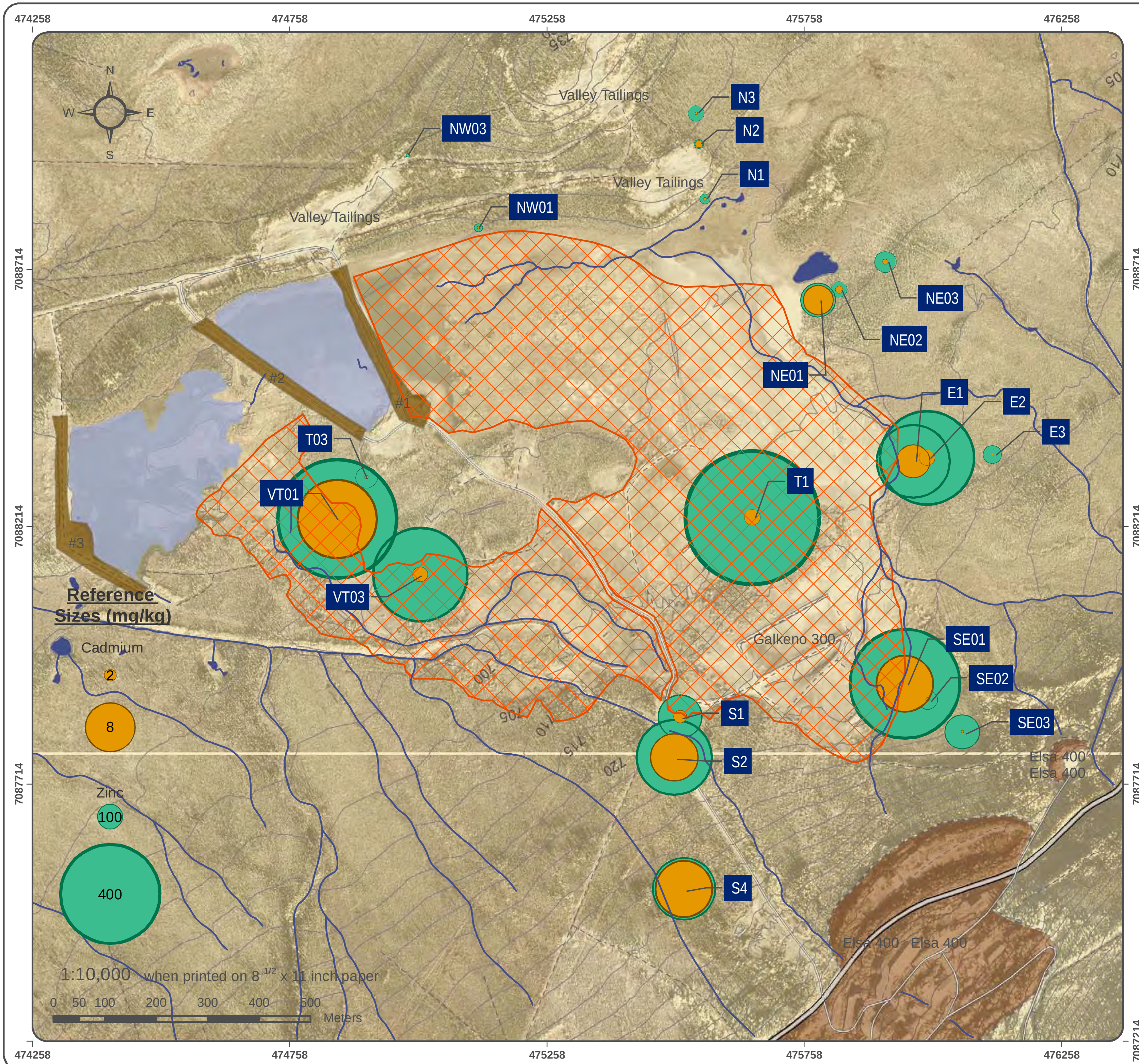
KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-29
VALLEY TAILINGS ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012



- Willow Cadmium (mg/kg) * 5
- Willow Zinc (mg/kg) / 5
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- Valley Tailings Pond
- Valley Tailings
- Dam
- ERDC Owned Quartz Claims
- Waste Rock Dump

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Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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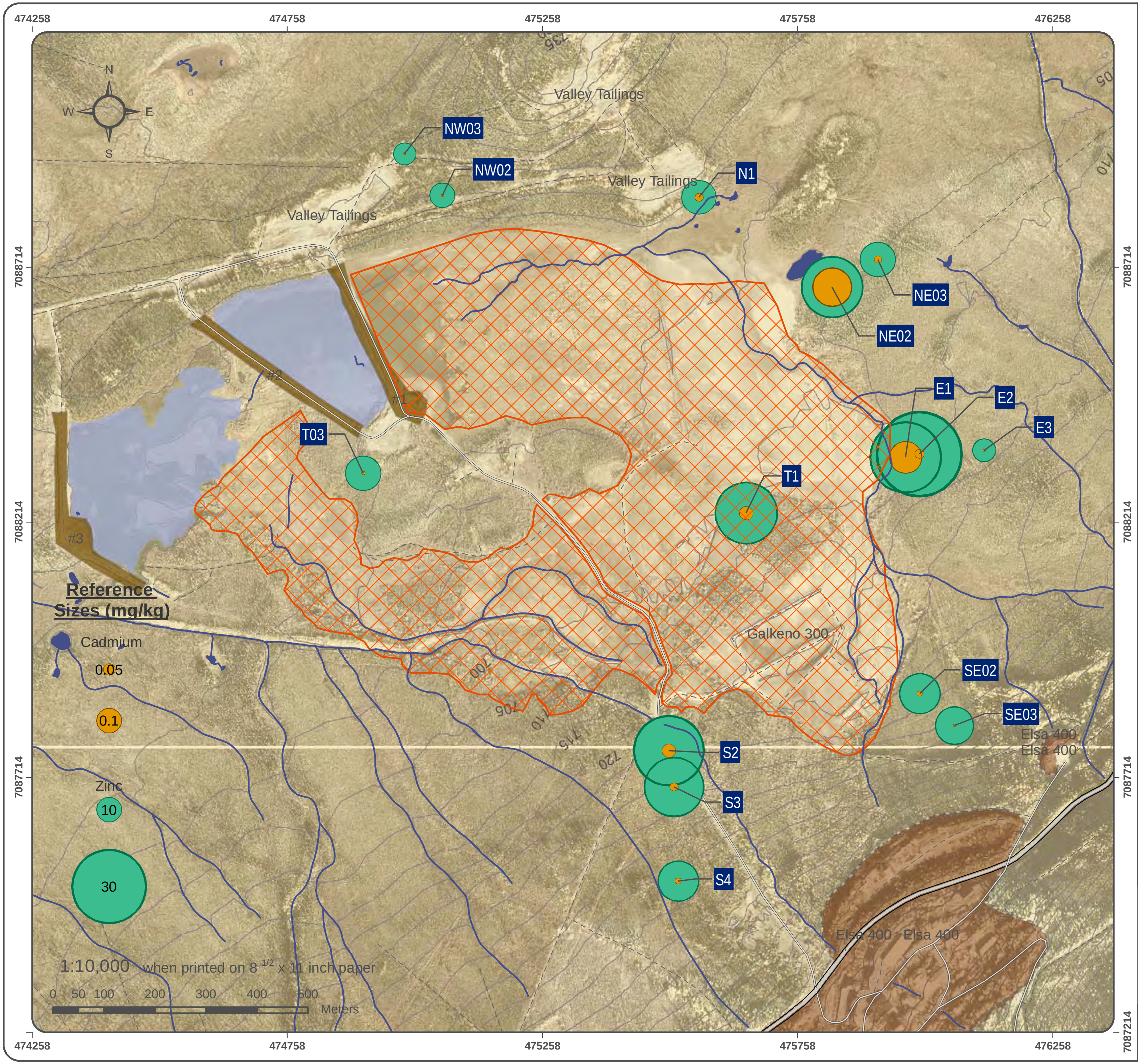

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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-30 VALLEY TAILINGS ZN AND CD CONCENTRATIONS IN LEDUM LEAVES, 2011

MAY 2012

- Ledum Cadmium (mg/kg) * 200
- Ledum Zinc (mg/kg) * 2
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- Valley Tailings Pond
- Valley Tailings
- Dam
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

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2.8 OTHER DISTRICT SAMPLING SITES

This is the initial baseline survey for Hector, Calumet and Calumet C waste dump areas, only a small number of plots were put in, so the data for all three areas are contained in one table (Table 2-21). The sampling sites were all downhill of waste rock dumps (Figure 2-31). Below Hector, was a swath of dead trees and shrubs, moss was covering moist areas of otherwise bare soil (Photo 18). Some of the vegetation sampled was regenerating on coarse fragments of mining waste that now cover the original forest floor.

Calumet area is similar in appearance; the vegetation regenerating at this site has a higher percent cover and is less stressed than at Hector. The Calumet C waste area is less disturbed has more shrub cover and vegetation succession has progressed further than at Hector and Calumet (Photo 19). The heavy metal uptake by willow is also lower at Calumet C than at Calumet and Hector (Table 2-21).

Table 2-21 Metal Concentrations in Soil Samples at Calumet, Calumet C and Hector Waste Dumps

Metals(mg/Kg) CCME Industry Limit (mg/Kg)	Calumet CAL01	Calumet CAL02	Calumet C CC01	Calumet C CC02	Hector H01	Hector H02	Hector H03	Hector H04	Average Control Value
Sb (40)	0.7	0.6	1	1.1	1.5	1.3	1.1	1.1	1.8
As (12)	46.9	16.1	13.3	14.5	11.1	15.9	13.1	11.3	28.8
Ag (40)	6.24	3.07	0.23	0.25	1.51	1.31	1.19	1.13	0.19
Cd (22)	2.75	0.98	0.2	0.22	12.6	13.3	4.03	23.9	0.41
Cu (91)	27.3	12.5	20.1	22	15.1	16.2	12.5	12.1	25.2
Fe	333000	238000	23200	24500	19100	22500	24000	18000	24000
Ni (50)	25.1	18.5	16.2	19.2	44.7	40.3	20.5	20.4	20.5
Pb (600)	155	87.9	27.2	23.1	72.4	62.7	44.1	26	25.0
Zn (360)	232	156	62	65	2240	962	534	461	91.6

The Hector area soil samples have the higher concentrations of Zn and Cd in all four of the plots situated down slope of the Hector waste rock apron, Zn is persistently high and over the CCME guideline levels. Calumet area, particularly plot CAL01 has the relatively higher concentrations of Pb and Cu, but neither of these two metals were over their CCME guideline thresholds for industrial sites. The Waste area of Calumet C had the least amount of COPC, and soil concentrations were well below CCME guideline thresholds. This area has recovered from past disturbances and has a healthy cover of willow and scrub birch (Photo 19).

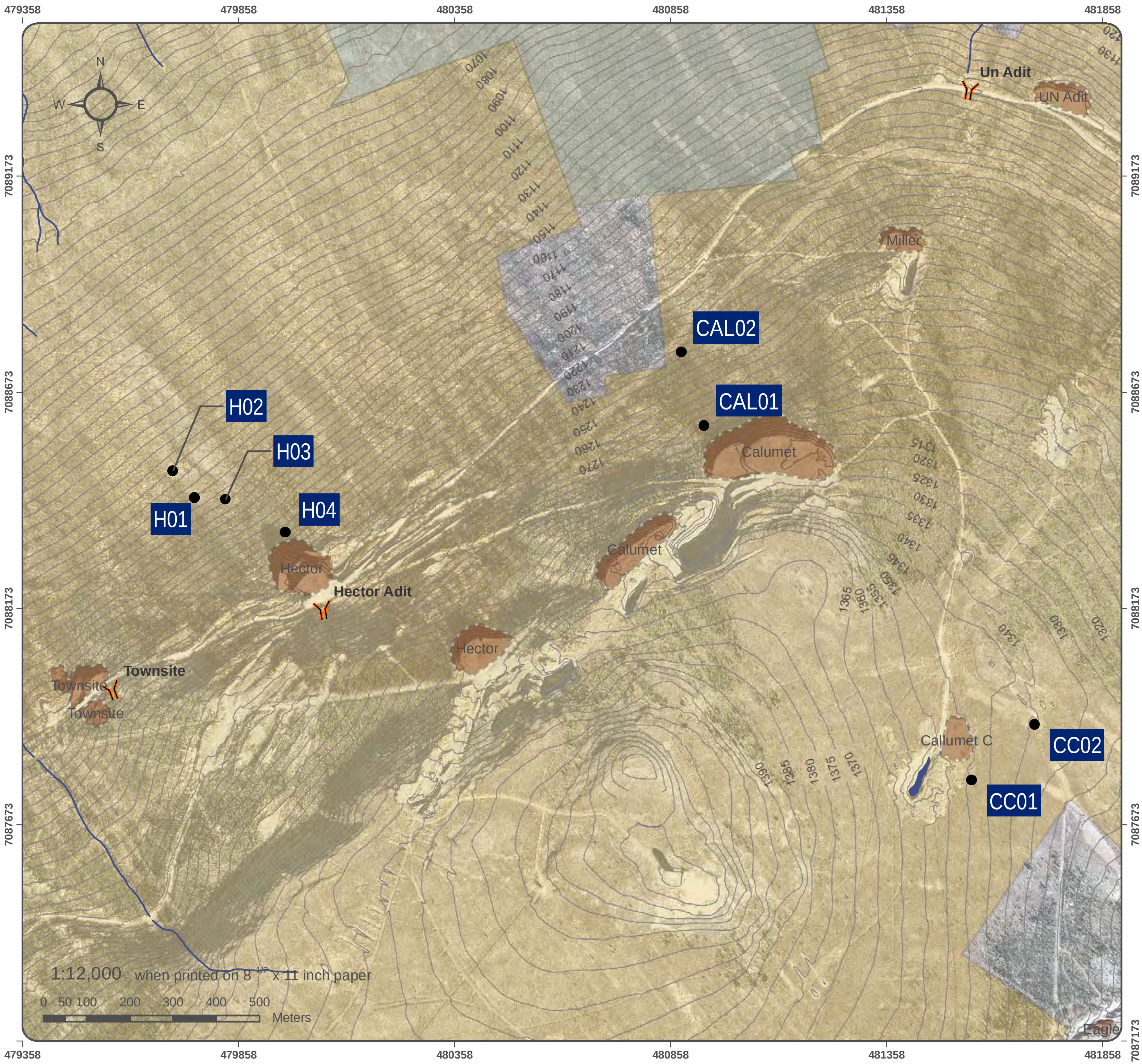

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FIGURE 2-31 HECTOR, CALUMET AND CALUMET C SAMPLE SITES

MAY 2012

- Sample Sites
- Adit
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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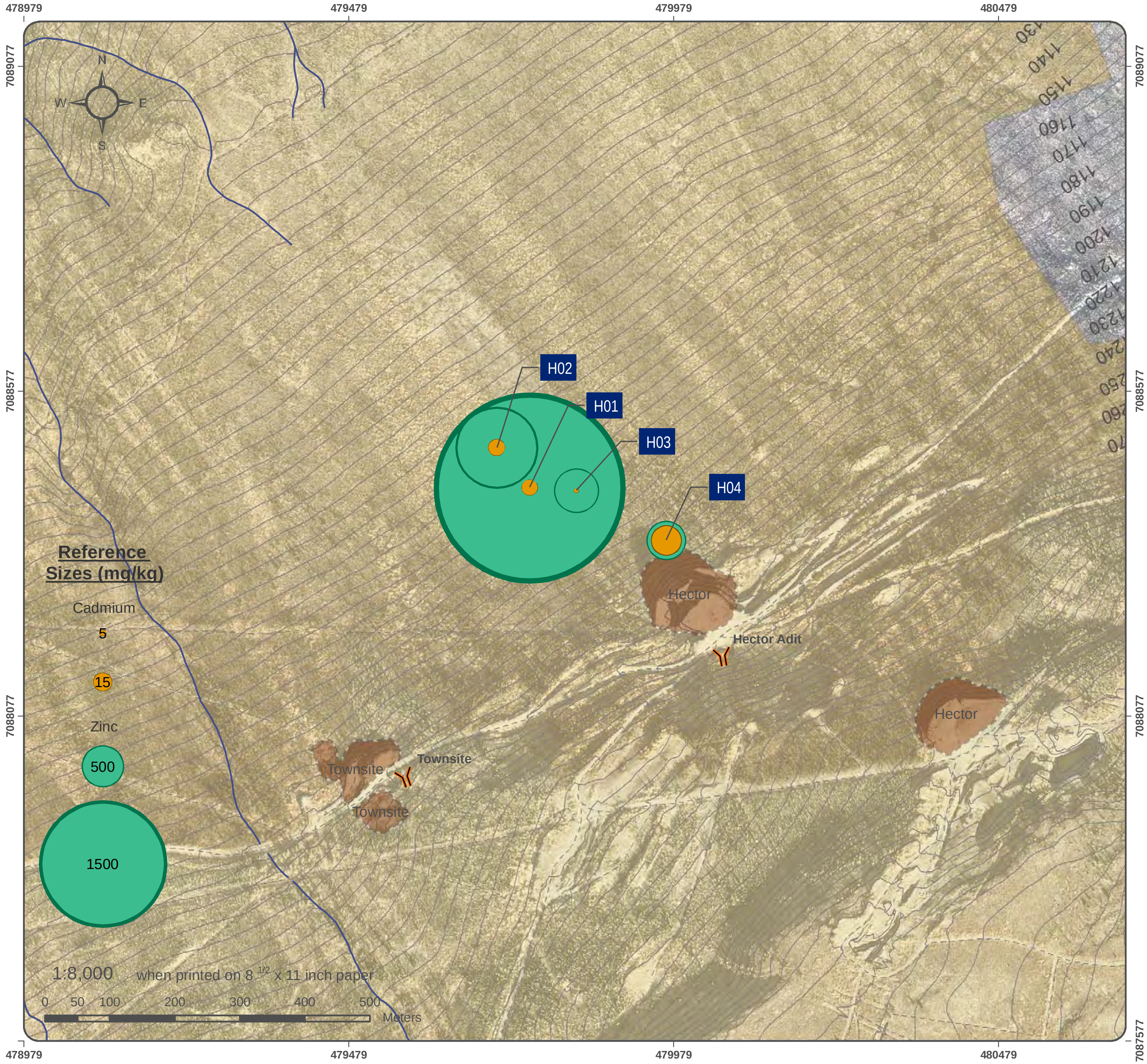

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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-32
HECTOR
ZN AND CD CONCENTRATIONS IN SOIL, 2011

MAY 2012

Soil Cadmium (mg/kg)
Soil Zinc (mg/kg) / 15
Adit
Silver Trail Highway
Secondary/Local Road
Trails/Track
Watercourse
Waterbody
ERDC Owned Quartz Claims
Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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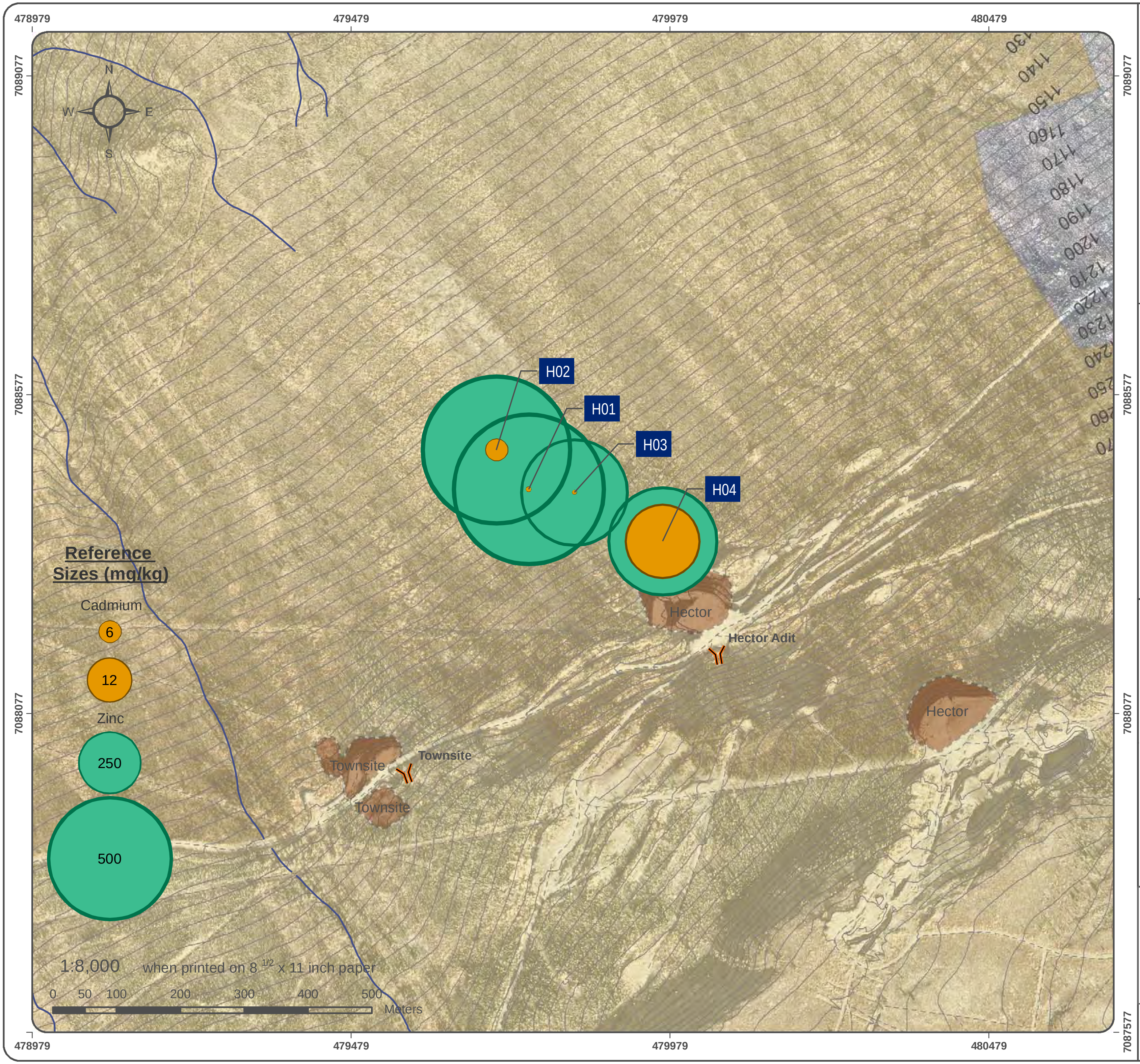
In the above map the higher zinc content in the soil samples was at H01, about 200m below the waste dump. The high Cd concentrations in soils are located closer to the waste rock apron. The willows growing in the tailings swath, although stressed, are surviving and accumulating zinc in the 400 to 600 mg/kg range. The sampling program could be extended to determine the disposition pattern of the COPCs in this area and further investigate the plants surviving in high heavy metal environment that could be useful in reclamation efforts.

Table 2-22 Metal Concentrations in Willow Leaf Tissue at Calumet, Calumet C and Hector Waste Dumps

Metals(mg/Kg) CCME Industry Limit (mg/Kg)	Calumet CAL01	Calumet CAL02	Calumet C CC01	Calumet C CC02	Hector H01	Hector H02	Hector H03	Hector H04	Average Control Value
As	0.02	0.02	0.01	0.01	0.02	0.02	0.03	0.03	0.04
Cd	9.05	4.12	0.562	1.32	1.47	6	1.23	19.9	1.02
Cu	1.47	1.02	1.21	1.99	2.11	0.62	0.9	0.8	1.32
Fe	25	16	34	16	13	16	32	11	20.2
Ni	1.74	0.74	3.24	4.77	2.67	4.65	1.93	0.189	2.1
Pb	0.176	0.121	0.107	0.078	0.168	0.105	0.193	0.189	0.2
Zn	289	108	15.4	74.7	612	601	430	440	36.8

Willow uptake of Zn is very high below the Hector waste rock pile. This could be one of the causes of plant die off in the sampling vicinity. When zinc is overly abundant it harms the soil microorganisms and fungus interrupting the metabolic activity that helps provide nutrients to plant roots.



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KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-33
HECTOR
ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012

- Willow Cadmium (mg/kg) * 3
- Willow Zinc (mg/kg) / 5
- **Adit**
- **Silver Trail Highway**
- **Secondary/Local Road**
- **Trails/Track**
- **Watercourse**
- **Waterbody**
- ERDC Owned Quartz Claims
- Waste Rock Dump

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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2.9 KENO CITY SOIL AND VEGETATION SAMPLING PROGRAM

As part of the Keno Hill Closure Plan a human health and ecological risk assessment (HHERA) of Keno City is being conducted by SENES. In support of the HHERA program Access undertook the soil and vegetation sampling in the Keno City area. The sites for sampling were randomly generated by placing a north –south and east-west grid over an aerial map of the town site and environs. The plots were situated at the intersection of the grid's vertical and horizontal lines at a distance of 100m apart. The plot locations were then downloaded on to handheld Garmin 60CX GPS unit, so points could be navigated to. If a plot was on a site that was not feasible to sample e.g. road or house, the plot was moved in 15 m increments to an appropriate sampling spot along the grid line in the direction of travel. (Figure 1-2)

At each site a soil pit was excavated and a soil sample taken from the rooting zone. Then vegetation samples were collected from shrubs that were rooted in the soil pit or in close proximity. Two types of plants were chosen for leaf sampling, willow (Salix sp) and Labrador tea (Ledum sp.). As the summer conditions were poor for bog blueberry (*Vaccinium uliginosum*) production only one sample was gathered at plot 131.

Soils and Metals of Concern

A total of 51 soil samples were analyzed for a full metal profile, the metals of primary concern are Zn and Cd as these two metals are known to accumulate in plants and can move into the local food web. Arsenic is considered toxic at low levels and is consistently over its CCME threshold for industrial sites (12mg/Kg) not only in Keno City, but throughout the district. Since the control concentrations of As is elevated and above CCME guidelines it is a contaminate that is naturally occurring . Arsenic is not accumulating in the leaf tissues samples in this study. Plots 51 and 53 were the only plots to have Lead (Pb) concentrations over the CCME thresholds for industrial standards (120mg/Kg). Plot 51 is in a shallow swale on the north side of Duncan Creek road which would receive road wash during wet weather and at plot 53 is an old road/trail in a ravine that drains to Lightning Creek below town. The highest levels of Cd and Zn in willow leaf tissue were located at plot 127 (Figure 2-36), downhill from the Onek 400 Adit, unfortunately a soil sample was not taken due to safety concerns at the time of sampling. The higher concentration of both Zn and Cd occur in the northern samples sites near the historic Onek mine. There is one apparent hotspot of elevated Zn and Cd concentration in willow leaves at plot 82 north of the Keno City Fire Hall.

Table 2-23 Metal Concentrations in Keno City Soil Samples

	Metals & CCME Residential Threshold in brackets					
Station Name	Ag mg/kg (20)	As mg/kg (12)	Cd mg/kg (10)	Cu mg/kg (63)	Pb mg/kg (140)	Zn mg/kg (200)
KC-38A	0.94	**39**	1.62	29.2	81.9	181
KC-39	1.44	**41.4**	2.33	31.3	126	**232**
KC-40	0.39	**87**	0.37	21.5	37.1	124
KC-48	0.31	**49.5**	0.39	42.7	24.3	113
KC-49	0.51	**59.1**	1.14	48.3	31.3	152
KC-50	0.24	**38.6**	0.23	32.3	21.7	82
KC-51	4.68	**71.3**	5.98	**74.7**	**292**	**433**
KC-52	0.61	**86.2**	1.13	49.5	42.8	164
KC-53	2.99	**65.2**	3.67	59	**255**	**398**
KC-54	0.52	**82.4**	0.39	**77.1**	37.9	115
KC-55	0.48	**72.5**	1	20.8	28.6	142
KC-56	0.47	**28.5**	0.8	43	51.9	106
KC-63	0.19	**38.5**	0.31	32.6	19.8	92
KC-64	0.18	**45.8**	0.31	30.3	20.3	102
KC-65	0.19	**62.1**	0.37	33.7	29	110
KC-66	0.37	**41.3**	0.94	41.3	27.3	136
KC-67	0.33	**59.3**	1.2	50.4	37.1	144
KC-68	0.99	**105**	2.5	62.7	63.9	**666**
KC-69	0.94	**28.8**	1.59	44.2	70.3	183
KC-70	0.39	**60**	0.6	34.5	28.8	110
KC-71	0.77	**112**	1.33	**70.7**	45	135

	Metals & CCME Residential Threshold in brackets					
Station Name	Ag mg/kg (20)	As mg/kg (12)	Cd mg/kg (10)	Cu mg/kg (63)	Pb mg/kg (140)	Zn mg/kg (200)
KC-72	0.28	**31.4**	0.28	24.8	28.6	92
KC-73	0.23	**26.8**	0.21	37	18.4	60
KC-80	0.31	**49.6**	0.52	46.2	27.6	116
KC-81	0.45	**67.9**	1.17	41	34.4	142
KC-82	0.16	**31.4**	0.38	23.2	22	115
KC-84	2.05	**73.6**	2.58	54.7	**257**	**385**
KC-85	1.48	**34.4**	9.03	62	100	**552**
KC-86	0.41	**14.9**	0.79	16.6	32.9	78
KC-87	0.4	**33.2**	0.61	43	46.7	133
KC-88	0.18	**25**	0.39	46.1	76.9	94
KC-96	1.64	**18.4**	1.22	35.8	**258**	167
KC-97	1.76	**46**	2.55	62	126	**211**
KC-99	2.22	**67.1**	1.71	48.7	**162**	179
KC-100	0.69	**16.9**	1.83	20.6	73.4	**246**
KC-101	0.81	**20.5**	4.3	37	96.6	**660**
KC-102	0.55	**31.6**	0.65	55.1	49	178
KC-103	0.35	**26.6**	0.49	42.9	45.4	97
KC-111	0.21	**54.5**	1.6	25.4	32.4	**208**
KC-112	0.16	**44.8**	0.25	25.1	28.7	101
KC-113	1.15	**53.6**	1.83	**116**	82.7	143
KC-114	1.36	**27.4**	5.61	45.2	**230**	**361**
KC-115	1.36	**18.7**	0.59	20.1	**215**	151
KC-116	9.27	**22.5**	7.38	59.2	**519**	**320**
KC-126	0.41	**19.5**	0.78	30.1	37.6	105
KC-128	1.08	**46.6**	**10.7**	31.3	52	**509**
KC-129	0.32	**36.6**	0.6	**316**	12.5	125
KC-130	4.27	**24.6**	1.75	43	**662**	179
KC-131	3.01	**21**	1	27.7	**452**	**233**
Average	1.1	**43.2**	1.8	48.3	**105.3**	**201.2**

Note: Exceedances are shown in red

General Observations:

- At KC 98 and KC 83 plants at these sites were rooted in organic substrate, no soil sample was taken, only vegetation samples.
- KC-71 has the highest concentration of As 112 g/kg
- KC-128 has the highest Cd concentration 10.7 g/kg which is only slightly over the CCME threshold of 10mg/kg.
- KC-129 has the highest Cu concentration 316 g/kg about approximately 20m south of Onek 400 adit KC130 has the highest Pb concentration 662 g/kg about 170m from base of Onek waste rock dump.
- KC-68 has the highest Zn concentrations 666 g/kg in the front yard of house
- There were three plots (83, 98, 127) where only vegetation was collected not soils. At 98 and 83 the organic layer was more than a meter deep and water table was high, so it was difficult to excavate.
- The soil samples with the highest concentrations of COCPs are in proximity of the Onek 400 Adit and downhill of the Onek waste rock dump. The sites with the highest As levels were found on southwest facing slope of Keno Hill.
- Plot 129 had the highest Co and Cr levels for all the soil samples taken thus far in the district, although concentration are still below CCME residential Guidelines.
- There were five occurrences of Cu concentrations being over the CCME guideline threshold for residential/parkland, the two sites that were over the industrial guidelines were near the adit and within 200m of each other.
- At 11 sites Pb exceeds the residential/parkland guidelines, and at 14 sites residential/parkland guidelines were exceeded for zinc.

Figure 1-2 shows the relative concentration of Cd and Zn in the soil samples taken around Keno City. Zinc concentrations have been reduced by a factor of 20 so it can be represented in comparison with Cd on the same map scale. Zn is a more plentiful element than Cd, but they commonly occur together in silver deposits. Cd is more toxic on a mass basis as its CCME threshold for industrial sites is lower.

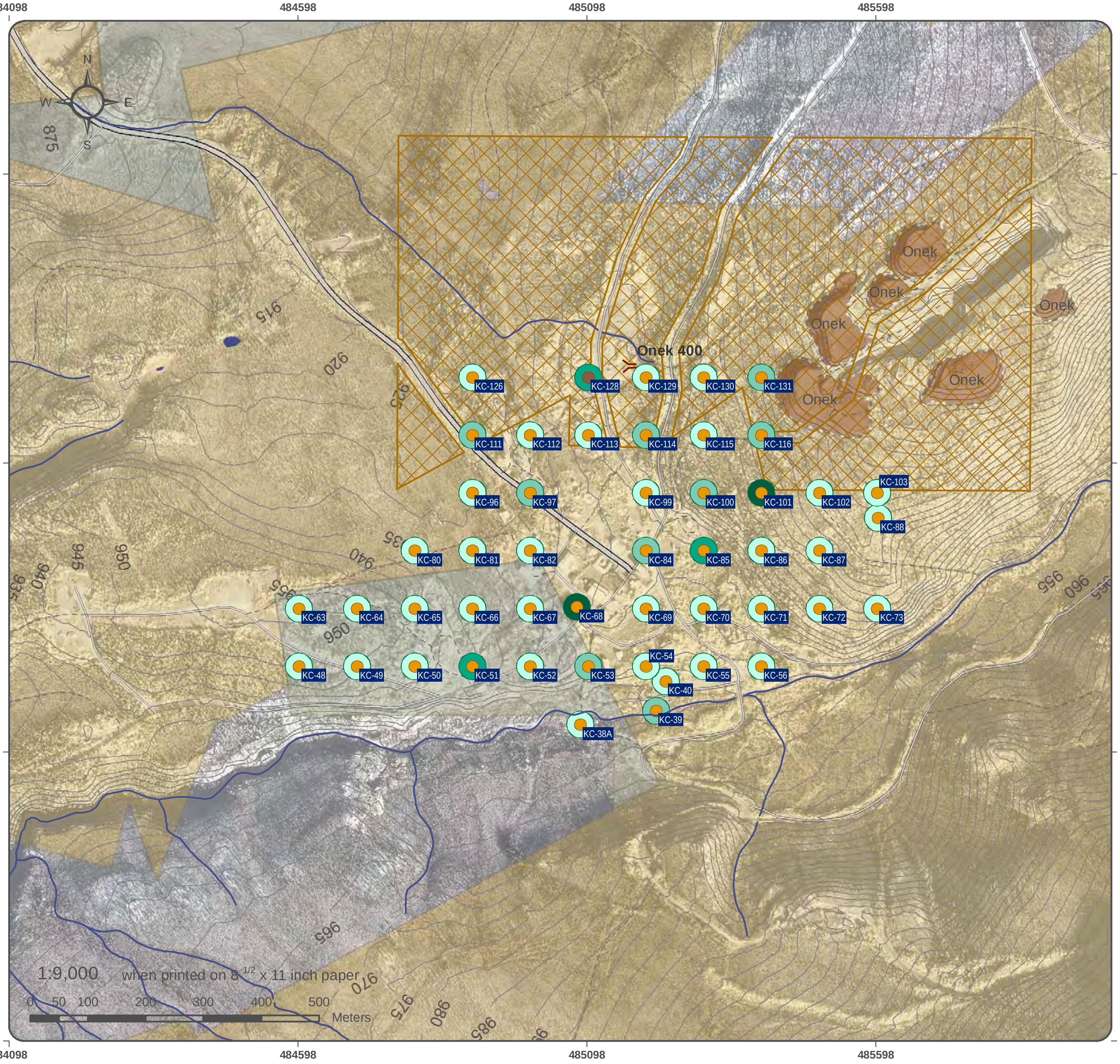

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FIGURE 2-34 KENO CITY ZN AND CD CONCENTRATIONS IN SOIL, 2011

MAY 2012

Soil Cadmium (mg/kg)
- 0 - 10
- 10 - 11

Soil Zinc (mg/kg)
- 0 - 200
- 200 - 400
- 400 - 600
- 600 - 700

- Adit
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- ERDC Owned Quartz Claims
- Other Alexco Owned Quartz Claims
- Waste Rock Dump
- Lot 960

CCME Residential Park Land Standards:
Zinc - 200 mg/kg
Cadmium - 10 mg/kg

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

Projection : NAD 83 UTM Zone 8N

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The Zn and Cd concentration levels in willow leaves is highest at plot KC-127, the two adjacent plots KC-126 and KC-128 also show elevated levels as well (Figure 2-35).

It was not possible to collect Ledum leaf samples at many of the Keno City plots as they were not growing at many of the randomly generated sites. The concentrations in the Ledum leaf samples that were collected were relatively low (Figure 2-36). The highest Cd and Zn concentrations in Ledum samples are only 0.066 mg/kg and 18.2 mg/kg respectively, both at plot KC-80. This plot is located in a boggy area behind the Keno City Fire Hall.

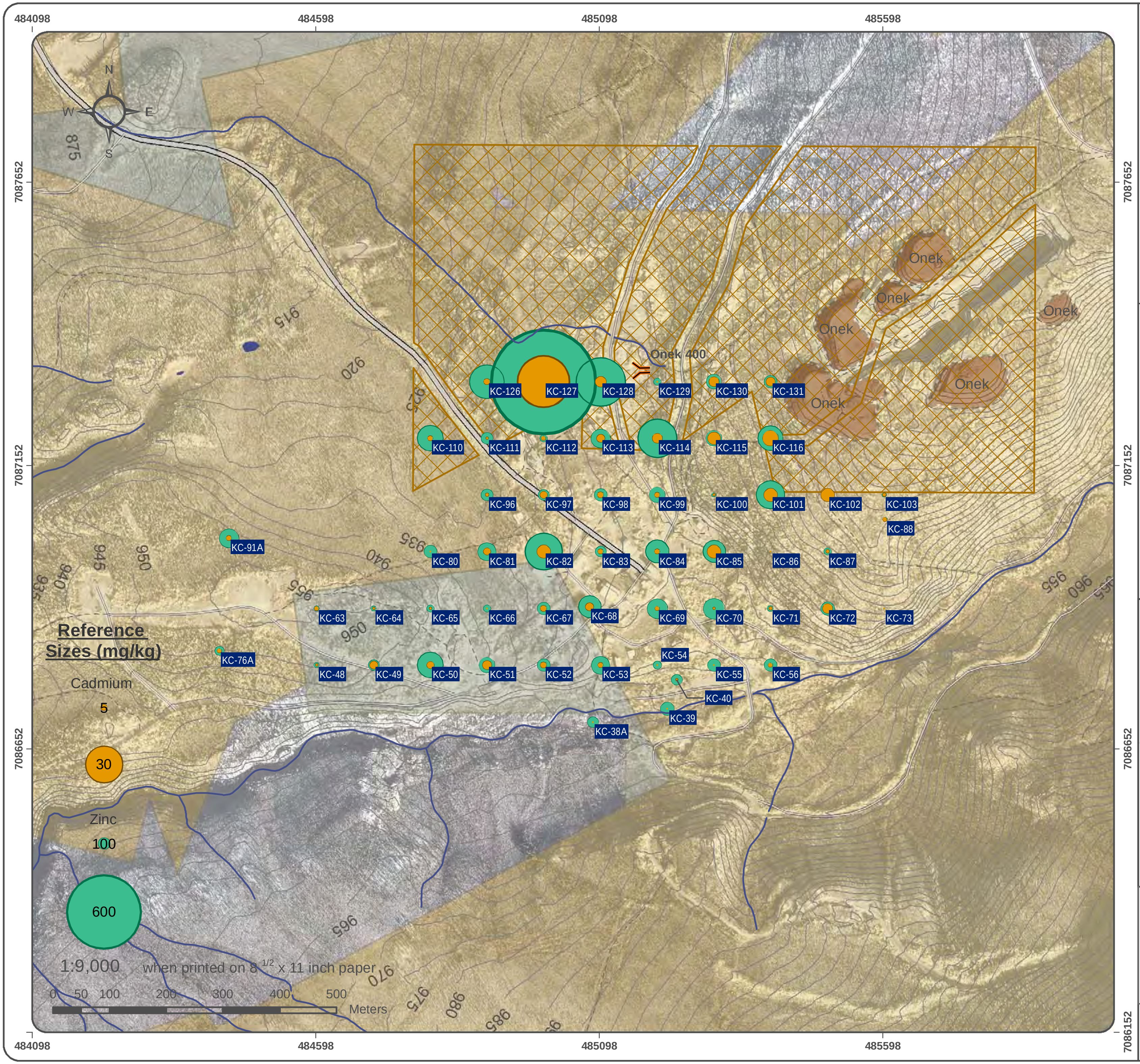

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FIGURE 2-35
KENO CITY
ZN AND CD CONCENTRATIONS IN WILLOW LEAVES, 2011

MAY 2012

- Willow Cadmium (mg/kg)
- Willow Zinc (mg/kg) / 10
- Adit
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- Other Alexco Owned Quartz Claims
- ERDC Owned Quartz Claims
- Waste Rock Dump
- Lot 960

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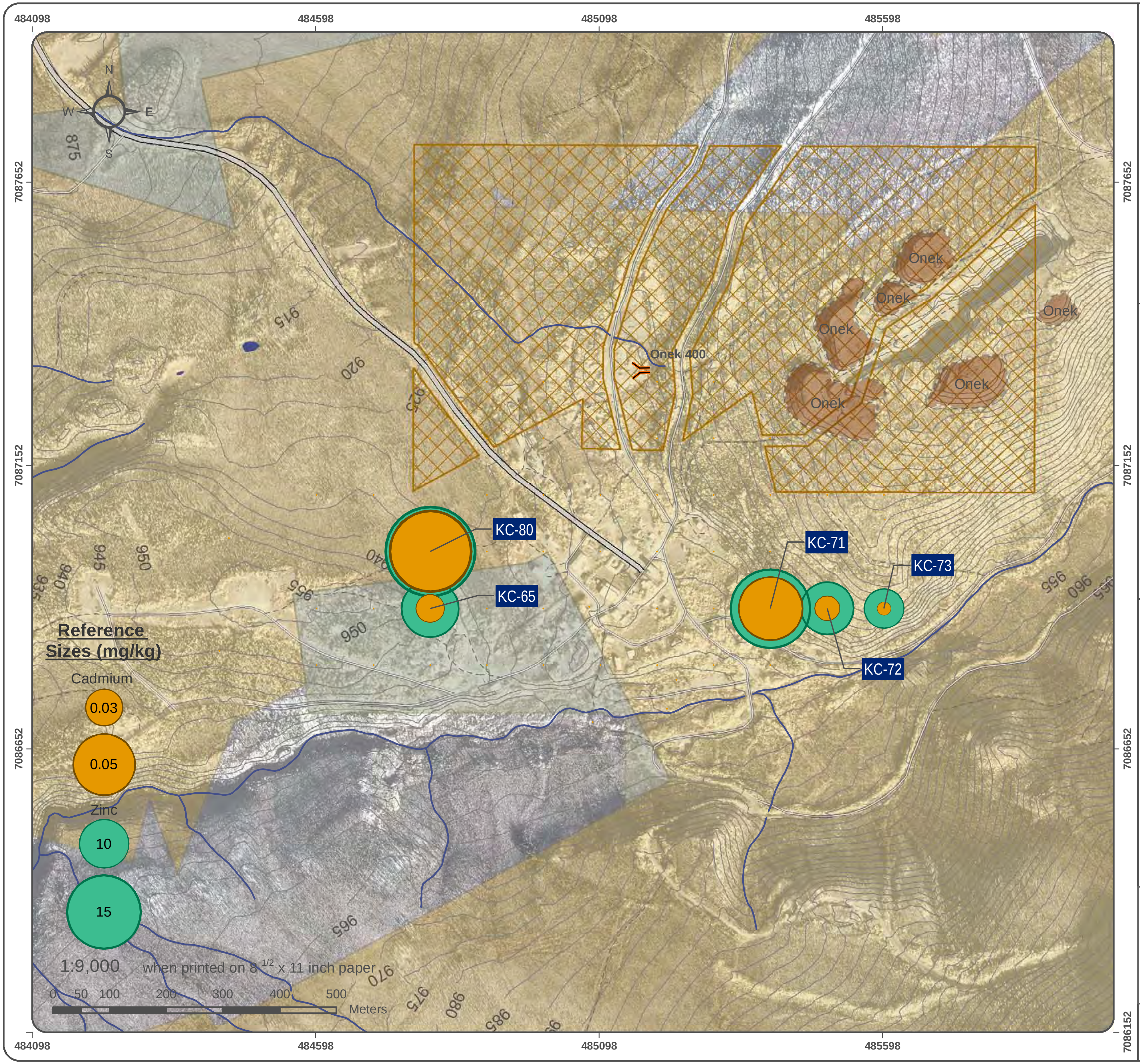
KENO DISTRICT SOIL AND VEGETATION BASELINE STUDY AND HEAVY METAL ANALYSIS

FIGURE 2-36
KENO CITY ZN AND CD CONCENTRATIONS IN LEDUM LEAVES, 2011

MAY 2012



- Ledum Cadmium (mg/kg) * 1000
- Ledum Zinc (mg/kg) * 4
- Adit
- Silver Trail Highway
- Secondary/Local Road
- Trails/Track
- Watercourse
- Waterbody
- Other Alexco Owned Quartz Claims
- ERDC Owned Quartz Claims
- Waste Rock Dump
- Lot 960

Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13th and 14th 2006.

Site hydrography and contours derived from 2006 aerial imagery obtained from Aero Geometrics, Calgary Alberta.

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2.10 TOLERANT PLANT SPECIES OBSERVED

Unlike organic pollutants, heavy metals are elements that cannot be degraded, but instead persist indefinitely in the environment, complicating their remediation. Certain plants have the ability to grow on heavy-metal contaminated soils, and some of them can accumulate heavy metals, which have no known biological function. Such plants can be use phytoremediation efforts, i.e. the use of plants to remove, contain or transform environmental contaminants, which is considered one of the most promising new technologies for heavy metal remediation. Metals such as antimony, arsenic, cadmium, copper, mercury, nickel, selenium and zinc can be extracted from the soil by hyperaccumulator plants and concentrated into their roots and shoots.

Plants identified in areas of high heavy metal contamination are:

Populus balsamifera	Balsam popular
Salix alaxensis	Felt-leafed willow
Salix glauca	Grey-leaf willow
Equisetum arvense	Common horsetail
Calamagrostis canadensis	Bluejoint
Calamagrostis lapponica	Lapland reedgrass
Carex aquatilis	Water sedge
Carex saxatilis	Russet sedge
Carex utriculata	Beaked sedge
Agrostis scabra	Ticklegrass

3 DISCUSSION

In terms of the project objectives set out in the beginning of the report, several goals were achieved.

> *Objective: Continuation of soil and vegetation metal concentration data collection through revisiting previous sites and expanding the study into other areas;*

The soil and vegetation baseline survey was expanded into new areas within the UKHM district. These areas included Sadie Ladue, Hector, Bermingham, Calumet and Keno City. The sample sites established in 2009 and 2010 at No Cash, Silver King, Husky, Valley Tailings and MacKeno Tailings were revisited and sampled. Some of the old plots were dropped either because they were difficult to locate or to reduce duplication in data gathering.

> *Objective: Develop a databank on metal concentrations in soil and vegetation samples by location;*

The analysis results of metal concentrations in soils and vegetation samples (willow and *Ledum)* have been compiled into a manageable database. All sample data is tied to a location, so permanent plots can be established and further monitoring can show changes in attributes over time. The databank will aid in determining information gaps and effectiveness of sampling locations, it will be useful in planning future baseline surveys. Databank software tools will improve data analysis and maintain an accessible record for other researchers.

> *Objective: To help monitor the effectiveness of future reclamation measures by establishing a current profile of metal contamination levels by location.*

As the database is further developed there will be a record of the type and extent of COPC contamination and where it is occurring within the UKHM claims and leases. This information can also be used to create maps that show contamination "hotspots" and where to find plants that have a tolerance to heavy metal contamination. These plants could be utilized for future revegetation efforts. Also, areas that are naturally regenerating can be monitored and used as models for reclamation efforts. As the COPC uptake potential of certain species of local plants is better understood this knowledge can be integrated into reclamation plans. Comparisons can be made over time to determine if vegetation in a particular location is developing higher concentrations as a function of time.

> *Objective: Produce a "quick study" map atlas that show relative concentration of Zn and Cd in soils, willows and Ledum species per specific study area, that can be easily updated.*

The maps that have been generated for this report, give a quick visual reference to the distribution and level of Zn and Cd contamination in a particular study areas. The maps are meant to be used in locating: information gaps, potential sampling sites, revegetation material, contaminate sources and deducing patterns of disturbance. Maps can be generated that focus on other metals and tailored to particular concerns e.g. Cu concentrations in riparian zones. The maps can be produced to create a booklet that can be easily used in the field.

> *Objective: Locate and sample control plots to determine natural mineral background concentration levels to clarify the extent of anthropogenic contaminant contribution.*

Five control plots were located outside of the UKHM district, the metal concentrations for soils samples were pooled and the average value for each COPC was calculated. The same was done for willow and *Ledum* leaf tissue samples. These averaged values were compared to the baseline samples to gage the level of metal contamination to natural levels and to determine to the degree samples exceeded background metal content. The two Mayo Bridge control samples had higher concentrations of certain metals (Sb, As, Cu, Pb, Ni and Zn) this would have skewed the average values higher. Arsenic was persistently high in all five control samples and also at the district soil sample sites. A common mineral in the area is arsenopyrite (FeAsS) which is a major source of As, so the area has a naturally heighten presence of As, in addition of released As from fractured ores resulting from mining and milling.

For future baseline studies, if required, it would be beneficial to increase the number of control plots, and locate them closer to the study areas. This will better reflect the local mineralogy in average control values and a greater number of controls will provide a greater degree of certainty for the measure of background metal concentrations.

Objective: Determine the relationship between concentration of metals in plant tissues and the concentration of metals in the soils that the plants are rooted in;

The literature review revealed that it is generally accepted that plants absorb minerals/metals through their root systems, particularly metals that are necessary for enzymatic function. However, metal uptake by plants is a complex process and is reliant on many variables:

- The major factor governing metal availability to plants in soils is the solubility of the metal, for root uptake to occur, a soluble metal must exist adjacent to the root membrane for some period. The rate of release and the form of this soluble species will have a strong influence on the rate and extent of uptake.
- Factors influencing the bioavailability of metals (i.e., a soluble species adjacent to a root and the capacity of the root to uptake the metal) and their occurrences in plants were: soil pH, cation exchange capacity, organic matter content, soil texture, and interaction among the COPCs and other elements. The amount of organic material in soil will also influence metal uptake;
- Metals, roots and bacteria have complex interactions and chelating affects that occur in the rhizosphere;
- Plant absorption of metals is selective. Willows will hyper-accumulate Cd and easily uptake Zn, but not Mn. So even if some metals are available in the soil matrix and soluble, they are not necessarily absorbed by the plant or stored in leaf tissue;
- Different metals are stored or utilized in different parts of plants; in general Cd, Pb and Cu concentration trend roots>leaves>flowers>stems, as where Zn is concentrated leaves>roots>flowers>stems.

Other considerations that emerged during the 2011 soil and vegetation baseline study are:

- Very wet conditions during 2011 may have caused more dilution and pushed contaminants further downstream as compared to previous summers where climatic conditions were different.
- Air borne metal depositions of metals has been proposed as the mechanism that contributes to high metal concentrations in some leaf samples (EDI, 2010). It was noticed that the 2009 data had significantly higher COPC concentrations than the 2011 vegetation samples. The differences in the metal analysis results may be attributed to difference in sample collection and processing. The 2009 leave samples were not washed prior to metal analysis, as to emulate the natural consumption of the plant by humans. In the 2011 study the leaves were washed prior to metal analysis.

4 RECOMMENDATIONS

Through the process of conducting research, field work and data preparation for the soil and vegetation baseline study certain thoughts and criticisms were generated as how this program could be improved for future efforts. The following are some recommendations to build efficiencies and more accuracy into this ongoing project:

- There are data gaps and inconsistencies that exist in the sampling programs from year to year. The sampling protocols need to be refined and standardized so that the quality of information is consistent. E.g. leaf collection of plants should occur within the same 2 week period each year and from off the shrub, not from the ground when leaves have fallen.
- Review the location and number of soil and vegetation sampling sites. In a few locations there are numerous vegetation sampling spots that do not render any additional information that one vegetation sample site would.
- Ensure that plants to be sampled are rooted in or very close to where soil sample is being taken and that soil is collected at the rooting depth.
- Microtopography should be considered when sampling vegetation. Ledum tends to grow atop of mossy hummocks and does not tolerate water saturation as some species of willows do. So it is expected that influx of water borne COPCs would be different at the top of hummocks than in depressions.
- Review plant selection for COPC uptake potential. Willow is a good candidate as it is widespread, grows in mineral and organic soils, accumulates Zn and Cd, and is tolerant to high levels of heavy metals. Ledum prefers to grow in organic soils, therefore is restricted to where there is a deep humus or peat layer. Ledum does not accumulate COPCs as well as willow - scrub birch (*Betula glandulosa*) would be a better candidate to evaluate the potential for COPC accumulation.
- Permanent vegetation /soil plots need to be established so location for future measurement is easier. The plots should be well marked with flagging tape and painted metal stake at soil collection spot. GPS coordinates should be recorded on field data sheets and captured on GPS unit in the field.
- Use standardized data collection field cards, so the same data is captured at each site, a written record is available, and location coordinates copied. A field data card can be easily designed.
- Use existing plots that exhibit the most consistent data collection thus far and strategically add plots at locations, such as at creek confluences.
- Where possible, ensure that all plant types to be sampled, that are considered potentially relevant to animal/human exposure and can all be collected at the plots established. This lends more continuity to patterns of COPCs uptake by plants. Often only willow could be collected at a plot, not *Ledum.*
- Multivariate statistical models could be used to improve the validity of plant/soil sampling design and analysis.
- Expand sampling at other known point sources, for example: Bermingham, Porcupine Creek, and Christal Creek.
- To determine the difference of windborne deposition of Zn and Cd on plant leaves versus root uptake. Two leaf samples could be taken from the same plant, but prepared differently for metal

analysis. One sample would be washed and the other sample not, several selected plant samples could tested this way. The results may help clarify the differences in data from previous years to this study.

- Incorporate data from other ongoing studies, like natural attenuation, sediment and water quality, to continue to refine the understanding of contamination pathways and inform baseline study design and analysis.
- Metal availability in the water column and organics in the lower reaches need to be compared to plant tissue metal concentration, as the willow and Ledum collected in the valley areas are growing in organics, not mineral soil.
- Collect more bog blueberries (Vaccinium uliginosum), to determine metal uptake levels when better growth conditions prevail.
- Replicate plant samples could be collected and analyzed to ensure lab results are consistent.
- Expand Keno City Study area further north and along the drainage route from Onek 400 Adit.
- Look at data from ITL attenuation sample sites and pair with leaf samples to determine if there is a relationship between mineral content in organic soils to plant uptake.
- Continue to search and note locations of heavy metal tolerant plant species, during baseline studies. Seeds could be collect and propagation started on a trial basis.

5 CONCLUSION

The 2011 Keno District Soil and Vegetation Baseline was undertaken as a preliminary investigation to better understand the extent and degree of heavy metal contamination in the district soils and vegetation. The selected locations for soil and vegetation sampling were based around three types of source disturbances:

1) Point sources: Silver King, Husky, No Cash Creek and Sadie Ladue;
2) Tailings impoundments: Valley Tailings and MacKeno Tailings;
3) Area contamination, such as waste dumps: Hector, Calumet and Calumet C.

Point sources such as old mine adits, did contribute COPC to down slope sites through water transport. Spikes in Zn and Cd concentrations in soil usually occurred at or below stream confluences. There could also be seeps and/or natural sources of contaminants that are contributing to metal loads to sampling site areas that have not yet been identified. The lower sampling sites of Husky and Galena Creek study areas are receiving water and heavy metals from several water systems which could explain the elevated levels of COPC at lower sample sites even though they are at greater distance from the adit point sources.

The Valley and MacKeno Tailings study areas had very high concentrations of COPC in the middle and exposed portions of these impoundments. There was a slight halo effect where sampling sites near the edge of the tailings showed elevated COPC levels. The heavy metals from the tailings are likely being transported past the edges of their containment by water, wind, equipment and along access roads/trails. Plants samples taken in or adjacent to tailings impoundments showed higher uptake of COPC as well. The plants that are surviving in the tailings areas are metal tolerant and need to be investigated as possible stock for reclamation efforts.

This study did expand into new areas around waste dumps and adits on Galena Hill. Only a few samples were taken at the three areas: Hector, Calumet and Calumet C. The soil samples taken nearest the waste rock aprons (CAL01 and H01) had the higher concentrations of COPC. Calumet are had higher Cd concentration, as Hector had higher Zn levels. In both areas the vegetation has died back or appeared stressed, chlorotic and stunted, which are indicators Zn toxicity.

The plant uptake of Cd and Zn appeared to be in tandem, especially in willow leaf tissue samples although this relationship was not consistent across all sampling sites. Often, it seemed that higher Zn and Cd levels in willow leaves happened in the sample site below a site where Zn and Cd had high concentrations in soil. The metals may be moving along with the water column through the soil matrix down slope and being absorbed in plants at these lower elevations. This phenomenon would need to be investigated further to confirm.

Certain plants, such as willows, have the ability to grow on heavy-metal contaminated soils, accumulate certain heavy metals, like Cd. Plants primarily uptake metals through their root systems where the nutrients and minerals needed for growth and sustainment are in solution and in close proximity to the rooting matrix. Metals such as antimony, arsenic, cadmium, copper, mercury, nickel, selenium and zinc can be extracted from the soil by hyperaccumulator plants and be concentrated into their roots, leaves and/or stems. The absorption of metals into plants is difficult to quantify as it is not a simple relationship, however it was apparent that vegetation sampled in the study area was absorbing heavy metals. The high amount of COPCs that were appearing in willow and to a lesser extent, *Ledum* leaf tissues samples compared to the control concentrations, confirmed that plants at the sample sites were accessing and storing metals, like Cd and Zn into their leaves.

There exists data gaps and inconsistency in the baseline study that need to be closely examined and improvements made to future sampling designs so statistically valid interpretations can be made. Additional testing and follow-up sampling will need to be preformed to insure that data collection is consistent and all significant sources of contamination are identified. To accomplish this, permanent plots should be established, the number of original plots should be streamlined and upslope and surrounding area should be explored more fully.

The new database created in this study will help to store and allow interpretation of the results from this survey and previous ones, making future data readily comparable to this existing dataset. .

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