Appendix J: Risk Management Plan Annual Report

Fugitive Dust Risk Management Plan
2017 Annual Report

Red Dog Operations
Teck Alaska Incorporated
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Teck

Contents

Acronyms and Abbreviations

CAKR	Cape Krusenstern National Monument
CSB	Concentrate Storage Building
CSP	DEC Contaminated Sites Program
DEC	Alaska Department of Environmental Conservation
DFG	Alaska Department of Fish and Game
DMTS	DeLong Mountain Transportation System
ITW	Ikayuqtit Team Technical Workgroup
MSHA	Mine Safety and Health Administration
NANA	NANA Regional Corporation
OSHA	Occupational Safety and Health Administration
PAC	Personnel Accommodations Complex
RDO	Red Dog Operations
RMP	Fugitive Dust Risk Management Plan
TDam	Main Tailings Dam
TEOM	tapered element oscillating microbalance
TSP	total suspended particulates
VEE	visible emissions evaluation
XRF	x-ray fluorescence analyzer

Summary

This document presents the Fugitive Dust Risk Management Plan (RMP) Annual Report for 2017 for Red Dog Operations (RDO), including the mine, road, and port areas. This report presents results from efforts related to each of the risk management implementation plans, including the Communication Plan, Dust Emissions Reduction Plan, Remediation Plan, Worker Dust Protection Plan, Uncertainty Reduction Plan, and Monitoring Plan. Activities are summarized below in relation to each of these plans.

Activities relating to the Communication Plan center around maintaining clear communication with local communities and other interested parties about fugitive dust risk management efforts at the mine. Communication Plan activities during 2017 included regularly scheduled village visits, meetings with NANA, the Subsistence Committee, and other stakeholders and organizations who expressed an interest in mine operations. A variety of other outreach, engagement, and educational efforts were undertaken in 2017.

Activities relating to the Dust Emissions Reduction Plan in 2017 included application of dust control product to the tailings beaches in the tailings impoundment. The port road was treated with calcium chloride and regular watering during the summer months for dust suppression. At the port, a new calcium spreader and water truck was acquired and put into service, and a waterless "air wash" was designed for future installation at the port truck unloading building.

Activities related to the Remediation and Reclamation Plan in 2017 involved revisiting previously remediated sites to determine if ground cover was growing. In 2016, it was noted that ground cover failed to establish at the site of a previous zinc concentrate truck spill at MS-13. After consulting with the Alaska Native Plant Center biologist, it was confirmed that the seeds used for revegetation had low germination rates. New seeds were purchased in 2017 and applied to the spill site, and ground cover began to get established.

Activities related to the Worker Dust Protection Plan include ongoing programs designed to monitor and minimize workers' exposure to dust while at Red Dog, and to facilitate comprehensive communication about these programs, policies, and practices. In 2017, worker

health monitoring continued through regular blood lead level testing, results of which are reported directly to the State of Alaska by the testing laboratory, and by environmental monitoring performed by the on-site Safety & Health department. Strictly enforced policies remain in place to ensure that worker health is protected and that all work environments are safe. Teck takes employee health extremely seriously, and noncompliance with health and safety policies is not tolerated.

Activities related to the Uncertainty Reduction Plan include research or studies to reduce uncertainties related to the assessment and management of risk to humans and the environment. In 2017, a study was planned to evaluate lead, zinc, and cadmium concentrations in bone and marrow collected from caribou that overwinter near Red Dog. The study plan was shared with the Ikayuqtit Team in October 2017, and after comments were solicited, the plan was finalized. The caribou collection was planned for 2018.

Activities related to the Monitoring Plan are intended to provide the necessary operational and environmental monitoring data to facilitate continued reduction of fugitive metals emissions and dust emissions, verify the continued safety of caribou and other subsistence foods and water, as well as the health of ecological environments and habitats in the vicinity of the mine, road, and port. In 2017, monitoring activities proceeded on schedule, and statistical analyses were performed on multi-year data sets to identify and evaluate any trends and patterns. In 2017, the following monitoring programs were implemented:

- Visual emissions evaluations
- Source monitoring at the mine and port with real time air samplers
- Real-time alarm system monitoring for dust at the mine
- Road surface monitoring to assess tracking of metals
- Dustfall jar monitoring at the mine, road, and port
- Soil and vegetation monitoring

Results from the monitoring programs largely indicate that concentration trends are flat over the most recent four-year period (i.e., no increasing or decreasing trend), with the exception of the area outside the Truck Unloading Building at the port. Overall, environmental media concentrations remain similar to or lower than those evaluated in the DMTS risk assessment (Exponent 2007).

Introduction

In accordance with the risk management plan (Exponent 2008), the purpose of this report is to provide a summary of risk management activities conducted at the Red Dog operation in the prior calendar year.

Background

The Red Dog Mine is approximately 50 miles inland of the Chukchi Sea, in the western end of the Brooks Range of Northern Alaska. The mine is located on land owned by NANA and operated by Teck Alaska Incorporated (Teck). Base metal mineralization occurs naturally throughout much of the western Brooks Range, and strongly elevated zinc, lead and silver concentrations have been identified in many areas (Exponent 2007). The Red Dog Mine has been in operation since 1989.

At the mine, ore containing lead sulfide and zinc sulfide is mined and milled to produce lead and zinc concentrates in a powder form. These concentrates are hauled year-round from the mine via the DMTS road to concentrate storage buildings (CSBs) at the port, where they are stored until being loaded onto ships during the summer months. The storage capacity allows mine operations to continue year-round. During the shipping season, the concentrates from the storage buildings are loaded into an enclosed conveyor system and transferred to the shiploader, and then into barges. The barges have built-in and enclosed conveyors that are used to transfer the concentrates to the holds of deepwater ships. The DMTS road passes through the Cape Krusenstern National Monument (CAKR), which is managed by the National Park Service (NPS). A study conducted by NPS in 2000 found elevated levels of metals in moss near the DMTS road, declining with distance from the road (Ford and Hasselbach 2001).

Teck conducted studies to characterize the dust issue throughout the mine, road, and port areas, and subsequently conducted a human health and ecological risk assessment (Exponent 2007) to estimate possible risks to human and ecological receptors[1] posed by exposure to metals in soil, water, sediments, and plants and animals in areas surrounding the DMTS, and in areas surrounding the Red Dog Mine ambient air/solid waste permit boundary and port site. The human health risk assessment evaluated potential exposure to DMTS-related metals through

[1] Plants and animals

incidental soil ingestion, water ingestion, and subsistence food consumption under three scenarios: 1) child subsistence use, 2) adult subsistence use, and 3) combined worker/subsistence use.

The human health risk assessment, which included subsistence foods evaluations, found that it is safe to continue harvesting of subsistence foods from all areas surrounding the DMTS and mine, including in unrestricted areas near the DMTS, without restrictions. Although harvesting remains off limits within the DMTS, human health risks were not elevated even when data from restricted areas were included in the risk estimates.

The ecological risk assessment evaluated potential risks to ecological receptors inhabiting terrestrial, freshwater stream and pond, coastal lagoon, and marine environments from exposure to DMTS-related metals. The ecological risk assessment found that:

- In the tundra environment, changes in plant community composition (for example, decreased lichen cover) were observed near the road, port, and mine, although it was not clear to what extent those effects may have resulted from metals in fugitive dust, or from other chemical and physical effects typical of dust from gravel roads in Alaska.
- The likelihood of risk to populations of animals was considered low, with the exception of possible risks related to lead for ptarmigan living closest to the port and mine.
- No harmful effects were observed or predicted in the marine, coastal lagoon, freshwater stream, and tundra pond environments, although the potential for effects to invertebrates and plants could not be ruled out for some small, shallow ponds found close to facilities within the port site. However, no effects were observed in these port site ponds during field sampling.

Subsequent to completion of the risk assessment, Teck prepared a Risk Management Plan (RMP) designed to minimize the potential for effects to human health and the environment over the remaining mine life and beyond (Exponent 2008).

Risk Management Plan Overview

Based on the results of the risk assessment, and stakeholder input on risk management objectives, a risk management plan (RMP) was developed to combine and build upon prior and ongoing efforts by Teck Alaska Incorporated (Teck) to reduce dust emissions and minimize potential effects to human health and the environment over the life of the mine. Specifically, the overarching risk management goal is to: "*Minimize risk to human health and the environment surrounding the DMTS and outside the Red Dog Mine boundary over the life of the mine*."[2]

Although human health risks were not found to be elevated, and potential ecological risks were found to be limited, conditions may change over time, and this possibility was also considered in the design of the RMP. Future changes in conditions and in potential human and ecological exposures over the life of the operation can be addressed through implementation of risk management, dust emissions control, and monitoring activities. More specifically, the RMP established a set of seven risk management objectives (Exponent 2008), which formed the basis for preparation of six implementation plans. Each of the six implementation plans addresses one or several of the overall objectives of the RMP (Figure 1), and includes the planned scope of work to achieve the objectives.

This annual report assumes that the reader has some familiarity with the Fugitive Dust Risk Management program, and is therefore not intended to be a thorough discussion of that program, nor is it intended to provide complete background on either the risk management program or risk assessment that lead to the development of the RMP. To develop a more thorough understanding of the risk management programs, interested parties are encouraged to review the human health and ecological risk assessment documents (Exponent 2007), as well as the RMP (Exponent 2008) and its component implementation plans:

- Communication Plan (Exponent 2010)
- Dust Emissions Reduction Plan (Exponent 2011a)
- Remediation Plan (Exponent 2011b)
- Worker Dust Protection Plan (Exponent 2011c)
- Monitoring Plan (Exponent 2014)
- Uncertainty Reduction Plan (Exponent 2012)

These plans are available for review at http://www.teck.com/operations/united-states/operations/red-dog/.

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[2] Note that the mine closure and reclamation plan addresses risk management within the mine solid waste permit boundary (collocated with the ambient air boundary, see Figure 3).

Data Collection and Reporting Objectives

The risk management program includes collection of a large amount of data for various implementation plans (discussed below) that are intended for either operational or regulatory purposes. Data collected for operational purposes are intended to provide Teck with information on the effectiveness of dust emissions control and reduction efforts. Data collected for regulatory purposes are intended to provide Alaska Department of Environmental Conservation (DEC) with the necessary information to verify that conditions are protective of human health and the environment.

The soil monitoring and marine sediment monitoring programs (described in the section below regarding the summary of monitoring results) are intended to satisfy a number of requirements, including the regulatory requirements under DEC Contaminated Sites Program (CSP), pursuant to 18 AAC 75.360. These two programs are intended to provide DEC with a means to continue oversight and implement enforcement actions as needed. As such, the results of these programs are formally documented in separate reports to DEC after each monitoring event. In 2017, soil monitoring took place. The next sediment monitoring event is scheduled for summer 2018. These monitoring programs are discussed in the "Monitoring Programs for DEC Oversight" section below, within the "Monitoring Actions" section.

Report Organization

The annual report summarizes work that was conducted during the 2017 calendar year related to each of the implementation plans that are part of the overall RMP. Sections are provided that document the communication, dust emissions reduction, remediation, worker dust protection, uncertainty reduction, and monitoring actions taken in 2017.

Risk Management Actions Taken in 2017

The following sections of this 2017 annual report summarize each implementation plan, the corresponding risk management objectives, and the actions taken during the 2017 calendar year toward achieving these objectives.

Communication Actions

The Communication Plan follows from Risk Management Plan Objective #6: *Improve collaboration and communication among all stakeholders to increase the level of awareness and understanding of fugitive dust issues*. In order to achieve this objective, the Communication Plan was developed with the goal: "To establish consistent methods for communication and collaboration among stakeholders regarding efforts related to dust emission issues." The plan identified multiple types of communication actions, within three categories: communication, collaboration, and education and outreach. A number of methods from these three categories have been implemented as part of the various risk management programs within the RMP. The actions taken in 2017 are outlined below.

The following actions were taken in 2017 in order to increase communication and participation, and to ensure that information is being communicated to all stakeholders and communities of interest in an effective manner:

- **Community Meetings.** Red Dog continued to hold annual community visits/meetings in the surrounding communities. The community meetings provide an opportunity for Red Dog to give the communities updated information on operations, including environmental matters. It also provides an opportunity for community members to raise any concerns.
- **Subsistence Committee Meetings.** Red Dog holds quarterly meetings with the Red Dog Subsistence Committee. This provides a key opportunity to obtain input from traditional ecolgoical knowledge holders and elders from Kivalina and Noatak.
    - In 2017, Red Dog shared information about concentrate spill clean-up efforts, Red Dog longevity, shipping season, port security procedures and caribou hunting safety, and fugitive dust control.
    - The Subsistence Committee expressed its appreciation for the work Red Dog did in 2017 to address its letter of concern regarding dust control matter in 2016. The committee was updated on a quarterly basis on the progress Teck made to address those concerns stated in the letter.
- **Meetings with the Kivalina IRA.** Red Dog meets regularly with the Kivalina IRA Council through via the Siñgaqmiut Working Group. The Working Group was formed to address environmental concerns, human health issues, traditional land use, and other topics decided on by the Kivalina representatives. To date, topics have focused on water

quality testing in the community, tailings dam information sharing, human health study and employment.

- **Outreach and Education.** Red Dog Operations continued working in collaboration with fuse & traverse, LLC and Alaska Plant Materials Center to develop a native seed collection program in the village of Noatak. The intent of the program is to use the seed for Red Dog reclamation activities, including concentrate spill sites. Progress on this effort includes the following steps:
  - In 2015, NANA conducted Phase I of the seed pilot study to determine if native plants were available to harvest locally, and to train local people to collect seed.
  - In 2016, Teck funded Phase II of the seed pilot study to establish a fair price per unit weight or volume for native seeds so that local people who wish to collect native plant seeds for remediation/reclamation can operate as independent business owners.
  - In 2017, Teck transitioned from paying harvesters an hourly rate to purchasing seed directly from the harvesters. A guide was prepared that described how to weigh and purchase seed and the pricing schedule. Pre-weighed seed bags, a scale and calibration weights were left with the NANA representatives in Noatak. Native seed harvesters are now able to harvest seeds on their own and offer them for sale to Red Dog.

Dust Emissions Reduction Actions

The Dust Emissions Reduction Plan is intended to achieve Risk Management Plan Objective #1: *Continue reducing fugitive metals emissions and dust emissions*. In order to achieve this objective, the Dust Emissions Reduction Plan was developed with the goal: “To reduce the amount of fugitive dust released into the environment near the DMTS and Red Dog Mine to protect human health and the environment.”

Road Dust Emissions Reduction Actions. During the warmer months when snow and ice are no longer present, calcium chloride is applied to the gravel roads as a dust suppressant because it retains moisture for prolonged periods. Additionally, water trucks spread water on the port and mine site roads. Using the calcium chloride with water applications holds down dust and stabilizes unpaved road surfaces. In October 2016, the Subsistence Committee expressed concern that water trucks were not available for port road dust control when needed during summer 2016, due to repairs. In 2017, RDO continued to place high priority for repairs on water trucks used for dust suppression along the port road.

A new dust suppression product called Envirokleen was purchased and shipped to site in October 2017. The product has been used on Canadian Arctic runways for dust suppression with success. The product will be tested on the port road in summer 2018 to determine its effectiveness relative to calcium chloride.

Tailings Beach Dust Suppression. In 2017, a new dust suppression product was used on the tailings impoundment beach at Red Dog Operations. The product, called Pine Bind, is comprised of tall pine rosins and tall pine pitch, substances that are produced during the processing of non-bleached pulp and paper. The product is non-water soluble once cured, non-hazardous, non-toxic, and ecologically safe according to the manufacturer National Land Management. The product was ordered and applied by a crop duster airplane from Glenn Air to all exposed tailings beaches. Depending on effectiveness, the product may be used again in fall 2018 for tailings dust suppression.

New End-Dump Trailer for Truck Unloading Building. In 2017, a new end-dump trailer with a hydraulically operated lid and rubber seal around the perimeter of the frame was purchased to replace the old end-dump that is manually covered by a heavy duty tarp. The end-dump is used to store floor sweepings that are collected during periodic maintenance of the Truck Unloading Building at the Port. When full, the trailer is transported to the mine where the floor sweepings are then added to the milling process. The new trailer arrived on a barge in 2017, and in early fall 2017, a retaining wall was built next to the tub to provide an easily accessible space for the new end-dump trailer. Also, a 6-inch pipe will be buried underground at the same time to accommodate the hydraulic lines. The new end-dump trailer was fully operational by fall 2017.

Dust Suppression Equipment Dedicated to the Port Site. In 2017, the port site purchased a calcium spreader and connected it to Kubota Cart. The system is used to spread calcium around the port site by personnel whenever the condition arises, from the auxiliary roads around the Concentrate Storage Buildings, and the DMTS Port Road up to Pit 2. From Pit 2 to the mine site, mine surface crew will continue to spread calcium on the road as part of their normal operations. In addition, a port site water truck was converted to a water spraying truck. After calcium is spread on the roads, the water truck is used to help the calcium set up on the roads for dust prevention. The water truck is now totally dedicated to port operations. Finally, to create a water source down at the port, where freshwater is limited, the Pit 2 pond was dredged out. Snow accumulates in the area in the winter months, so it will melt and accumulate in the pond. The water will then be used for additional watering of the port roads in the summer months.

Year-Round Air Wash. For multiple years, the idea of truck wash to reduce fugitive dust has been considered as a preventative measure to be used at Red Dog. However, the extreme cold conditions would prevent a water-based truck wash from being used during six months of the year, and at the port site, fresh water is limited. After some study, RDO's Fugitive Dust Task Force decided to install a "waterless" air truck wash at the Port Truck Unloading Building (TUB), using high-powered blowers to remove residual dust off the trucks following truck loading, and before exiting the TUB. The system designed for the TUB consists of six high-powered air blowers that are typically used to dry cars in automatic car washes. This air wash system will blow residual dust off the concentrate trucks and keep the dust entrained in the TUB, where huge dust collectors (baghouses) collect the air and filter out the fugitive dust. The air blowers were shipped to Red Dog in 2017, and the system is expected to be operational by summer 2018.

Operational Changes to Truck Unloading Dust Collection Systems. Following interviews with port personnel, it was concluded that the timing of the baghouse dust control operation should be modified to improve dust control within the TUB. Therefore, in 2017, the baghouses operations were modified to turn on the collection system sooner, before the concentrate trucks enter the building, and to keep the baghouses operating longer, until the trucks complete air washing and exit the building.

Remediation Actions

The Remediation Plan is intended to facilitate the achievement of the Risk Management Plan Objective #2: *Continue remediation or reclamation of selected areas to reduce human and ecological exposure.* In order to achieve this objective, the Remediation Plan was developed with the goal: "To define a consistent method for identifying and selecting affected areas and implementing remediation and/or reclamation" (for metals or ore concentrate affected areas).

Specific requirements for remediation are set forth in various permits and approved documents such as the Reclamation and Closure Plan (Teck 2011), and are referenced in the Remediation Plan.

Additional reclamation of some previous spill sites was conducted in 2017. Extensive cleanup measures occurred in 2016 at the MS-13 zinc concentrate spill site (described in detail in the 2016 Annual Report). After the major recovery effort to collect the spilled concentrate from the tundra, and after areas with elevated zinc concentrations were excavated and removed from the site, the site was stabilized with coir logs, diversion ditches, and rock check dams. The entire area was then seeded with a hydroseeder twice in 2016, and watered a few times per week to provide sufficient moisture for seed germination. However, the ground cover failed to establish. Seed samples were sent to Peter Johnson at Alaska Department of Natural Resources (Plant Materials Center) for testing. Unfortunately, the seed tests suggested rates of germination from 0 to 7%. Therefore, additional fresh seeds were ordered and arrived at site in 2017. In summer 2017, the spill site was revegetated with the new seeds and watered a few times a week. Ground cover established and additional plant growth was evident by August 2017.

Worker Dust Protection Actions

The Worker Dust Protection Plan was developed in response to Risk Management Plan Objective #7: *Protect worker health*. In order to achieve this objective, the Worker Dust Protection Plan was developed with the goal: “To minimize worker exposure to fugitive dust, provide ongoing monitoring of exposure, and ensure a comprehensive communication system.”

Safety is a core value for Teck, and Teck is committed to providing leadership and resources for managing safety and health. Accordingly, the company has developed Environment, Health, Safety and Community Management Standards applicable to their operations worldwide. In addition, Teck has a comprehensive Occupational Safety and Health Program tailored specifically to Red Dog Operations to protect worker health. The program complements the corporate standards and is designed to manage all aspects of workplace safety and health, including worker dust protection. The Worker Dust Protection Plan ties in closely with the existing health and safety programs at the mine, which are overseen by the Safety & Health Department and the Medical Department.

Worksite blood lead monitoring was conducted in 2017 by the Safety & Health Department and Medical Department. Blood lead level testing is performed for all employees on a regular basis and the State of Alaska receives copies of all laboratory results directly from the third-party laboratory. In 2017, blood lead monitoring results indicated exposures were below both the MSHA/OSHA standards. Seven males (no females) exhibited blood lead levels that were slightly greater than the more stringent Red Dog standards, ranging from 25.2 to 37.3 µcg/dL. Four of the seven males had blood lead levels in the 25-29 µcg/dL range. The other three employees had blood lead levels in the range of 30 to 34 µcg/dL and therefore underwent additional blood lead monitoring received counseling. No workers were removed from the job due to blood lead levels in 2017.

Uncertainty Reduction Actions

The Uncertainty Reduction Plan follows from Risk Management Plan Objective #5: *Conduct research or studies to reduce uncertainties in the assessment of effects to humans and the environment*. In order to achieve this objective, the Uncertainty Reduction Plan was developed with the goal: "To identify and prioritize prospective research or studies to reduce uncertainties in the assessment of effects of fugitive dust to humans and the environment."

Caribou Subsistence Use. Because caribou are an important subsistence resource, in 2017, a scientific research article was prepared that addresses the Western Arctic Herd caribou that overwinter near Red Dog. In the article, multiple lines of evidence are discussed that indicates fugitive dust emissions from RDO are not a significant source of metals in caribou. Also, caribou that overwinter near Red Dog are not at risk, nor are subsistence consumers of caribou. Additionally, this paper discusses how caribou do not avoid the area of RDO and Port Road, and yet remain safe for human consumption. The research article is titled "Application of a weight of evidence approach to evaluating risks associated with subsistence caribou consumption near a lead/zinc mine" and was published in a peer-reviewed scientific journal, "Science of the Total Environment". The published article is available at https://doi.org/10.1016/j.scitotenv.2017.11.149.

Upcoming Caribou Cooking Study. The results of the risk assessment (Exponent 2007) indicated that overall human health risks were low, including potential risks associated with consumption of metals in caribou tissue. Consumption of caribou muscle (meat), liver, and kidney was evaluated in the risk assessment, but bone and bone marrow were not directly evaluated. Community members expressed concern that they could be exposed to lead stored in caribou bone, therefore an additional study is planned to evaluate bone and bone marrow. The primary objective of the study is to conduct an analysis to determine typical bone lead levels in caribou and the potential availability of lead from bone in food after cooking. The scientific questions that this study seeks to address include the following:

1. What are the lead concentrations in bone and bone marrow in caribou harvested near Red Dog?
2. Are lead concentrations in marrow and bone from caribou harvested near Red Dog different from those in reference caribou harvested elsewhere?
3. How much lead does marrow/bone contribute to food cooked by the local community with those ingredients?
4. How do lead concentrations in marrow/bone from other meats (e.g., beef) compare to caribou?

The detailed caribou cooking study plan was issued to the Ikayuqtit Review Team in October 2017 for review. Sampling of caribou and implementation of the first phase of the study is planned for spring 2018.

Monitoring Actions

The Monitoring Plan (Exponent 2014) is intended to facilitate the achievement of the following Risk Management Plan objectives:

- Objective 1: Continue reducing fugitive metals emission and dust emissions [this objective is indirectly addressed through monitoring, to verify effectiveness of operational dust control measures]
- Objective 3: Verify continued safety of caribou, other representative subsistence foods, and water
- Objective 4: Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered
- Objective 6: Improve collaboration and communication among all stakeholders to increase the level of awareness and understanding of fugitive dust issues.

In order to achieve these objectives, the Monitoring Plan (Exponent 2014) was developed with the goal: "To monitor changes in dust emissions and deposition over time and space, using that information to: 1) assess the effectiveness of operational dust control actions, 2) evaluate the effects of the dust emissions on the environment and on human and ecological exposure, and 3) trigger additional actions where necessary."

Actions included in the Monitoring Plan were developed from priority actions identified during development of the Risk Management Plan, with input from local stakeholders, technical experts, and State and Federal regulatory agencies. This section presents the results of the Monitoring Plan actions implemented during 2017. An overview of the components of the monitoring program with frequencies of monitoring is shown in Figure 2. A map-based illustration of monitoring program components and monitoring stations and sites is shown in Figure 3.

Monitoring Programs for DEC Oversight

The marine sediment and soil monitoring programs are ongoing for DEC oversight, and results are also used for trend analysis at Red Dog Operations. Sediment monitoring was conducted in 2016, and is planned again for 2018. Soil monitoring was conducted in 2017, and the results are summarized below.

Soil Monitoring

A third soil monitoring event was conducted in the summer of 2017. The soil monitoring stations are collocated with the previously established vegetation community monitoring stations (see Figure 3). Soil monitoring provides a means of evaluating dust deposition and accumulation in the environment surrounding the DMTS and Red Dog mine, and verifies that conditions continue to pose no threat to human health and the environment (Exponent 2017).

Metals concentrations in soil are monitored to understand whether exposures of wildlife receptors in the tundra environment are increasing or decreasing, and whether concentrations may be increasing or decreasing in vascular plants rooted in those soils, as the plants can be consumed by wildlife and/or harvested for subsistence foods. The primary constituents of interest in soil, which were identified for use in ongoing monitoring in Exponent (2014), include aluminum, barium, cadmium, calcium, iron, lead, and zinc; soil samples were also analyzed for pH and TOC.

Concentrations of all metals measured in soil samples were below their respective DEC Arctic Zone default cleanup levels, with the exception of some stations within the operational mine permit boundary. These findings confirm that concentrations in soil surrounding RDO continue to pose no elevated risks to human health and the environment.

The soil monitoring report is included in Appendix A. Note that all associated laboratory reports are available upon request.

Operational Monitoring

U.S. EPA Method 22 – Visible Emissions Evaluation

Visible Emissions Evaluations (VEE) were conducted as required for the Title V air permit at the mine. Monitoring occurs at multiple locations within the mine boundary and at the port. Along the DMTS road, VEE observations are conducted daily when road surfaces are dry but not frozen. Typical VEE monitoring locations are shown on Figure 3, though the locations depicted are not all-inclusive, as the locations may vary. All VEE readings that are required under the Title V permit have been performed and are submitted twice a year to ADEC within the Title V Facility Operating Report.

In addition, when operational changes are made for which additional VEE readings are used to evaluate before/after results, these results are reported in the Annual Report. No such changes occurred in 2017; therefore there is no additional VEE monitoring to report for 2017.

TEOM Source Monitoring

Tapered element oscillating microbalance (TEOM) samplers are used for air quality monitoring at four locations near sources within the mine and port (Figure 3). Mine TEOMs are located downwind of the pit and crusher at the Personnel Accommodations Complex (PAC), and at the main tailings dam (Tdam) downwind of the tailings beach, mill, and other facilities (Figure 4). Port TEOMs are located downwind of the Concentrate Storage Buildings (CSBs) and in the lagoon area downwind of the concentrate conveyor (Figure 5).

The TEOMs produce real-time measurements of dust in air, and collect discrete samples which are then analyzed to provide airborne metals concentrations. Measurements are reported as Total Suspended Particulates (TSP), and zinc and lead concentrations are reported as TSP-Zn and TSP-Pb, respectively. TEOMs are operated continuously[3] to measure real-time TSP. Filters are used to collect TSP over 24-hour periods every third day at the mine and every sixth day at the port to be analyzed for TSP-Zn and TSP-Pb.

The calculated monthly averages of 2014, 2015, 2016, and 2017 TSP-Pb and TSP-Zn concentrations are shown on Figure 6a for all four mine and port TEOM locations. The concentrations of lead and zinc at the mine area are typically higher than those at the port area (Figure 6a).

- **Mine TEOM Results.** At the mine, (Figure 6b), lead and zinc concentrations were typically lowest in summer months (the months with higher humidity and more road watering for dust control), and highest in winter months (the coldest, driest, and lowest humidity months, when road watering is not possible because of freezing conditions). In the Mine TDam TEOM, concentrations are comparable in the past four years, while concentrations in the mine PAC TEOM were generally lower in 2017 in winter months than the past few years with the exception of February.

- **Port TEOM Results.** At the port (Figure 6c), measured lead and zinc TEOM concentrations are highest from June through November, corresponding with the peak shipping season. Lead and zinc concentrations detected in the port lagoon TEOM were generally lower in 2017 than past years, while the port CSB TEOM measurements were comparable to past years.

Statistical Trend Analysis for TEOM Data. Statistical testing methods were used to evaluate whether TEOM datasets have statistically significant temporal trends in metals concentrations. The Seasonal Mann-Kendall (SMK) trend test is a nonparametric method to investigate temporal trends in time series containing substantial seasonal variability. In this case, TEOM data were summarized on a monthly basis. Seasonal trend tests were conducted using monthly means and monthly 95th percentile concentrations to evaluate both average conditions and a measure of the upper limit. Seasonal trend tests require valid data within each month for at least three years within the time frame considered.

[3] Occasional system upsets do occur as a result of weather or equipment failure. TEOM readings are monitored frequently so that system upsets are noted and corrected as soon as possible. Missing or unusable data are noted in the raw data files, and are not used in statistical trend evaluations.

Results of the statistical trend tests for TEOM data (lead and zinc concentrations) in four locations (Mine PAC, Mine Tdam, Port CSB, and Port Lagoon) are summarized in Table 1. Port CSB and Lagoon results were also analyzed as a combined data set. This combined analysis is supported by the proximity of the two port locations and the similarities in monthly average concentrations for both lead and zinc (Figures 7a and 7b).

For the most recent four-year period (2014-2017), statistical analysis indicates that Port area and Mine area have been relatively stable to declining in lead and zinc concentrations, both in mean and 95th percentile concentrations (Table 1, Figures 7a and 7b), with the exception of 95th percentile concentration in the Mine TDam. In fact, the Port Lagoon TEOM has shown a significant decreasing trend in mean zinc concentration over the last four years.

TEOM Real Time Alarm System Monitoring

Real-time TEOM data is used internally to monitor for high dust events so that mine activities can be modified (where possible) to reduce dust levels. When air quality measurements exceeded a warning level or an alarm level, the alarm status was displayed on the Red Dog weather intranet web page to notify personnel within the Mine Operations and Environmental departments to take corrective action. Examples of these corrective actions include ordering water on the roads or stock-piles, or shutting down loading operations during windy conditions.

Road Surface Monitoring

Loose fine materials subject to airborne transport into the surrounding environment are sampled from the road surface at eight locations every two months. From the mine site to the port, the eight road surface monitoring station locations are:

- Mine CSB (near exit from truck loading portion of CSB)
- The Y (near the back dam, between the CSB and the Airport)
- Airport
- MS-13 (former material site where road crosses the mine boundary)
- MS-9 (material site between the mine and CAKR)
- R-Boundary (northern boundary of CAKR)
- MS-2 (material site just inside the northern boundary of the port)
- Port CSB Track (road near exit from truck unloading building at the port CSBs)

Samples were analyzed onsite using a portable XRF (x-ray fluorescence) analyzer to determine lead, zinc, and cadmium concentrations within road surface materials. The “Mine CSB” and “The Y” stations (inside the mine boundary) often exceed the cleanup levels, and are managed so as to reduce tracking of metals concentrates toward the port. Final remediation of the mine areas will occur after mine closure according to the methods outlined in the Red Dog Mine Waste Management, Reclamation and Closure Monitoring Plan (Teck 2011).

For the most recent four-year period (2014-2017), statistical analysis indicates that road surface samples have been relatively stable in mean lead, zinc, and cadmium concentrations (Table 2, Figures 8a, 8b, and 8c). Note, if measured road surface concentrations at stations outside the mine boundary exceed Arctic Zone Industrial Cleanup Levels for lead, zinc, or cadmium (800, 41,100 and 110 mg/kg respectively[4]) for more than two consecutive sampling periods, that road section is to be remediated and resurfaced as described in the Remediation Plan (Exponent 2011).

Results for stations outside the mine and port boundaries did not exceed Arctic Zone Industrial Cleanup Levels for lead, zinc, or cadmium over the time period 2011-2017 (Figures 8a, 8b, and 8c). However, at the Port CSB Track, lead concentrations exceeded the cleanup levels for two consecutive sampling periods in 2017 (Figure 8a). Thus at the Port CSB Track, where lead concentrations exceeded the cleanup levels in consecutive sampling periods in 2017 (Figure 8a), remediation work will be implemented at the port site in 2018.

Dustfall Jar Monitoring

Dustfall jars are passive continuous collectors for measuring dust deposition; samples are collected every two months at all locations. Approximately 86 dustfall stations are located around the mine, port, and DMTS road, as follows:

- At the mine, approximately 34 jars are placed in locations around the facilities (Figure 3).
- Along the DMTS road, 12 dustfall jars are located at three stations, each with four dustfall jars, two on either side of the road. The DMTS road stations are collocated with road surface sampling stations near the port boundary, the CAKR northern boundary,

[4] Cleanup levels according to 18 AAC 75.341, as revised in 2008 (available on the internet at https://dec.alaska.gov/spar/csp/docs/75mas_art3.pdf). Note that the cadmium and zinc cleanup level would be lower, at 79 and 30,400 mg/kg, if the zone were considered to be the “Under 40 inch Zone” by DEC, which is a function of the definitions at 18 AAC 75.990.

and midway between CAKR and the mine. The dustfall jars are located approximately 100 m from the shoulder of the DMTS, with 100 m between them, oriented parallel to the road (Figure 3).

- At the port, 38 jars are placed roughly in a rectangular grid throughout the area (Figure 3).
- An additional two jars are considered reference stations, one upwind of the road near Evaingiknuk Creek, and another near the Wulik River, to the north of the operation (Figure 3).

Statistical Trend Analysis for Dustfall Jar Data. Temporal trends in deposition rates or metals concentrations in dustfall jars data were evaluated using seasonal trend tests conducted with bi-monthly mean and 95th percentiles (method as discussed above in TEOM section).

- **Lead.** For lead, dustfall deposition rates and concentrations have been relatively stable over the most recent four-year period. No statistically-significant trends were identified during the most recent four-year monitoring period at the mine or along the DMTS road (Table 3). However, a statistically significant increase in lead dustfall deposition rates at the port was detected, for both in average and upper limits. Time series plots of lead dustfall deposition rates and concentrations are presented in Figures 9 and 10, respectively.
- **Zinc.** For zinc, dustfall deposition rates and concentrations have been stable over the most recent four-year period. No statistically-significant trends were identified at any location over the most recent four-year period, either in average or upper limits (Table 3). Time series plots of zinc dustfall deposition rates and concentrations are shown in Figures 11 and 12, respectively.
- **Total Solids.** For total solids, the deposition rates have been stable with no statistically-significant trends identified at any location over the most recent four-year period, either in average or upper limits (Table 3). Time series plots of total solids dustfall rates are presented in Figure 13.

Caribou Tissue Monitoring

Red Dog Mine is located within the normal annual range of the Western Arctic Herd. Surveys of caribou have been conducted periodically since 1984 by the Alaska Department of Fish and Game (ADFG), and have provided baseline information against which more current studies may be compared. Caribou tissue monitoring for dust-related constituents under the RMP program was planned to occur in 2015 and then again in 2016, but due to lack of caribou overwintering near the road, it was postponed until 2017. In 2017, the caribou monitoring was postponed to coincide with the Uncertainty Reduction Study for caribou bone and marrow, therefore caribou collection was delayed until 2018 to support both studies.

Summary of Monitoring Results

Dust monitoring data from the TEOM air samplers, road surface samples, and the dustfall jars were statistically evaluated to assess the current trends over the most recent four-year period. The data indicates that the measured concentrations and deposition rates at the mine, port and road areas are stable and not significantly increasing. The one exception is for the port, where dustfall jars indicate a significant increase in lead deposition rate. Also road surface samples at the port exceeded the Arctic Zone cleanup levels for more than two consecutive sampling periods, so in 2018 road remediation at the port will take place. On the other hand, the Port Lagoon TEOM has shown a significant decreasing trend in mean zinc concentration.

A summary of statistical trend analysis results for TEOM, road surface and dustfall jar monitoring programs is presented in Table 4. This table provides an at-a-glance overview of results of dust monitoring programs. Results from the monitoring programs largely indicate that concentration trends are flat (i.e., no increasing or decreasing trend).

Soil monitoring found that concentrations of all metals measured in soil samples were below their respective DEC Arctic Zone default cleanup levels, with the exception of some stations within the operational mine permit boundary. These findings confirm that concentrations in soil surrounding RDO continue to pose no elevated risks to human health and the environment.

Overall, environmental media concentrations remain similar to or lower than those evaluated in the DMTS risk assessment (Exponent 2007). Additional work at the port will take place in 2018 to ensure that dust levels remain low, and the effects of the multiple dust reduction improvements that were initiated at the port site in 2017 will be evaluated and discussed in the 2018 annual report.

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Fugitive Dust Risk Management Plan

RISK MANAGEMENT OBJECTIVES	Communication Plan	Dust Emission Reduction Plan	Remediation/ Reclamation Plan	Monitoring Plan	Uncertainty Reduction Plan	Worker Dust Protection Plan
1. Continue reducing fugitive metals emissions and dust emissions	□	■	□	■	□	
2. Conduct remediation or reclamation in selected areas	□		■	□	□	
3. Verify continued safety of caribou, other representative subsistence foods, and water	□			■	□	
4. Monitor conditions in various ecological environments and habitats, and implement corrective measures when action levels are triggered	□			■	□	
5. Conduct research or studies to reduce uncertainties in the assessment of effects to humans and the environment	□			□	■	□
6. Improve communication and collaboration among all stakeholders	■	□	□	□	□	□
7. Protect worker health	□	□	□	□	□	■

■ Implementation plan directly addresses objective

□ Implementation plan indirectly addresses objective

Figure 1. Risk management objectives and associated implementation plans

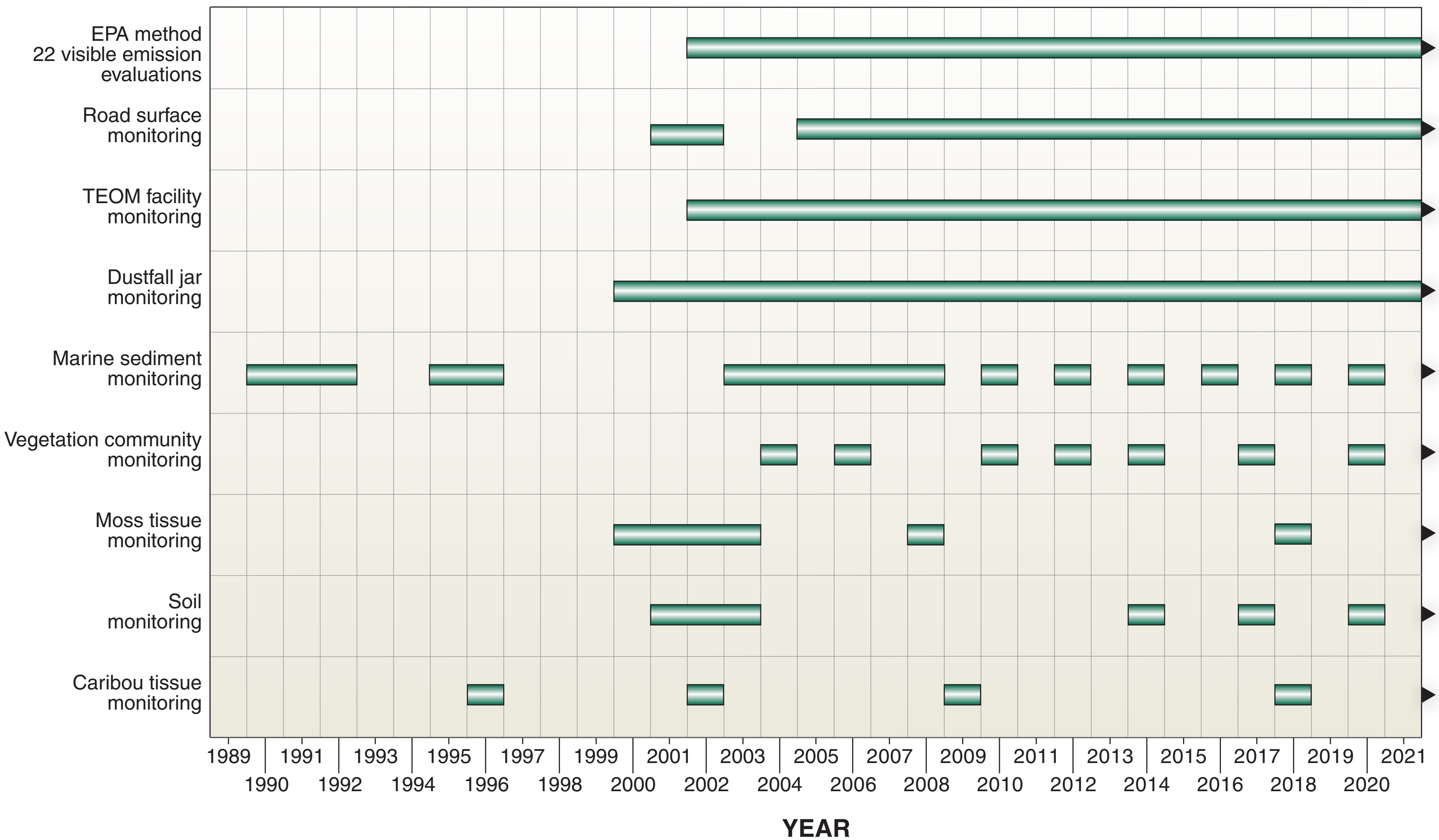


Figure 2. Monitoring timeline with program frequencies

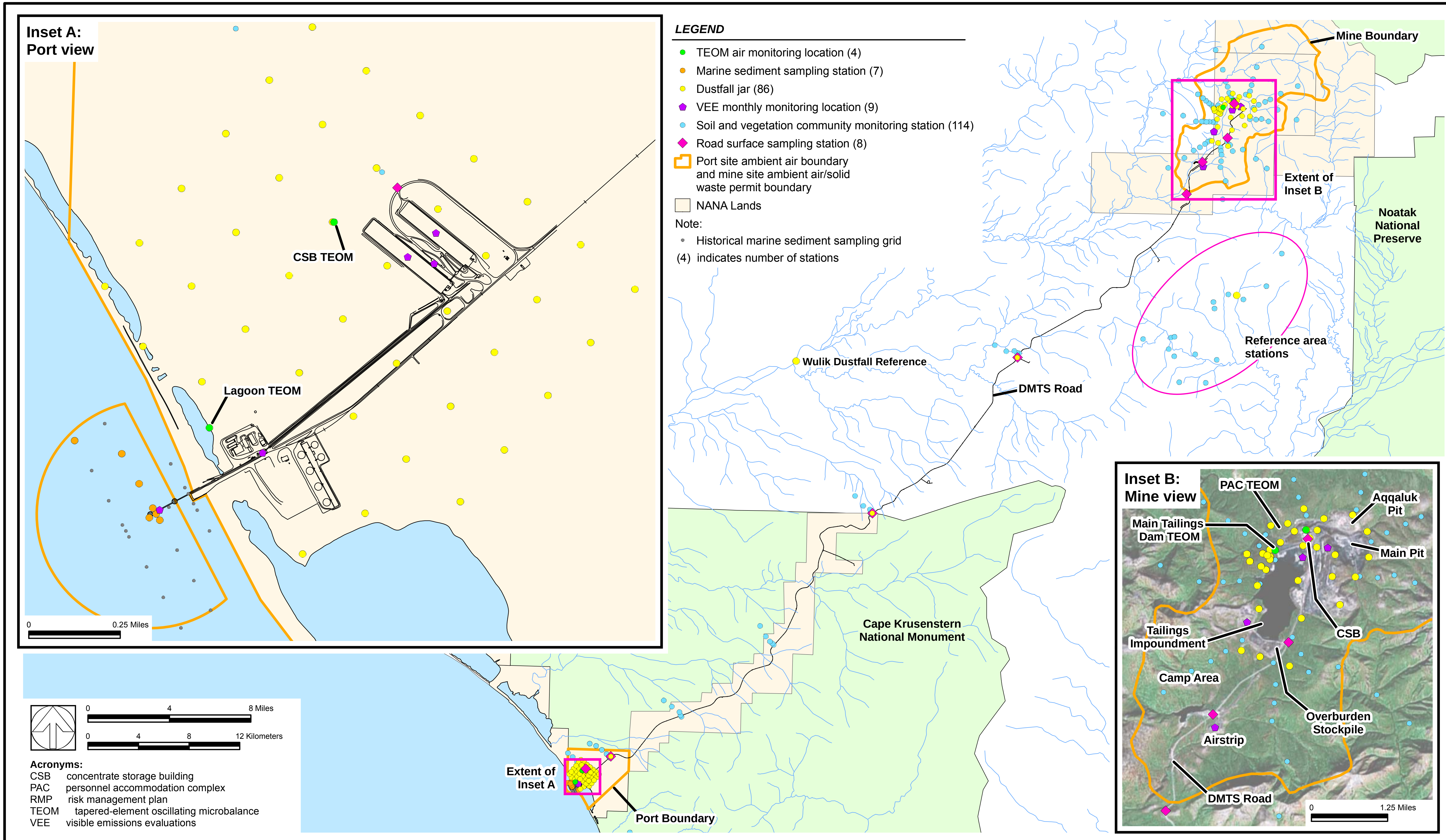


Figure 3. Overview of risk management monitoring programs

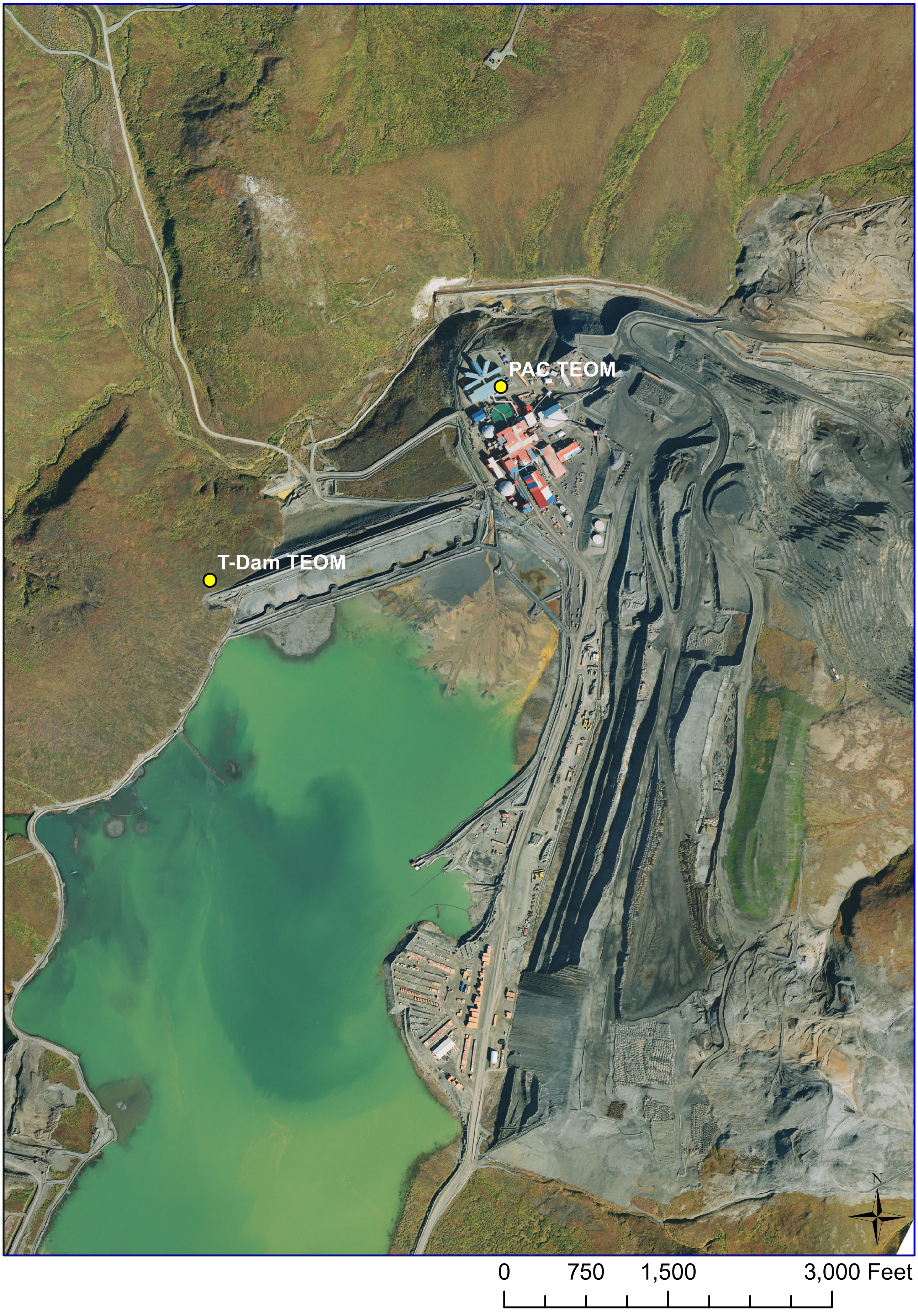
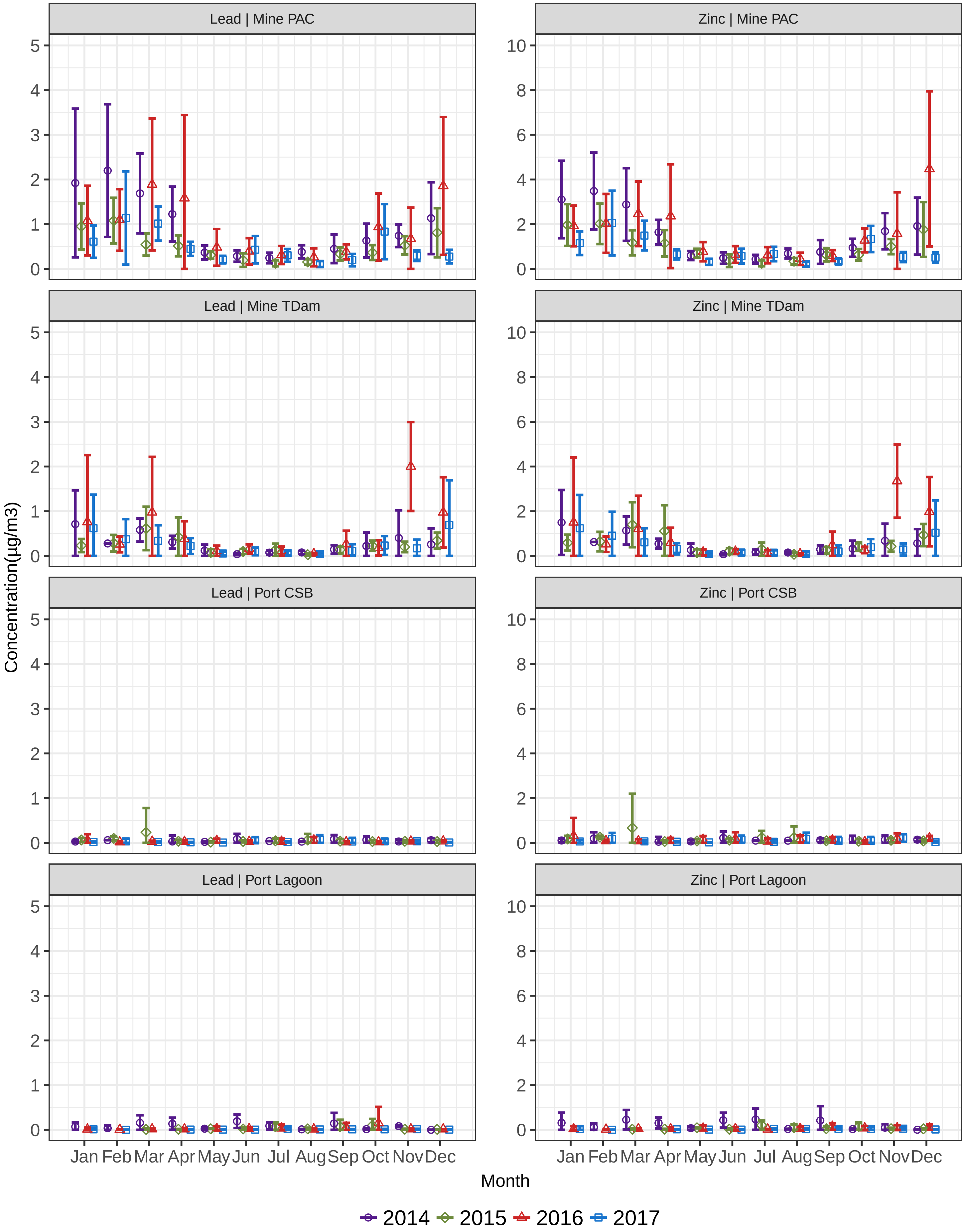


Figure 4. Mine TEOM locations

Figure 5. Port TEOM locations



Note: Different vertical axis scales are used for lead and zinc TEOMs.

Figure 6a. TEOM monthly monitoring data comparison, 2014−2017

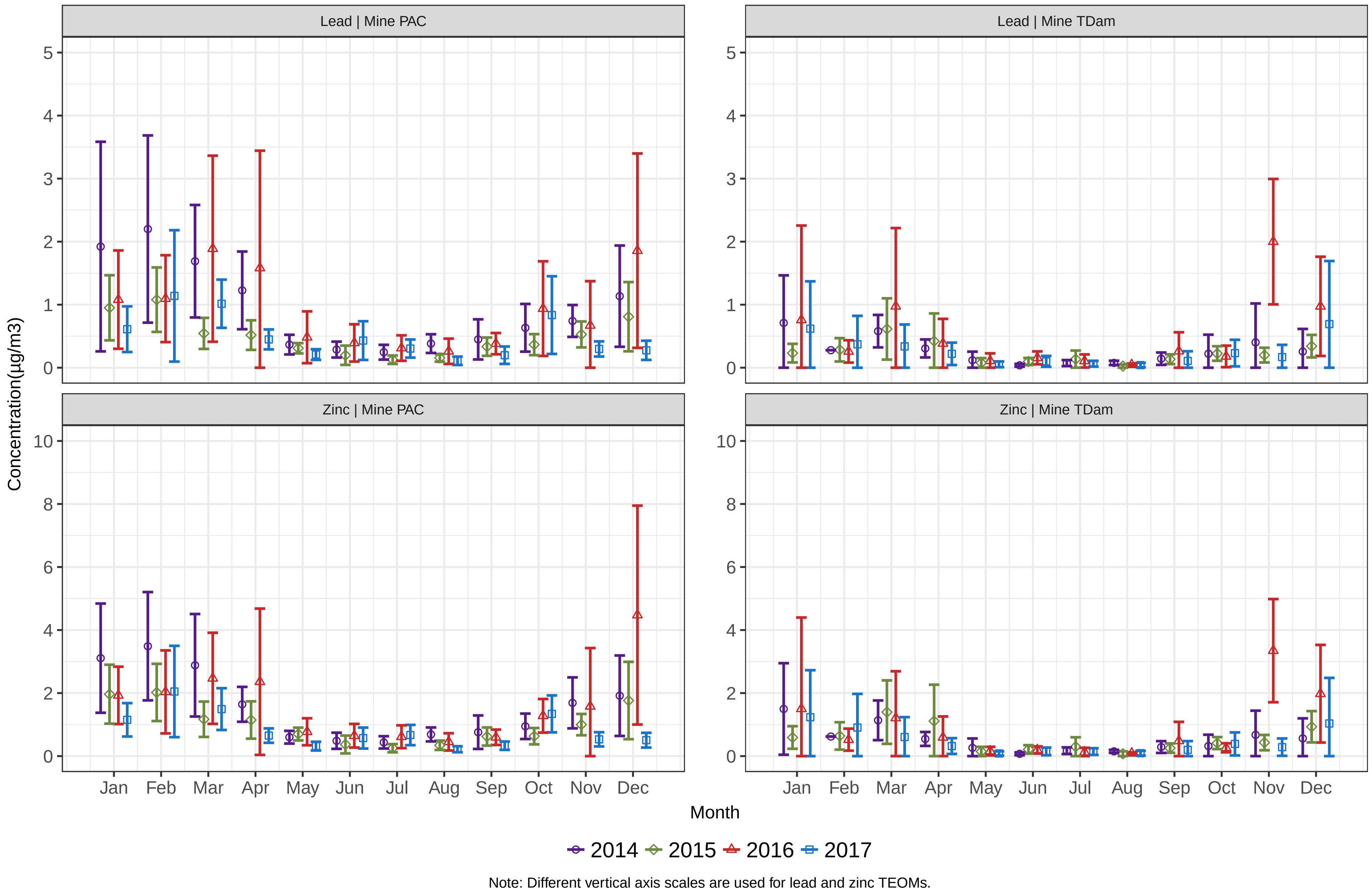


Figure 6b. Mine area TEOM monthly monitoring data comparison, 2014−2017

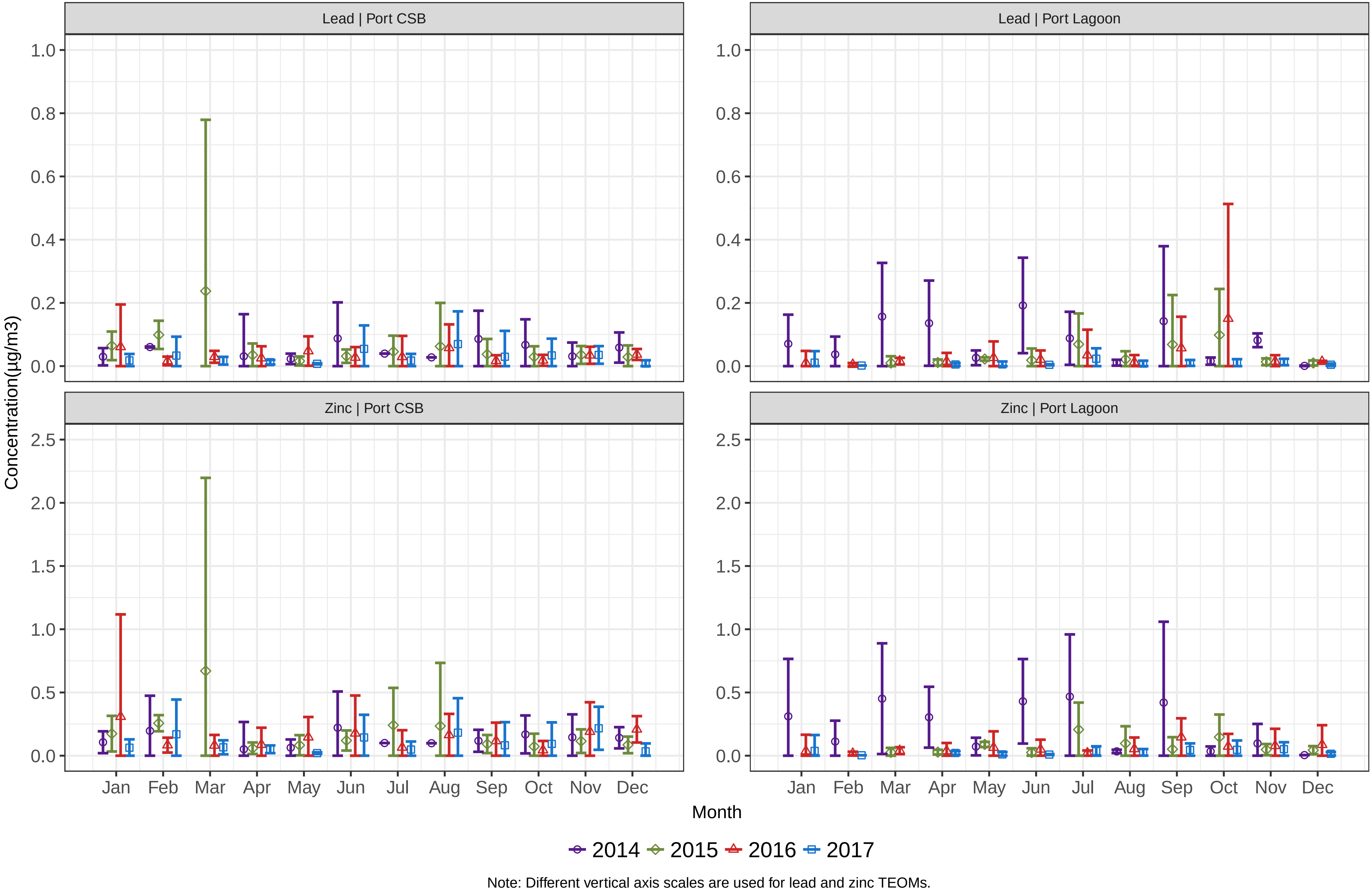


Figure 6c. Port area TEOM monthly monitoring data comparison, 2014−2017

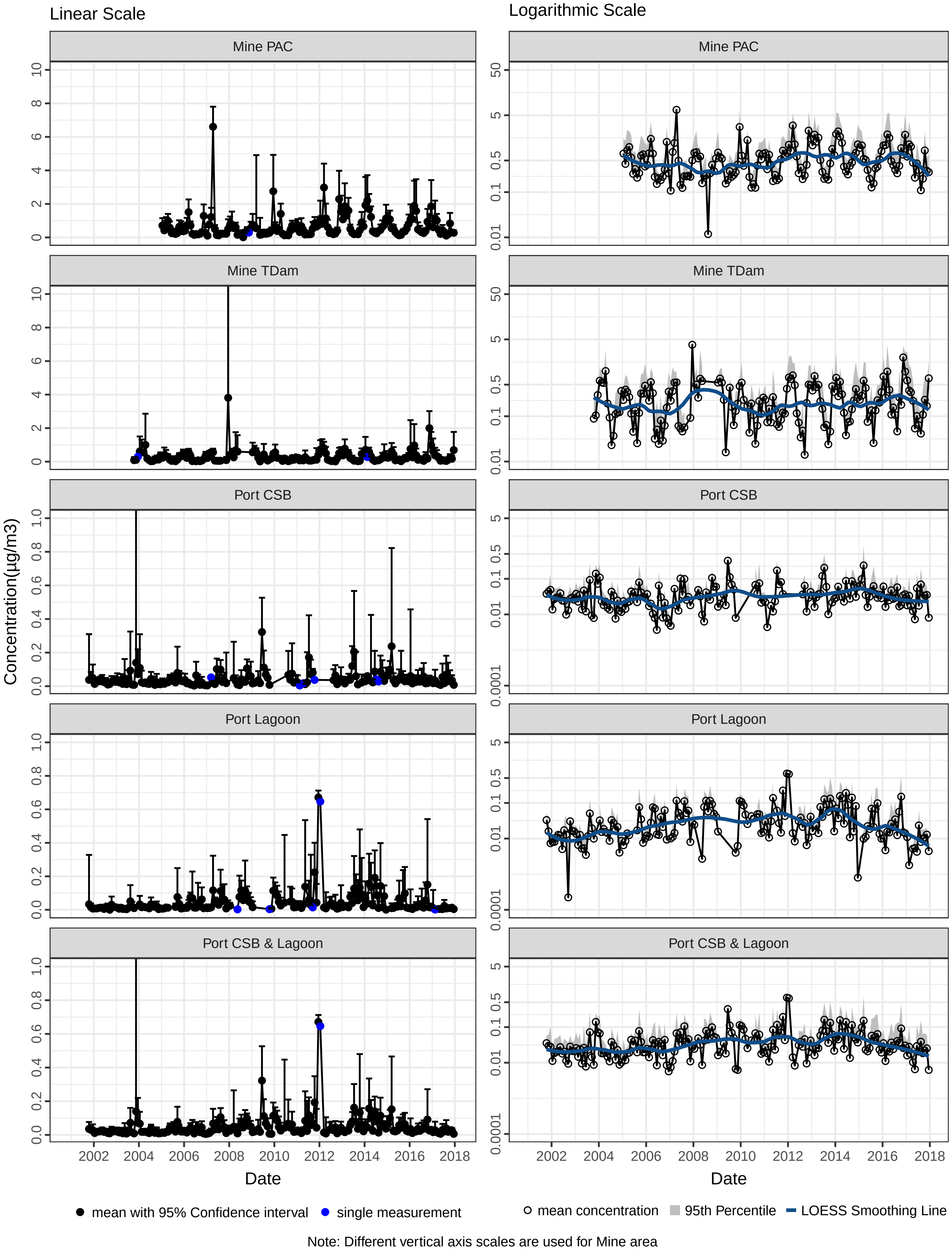


Figure 7a. TEOM Lead Concentration plots (all years)

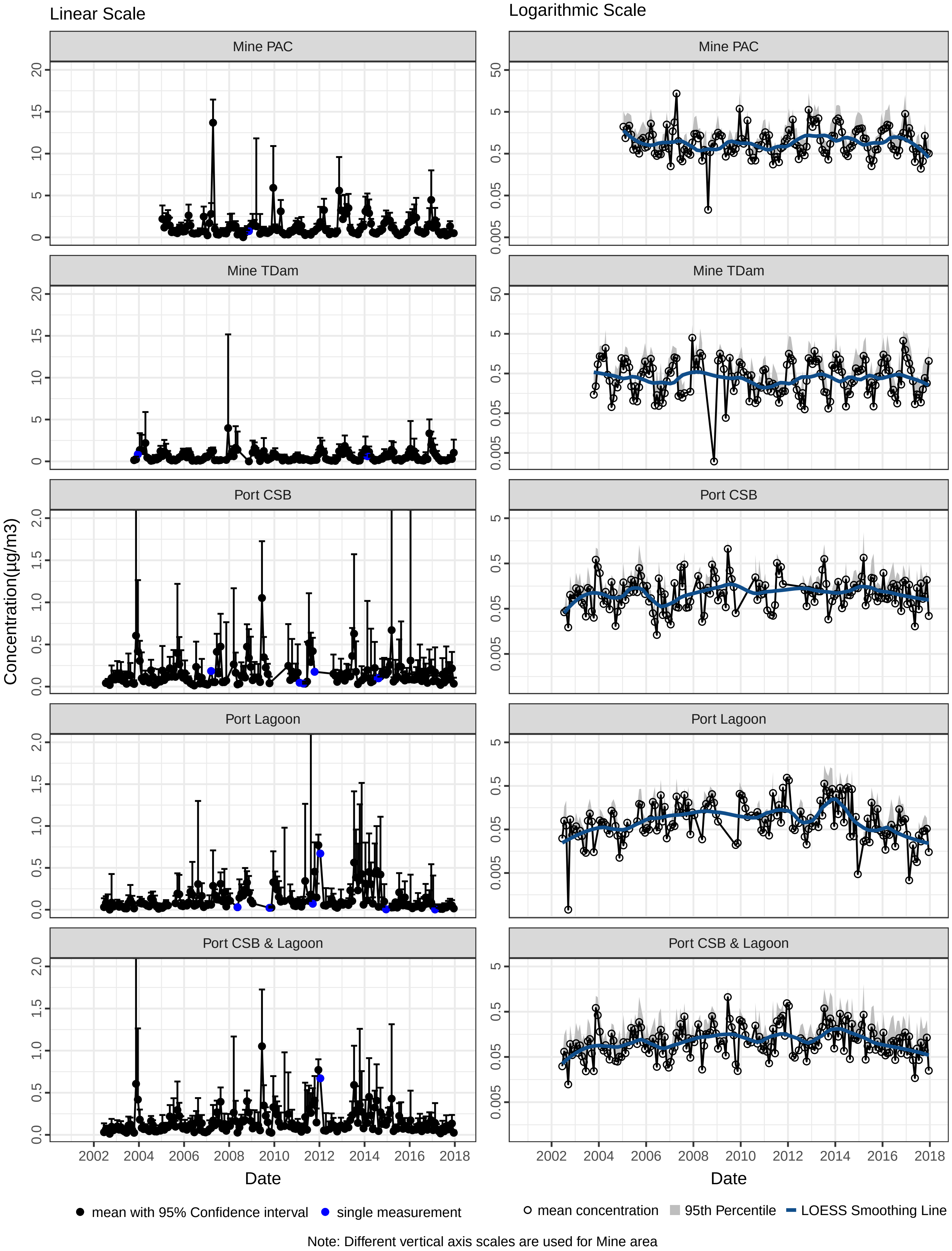


Figure 7b. TEOM Zinc Concentration plots (all years)

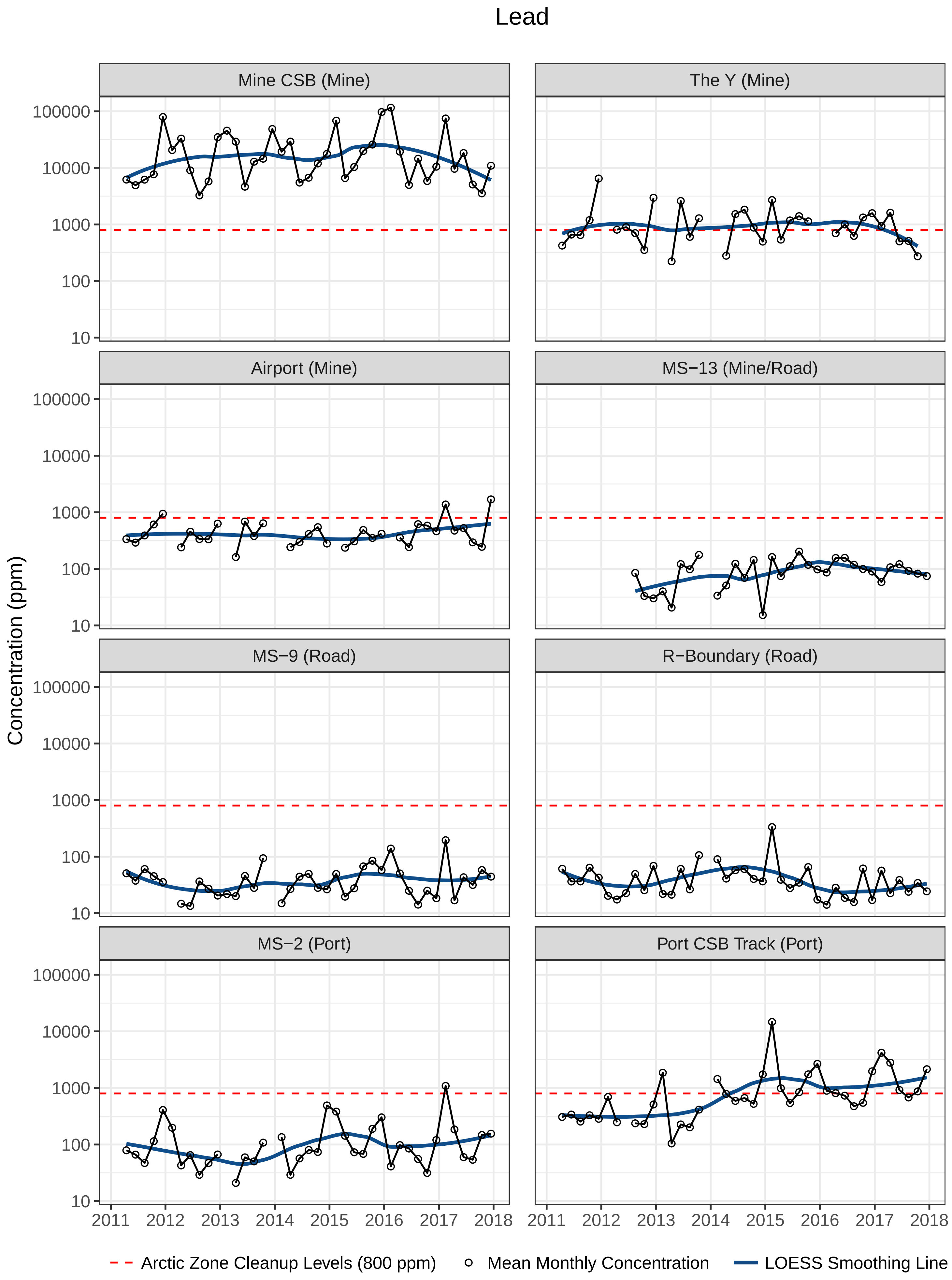


Figure 8a. Road Surface Lead Concentration plots (all years)

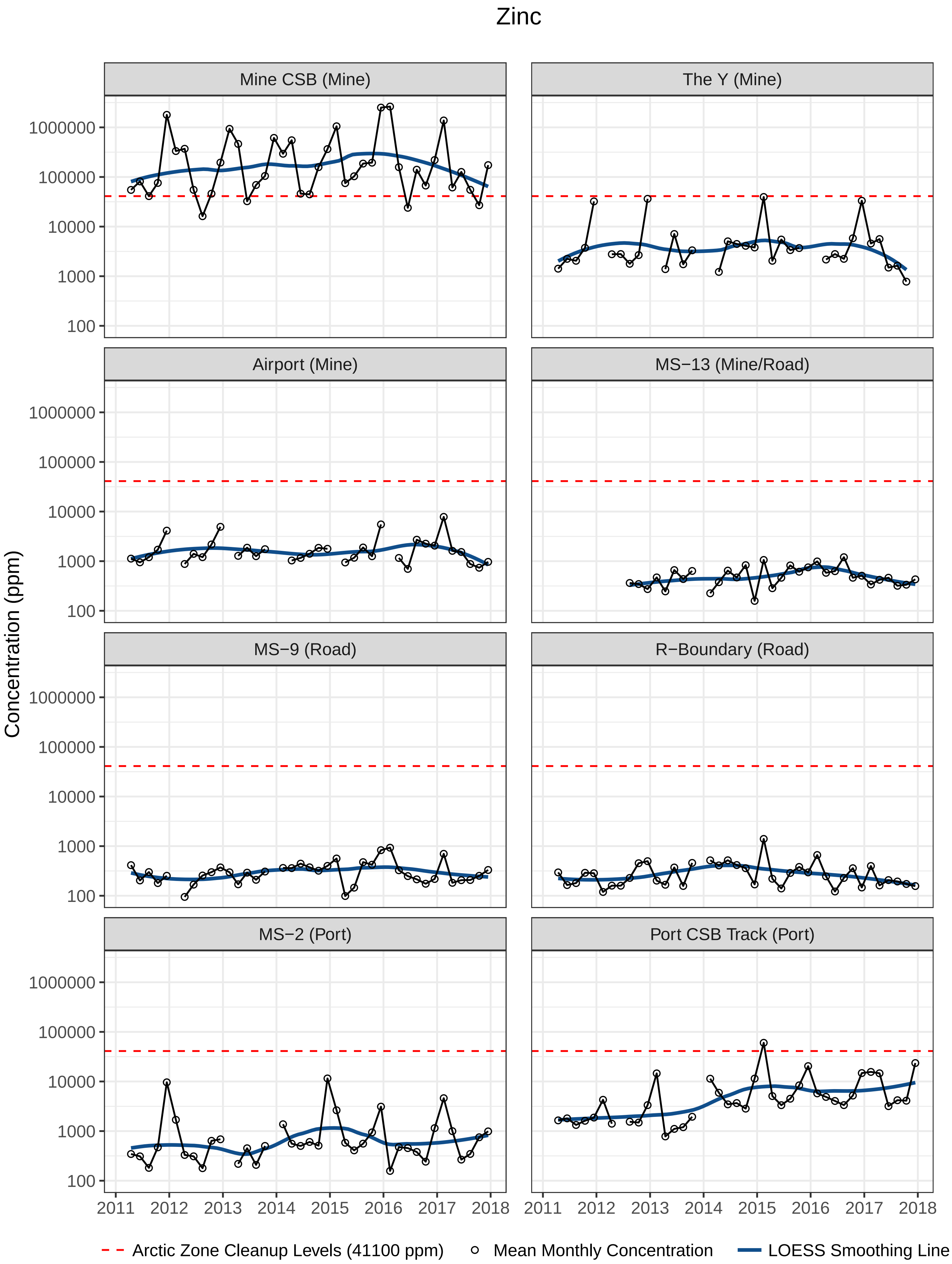


Figure 8b. Road Surface Zinc Concentration plots (all years)

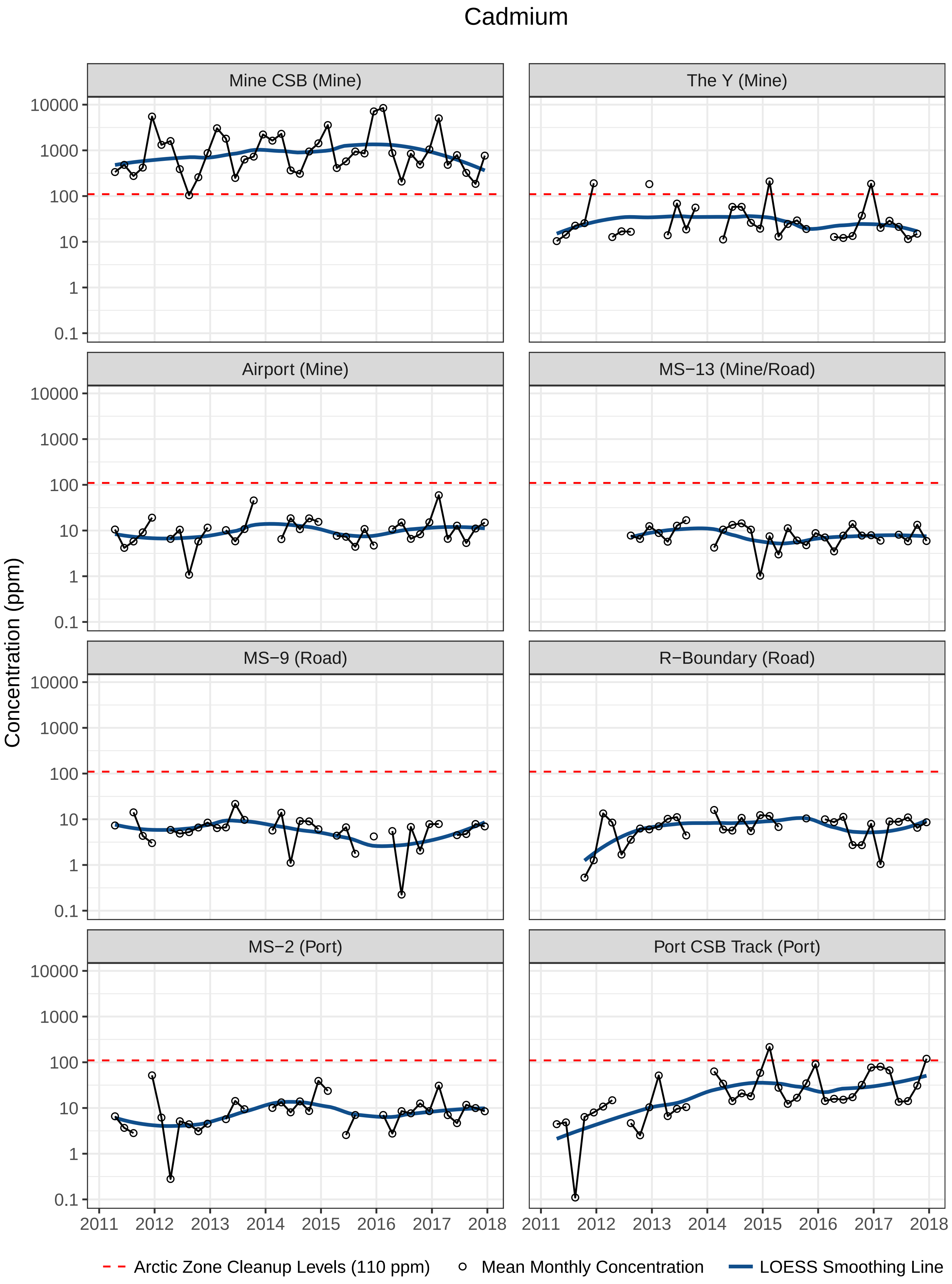


Figure 8c. Road Surface Cadmium Concentration plots (all years)

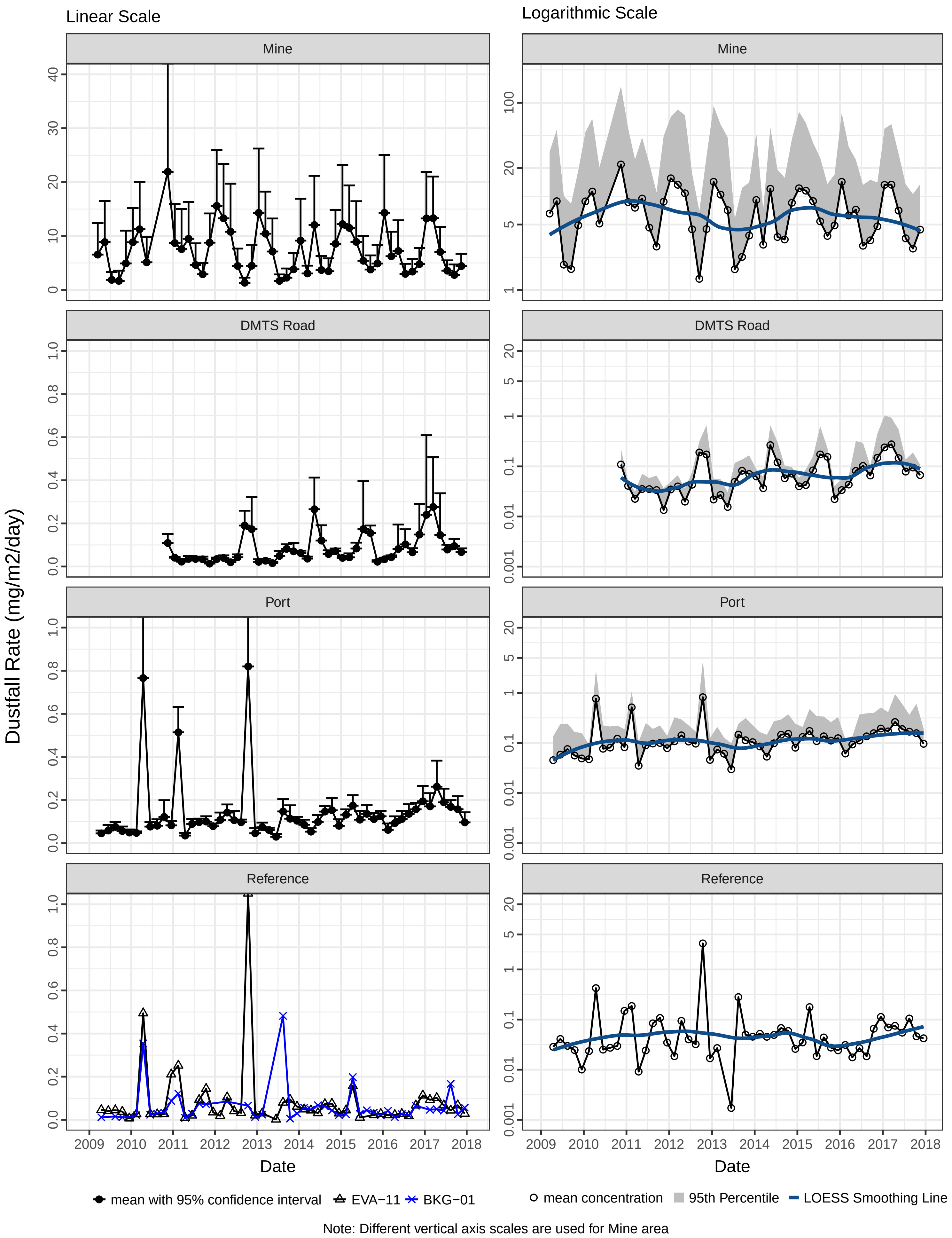
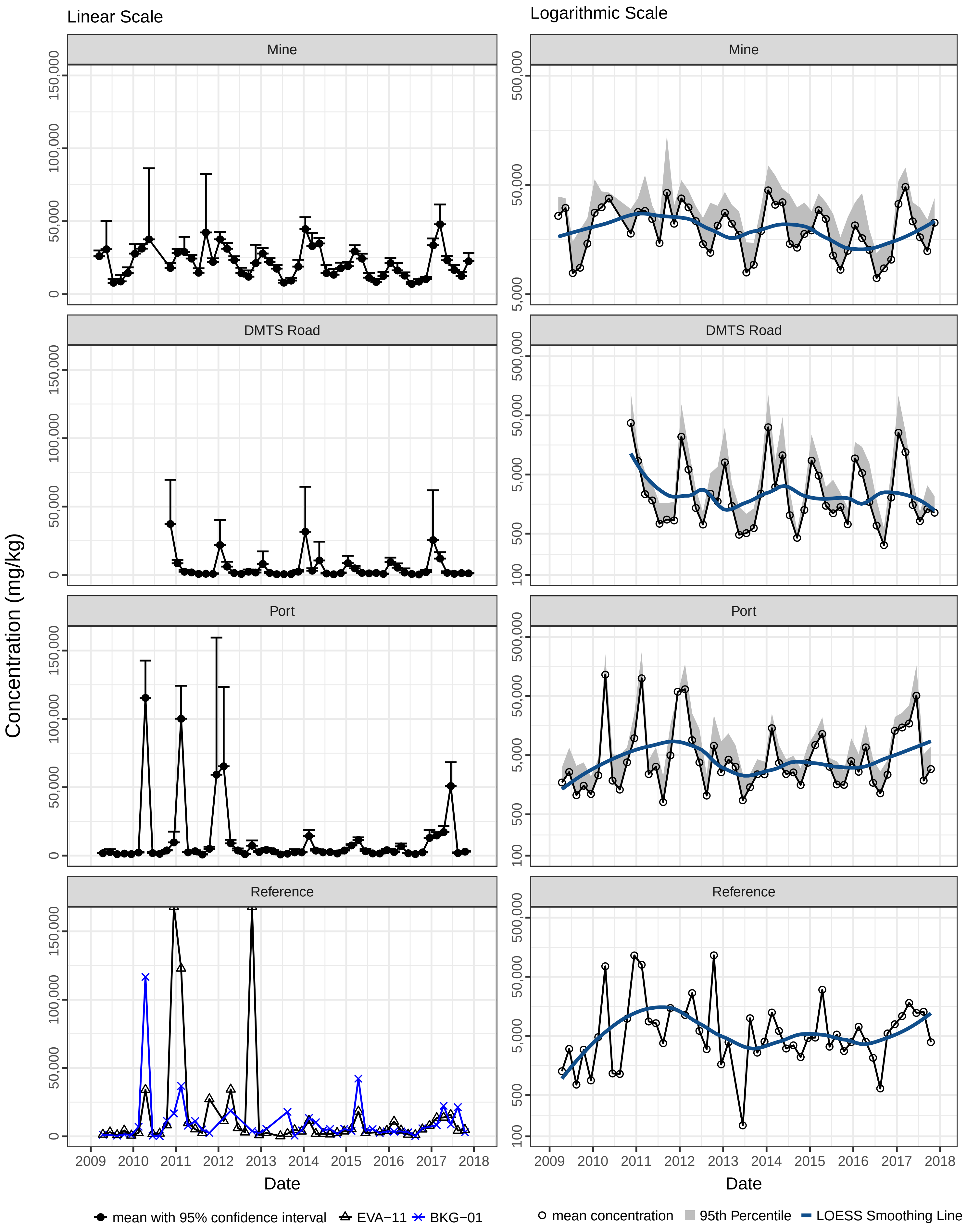


Figure 9. Dustfall Jars Lead Deposition Rate plots (all years)



Note: Different vertical axis scales are used for Mine area

Figure 10. Dustfall Jars Lead Concentration plots (all years)

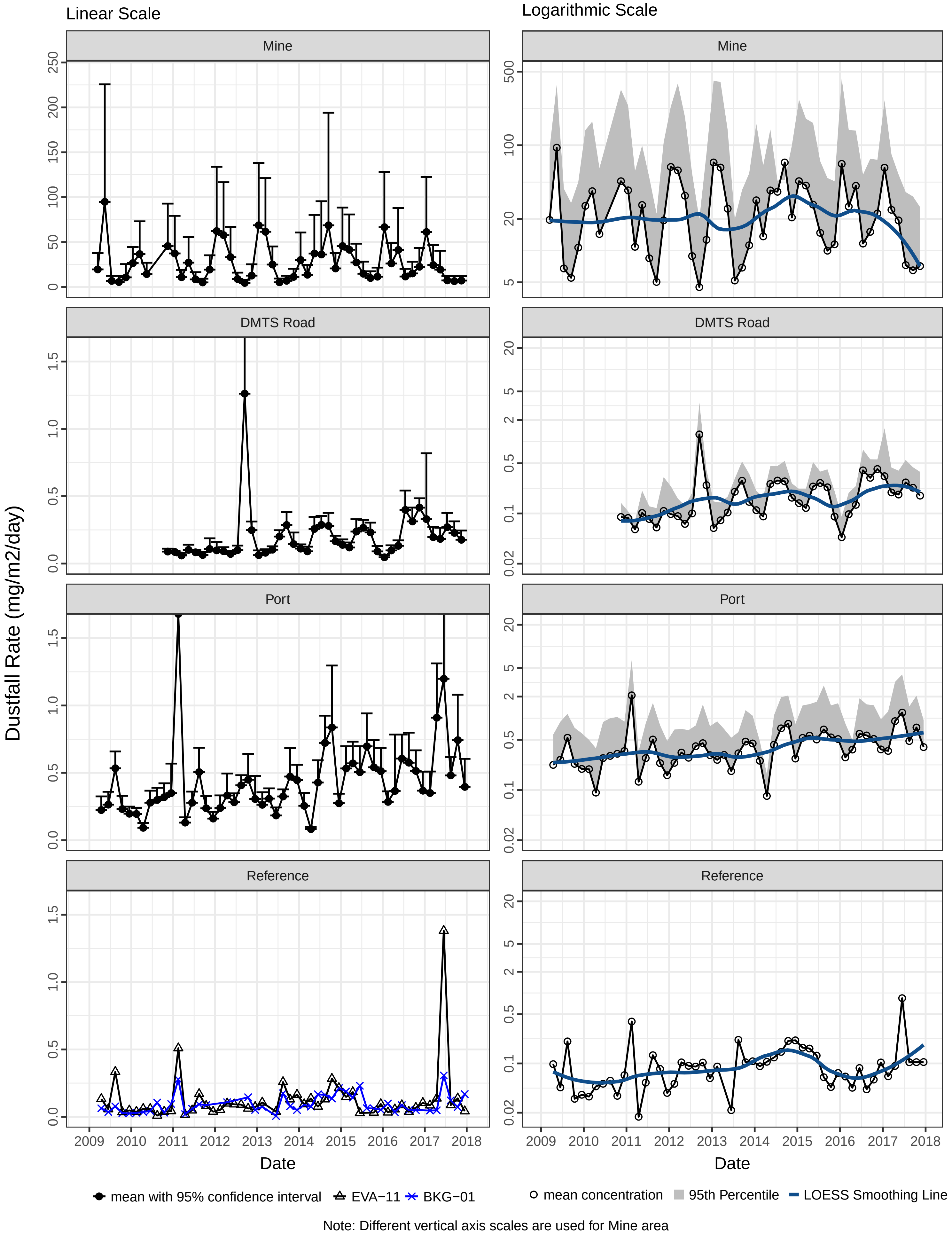


Figure 11. Dustfall Jars Zinc Deposition Rate plots (all years)

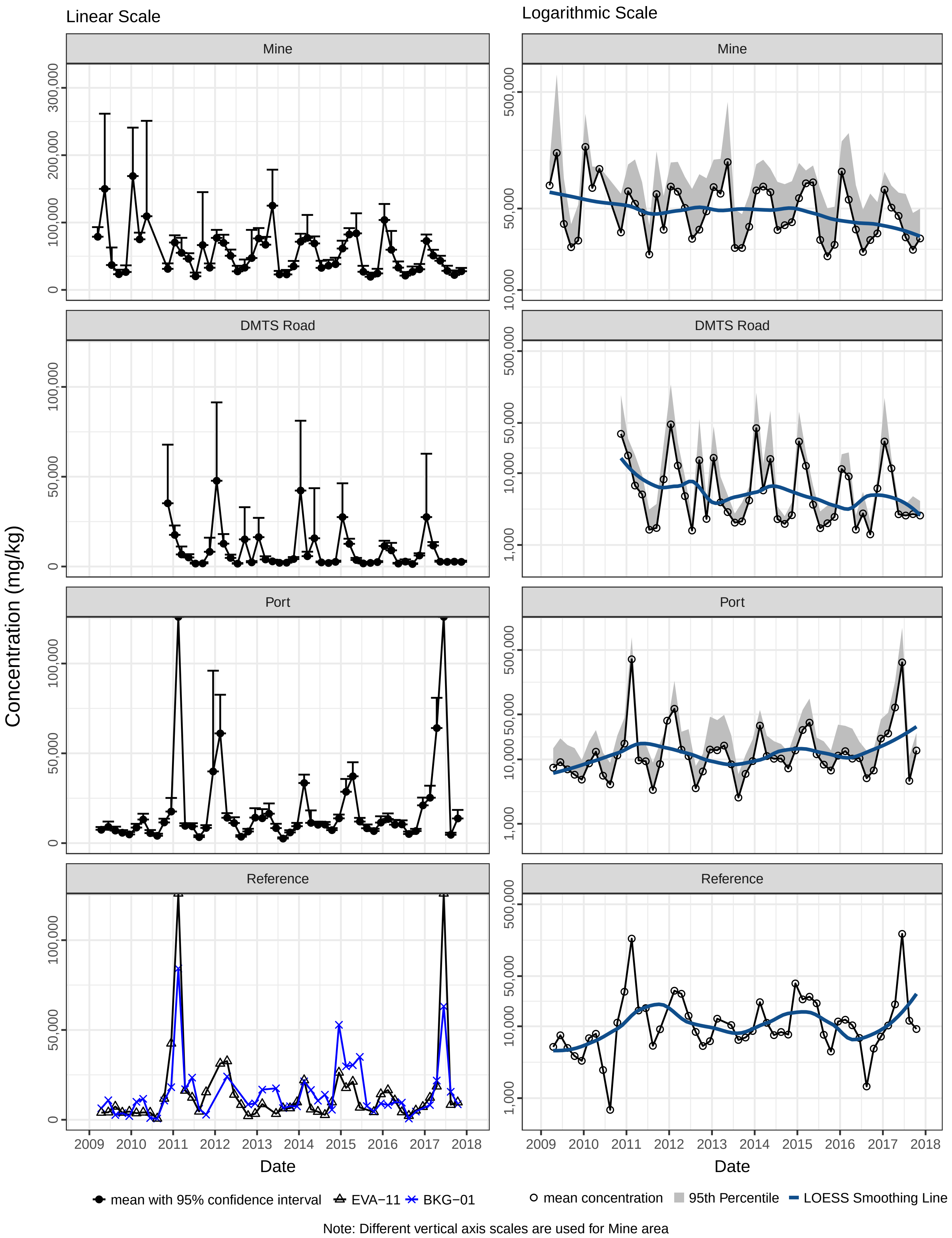
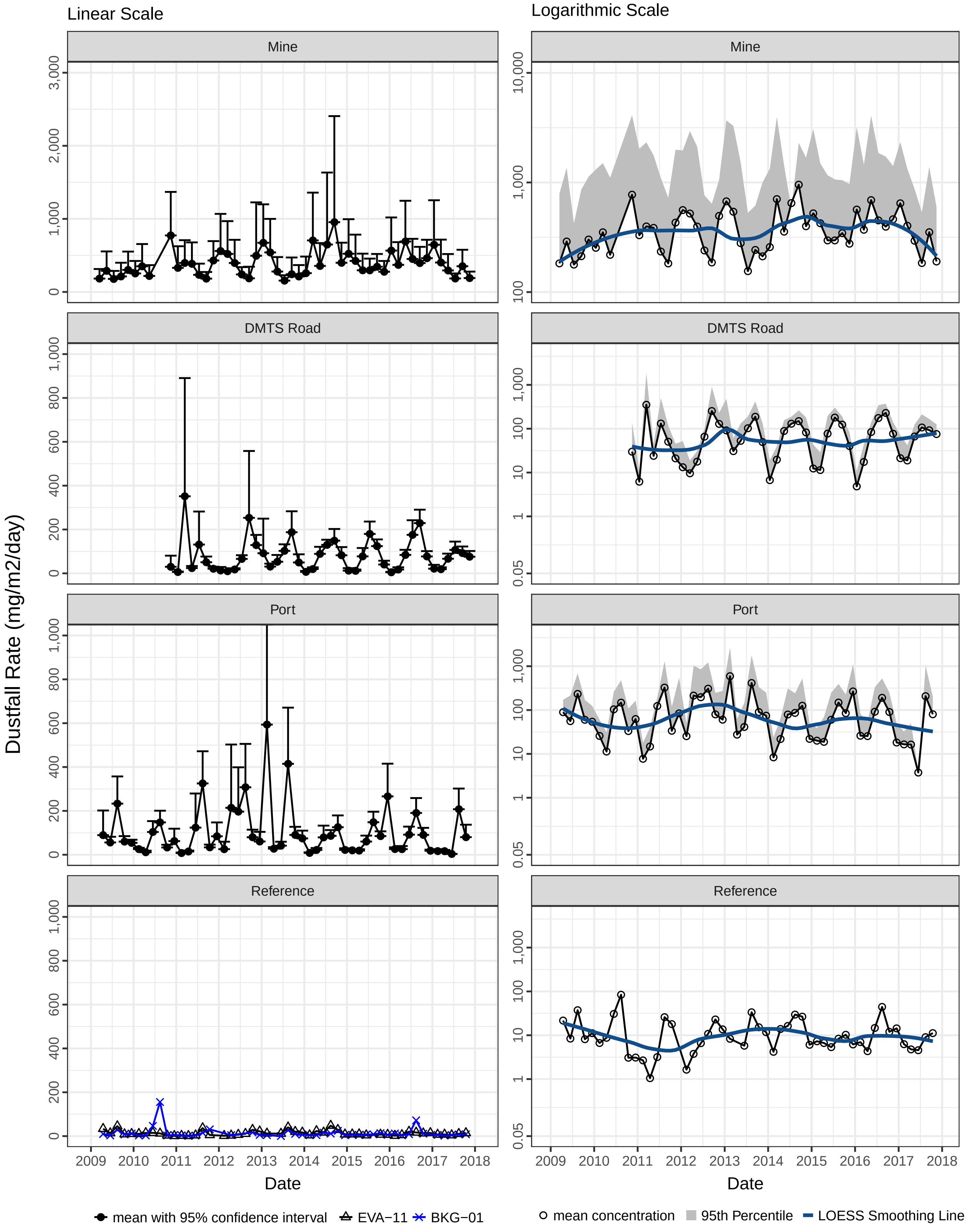


Figure 12. Dustfall Jars Zinc Concentration plots (all years)



Note: Different vertical axis scales are used for Mine area

Figure 13. Dustfall Jars Solids Deposition Rate plots (all years)

Table 1. TEOM concentration statistical trend analysis (seasonal Mann Kendall trend test)

For 1/2014 - 12/2017; Mean concentration:

LEAD	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.194	0.170	No
Mine TDam	-0.028	0.845	No
Port CSB	-0.304	0.035	No
Port Lagoon	-0.492	0.001	Yes; Decreasing
Port CSB & Lagoon	-0.556	8.77E-05	Yes; Decreasing

ZINC	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.222	0.117	No
Mine TDam	-0.111	0.433	No
Port CSB	-0.188	0.191	No
Port Lagoon	-0.429	0.004	Yes; Decreasing
Port CSB & Lagoon	-0.417	0.003	Yes; Decreasing

[a] Significant at p<0.05/2 (i.e., p<0.025 with Bonferroni adjustment because multiple [2] related hypotheses are tested).

[b] Excluded February data (see text for explanation)

For 1/2014 - 12/2017; Top 95% concentration:

LEAD	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.194	0.170	No
Mine TDam	0.111	0.433	No
Port CSB	-0.275	0.056	No
Port Lagoon	-0.460	0.002	Yes; Decreasing
Port CSB & Lagoon	-0.417	0.003	Yes; Decreasing

ZINC	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	-0.194	0.170	No
Mine TDam	0.028	0.845	No
Port CSB	-0.072	0.615	No
Port Lagoon	-0.365	0.015	Yes; Decreasing
Port CSB & Lagoon	-0.333	0.019	Yes; Decreasing

[a] Significant at p<0.05/2 (i.e., p<0.025 with Bonferroni adjustment because multiple [2] related hypotheses are tested).

Table 2. Road surface concentration statistical trend analysis (seasonal Mann Kendall trend test)

For 1/2014 - 12/2017; Mean concentration:

LEAD		Concentration (µg/m³)		
		tau statistic	p value	significant trend?[a]
Mine		-0.111	0.579	No
Road		-0.111	0.579	No
Port		0.167	0.405	No
Mine CSB (Mine)	Only for years 2014 - 2017	-0.111	0.579	No
The Y (Mine)[c]		-0.250	0.308	No
Airport (Mine)[b]		0.333	0.129	No
MS-13 (Mine/Road)		-0.056	0.782	No
MS-9 (Road)		0.000	1.000	No
R-Boundary (Road)		-0.500	0.013	Yes; Decreasing
MS-2 (Port)		-0.056	0.782	No
Port CSB Track (Port)		0.333	0.096	No

ZINC		Concentration (µg/m³)		
		tau statistic	p value	significant trend?[a]
Mine		-0.111	0.579	No
Road		-0.222	0.267	No
Port		-0.056	0.782	No
Mine CSB (Mine)	Only for years 2014 - 2017	-0.167	0.405	No
The Y (Mine)[c]		-0.250	0.308	No
Airport (Mine)[b]		0.067	0.761	No
MS-13 (Mine/Road)		-0.222	0.267	No
MS-9 (Road)[c]		-0.222	0.267	No
R-Boundary (Road)		-0.556	0.006	Yes; Decreasing
MS-2 (Port)		-0.333	0.096	No
Port CSB Track (Port)		0.056	0.782	No

CADMIUM		Concentration (µg/m³)		
		tau statistic	p value	significant trend?[a]
Mine		-0.167	0.405	No
Road		-0.111	0.579	No
Port		-0.056	0.782	No
Mine CSB (Mine)	Only for years 2014 - 2017	-0.167	0.405	No
The Y (Mine)[c]		-0.333	0.174	No
Airport (Mine)[b]		-0.200	0.362	No
MS-13 (Mine/Road)		-0.212	0.307	No
MS-9 (Road)[b]		-0.083	0.729	No
R-Boundary (Road)		0.037	0.869	No
MS-2 (Port)		-0.037	0.869	No
Port CSB Track (Port)		0.000	1.000	No

[a]Significant at p<0.05/3 (i.e., p<0.017 with Bonferroni adjustment because multiple [3] related hypotheses are tested)

[b]Excluded February (see text for explanation)

[c]Excluded February, December (see text for explanation)

Table 3. Dustfall rate and concentration statistical trend analysis (seasonal Mann Kendall trend test)

For 1/2014 - 12/2017; Mean Deposition Rate and Concentration:

LEAD	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	-0.278	0.166	No	-0.111	0.579	No
Road	0.056	0.782	No	0.056	0.782	No
Port	0.500	0.013	Yes; Increasing	0.394	0.058	No
Reference	0.111	0.579	No	0.273	0.189	No

ZINC	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	-0.278	0.166	No	-0.278	0.166	No
Road	0.056	0.782	No	0.000	1.000	No
Port	0.167	0.405	No	-0.030	0.884	No
Reference	-0.111	0.579	No	-0.091	0.662	No

TOTAL SOLIDS	Dustfall Desposition Rate ($mg/m^2/day$)		
	tau statistic	p value	significant trend?[a]
Mine	-0.222	0.267	No
Road	-0.222	0.267	No
Port	-0.030	0.884	No
Reference	-0.212	0.307	No

[a]Significant at $p<0.05/3$ (i.e., $p<0.017$ with Bonferroni adjustment because multiple [3] related hypotheses are tested).

For 1/2014 - 12/2017; Top 95% Deposition Rate and Concentration:

LEAD	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	-0.389	0.052	No	-0.167	0.405	No
Road	0.056	0.782	No	0.056	0.782	No
Port	0.500	0.013	Yes; Increasing	0.455	0.029	No

ZINC	Dustfall Desposition Rate ($mg/m^2/day$)			Concentration (mg/kg-total solid)		
	tau statistic	p value	significant trend?[a]	tau statistic	p value	significant trend?[a]
Mine	-0.222	0.267	No	-0.500	0.013	Yes; Decreasing
Road	0.222	0.267	No	0.000	1.000	No
Port	0.222	0.267	No	0.273	0.189	No

TOTAL SOLIDS	Dustfall Desposition Rate ($mg/m^2/day$)		
	tau statistic	p value	significant trend?[a]
Mine	-0.333	0.096	No
Road	-0.056	0.782	No
Port	-0.091	0.662	No

[a]Significant at $p<0.05/3$ (i.e., $p<0.017$ with Bonferroni adjustment because multiple [3] related hypotheses are tested).

Table 4. Summary of dust monitoring trends

For most recent 4 years (2014-2017)

Location and Measure	Road Surface (Concentration) Mean Concentration Pb	Zn	Cd
Mine (Conc.)	—	—	—
Mine CSB (Conc.)	—	—	—
The Y (Conc.)	—	—	—
Airport (Conc.)	—	—	—
Road (Conc.)	—	—	—
MS-13 (Conc.)	—	—	—
MS-9 (Conc.)	—	—	—
R-boundary (Conc.)	↘	↘	—
Port (Conc.)	—	—	—
MS-2 (Conc.)	—	—	—
Port CSB Track (Conc.)	—	—	—

Location and Measure	TEOM (Air Concentration) Mean Concentration		95th Percentile	
	Pb	Zn	Pb	Zn
Mine Tdam (Conc.)	—	—	—	—
Mine PAC (Conc.)	—	—	—	—
Port CSB (Conc.)	—	—	—	—
Port Lagoon (Conc.) [b]	↘	↘	↘	↘
Port CSB & Lagoon (Conc.)	↘	↘	↘	↘

Location and Measure	Dustfall Jars (Concentration and Deposition Rate) Mean Concentration			95th Percentile		
	Pb	Zn	Solids	Pb	Zn	Solids
Mine (Conc.)	—	—	a	—	↘	a
Mine (Rate)	—	—	—	—	—	—
Road (Conc.)	—	—	a	—	—	a
Road (Rate)	—	—	—	—	—	—
Port (Conc.)	—	—	a	—	—	a
Port (Rate)	↗	—	—	↗	—	—
Reference (Conc.)	—	—	a			
Reference (Rate)	—	—	—			

[a] Concentration is not evaluated for solids, because total solids is the entire sample mass.

[b] Excluded February data (see text for explanation)

1. Results are summarized from statistical test results in Tables 1, 2, and 3 for air concentrations, road surface concentrations, concentrations in dustfall, and dustfall rates, respectively.
2. Results are presented for statistical testing using data from the past four years.

Notes:

—	Indicates no statistically significant change over time period tested (trend is FLAT).
↗	Indicates a statistically significant increase over time period tested (trend is UP).
↘	Indicates a statistically significant decrease over time period tested (trend is DOWN).

TEOM = tapered element oscillating microbalance (air sampling device)
Conc = air concentration (TEOM air sampling) or concentration in dustfall (dustfall jars)
Rate = dustfall deposition rate based on dustfall jar measurements

Tdam = mine tailings dam
PAC = personnel accommodations complex
CSB = concentrate storage building

DRAFT

2017 Soil Monitoring Report

Red Dog Operations Fugitive Dust Risk Management Monitoring Program

ADEC File No. 475.38.010

Teck Alaska Incorporated
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October 2018

DRAFT

2017 Soil Monitoring Report

Red Dog Operations Fugitive Dust Risk Management Monitoring Program

ADEC File No. 475.38.010

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Acronyms and Abbreviations

ACZ	ACZ Laboratories, Inc.
ASTM	ASTM International
DEC	Alaska Department of Environmental Conservation
DMTS	DeLong Mountain Regional Transportation System
EPA	U.S. Environmental Protection Agency
ICP-AES	inductively coupled plasma/atomic emission spectroscopy
ICPMS	inductively coupled plasma/mass spectrometry
MDL	method detection limit
RMP	risk management plan
RDO	Red Dog Operations
Teck	Teck Alaska Incorporated
TOC	total organic carbon

Introduction

This report describes the findings of soil monitoring conducted in summer 2017 in the vicinity of the Red Dog mine and the DeLong Mountain Regional Transportation System (DMTS) road and port facilities (collectively, Red Dog Operations, or RDO). The soil monitoring program was established as a means of evaluating the potential effects of ongoing dust deposition on soil concentrations in the environments surrounding RDO, and to verify that conditions continue to pose no elevated risks to human health and the environment. The data collection for this monitoring program was designed to meet the Alaska Department of Environmental Conservation's (DEC's) requirements for decision-making purposes and to satisfy regulatory requirements under the DEC Contaminated Sites Program.

The following sections provide background information, methods for the monitoring sample collection, results of the field sampling and of statistical data analyses, and conclusions regarding the monitoring findings. In addition, a data quality assurance review, field notes (taken electronically), laboratory reports, and complete soil sampling results are included as appendices.

Background

In August 2008, the Draft Fugitive Dust Risk Management Plan (RMP) was prepared as part of a program designed to minimize risks associated with fugitive dust emissions from operations at the Red Dog Mine (Exponent 2008). The RMP combined and expanded upon a variety of prior and ongoing efforts by Teck Alaska Incorporated (Teck) to reduce dust emissions. The RMP identified seven fundamental risk management objectives that address the overall goal of minimizing risk to human health and the environment, identified and evaluated risk management options to achieve those objectives, and described a process for developing six implementation plans to achieve the fundamental objectives. The development of the Red Dog Monitoring Plan (Exponent 2014a) is part of the process identified in the RMP to address the objectives. The other five implementation plans are as follows:

- Communication plan
- Dust emissions reduction plan
- Remediation/reclamation plan
- Uncertainty reduction plan
- Worker dust protection plan.

The monitoring plan details techniques to detect, observe, and record fugitive dust-related changes in the environment to address the following fundamental objectives:

- Assess the effectiveness of operational dust control actions.
- Evaluate the effects of the dust emissions on the environment and on human and ecological exposure.
- Trigger additional actions where necessary.
- Continue reducing fugitive metals emissions and dust emissions (this objective is addressed indirectly through monitoring to verify the effectiveness of operational dust control measures).
- Verify continued safety of caribou, other representative subsistence foods, and water.
- Monitor conditions in various ecological environments and habitats and implement corrective measures when action levels are triggered.

The first soil monitoring event was conducted in the summer of 2014 at previously established vegetation community monitoring stations. This report presents and discusses the results of the second soil monitoring event conducted in 2017 near the mine, road, and port facilities.

The soil monitoring program is intended to provide data in support of oversight by the DEC Contaminated Sites Program, pursuant to 18 AAC 75.360. In addition, the soil monitoring program also provides data for Teck’s use in operational monitoring.

Soil Monitoring

Soil sampling was conducted in the summer of 2017 at the same stations as sampled in the 2014 event (Exponent 2014b) (Figure 1, Table 1), with the exception of one station (AT4-0060) that no longer exists due to permitted modifications associated with the tailings impoundment.

The primary constituents of interest in soil, which were identified for use in ongoing monitoring in Exponent (2014a), include the following:

- **Lead, Cadmium, and Zinc—**The primary constituents of interest, present in the lead and zinc concentrates transported along the road and in fugitive dust.
- **Barium—**Rich in the ore deposits at the mine site but not in the concentrates transported along the road, although it can be tracked from the mine site by vehicles.
- **Calcium—**A general indicator of road dust, because calcium chloride is added to the road surface as a humectant.
- **Aluminum and Iron—**Fill materials are rich in these crustal elements used to construct and maintain the road.

These constituents, plus pH and total organic carbon (TOC), were analyzed in soil samples collected as part of the monitoring program. The soil monitoring program methods and results are described in the following sections.

Methods

Soil samples were collected from July 31 through Aug 11, 2017, at the locations shown in Figure 1. The samples were collected by Cedar Creek Associates and submitted to ACZ Laboratories, Inc. (ACZ), located in Steamboat Springs, Colorado, to measure concentrations of the constituents of interest. The data provided by ACZ were assessed by Exponent, and data qualifiers were added according to U.S. Environmental Protection Agency (EPA) guidelines and method-specific requirements, consistent with the quality assurance project plan included as Appendix A to the monitoring plan (Exponent 2014a). Exponent's quality assurance review is provided in Appendix A herein. Field notes are provided in Appendix B. A full tabulation of analytical results is provided in Appendix C. Analytical laboratory reports are provided in Appendix D.

Four hundred fifty-two (452) soil samples, 24 field replicate soil samples, 24 equipment rinsate blanks, and 1 source water sample (water used in cleaning and rinsing) were collected as part of the sampling event. Soil samples were collected from stations along nine previously established 4-km vegetation community monitoring transects that radiate away from the mine facilities, from monitoring stations at the DMTS port site and along the DMTS road, and from vegetation community study reference locations (Figure 1).

Four samples were collected from each field station using a 2-inch-diameter core sampling device with a polyethylene liner. Upon retrieving the sampling device from the borehole, the polyethylene liners were removed from the corer, capped on both ends, labeled, and bagged in self-sealing (e.g., Ziploc®) plastic bags. The four samples from each station were subsequently placed together in a gallon size Ziploc® bag and labeled.

Upon receipt at the laboratory, all of the soil samples were analyzed for aluminum, barium, cadmium, calcium, iron, lead, and zinc, as well as TOC, total solids, and pH. One difference from the 2014 sampling was that the laboratory analyzed each of the four subsamples in 2017, rather than compositing the four subsamples for a single analysis for the station as done in 2014.

In tussock tundra environments (mainly road and port areas), the core samples were collected from exposed or partially exposed soil areas between tussocks. In the hillslope or other rocky environments (particularly in the mine area), samples were collected as near as possible to the transect station in areas where conditions allowed soil collection. The sample locations were measured and mapped with reference to the vegetation transect layout. Core samples were placed a minimum of 6−12 in. from previous sample locations.

Woody debris or live moss that obstructed sampling was removed from the surface to facilitate coring organic and inorganic soil materials. Soil sample collection was targeted at a depth interval of 0–2 cm. This depth interval was intended to represent surface soils that may have been affected over time by deposition and accumulation of metals-bearing dust. Actual sample depth intervals varied as a result of differing conditions at each subsample location, which affected the ease or difficulty of sampling the target interval with the handheld corer (see Appendix B). Procedures and equipment selection are under review with the objective of improving repeatability of the sample collection depth interval in future events.

Mine Site—Soil sampling at the mine site was conducted along nine previously established 4-km vegetation community monitoring transects that radiate away from the mine facilities (Figure 1). Monitoring plots were generally located on each transect at distances of 0, 500, 1,000, 1,500, 2,500, and 4,000 m from the transect origin. Several transects included additional plot locations. Plot locations were established based on landscape features (wind shelter, snow bed locations, slope, and aspect) and plant community structure.

Sixty-four (64) monitoring plots are located on nine transects that radiate from the mine facilities. At the mine-area transect stations, the vegetation plots are rectangular (5 × 10 m), and soil samples are collected outside the perimeter of the vegetation plot, as illustrated in Figure 2. The soil sampling layout relative to the vegetation survey plot was intended to minimize any trampling or tracking of dust on boots into areas where the soil samples are collected. Care was taken by the field team to avoid walking on the areas used for ongoing monitoring of metals concentrations in soil.

DMTS Port and Road—A total of 32 monitoring locations at the port site and along the DMTS road employed a different sampling configuration from the mine site. Sampling occurred at six transect locations—two within the port boundary (one at the concentrate storage building loop and one along the road near the port boundary) and four along the road (Figure 1). On each transect, soil samples were collected along five different 100-m survey lines oriented parallel to the road and parallel to operational dust sources. The survey lines were located along the transect at distances of 100, 250, 500, 1,000, and 2,000 m from the road (Figure 1). Each 100-m survey line had four sample locations at intervals spaced 12.5, 37.5, 62.5 and 87.5 m (five survey-line segments of 12.5, 25, 25, 25, and 12.5 m). Four soil samples were collected along the length of each survey line, as illustrated in Figure 2. The soil sampling layout with respect to the vegetation survey lines was intended to minimize any trampling or tracking of dust on boots into areas where the soil samples were collected. Care was taken by the field team to avoid walking on the areas used for ongoing monitoring of metals concentrations in soil.

Reference Areas—Soil monitoring was implemented at 17 reference sites located in areas away from mine activities, collocated with vegetation community survey reference sites (Figure 1). The reference stations were used to help assess the range and variability of conditions away from mine activities. Similar to the site stations, the soil sampling layout relative to the vegetation survey transects or plots was intended to minimize any trampling or tracking of dust on boots into areas where the soil samples were collected. Care was taken by the field team to avoid walking on the areas used for ongoing monitoring of metals concentrations in soil.

The analytical laboratory performed the soil and associated equipment blank analyses with reference to the following methods, as discussed in detail in Appendix A:

Analysis	**Method Reference**
Total Metals (soils)	SW-846 Method 6010B, Inductively Coupled Plasma/Atomic Emission Spectroscopy (ICP-AES)
Total Metals (aqueous)	EPA Method 200.7, Determination of Metals and Trace Elements in Water and Wastes by ICP-AES
Total Organic Carbon (TOC) (soils)	ASA No.9 29-2.2.4 (ACZ SOPSO032.09.13.16), High-Temperature Combustion/Infrared Detection
TOC (aqueous)	SM 3510B, High-Temperature Combustion Method
pH (soils)	SW-846 9045D/9045C, Soil and Waste pH
pH (aqueous)	EPA 150.1 Electrometric Method
Total Solids	ASTM D2216-80, Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass, Standard Test Methods

All the soil data were considered usable, as qualified, for project decision-making. Data qualifiers included a laboratory-assigned “J” qualifier that was retained for all results less than the maximum reporting limit but greater than the method detection limit (MDL). A complete Quality Assurance Review is provided in Appendix A.

Results

Soil Sampling Results

Table 2 summarizes the mean soil metals concentrations, pH, total solids, and TOC[1] from four subsamples collected in summer 2017 at each station in the mine, road, port, and reference areas. A complete table of subsample results is provided in Appendix C. Soil monitoring results for aluminum, barium, cadmium, calcium, iron, lead, and zinc, as well as pH levels, are mapped in Figures 3–10.

The concentrations of all metals measured in soil samples were below their respective DEC Arctic Zone default cleanup levels, with the exception of some stations within the mine permit boundary. For those metals that have default cleanup levels published by DEC, concentrations are presented in relation to these default levels on the maps; specifically, barium (Figure 4), cadmium (Figure 5), lead (Figure 8), and zinc (Figure 9). These findings confirm that concentrations in soil surrounding RDO continue to pose no elevated risks to human health and the environment.

Concentrations of aluminum, barium, cadmium, lead, and zinc were generally highest within the mine boundary and lower outside the mine boundary and in the port and reference areas. There were moderately higher aluminum, calcium, and iron levels in stations along the road and at some reference-area stations, potentially reflecting the influence of road-dust to a greater degree than influence of metals concentrates (lead, zinc, cadmium). Soil pH results also indicated the possible influence of dust deposition, particularly in the vicinity of mine facilities and the road, as indicated by higher pH values than those in reference-area samples.

Statistical Analysis

The monitoring plan (Exponent 2014a) calls for the following evaluation of soil monitoring results:

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[1] For non-detect sample results, half of the MDL was used when calculating the mean concentration.

Soil monitoring results will provide a measure of concentrations at the same soil sampling stations along the DMTS road, port, and mine over time. Data will be compared from one sampling event to another to determine changes in soil concentrations over time. Statistical analysis will be performed for each set of sample replicates to quantify the variation in the sample population, and assess changes in metals concentrations over time. Standard paired t-tests or analysis of variance will be used for comparisons between years unless the underlying assumptions are not met by the data. In that case, the non-parametric Wilcoxon test will be used. Trends will be quantified using standard regression analysis when the underlying assumptions are met by the data. When these assumptions are not met the non-parametric sign test may be used. Trends and differences between years will also be evaluated on a qualitative basis using plots. If results indicate changes are occurring, the results will be compared with other monitoring data to corroborate the findings (e.g., comparison with dustfall jar data and TEOM data at the mine and port, and road surface and dustfall jar data along the DMTS road). If statistically significant increases are found and corroborated by other monitoring data, then additional dust control measures will be implemented as defined in the dust emissions reduction plan.

The data for each station was assigned to one of six station groups, which are based on the station's proximity and orientation to operational sources. These station groups include Mine (Northwest), Mine (Southeast), Road, Port, Reference (Mine/Road), and Reference (Port). The station group assignments are listed in Table 2. For each of the station groups,[2] normality tests (Shapiro-Wilk test), equivalence of variance tests (F-test), standard non-paired t-tests, and Wilcoxon Rank Sum tests were used on both as-measured and log-transformed data for comparisons of metals concentrations, TOC, total solids, and pH results to determine whether there are any statistically significant changes between 2014 and 2017 events. The results are summarized below and in Table 3.

- **Lead, Cadmium, and Zinc—**Significantly increased concentrations were found in the Road station group for both cadmium and zinc, as well as in the

[2] With the exception of the Reference (Port) group, which has too few stations (two) for statistical analysis.

Mine/Road Reference station group for cadmium. No detectable differences were found in any station group for lead.

- **Barium—**No detectable changes were found for barium in any station group.
- **Calcium—**Significantly increased concentrations were found for calcium in both the Road and Port station groups. This may reflect calcium-bearing dust from the road and/or a greater proportion of inorganic soil in the core samples in 2017 in comparison with samples from 2014.
- **Aluminum and Iron—**Significantly decreased concentrations were found in the Road station group for both aluminum and iron and in the Port station group for aluminum. These may reflect a decrease in road dust deposition and/or a lesser proportion of inorganic soil in the core samples (i.e., greater TOC).
- **pH—**No detectable changes were found in any station group for pH values.
- **TOC—**A significant reduction of TOC was found in the Mine Northwest station group, while a significant increase of TOC was found in the Road station group. No significant changes were found in other station groups. These differences may reflect variability in the core sample composition of inorganic and organic soils, rather than an actual change between monitoring events.

Field variability was evaluated by review of replicate sample results and evaluation of station subsample results. Replicate sample results reflect small-scale variability in adjacent core samples, whereas station subsample results reflect station-scale variability. Replicate sample results are presented in Appendix A (Table A-3), and subsample results are presented in Appendix C (Table C-1). Variability among replicate and subsample analytical results was notable, highlighting the differences that can be observed in soil sample results collected at the small spatial scales reflected by station subsampling. These observations support the need to aggregate results into area-based station groupings to compare events and conduct trend analysis, which will be implemented for future monitoring events.

Statistical findings for cadmium and zinc concentrations were further evaluated and compared with other monitoring data (dustfall jars, TEOM air samplers, and road surface soils).[3] Although significant increases of both cadmium and zinc concentrations were found in the Road station group, there were no similar trends found in either the road surface monitoring data or the dustfall jar monitoring data during the same time frame. Although there was a significant increase in the zinc deposition rate for the dustfall jars of the road station group between earlier events (from 2011 to 2014), no difference was identified between the 2014 and 2017 events. This review indicates that the other monitoring data do not corroborate the findings of significance for cadmium and zinc. Trends should be re-evaluated in the future after completion of the third soil monitoring event.

[3] Of these three monitoring measures, cadmium concentrations are only measured in road surface samples. Zinc concentrations are available in all three of these monitoring measures. These additional monitoring data are to be published separately in the 2017 fugitive dust risk management plan annual report, as they were in the 2016 annual report (Teck 2016).

Conclusions

This report describes the findings of soil monitoring conducted in the summer of 2017 at the previously established vegetation community monitoring stations (Figure 1, Table 1) in the vicinity of the Red Dog mine and the DMTS road and port facilities. The soil monitoring program was established as a means of evaluating the potential effects of ongoing dust deposition on soil concentrations in the environments surrounding RDO, and to verify that conditions continue to pose no elevated risks to human health and the environment. The stations sampled during the 2017 monitoring event were the same as those from which soil samples were collected in 2014, except for station AT4-0060, which no longer exists as a result of the increased elevation of the tailings impoundment.

The current study obtained concentration data for aluminum, barium, cadmium, calcium, iron, lead, and zinc, as well as TOC, total solids, and pH measurements, in soil samples collected at stations near the mine, road, and port facilities and in reference areas away from operational activities (Figure 1).

Concentrations of all metals measured in soil samples were below their respective DEC Arctic Zone default cleanup levels, with the exception of some stations within the mine permit boundary. For those metals that have default cleanup levels published by DEC, concentrations are presented in relation to these default levels on the maps; specifically, barium (Figure 4), cadmium (Figure 5), lead (Figure 8), and zinc (Figure 9). These findings confirm that concentrations in soil surrounding RDO continue to pose no elevated risks to human health and the environment.

Levels of aluminum, barium, cadmium, lead, and zinc were generally highest within the mine boundary and lower outside the mine boundary and in port and reference areas (Figures 3, 4, 5, 8, and 9). There were moderately higher aluminum, calcium, and iron levels in stations along the road and at some reference-area stations (Figures 3, 6, and 7), potentially reflecting a greater influence of road-dust rather than an influence of metals concentrates (lead, zinc, cadmium). Soil pH results also indicated the possible influence of dust deposition, particularly in the vicinity of mine facilities and the road, as indicated by higher pH values than those in reference-area samples (Figure 10). These patterns of dust-related influences appear to be generally consistent with deposition patterns indicated by previous moss monitoring studies conducted in the same areas, as documented and evaluated in the DMTS fugitive dust risk assessment (Exponent 2007).

Standard unpaired t-tests and Wilcoxon Rank Sum tests were performed to analyze the significance of changes from 2014 to 2017 between five station groups, formed based on their locations. The test results indicate significant increases in several measures, including cadmium in the Road and Reference (Mine/Road) stations, calcium in the Road and Port stations, and zinc in the Road stations. The cadmium and zinc increases may be the result of ongoing fugitive dust deposition. The calcium increase may also reflect road dust deposition that includes calcium chloride that is applied to the road as a humectant.

Variability among replicate and subsample analytical results was notable, highlighting the differences observable at the small spatial scales of these soil subsamples. These observations support the need to aggregate results into area-based station groupings to compare events and conduct trend analysis, which will be implemented for future monitoring events.

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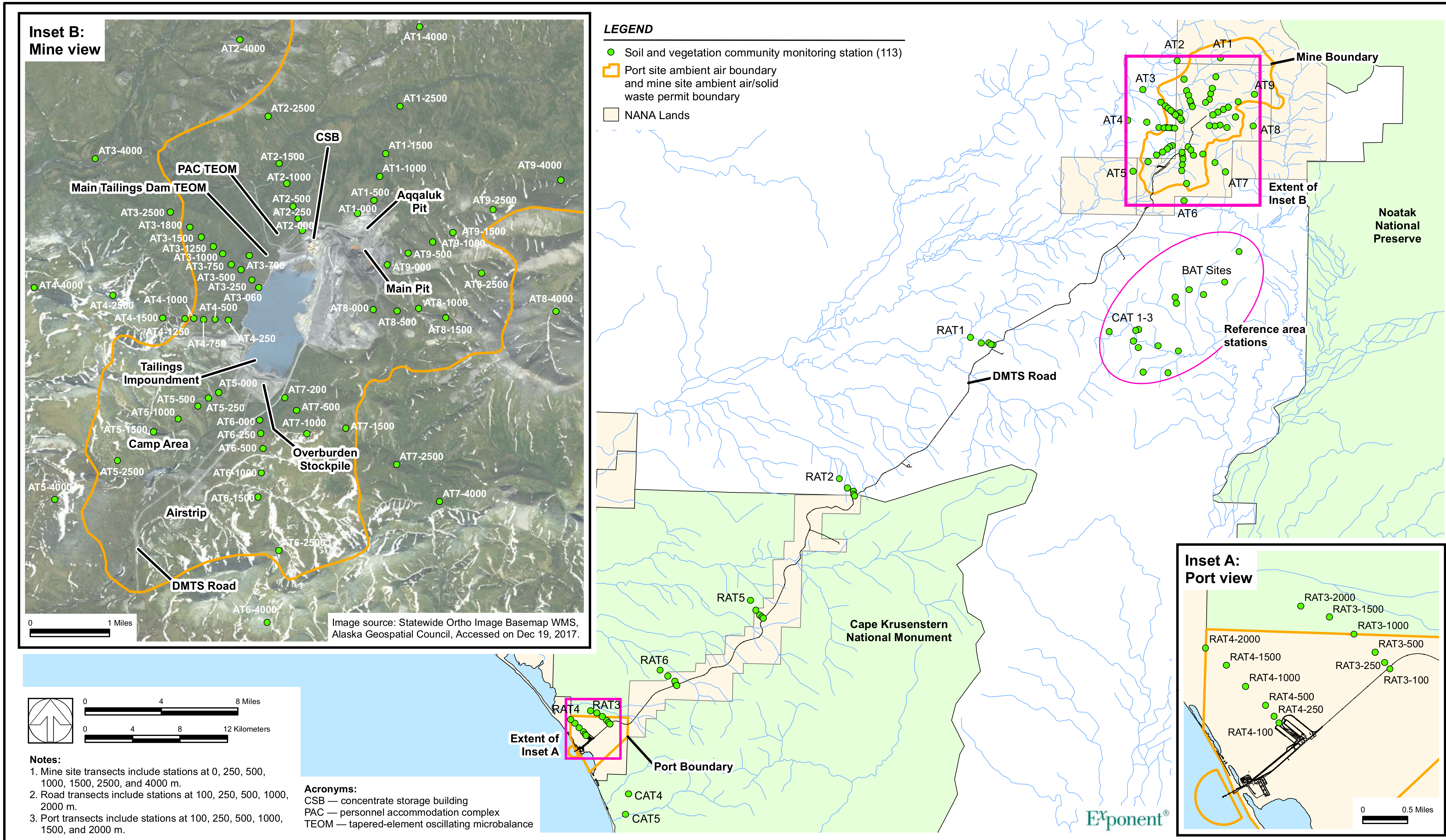
Figures



Notes:
1. Mine site transects include stations at 0, 250, 500, 1000, 1500, 2500, and 4000 m.
2. Road transects include stations at 100, 250, 500, 1000, 2000 m.
3. Port transects include stations at 100, 250, 500, 1000, 1500, and 2000 m.

Acronyms:
CSB — concentrate storage building
PAC — personnel accommodation complex
TEOM — tapered-element oscillating microbalance

Figure 1. Soil monitoring station locations (2017)

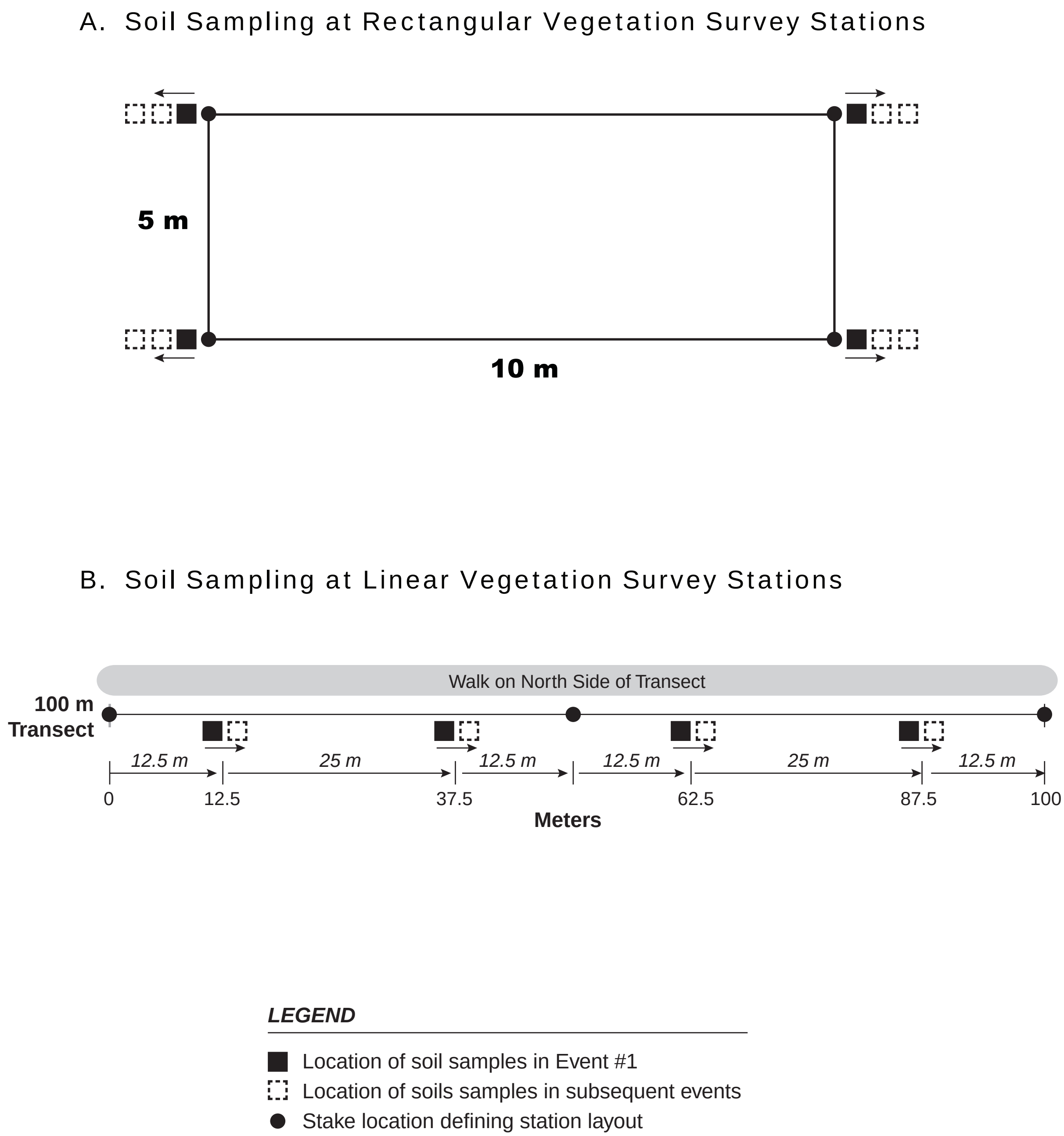


Figure 2. Soil sampling layout at vegetation survey stations

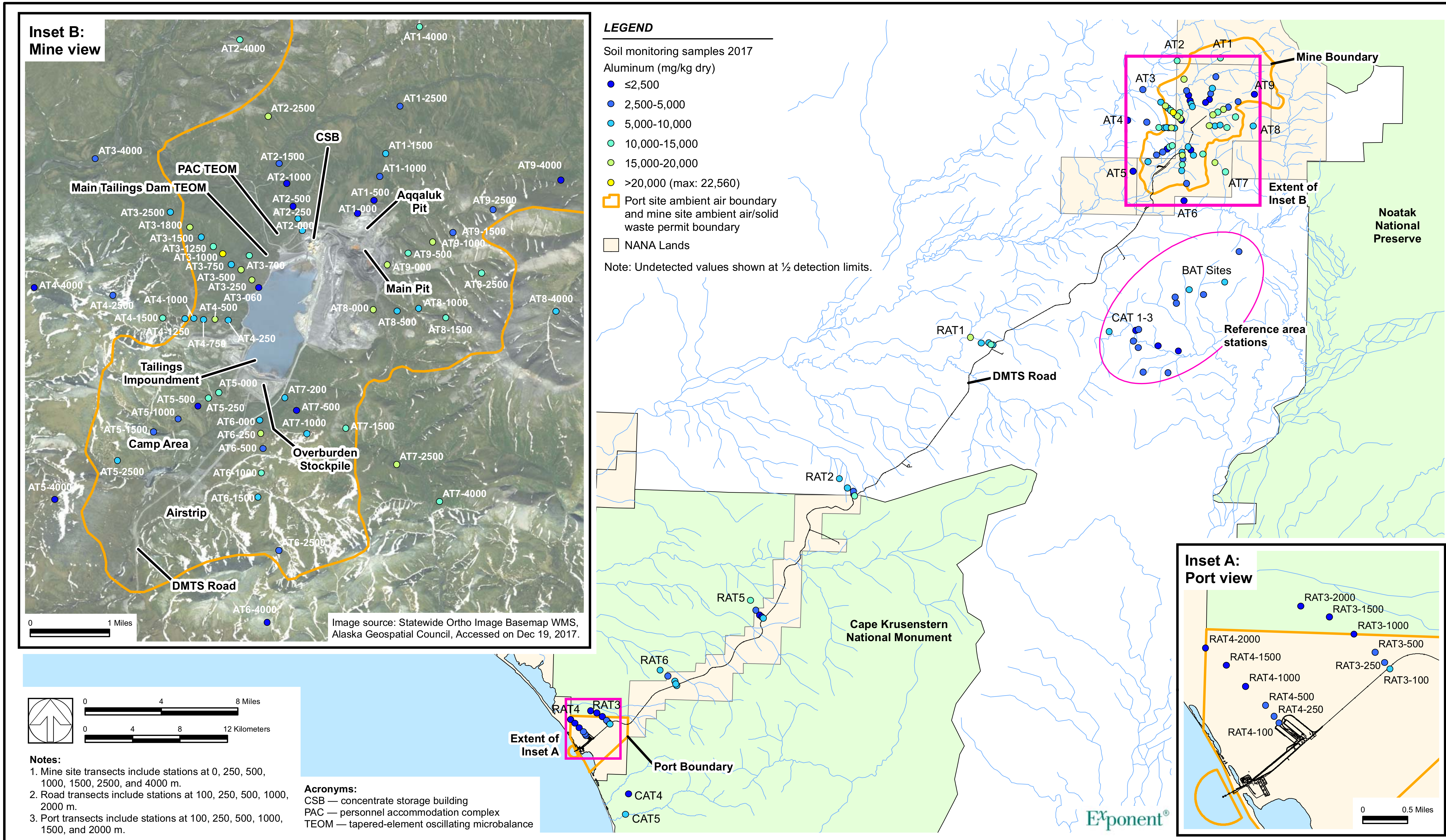


Figure 3. Soil monitoring results (2017) - Aluminum concentrations

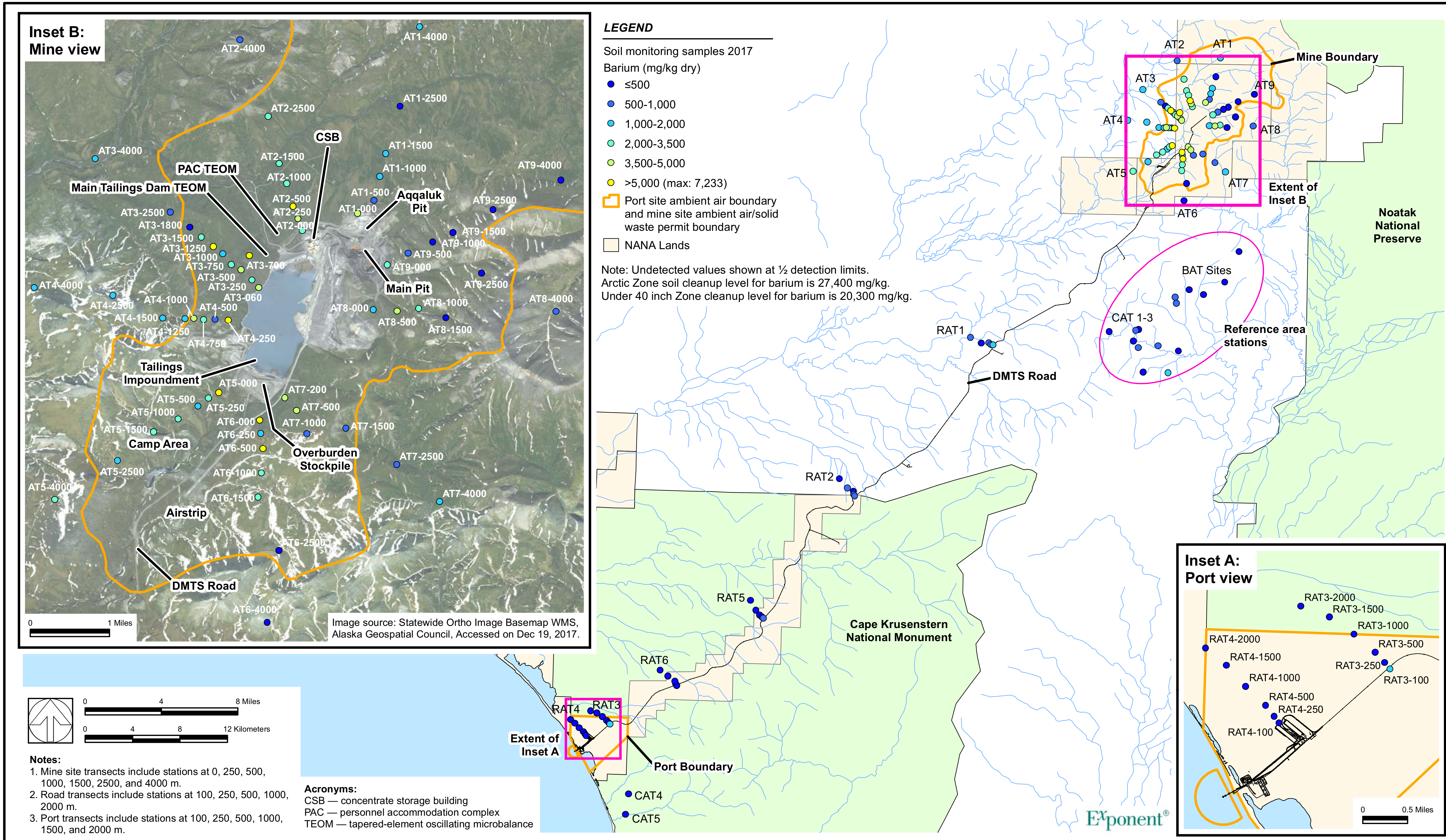


Figure 4. Soil monitoring results (2017) - Barium concentrations

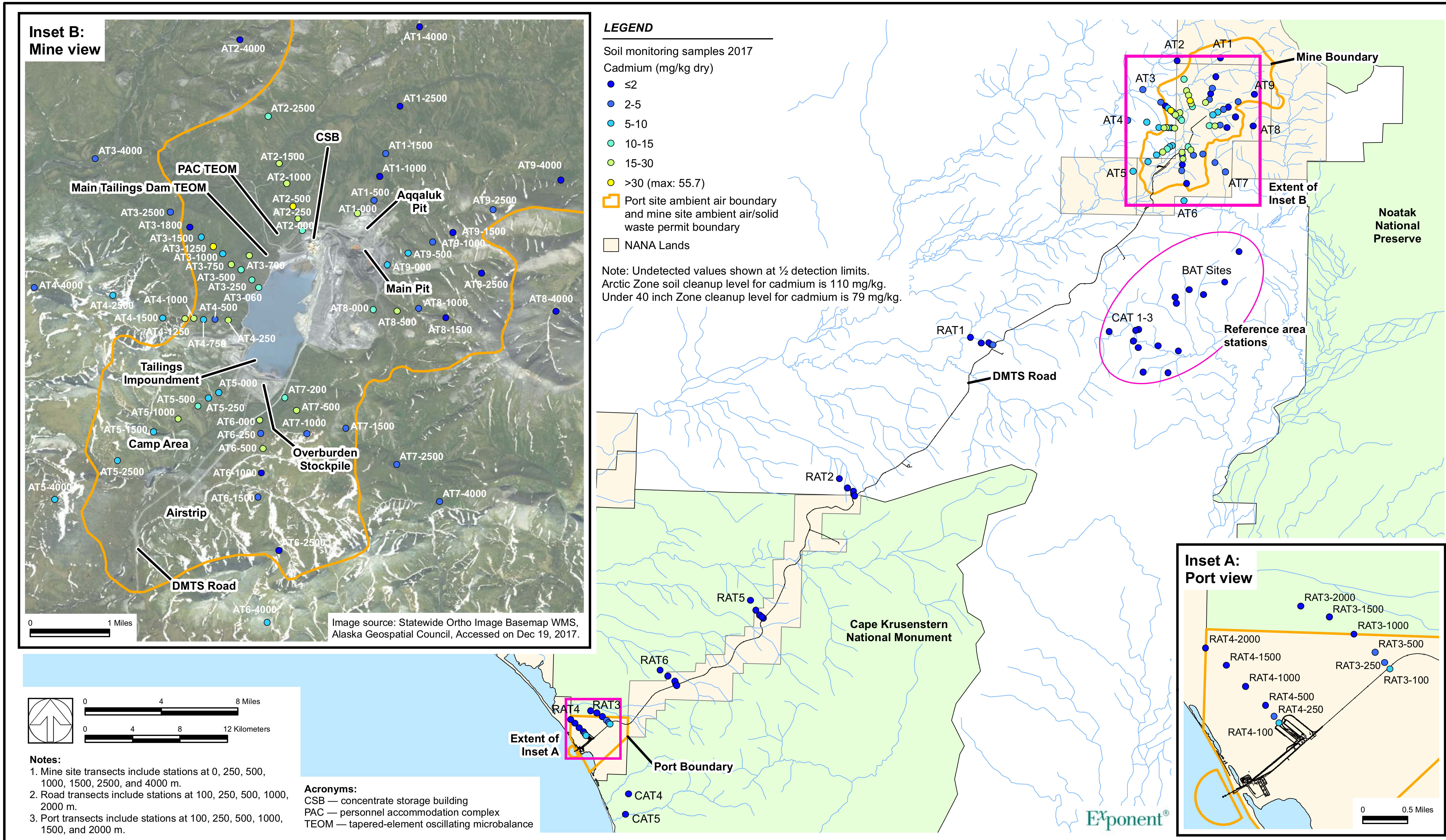


Figure 5. Soil monitoring results (2017) - Cadmium concentrations

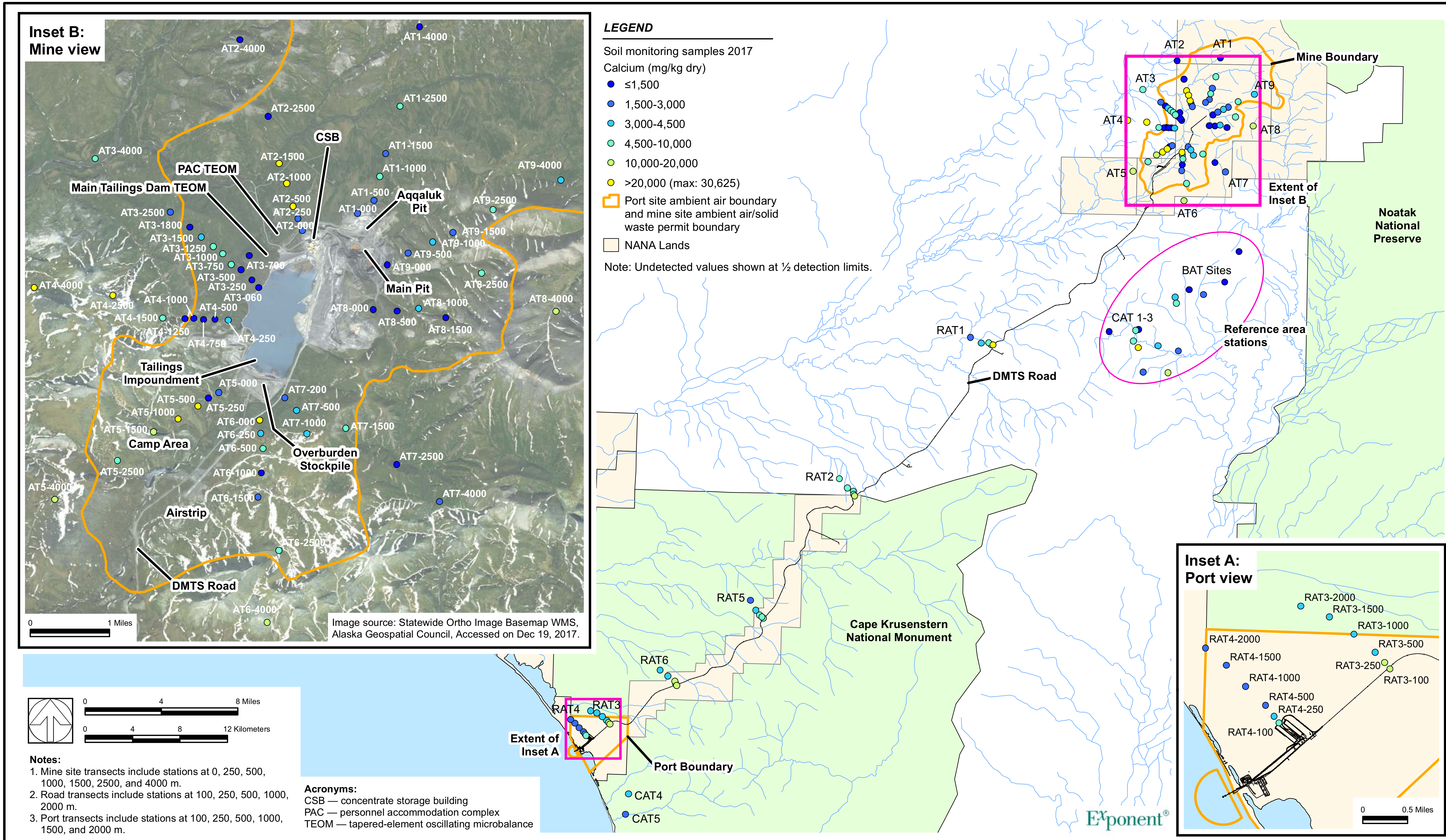


Figure 6. Soil monitoring results (2017) - Calcium concentrations

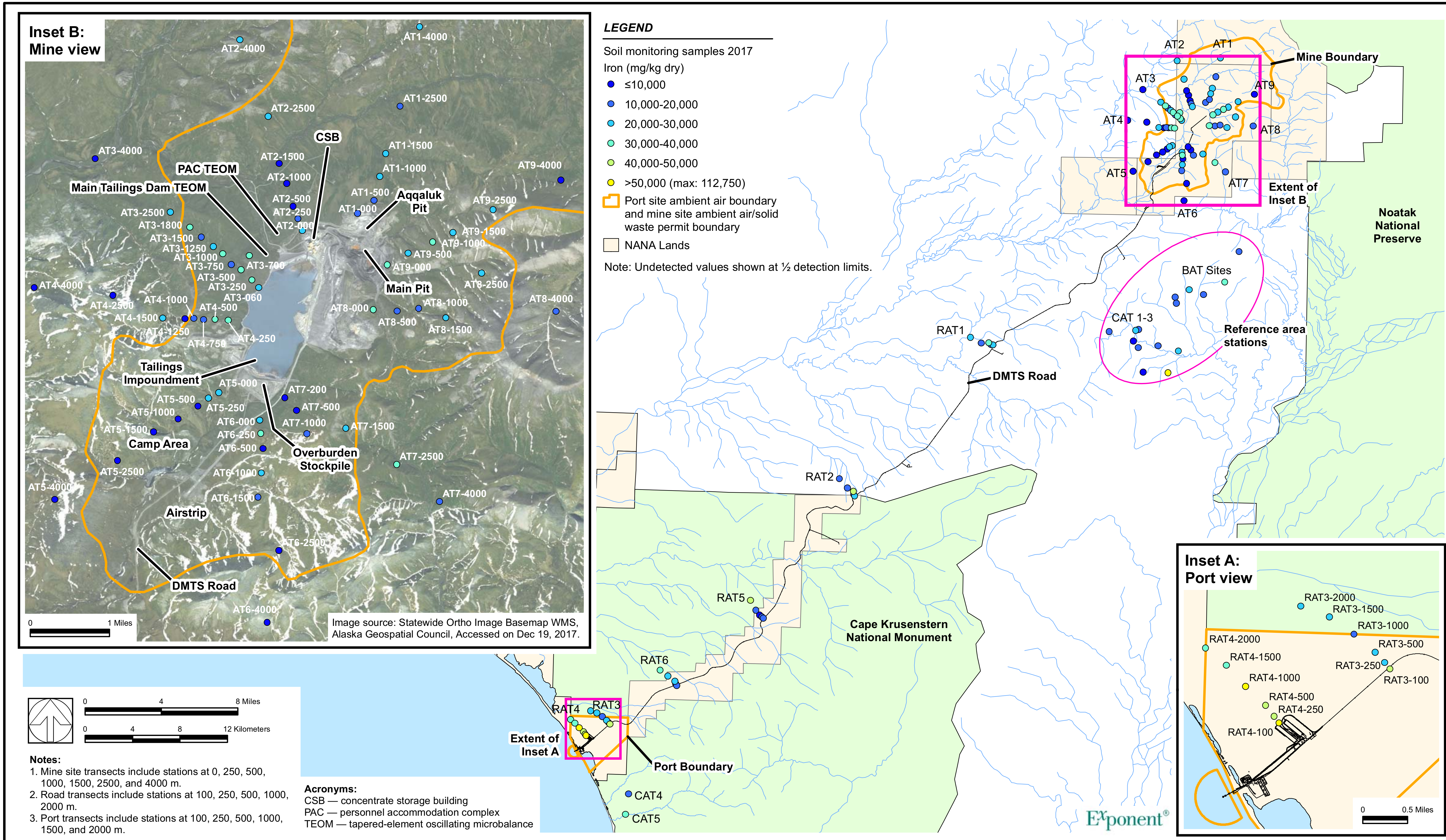


Figure 7. Soil monitoring results (2017) - Iron concentrations

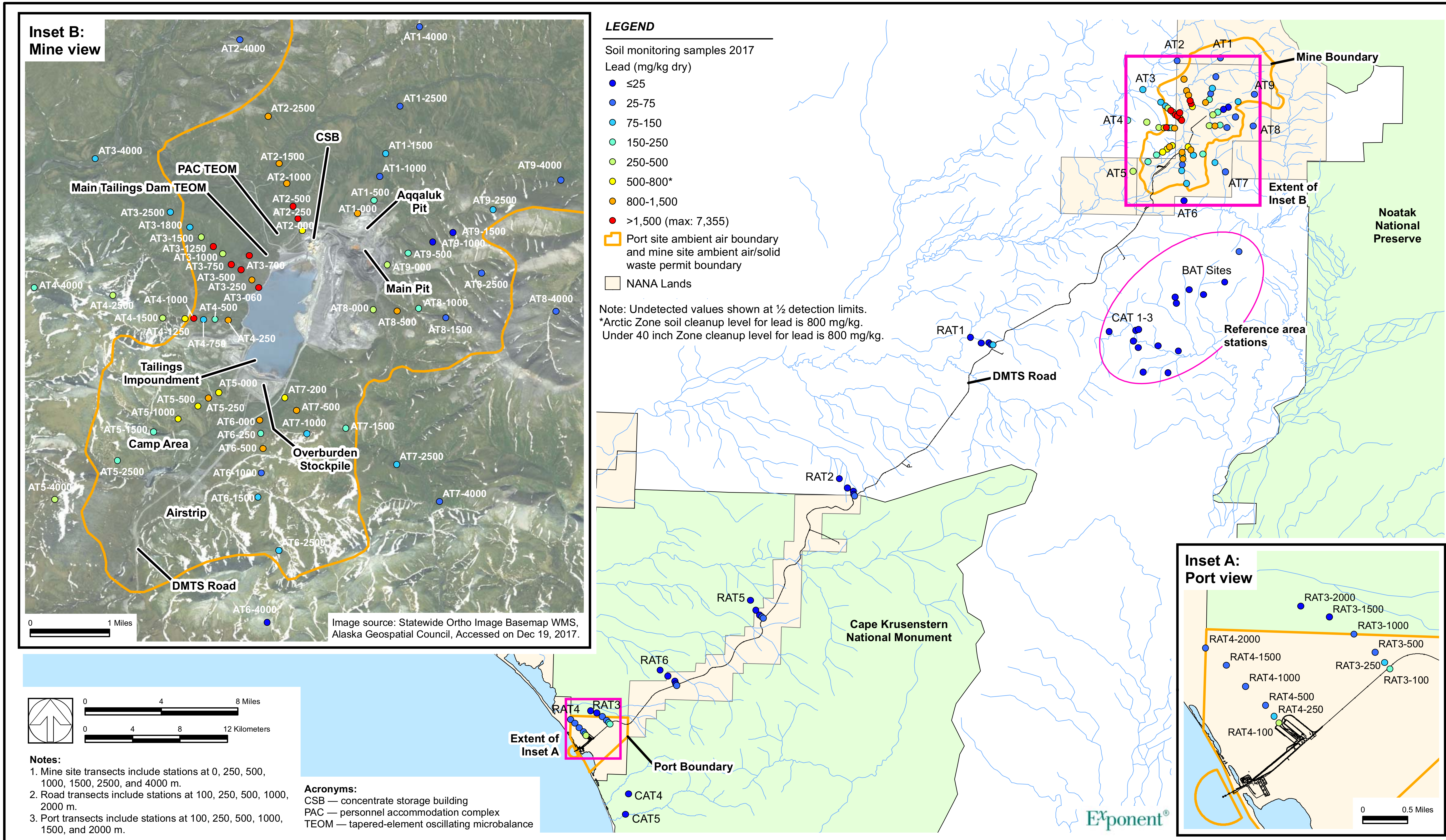


Figure 8. Soil monitoring results (2017) - Lead concentrations

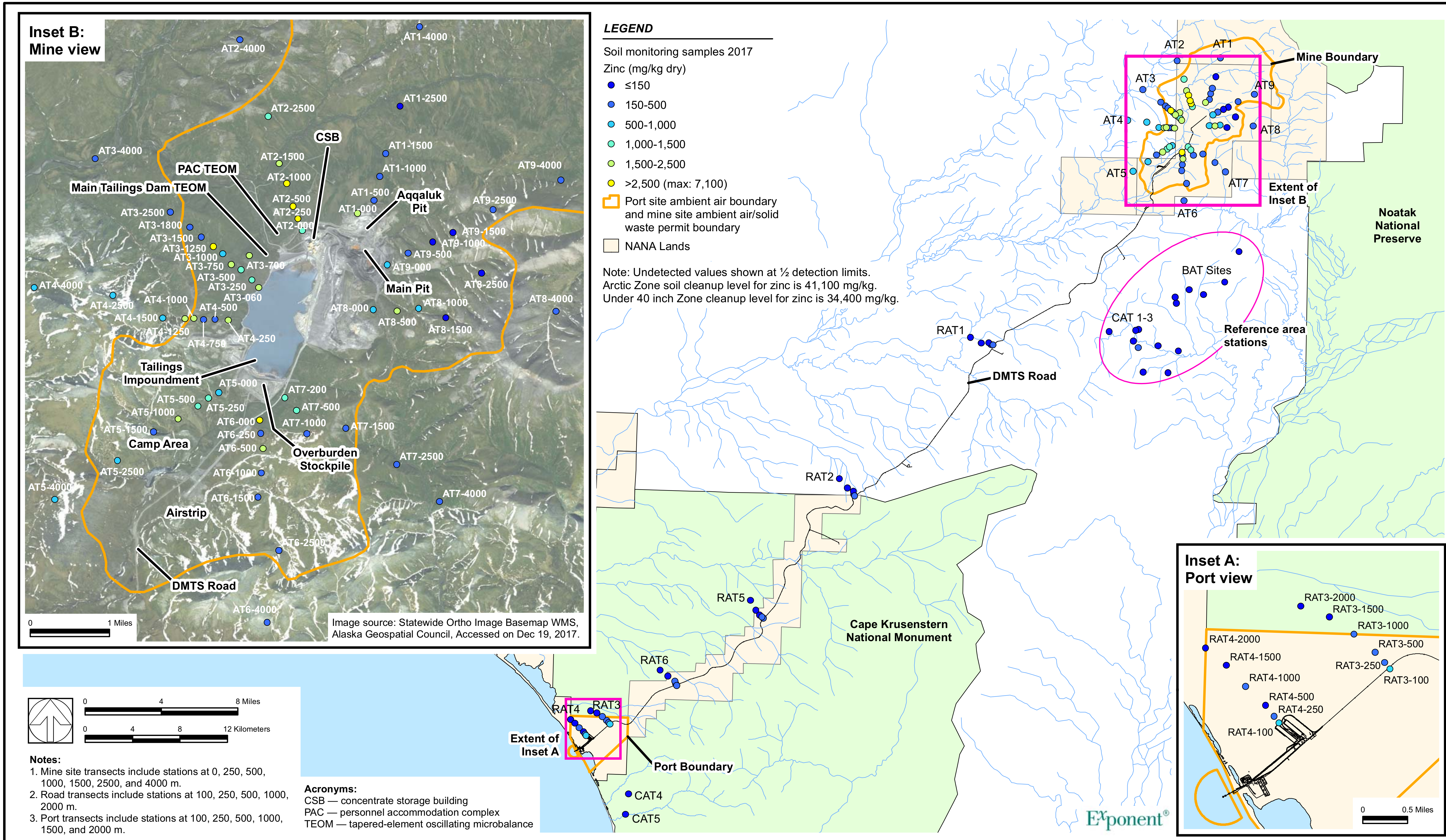


Figure 9. Soil monitoring results (2017) - Zinc concentrations

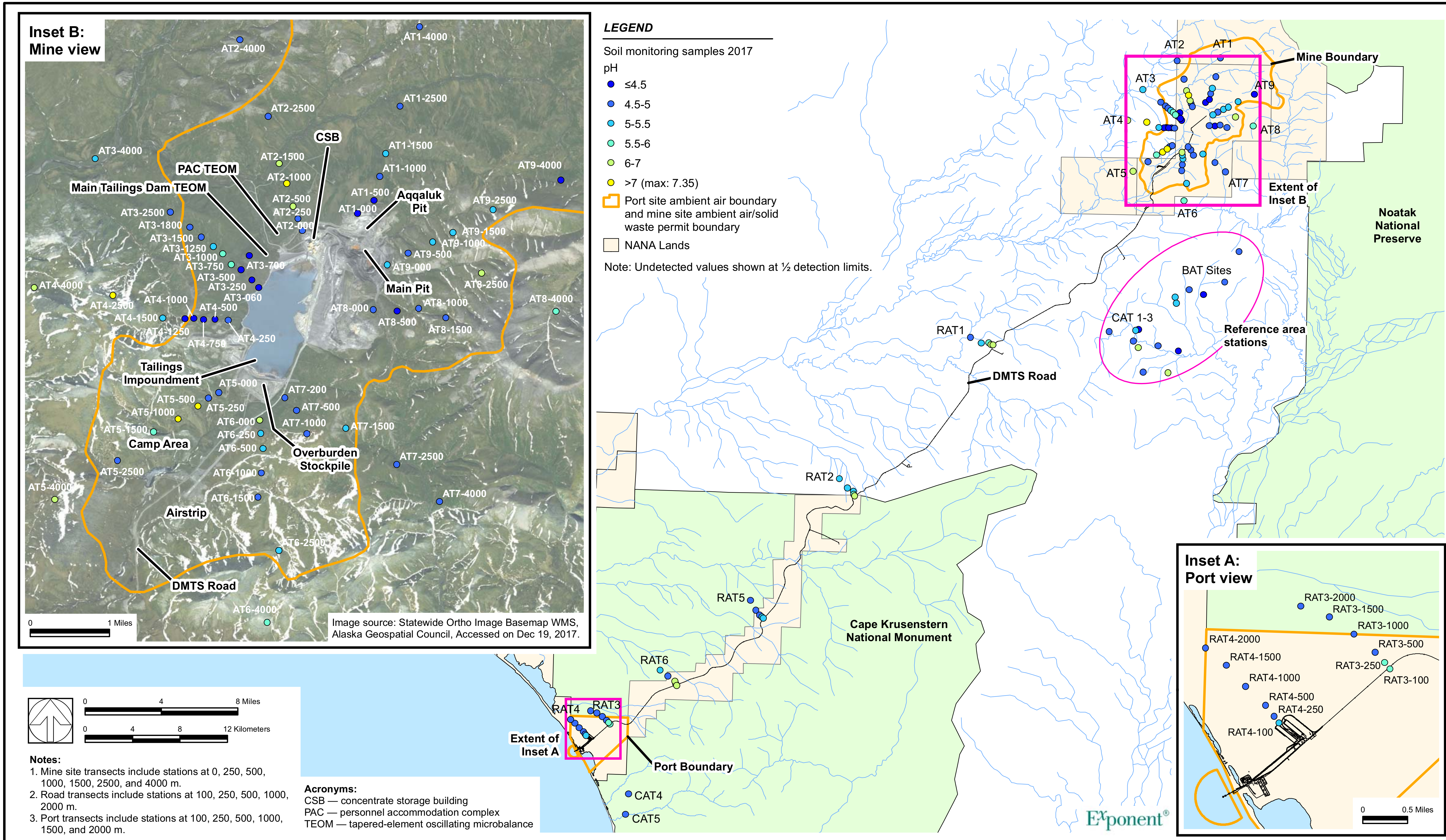


Figure 10. Soil monitoring results (2017) - pH

Tables

Table 1. Soil monitoring station locations sampled in 2017

Transect ID	Vegetation Sample Stations (m)	Easting	Northing
Mine Site Soil Monitoring Locations			
AT 1	000	590410	7553155
	500	590734	7553429
	1,000	590822	7553922
	1,500	590924	7554391
	2,500	591170	7555363
	4,000	591486	7556994
AT 2	000	589313	7552750
	250	589214	7552982
	500	589100	7553230
	1,000	588951	7553691
	1,500	588774	7554080
	2,500	588504	7555029
	4,000	587858	7556546
AT 3	060	588486	7551551
	250	588343	7551697
	500	588110	7551895
	700	588265	7552191
	750	587905	7551993
	1,000	587725	7552198
	1,250	587523	7552337
	1,500	587276	7552517
	1,800	587030	7552705
	2,500	586620	7552995
	4,000	585052	7553999
AT 4	250	587897	7550858
	500	587634	7550864
	750	587399	7550851
	1,000	587203	7550864
	1,250	587025	7550848
	1,500	586571	7550840
	2,500	585541	7551252
	4,000	583941	7551328
AT 5	000	587781	7549391
	250	587574	7549269
	500	587373	7549090
	1,000	586986	7548811
	1,500	586499	7548532
	2,500	585795	7547915
	4,000	584565	7547065
AT 6	000	588636	7548870
	250	588668	7548607
	500	588731	7548299
	1,000	588721	7547800
	1,500	588681	7547309
	2,500	589148	7546249
	4,000	588990	7544788

Table 1. (cont.)

Transect ID	Vegetation Sample Stations (m)	Easting	Northing
AT 7	000	589126	7549351
	500	589374	7549105
	1,000	589602	7548642
	1,500	590385	7548791
	2,500	591451	7548110
	4,000	592354	7547400
AT 8	000	590825	7551218
	500	591309	7551211
	1,000	591743	7551290
	1,500	592306	7551125
	2,500	592979	7552069
	4,000	594526	7551364
AT 9	000	591067	7552137
	500	591472	7552395
	1,000	591963	7552649
	1,500	592361	7552861
	2,500	593154	7553360
	4,000	594490	7554027
DMTS Port and Road Soil Monitoring Locations			
RAT 1	100	573493	7531840
	250	573321	7531871
	500	573113	7532009
	1,000	572476	7531948
	2,000	571551	7532388
RAT 2	100	562455	7518544
	250	562367	7518667
	500	562325	7518936
	1,000	561782	7519200
	2,000	561097	7519942
RAT 3	100	542727	7498310
	250	542624	7498422
	500	542447	7498598
	1,000	542054	7498905
	1,500	541593	7499196
	2,000	541071	7499361
RAT 4	100	540785	7497244
	250	540693	7497363
	500	540528	7497551
	1,000	540152	7497875
	1,500	539789	7498234
	2,000	539402	7498530
RAT 5	100	555232	7507878
	250	555117	7507977
	500	554917	7508127
	1,000	554570	7508506
	2,000	554073	7509318
RAT 6	100	548217	7501835
	250	548133	7501961
	500	548045	7502205
	1,000	547423	7502612
	2,000	546754	7503055

Table 1. (cont.)

Reference Station ID	Easting	Northing
Reference Station Locations		
CAT 1	583239	7533436
CAT 2	585302	7532745
CAT 3	586252	7530164
CAT 4	544593	7492494
CAT 5	544410	7490762
BAT 1	591006	7536952
BAT 2	592762	7538085
BAT 3	593859	7540723
BAT 4	589137	7532085
BAT 5	585451	7533662
BAT 6	587404	7532429
BAT 7	585699	7533741
BAT 8	588649	7536631
BAT 9	589804	7537292
BAT 10	588758	7536118
BAT 11	585747	7532194
BAT 12	588350	7530221

Table 2. Red Dog mine, road, port, and reference areas soil samples data (station arithmetic mean)

Station Group	Survey station	Aluminum (mg/kg dry)	Barium (mg/kg dry)	Cadmium (mg/kg dry)	Calcium (mg/kg dry)	Iron (mg/kg dry)	Lead (mg/kg dry)	Zinc (mg/kg dry)	pH	Total solids (% as rcvd)	Total organic carbon (% dry)
MINE_SE	AT1-0000	2,343	4,798	16.6	2,343	15,850 J	981 J	2,114	4.2 J	15.9 J	27.8 J
MINE_SE	AT1-0500	1,613	726	3.0 J	1,995	19,790 J	163 J	355	4.3 J	14.7 J	32.1 J
MINE_SE	AT1-1000	2,918	1,255	1.2 J	4,518	25,338 J	50 J	155	4.8 J	13.4 J	28.0 J
MINE_SE	AT1-1500	5,320	1,115	2.3 J	2,623	22,950 J	91 J	260	5.1 J	46.2 J	10.2 J
MINE_SE	AT1-2500	4,848	361	0.7 J	4,588	11,693 J	34 J	141	4.6 J	33.1 J	19.9 J
MINE_SE	AT1-4000	12,873	1,275	1.9 J	995	20,750	53	154	4.6 J	50.2 J	18.5 J
MINE_SE	AT6-0000	7,595	6,393	24.8	21,725	20,150	1,425 J	3,485	6.7 J	33.1 J	9.5 J
MINE_SE	AT6-0250	19,325	1,735	3.6	3,015	30,350	155 J	315	5.1 J	20.8 J	16.1 J
MINE_SE	AT6-0500	4,853 J	5,983	20.2	4,728 J	6,373 J	1,167 J	1,900 J	5.1 J	18.9 J	29.1 J
MINE_SE	AT6-1000	11,650 J	2,138 J	0.9 J	223 J	26,600 J	56 J	151 J	4.8 J	74.7 J	5.0 J
MINE_SE	AT6-1500	9,113 J	2,705 J	2.7 J	2,545 J	15,343 J	143 J	363 J	4.7 J	40.4 J	28.7 J
MINE_SE	AT6-2500	3,998 J	451 J	1.8 J	4,925 J	5,718 J	77 J	187 J	5.2 J	28.5 J	29.2 J
MINE_SE	AT6-4000	1,401 J	97 J	4.5 J	16,435 J	4,953 J	9 J	204 J	5.5 J	35.3 J	35.3 J
MINE_SE	AT6-4000*	2,178 J	128 J	5.5 J	17,125 J	7,535 J	10 J	275 J	6.0 J	46.0 J	29.2 J
MINE_SE	AT7-0200	5,870	3,903	11.3	2,025	8,650	628	1,189	4.7 J	31.6 J	29.3 J
MINE_SE	AT7-0500	1,972	4,244	15.7	3,400	3,638	831	1,488	4.5 J	19.4 J	37.5 J
MINE_SE	AT7-1000	7,630	832	3.1	3,125	13,613	127	339	4.7 J	44.8 J	37.0 J
MINE_SE	AT7-1500	12,860	862	3.8 J	4,465 J	26,375 J	147 J	351 J	5.6 J	40.5 J	25.7 J
MINE_SE	AT7-1500*	11,560	759	4.5	5,155 J	22,725 J	169 J	370 J	5.4 J	35.8 J	25.3 J
MINE_SE	AT7-2500	16,150	971	4.1	853	33,400	150	443	4.7 J	48.5 J	12.3 J
MINE_SE	AT7-4000	10,013	1,064	2.4	2,918	13,775	54	168	4.5 J	24.5 J	27.8 J
MINE_SE	AT8-0000	17,625	1,905	11.0	1,010	31,200	433	906	4.7 J	68.7 J	13.1 J
MINE_SE	AT8-0500	8,015	4,068	15.5	635	13,975	980	1,701	4.3 J	38.4 J	22.0 J
MINE_SE	AT8-1000	8,780	3,090	4.0	3,430	16,785	195	505	4.9 J	39.3 J	26.8 J
MINE_SE	AT8-1500	14,953	476	0.7 J	1,033	28,350	36	145	5.0 J	51.0 J	19.3 J
MINE_SE	AT8-2500	11,475	333	0.6 J	5,988	26,000	43	125	6.2 J	46.0 J	18.1 J
MINE_SE	AT8-4000	6,215	815	2.0 J	13,360	13,103	30	165	5.8 J	33.7 J	28.7 J
MINE_SE	AT9-0000	18,025	2,885	9.3	1,315	36,500	473	929	5.0 J	64.4 J	11.3 J
MINE_SE	AT9-0500	12,475	777	5.2 J	2,355 J	29,350 J	184 J	438 J	5.0 J	45.1 J	17.9 J
MINE_SE	AT9-1000	16,550	214	2.4 J	3,608 J	37,850 J	25 J	105 J	5.3 J	43.9 J	18.0 J
MINE_SE	AT9-1500	3,870	208	1.6 J	2,270 J	23,125 J	19 J	66 J	5.4 J	64.9 J	15.6 J
MINE_SE	AT9-2500	2,795	447	3.4	6,060 J	26,375 J	111	243 J	5.5 J	37.7 J	23.3 J
MINE_SE	AT9-4000	1,041	263	0.8 J	3,363 J	3,825 J	36 J	165 J	4.3 J	20.0 J	41.7 J
MINE_NW	AT2-0000	9,525	2,185	13.4 J	2,425	21,425	573	1,070	4.9 J	32.9 J	12.7 J
MINE_NW	AT2-0250	5,805	4,940	23.4 J	2,020	15,625	1,574	2,505	4.5 J	37.9 J	17.3 J
MINE_NW	AT2-0500	809	6,403	55.7 J	25,450	9,390	2,603	7,100	6.7 J	13.6 J	34.2 J
MINE_NW	AT2-1000	1,327	2,403	23.8 J	30,625	4,770	1,405	2,878	7.1 J	17.6 J	33.0 J
MINE_NW	AT2-1500	3,100	2,300	22.2	21,850	8,775	874	1,795	6.6 J	24.0 J	27.8 J
MINE_NW	AT2-2500	16,175	2,580	10.5 J	825	28,675	1,040	1,314	4.7 J	53.8 J	12.9 J
MINE_NW	AT2-4000	13,773	675	1.5 J	1,218	24,460	69	185	4.7 J	54.1 J	16.7 J
MINE_NW	AT3-0060	2,250	3,680	13.9 J	538	25,700	5,818	2,133	3.1 J	23.5 J	23.6 J
MINE_NW	AT3-0250	17,600	3,133	13.6	828	31,300	879	1,263	4.2 J	63.5 J	13.2 J
MINE_NW	AT3-0500	19,513	4,893	11.5	600	36,575 J	1,593	1,174 J	4.0 J	62.4 J	8.7 J
MINE_NW	AT3-0700	13,213	7,233	16.3	773	34,725 J	7,355	2,070 J	3.7 J	48.6 J	16.4 J
MINE_NW	AT3-0750	5,519	3,175 J	23.3	9,898	13,815 J	1,576	2,399 J	6.0 J	14.0 J	27.1 J
MINE_NW	AT3-1000	22,598	1,242 J	7.1 J	6,865	36,250 J	280	665 J	5.8 J	53.1 J	15.8 J
MINE_NW	AT3-1250	14,285	7,060	48.2	6,125	23,655 J	2,673	4,175 J	5.5 J	37.9 J	20.9 J
MINE_NW	AT3-1500	8,455	3,255	7.1	4,043	12,165	252	495	5.0 J	34.1 J	24.6 J
MINE_NW	AT3-1800	16,400	491	2.0 J	828	33,575	84	192	4.6 J	65.4 J	12.7 J
MINE_NW	AT3-2500	9,989	615	3.4 J	2,730	20,858	118	307	4.9 J	45.6 J	24.2 J
MINE_NW	AT3-4000	2,622	1,589	3.1	8,703	6,471	79	326	5.3 J	26.9 J	28.4 J
MINE_NW	AT4-0250	9,283	6,210	20.2	3,133	34,175	1,040	1,895	4.8 J	23.1 J	25.1 J
MINE_NW	AT4-0500	18,900	709	2.5 J	513	31,950	155	255	4.2 J	61.2 J	6.2 J
MINE_NW	AT4-0750	6,578	2,160	6.5	1,485	10,353	143	490	4.3 J	28.4 J	27.9 J
MINE_NW	AT4-1000	8,015	4,703	17.7	330	17,300	1,690	1,707	3.9 J	55.6 J	15.2 J
MINE_NW	AT4-1250	5,523	1,787	19.0	828	9,380	563	1,529	4.0 J	53.9 J	23.1 J
MINE_NW	AT4-1500	13,175	1,400	8.4 J	6,763	24,220	481	769	5.5 J	43.2 J	18.6 J
MINE_NW	AT4-2500	3,855	1,344	8.4	24,275	8,593	385	894	7.0 J	25.9 J	28.3 J
MINE_NW	AT4-4000	1,354	1,558	5.0	21,325	2,143	199	661	6.7 J	16.3 J	36.0 J
MINE_NW	AT5-0000	13,625	5,638 J	9.6 J	1,555 J	20,650 J	944 J	924 J	4.9 J	51.3 J	13.7 J
MINE_NW	AT5-0000*	15,275	4,710 J	6.0 J	1,450 J	23,538 J	651 J	676 J	5.0 J	47.6 J	11.0 J

Table 2. (cont.)

Station Group	Survey station	Aluminum (mg/kg dry)	Barium (mg/kg dry)	Cadmium (mg/kg dry)	Calcium (mg/kg dry)	Iron (mg/kg dry)	Lead (mg/kg dry)	Zinc (mg/kg dry)	pH	Total solids (% as rcvd)	Total organic carbon (% dry)
MINE_NW	AT5-0250	12,810	3,400 J	9.9	1,455 J	23,398 J	827 J	1,269 J	4.7 J	47.6 J	14.6 J
MINE_NW	AT5-0500	1,755	1,778 J	11.1	25,275 J	3,240 J	524 J	1,122 J	7.4 J	13.5 J	35.3 J
MINE_NW	AT5-1000	4,435	2,795 J	17.3	24,350 J	7,813 J	571 J	1,583 J	7.2 J	36.4 J	25.5 J
MINE_NW	AT5-1500	3,945	2,323	6.3	17,475	3,850	213 J	429	5.9 J	21.0 J	38.7 J
MINE_NW	AT5-2500	5,520	1,318	5.1	5,053	6,778	247 J	523	4.9 J	62.6 J	21.4 J
MINE_NW	AT5-4000	1,619	2,028	7.9	17,450	2,918	304 J	827	6.2 J	24.7 J	36.7 J
ROAD	RAT1-0100	8,688	1,091 J	2.4 J	29,778 J	21,100 J	91	358 J	7.0 J	34.6 J	17.2 J
ROAD	RAT1-0250	10,435	633	0.5 J	8,423 J	19,700	19 J	97	6.2 J	34.2 J	22.9 J
ROAD	RAT1-0500	6,120	625	0.6 J	9,273 J	26,710 J	15 J	106 J	5.9 J	24.2 J	30.8 J
ROAD	RAT1-0500*	5,705	609	0.7 J	9,050 J	35,550 J	16 J	99 J	5.8 J	17.5 J	27.1 J
ROAD	RAT1-1000	7,755	490	0.4 J	3,443 J	16,920	11 J	78	5.0 J	25.5 J	27.8 J
ROAD	RAT1-2000	15,160	622	0.3	1,943 J	24,820	17 J	64	5.0 J	47.8 J	17.4 J
ROAD	RAT2-0100	10,408	893	1.5 J	12,288 J	21,040	50	200	7.0 J	37.1 J	16.2 J
ROAD	RAT2-0250	1,842	590	0.7 J	8,668 J	18,175	8 J	53	5.9 J	11.9 J	38.6 J
ROAD	RAT2-0500	3,148	482	0.9 J	4,720 J	43,753	8 J	59	5.4 J	11.9 J	31.6 J
ROAD	RAT2-1000	5,753	890	0.6 J	4,635 J	15,065	16 J	84	5.2 J	18.6 J	32.0 J
ROAD	RAT2-2000	7,287	377	0.4 J	4,685 J	13,508	14 J	89	5.4 J	29.3 J	27.1 J
ROAD	RAT5-0100	7,263	506	1.1 J	5,718	18,925	41 J	159	5.4 J	27.8 J	20.6 J
ROAD	RAT5-0250	2,243	398	1.2 J	5,748	11,455	34 J	168	5.2 J	12.4 J	32.6 J
ROAD	RAT5-0500	1,476	328	0.8 J	4,638	5,943	23 J	131	4.8 J	12.7 J	36.3 J
ROAD	RAT5-1000	3,693	372	0.3	3,588	14,953 J	6 J	57	4.8 J	16.4 J	35.7 J
ROAD	RAT5-2000	13,940	422	0.3	1,848	42,775 J	14 J	62	5.0 J	29.6 J	15.0 J
ROAD	RAT6-0100	6,265	272	1.8 J	14,890	13,983 J	60 J	300	6.5 J	28.7 J	20.6 J
ROAD	RAT6-0250	8,665	186	0.6 J	8,203	13,648 J	21 J	143	6.0 J	40.8 J	20.9 J
ROAD	RAT6-0500	5,355	287	0.8 J	12,138	20,628 J	12 J	199	6.3 J	29.0 J	27.0 J
ROAD	RAT6-1000	3,905	171	0.3	3,575	21,225 J	13 J	72	4.8 J	27.8 J	26.5 J
ROAD	RAT6-2000	5,038	232	0.4 J	3,725	36,400 J	10 J	52	5.1 J	20.5 J	24.7 J
PORT	RAT3-0100	6,628	1,006	6.0	11,690	43,975 J	233	750	5.7 J	16.3 J	15.2 J
PORT	RAT3-0250	2,853	424	2.6 J	10,750	23,925 J	81	324	5.7 J	14.2 J	29.9 J
PORT	RAT3-0500	4,620	273	2.1 J	3,295	27,908 J	65	178	4.9 J	25.3 J	24.8 J
PORT	RAT3-1000	2,153	349	1.5 J	3,930	12,115 J	47	217	4.6 J	12.4 J	31.6 J
PORT	RAT3-1500	1,890	239	1.2 J	3,390	24,195 J	15 J	91	4.7 J	16.1 J	31.0 J
PORT	RAT3-2000	2,303	347	0.3	3,798	25,650	17 J	81	4.6 J	12.0 J	37.0 J
PORT	RAT4-0100	3,028	463	5.4	5,020	65,750	311	804	5.1 J	9.9 J	24.2 J
PORT	RAT4-0250	3,073	449	2.5 J	3,853	50,000	105	370	5.0 J	12.6 J	27.5 J
PORT	RAT4-0500	4,393	303	0.8 J	2,313	42,500	36 J	145	4.7 J	15.2 J	30.5 J
PORT	RAT4-1000	1,440	270	0.7 J	2,545	51,500	48 J	171	4.7 J	10.3 J	29.5 J
PORT	RAT4-1500	1,998	240	0.7 J	1,993	37,875	33	107	4.7 J	10.3 J	30.2 J
PORT	RAT4-2000	1,491	217	0.7 J	2,408	35,253	33	103	4.8 J	8.8 J	32.4 J
REF	BAT1	4,243	249 J	0.3 J	1,945 J	8,995 J	11 J	61 J	4.5 J	38.0 J	32.4 J
REF	BAT1*	4,683	159 J	0.3	1,148 J	13,135 J	9 J	37 J	4.5 J	40.6 J	24.6 J
REF	BAT2	8,150 J	74 J	0.3	205 J	33,900 J	15 J	37	5.1 J	80.0 J	1.1 J
REF	BAT2*	5,993 J	98 J	0.3	548 J	31,000 J	15 J	41	4.8 J	70.6 J	5.5 J
REF	BAT3	4,290 J	185 J	0.5 J	1,455	15,715 J	30 J	74	4.7 J	55.3 J	15.1 J
REF	BAT4	2,318 J	373 J	0.3	1,973	24,850 J	5 J	33	4.4 J	12.5 J	36.8 J
REF	BAT5	1,251 J	541 J	0.3	5,978	21,083 J	6 J	45	5.4 J	9.1 J	37.5 J
REF	BAT6	1,850	665	0.5 J	4,350	12,600	9 J	38	5.0 J	12.6 J	38.5 J
REF	BAT7	4,645	168	0.3	1,073	11,728	12 J	33	4.3 J	47.6 J	18.9 J
REF	BAT8	3,505	692	1.0 J	3,750	10,715	14 J	64	5.1 J	26.6 J	32.1 J
REF	BAT9	5,805	228	0.5 J	1,178	22,225	15 J	40	4.8 J	47.9 J	8.5 J
REF	BAT10	2,760	929	0.5 J	8,528	18,825	5 J	43	5.3 J	15.6 J	35.2 J
REF	BAT11	2,963	951	0.4 J	20,950	16,318	7 J	157	6.3 J	20.7 J	35.1 J
REF	BAT12	2,773	1,014	1.8 J	14,275	112,750	13 J	54	6.6 J	12.2 J	26.5 J
REF	CAT1	7,448	108	0.3	655	18,583	12 J	41	4.7 J	65.7 J	12.3 J
REF	CAT2	3,773	475 J	0.5 J	5,228 J	8,248 J	8 J	59 J	4.9 J	17.2 J	35.2 J
REF	CAT3	4,125	285 J	0.3	2,795 J	7,500 J	6 J	45 J	4.5 J	29.0 J	36.1 J
PORT REF	CAT4	2,168	390 J	0.9 J	3,915 J	15,075 J	11 J	84 J	5.0 J	13.7 J	36.0 J
PORT REF	CAT5	7,650	179 J	0.4 J	1,605 J	30,025 J	9 J	43 J	4.7 J	28.6 J	24.3 J

Notes:

Arithmetic mean values were calculated from four subsamples at each location.

Half method detection limits were used if the analyte was non-detected.

J qualifier was shown on the table if any of the subsamples has either J or J- qualifier (See Appendix CL for complete sample data)

REF – Indicates reference area stations

* – Indicates field replicate sample

Table 3. Summary of statistical comparisons of metals concentrations in soil from 2014 to 2017 by station group

	2014 Concentrations (mg/kg)		2017 Concentrations (mg/kg)		As Measured			Log-Transform			Comparison Tests			
					Shapiro-Wilk Test			Shapiro-Wilk Test						
Station Group	Mean	SD	Mean	SD	2014	2017	F-Test	2014	2017	F-Test	T-Test[a]		Wilcoxon	Conclusion
Aluminum														
Reference (Mine/Road)	6,181	3,302	3,936	1,786	0.6846	0.5233	0.0283	0.0711	0.8991	0.1412	0.1235	L,eq	0.0675	No detectable change
Mine (Northwest)	7,847	6,100	8,914	6,235	0.0093	0.0384	0.9029	0.0201	0.0450	0.3871	0.3458	L,eq	0.4441	No detectable change
Mine (Southeast)	7,697	5,455	8,513	5,511	0.0059	0.0606	0.9560	0.4124	0.0929	0.8915	0.5947	L,eq	0.5663	No detectable change
Road	12,620	4,348	6,711	3,754	0.1006	0.3453	0.5286	0.0004	0.5162	0.2871	<0.0001	N,eq	0.0001	Significant reduction
Port	6,598	4,025	2,989	1,534	0.0091	0.0579	0.0034	0.0243	0.7094	0.1952	0.0096	L,eq	0.0145	Significant reduction
Barium														
Reference (Mine/Road)	433	373	460	322	0.0020	0.0783	0.5902	0.6087	0.4176	0.9968	0.7627	L,eq	0.6236	No detectable change
Mine (Northwest)	3,368	2,027	2,925	1,908	0.0424	0.0070	0.7354	0.4413	0.3585	0.7082	0.3221	L,eq	0.4143	No detectable change
Mine (Southeast)	2,247	2,190	1,818	1,771	0.0002	0.0002	0.2512	0.2199	0.5623	0.9020	0.5025	L,eq	0.5475	No detectable change
Road	442	189	493	247	0.6095	0.1254	0.2484	0.2992	0.9212	0.8171	0.5790	L,eq	0.6395	No detectable change
Port	361	183	381	214	0.0031	0.0006	0.6085	0.1073	0.0663	0.9082	0.7985	L,eq	0.7987	No detectable change
Cadmium														
Reference (Mine/Road)	0.31	0.18	0.50	0.40	0.0500	0.0001	0.0061	0.5444	0.0093	0.8581	0.0431	L,eq	0.0453	Significant increase
Mine (Northwest)	13.69	9.17	13.72	11.93	0.0242	<0.0001	0.1414	0.2130	0.7780	0.5783	0.7330	L,eq	0.8088	No detectable change
Mine (Southeast)	6.63	7.01	5.86	6.44	<0.0001	<0.0001	0.6447	0.2916	0.2651	0.8730	0.5724	L,eq	0.6851	No detectable change
Road	0.40	0.28	0.79	0.56	0.0015	0.0029	0.0038	0.5231	0.6262	0.8263	0.0024	L,eq	0.0024	Significant increase
Port	1.47	1.71	2.02	1.87	0.0003	0.0089	0.7748	0.3275	0.8172	0.7786	0.2737	L,eq	0.2657	No detectable change
Calcium														
Reference (Mine/Road)	3,919	5,798	4,941	5,761	<0.0001	0.0010	0.9813	0.5078	0.9968	0.8395	0.5055	L,eq	0.4864	No detectable change
Mine (Northwest)	8,203	9,183	8,411	9,682	<0.0001	<0.0001	0.7666	0.0712	0.0208	0.7642	0.8560	L,eq	0.8088	No detectable change
Mine (Southeast)	4,229	3,930	4,276	4,717	<0.0001	<0.0001	0.3228	0.4159	0.3358	0.9755	0.9090	L,eq	0.8449	No detectable change
Road	3,274	3,360	7,590	6,338	<0.0001	0.0001	0.0081	0.1583	0.6737	0.8755	0.0003	L,eq	0.0004	Significant increase
Port	3,076	2,700	4,582	3,221	0.0038	0.0011	0.5678	0.3011	0.0613	0.3527	0.0717	L,eq	0.0449	Significant increaseb
Iron														
Reference (Mine/Road)	23,043	16,657	22,977	25,737	0.0021	<0.0001	0.1152	0.0407	0.0425	0.4980	0.8729	L,eq	0.3892	No detectable change
Mine (Northwest)	16,831	11,768	18,073	11,261	0.0499	0.0218	0.8047	0.0154	0.0121	0.3889	0.6629	N,eq	0.5491	No detectable change
Mine (Southeast)	17,692	12,164	19,716	9,772	0.0178	0.4348	0.2362	0.6881	0.0064	0.3933	0.4728	N,eq	0.2933	No detectable change
Road	28,100	8,733	21,257	10,065	0.6547	0.0177	0.5422	0.9728	0.3582	0.0882	0.0116	L,eq	0.0112	Significant reduction
Port	30,525	11,728	36,720	14,934	0.7335	0.9602	0.4354	0.3392	0.5929	0.8704	0.3417	L,eq	0.3474	No detectable change
Lead														
Reference (Mine/Road)	8.07	2.52	11.11	6.38	0.7878	0.0040	0.0013	0.0483	0.6150	0.3117	0.1286	L,eq	0.2169	No detectable change
Mine (Northwest)	935	1,098	1,121	1,580	<0.0001	<0.0001	0.0432	0.8648	0.7866	0.2467	0.8504	L,eq	0.8585	No detectable change
Mine (Southeast)	304	361	288	387	<0.0001	<0.0001	0.7013	0.2158	0.2690	0.5052	0.4653	L,eq	0.5382	No detectable change
Road	18.15	7.12	24.12	21.44	0.0001	0.0002	<0.0001	0.0096	0.3965	0.0006	0.7341	L,un	0.7788	No detectable change
Port	66.51	69.12	85.02	92.42	0.0016	0.0015	0.3496	0.3728	0.6391	0.9778	0.5465	L,eq	0.4776	No detectable change

Table 3. (cont.)

	Station Group	2014 Concentrations (mg/kg) Mean	SD	2017 Concentrations (mg/kg) Mean	SD	As Measured Shapiro-Wilk Test 2014	2017	F-Test	Log-Transform Shapiro-Wilk Test 2014	2017	F-Test	Comparison Tests T-Test[a]		Wilcoxon	Conclusion
Zinc															
	Reference (Mine/Road)	53	40	54	31	<0.0001	<0.0001	0.3266	0.0023	0.0073	0.5838	0.7240	L,eq	0.5668	No detectable change
	Mine (Northwest)	1,436	1,021	1,418	1,355	0.0011	<0.0001	0.1144	0.7069	0.9302	0.3527	0.5409	L,eq	0.5837	No detectable change
	Mine (Southeast)	748	900	622	777	<0.0001	<0.0001	0.4249	0.0372	0.0486	0.9840	0.4538	L,eq	0.4583	No detectable change
	Road	79	39	126	85	0.0002	0.0014	0.0014	0.0088	0.1475	0.1144	0.0209	L,eq	0.0245	Significant increase
	Port	231	246	278	250	0.0003	0.0028	0.9568	0.1067	0.2216	0.8648	0.4610	L,eq	0.4428	No detectable change
pH															
	Reference (Mine/Road)	4.79	0.43	5.02	0.67	0.1294	0.0217	0.1102	0.2047	0.0809	0.1946	0.2886	L,eq	0.4124	No detectable change
	Mine (Northwest)	5.18	1.03	5.24	1.13	0.0067	0.1362	0.6193	0.0195	0.3881	0.5802	0.9025	L,eq	0.6649	No detectable change
	Mine (Southeast)	4.92	0.61	4.99	0.58	0.0085	0.0250	0.7433	0.0836	0.1769	0.7198	0.5811	L,eq	0.5019	No detectable change
	Road	5.45	0.74	5.58	0.71	0.0031	0.0404	0.8317	0.0094	0.0736	0.8504	0.5387	L,eq	0.4135	No detectable change
	Port	4.92	0.41	4.91	0.38	0.3390	0.0055	0.7861	0.5115	0.0087	0.7457	0.9817	L,eq	0.7987	No detectable change
TOC															
	Reference (Mine/Road)	25.62	14.19	26.62	11.88	0.1367	0.0184	0.5141	0.1050	0.0012	0.9134	0.8354	N,eq	0.9674	No detectable change
	Mine (Northwest)	29.26	11.59	22.27	8.73	0.0129	0.3524	0.1147	0.0083	0.1215	0.9720	0.0073	N,eq	0.0136	Significant reduction
	Mine (Southeast)	27.80	12.61	22.94	9.01	0.0648	0.7137	0.0703	0.0072	0.0267	0.3168	0.0856	N,eq	0.1186	No detectable change
	Road	14.76	10.84	25.96	7.07	0.0034	0.5695	0.0704	0.3829	0.4513	0.0002	0.0001	L,un	0.0008	Significant increase
	Port	26.96	14.74	28.64	5.42	0.0188	0.1042	0.0025	0.0199	0.0084	0.0009	0.7159	N,un	0.9323	No detectable change

Notes: Statistical evaluations included undetected concentrations at half the detection limit.
P-values reported have not been adjusted for the number of comparisons.
Conclusion of significance is based on the standard 0.05 significance level, without adjustment for the number of comparisons.
[a] T-test is based on as-measured (N) or log-transformed (L) concentrations assuming equal (eq) or unequal (un) variances as determined from the Shapiro-Wilk normality tests and F-tests of equal variances.
[b] Change in concentration is marginally significant (T-test p-value is >0.05 and Wilcoxon test p-value is <0.05).