Fugitive Dust Risk Management Plan
2014 Annual Report

Red Dog Mine
Teck Alaska Incorporated
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Teck

Contents

Figures and Tables are presented immediately following the text.

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
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 2014. A history of RMP activities was provided in the first (2011) Annual Report (Teck 2012) and will not be repeated here. This report is not intended to give the reader a complete background of the RMP or the RMP Implementation Plans; if background is needed, the reader is encouraged to review the RMP, Implementation Plans, and previous Annual Reports available at www.RedDogAlaska.com.

Included in this report are 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 related to these implementation plans are summarized below.

The Communication Plan contains a description of Red Dog's efforts to maintain clear communication with all interested parties and local communities about current fugitive dust risk management efforts underway at the mine. Communication activities during 2014 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 2014. Volunteers for the Red Dog Environmental Observer program are being asked to participate; interest should be made aware to Red Dog Environmental Group or Red Dog Public Relations Group. Also, establishment of fair unit prices for a native seed collection program in the village of Noatak was started in 2014.

The Dust Emissions Reduction Plan describes current dust reduction efforts underway at the mine. Dust emissions reduction activities during 2014 included purchase of a new dust suppression product made of guar gum for hydroseeder application, purchase of a new dust suppression product for helicopter spray bar application (manufacturing of the previous dust suppressant was discontinued), and port road dust suppression using chlorides was completed in the summer months.

The Remediation Plan is designed to facilitate the identification and selection of metals or ore concentrate affected areas for implementation of remediation and/or reclamation, to reduce the potential for human and ecological exposure. Remediation and reclamation activities in 2014 included remediation activities at two zinc concentrate spills along the port road, and additional follow-up filling and reclamation work occurred at Mile 34.5 Spill Site.

The Worker Dust Protection Plan details those programs in place to monitor and minimize workers' exposure to dust while at Red Dog, and to facilitate comprehensive communication about these programs, policies, and practices. In 2014, 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.

The Uncertainty Reduction Plan is intended to identify and implement research or studies to reduce uncertainties related to the assessment and management of risk to humans and the environment. Uncertainty reduction studies implemented in 2014 were focused on caribou. A study was planned to evaluate bone and bone marrow consumption. Part of the study incorporates a cooking competition so that individuals from Kivalina and Noatak can prepare dishes that include caribou bone, and lead concentrations will be measured in those dishes. Secondly, a study on the fractional intake (FI) assumption used in risk assessment was conducted. The goal of the study was to estimate the fraction of time a "typical" caribou spent in the "site" area relative to the entire period of time represented by the tracking data. This type of data was relied upon in the risk assessment to estimate the relative amount of a person's chemical exposure that might come from a specific study area. The results of this study confirm that the assumed FI value used in the risk assessment was protective of human health.

The Monitoring Plan is 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

2013, monitoring activities described in the Monitoring Plan proceeded on schedule and statistical analyses were performed on multi-year data to identify and evaluate any trends and patterns; specific results are presented in the Monitoring Plan section. In 2014, the following monitoring programs were implemented:

- **Monitoring Programs for DEC Oversight.** Marine sediment monitoring and soil monitoring was conducted in 2014.

- **Operational Monitoring.** Operational monitoring implemented in 2014 included 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, and vegetation community monitoring.

Results from the monitoring programs largely indicate that concentration trends are flat (i.e., no increasing or decreasing trend). The exception is that lead and zinc concentrations in mine the mine are has increased significantly since 2011, however dustfall jars at the mine area do not indicate a similar increase. 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),[1] 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[2] 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

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[1] Exponent (2008) is a draft plan. Publication of a revised risk management plan for DEC approval is anticipated in 2015.
[2] Plants and animals

human health risk assessment evaluated potential exposure to DMTS-related metals through 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 was 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*."[3]

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 2014a)
- Uncertainty Reduction Plan (Exponent 2012)

These plans are available for review at www.RedDogAlaska.com.

[3] 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. 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 2014 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 2014.

Risk Management Actions Taken in 2014

The following sections of this 2014 annual report summarize each implementation plan, the corresponding risk management objectives, and the actions taken during the 2014 calendar year toward achieving these objectives.

Communication Actions

The Communication Plan follows from Risk Management 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. Those actions that were taken in 2014 are outlined below.

The following actions were taken in 2014 in order to increase communication and participation, and to ensure that information is being communicated to all stakeholders in the most effective manner:

- **Community Meetings.** Continuation of annually scheduled community visits/meetings in all eleven communities, quarterly meetings with the Red Dog Subsistence Committee, and at a minimum, quarterly meetings with the Kivalina IRA Council. Verbal suggestions and comments received during village visits are documented and tracked to ensure that appropriate responses are provided to the interested parties and that suggestions are incorporated into risk management activities where appropriate. Topics discussed in 2014 included:
    - Results of berry and water sampling studies that were conducted in August 2013
    - Review of fish studies conducted using in-kind funding provided to Alaska Department of Fish and Game (ADF&G) for monitoring
    - Port traffic and shipping schedules
    - Fuel shipment updates
    - Marine mammal surveys
    - Spill remediation activities
    - Air sampling related to pit blasting

- **Outreach and Education.** Red Dog is constantly looking for additional opportunities for stakeholders to gain more understanding of and participation in Red Dog operations as a whole.

- The Red Dog Environmental Observer program was started to encourage community members to accompany the Red Dog environmental technicians in the field during sampling events. In 2014, no additions to the list of observers, which includes some community members and members of the Subsistence Committee, was requested. In 2015, the environmental observer program will be focused on providing additional opportunities for stakeholders to gain more understanding of and health and environmental monitoring efforts.
- Red Dog has been working in collaboration with the Alaska Plant Materials Center to develop a native seed collection program in the village of Noatak, with the intent to use the seed for Red Dog reclamation activities including historic spill sites. The pilot study hopes to establish a fair price/unit for native seeds so that stakeholders who wish to collect native plant seeds for remediation/reclamation can operate as independent business owners.

Dust Emissions Reduction Actions

The Dust Emissions Reduction Plan is intended to achieve Risk Management 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.”

Dust Emissions Reduction Actions in 2014. Dust reduction actions taken in 2014 included the following:

- **Purchase of New Dust Control Agent for Hydroseeder.** A dust suppression product made using guar gum (Earthbound Scientific made by Terra Novo, Inc.) was evaluated and selected to replace the previous polymer product that was discontinued by 3M (LSP-1000C). The product was purchased in 2014 and will be applied to tailings beach areas via hydroseeder in August-September 2015.
- **Purchase of New Dust Control Agent for Helicopter Application**. A new dust suppression product was ordered, tested in the Red Dog laboratories, and purchased for use in 2015 on tailings beaches. The product, Envirotac II, is non-toxic, non-hazardous, and environmentally safe dust control and soil stabilization product.

- **Dust Control Planning.** Three new sustainable and effective dust control products were investigated for potential use on the Port Road. Samples were obtained in 2014, will be tested in the laboratory in 2015 for potential use at Red Dog, and if possible, trials are scheduled for summer 2016.

Dust control and reduction efforts as well as research into new methods and technologies are ongoing. The results of these efforts will be reported in the next annual report.

Remediation Actions

The Remediation Plan is intended to facilitate the achievement of the Risk Management 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.

Two zinc concentrate spills occurred on the tundra in 2014. Some remediation and reclamation activities occurred in 2014, including the following:

- **Mile 34.5 Zinc Concentrate Spill Follow-up.** On March 15, 2011, a zinc concentrate spill occurred at Mile 34.5 on the DMTS road. Backfilling and reclamation of the site occurred in 2014.
- **Mile 3 Zinc Concentrate Spill Planning.** A zinc concentrate occurred on the road on January 20, 2014. Initial cleanup and recovery efforts were completed using the port vacuum. Plastic was placed on top of the remaining zinc concentrate that could not be vacuumed up. A work plan was developed and final cleanup and reclamation will occur in 2015.
- **Mile 13 Zinc Concentrate Spill Reclamation Planning**. A zinc concentration spill occurred on August 20, 2014. Initial cleanup and recovery efforts were completed using a vacuum truck and shovels on August 26, 2014. The area that would require excavation was delineated and then covered with plastic. A cleanup plan was developed in 2014, and reclamation will occur in 2015 per DEC approval.

Worker Dust Protection Actions

The Worker Dust Protection Plan was developed in response to Risk Management 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."

Teck considers safety a core value and 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 developed 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 and Medical Departments.

Worksite blood lead monitoring was conducted in 2014 by the Safety & Health and Medical departments. 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 2014, all blood lead monitoring results indicated exposures were below both the MSHA/OSHA standards (summarized below). Six people exhibited blood lead levels that were slightly greater than the more stringent Red Dog standards, ranging from 25.2 to 30.1 µg/dL(summarized below). Therefore, those individuals received counseling and had additional blood lead monitoring. No workers were removed from the job due to blood lead levels in 2014.

	MSHA/OSHA Standard	Red Dog Policy
Monitoring every 6 months	< 40 µg/dL	< 25 µg/dL
Blood Lead—26 to 35 µg/dL	Monitor every 6 months	Monitor every 3 months
Blood Lead—36 to 40 µg/dL	Monitor every 6 months	Monitor monthly, training & counseling
Blood Lead—41 to 50 µg/dL	Monitor every 6 months	Monitor monthly, training & counseling
Blood Lead—> 50 µg/dL	Removal from job duties	Removal from job duties, training, counseling, continued medical monitoring
Pregnant workers	Monitor every 6 months	Monitor every 3–4 weeks
Pregnant workers removed from job duties	>30 µg/dL	>10 µg/dL

Uncertainty Reduction Actions

The Uncertainty Reduction Plan follows from Risk Management 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." Work was conducted on the following uncertainty reduction studies in 2014.

Caribou Cooking Study Plan Development

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 consumption. The primary objective of the study is to conduct an analysis to determine typical bone lead levels in caribou and transfer of lead from bone to food during cooking. In addition, a cooking competition will be incorporated into the study so that individuals from Kivalina and Noatak can prepare dishes that include caribou bone, and lead concentrations will be measured in those dishes. 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?

A draft outline of the study plan was developed in 2013. A detailed phase one study plan (the laboratory-based cooking study) was in development in 2014. Presently, the detailed phase one study plan is anticipated to be issued for review by stakeholders in Fall 2015. Following stakeholder review, the detailed phase one study plan will be updated as needed and then posted to www.RedDogAlaska.com. Sampling of caribou and implementation of the first phase of the study is anticipated for 2016, with development of the detailed phase two study plan (the community-based cooking study) to follow later in 2016.

Caribou Site Use Study

In the human health risk assessment (Exponent 2007), although overall the human health risks were low, risks associated with consumption of metals in caribou tissues were among the primary risk drivers identified. A fractional intake (FI) assumption is used in risk assessment equations to estimate the relative amount of a person's chemical exposure that might come from a specific study area. The FI assumption incorporates the amount of time that a food source such as caribou spends in the area a fraction of time spent in their entire home range.

For the human health risk assessment previously conducted, the FI used was conservatively estimated, but did not take into account time caribou spent at the site, nor the total home range of caribou that spend time in the vicinity of Red Dog. The goal of this study was to estimate the fraction of time a "typical" caribou spent in the "site" area relative to the entire period of time represented by the tracking data.

Satellite collar data collected from 2000 to 2012 by Jim Dau from Alaska Department of Fish and Game 2000 to 2012 were utilized. Quantitative analysis of the caribou use of the DMTS study area using the satellite data indicates that the FI estimated used in the DTMS Fugitive Dust Risk Assessment overestimates actual site use by approximately an order of magnitude, or more. The results of this study suggest that the assumed FI value used in the risk assessment was protective of human health.

Monitoring Actions

The Monitoring Plan (recently revised, see Exponent 2014a) is intended to facilitate the achievement of the following risk management 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 2014a) 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 2014. 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.

Marine Sediment Monitoring

Marine sediment sampling was conducted in the fall of 2014 to monitor operational-scale dust deposition in the marine environment surrounding the DMTS port ship loader facilities (Exponent 2014b). The sediment samples were collected from seven locations around the Red Dog port facility which had exhibited elevated metals concentrations when sampled in 1990 (Figure 3). These locations have been periodically re-sampled since 2003 as part of the ongoing marine sediment monitoring program to evaluate temporal changes in the average metal concentrations. The purpose of the marine sediment sampling program is to measure and track over time the concentration and distribution of metals in marine sediments in the vicinity of the port shiploader (Figure 4).

Samples were analyzed for cadmium, lead, and zinc, which are the primary constituents of concern and risk drivers that are present in the lead and zinc concentrates transported via the shiploader and barges. As specified in the monitoring plan (Exponent 2014a), the measured levels are compared with the ER-L guideline values developed by Long et al. (1995) for marine sediment.

Levels of cadmium, lead, and zinc were generally below ER-L guideline values. There was one zinc sample that exceeded its ER-L guideline value (Figure 4). Note that all reported zinc values are considered to be estimates due to low matrix spike replicate recovery and field replicate imprecision, indicating potential matrix heterogeneity.

Cadmium, lead and zinc concentrations did not exceed the ER-Ls at more than one station for more than two annual monitoring events in a row in 2010, 2012, and 2014. Therefore, according to the protocol in the monitoring plan (Exponent 2014a), monitoring continues on a biennial basis, with the next marine sediment monitoring sampling event scheduled for 2016.

Soil Monitoring

Soil sampling was conducted for the first time in the summer of 2014 at the previously established vegetation community monitoring stations (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 2014c).

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 (2014a), include aluminum, barium, cadmium, calcium, iron, lead, and zinc; soil samples were also analyzed for pH.

Levels of aluminum, barium, cadmium, lead, and zinc were generally highest within the mine boundary, and lower outside the mine boundary and in port, reference, and port 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. 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).

The results of the 2014 mine, road, and port soil monitoring make up the first round in an ongoing monitoring effort that will occur once every three years. Data will be compared from one sampling event to another to determine changes in soil concentrations over time. Statistical analyses will be performed for each set of sample replicates (as discussed in Exponent [2014a]) to quantify the variation in the sample population and assess changes in metals concentrations over time. 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.

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 2014; therefore there is no additional VEE monitoring to report for 2014.

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 5). Port TEOMs are located downwind of the Concentrate Storage Buildings (CSBs) and in the lagoon area downwind of the concentrate conveyor (Figure 6).

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[4] 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 2011, 2012, 2013, and 2014 TSP-Pb and TSP-Zn concentrations are shown on Figure 7a 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 7a).

- **Mine TEOM Results.** At the mine, (Figure 7b), 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).

- **Port TEOM Results.** At the port (Figure 7c), lagoon TEOM lead and zinc concentrations are highest from July through November, corresponding with the peak shipping season. Port CSB TEOM lead and zinc concentrations were highest in July (Figure 7c), corresponding with the beginning of the shipping season (July – October).

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.

[4] 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.

Seasonal trend tests require valid data within each month for at least three years within the time frame considered. Therefore those months with less than three data points within the most recent four-year period were excluded from the test, namely March for Port CSB, and February for Port Lagoon.

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. To reduce the impact of missing data in the port area 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 8 and 9).

For the most recent four-year period (2011-2014), statistical analysis indicates that Port area and Mine Tdam area have been relatively stable in lead and zinc concentrations, both in mean and 95th percentile concentrations (Table 1, Figures 8 and 9). The Mine PAC TEOM, however, has had significant increasing trends[5] in mean concentration and 95th percentile concentration of both lead and zinc (Table 1, Figures 8 and 9).

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

[5] The significance level was evaluated using the Bonferroni correction for multiple hypothesis testing (Weisstein 2014). The specific p-values used are presented in the tabular results.

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).

Results for stations outside the mine boundary do not exceed Arctic Zone Industrial Cleanup Levels for lead, zinc, or cadmium over the time period 2011-2014 (Figures 10, 11 and 12).

If sample results 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[6]) for more than two consecutive sampling periods, that road section is to be remediated and resurfaced as described in the Remediation Plan (Exponent 2011). Based on results, no remediation or resurfacing is needed at this time.

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[6] 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.

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, 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).

In 2014, total solids deposition rates were similar or less than those measured in the prior five years (2009-2013) [Figures 13, 14 and 15]. However, for some months in 2014, zinc dustfall rates at the mine (Figure 13) and port (Figure 15) showed upward trends compared to the prior five years, while lead dustfall rates showed increases along the road during some months in 2014 (Figure 14). Statistical analyses are presented below.

Statistical Trend Analysis for Dustfall Jar Data. Temporal trends in deposition rates or metals concentrations in dustfall jars data were evaluated using the same statistical methods used for the TEOM analyses, using seasonal trend tests conducted with monthly mean and 95th percentiles (discussed above in TEOM section).

- **Lead.** For lead, dustfall deposition rates and concentrations have been stable over the most recent four-year period, both in mean and 95th percentile concentrations (Table 2). Time series plots of lead dustfall deposition rates and concentrations are presented in Figures 16 and 19, respectively.

- **Zinc.** For zinc, the mean dustfall deposition rates and concentrations have been stable in all areas except the DMTS road, which has shown a significant increasing trend for the most recent four-year period. Meanwhile, the 95th percentile deposition rates and concentrations have been stable in all areas over the same time period. Time series plots of zinc dustfall deposition rates and concentrations are shown in Figures 17 and 20, respectively.

- **Total Solids.** For total solids, the deposition rates have been stable. No statistically-significant trends were identified at any location over the most recent four-year period, either in average or upper limits (Table 2). Time series plots of total solids dustfall rates are presented in Figure 18.

Vegetation Community Monitoring

The objective of the vegetation community monitoring effort is to provide a means to consistently evaluate the effectiveness of dust control efforts, as expressed by vegetation community health primarily through three key measures: 1) moss cover, 2) lichen cover, and 3) vascular plant cover and composition. An array of established community survey sites located around the mine, road, and port (see Figure 3) are monitored periodically according to the schedule (Figure 2).

The collection of these vegetation, moss, and lichen cover values facilitates long-term evaluation of sites within a 4,000 m radius of the mine and within 2,000 m downwind of the DMTS and partially downwind of the Port Facilities. Total vegetation, total lichen, and total moss cover results as measured in 2010, 2012, 2014 are shown in Figure 21.

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 Department of Fish and Game, and have provided baseline information against which more current studies may be compared.

Caribou tissue monitoring for dust-related constituents under the RMP program is next scheduled to occur in 2015.

Summary of Monitoring Results

Dust monitoring data from the TEOM air samplers and the dustfall jars was statistically evaluated to assess the current trends over the most recent four-year period. Statistical analysis of the Mine PAC TEOM data indicates that the current trends in the mine area are showing significant increasing in lead and zinc concentrations, both in terms of average concentrations and of measures of upper limits. However, the dustfall jars do not indicate the same trends. Concentrations have been stable is all other locations.

Trend test results of dustfall data indicate the mean deposition rates and concentrations of lead and zinc are stable over the most recent four-year period. Mean zinc concentrations show a significant increasing trend in the DMTS road area, however the measure of the upper limits (95^{th} percentile) deposition rates and concentrations of lead and zinc have been stable in all areas. Finally, the deposition rates of total solids have been stable over the most recent four-year period, both in average and upper limits.

A summary of statistical trend analysis results for TEOM and dustfall jar monitoring programs is presented in Table 3. 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). Overall, environmental media concentrations remain similar to or lower than those evaluated in the DMTS risk assessment (Exponent 2007).

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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

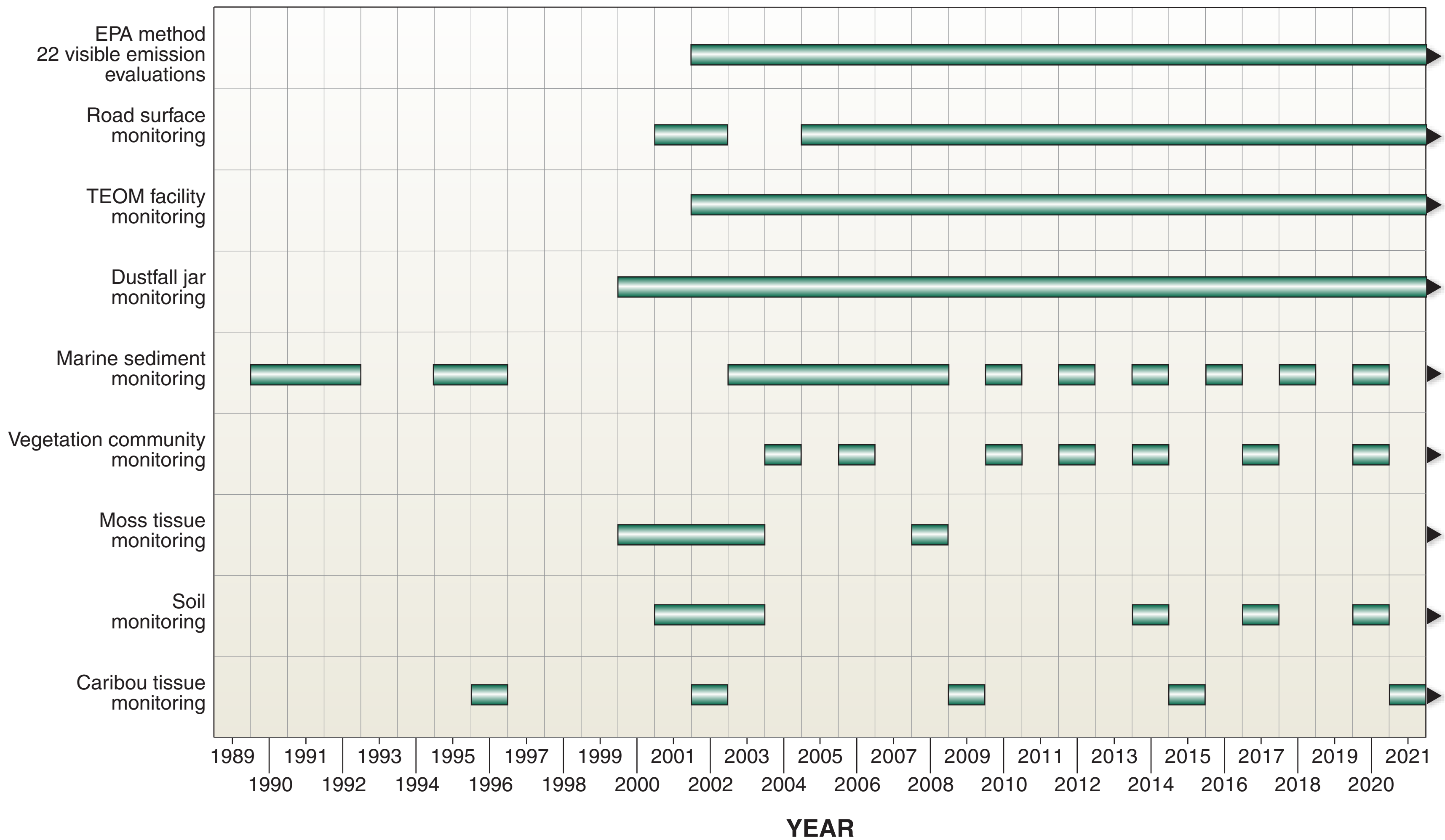


Figure 2. Monitoring timeline with program frequencies

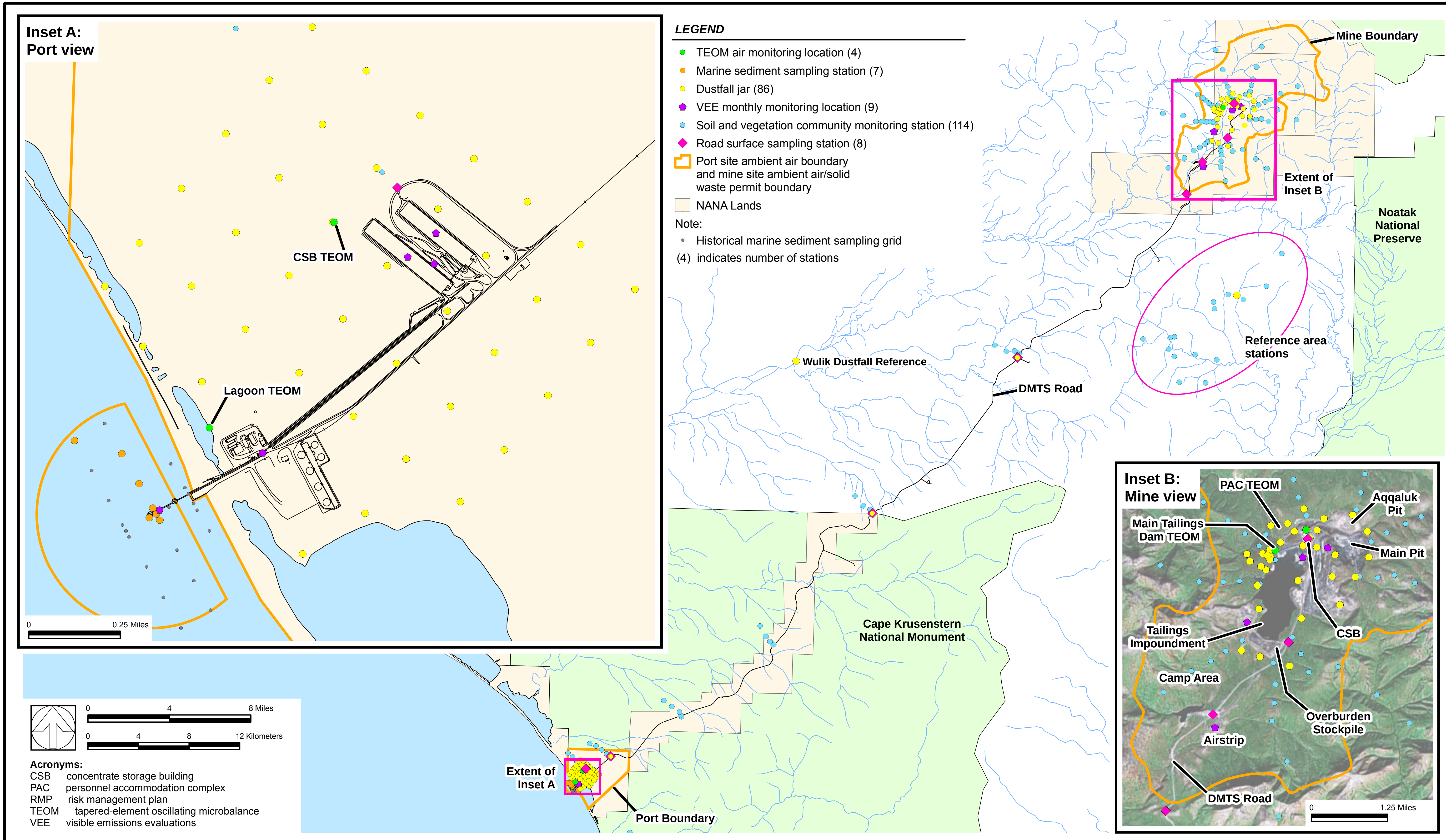
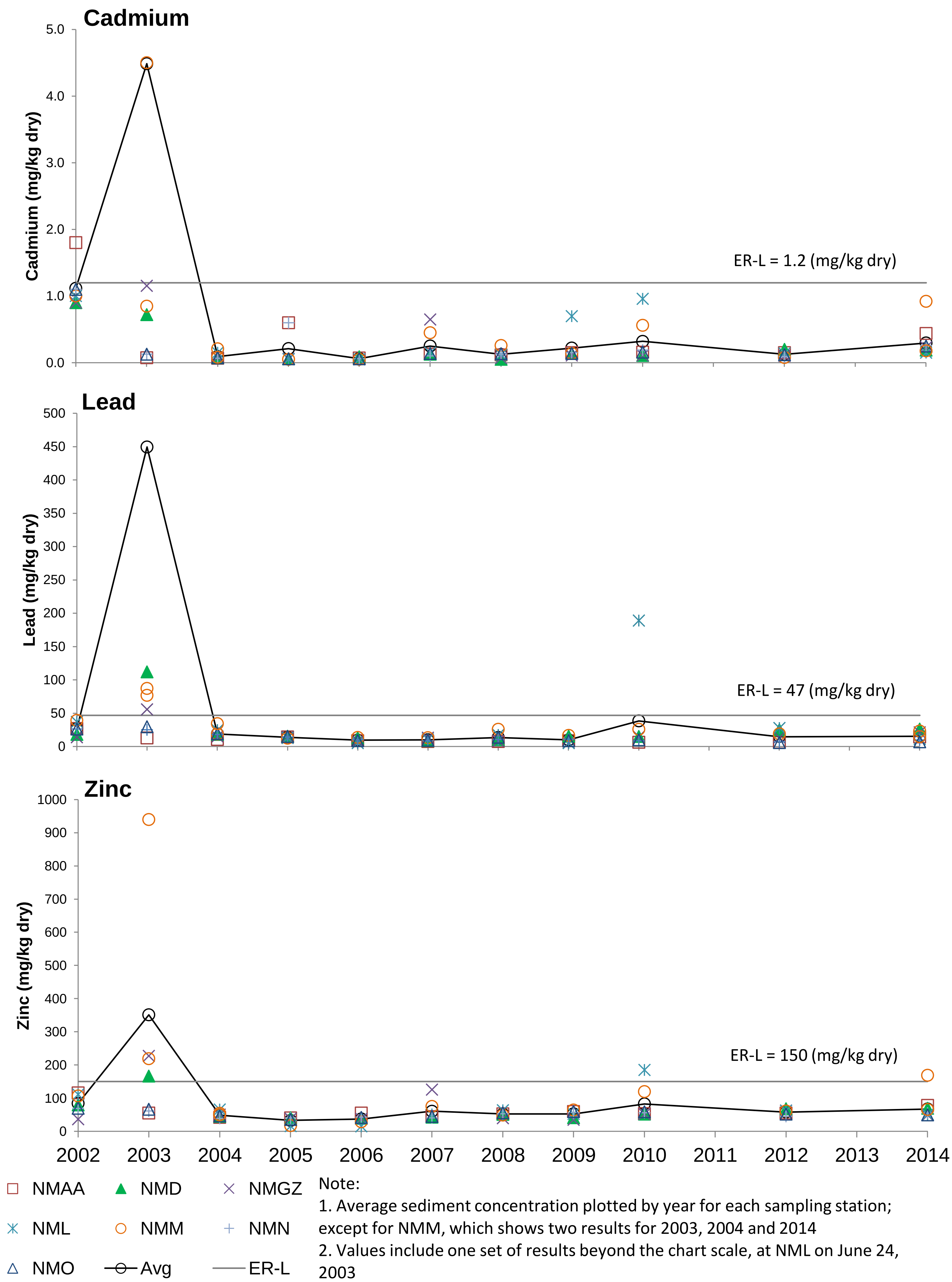


Figure 3. Overview of risk management monitoring programs



Note:

1. Average sediment concentration plotted by year for each sampling station; except for NMM, which shows two results for 2003, 2004 and 2014
2. Values include one set of results beyond the chart scale, at NML on June 24, 2003

Figure 4. Time series for sediment concentrations of cadmium, lead, and zinc relative to ER-L guideline values

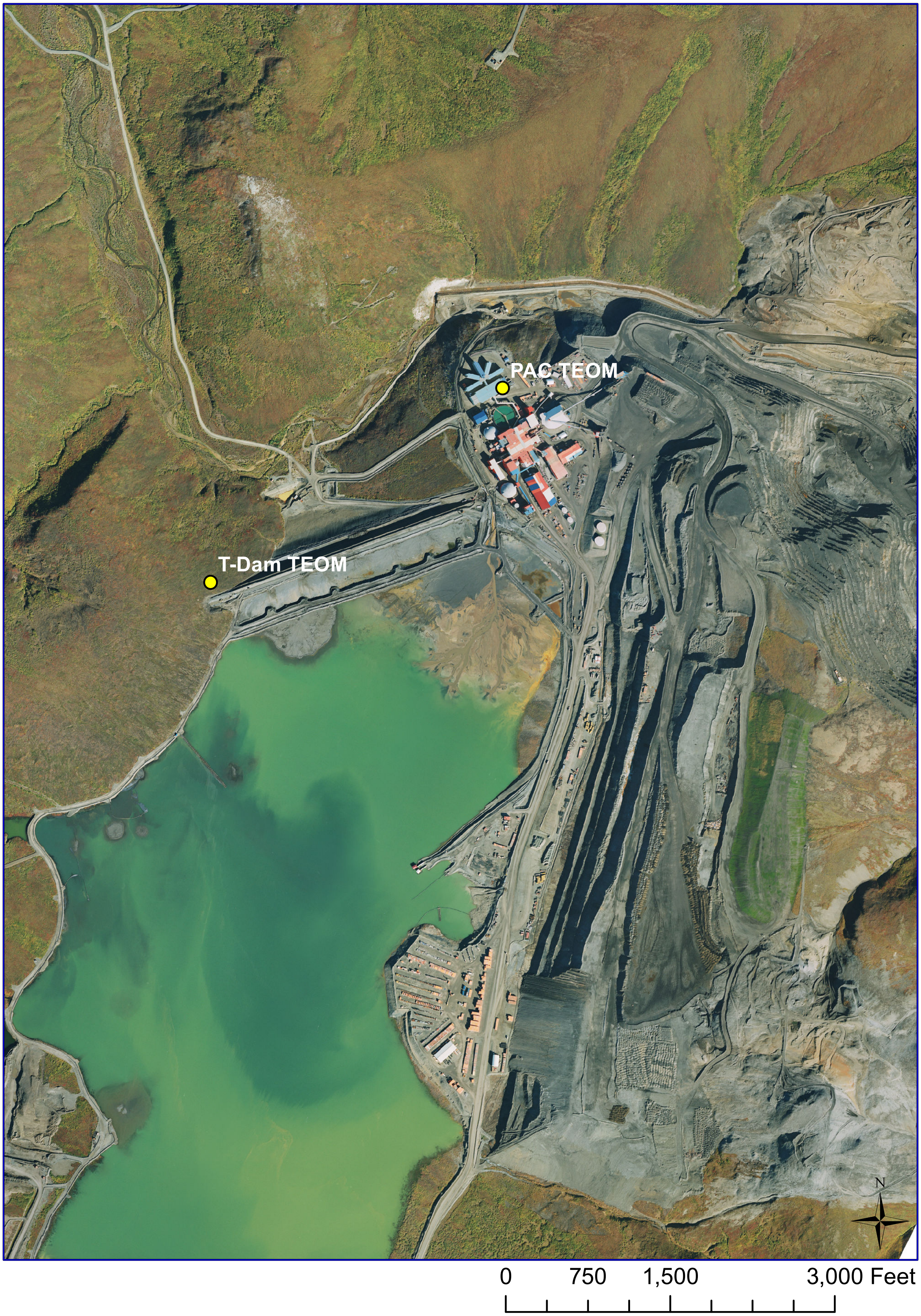
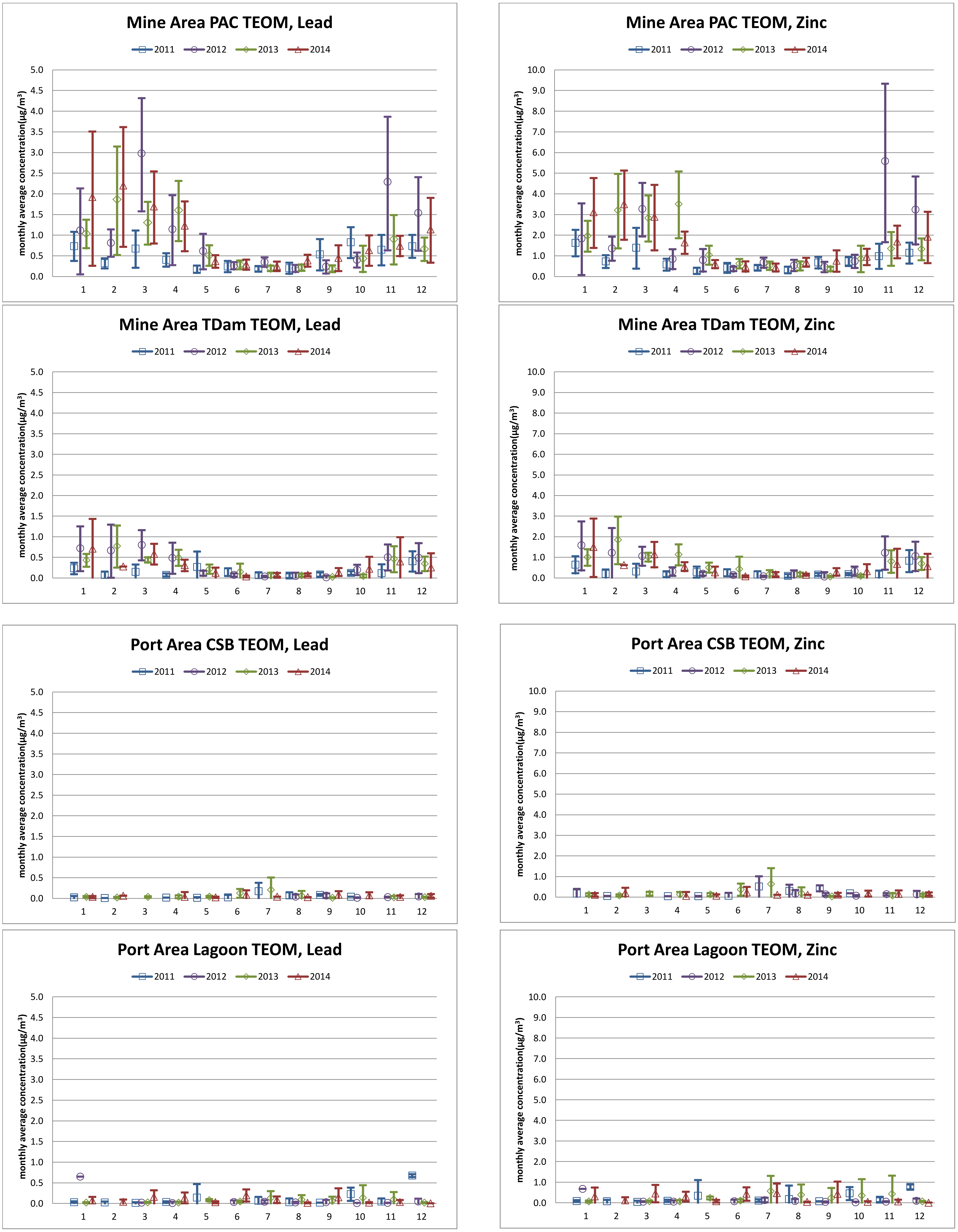


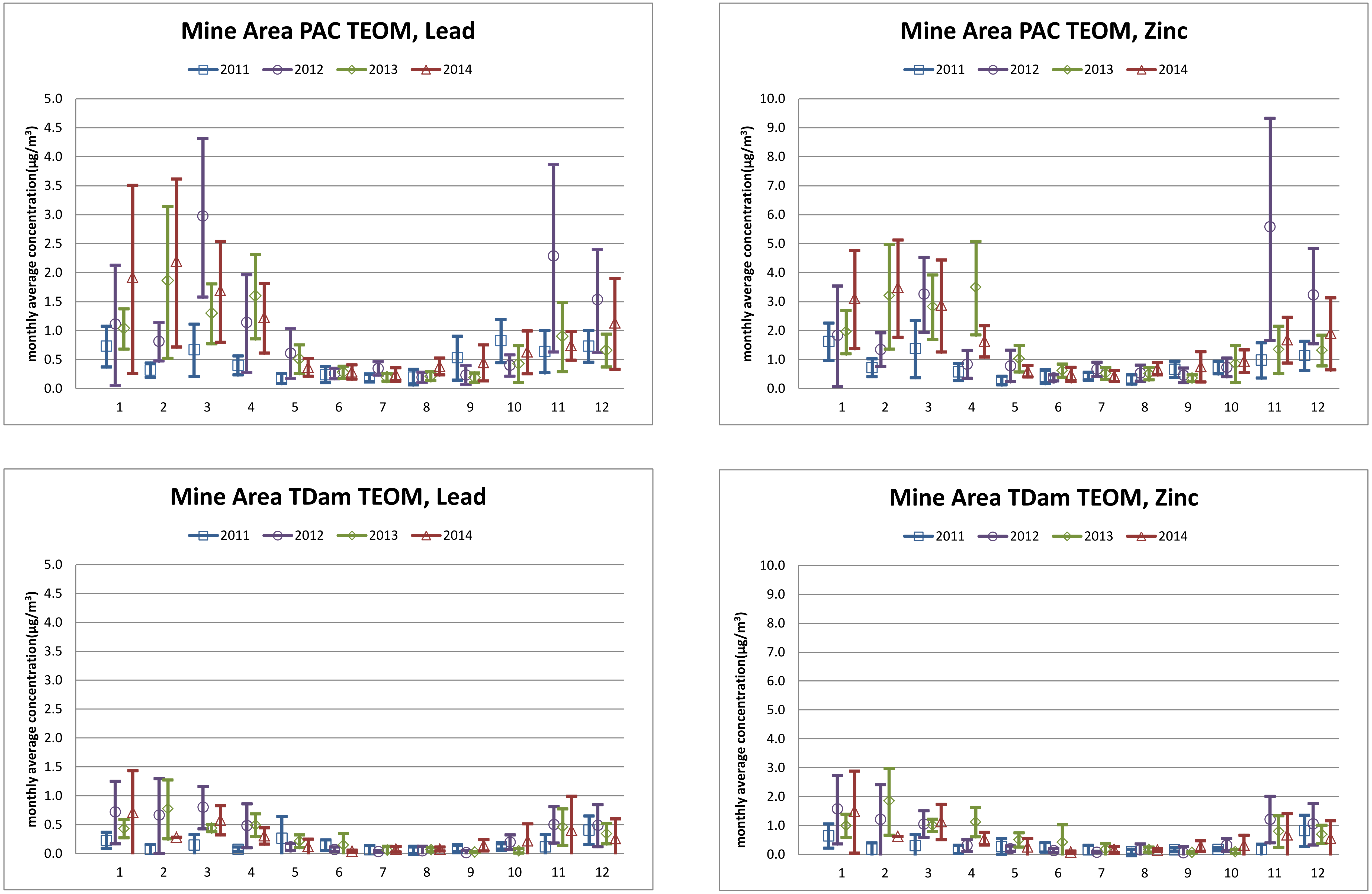
Figure 5. Mine TEOM locations

Figure 6. Port TEOM locations



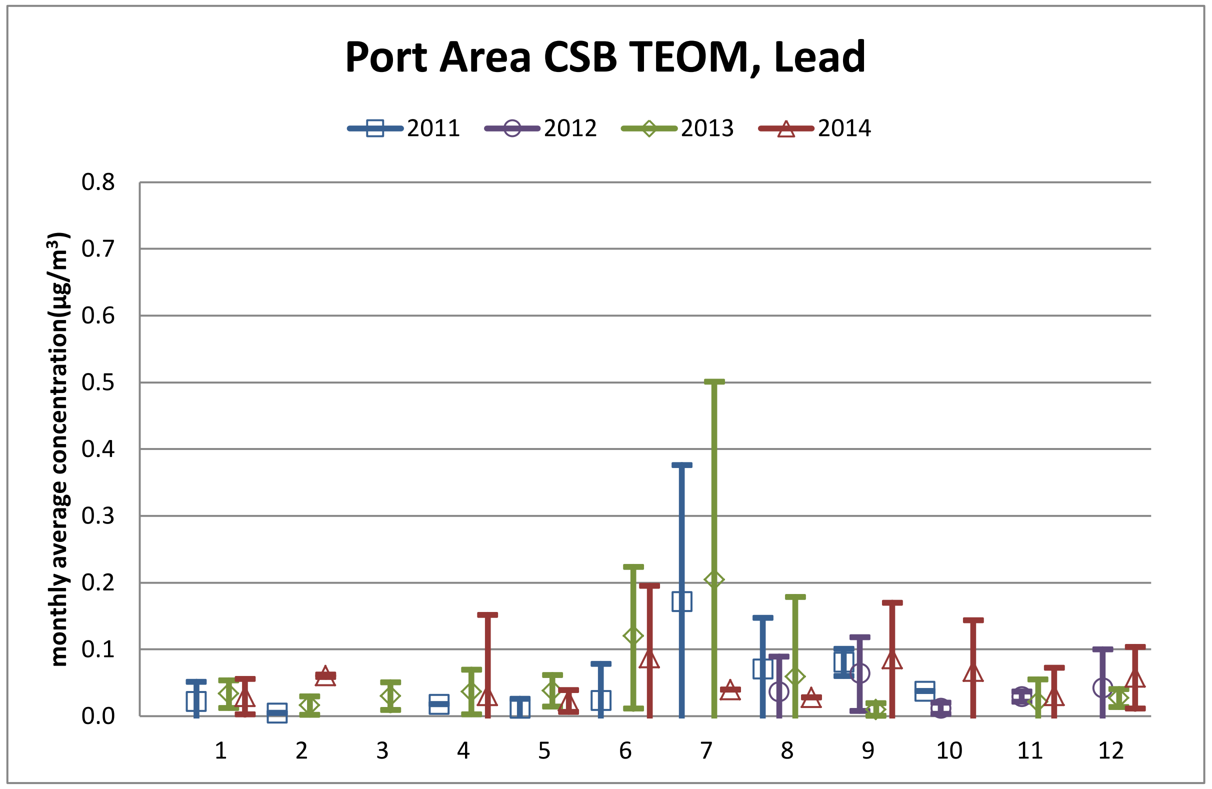
Note: Different vertical axis scales are used for lead and zinc, and for Mine and Port TEOMs.

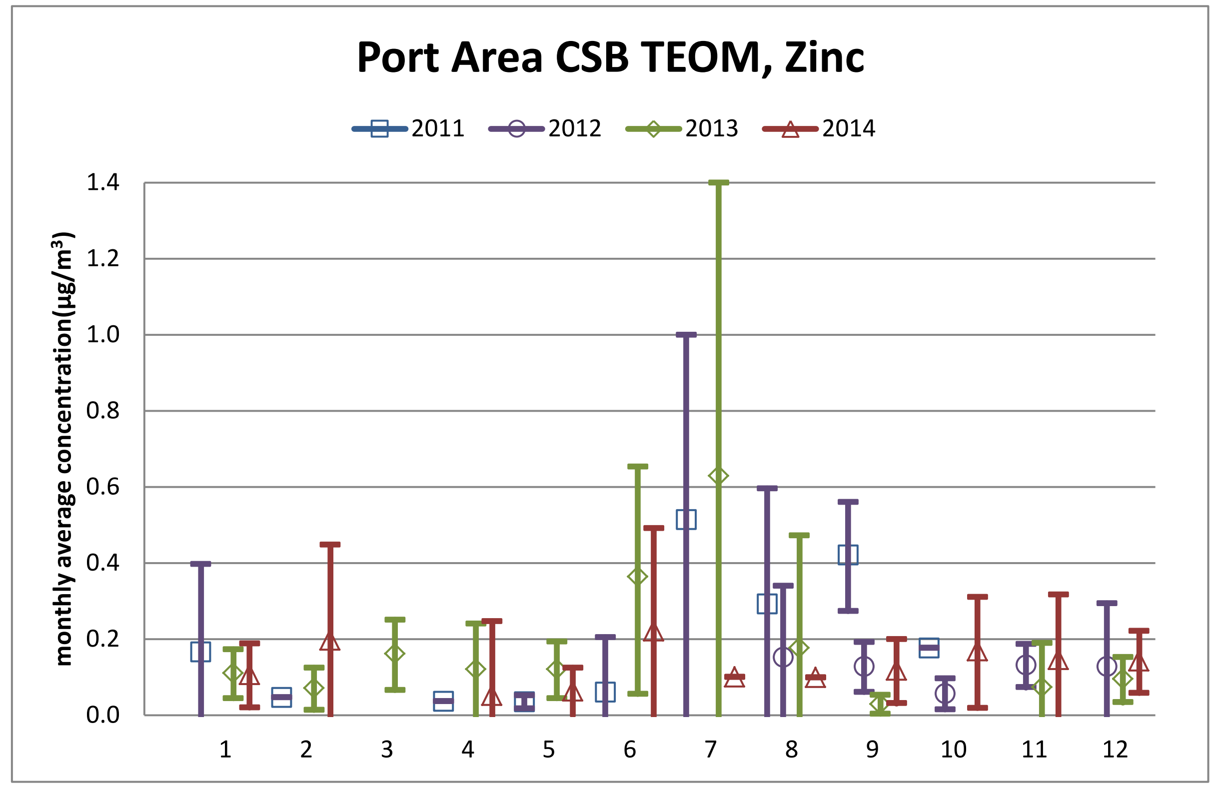
Figure 7a. TEOM monthly monitoring data comparison, 2011-2014

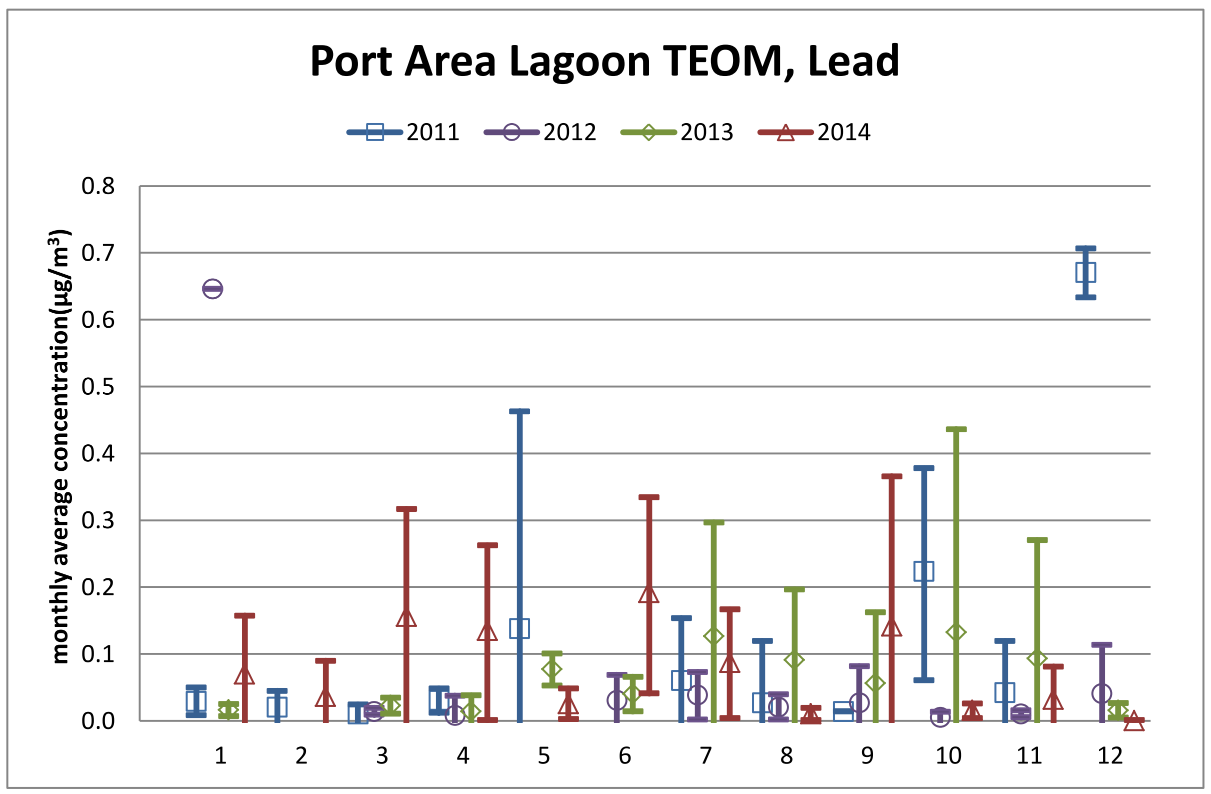


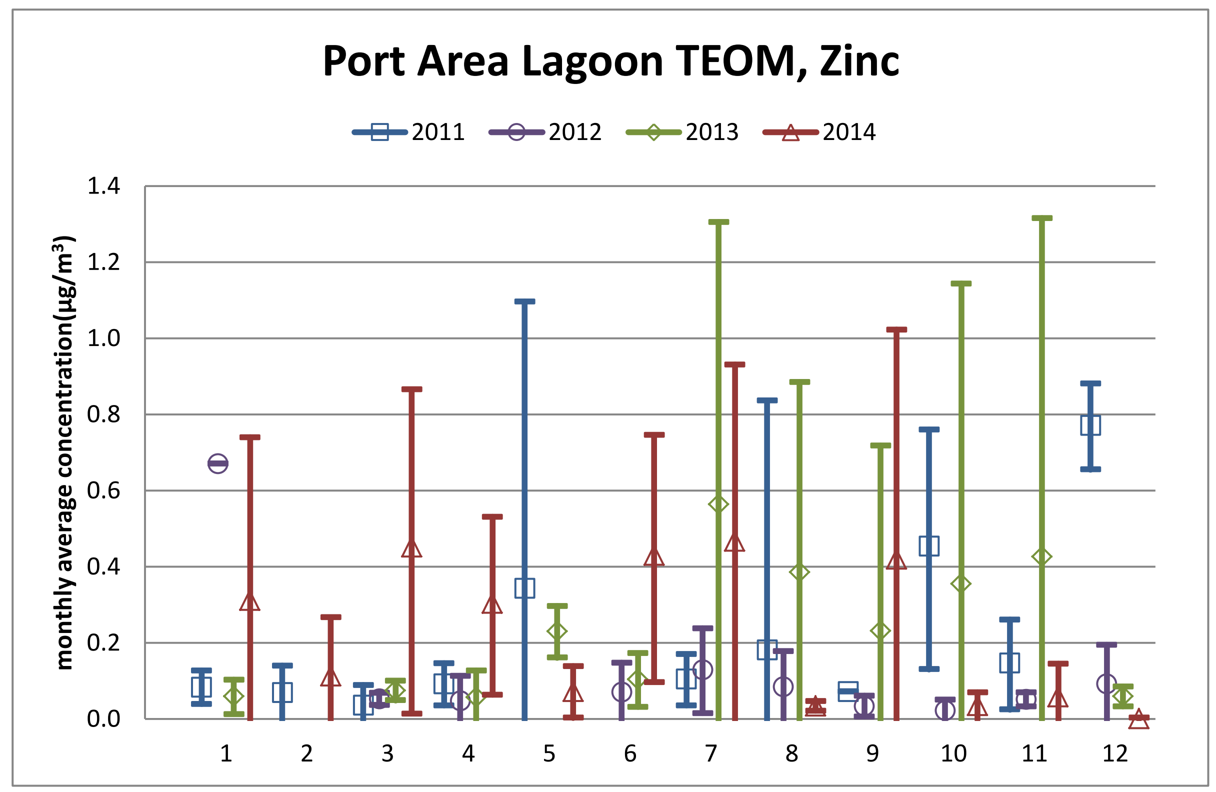
Note: Different vertical axis scales are used for lead and zinc

Figure 7b. Mine area TEOM monthly monitoring data comparison, 2011-2014









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

Figure 7c. Port area TEOM monthly monitoring data comparison, 2011-2014

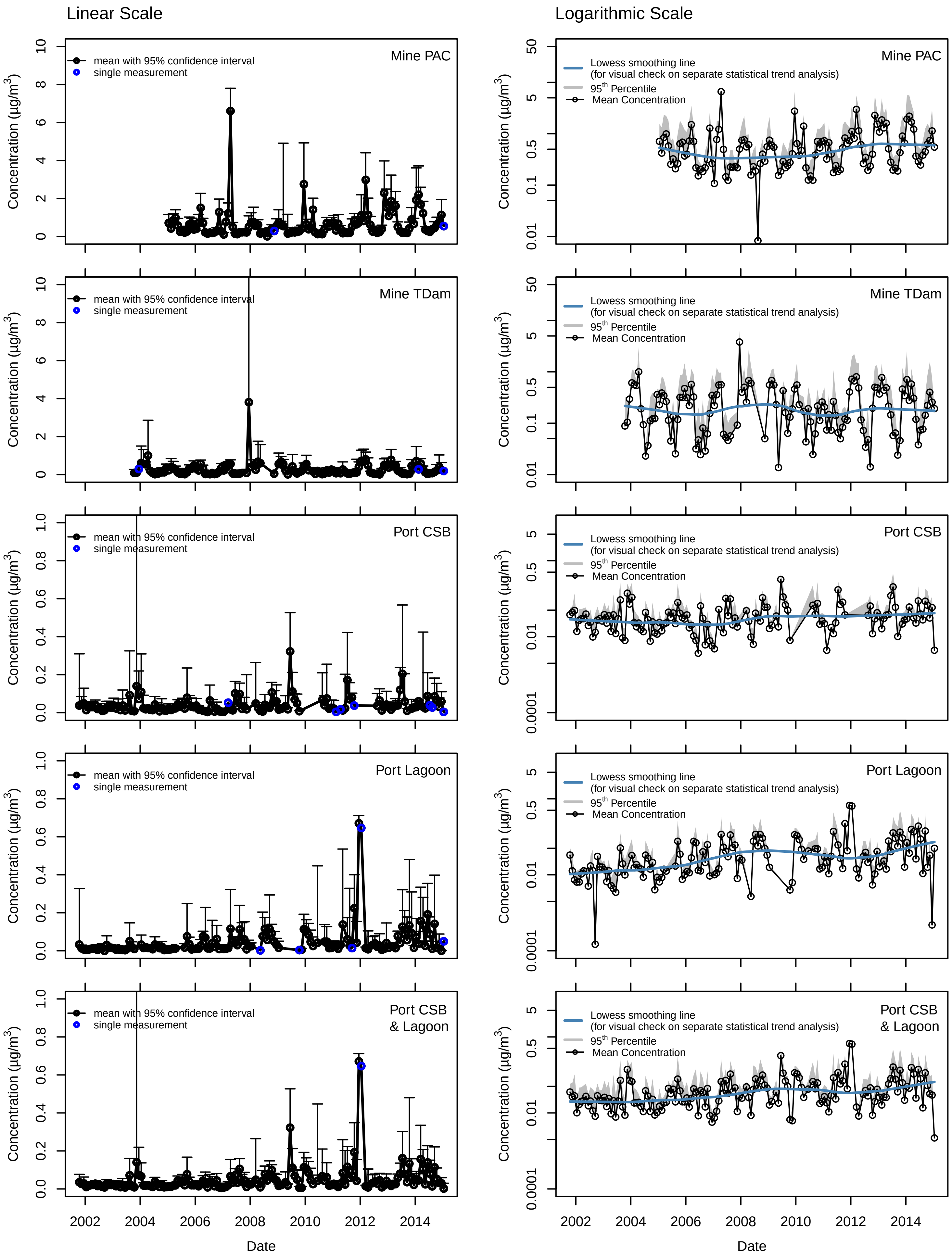


Figure 8. TEOM Lead Concentration plots (all years)

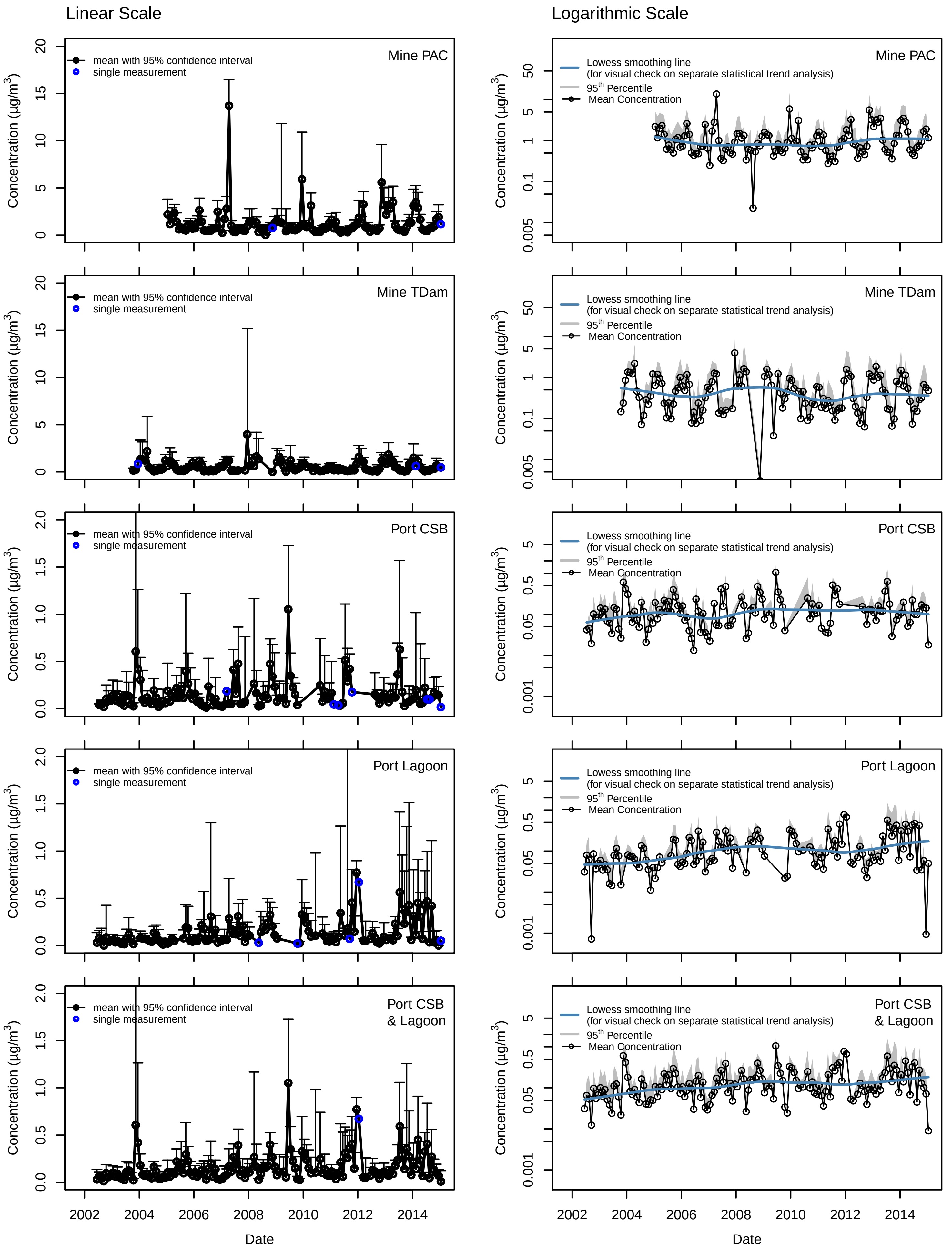


Figure 9. TEOM Zinc Concentration plots (all years)

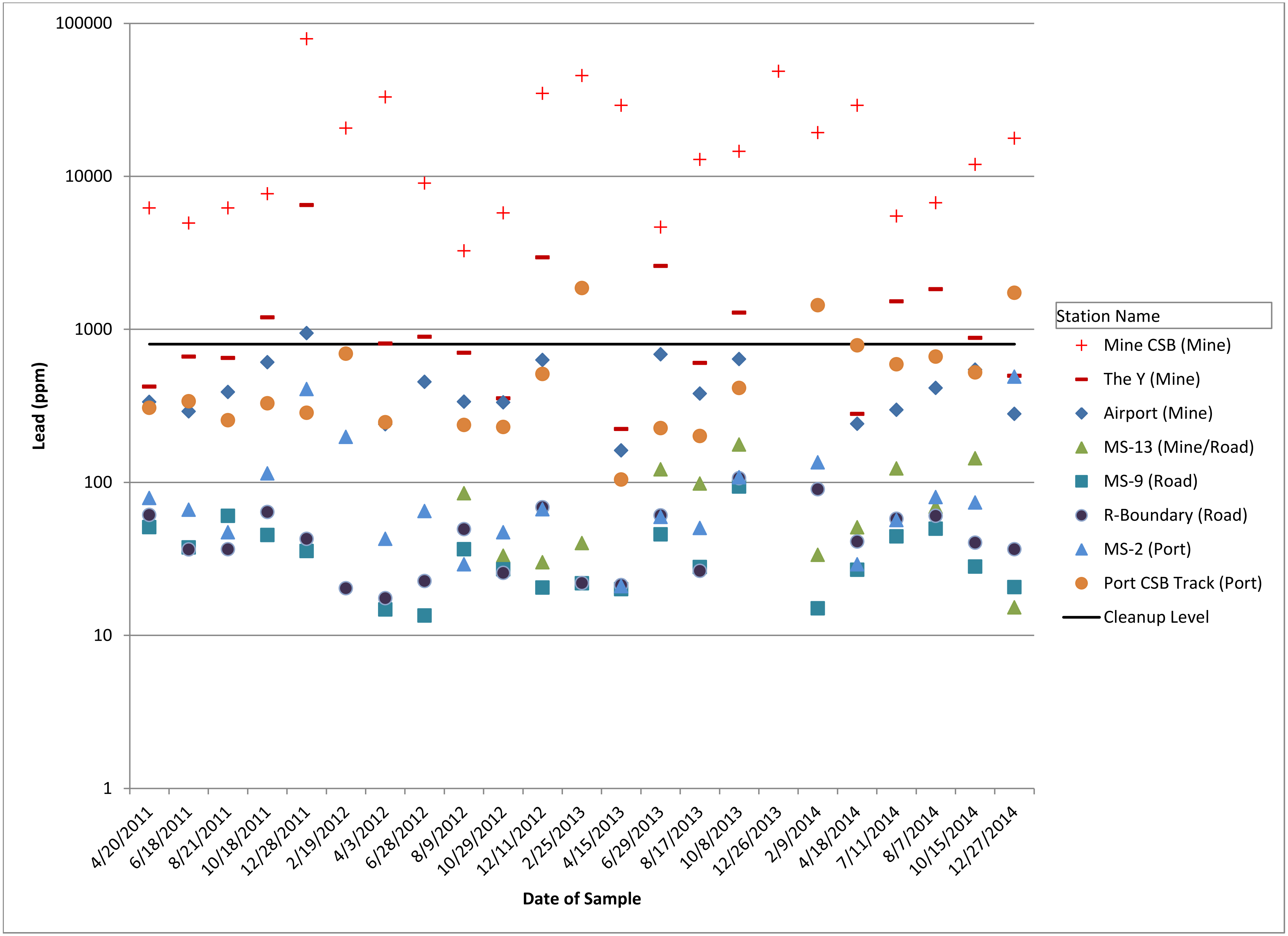


Figure 10. Road surface soil lead monitoring results for 2014 (Arctic Zone Cleanup Level = 800 ppm)

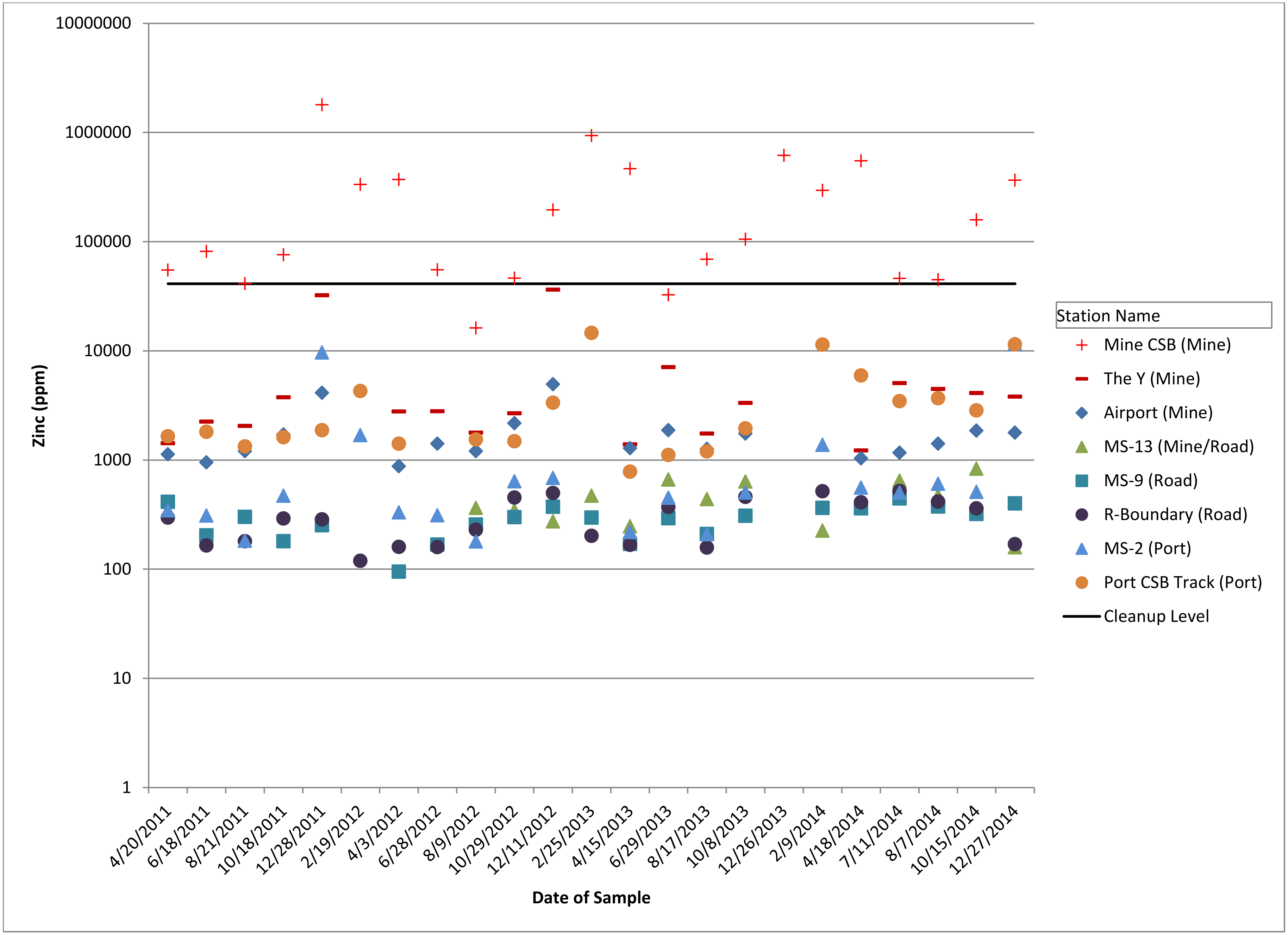


Figure 11. Road surface soil zinc monitoring results for 2014 (Arctic Zone Cleanup Level = 41,100 ppm)

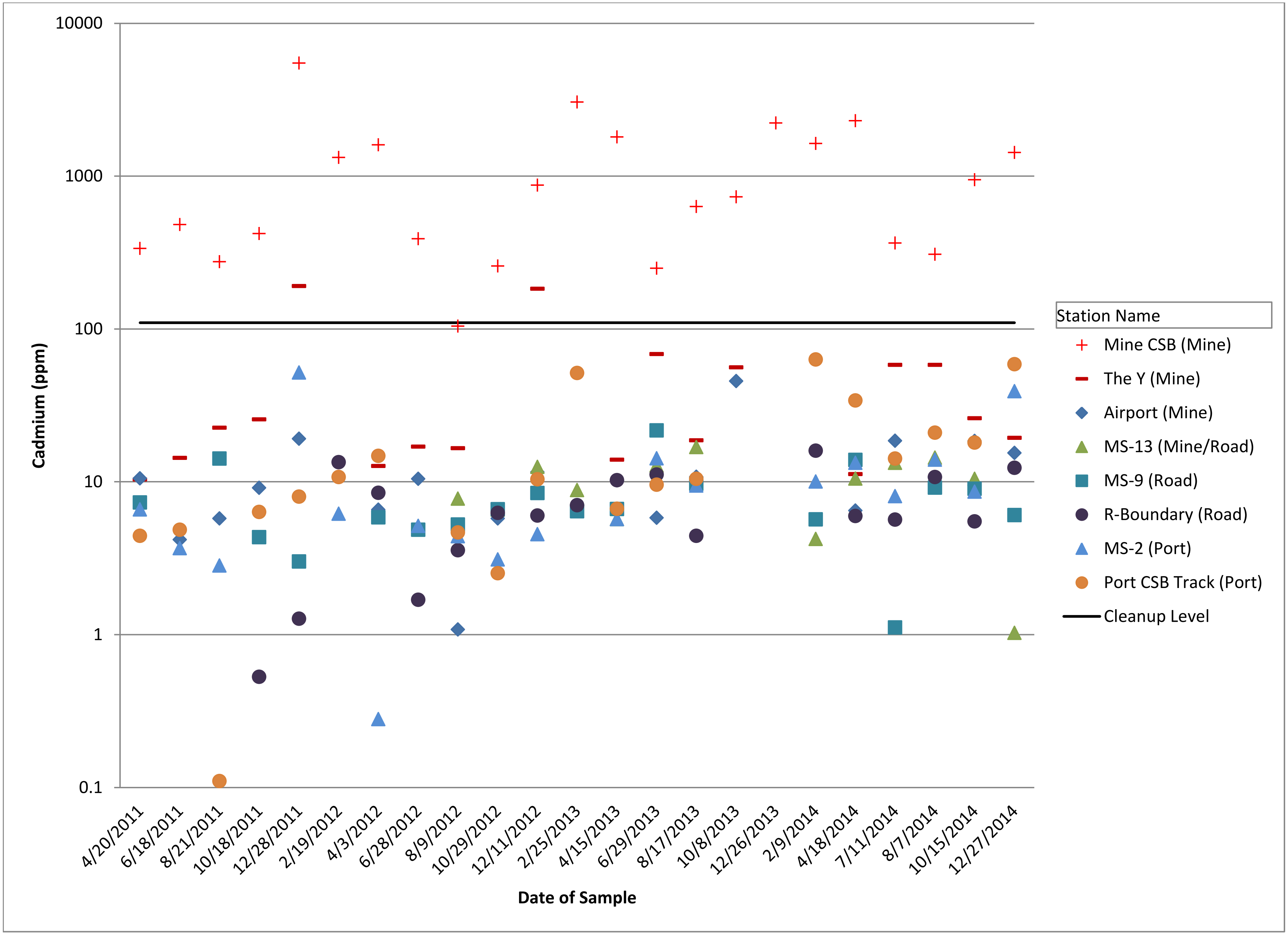


Figure 12. Road surface soil cadmium monitoring results for 2014 (Arctic Zone Cleanup Level = 110 ppm)

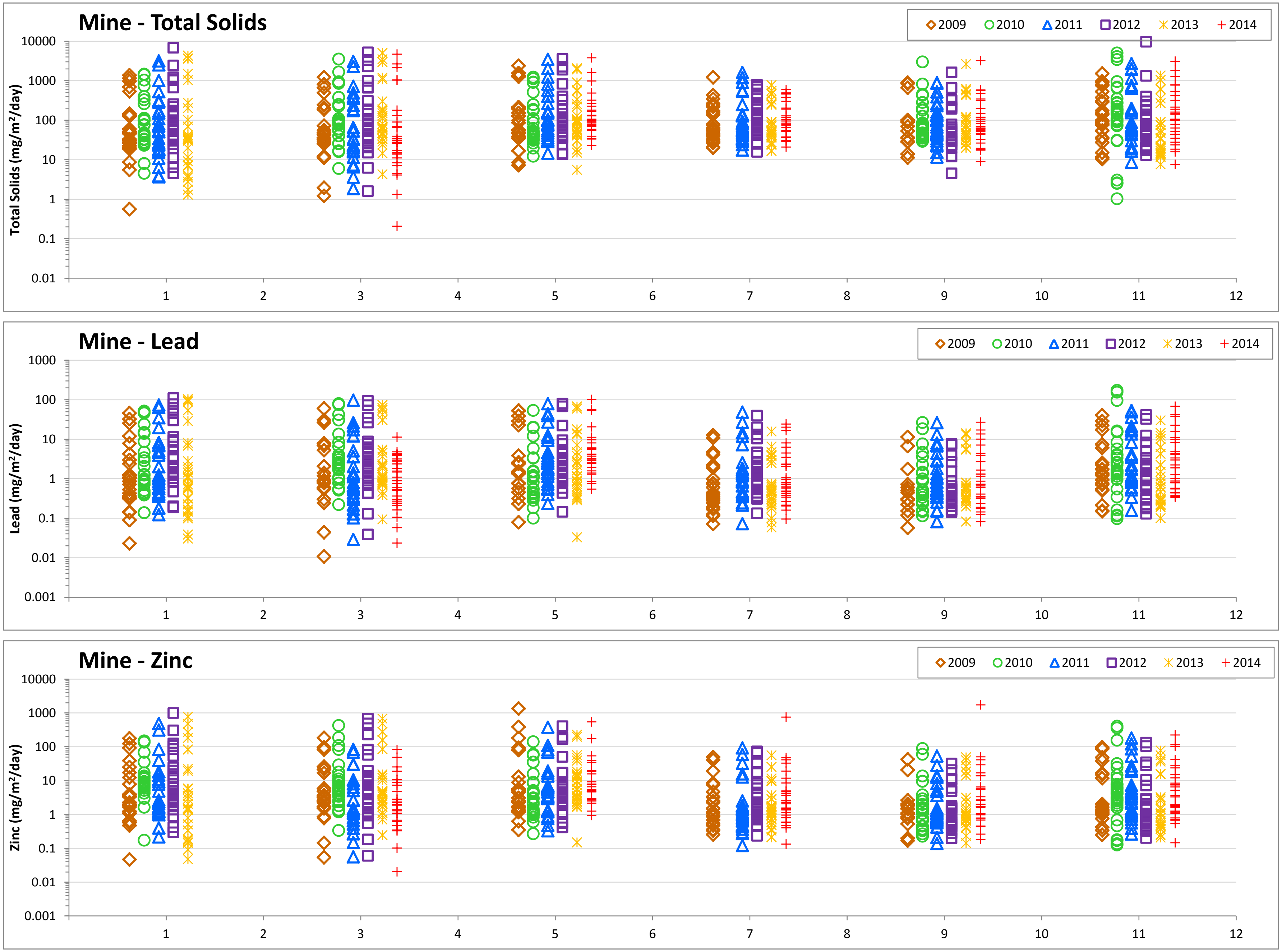


Figure 13. Mine dustfall rate data for total solids, lead, and zinc (2009 - 2014)

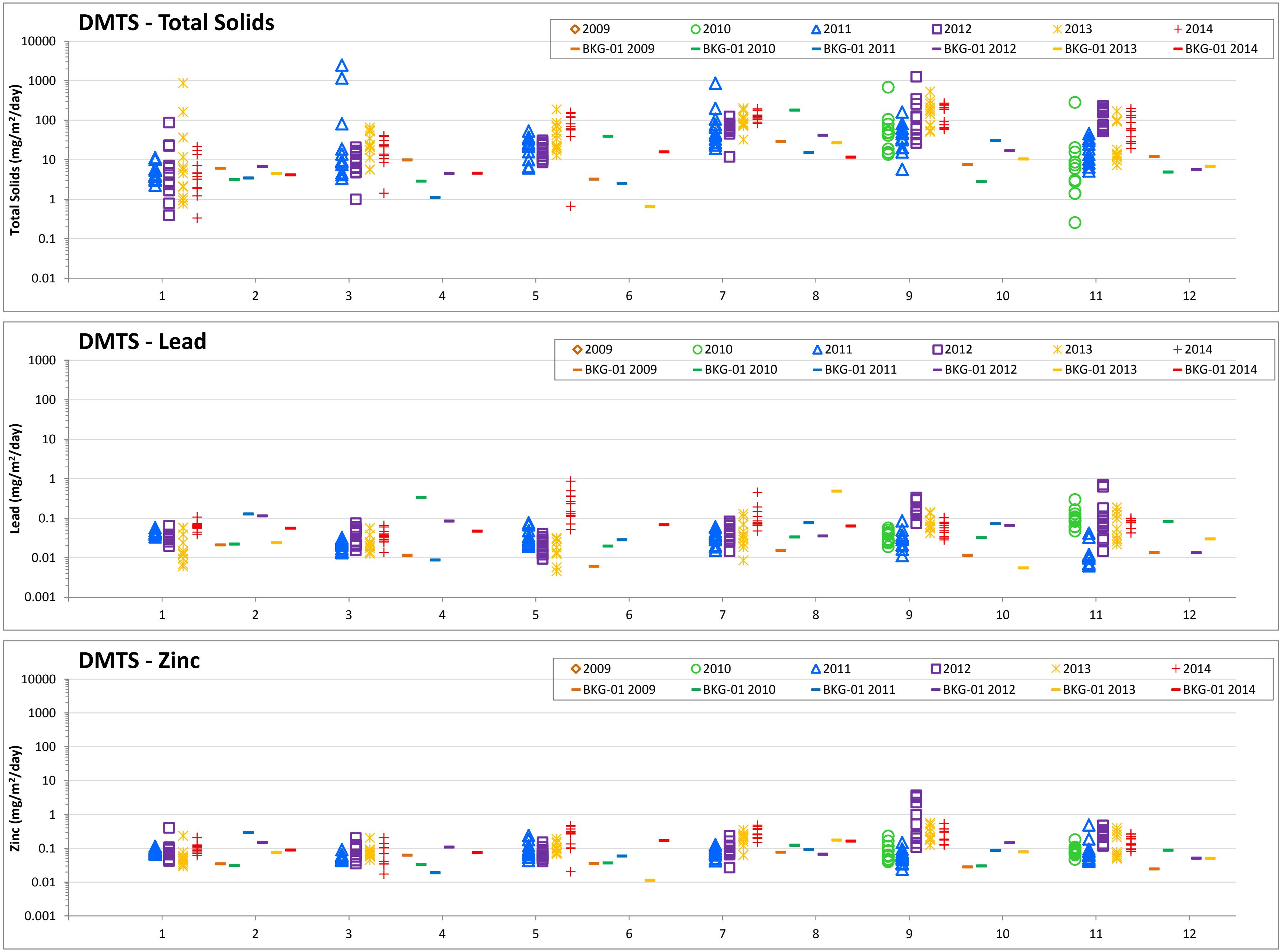


Figure 14. DMTS road dustfall rate data for total solids, lead, and zinc (2010 - 2014)

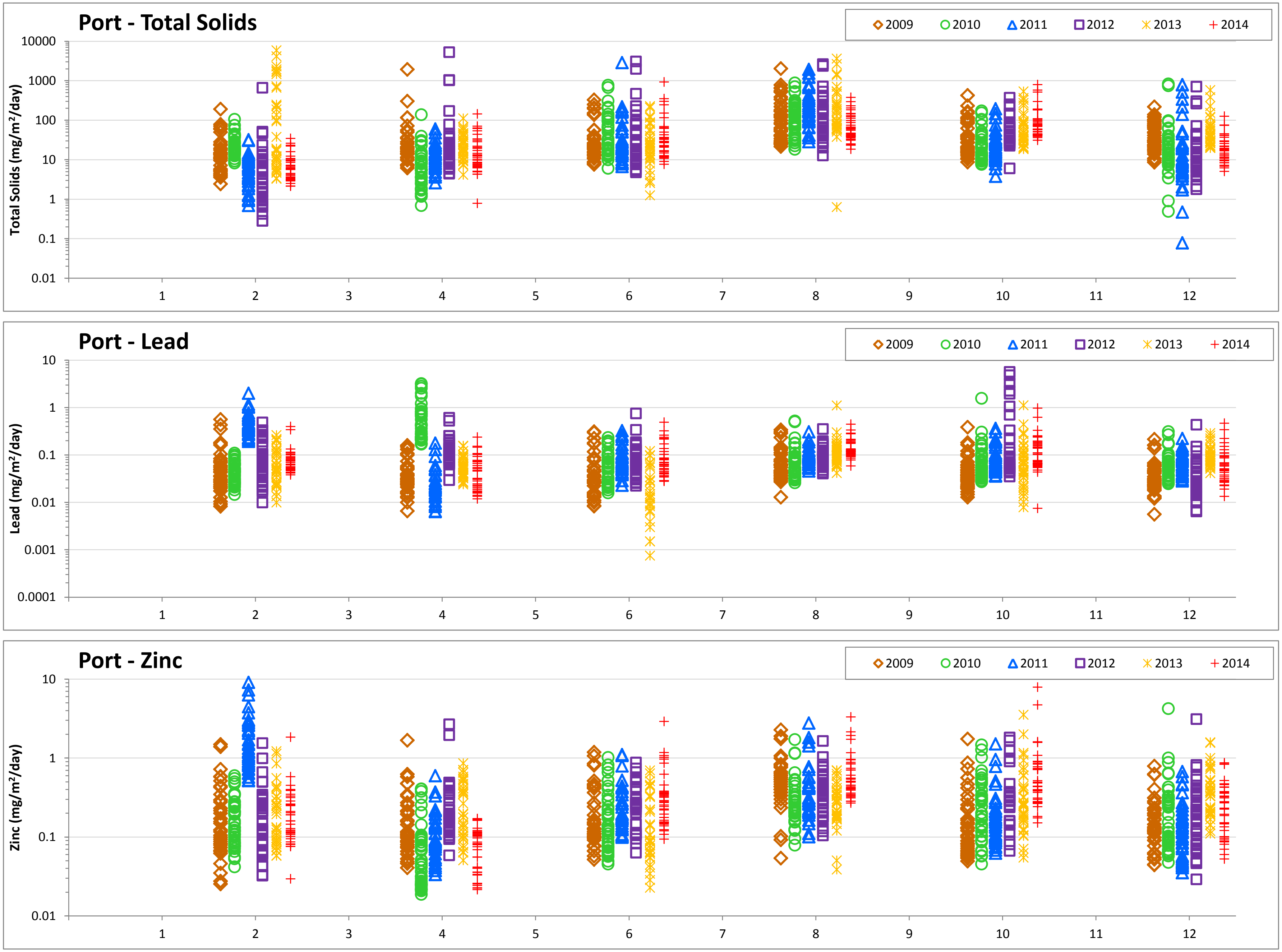


Figure 15. Port dustfall rate data for total solids, lead, and zinc (2009 - 2014)

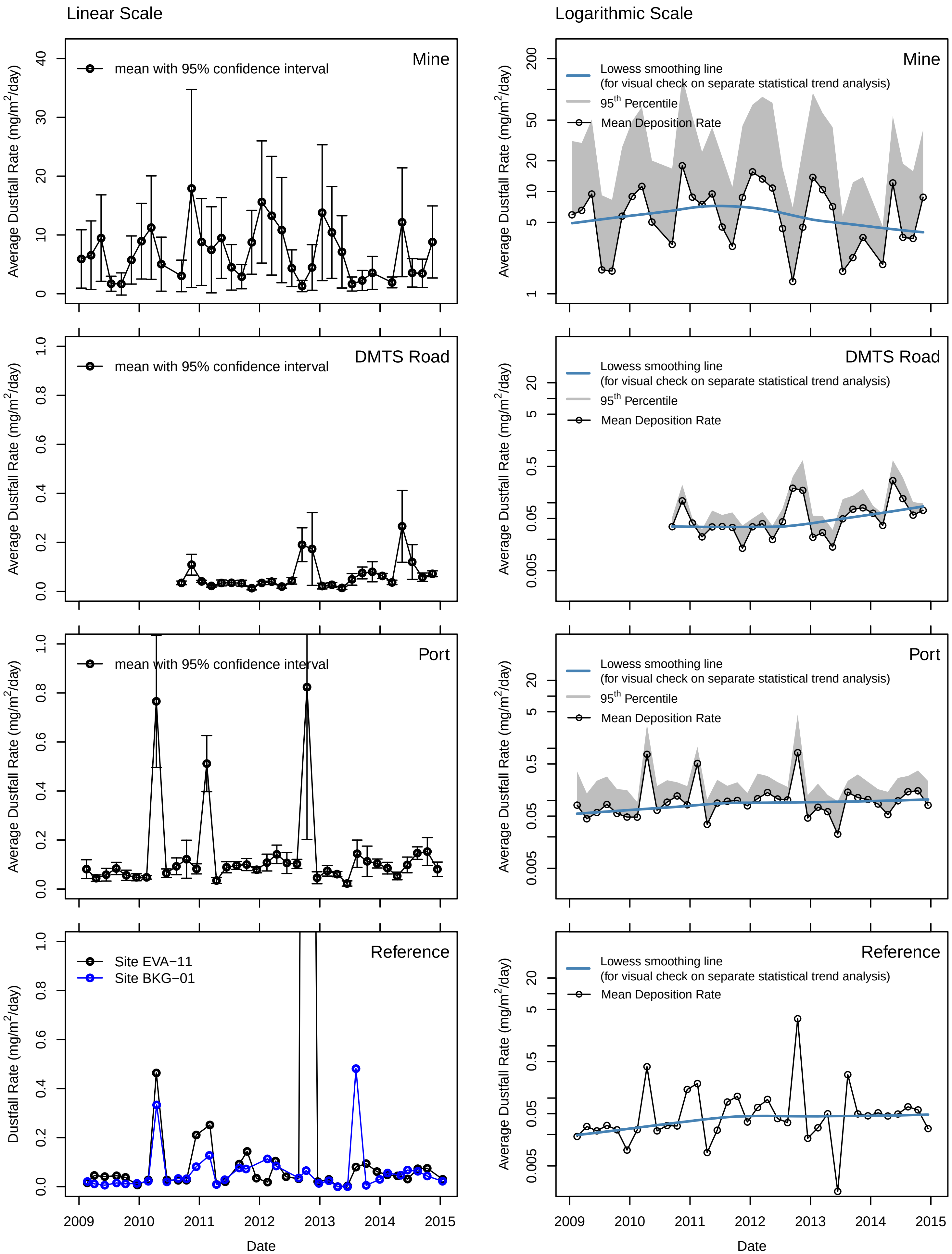


Figure 16. Dustfall Jars Lead Deposition Rate plots (all years)

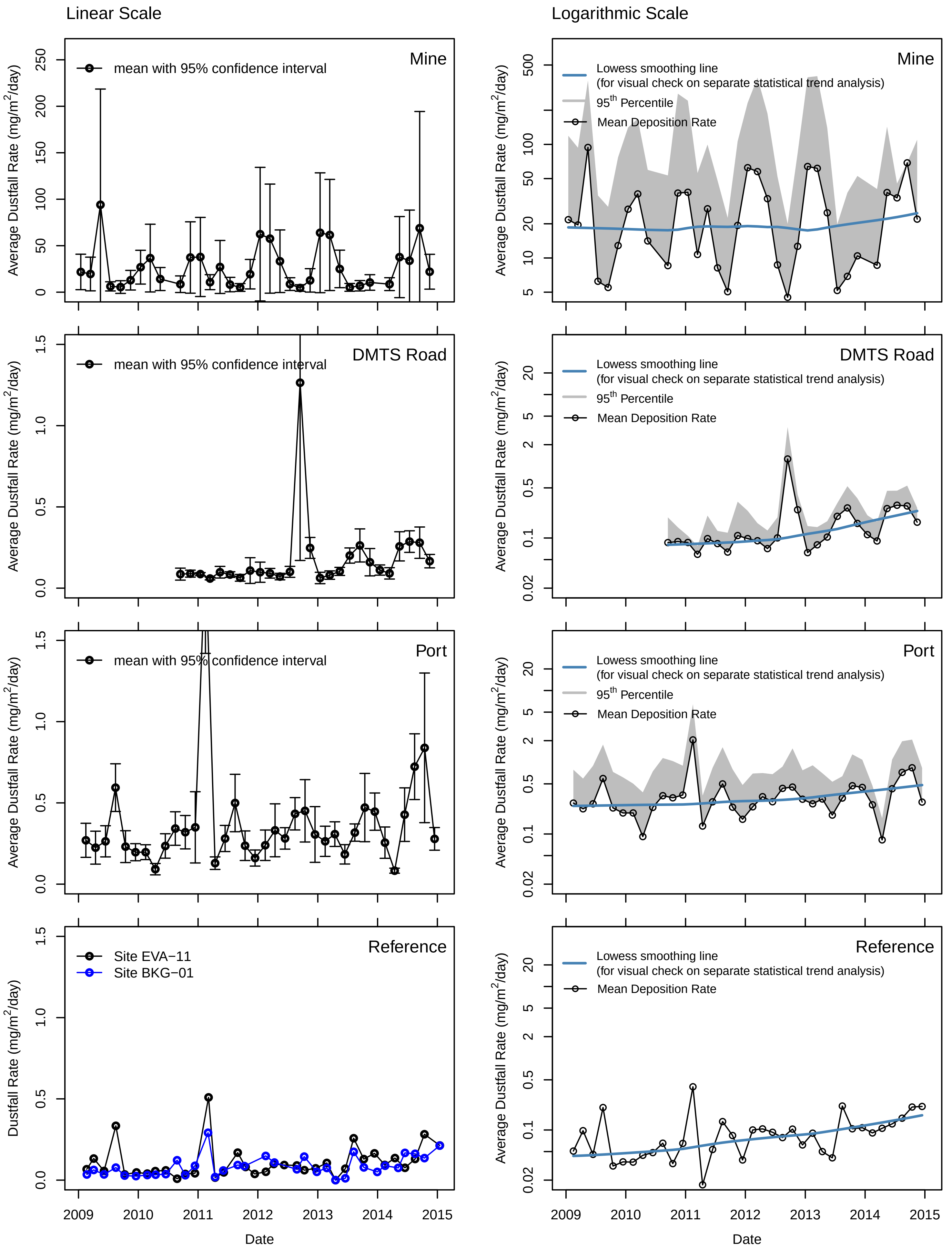


Figure 17. Dustfall Jars Zinc Deposition Rate plots (all years)

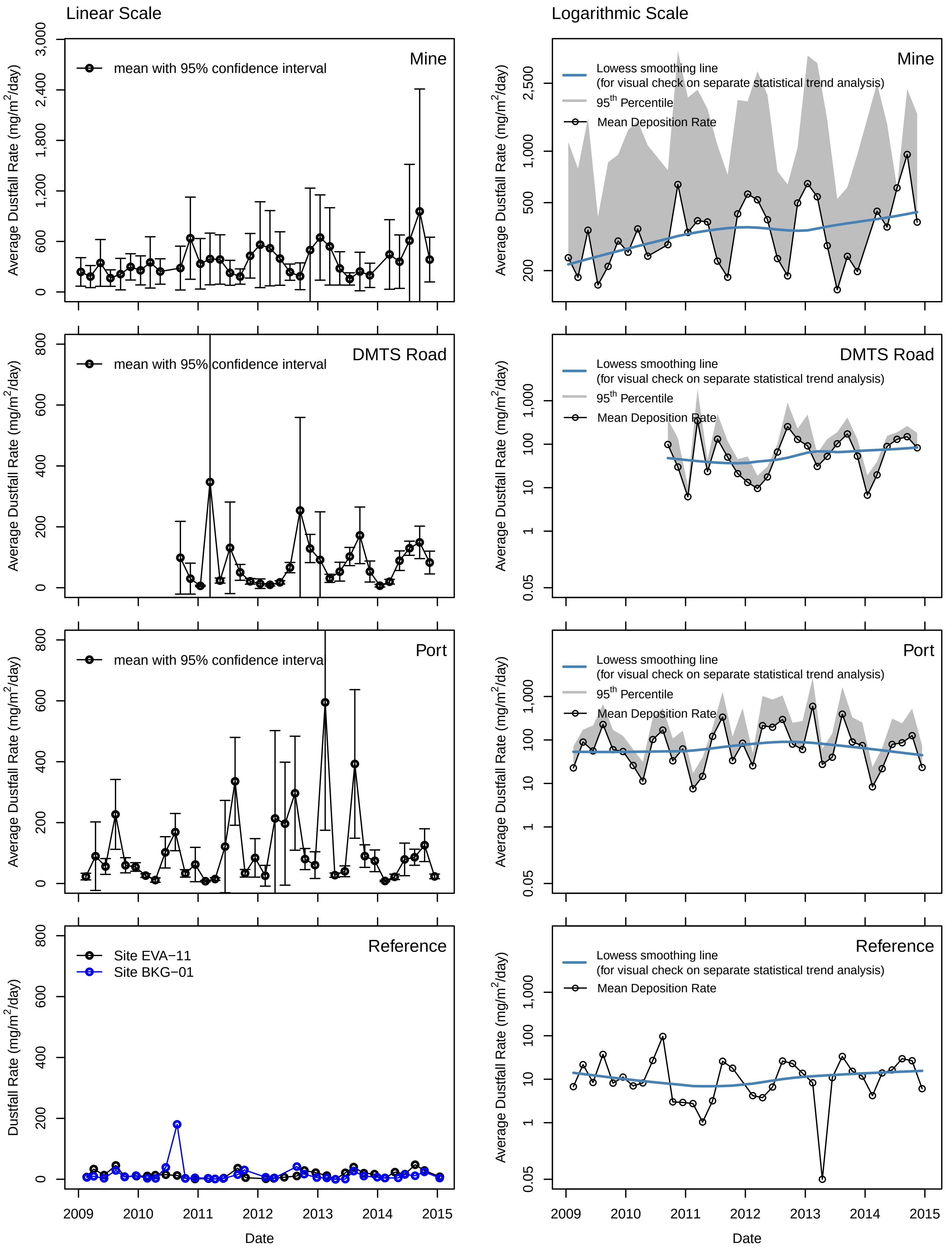


Figure 18. Dustfall Jars Solids Deposition Rate plots (all years)

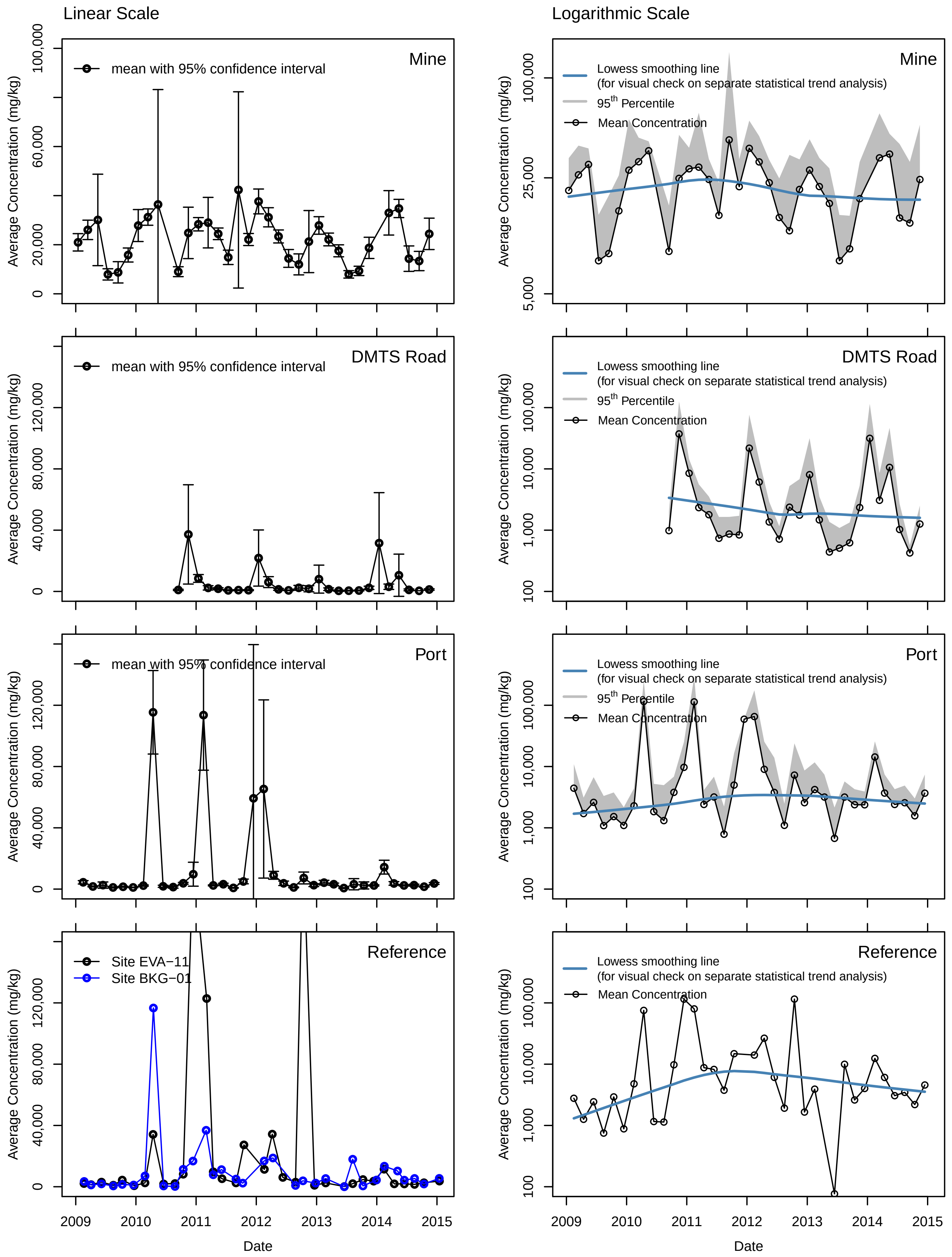


Figure 19. Dustfall Jars Lead Concentration plots (all years)

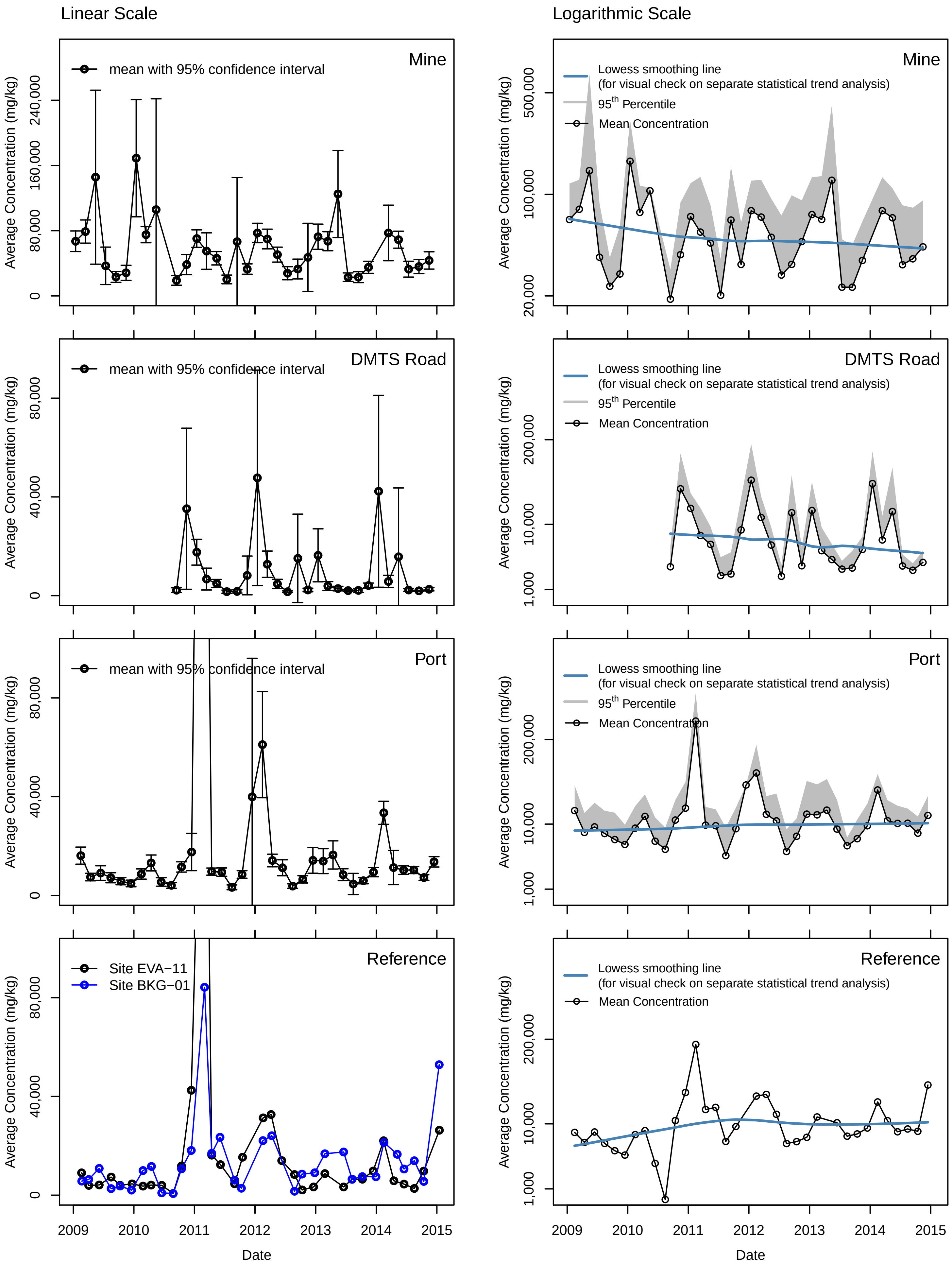


Figure 20. Dustfall Jars Zinc Concentration plots (all years)

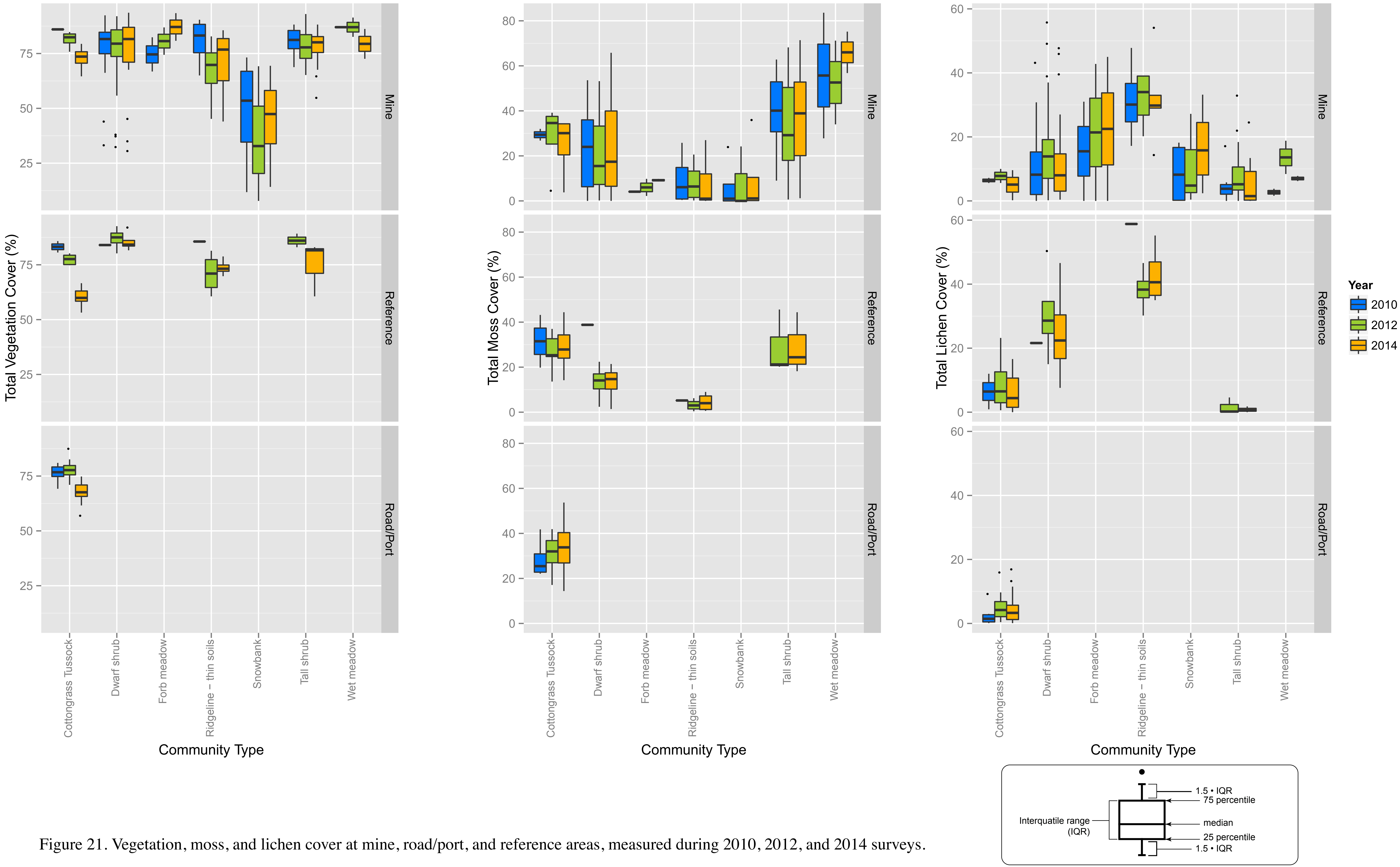


Figure 21. Vegetation, moss, and lichen cover at mine, road/port, and reference areas, measured during 2010, 2012, and 2014 surveys.

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

For 1/2011 - 12/2014; Mean concentration:

LEAD	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	0.361	0.011	yes; increasing
Mine TDam	0.139	0.327	no
Port CSB[b]	0.128	0.481	no
Port Lagoon[c]	0.100	0.516	no
Port CSB & Lagoon	0.061	0.680	no

ZINC	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	0.500	0.000	yes; increasing
Mine TDam	0.167	0.239	no
Port CSB[b]	-0.128	0.481	no
Port Lagoon[c]	0.100	0.516	no
Port CSB & Lagoon	0.121	0.409	no

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

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

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

For 1/2011 - 12/2014; Top 95% concentration:

LEAD	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	0.361	0.011	yes; increasing
Mine TDam	0.167	0.239	no
Port CSB[b]	0.333	0.067	no
Port Lagoon[c]	0.033	0.829	no
Port CSB & Lagoon	0.212	0.149	no

ZINC	Concentration (μg/m^3)		
	tau statistic	p value	significant trend?[a]
Mine PAC	0.417	0.003	yes; increasing
Mine TDam	0.250	0.078	no
Port CSB[b]	-0.077	0.672	no
Port Lagoon[c]	0.133	0.386	no
Port CSB & Lagoon	0.242	0.099	no

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

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

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

Table 2. Dustfall rate and concentration statistical trend analysis (seasonal Mann Kendall trend test)

For 1/2011 - 12/2014; 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	-0.030	0.884	no	-0.152	0.466	no
Road	0.222	0.267	no	0.000	1.000	no
Port	0.167	0.405	no	-0.167	0.405	no
Reference	-0.111	0.579	no	-0.333	0.123	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	0.333	0.109	no	0.394	0.058	no
Road	0.500	0.013	yes; increasing	0.000	1.000	no
Port	0.167	0.405	no	-0.056	0.782	no
Reference	0.389	0.052	no	-0.133	0.537	no

TOTAL SOLIDS	Dustfall Desposition Rate (mg/m^2/day)		
	tau statistic	p value	significant trend?[a]
Mine	0.273	0.189	no
Road	0.167	0.405	no
Port	0.000	1.000	no
Reference	0.455	0.029	no

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

For 1/2011 - 12/2014; 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	0.091	0.662	no	-0.091	0.662	no
Road	0.333	0.096	no	0.000	1.000	no
Port	0.167	0.405	no	-0.222	0.267	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	0.152	0.466	no	0.273	0.189	no
Road	0.389	0.052	no	-0.111	0.579	no
Port	0.056	0.782	no	-0.167	0.405	no

TOTAL SOLIDS	Dustfall Desposition Rate (mg/m^2/day)		
	tau statistic	p value	significant trend?[a]
Mine	-0.212	0.307	no
Road	0.111	0.579	no
Port	0.056	0.782	no

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

Table 3. Summary of dust monitoring trends

For 1/2011 - 12/2014

Location and Measure	TEOM (Air Concentrations)				Location and Measure	Dustfall Jars (concentration and deposition rate)					
	Mean Concentration		95th Percentile			Mean Concentration			95th Percentile		
	Pb	Zn	Pb	Zn		Pb	Zn	Solids	Pb	Zn	Solids
Mine Tdam (Conc.)	—	—	—	—	Mine (Conc.)	—	—	a	—	—	a
Mine PAC (Conc.)	↗	↗	↗	↗	Mine (Rate)	—	—	—	—	—	—
					Road (Conc.)	—	—	a	—	—	a
					Road (Rate)	—	↗	—	—	—	—
Port CSB (Conc.) [b]	—	—	—	—	Port (Conc.)	—	—	a	—	—	a
Port Lagoon (Conc.) [c]	—	—	—	—	Port (Rate)	—	—	—	—	—	—
Port CSB & Lagoon (Conc.)	—	—	—	—	Reference (Conc.)	—	—	a	—	—	a
					Reference (Rate)	—	—	—	—	—	—

[a] Concentration is not evaluated for solids, because total solids is the entire sample mass.
[b] Excluded March data (see text for explanation)
[c] Excluded February data (see text for explanation)

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). Slope is proportional to the strength of the trend.
↘	Indicates a statistically significant decrease over time period tested (trend is DOWN). Slope is proportional to the strength of the trend.

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

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