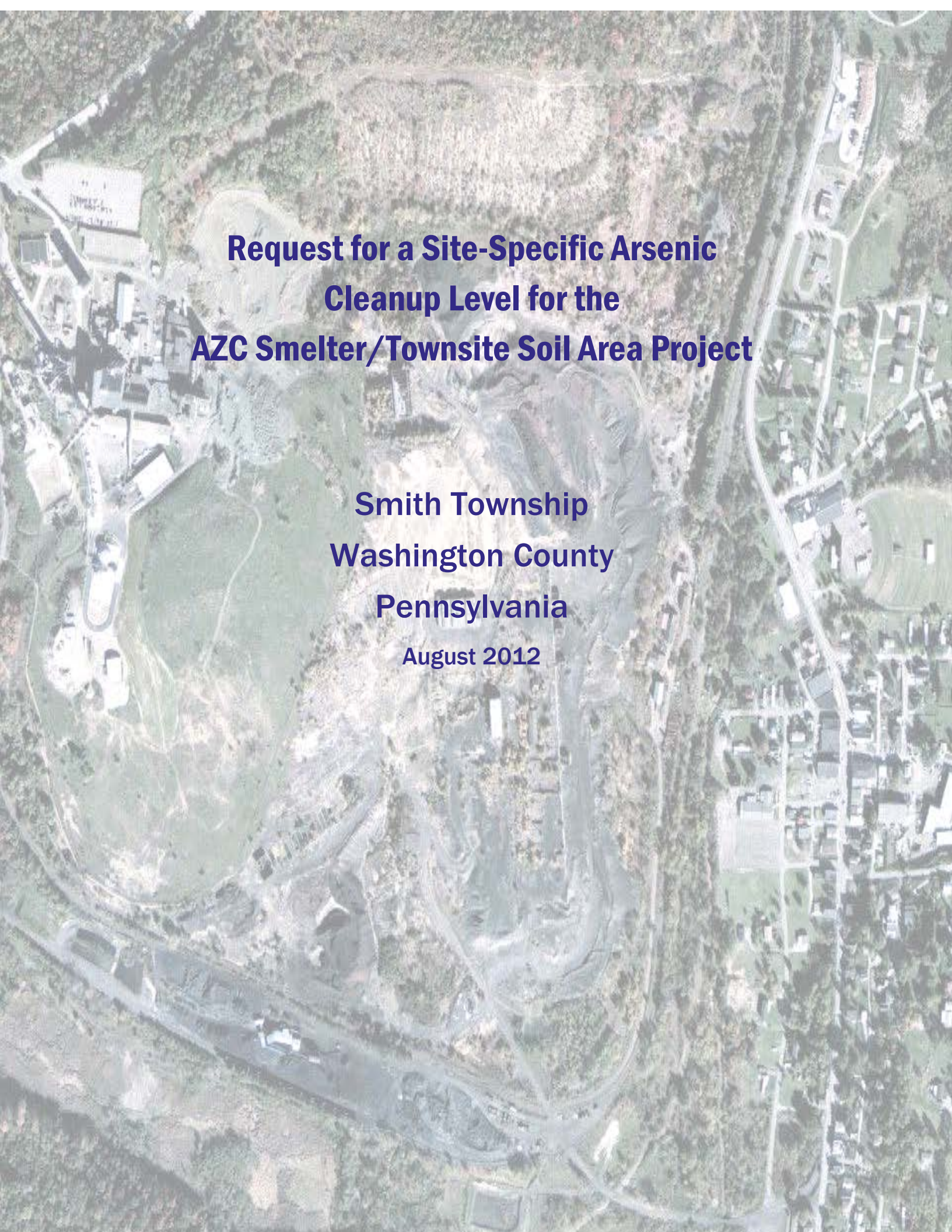

Request for a Site-Specific Arsenic Cleanup Level for the AZC Smelter/Townsite Soil Area Project

Smith Township

Washington County

Pennsylvania

August 2012

Request for a Site-Specific Arsenic Cleanup Level for the AZC Smelter/Townsite Soil Area Project

Prepared for
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August 2012

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List of Abbreviations

µg/L	Micrograms per Liter
ATSDR	Agency for Toxic Substances and Disease Registry
AZC/TSA	Former AZC Smelter Site/Townsite Soil Area
BC	Brown and Caldwell
BCC	Bologna Coal Company
CDI	Chronic Daily Intake
CO&A	Consent Order and Agreement
COC	Chemical of Concern
CSF	Cancer Slope Factor
HI	Hazard Index
HQ	Hazard Quotient
HRA	Health Risk Assessment
LMC	Langeloth Metallurgical Company
mg/kg	Milligram per Kilogram
MSC	Medium-Specific Concentration
PADEP	Pennsylvania Department of Environmental Protection
RfC	Reference Concentration
RfD	Reference Dose
SHS	Statewide Health Standard
TC	Target Constituents
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Section 1
Introduction

This document presents a risk assessment report (RAR) that has been prepared in support of a request for a site-specific remediation standard for arsenic for the AZC Smelter Site/Townsite Soil Area Project (AZC/TSA Project). This report evaluates the potential cumulative health risks associated with selected metals in soil outside of the Former AZC Smelter Site (Smelter Site) boundaries located in Smith Township, Washington County, Pennsylvania. Zinc smelting operations occurred within the Smelter Site from 1914 until 1947, when the smelter was permanently closed. Historical smelter activities resulted in increased levels of metals in surrounding soils, both within the former Smelter Site boundary proper, and potentially in soil outside of that boundary. These off-site areas are now populated by residents and commercial businesses.

The AZC/TSA Project is being performed pursuant to a pending Consent Order and Agreement (CO&A), authorized by the Hazardous Sites Cleanup Act, between Cyprus AMAX Minerals Company and the Pennsylvania Department of Environmental Protection (PADEP). The CO&A limits the scope of the AZC/TSA Project to soil within residential and commercial properties located outside of the Smelter Site boundaries. Impacts to on-site soils, groundwater, and surface water, as well as ecological risks that may be associated with the former smelter operations, are being addressed by a separate project.

The CO&A specifies that arsenic, cadmium, and lead be used as target constituents (TCs) for determining if remediation is performed at a given property within the AZC/TSA Project area. The basis for the selection of these three metals as the TCs is discussed in Section 3.0. Although groundwater is not being addressed by the CO&A, Cyprus has agreed to use the lower of either the Statewide Health Standards (SHS) specified in 25 Pa. Code § 250 Appendix A, Table 4.A (Direct Contact Numeric Values). 4.B (Soil to Groundwater Numeric Values), or an alternative Soil to Groundwater Numeric Value as the remediation standard (hereinafter referred to as Cleanup Levels) for cadmium and lead. The CO&A also specifies that the arsenic Cleanup Level will be the lower of the Table 4.B Soil to Groundwater Numeric Value or a Site-specific Direct Contact Numeric Value that is based on a human health risk assessment (HRA) approved by PADEP. This RAR present the details of the HRA that supports the use of a site-specific Cleanup Level (discussed in Section 4.4) for arsenic.

Although the TCs are limited to arsenic, cadmium, and lead, there are other metals (antimony, copper, and zinc) found within Smelter Site soils that have been identified as being associated with the former Smelter Site operations (Table 2, United States Geological Survey [USGS], 2010). Accordingly, the HRA considers the cumulative risk that may be associated with these metals, as well as the TCs, in evaluating whether the site-specific Cleanup Level for arsenic is protective of human health.

The remainder of this report is organized as follows:

- Background
- Data Used in the Risk Assessment
- Identification of Chemicals of Concern
- Exposure Assessment
- Risk Characterization
- Uncertainty Analysis

Section 2
Background

2.1 Former AZC Smelter Site Description

The Smelter Site is located in Smith Township, Washington County, Pennsylvania. The Smelter Site is bounded on the west by the Langeloth Metallurgical Company (LMC), then the Town of Langeloth, and on the south by undeveloped land owned by the Bologna Coal Company (BCC), including a strip of land formerly used by BCC for coal processing. Also bordering the Smelter Site on the south is property owned by Smith Township, and currently used as a solar panel farm. The eastern boundary is adjacent to a former railroad, then the Town of Slovan. The Smelter Site is bounded on the north by developed and undeveloped property owned by LMC and then the Town of Burgettstown. The Smelter Site property boundary and nearby municipalities are shown in Figure 1.

The Smelter Site consists of approximately 157 contiguous acres, divided into two areas, the Eastern Area and the Western Area. The Eastern Area consists of approximately 120 acres while the Western Area consists of approximately 37 acres. Current property owners of the Eastern Area include the Bologna Coal Company (approximately 84 acres), Peterson Industries (approximately 28 acres), Smith Township (approximately 5 acres) and LMC (approximately 3 acres). The Western Area is owned entirely by LMC.

2.2 Overview of the AZC Smelter Site/Townsite Soil Area Project

The purpose of the AZC/TSA Project is to address TC concentrations that may be elevated due to historical smelter operations within soil located on properties outside of the Smelter Site boundaries that are in either a commercial or residential type of use. Implementation of the AZC/TSA Project will include sampling of each individual use area (e.g. front yard, backyard, driveway, etc.) within a given property at separate depth intervals. Soil within the use area that has TC concentrations above the PADEP-approved Cleanup Levels will be removed and replaced with clean soil. Therefore, exposure point concentrations (EPCs) (the soil concentrations used as the basis for risk calculations or Cleanup Level comparison) for soil within each use area will not exceed the Cleanup Level for each TC.

Section 3

Identification of Chemicals of Concern

All soils data collected within the Smelter Site proper were used as the basis for selection of the TCs and determination of EPCs (Section 4.4) for all metals evaluated within this HRA. These data include 163 soil and smelter waste samples collected from depths ranging from zero to 45 ft bgs (Appendix A, Table A-1). Locations for all the soil samples used in this HRA are shown in Figure 2. Since concentrations of metals would be expected to be highest closest to the smelter, there is no reason to expect more distant metal concentrations within the AZC/TSA Project area to be higher than these concentrations within the Smelter Site; therefore, this set of data was considered to best represent the complete range of possible soil concentrations that may be found in the AZC/TSA Project area. Complete details regarding the sampling and analysis of these soil samples are provided in the remedial investigation prepared for the Smelter Site proper (Brown and Caldwell, 2011a).

As indicated previously, the CO&A specifies arsenic, cadmium, and lead as TCs for determining if remediation will be performed within a given use area on a property located within the AZC/TSA Project area. As indicated in Section 1.0, these three metals have been identified as being associated with the historical operations at the Smelter Site and were found to have persistent exceedances of the lower of the PADEP SHS Direct Contact Numeric Value or the Soil to Groundwater Numeric Value in samples from the former Smelter Site proper. In addition, concentrations of antimony, copper, and zinc (the other metals that have been identified as being associated with the historical Smelter Site operations) only exceed the SHSs in the presence of a TC which also exceeds the Cleanup Level.

Notwithstanding the basis for using arsenic, cadmium, and lead as TCs, this RAR will consider all of the foregoing metals as COCs in this HRA.

Section 4
Exposure Assessment

The objectives of the Exposure Assessment section of an HRA are to: 1) identify the relevant receptor (potentially exposed) population groups, 2) identify relevant exposure pathways for each of those receptor populations, 3) present a risk assessment conceptual site model, 4) calculate EPCs (which serve as the basis for the exposure and risk calculations), and 5) calculate chemical exposure levels, typically referred to as Chronic Daily Intakes or CDIs for the ingestion route of exposure (USEPA, 1989), and air concentrations for the inhalation route. Each of these are described in detail below.

4.1 Relevant Receptor Populations

Both residential and commercial types of land use are present in the AZC/TSA Project area; therefore, health risks were calculated for both residential and commercial worker (nonresidential) receptor populations.

4.2 Relevant Exposure Pathways

PADEP risk assessment regulations state that when a health risk assessment is prepared under the site-specific standard the exposure assessment must consider "ingestion, inhalation, and volatilization pathways" (§250.602 Risk Assessment Procedures). None of the COCs included in this HRA are volatile. In addition, groundwater is not being addressed by the AZC/TSA Project per the pending CO&A, therefore, the relevant exposure pathways are soil ingestion and inhalation of outdoor air (i.e. inhalation of resuspended soil particulates).

4.3 Conceptual Site Model

Figure 3 presents a conceptual site model graphically summarizing the relationships between the primary (or original) potential source of elevated soil COC concentrations within the AZC/TSA Project area, current and future release mechanisms within the AZC/TSA Project area, secondary sources, exposure pathways, and receptor populations. Figure 3 shows that the primary potential source of elevated soil COC concentrations within the AZC/TSA Project area is historical smelting activities. The primary on-going release mechanism within the AZC/TSA Project area is wind erosion of surface soils resulting in resuspension of metal particulates, and subsequent inhalation. The other exposure pathway is incidental ingestion of soil within the AZC/TSA Project use areas. Both inhalation and incidental soil ingestion pathways are applicable to off-site residents and commercial workers at individual properties within the AZC/TSA Project area.

4.4 Development of Exposure Point Concentrations

A request for site-specific arsenic Cleanup Levels for residential and commercial use of 37 mg/kg and 166 mg/kg, respectively, was previously submitted to PADEP (Brown and Caldwell, 2011b). These Cleanup Levels were calculated using all standard PADEP exposure assumptions except that a bioavailability of 0.32 was used instead of the PADEP default value of 1.0. The bioavailability of 0.32 was based on a correlation between *in vivo* bioavailability studies reported in the literature and site-specific metals speciation performed on samples from the Smelter Site. Key excerpts from the 2011 submittal are included in Appendix B. In discussions following the 2011 submittal, PADEP requested

that a bioavailability of 0.5 be used for assessing the potential human health risk associated with soil arsenic concentrations. Given the foregoing, the HRA used site-specific residential and non-residential Cleanup Levels of 37 and 166 mg/kg, respectively as EPCs for arsenic. However, the calculation of exposure levels (Section 4.5) for arsenic was based on a bioavailability of 0.5.

With respect to cadmium, the PADEP Direct Contact Numeric Value of 110 mg/kg was used as the EPC for residential use, and 1,400 mg/kg for commercial use. As indicated previously, the CO&A allows Cyprus the option, but not the obligation, to develop an alternate Soil to Groundwater Numeric Value for cadmium. Cyprus has not yet determined whether an alternate Soil to Groundwater Numeric Value will be pursued and it is currently unknown whether an alternate Soil to Groundwater Numeric Value would be higher than the Direct Contact Numeric Value. To be conservative in evaluating cumulative risk, as part of demonstrating that the proposed site-specific arsenic Cleanup Level is protective, the PADEP Direct Contact Numeric Value was used as the EPC for cadmium.

Use of the Cleanup Levels as EPCs for arsenic and cadmium is based on the assumption that soil having a concentration above the Cleanup Level within a given use area will be removed and replaced with soil that has metal concentrations which meet the requirements for clean fill specified in PADEP's Management of Fill Policy Document No. 258-2182-773.

EPCs for antimony, copper, and zinc, were calculated using the USEPA statistical software *ProUCL* (USEPA, 2010) using all 163 on-site soil samples described previously and included in Appendix A.

4.5 Calculation of Exposure Levels

Levels of exposure to COCs were calculated for each exposure pathway using the appropriate equations and exposure assumptions from the PADEP risk assessment regulations, specifically, §250.306 Ingestion Numeric Values, for the soil ingestion pathway and §250.307 Inhalation Numeric Values, for the inhalation pathway. Note that different equations are used for purposes of cancer and non-cancer risk estimation. Equations from those sections were rearranged to solve for the CDI (for the ingestion route) or the air concentration (for the inhalation route). These equations are shown below. Exposure assumptions for the equations for resident and commercial worker receptors are summarized in Table 1.

Soil Ingestion CDI Calculation for Non-cancer Risk

The CDI for soil ingestion (non-cancer risk) was calculated as follows:

$$CDI_{ing/nc} = \frac{C_{soil} \ x \ ABS \ x \ EF \ x \ ED \ x \ IngR \ x \ CF_{ing}}{BW \ x \ AT_{nc} \ x \ 365}$$

Where:

$CDI_{ing/nc}$	=	Chronic Daily Intake for incidental soil ingestion (mg/kg/day)
C_{soil}	=	concentration of COC in soil (mg/kg)
ABS	=	gastrointestinal absorption efficiency (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
IngR	=	rate of incidental soil ingestion (mg/day)

CF_{ing}	=	unit conversion factor (1E-06 kg/mg)
BW	=	body weight (kg)
AT_{nc}	=	averaging time (days)
365	=	days per year

Soil Ingestion CDI Calculation for Cancer Risk

The CDI for soil ingestion (cancer risk) was calculated as follows:

$$CDI_{ing/c} = \frac{C_{soil} \ x \ ABS \ x \ EF \ x \ IF_{adj} \ x \ CF_{ing}}{AT_c \ x \ 365}$$

Where all terms are defined as for non-cancer risk except AT_c is the averaging time for cancer risk calculation and IF_{adj} is the ingestion factor in units of mg-year/kg-day.

Calculation of Inhalation Exposure Levels

Unlike for the ingestion exposure route, and per the PADEP risk guidance, a CDI is not calculated for inhalation non-cancer and cancer risk estimation. Instead, the inhalation route health risks are calculated based on the air concentration corresponding to the soil EPC. In the case of non-cancer risk estimation this air concentration is calculated as follows:

$$Conc_{air/nc} = \frac{C_{soil} \ x \ ET \ x \ EF \ x \ ED}{AT_{nc} \ x \ 365 \ x \ 24 \ x \ TF}$$

Where all parameters are as defined previously except ET is the exposure time (hours/day), TF is the transport factor (m^3/kg) and 24 is hours/day. The TF is used to convert the COC soil concentration to an air concentration. It is not chemical-specific.

For inhalation cancer risk the air concentration is calculated as follows (per PADEP risk guidance):

$$Conc_{air/c} = \frac{C_{soil}}{TF}$$

The resulting air concentrations for non-cancer and cancer risk are used along with the appropriate inhalation toxicity criteria to calculate inhalation health risks. This is shown in detail in the Risk Characterization section (Section 6.0).

Section 5

Toxicity Assessment

The purpose of the Toxicity Assessment section of a HRA is to assemble the toxicity criteria used to convert COC exposure levels to cancer and non-cancer risk estimates. For ingestion routes of exposure the relevant toxicity criteria include the oral Reference Dose (RfD) for non-cancer risk estimation, and the oral route cancer slope factor (CSF) for estimating cancer risks. For inhalation routes of exposure the relevant toxicity criteria include the Reference Concentration (RfC) for non-cancer risk estimation, and the inhalation unit risk (IUR) for cancer risk estimation. Toxicity criteria for each of the COCs were obtained from the PADEP risk regulations (Chapter 250 of the Pennsylvania Code, Appendix A, Table 5 – Physical and Toxicological Properties. B. Inorganic Regulated Substances) and are summarized in Table 2. Note that of the COCs, only arsenic and cadmium are carcinogenic by any route of exposure. Arsenic is considered carcinogenic via both oral and inhalation routes of exposure while cadmium is considered carcinogenic only via the inhalation route of exposure.

Section 6

Risk Characterization

The health risks of a chemical are quantified in terms of non-cancer risks, as well as carcinogenic risks if the chemical is also considered a carcinogen. Non-cancer health risks refer to all other adverse health effects besides cancer. The methods used to assess non-cancer risks are the same for virtually all chemicals except lead.

6.1 Non-cancer Risks

The risk of non-cancer health effects for all chemicals except lead is evaluated by comparing the CDIs or, in the case of an inhalation exposure pathway, the air concentration, to the corresponding route-specific toxicity criteria. For ingestion exposure pathways, the USEPA ingestion route RfD is used. The RfD is defined by USEPA as "An estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (USEPA, 1989). For inhalation pathways the RfC is used.

The risk of non-cancer health effects is calculated as the ratio of the CDI to the RfD (for ingestion routes) or the air concentration to the RfC. In both cases, this ratio is termed the Hazard Quotient (HQ). For example, in the case of an oral or ingestion exposure (such as soil ingestion):

$$HQ = \frac{CDI_{oral}}{RfD_{oral}}$$

And for inhalation exposure:

$$HQ = \frac{Conc_{air}}{RfC}$$

The HQs for all routes of exposure for any given COC are summed to obtain a total HQ for each COC. An HQ value greater than 1 indicates that the chemical exposure exceeds the level considered safe for long-term exposure by USEPA. However, it does not necessarily mean adverse health effects will occur. HQs for each exposure pathway (soil ingestion and inhalation of outdoor air) and the total HQ for each COC are shown in Table 2 for the residential receptor, and Table 3 for the commercial worker. These tables show that none of the COCs have a HQ greater than 1.

It is possible for the total HQ (for all exposure pathways) for each COC at a site to be less than 1 but still present a potential for adverse non-carcinogenic effects. This can happen from the cumulative effects of COCs that have a similar toxic mechanism and/or target organ. Although each COC exposure level may be acceptable when considered separately, the total cumulative effect of similarly acting toxicants can create a potential for an adverse effect. To ensure that the cumulative non-carcinogenic risk from multiple similarly acting COCs is adequately considered, the total HQs across all COCs are summed to obtain an initial Hazard Index (HI) as follows:

$$HI = HQ_1 + HQ_2 + HQ_3 .... + HQ_n$$

Note that this is a conservative first step in the analysis of cumulative effect potential because it disregards the specific mechanism of toxicity or target organ. In other words, it assumes that all COCs act by a similar mechanism of action or have a similar toxic effect when in fact it is likely they do not. If the resulting cumulative HI using this conservative approach is greater than 1 a more refined analysis can be conducted. In the refined analysis, referred to by USEPA as a "segregation of hazard indices" (USEPA, 1989), the COCs are divided into subgroups based first on similarity of effect/target organ. A cumulative HI is then calculated for each subgroup. If an HI of greater than 1 is still obtained for one of the subgroups, then the subgroup may be further classified based on mechanism of toxicity or critical effect, and the subgroup HI values recalculated. The critical effect is the toxic effect that serves as the basis for the USEPA toxicity criterion.

Table 2 shows an initial HI of 2.4 for the resident, exceeding the non-cancer risk threshold of 1. The HI for the commercial worker shows an HI of 1.2 (Table 3), slightly exceeding the threshold of 1. Since the initial HI for the resident and commercial worker exceeds 1.0, a segregation of Hazard Indices was performed based on target organ, critical effect (as defined by the USEPA ingestion route RfD), and taking into consideration primary route of exposure (i.e. ingestion as opposed to inhalation). This analysis was conducted by a board certified, PhD-level toxicologist, and is shown in Table 4 (resident) and Table 5 (commercial worker). Tables 4 and 5 show that based on target organ, the HI exceeds 1.0 only for the residential receptor and only in the case of the kidney, and this is due to both cadmium and copper acting on the kidney. Consistent with USEPA guidance, and to further refine the segregation of Hazard Indices for copper and cadmium, the respective critical effects of these two chemicals were determined. The critical effect is the most sensitive effect occurring at low levels of exposure, and is therefore most relevant to environmental exposures.

Based on the USEPA cadmium ingestion route RfD, the critical effect of cadmium kidney toxicity is proteinuria (protein in the urine). In contrast to cadmium, kidney toxicity from copper ingestion is only observed at very high, acute, doses (Agency for Toxic Substances Disease Registry [ATSDR], 2012). Such doses are very unlikely to occur via soil ingestion or inhalation of resuspended soil. On the other hand, the most sensitive toxic effect of copper via ingestion exposure is gastrointestinal symptoms, and gastrointestinal symptoms have been proposed as the critical effect for a copper RfD (Beck et al., unpublished). Thus, even though both cadmium and copper can target the kidney, the latter does so only at very high acute doses. In addition, the critical effects of cadmium and copper, which are more relevant to environmental exposures, are quite different, acting on two entirely different organs. Thus, it can be concluded that the HQs for these two COCs should not be added and this results in a final maximum HI of 1.0 for cadmium for both resident and commercial worker receptors.

6.2 Lead Risks

Off-site lead concentrations will be remediated to a level at or below the current PADEP Direct Contact Numeric Value for lead of 500 mg/kg in residential areas, and 1,000 mg/kg in commercial areas. It should also be noted that lead risks are based on blood lead concentration and therefore lead risks are not cumulative with other COC non-cancer risks. Specifically, lead risks cannot be included in the HI calculation as in the case for all other COCs.

6.3 Cancer Risks

Only two of the COCs addressed in this HRA are carcinogenic. These include arsenic via both ingestion and inhalation routes of exposure, and cadmium only via the inhalation exposure route. Cancer risks for ingestion route exposure pathways are calculated by multiplying the total CDI for all ingestion-route exposure pathways by the oral (or ingestion route) Cancer Slope Factor (CSF) as follows:

$$Cancer\ Risk = CSF_o\ x\ CDI$$

For inhalation route exposure pathways, and per PADEP risk guidance, cancer risks are calculated by multiplying the air concentration by the inhalation unit risk (IUR) as follows:

$$Cancer\ Risk = Conc_{air/c}\ x\ CF\ x\ IUR$$

Where:

$Conc_{air/c}$	=	concentration in air (mg/m^3)
CF	=	unit conversion factor (1,000 µg/mg)
IUR	=	inhalation unit risk (risk per µg/m^3)

Cancer risks are summed across all exposure pathways for all carcinogens to determine cumulative lifetime cancer risk for each receptor population. Cancer risks for each carcinogenic COC and cumulative cancer risks are shown in Tables 2 and 3 for the resident and commercial worker, respectively. These tables show that cumulative cancer risks are 2E-05 for both residents and commercial workers. This unusual result is because even though the commercial worker normally has less exposure to soil compared to the resident, the site-specific standard used as the arsenic EPC for commercial workers is much higher (166 mg/kg) than the site-specific standard for the resident (37 mg/kg).

Per previous discussions with PADEP, cumulative cancer risks that are greater than or equal to 1E-05 but less than 1E-04 are considered acceptable for the AZC/TSA Project. This is also consistent with USEPA baseline risk assessment policy as follows (USEPA, 1991):

> Generally, where the baseline risk assessment indicates that a cumulative site risk to an individual using reasonable maximum exposure assumptions for either current or future land use exceeds the 10(-4) lifetime excess cancer risk end of the risk range, action under CERCLA is generally warranted at the site. For sites where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10(-4), action generally is not warranted, but may be warranted if a chemical specific standard that defines acceptable risk is violated or unless there are non-carcinogenic effects or an adverse environmental impact that warrants action.

Section 7

Summary and Conclusions

A HRA was conducted to determine if site-specific arsenic Cleanup Levels of 37 mg/kg and 166 mg/kg for residential and commercial use, respectively, within the AZC/TSA Project area, would be protective of human health when the cumulative risk of all COCs that may be related to the historical operations at the Smelter Site are considered.

Soil concentrations of arsenic, cadmium, and lead will be used as TCs to determine if remediation of a use area within a given property located within the AZC/TSA Project area will be performed. If the soil concentration of any one of these TCs is higher than the Cleanup Level for that TC, the soil within the use area will be removed and replaced with soil that has metal concentrations which meet the requirements for clean fill specified in PADEP's Management of Fill Policy Document No. 258-2182-773. Therefore, the EPCs for these TCs will not exceed their Cleanup Levels. Risk calculations for cadmium were therefore based on the cadmium Direct Contact Numeric Values as the EPCs.

For all other COCs (antimony, copper, and zinc), risk calculations were based on soil EPCs that were calculated using all on-site soil samples as a surrogate for soil concentrations in the AZC/TSA Project Area. This approach was used due to the fact that soil concentration data within the AZC/TSA Project area will be generated on a property-by-property basis during implementation of the AZC/TSA Project. It is reasonable to assume that use of the Smelter Site soil concentrations would be a conservative estimate of soil concentrations outside of the Smelter Site, which are more distant from the smelter.

Non-cancer and cancer risks were calculated using the methods and assumptions described in the PADEP risk guidance. With the exception of the arsenic bioavailability parameter, all default assumptions were used. An arsenic bioavailability of 0.5 was used for the arsenic risk calculations.

The HRA shows that non-cancer risks have a cumulative HI of 1.0 or less for both resident and nonresident receptors for those COCs which affect the same target organ or act by the same mechanism of toxicity. Cumulative cancer risks are 2E-05 for both resident and nonresident, which is within the range of 1E-05 and 1E-04 that PADEP has indicated would be protective of human health for the AZC/TSA Project.

Section 8

Uncertainty Analysis

Due to limitations of available scientific data and in the amount and type of site investigation data collected, every risk assessment will have uncertainties associated with it. The primary sources of uncertainty for the present risk assessment include:

- uncertainties in exposure parameter assumptions
- uncertainties in the toxicity criteria used, and
- uncertainties in extrapolating on-site soil concentrations to the AZC/TSA

Uncertainties in exposure parameter assumptions are related to the limited number of quantitative studies describing important aspects of human behavior such as incidental soil ingestion rates, length of time spent at one residence, time spent outdoors, etc. In general, this uncertainty has been dealt with by erring on the conservative side and using upper-bound exposure assumptions that will tend to overestimate the exposure occurring to most individuals. This approach to exposure parameter uncertainty is the basis for the Reasonable Maximum Exposure (RME) concept, and will tend to result in an upper-bound estimate of health risks (USEPA, 1989).

Important uncertainties in toxicity criteria include: 1) the absence of RfCs for some chemicals (for example, antimony, copper and zinc), 2) the lack of an adequate toxicological basis for some toxicity criteria, 3) and the uncertainties associated with extrapolating from high-dose studies in laboratory animals to the much lower concentrations typically associated with environmental exposures.

There is also uncertainty related to the use of the COC concentrations for soils located within the Smelter Site as a surrogate for some COC soil concentrations within the AZC/TSA Project area (antimony, copper, and zinc). However, it is most likely that soil concentrations within the Smelter Site would be higher than off-site concentrations due to their closer proximity to the smelter itself and due to related historic activities that would occur virtually entirely within the Smelter Site (e.g. storage and manipulation of smelter waste piles). Thus, it is expected that use of the Smelter Site soil concentrations as a surrogate for soil concentrations in the AZC/TSA Project area would overestimate actual health risks associated with exposure to soil within the AZC/TSA Project area.

Section 9

References

ATSDR. 2012. Toxicological Profile for Copper. (http://www.atsdr.cdc.gov/toxprofiles/index.asp).

Beck, B.D., Daly, H.E. and T. M. Slayton. Development of copper toxicity values for human health risk assessment. Poster presented at the Society of Toxicology Annual Meeting, Washington, D.C. 2011.

Brown and Caldwell. 2011a. Remedial Investigation Report. Former AZC Site. Smith Township. Washington County, Pennsylvania.

Brown and Caldwell. 2011b. Site-Specific Concentrations for Arsenic. Smith Township, Washington County, Pennsylvania.

USEPA (United States Environmental Protection Agency). 1989. Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part A), Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89-002. Washington, D.C.

USEPA. 1991. Role of the Baseline Risk Assessment in Superfund Remedy Decisions. OSWER Directive 9355.0-30. Washington, D.C.

USEPA. 2010. ProUCL Version 4.1.00 Technical Guide (Draft). Office of Research and Development. EPA/600/R-07/041.

USGS. 2010. Historical Zinc Smelting in New Jersey, Pennsylvania, Virginia, West Virginia, and Washington, D.C., with Estimates of Atmospheric Zinc Emissions and Other Materials. USGS. Reston, Virginia.

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TABLE 1

EXPOSURE PARAMETERS

AZC SMELTER/TOWNSHIP SOIL AREA, WASHINGTON COUNTY, PENNSYLVANIA

Exposure Parameter	Notation	Receptor Population		Units
		Resident	Nonresident	
Soil Ingestion				
Body weight	BW	15	70	kg
Averaging time - noncancer risk calculation	AT_{nc}	6	25	years
Averaging time - cancer risk calculation	AT_c	70	70	years
Gastrointestinal absorption efficiency - arsenic	Abs	0.5	0.5	unitless
Gastrointestinal absorption efficiency - other metals	Abs	1	1	unitless
Exposure frequency	EF	250	180	days/year
Exposure duration	ED	6	25	years
Soil ingestion rate - noncancer risk calculation	IngR	100	50	mg/day
Soil ingestion factor - cancer risk calculation	IFadj	57	17.9	mg-yr/kg-day
Conversion factor	CF_{ing}	1.E-06	1.E-06	kg/mg
Inhalation of Outdoor Air				
Body weight	BW	15	70	kg
Averaging time - noncancer risk calculation	AT_{nc}	6	25	years
Averaging time - cancer risk calculation	AT_c	70	70	years
Exposure frequency	EF	250	180	days/year
Exposure duration	ED	6	25	years
Exposure time	ET	24	8	hours/day
Transport factor	TF	1.E+10	1.E+10	m^3/kg

Note: All values obtained from PADEP risk guidance (§ 250. 306 and 250.307 of the Pennsylvania Code)

TABLE 2

CHRONIC DAILY INTAKE AND RISK SUMMARY TABLE FOR THE RESIDENTIAL RECEPTOR

AZC SMELTER/TOWNSHIP SOIL AREA, WASHINGTON COUNTY, PENNSYLVANIA

Chemical of Concern	EPC (mg/kg)	Ingestion CDI (noncancer) (mg/kg/day)	Ingestion CDI (cancer) (mg/kg/day)	RfD_o (mg/kg/day)	CSF_o $(mg/kg/day)^{-1}$	RfC (mg/m^3)	IUR ($\mu g/m^3$)	HQ_{ing}	HQ_{inh}	HQ_{Total}	Cancer Risk (soil ingestion)	Cancer Risk (inhalation)	Cancer Risk (total)
Antimony	42	1.9E-04	NC	4.0E-04	NC	NA	NC	4.8E-01	NA	4.8E-01	NC	NC	NC
Arsenic	37	8.4E-05	1.0E-05	3.0E-04	1.5E+00	1.5E-05	4.3E-03	2.8E-01	1.7E-04	2.8E-01	1.6E-05	1.6E-08	1.6E-05
Cadmium	110	5.0E-04	NC	5.0E-04	NC	1.0E-05	1.8E-03	1.0E+00	7.5E-04	1.0E+00	NC	2.0E-08	2.0E-08
Copper	2,510	1.1E-02	NC	3.7E-02	NC	NA	NC	3.1E-01	NA	3.1E-01	NC	NC	NC
Zinc	20,572	9.4E-02	NC	3.0E-01	NC	NA	NC	3.1E-01	NA	3.1E-01	NC	NC	NC
Hazard Index								2.4E+00	9.2E-04	2.4E+00			
Cumulative Cancer Risk											2.E-05	4.E-08	2.E-05

NA = Not available.

NC = Not carcinogenic via this route of exposure.

TABLE 3

CHRONIC DAILY INTAKE AND RISK SUMMARY TABLE FOR THE COMMERCIAL WORKER (NONRESIDENTIAL) RECEPTOR

AZC SMELTER/TOWNSHIP SOIL AREA, WASHINGTON COUNTY, PENNSYLVANIA

Chemical of Concern	EPC (mg/kg)	Ingestion CDI (noncancer) (mg/kg/day)	Ingestion CDI (cancer) (mg/kg/day)	RfD_o (mg/kg/day)	CSF_o $(mg/kg/day)^{-1}$	RfC (mg/m^3)	IUR ($\mu g/m^3$)	HQ_{ing}	HQ_{inh}	HQ_{Total}	Cancer Risk (soil ingestion)	Cancer Risk (inhalation)	Cancer Risk (total)
Antimony	42	1.5E-05	NC	4.0E-04	NC	NA	NC	3.7E-02	NA	3.7E-02	NC	NC	NC
Arsenic	166	2.9E-05	1.0E-05	3.0E-04	1.5E+00	1.5E-05	4.3E-03	9.7E-02	1.8E-04	9.8E-02	1.6E-05	7.1E-08	1.6E-05
Cadmium	1,400	4.9E-04	NC	5.0E-04	NC	1.0E-05	1.8E-03	9.9E-01	2.3E-03	9.9E-01	NC	2.5E-07	2.5E-07
Copper	2,510	8.8E-04	NC	3.7E-02	NC	NA	NC	2.4E-02	NA	2.4E-02	NC	NC	NC
Zinc	20,572	7.2E-03	NC	3.0E-01	NC	NA	NC	2.4E-02	NA	2.4E-02	NC	NC	NC
Hazard Index								1.2E+00	2.5E-03	1.2E+00			
Cumulative Cancer Risk											2.E-05	3.E-07	2.E-05

NA = Not available.

NC = Not carcinogenic via this route of exposure.

TABLE 4

SEGREGATION OF HAZARD INDICES BASED ON TARGET ORGAN, CRITICAL EFFECT, AND ROUTE OF EXPOSURE FOR THE RESIDENTIAL RECEPTOR

AZC SMELTER/TOWNSHIP SOIL AREA, WASHINGTON COUNTY, PENNSYLVANIA

Chemical of Concern	Target Organ												Critical Effect
	GI Tract	Bone	Cardiovascular	Developmental	Eye	Hematologic	Immune	Kidney	Nervous	Reproductive	Respiratory	Skin	
Antimony	0.48										NA		Longevity, blood glucose, cholesterol
Arsenic			0.28	0.28		0.28			0.28	0.28	NA	0.28	Hyperpigmentation, keratosis and possible vascular complications
Cadmium								1.0			NA		Significant proteinuria
Copper	0.31					0.31		0.31			NA		Gastrointestintal symptoms (proposed critical effect - see text)
Zinc						0.31					NA		Decreases in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity in healthy adult male and female volunteers
Total HI[1]	0.8		0.3	0.3		0.9		1.3	0.3	0.3		0.3	

Notes:
Critical effects based on ingestion route RfD obtained from the USEPA Integrated Risk Information System (IRIS) (www.epa.gov/iris).
[1]See Section 6.1 for additional discussion regarding further refinement of the HI based on critical effect.
NA = not applicable as none of the COCs had significant HQs via the inhalation route.

TABLE 5

SEGREGATION OF HAZARD INDICES BASED ON TARGET ORGAN, CRITICAL EFFECT, AND ROUTE OF EXPOSURE FOR THE COMMERCIAL WORKER (NONRESIDENTIAL) RECEPTOR

AZC SMELTER/TOWNSHIP SOIL AREA, WASHINGTON COUNTY, PENNSYLVANIA

Chemical of Concern	Target Organ												Critical Effect
	GI Tract	Bone	Cardiovascular	Developmental	Eye	Hematologic	Immune	Kidney	Nervous	Reproductive	Respiratory	Skin	
Antimony	0.037										NA		Longevity, blood glucose, cholesterol
Arsenic			0.098	0.098		0.098			0.098	0.098	NA	0.098	Hyperpigmentation, keratosis and possible vascular complications
Cadmium								1.0			NA		Significant proteinuria
Copper	0.02					0.02		0.02			NA		Gastrointestintal symptoms (proposed critical effect - see text)
Zinc						0.02					NA		Decreases in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity in healthy adult male and female volunteers
Total HI[1]	0.1		0.1	0.1		0.1		1.0	0.1	0.1		0.1	

Notes:
Critical effects based on ingestion route RfD obtained from the USEPA Integrated Risk Information System (IRIS) (www.epa.gov/iris).
[1]See Section 6.1 for additional discussion regarding further refinement of the HI based on critical effect.
NA = not applicable as none of the COCs had significant HQs via the inhalation route.

Figures

Figure 1. Former AZC Smelter Site Boundary
Figure 2. On-Site Sampling Locations
Figure 3. Health Risk Assessment Conceptual Site Model

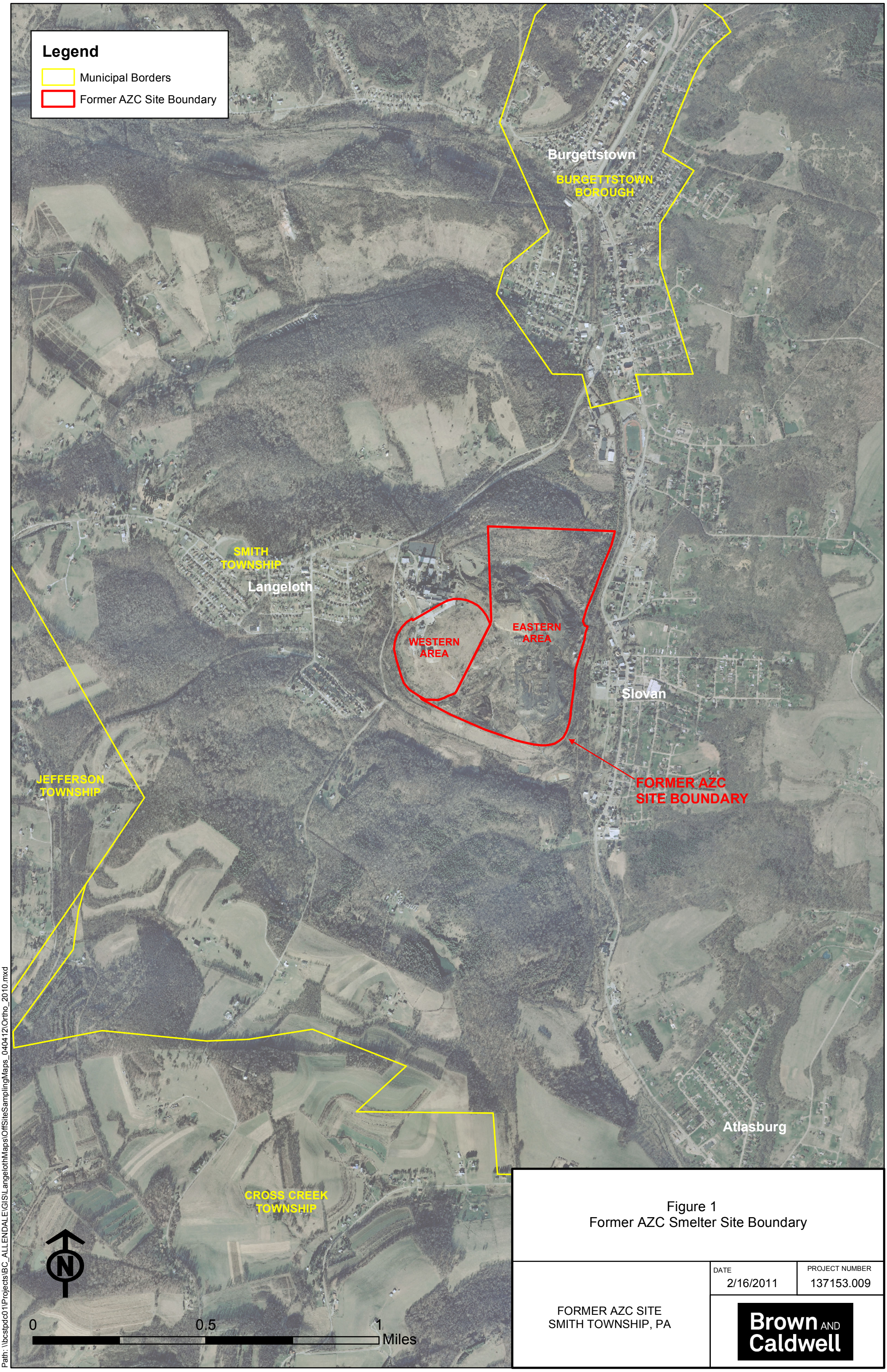


Figure 1
Former AZC Smelter Site Boundary

	DATE	PROJECT NUMBER
FORMER AZC SITE SMITH TOWNSHIP, PA	2/16/2011	137153.009

Brown AND Caldwell

Path: \\bcstpdc01\Projects\BC_ALLENDALE\GIS\LangelothMaps\OffSiteSamplingMaps_040412\Ortho_2010.mxd

Legend

Sample Locations

- Background Surface Soil Sample Location
- Representative Fill Sample Location
- Representative Non-Piles Smelter Material Sample Location
- Soil Boring
- Soil Cover Sample Location
- Surface Soil Sample Location
- Test Trench
- Site Boundary
- Ground Surface Contours (Interval = 10 ft)
- Smelter Material Stockpile

N

BGSS-01 BGSS-02 BGSS-03 BGSS-04 BGSS-05
SS-01 SS-02 SS-03 SS-04 SS-05
SS-06 SS-07 SS-08 SS-09
WP-10-1 WP-10-2 WP-10-3
WP-11-1 WP-11-2 WP-11-3
North Pond
Northern Unnamed Tributary
SB-01 SS-10 SB-02 SB-03 SB-04
SS-11 SS-12 SS-13
WP-05-1 WP-06-3 WP-06-2 WP-05-2
WP-04-1 WP-04-2 WP-04-3
WP-06-1 WP-05-3
SB-05 SB-06 SB-07 SB-08
SS-14 SS-15 SS-16 SS-17
EASTERN AREA
WESTERN AREA
SB-39 TT-01 TT-02 TT-03 SB-40 SB-41
SB-36 SC-2 SB-37 SC-1 SB-38
SB-09 SS-18 SB-10 SS-19
SS-38 SS-39 SS-35 W-06 SS-20
SS-37 SB-11 SS-36
WP-07-3 WP-07-2 WP-07-1
SB-12 SB-13 SS-21
SB-33 SB-34 SC-3 SB-35
SS-22 W-04 SB-14
SS-23 W-02 SB-15
SS-40 SS-44 SS-41 SS-42
WP-08-1 SB-17 SS-25
SB-16 SS-24 SS-43
SC-5 SB-31 SC-4 SB-32 SB-18
SB-23 WP-03-1 WP-03-2 SS-34 WP-03-3
SB-19 W-03 SS-26 WP-02-2 WP-02-1 WP-02-3
Piped Seep
WP-09-3 WP-08-2
W-05 SS-27 SB-20
SB-21 SB-22
WP-09-2 SS-28 WP-09-1 SS-29
WP-08-3
WP-01-1 WP-01-3 WP-01-2 SS-30
SB-24 SB-25
SS-31 SB-26
W-01 SS-32 SB-27
SB-28 SS-33
Burgetts Fork
SB-30 SB-29
Former South Lake
Southeastern Unnamed Tributary

0 250 500 1,000 Feet

Figure 2
On-Site Sampling Locations

FORMER AZC SITE
SMITH TOWNSHIP, PA

DATE 2/16/2011

PROJECT NUMBER 137153.009

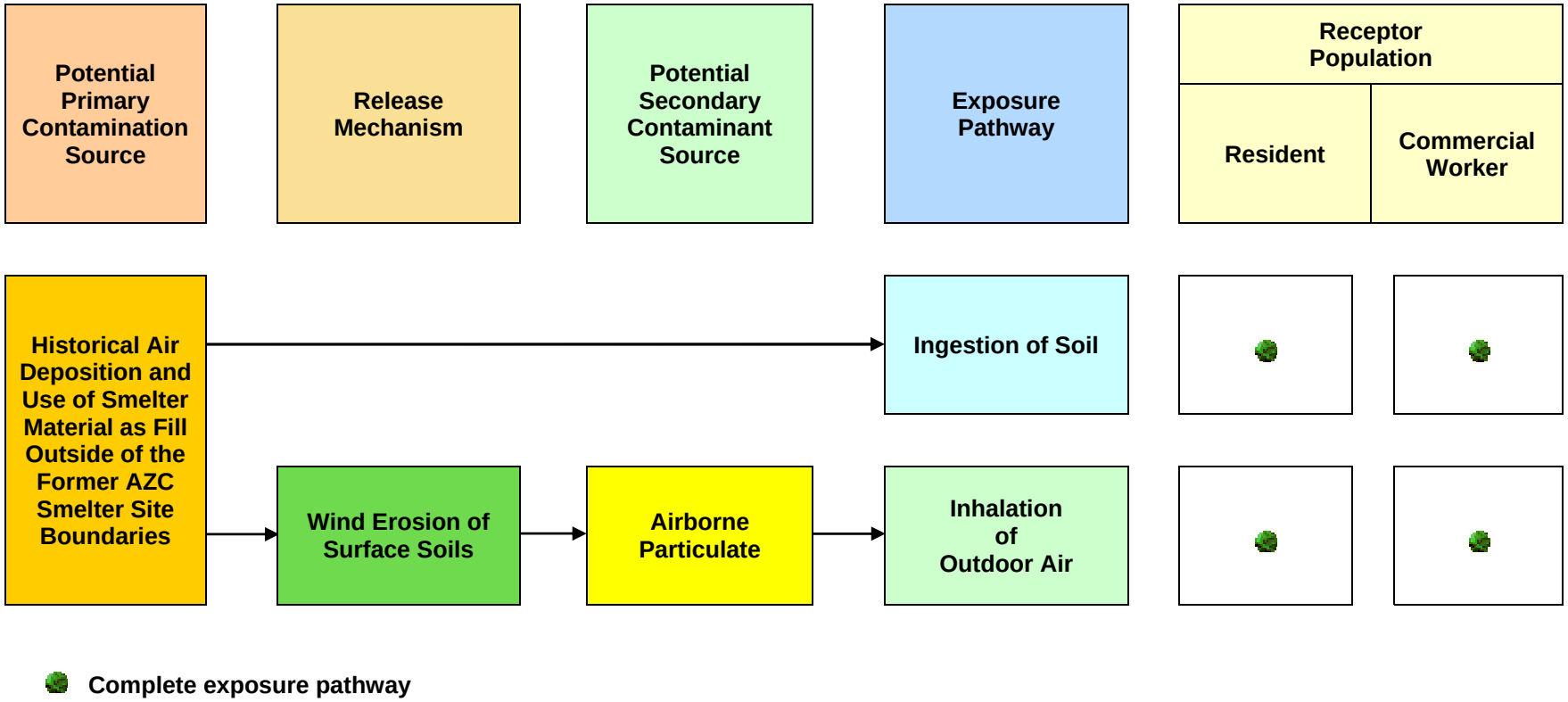
Brown AND Caldwell

Path: \\bcstpdc01\Projects\BC_ALLENDALE\GIS\LangelothMaps\OffSiteSamplingMaps_040412\OnSiteSamplingLocations.mxd

FIGURE 3

HEALTH RISK ASSESSMENT CONCEPTUAL SITE MODEL

FORMER AZC SMELTER/TOWNSHIP SOIL PROJECT AREA, WASHINGTON COUNTY, PENNSYLVANIA



Appendix A: Soil Data Used in the Risk Assessment

APPENDIX A. ON-SITE SOILS DATA USED IN THE RISK ASSESSMENT

LocationType	MatrixID	LocationName	Depth	Arsenic	Cadmium	Antimony	Copper	Zinc
BG & Depo	SUS	BGSS-01	0 - 2	28.9	0.3	0.57	27.7	80.6
BG & Depo	SUS	BGSS-02	0 - 2	14.7	6.6	1.9	92.7	571
BG & Depo	SUS	BGSS-03	0 - 2	12.6	2.1	2.1	96.8	265
BG & Depo	SUS	BGSS-04	0 - 2	10.7	3.6	0.46	18.6	635
BG & Depo	SUS	BGSS-05	0 - 2	3.8	0.58	0.5	30.4	106
Borehole	SSS	SB-02	18 - 19	1580	39.6	71.4	603	18500
Borehole	SSS	SB-03	18 - 19	10.8	27.8	0.8	38.7	6760
Borehole	SSS	SB-04	36 - 38	8	0.85	0.49	28.1	192
Borehole	SSS	SB-04	44 - 45	8.7	236	0.67	53.6	16400
Borehole	SSS	SB-05	6 - 8	12.7	7	2.1	124	2060
Borehole	SSS	SB-06	4 - 5	29	10.5	13.6	1040	8160
Borehole	SSS	SB-07	9 - 10	1.7	0.19	0.16	42.9	100
Borehole	SSS	SB-07	14 - 15	4.1	0.31	0.13	26.4	59.7
Borehole	SSS	SB-09	4 - 5	15.2	3.1	1.2	38.3	387
Borehole	SSS	SB-11	4 - 5	82.4	15.2	5.7	121	3770
Borehole	SSS	SB-12	15 - 16	9.6	3.9	0.43	38	2310
Borehole	SSS	SB-14	3 - 4	23.7	147	4.2	210	11200
Borehole	SSS	SB-14	6 - 7	12.6	221	0.39	64.7	30500
Borehole	SSS	SB-15	3 - 4	426	611	33.2	8680	40800
Borehole	SSS	SB-15	14 - 15	5.6	0.11	0.28	19.6	54.7
Borehole	SSS	SB-16	8 - 9	4.9	1	0.33	32.7	80.7
Borehole	SSS	SB-17	4 - 5	86.2	12	4.6	2500	47000
Borehole	SSS	SB-17	27 - 28	18	0.23	0.4	38.8	64.9
Borehole	SSS	SB-18	10 - 11	8.5	6.8	1.8	109	2230
Borehole	SSS	SB-19	16 - 18	7.3	0.58	0.75	57.2	265
Borehole	SSS	SB-19	32 - 34	9.1	0.49	0.4	20	98.7
Borehole	SSS	SB-20	7 - 8	68.2	23.3	28.5	570	1970
Borehole	SSS	SB-20	27 - 28	1.3	0.16	0.21	9.6	18.8
Borehole	SSS	SB-22	4 - 5	37.9	8.1	4.4	204	13300
Borehole	SSS	SB-22	20 - 21	1.2	2.7	0.11	11.3	336
Borehole	SSS	SB-23	4 - 5	9.7	9.1	2.2	103	2250
Borehole	SSS	SB-23	13 - 14	0.98	3.2	0.19	35.8	705
Borehole	SSS	SB-24	7 - 8	14.2	14.3	3.2	316	8060
Borehole	SSS	SB-25	5 - 6	1.6	0.5	0.18	10.4	94.4
Borehole	SSS	SB-27	6 - 7	6.8	32.5	0.41	33	8020
Borehole	SSS	SB-28	2 - 3	20.4	19.8	1.7	138	5310
Borehole	SSS	SB-29	2 - 3	11.5	10.2	1.5	90.6	1780
Borehole	SSS	SB-30	5 - 6	11.7	7	0.82	108	1770
Borehole	SSS	SB-31	23 - 24	7	0.15	0.13	28.5	64.2
Borehole	SSS	SB-32	6 - 6.5	6.4	5.2	1	46.7	1320
Borehole	SSS	SB-32	20 - 21	1.6	0.13	0.12	37	66.6
Borehole	SSS	SB-33	10 - 11	2.6	0.93	0.14	32.7	193
Borehole	SSS	SB-34	5 - 6	14.4	0.2	0.32	31.3	91.4
Borehole	SSS	SB-35	6 - 6	13.1	744	0.93	86	17700
Borehole	SSS	SB-35	26 - 27	0.94	0.26	0.15	20.5	66.8
Borehole	SSS	SB-36	11.5 - 12	46.5	0.46	1.5	49.9	97.4
Borehole	SSS	SB-37	7 - 8	35.3	0.43	1	22	56.9
Borehole	SSS	SB-37	18 - 19	5.9	0.2	0.23	22.6	33.9
Borehole	SSS	SB-38	2 - 3	18.5	2.4	0.55	31.6	169
Borehole	SSS	SB-38	6 - 6.5	3.2	0.23	0.26	24.3	68.3
Borehole	SSS	SB-39	6 - 6.5	59.4	0.76	1.2	41.3	187
Borehole	SSS	SB-40	5 - 6	90.9	6.7	3.4	83.2	550

LocationType	MatrixID	LocationName	Depth	Arsenic	Cadmium	Antimony	Copper	Zinc
Borehole	SSS	SB-41	5.5 - 6.5	29.4	27.7	1.8	47.9	6380
Borehole	SUS	SB-01	1 - 2	5.1	0.35	0.28	30.3	72.4
Borehole	SUS	SB-08	1 - 2	39.8	4.2	1.7	239	2990
Borehole	SUS	SB-10	0 - 1	48.9	49.6	8.2	374	6540
Borehole	SUS	SB-13	0 - 1.5	7.2	2.2	0.54	131	566
Borehole	SUS	SB-16	0 - 1	50.1	15.8	10.1	400	10900
Borehole	SUS	SB-21	0 - 1	15.5	1.1	2.2	159	420
Borehole	SUS	SB-26	1 - 2	9.1	0.83	0.34	29	124
Borehole	SUS	SB-31	1 - 1.5	3.3	8.6	0.19	23.2	1750
Borehole	SUS	SB-32	1 - 1.5	37	14.5	6.6	428	4270
Borehole	SUS	SB-33	0.2 - 1	0.51	0.5	0.17	33.6	200
Borehole	SUS	SB-34	0.5 - 1	1.6	1.2	0.16	19.5	263
Borehole	SUS	SB-35	1 - 2	31.8	33.1	7.1	385	22700
Borehole	SUS	SB-36	0.2 - 0.5	0.6	0.37	0.1	38	116
Borehole	SUS	SB-37	1 - 2	11.5	1.1	0.55	34.7	233
Borehole	SUS	SB-38	1 - 2	19.8	5.6	0.93	48.7	359
Borehole	SUS	SB-39	0.3 - 1	2.3	0.5	0.18	38	114
Borehole	SUS	SB-40	0.5 - 1	7.6	1.3	0.33	35.4	173
Borehole	SUS	SB-41	0.3 - 1	11.2	0.6	0.36	24.9	78.9
SM Surface	SMM	W-01	0 - 2	56.5	6.6	9.4	1010	14000
SM Surface	SMM	W-02	0 - 2	374	98	30.9	7090	33000
SM Surface	SMM	W-03	0 - 2	29	33.2	9.7	269	8770
SM Surface	SMM	W-04	0 - 2	17.4	22.5	3.5	68.5	597
SM Surface	SMM	W-05	0 - 2	126	23.5	30.4	1320	8580
SM Surface	SMM	W-06	0 - 2	72.9	139	8.5	880	17200
SM Pile	SMM	WP-01-1	0 - 2	114	0.1	117	1290	1090
SM Pile	SMM	WP-01-2	0 - 2	133	0.29	240	7660	6740
SM Pile	SMM	WP-01-3	0 - 2	207	0.085	473	1320	392
SM Pile	SMM	WP-02-1	0 - 2	77.8	10	163	9270	90000
SM Pile	SMM	WP-02-2	0 - 2	148	21	119	13300	94200
SM Pile	SMM	WP-02-3	0 - 2	4.1	11.5	4.2	2640	13500
SM Pile	SMM	WP-03-1	0 - 2	168	23.9	119	22000	95700
SM Pile	SMM	WP-03-2	0 - 2	137	7	70.4	14300	26100
SM Pile	SMM	WP-03-3	0 - 2	250	18	272	8490	83700
SM Pile	SMM	WP-04-1	0 - 2	149	10.9	98.1	17000	123000
SM Pile	SMM	WP-04-2	0 - 2	147	8.8	131	13500	89000
SM Pile	SMM	WP-04-3	0 - 2	157	10.9	165	13600	80300
SM Pile	SMM	WP-05-1	0 - 2	26.8	12	5.3	579	19900
SM Pile	SMM	WP-05-2	0 - 2	40.7	26.1	5.7	554	71700
SM Pile	SMM	WP-05-3	0 - 2	49.9	6.5	29.4	2830	13700
SM Pile	SMM	WP-06-1	0 - 2	229	6.3	39.7	909	10100
SM Pile	SMM	WP-06-2	0 - 2	1090	14.8	150	1020	30200
SM Pile	SMM	WP-06-3	0 - 2	287	19.9	154	363	17100
SM Pile	SMM	WP-07-1	0 - 2	23.5	0.38	2.3	135	278
SM Pile	SMM	WP-07-2	0 - 2	157	10.5	80.5	8110	42900
SM Pile	SMM	WP-07-3	0 - 2	23.1	3.1	8.2	419	2060
SM Pile	SMM	WP-08-1	0 - 2	61.8	22.3	15.2	1670	35800
SM Pile	SMM	WP-08-2	0 - 2	252	25	36	2100	40700
SM Pile	SMM	WP-08-3	0 - 2	30	38.8	4.3	1970	22000
SM Pile	SMM	WP-09-1	0 - 2	40.4	4.8	12.1	1950	5270
SM Pile	SMM	WP-09-2	0 - 2	1650	94.8	17.2	1890	79500
SM Pile	SMM	WP-09-3	0 - 2	5.3	1.1	0.78	39.2	306
SM Pile	SMM	WP-10-1	0 - 0	130	24.1	11.4	1150	53000
SM Pile	SMM	WP-10-1	- 2	114	28.4	10.1	1100	38600

LocationType	MatrixID	LocationName	Depth	Arsenic	Cadmium	Antimony	Copper	Zinc
SM Pile	SMM	WP-10-2	0 - 2	35.5	18.3	6.2	614	54400
SM Pile	SMM	WP-10-3	0 - 2	40.5	20.7	8.4	1750	53600
SM Pile	SMM	WP-11-1	0 - 2	54	1.4	0.51	32.6	141
SM Pile	SMM	WP-11-2	0 - 2	45.4	0.99	1.4	196	591
SM Pile	SMM	WP-11-3	0 - 2	38	16.3	6.6	348	12200
Soil Cover	SUS	SC-1	0 - 0.6	5.4	1.7	0.27	31.7	205
Soil Cover	SUS	SC-2	0 - 1	10.7	1.1	0.44	43.8	145
Soil Cover	SUS	SC-3	0 - 0.6	41.6	16.4	6.4	193	4310
Soil Cover	SUS	SC-4	0 - 1	10.5	11.7	1.3	56.2	3230
Soil Cover	SUS	SC-5	0 - 1	8	4.3	1.1	74.7	1610
Grid - Depo	SUS	SS-01	0 - 2	10.1	1.3	0.95	54.4	215
Grid - Depo	SUS	SS-02	0 - 2	9.2	3.7	1.3	62.8	324
Grid - Depo	SUS	SS-03	0 - 2	8.3	11.5	0.68	53.1	750
Grid - Depo	SUS	SS-04	0 - 2	44.7	4.3	1	65.7	326
Grid - Depo	SUS	SS-05	0 - 2	18.7	0.85	0.6	42.4	185
Grid - Depo	SUS	SS-06	0 - 2	6.8	1.7	0.52	53.2	248
Grid	SUS	SS-07	0 - 2	52.8	6.5	3	390	9300
Grid - Depo	SUS	SS-08	0 - 2	14.5	0.93	0.58	43	135
Grid - Depo	SUS	SS-09	0 - 2	14.7	1.2	0.69	33.8	129
Grid	SUS	SS-10	0 - 2	801	29.9	71.8	492	12600
Grid	SUS	SS-11	0 - 2	84.2	12.1	52.1	622	19200
Grid	SUS	SS-12	0 - 2	220	12.1	74	772	13100
Grid	SUS	SS-13	0 - 2	31.8	2.7	2.3	187	2000
Grid	SUS	SS-14	0 - 2	11	22.2	1.2	109	4850
Grid	SUS	SS-15	0 - 2	5.3	7.4	1.2	173	1280
Grid	SUS	SS-16	0 - 2	99.2	7.1	12.6	671	9920
Grid	SUS	SS-17	0 - 2	31.2	2.6	7.3	504	3810
Grid	SUS	SS-18	0 - 2	8.7	12.1	1.4	26.3	716
Grid	SUS	SS-19	0 - 2	14.8	15.9	3.3	111	2700
Grid	SUS	SS-20	0 - 2	22.8	9	3	76.2	6380
Grid	SUS	SS-21	0 - 2	105	25.2	39.6	2200	27400
Grid	SUS	SS-22	0 - 2	17.2	17.1	8.9	464	6630
Grid	SUS	SS-23	0 - 2	45.2	54.6	9	302	12200
Grid	SUS	SS-24	0 - 2	16.7	7.3	4.9	311	5000
Grid	SUS	SS-25	0 - 2	60.8	18.7	15.2	951	22400
Grid	SUS	SS-26	0 - 2	155	43.1	95	6000	30600
Grid	SUS	SS-27	0 - 2	21.5	29.2	9.2	1020	17800
Grid	SUS	SS-28	0 - 2	116	22.8	15.3	2000	25300
Grid	SUS	SS-29	0 - 2	57.2	35.7	10.7	274	27600
Grid	SUS	SS-30	0 - 2	139	1.5	168	7660	8290
Grid	SUS	SS-31	0 - 2	30.8	9.5	10.4	709	8620
Grid	SUS	SS-32	0 - 2	57.1	11.6	5	999	11400
Grid	SUS	SS-33	0 - 2	96.2	9.7	14.1	1380	8330
Grid	SUS	SS-34	0 - 2	174	24	54.5	4350	29000
Grid - Shop	SUS	SS-35	0 - 2	118	8.9	13.1	1240	5620
Grid - Shop	SUS	SS-36	0 - 2	34.7	13.3	8.8	520	9930
Grid - Shop	SUS	SS-37	0 - 2	10.9	25.4	1.2	75.9	9650
Grid - Shop	SUS	SS-38	0 - 2	30.6	2.7	0.77	44.6	622
Grid - Shop	SUS	SS-39	0 - 2	6.2	8.3	0.48	36.4	817
Grid - Trans	SUS	SS-40	0 - 2	62	41.3	22.9	530	12300
Grid - Trans	SUS	SS-41	0 - 2	41	52.9	7.5	1930	10200
Grid - Trans	SUS	SS-42	0 - 2	79.6	10.6	14.7	163	5730
Grid - Trans	SUS	SS-43	0 - 2	31.5	9.6	8.6	290	5230
Grid - Trans	SUS	SS-44	0 - 2	14.1	9.8	5.5	422	6000

LocationType	MatrixID	LocationName	Depth	Arsenic	Cadmium	Antimony	Copper	Zinc
Test Pit	SSS	TT-01	2.5 - 3	116	0.23	1.3	20.7	18.5
Test Pit	SSS	TT-02	5 - 5.5	12.8	1.5	0.51	35.8	233
Test Pit	SUS	TT-03	1 - 1.5	3.2	0.23	0.16	30.6	81.3
Average:				**82**	**24**	**23**	**1365**	**12943**
Min:				**0.5**	**0.1**	**0.1**	**9.6**	**18.5**
Max:				**1650**	**744**	**473**	**22000**	**123000**
Count:				**163**	**163**	**163**	**163**	**163**

Appendix B: Site-Specific Standard for Arsenic

Section 2

Scientific Studies on Arsenic Bioavailability

This section presents an overview of the scientific research on arsenic bioavailability, and the studies identified that used acceptable methods of determining arsenic bioavailability. The studies identified and associated data on arsenic bioavailability are shown on Table 2-1.

2.1 Overview of Bioavailability Methods

Bioavailability studies can be conducted in animals (*in vivo*), or by using analytical methods outside the body (*in vitro*) that are designed to simulate conditions in the stomach. Only studies that used *in vivo* methods were considered in this paper.

Bioavailability determined by in vivo studies can be measured as either "relative bioavailability" or "absolute bioavailability" (Ruby et al. 1999; Ng et al. 1998; Juhasz et al. 2007) and the definitions are as follows:

- Relative bioavailability refers to the comparative bioavailability of a substance (arsenic) in one medium to another medium. Most commonly, the relative bioavailability is the difference between the available arsenic in soil compared to that in water. (Note: Ruby et al. 1999 uses the term "relative absorption factor" interchangeably with relative bioavailability factor).
- Absolute bioavailability refers to the amount of arsenic available from a medium compared to the amount in the blood stream after intravenous injection of the arsenic.

Bioavailability can be expressed as a fraction or as a percent. In this report, the relative bioavailability factor (RBF) refers to the fraction.

In an *in vivo* bioavailability study, test animals are fed soil with arsenic and the amount of arsenic in the blood or urine is compared to that in the control animals after a certain period of time. The control animals are fed the pure arsenic salt or arsenic in water for relative bioavailability or given arsenic salt via intravenous injection for absolute bioavailability.

The test animals used in the studies reported in this report include monkeys, swine, rabbits and rats. Primates are considered most similar to man for these studies but immature swine are also similar to humans in terms of how they metabolize arsenic (Juhasz et al. 2007). The data compiled for this report are based on swine or monkeys, with the exception of one rabbit and one rat study.

The studies included all used test soil impacted with arsenic, which was either naturally elevated or elevated as the result of anthropogenic activities. No studies were used in which the arsenic was added to the soil in the laboratory just prior to feeding to the test animals as these conditions may not reflect the mineralogy of arsenic in soil in the environment.

2.2 Scientific Sources for Site-Specific Arsenic Bioavailability

Four research papers on arsenic bioavailability were identified as acceptable sources of bioavailability data (Table 2-1). Only one data point for each soil type was included to avoid any bias towards one single source of soil. A brief overview of each study and the data selected for calculation of the bioavailability is

presented in the following sections. A brief overview of each study and the data selected for use in determining a RBF for the Site is presented in the following sections

2.2.1 University of Florida Monkey Study (Roberts et al. 2007)

The University of Florida conducted relative bioavailability tests on 14 different soils from six states using arsenic blood levels in monkeys. The soils represent a wide range of sources of arsenic in soil, including orchards, mine tailings, slag, smelters, pesticides, cattle dip sites, chemical plant soil and volcanic.

2.2.2 University of South Australia Swine Study (Juhasz et al. 2007)

The University of South Australia measured relative and absolute bioavailability in swine using soil from railroad corridors, cattle dip sites, mine sites, and gossan soil with naturally elevated levels of arsenic. The report included a range of relative bioavailabilities for each group of soil, but not the individual results. The individual relative bioavailability results presented in Table 2-1 were supplied by the author (see email in Attachment A).

2.2.3 Critical Review (Ruby et al. 1999)

This Critical Review is a compilation of in vivo studies of arsenic relative bioavailability that summarizes the results of multiple other studies. The two major sources were swine studies conducted by Region VIII of the United States Environmental Protection Agency at seven sites in different states, and swine studies conducted by the University of Missouri on eight soils from different locations in Oklahoma. There are also two different studies with rabbits and monkeys on soil from the Anaconda, Montana site. The soils represent a range of sources of soil likely related to mining activities.

The results as presented in the Critical Review were relied upon, and the original studies were not reviewed because the publishing journal, Environmental Science and Technology, is a peer-reviewed journal and several of the authors are well-recognized as experts in this area.

Two samples of the 24 samples presented in the Critical Review were excluded. The two samples from Aspen were not included, as the text noted that the concentrations of arsenic were too low to give reliable results.

2.2.4 Cattle Dip Study (Ng et al. 1989)

This study determined the absolute bioavailability of arsenic in soil in the vicinity of a plunge dip site that used arsenical pesticides between 1946 and 1960. Ten composite samples of soil were collected in the vicinity of the plunge site. Bioavailability was measured in rats using arsenic in urine.

Twenty values for absolute bioavailability were reported, two for each of the ten samples (one for the pentavalent arsenic and one for trivalent arsenic). For this report, one value was selected for inclusion in the data compilation for the site-specific bioavailability because the test soil all came from the same location. The highest of the 20 values (9.87 percent for trivalent arsenic or an RBF of 0.0987) was used in the data compilation.

Section 3

Selection of Relevant Data Sets

The data presented in Section 2 were then evaluated to select the most appropriate RBF data for calculation of the SSCs. The first step was to determine if there were any trends in the RBFs due to the source of asrenic. The second step as to select the RBF data from studies with soil most similar to that at the AZC site based on chemical speciation.

3.1 Evaluation of Data

The RBFs from soil with arsenic likely to be related to mining activities (30 data points) (indicated in Table 2-1 with a "yes") were compared with soil containing arsenic unrelated to mining (19 data points) to determine if there was a difference in the RBFs for the two data sets. . The mean and maximum RBFs for the non-mining-related arsenic sources of 0.267 and 0.747, respectively, are higher than the mining-related data mean and maximum RBFs of 0.2348 and 0.52, respectively. Therefore, using the combined data set is conservative because the non-mine-related data tend to show higher bioavailability, which will result in more stringent (lower) SSCs.

3.2 Comparison of Speciation Data

Data on the speciation of the soil used in the studies on Table 2-1 were compared to speciation studies conducted on AZC site in response to a request by PADEP. These studies were performed by Dr. John Drexler of the University of Colorado on five composite samples taken from waste materials at the Site. Brown and Caldwell submitted the results of these speciation studies in a letter dated December 10, 2010 to Mr. Michael Maddigan of PADEP. Table 3-1 summarizes the speciation data for Site samples obtained in the studies including clarifications resulting from discussions with PADEP pertaining to the December 10 submittal.

Table 3-2 presents the available speciation data reported in the literature for the Table 2-1 *in vivo* studies. Except for one of the Anaconda samples, speciation data for all of the studies performed in the United States was either found within the literature or obtained from Dr. Drexler. Speciation data was not provided for the Australian *in vivo* studies. Table 3-2 also includes three *in vivo* studies reported by EPA which had a form of arsenic present similar to that found within the Site samples that were not included in the literature references discussed in Section 2. Table 3-2 also identifies the primary and secondary form of arsenic reported within each study.

A comparison of the speciation data for the Site samples indicates the following:

- The predominate form of arsenic (FeOOH) found within the Site samples is also the predominate form within 13 of the *in vivo* studies and the secondary form within another 16 of the studies.
- The mean RBF for those studies within Table 3-2 which have FeOOH as either the predominant or secondary form of arsenic is 25 percent and the 95th UCL of the mean calculated using EPA's ProUCLl software (Table 3-3) is 32 percent using the approximate gamma distribution recommended by the software.

In summary, there is a high level of confidence that the site-specific RBF of 32 percent meets USEPA and PADEP risk assessment guidance so that any actual exposure to materials from the Site, will not be underestimated (USEPA 2004; 25 PA Code Chapter 250). If 32 percent is used for the RBF and PADEP's default values are used for all other variables the equations in 25 Pa. Code Section 250.306 results in a SSC of 37 mg/kg for residential use and 166 mg/kg for non-residential.