# Evaluation of Background Metal Concentrations in Soil for the ASARCO LLC Hayden Plant Site

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## 1. Introduction and Purpose

The ASARCO LLC Plant Site (Site) is an active copper ore processing facility located in Hayden, Arizona. The U. S. Environmental Protection Agency (EPA) is currently conducting a remedial investigation (RI) to assess potential environmental impacts from Site operations on air, soil, groundwater, and Gila River surface water and sediments. As part of the soils investigations conducted by EPA in 2006, residential and nonresidential soil samples were collected from selected locations in and around the towns of Hayden, Winkelman, and the perimeter of the active Site.

The purpose of this memorandum is to present an evaluation of soil background metal concentrations based on available laboratory data and geologic and physiographic features of the Site. The main objective of this evaluation is to establish soil background concentrations for arsenic, copper, and lead, to better assess potential environmental impacts from ASARCO operations on residential soils in the towns of Hayden and Winkelman, and to provide reference values for use in the human health risk assessment (HHRA).

In addition, soil background data available for the state of Arizona have been used for a "macro-scale" comparison of soil background metal concentrations identified in this evaluation.

The background evaluation was conducted in general accordance with "*Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*" (EPA, 2002).

## 2. Site Geologic Setting

The Site and study area include the towns of Hayden, Winkelman, the surrounding areas along State Route 177, and State Route 77 in both Gila and Pinal Counties, Arizona. Hayden is located approximately 100 miles southeast of Phoenix and 50 miles northeast of Tucson. Winkelman is located approximately 1 mile southeast of Hayden.

Regionally, the Site is located near the western edge of the Mexican Highland portion of the Basin and Range physiographic province (SHB, 1992). This province is characterized by north-northwest trending mountain ranges separated by sediment-filled valleys derived from erosion of the adjacent ranges. Hayden is located on the southwestern flank of the

Dripping Spring Mountains, near the confluence of the Gila and San Pedro Rivers (see Figure 1). The background metals evaluation requires consideration of the physiographic and geologic setting. The geologic units exposed in the study area consist of a basement complex of older Precambrian through Paleozoic sedimentary rocks and minor igneous intrusives. Older Quaternary deposits such as alluvial fans and younger Quaternary alluvium are present along stream and river channels (SHH, 1994). In the specific case of the Site, the dominant feature is the alluvial basin formed by the Gila River and San Pedro River confluence, which generally trends in a southeast to northwest direction. On the Hayden side of this basin, adjacent to the Dripping Spring Mountain, are found Tertiary bedrock formations with locally variably amounts of Holocene alluvium/colluvium.

In a geologic map prepared by SHB (1992), the following map units are present in the vicinity of the Site, listed from youngest to oldest (the map designation code is in parentheses). The geologic map (see Figure 2, which was developed based on the SHB map) identifies the following geologic units in the vicinity of the Site:

1. **Fill Material** (**Fd**). The fill material consists primarily of mine tailings, and includes Tailings Impoundments AB/BC and D, and older tailings deposits in lower Kennecott Wash and west of Power House Wash.
2. **Quaternary Alluvium** (**Qal**). The Quaternary alluvium consists of silt, sand and gravel along washes and river channels (Gila River, San Pedro River, San Pedro Wash, and Power House Wash).
3. **Older Quaternary Deposits** (**Qo**). The older Quaternary deposits are present along stream terraces and alluvial fans, and presence includes nearly all of the Winkelman residential area and other terrace areas, especially adjacent to Tailings Impoundment D.
4. **Tertiary Sediments** (**Ts**). The Tertiary sediments consist primarily of tuffs and conglomerates, and presence includes all of the Hayden residential area located above the washes, extending into the far northwest portion of Winkelman.
5. **Cretaceous/Tertiary Intrusives and Volcanics** (**KTi**). These rock formations are located in the higher elevations north and east of Hayden, and adjacent to the further upstream portions of the Gila River.
6. **Paleozoic Sediments** (**Ps**). The Paleozoic sediments consist of limestones primarily located in a northeast to southwest trending band in the upland area north of Hayden, and adjacent to the near upstream portion of the Gila River.

Because Hayden and Winkelman are situated in the Ts and Qo units, respectively, evaluation of background concentrations of arsenic, copper, and lead in soil samples from these two geologic map units is the main focus of this technical memorandum.

# 3. Available Data

Data from available sources have been reviewed and compiled to evaluate soil background concentrations for metals in the Hayden and Winkelman area. These data sources include previous investigations conducted at the Site, the ongoing RI, and literature.

## 3.1 Data from Previous Investigations

Two previous investigations were conducted at the Site, and both included collection of background soil samples. These studies include the Expanded Site Inspection (ESI) (ADEQ, 2003), and the Removal Assessment (RA) (E&E, 2004).

### 3.1.1 Expanded Site Inspection – 2003

The ESI study included sampling of surface soil samples in and around Hayden, in addition to other media sampling. Most samples were collected near ASARCO operations and cannot be used in the background data evaluation because of proximity to active operations. However, background samples were collected at the following locations:

- BG-SS-01 and BG-SS-03, located northwest of Hayden in the Ts unit (note that duplicate sample BG-SS-04 was collected at the BG-SS-03 location)
- BG-SS-05 and BG-SS-06, located northeast of Hayden in the KTi unit.

Data from location BG-SS-02, located near BG-SS-01 and BG-SS-03 in the Ts unit, were considered anomalous (elevated concentrations of most analytes) and were not used in the background evaluation. The ESI reported average background concentrations (considering the four investigative and one duplicate sample from all geologic units) for arsenic, copper, and lead of 7.92 milligrams per kilogram (mg/kg), 622.2 mg/kg, and 682.5 mg/kg, respectively. However, the average background level for lead was elevated because of the high lead levels in BG-SS-03 and the duplicate BG-SS-04 (1,600 and 1,700 mg/kg, respectively). The ESI background data used as part of the current evaluation are presented in Table 1.

### 3.1.2 Removal Assessment – 2004 (RA)

Investigations during the RA (Ecology & Environment, 2004) included surface soil sampling activities at 209 randomly selected locations in the towns of Kearny (89), Winkelman (69), and Hayden (51). In addition, background samples were collected at six locations along State Highway 177, from a linear area approximately 12 to 17 miles south of Winkelman.

All background samples were collected from grade to approximately two inches below ground surface (bgs) and were analyzed for Target Analyte List (TAL) metals. The RA report indicates that, irrespective of geologic map units, background arsenic concentrations ranged from 2.99 to 8.53 mg/kg with an average concentration of 5.80 mg/kg; copper concentrations ranged from 145 to 687 mg/kg with an average concentration of 424.6; and lead concentrations ranged from 18.1 to 45.8 mg/kg with an average concentration of 29.8 mg/kg. Based on review of Figure 3-4 from the RA report, which depicts the background sample locations on an aerial photograph, it appears that all samples are located just above the Gila River floodplain in the Qo unit, with the exception of sample BKG-4 which appears to be located in younger Quaternary alluvium (Qa) associated with an east-west trending drainage/wash that connects to the Gila River. No background samples were collected from the Ts unit during the RA. The RA background data used as part of the current evaluation are presented in Table 2.

## 3.2 Current Remedial Investigation – 2007

During the current remedial investigation conducted by EPA, a total of 273 nonresidential samples and 1,406 residential samples were collected in the towns of Hayden, Winkelman, portions of the ASARCO Site perimeter, and the surrounding area. Of the 273 nonresidential samples taken, 243 samples were taken from the surface to a depth of two inches bgs, while 30 were taken from the subsurface at a depth of 10-12 inches bgs. Of the 1,406 residential samples, 1,280 samples were taken from the surface, while 126 were taken at depth. The nonresidential samples were mainly collected from the perimeter of ASARCO's plant facilities such as the former Kennecott smelter, the crusher and concentrator facilities, and the tailings impoundments. In addition, nonresidential soil samples were collected from the washes in Hayden (San Pedro and Power House, and Kennecott Avenue), public areas in the towns of Hayden and Winkelman, and at 13 locations intended to represent background conditions. Geologic map units have been assigned to each sample using a geologic map available for the area (SHB, 1994), as described above.

Review of the background sample data suggests that several samples are not useful in the background data evaluation due to the proximity to ASARCO operations. For the RI dataset, five sample locations can be considered background based on their location relative to ASARCO's plant operations. Three samples (UPA-02-SED-0, UPA-02-SED-0.66, and UPA-09) are from the Ts unit, and two samples (UPA-07-SED-0 and UPA-07-SED-0.66) are from the Qo unit. In addition, as described further below in Section IV, the nonresidential and subsurface residential data were reviewed to evaluate if any samples could be included in the core Ts and Qo background datasets. An additional 28 samples located in northwest Winkelman, along the boundary of a Ts outcropping, were also included in the Ts core background data sets. The core Qo background dataset was considered sufficient, and no additional RI samples (beyond the RI background samples) were added to this dataset.

The RI background data for the Ts and Qo units are included in Tables 1 and 2, respectively.

## 3.3 Statewide Data

Statewide data are available, however, in limited amounts. No soil metal concentration data specific to the Hayden and Winkelman area are available in the literature. One study provides data on soil background concentrations for the State of Arizona, and is entitled "Evaluation of Background Metals concentrations in Arizona Soils" (Earth Technology Corporation, 1991).

The 1991 study generated soil background metal concentrations for Arizona based on historical data compiled from 21 documents, including seven professional papers, 11 published maps and three published books. Two main sources of background concentrations of metals were identified in the study: (1) a set of 47 soil samples collected and analyzed by the U.S. Geological Survey (USGS), and (2) a set of 62 soil samples collected during various site investigations and obtained from records maintained by Arizona Department of Environmental Quality (ADEQ).

The 47 USGS samples were collected at approximate 50-mile intervals along routes of travel from one field area to another, throughout Arizona. Collection of samples was conducted away from road cuts and fills. No other information regarding site selection procedure or the criteria used in establishing background is provided in the Earth Technology

Corporation report (1991). Samples were collected at a depth of 8 inches bgs to avoid the effects of surface contamination. The 62 ADEQ samples were also collected throughout Arizona and were specifically noted as background samples in the investigations conducted in 10 different sites known to be contaminated. The depth of sample collection ranged from 0.25 feet to 9 feet bgs. The average, standard deviation, maximum, and minimum metal concentrations for the USGS and ADEQ samples are shown in Table 3. No information regarding the specific geologic units of the samples is available.

A general correlation of the USGS and ADEQ data with physiographic provinces was also conducted during this investigation. This correlation is presented in Table 4, and shows the relationship of USGS data to the three physiographic provinces in Arizona (Basin and Range, Transition Zone, and Colorado Plateau). No information is provided on the actual number of samples available for each physiographic province. The study concluded that background concentrations in the combined Transition Zone and Basin and Range provinces are approximately twice as high as those in the Colorado Plateau province. The fact that most of Arizona's mineral deposits are located in the southwestern two-thirds of the state is suggested as a possible explanation for that trend; however, the study points out that the majority of samples were taken several miles away from known metallic mineral deposits. For the USGS samples collected from the Transition Zone and/or Basin and Range Zone (where the Site is located), mean background levels for the three primary metals of interest are 12.7 mg/kg for arsenic, 34.4 mg/kg for copper, and 30 mg/kg for lead.

# 4. Background Evaluation Procedures

The background evaluation was conducted using combined soil data sets that were assembled from the three different data sources available for the Site, including the ESI (ADEQ, 2003), RA (E&E, 2004), and the current RI.

Upon review of the geologic map of the area (see Figure 3), the Hayden soils may be considered derived mainly from Ts, with younger Qal in the low lying wash areas. However, homes are generally not constructed in the low lying wash areas, and therefore the Ts geologic unit is of primary interest. Winkelman residential soils (with the exception of the WSCL sample locations) may be considered entirely derived from older Qo. Thus, to establish metal background concentrations for Hayden and Winkelman residential soils based on their geologic formation, only data from the Ts and Qo geologic map units were considered.

The primary approach consisted of establishing background levels for the geologic map units of interest (Ts and Qo) in accordance with EPA (2002). After the Ts and Qo datasets were compiled, a conventional statistical comparison of all data to establish background concentrations was performed.

## 4.1 Establish Ts and Qo Datasets

The initial Ts core background dataset included seven samples (four surface samples from the ESI and two surface and one subsurface sample from the RI). Because a relatively few number of background samples was available, further statistical data analysis was conducted to identify data that could be used to supplement the initial core background dataset. Attachment A presents three-dimensional (3-D) scatterplots of arsenic, copper, and

lead concentrations for all RI nonresidential soil samples collected from the Ts unit. These plots indicate that the 28 Winkelman School Complex Lobo Lane (designated "WSCL") samples, collected in the northwest portion of Winkelman and immediately west of the Winkelman school complex, cluster together and have notably lower concentrations than other Ts samples. The WSCL samples consist of 25 surface soil samples and 3 subsurface soil samples. To further evaluate the data, diagrams showing the cumulative frequency of arsenic, copper, and lead concentrations in various sample groups were prepared, in general accordance with EPA (2002), as presented in Attachment B. The cumulative frequency diagrams include the initial core Ts background samples combined with the 28 WSCL samples, and indicate that concentrations in this sample group plot well below other sample groups. Therefore, the initial core background samples and the WSCL samples were combined and used as the Ts background dataset (see Table 1).

For the Qo dataset, a total of six samples (five samples from the ESI and one surface soil sample from the RI) were used as the background data set (see Table 2).

## 4.2 Background Evaluation Using Statistical Evaluation

A statistical comparison to evaluate and establish background concentrations was performed for the Ts and Qo units. To perform the statistical comparison, the data sets were constructed for the Ts and Qo geological units. Then, ProUCL v.4.0 was used to identify any outliers and generate the summary statistics, including mean, standard deviation, minimum, maximum, and upper tolerance limit (UTL). The Dixon and Rosner's tests for outliers identified some data points as outliers, as indicated on Tables 1 and 2. The UTL parameter provides an accepted statistical method for determining a background value from a set of data (EPA, 2002). The UTL represents a value that 95 percent of the population will fall below with 95 percent confidence. Often, the UTL will be higher than the highest value in the background data set that was used to calculate the UTL. An adequate number of samples should be collected (ideally, eight samples per lithology or zone of concern, if available) for the UTL to represent site background conditions. The Ts dataset easily met the minimum sample number goal, but only six Qo samples were available. Because the Qo dataset are considered nonparametric, the maximum values are used for the UTLs. Any single data point from the site that exceeds the background UTL indicates that contamination is present. Only single data points are then to be compared to the background UTL.

Tables 1 and 2 present the summary statistics for the Ts and Qo units, respectively.

## 4.3 Additional Comparisons for Ts Dataset

Further evaluation of RI data was conducted for comparison of the Ts background arsenic, copper, and lead concentrations presented in Table 1. As indicated in the scatter plots in Attachment A, the lowest concentration Hayden residential subsurface samples appear to approach background concentrations, and therefore are likely not impacted by smelter operations. Data from the Hayden residential subsurface samples were grouped by zones, and scatterplots were created for data within these zones (see Attachment C). Although there is variability in the data, the samples from Zones 1-3, located in the southwest portion of Hayden and furthest from active operations, appear to plot near the lower end of the concentration ranges. Therefore, the 11 subsurface samples from Zones 1-3 were grouped

together and subjected to the same statistical evaluation as described above, using ProUCL. Outliers were identified within two of the samples. The source data and summary statistics for these samples from Zones 1-3 are presented in Table 5.

# 5. Results and Discussion

The background datasets for the Ts and Qo samples were selected based on a detailed statistical analysis of all available Site-specific data for these two geologic units. These new core background datasets are comprised of 35 Ts samples and six Qo samples and do not include any residential samples. Summary statistics, including mean and 95 percent UTLs for both Ts and Qo samples, are summarized in Table 6.

Based on Table 6, the overall background levels for arsenic, copper and lead, not taking into account geologic map units, are 6.3 mg/kg, 480.6 mg/kg, and 30 mg/kg, respectively.

Based on the evaluation of Ts data, the combined core background and WSCL sample dataset significantly increases the sample size, decreases the standard deviation, and provides greater confidence to the background values. As summarized in Table 6, the background mean and 95 percent UTL values are 6.3 and 12.5 mg/kg for arsenic, 460.5 and 1,270 mg/kg for copper, and 28.3 and 47.9 mg/kg for lead. For all three metals, the 95 percent UTL value is less than the maximum value for the background dataset.

Based on the evaluation of Qo data, the background mean and 95 percent UTL values are 6.3 and 9.1 mg/kg for arsenic, 500.8 and 882 mg/kg for copper, and 31.7 and 45.8 mg/kg for lead. For all three metals, the maximum value was used as the 95 percent UTL value as explained in section 4.2.

It is important to note that the arsenic, copper, and lead UTL values for the Qo dataset (9.1, 882, and 45.8 mg/kg, respectively) are in relatively close alignment with the UTL values for the Ts dataset (12.5, 1,270, and 47.9 mg/kg, respectively), indicating a relatively small difference associated with the Ts and Qo geologic settings. Based on Earth Technology Corporation (1991), the statewide averages for arsenic (12.7 mg/kg) and lead (30 mg/kg) are in relatively close alignment with these values; the statewide average for copper (34.4 mg/kg) is considerably less than the background values presented in this evaluation, but this is expected due to the Site's setting in a copper mineralization region.

# 6. References and Supporting Information

## 6.1 Publications

Arizona Department of Environmental Quality (ADEQ). 2003. *Expanded Site Inspection Report: ASARCO, Inc., Hayden Plant*. EPA ID No. AZD008397127. Prepared for the U.S. Environmental Protection Agency Region IX by ADEQ, Capacity Development Section, Site Assessment Unit. April 25.

CH2M HILL. 2007. Remedial Investigation Report for the ASARCO LLC Hayden Plant Site, Hayden, Gila County, Arizona. Prepared for the U.S. Environmental Protection Agency Region IX. January.

Earth Technology Corporation. 1991. Evaluation of Background Metals concentrations in Arizona Soils. Prepared for the Arizona Department of Environmental Quality Groundwater Hydrology Section. June.

Ecology and Environment, Inc. (E&E). 2004. *ASARCO Hayden Removal Assessment: Final Report*. Superfund Technical Assessment and Response Team, Contract No: 68-W-01-012. Prepared for the U.S. Environmental Protection Agency Region IX Emergency Response Section. December.

SHB – AGRA Earth & Environmental, Inc. (SHB) 1994. App Application Phase III, ASARCO, Inc. – Ray Complex, Gila and Pinal Counties, Arizona. March.

SHB Earth & Environmental, Inc. (SHB) 1992. APP Application Phase I, ASARCO, Inc. – Ray Complex, Gila and Pinal Counties, Arizona. June.

U.S. Environmental Protection Agency (EPA). 2002. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. EPA 540-R-01-003/OSWER 9585.7-41/September.

## 6.2 List of Figures

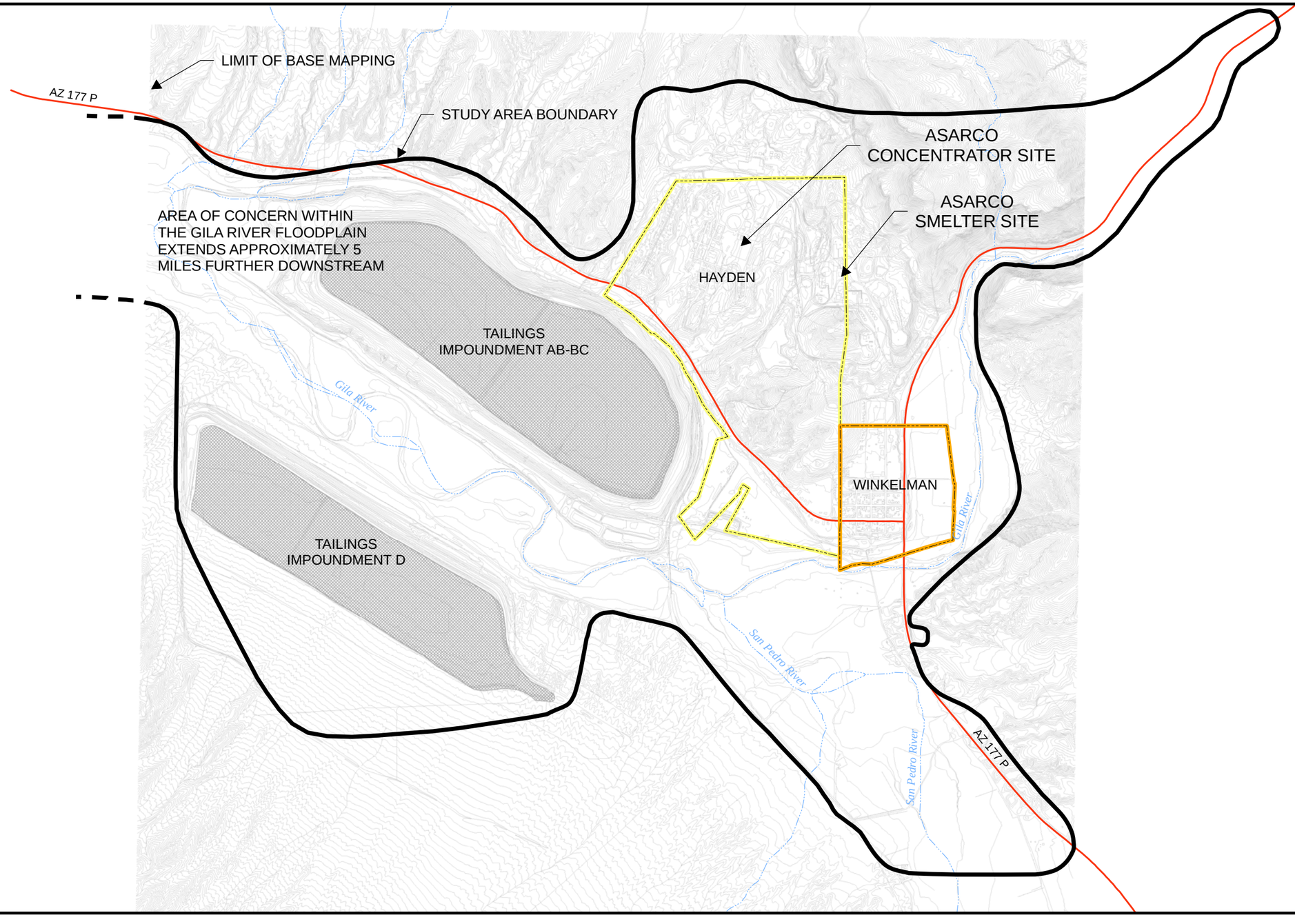


## 6.3 List of Tables



## 6.4 List of Attachments

# Figures




**Legend**

- Study Area Boundary
- Road
- River
- Active Tailings Impoundment
- Hayden Town Boundary
- Winkelman Town Boundary

N
W E
S

0 1,250 2,500 5,000 Feet

**FIGURE 1**
**SITE LOCATION MAP**

*ASARCO, LLC Hayden Plant Site*
*Hayden, Arizona*

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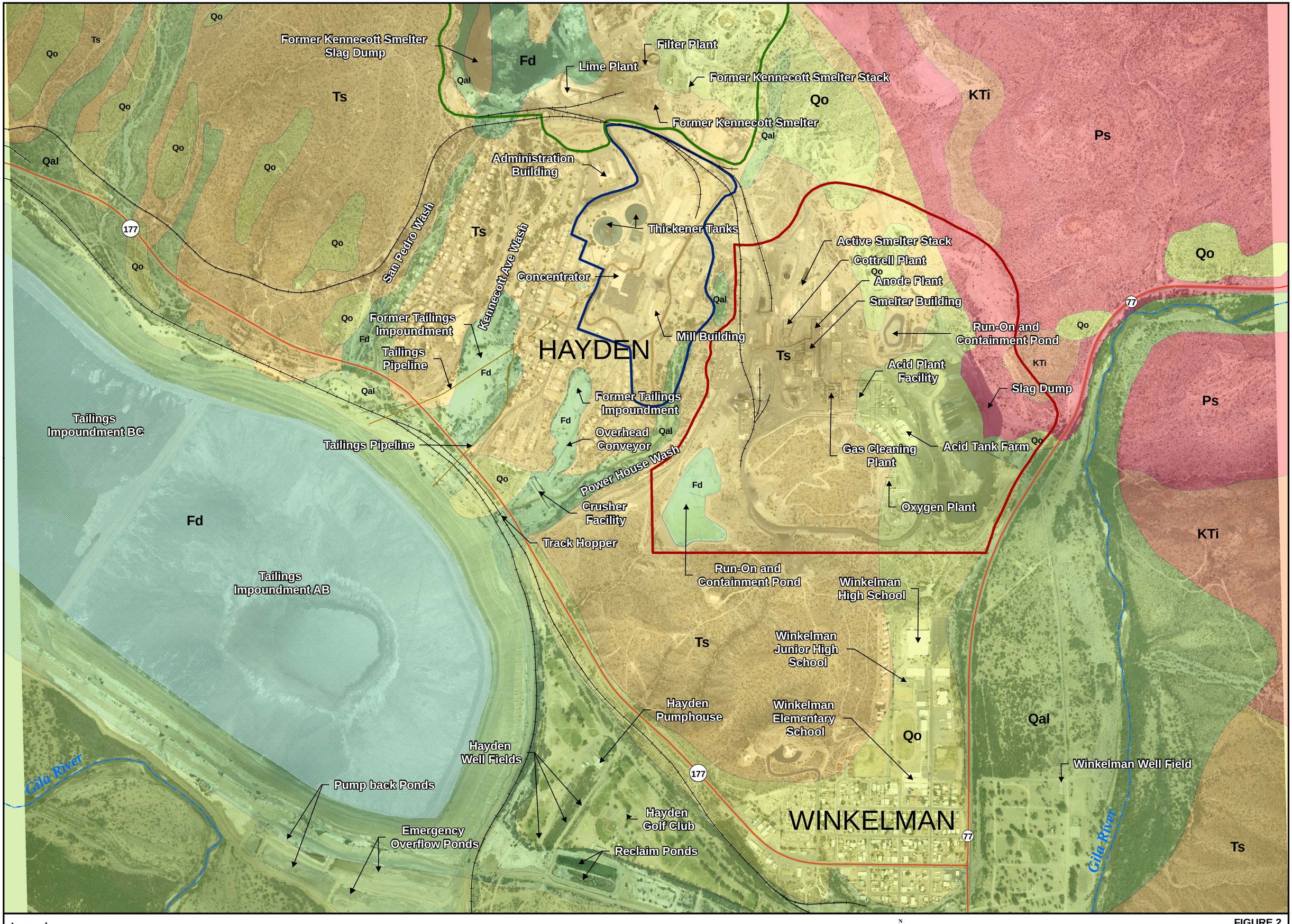


**Legend**

- Road
- Railroad
- River
- Tailings Pipeline - Above Ground
- Tailings Pipeline - Underground
- Active Tailings Impoundment
- ASARCO Hayden Smelter Boundary
- ASARCO Mill Boundary
- Former Kennecott Smelter Boundary

**Geology Formation**

- Fd - Fill Material
- Qal - Quaternary Alluvium
- Qo - Older Quaternary Deposits
- Ts - Tertiary Sediments and Airfall Deposits
- KTi - Cretzceous/Tertiary Intrusive and Volcanic
- Ps - Paleozoic Sediments and Metasediments

N W E S

0 350 700 1,400 Feet

Source: Sergent, Hauskins & Beckwith, 1992

**FIGURE 2**
**GEOLOGIC MAP OF SITE VICINITY**
*ASARCO, LLC Hayden Plant Site*
*Hayden, Arizona*

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BG-SS-02
BG-SS-03
BG-SS-01
BG-SS-04
Hayden
ASARCO Concentrator Site
ASARCO Smelter Site
Winkelman
UPA-09
TAILINGS IMPOUNDMENT AB-BC
UPA-07-SED-0
UPA-07-SED-0.66
TAILINGS IMPOUNDMENT D
WSCLA-01-SED-0 to WSCLA-10-SED-0
WSCLB-01-SED-0 to WSCLB-10-SED-0
WSCLC-01-SED-0 to WSCLC-10-SED-0
UPA-02-SED -0
UPA-02-SED-0.66
WSCLA-08-SED-0
WSCLA-09-SED-0
WSCLA-10-SED-0
WSCLA-04-SED-0
WSCLA-01-SED-0
WSCLA-03-SED-0
WSCLA-05-SED-0
WSCLA-07-SED-0
WSCLB-01-SED-0
WSCLB-09-SED-0
WSCLB-10-SED-0
WSCLB-08-SED-0
WSCLB-06-SED-0
WSCLB-02-SED-0
WSCLB-03-SED-0
WSCLB-05-SED-0
WSCLB-07-SED-0
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WSCLC-01-SED-0
WSCLC-07-SED-0
WSCLC-08-SED-0
WSCLC-02-SED-0
WSCLC-09-SED-0
WSCLC-04-SED-0
WSCLC-03-SED-0
WSCLC-05-SED-0
WSCLC-06-SED-0
BKG-1
BKG-2
BKG-3
BKG-5
BKG-6

**Legend**

- Tertiary Sediment Samples (Ts)
- Older Quaternary Deposit Samples (Qo)
- Active Tailings Impoundment

**Notes:**
BG-SS samples: ADEQ Background - from "Expanded Site Inspection Report, ASARCO Inc., Hayden Plant Site" (ADEQ, 2003)
WSCL samples: RI - Remedial Investigation (being conducted by EPA)
BKG samples: RA Background - from "ASARCO Hayden Removal Assessment Final Report" (Ecology & Environment, Inc., 2004)
UPA samples: RI - Remedial Investigation (being conducted by EPA)

**Basemap Source:** USGS Topos (DRGs), 7.5-minute, 1:24,000-scale quadrangle series

N
W E
S

0 0.75 1.5 3 Miles

# FIGURE 3
# BACKGROUND SAMPLE LOCATIONS

ASARCO, LLC Hayden Plant Site
Hayden, Arizona

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# Tables

**TABLE 1**

Background Soil Sample Data for Tertiary Sediment Geologic Map Unit

| Sample Date | Sample ID | Location Group | Relative Location | As | Cu | Pb |
|---|---|---|---|---|---|---|
| 02/24/2006 | WSCLA-01-SED-0 | WSCLA - RI | Surface | 5.3 | 448 | 25.1 |
| 02/24/2006 | WSCLA-03-SED-0 | WSCLA - RI | Surface | 7.8 | 568 | 47.9 |
| 02/24/2006 | WSCLA-04-SED-0 | WSCLA - RI | Surface | 9.1 | 489 | 31.2 |
| 02/24/2006 | WSCLA-05-SED-0 | WSCLA - RI | Surface | 10.3 | 2480a | 84.5a |
| 02/24/2006 | WSCLA-07-SED-0 | WSCLA - RI | Surface | 8.3 | 2670a | 91.4a |
| 02/24/2006 | WSCLA-08-SED-0 | WSCLA - RI | Surface | 4.3 | 193 | 24.2 |
| 02/24/2006 | WSCLA-09-SED-0 | WSCLA - RI | Surface | 9.7 | 205 | 24.7 |
| 02/24/2006 | WSCLA-10-SED-0 | WSCLA - RI | Subsurface | 5.5 | 49.3 | 16.5 |
| 02/24/2006 | WSCLB-01-SED-0 | WSCLB - RI | Surface | 7.5 | 144 | 23.6 |
| 02/24/2006 | WSCLB-02-SED-0 | WSCLB - RI | Surface | 3.8 | 369 | 23.3 |
| 02/24/2006 | WSCLB-03-SED-0 | WSCLB - RI | Surface | 5.2 | 302 | 24.9 |
| 02/24/2006 | WSCLB-04-SED-0 | WSCLB - RI | Surface | 7.2 | 113 | 21.1 |
| 02/24/2006 | WSCLB-05-SED-0 | WSCLB - RI | Surface | 5.3 | 542 | 30.1 |
| 02/24/2006 | WSCLB-06-SED-0 | WSCLB - RI | Surface | 6.5 | 1380 | 38.7 |
| 02/24/2006 | WSCLB-07-SED-0 | WSCLB - RI | Surface | 6.5 | 1270 | 38 |
| 02/24/2006 | WSCLB-08-SED-0 | WSCLB - RI | Surface | 6.1 | 668 | 27 |
| 02/24/2006 | WSCLB-09-SED-0 | WSCLB - RI | Surface | 3.5 | 715 | 29.3 |
| 02/24/2006 | WSCLB-10-SED-0 | WSCLB - RI | Subsurface | 6.3 | 85.2 | 18.4 |
| 02/24/2006 | WSCLC-01-SED-0 | WSCLC - RI | Surface | 3.5 | 350 | 19.4 |
| 02/24/2006 | WSCLC-02-SED-0 | WSCLC - RI | Surface | 4.2 | 501 | 19.6 |
| 02/24/2006 | WSCLC-03-SED-0 | WSCLC - RI | Surface | 1.9 | 181 | 24.3 |
| 02/24/2006 | WSCLC-04-SED-0 | WSCLC - RI | Surface | 4.4 | 174 | 15.8 |
| 02/24/2006 | WSCLC-05-SED-0 | WSCLC - RI | Surface | 6.2 | 203 | 14.8 |
| 02/24/2006 | WSCLC-06-SED-0 | WSCLC - RI | Surface | 2.6 | 64.3 | 9.6 |
| 02/24/2006 | WSCLC-07-SED-0 | WSCLC - RI | Surface | 6.9 | 930 | 37 |
| 02/24/2006 | WSCLC-08-SED-0 | WSCLC - RI | Surface | 5 | 418 | 20.6 |
| 02/24/2006 | WSCLC-09-SED-0 | WSCLC - RI | Surface | 5 | 659 | 30.7 |
| 02/24/2006 | WSCLC-10-SED-0 | WSCLC - RI | Subsurface | 2.8 | 71.6 | 11.9 |
| 05/31/2002 | BG-SS-01 | ADEQ Background | Surface | 4.6 | 501 | 52.3 |
| 05/31/2002 | BG-SS-02 | ADEQ Background | Surface | 53.8[a] | 2700[a] | 17900[a] |
| 08/07/2002 | BG-SS-03 | ADEQ Background | Surface | 14 | 840 | 1600[a] |
| 08/07/2002 | BG-SS-04 | ADEQ Background | Surface | 12 | 650 | 1700[a] |
| 02/22/2006 | UPA-09 | RI Background | Surface | 12.5 | 3250[a] | 84.4 |
| 02/22/2006 | UPA-02-SED -0 | RI Background | Surface | 5.8 | 983 | 46.7 |
| 02/22/2006 | UPA-02-SED-0.66 | RI Background | Subsurface | 4.6 | 210 | 17.5 |
| **SUMMARY STATISTICS** | | | n | 34 | 31 | 30 |
| | | | mean | 6.3 | 460.5 | 28.3 |
| | | | std dev | 2.8 | 349.1 | 14.9 |
| | | | min | 1.9 | 49.3 | 9.6 |
| | | | max | 14 | 1380 | 84.4 |
| | | | UTL | 12.5 | 1270 | 47.9 |
| | | | Distribution | Gamma | Gamma | Gamma |

Notes:

All concentrations are in mg/kg

All summary statistics generated using ProUCL v4.0
a Identified as an outlier by Dixon's Outlier Test, $p<0.01$, using ProUCL v4.0
n - number of samples
std dev - standard deviation
UTL - upper tolerance limit
RI - Remedial Investigation (being conducted by EPA)
ADEQ Background - from "Expanded Site Inspection Report, ASARCO Inc., Hayden Plant Site" (ADEQ, 2003)

TABLE 2

Background Soil Sample Data for Older Quaternary Deposits Geologic Map Unit

| Sample Date | Sample ID | Location Group | As | Cu | Pb |
|---|---|---|---|---|---|
| 2/22/2007 | UPA-07-SED-0 | RI Background | 9.1 | 882 | 41.1 |
| 10/21/2004 | BKG-1-10212004 | RA Background | 2.99 | 251 | 18.1 |
| 10/21/2004 | BKG-2-10212004 | RA Background | 4.57 | 639 | 45.8 |
| 10/21/2004 | BKG-3-10212004 | RA Background | 6.46 | 145 | 22 |
| 10/21/2004 | BKG-5-10212004 | RA Background | 8.53 | 687 | 27.5 |
| 10/21/2004 | BKG-6-10212004 | RA Background | 6.43 | 401 | 35.5 |
| **SUMMARY STATISTICS:** | | | | | |
| | | n | 6 | 6 | 6 |
| | | mean | 6.3 | 500.8 | 31.7 |
| | | std | 2.3 | 282.1 | 10.9 |
| | | min | 2.99 | 145 | 18.1 |
| | | max | 9.1 | 882 | 45.8 |
| | | UTL | 9.1 | 882 | 45.8 |
| | | Distribution | Normal | Normal | Normal |

Notes:

All concentrations are in mg/kg

All summary statistics generated using ProUCL v4.0

n - number of samples

std dev - standard deviation

UTL - upper tolerance limit (in this case, the maximum value)

RI - Remedial Investigation (being conducted by EPA)

RA Background - from "ASARCO Hayden Removal Assessment Final Report" (Ecology & Environment, Inc., 2004)

**TABLE 3**
Concentrations of Selected Metals in USGS and ADEQ Soil Samples

| Metal | USGS Soils Samples Metal Concentrations (mg/Kg) | | | | ADEQ Soil Samples Metal Concentrations (mg/Kg) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Std Dev** | **Max** | **Min** | **Mean** | **Std Dev** | **Max** | **Min** |
| Aluminum | 55,213 | 28,246 | 100,000 | 3 | 10,654 | 2,859 | 16,817 | 6,200 |
| Antimony | <1 | 0 | <1 | <1 | 1.7 | 1.81 | 3.8 | <0.4 |
| **Arsenic** | **9.8** | **17.2** | **97** | **1.4** | **9.4** | **3.8** | **24** | **3.1** |
| Barium | 565 | 269.7 | 1,500 | 200 | 161.3 | 30.5 | 230 | 72.6 |
| Beryllium | 0.52 | 1.01 | 5 | ND | 1.1 | 0.9 | 2.0 | 0.3 |
| Cadmium | - | - | - | - | 0.4 | 0.4 | 1.7 | ND |
| Chromium | 61.3 | 66 | 300 | 5 | 17.5 | 7.0 | 34 | 5.4 |
| Cobalt | 9.7 | 6.3 | 30 | ND | - | - | - | - |
| **Copper** | **30** | **30.5** | **200** | **5** | **16.6** | **5.9** | **27** | **6.0** |
| **Lead** | **23.4** | **20.7** | **100** | **ND** | **7.7** | **4.8** | **24.5** | **ND** |
| Mercury | 0.10 | 0.13 | 0.57 | 0.01 | 0.05 | 0.2 | 0.25 | ND |
| Molybdenum | 3.0 | 2.8 | 3.0 | ND | - | - | - | - |
| Nickel | 27.5 | 30.5 | 150 | ND | 18.2 | 5.3 | 28 | 9.2 |
| Selenium | 0.30 | 0.26 | 1.6 | <0.1 | 0.6 | 0.3 | 1.0 | <0.4 |
| Silver | - | - | - | - | 0.5 | 0.4 | 0.8 | <0.05 |
| Thallium | - | - | - | - | 0.7 | 0.4 | <1.0 | 0.5 |
| Vanadium | 71.3 | 46.4 | 300 | 10 | 12 | 16.7 | 23.8 | <0.2 |
| Zinc | 62.1 | 34 | 150 | 12 | 38.9 | 16.4 | 81 | 15 |

Notes:

USGS and ADEQ soil sample data was obtained from “Evaluation of Background Metals Concentrations in Arizona Soils,” Earth Technology Corporation, 1991.

ND = not detected

- = no data available

**TABLE 4**
Comparison of Selected Average Metal Concentrations in Soils from USGS Samples by Physiographic Provinces in Arizona

| Metal | Colorado Plateau (mg/Kg) | Transition Zone and Basin and Range (mg/Kg) |
|---|---|---|
| Aluminum | 39,118 | 66,667 |
| Antimony | 1 | 1 |
| **Arsenic** | **4.4** | **12.7** |
| Barium | 441 | 617 |
| Beryllium | ND | 2.5 |
| Cadmium | - | - |
| Chromium | 36.7 | 85.2 |
| Cobalt | 5.4 | 12.8 |
| **Copper** | **14.1** | **34.4** |
| **Lead** | **13.8** | **30** |
| Mercury | 0.05 | 0.12 |
| Molybdenum | ND | 0.75 |
| Nickel | 12.8 | 40.5 |
| Selenium | 0.2 | 0.3 |
| Silver | - | - |
| Thallium | - | - |
| Vanadium | 39.4 | 93.8 |
| Zinc | 35.6 | 72.8 |

Notes:

USGS soil sample data was obtained from “Evaluation of Background Metals Concentrations in Arizona Soils,” Earth Technology Corporation, 1991.

ND = not detected

- = no data available

**TABLE 5**

Summary Statistics for Selected Hayden Residential Subsurface Samples Collected in Tertiary Sediment Geologic Unit

| Sample Date | Sample ID | Zone | Relative Location | As | Cu | Pb |
|---|---|---|---|---|---|---|
| 09/12/2007 | HSS-C-1-101-07-185C | 1 | Subsurface | 7.6 | 121 | 22.4 |
| 09/13/2007 | HSS-C-1-101-07-193A | 1 | Subsurface | 6.6 | 478 | 117 |
| 09/16/2007 | HSS-G-1-101-07-216 | 1 | Subsurface | 4.5 | 97.2 | 283 |
| 09/05/2007 | HSS-G-1-101-07-244 | 2 | Subsurface | 16.5 | 3.3 | 202 |
| 09/06/2007 | HSS-E-1-101-07-247 | 2 | Subsurface | 25.4 | 1.1 | 419 |
| 12/06/2006 | HSS-C-1-101-07-176 | 2 | Subsurface | 4.6 | 544 | 36.5 |
| 09/16/2007 | HSS-H-1-101-07-202 | 2 | Subsurface | 4.6 | 497 | 67.1 |
| 09/04/2007 | HSS-H-1-101-07-242 | 2 | Subsurface | 8.4 | 1030 | 71.9 |
| 09/17/2007 | HSS-E-1-101-07-219 | 3 | Subsurface | 55.1 | 11.6 | 639 |
| 09/01/2007 | HSS-F-1-101-07-236 | 3 | Subsurface | 62.1 | 5.9 | 588 |
| 09/17/2007 | HSS-I-1-101-07-234 | 3 | Subsurface | 25.8a | 2600a | 506a |
| **SUMMARY STATISTICS** | | | | | | |
| | | | n | 10 | 10 | 10 |
| | | | mean | 5.82 | 461.52 | 75.7 |
| | | | std dev | 2.929 | 278.3 | 78.73 |
| | | | min | 1.1 | 97.2 | 16.5 |
| | | | max | 11.6 | 1030 | 283 |
| | | | 95% UCL | 7.518 | 622.8 | 132.3 |
| | | | UCL Basis | t UCL | Student's-t | Approximate |
| | | | 95/95 UTL | 14.3 | 1272 | 304.9 |
| | | | Distribution | Normal | Normal | Gamma |

Notes:

All concentrations are in mg/kg

All summary statistics generated using ProUCL v4.0

a Identified as an outlier by Dixon's Outlier Test, p<0.01, using ProUCL v4.0

n - number of samples

std dev - standard deviation

UTL - upper tolerance limit

All samples collected during the RI - Remedial Investigation (being conducted by EPA)

TABLE 6
Comparison of Mean and Upper Tolerance Limit Background Values for Hayden ASARCO Smelter Site with State-wide Background Values for Transition and Basin and Range Provinces

| Metal | Transition Zone and Basin and Range Background – Mean[a] | Overall Site Background-Mean[b] | Ts Background–Mean[c] | Ts Background – UTL[c] | Selected Hayden Ts Residential Subsurface – Mean[d] | Selected Hayden Ts Residential Subsurface – UTL[d] | Qo Background – Mean[e] | Qo Background – UTL[e] |
|---|---|---|---|---|---|---|---|---|
| Arsenic | 12.7 | 6.3 | 6.3 | 12.5 | 5.8 | 11.6 | 6.3 | 9.1 |
| Copper | 34.4 | 480.6 | 460.5 | 1,270 | 461.5 | 1,030 | 500.8 | 882 |
| Lead | 30 | 30 | 28.3 | 47.9 | 75.7 | 283 | 31.7 | 45.8 |

Notes:

All concentrations in mg/kg.

[a]Based on "Evaluation of Background Metals Concentrations in Arizona Soils" (Earth Technology Corporation, 1991)

[b]Based on all available site background samples, regardless of geologic map unit location (2003 ESI, 2004 RA, and current RI)

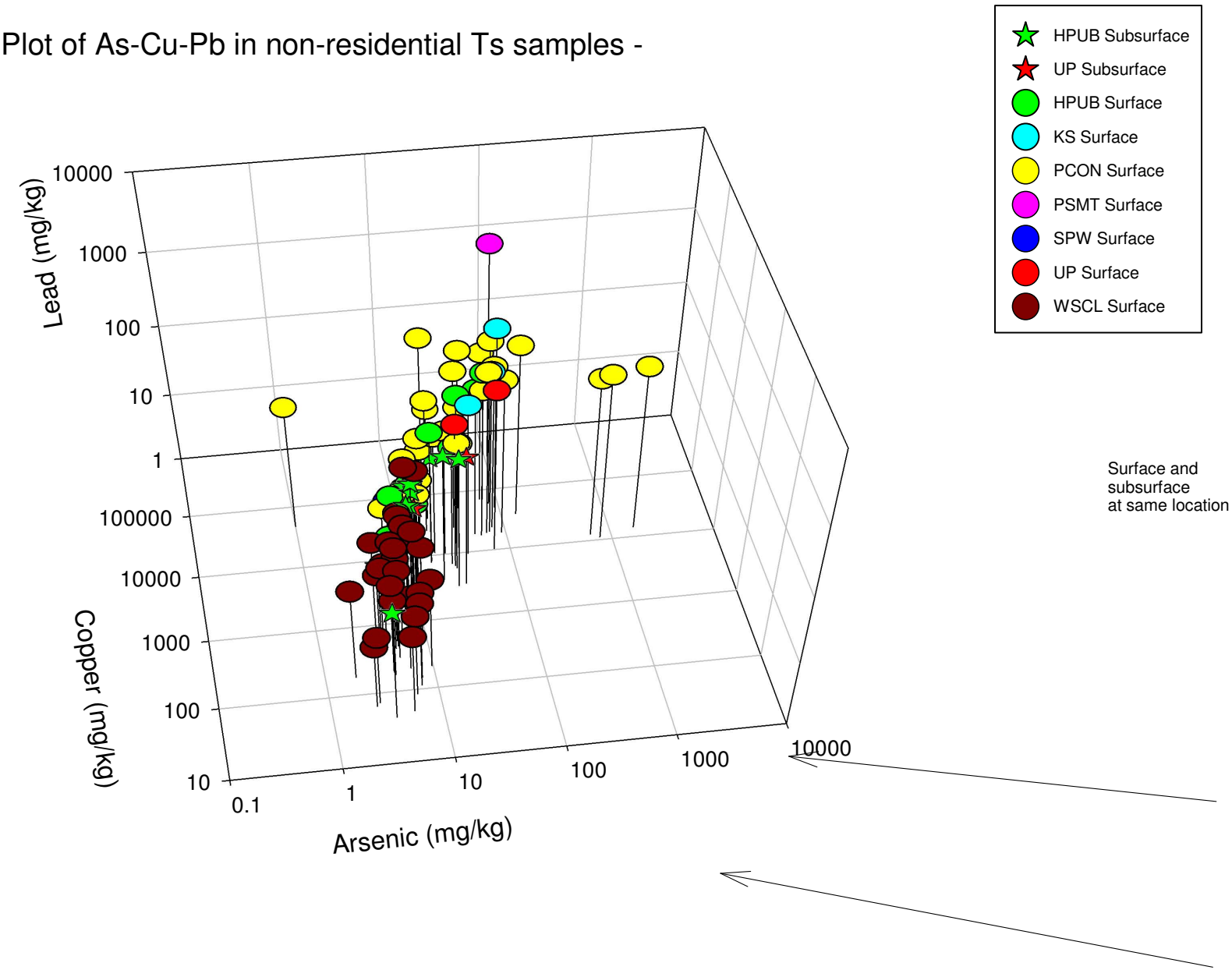
[c]Background soil sample data for Tertiary Sediment (Ts) geologic map unit, included expanded RI dataset; UTL - upper tolerance limit

[d] Comparison values only - based on current RI Hayden residential subsurface samples from Zones 1-3

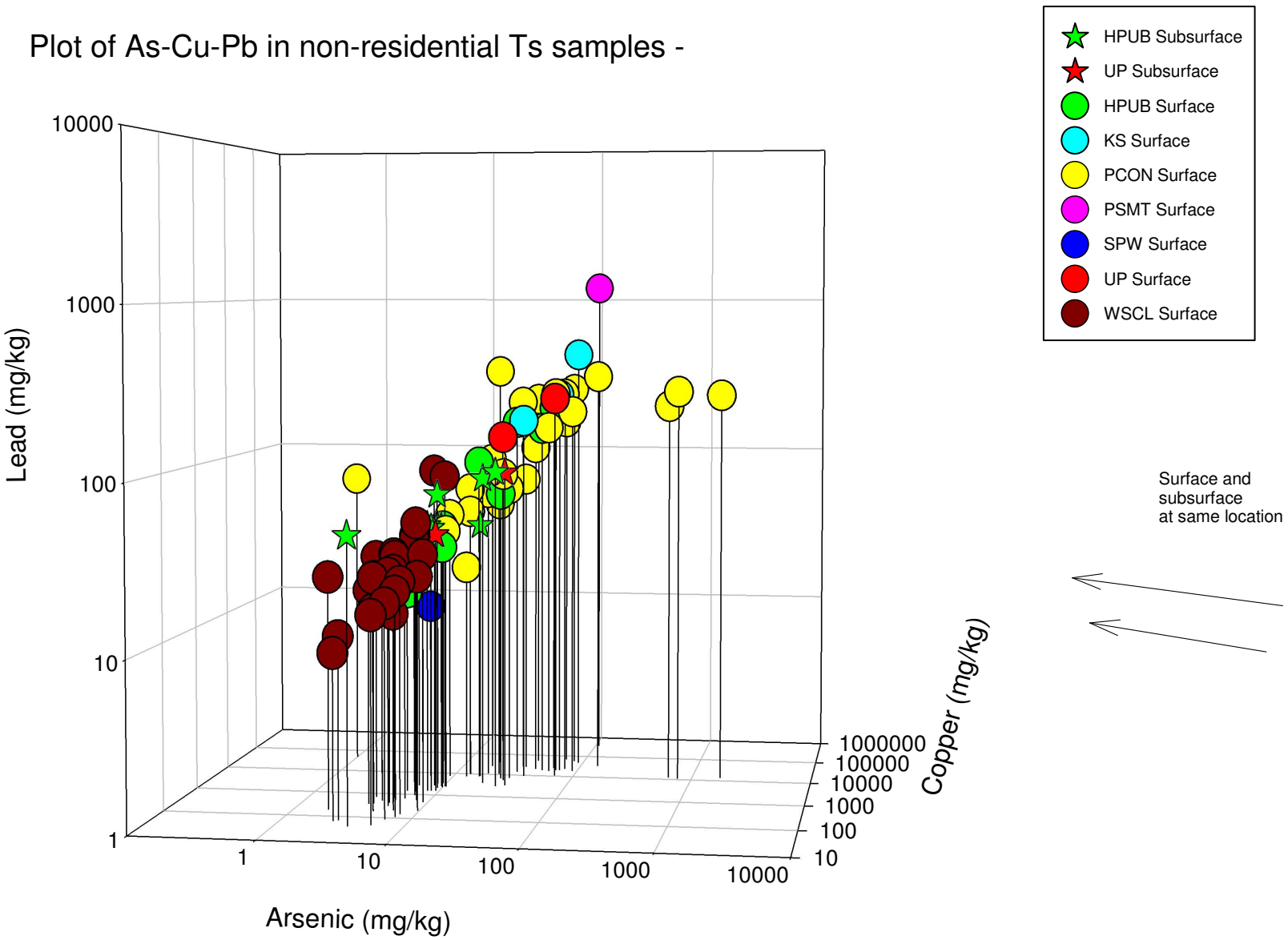
[e] Background soil sample data for Older Quaternary Deposits (Qo) geologic map unit; UTL - upper tolerance limit

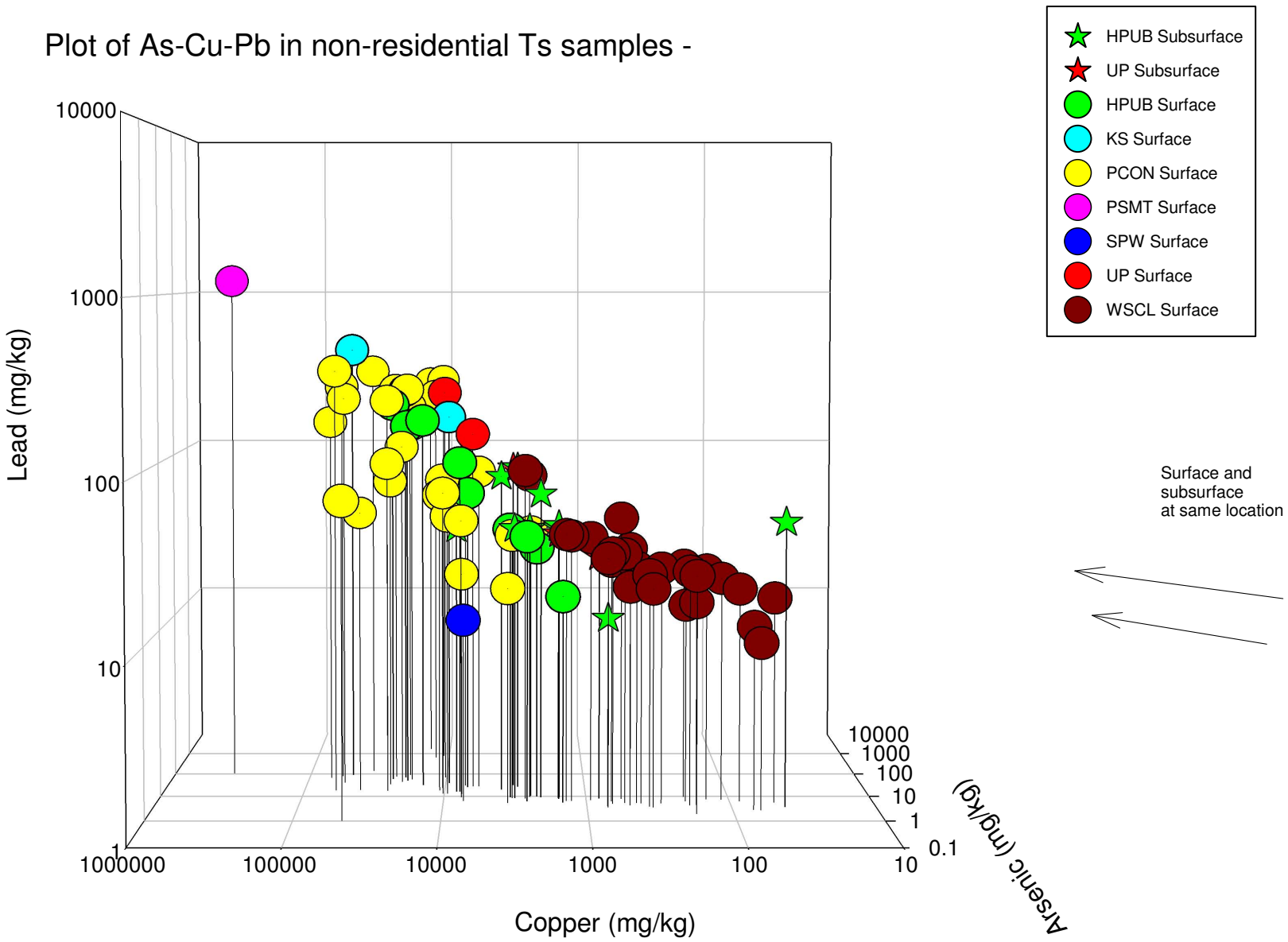
# Attachment A - Three-Dimensional Scatterplots of Selected Non-Residential Ts Data

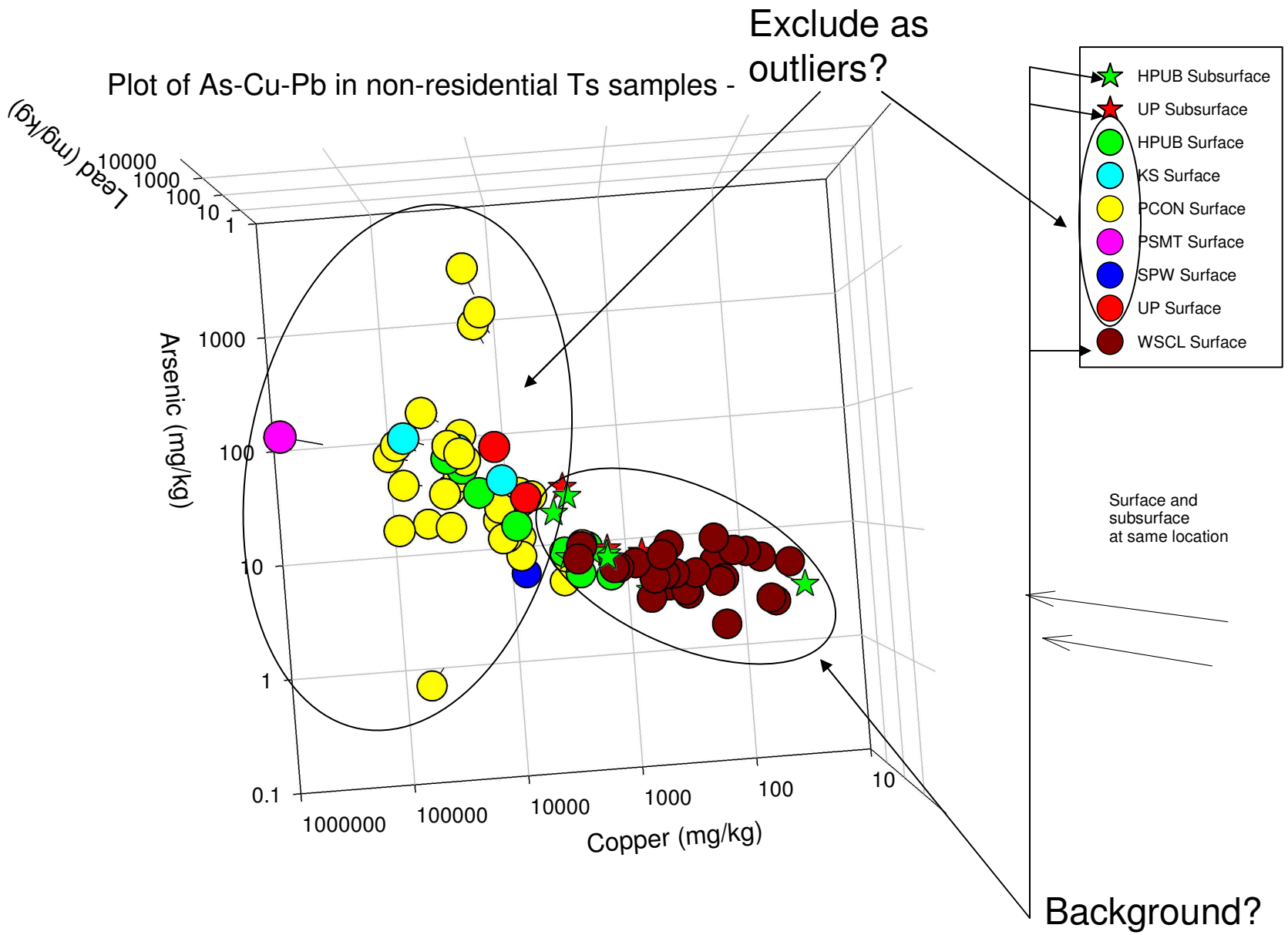
# Plot of As-Cu-Pb in non-residential Ts samples -



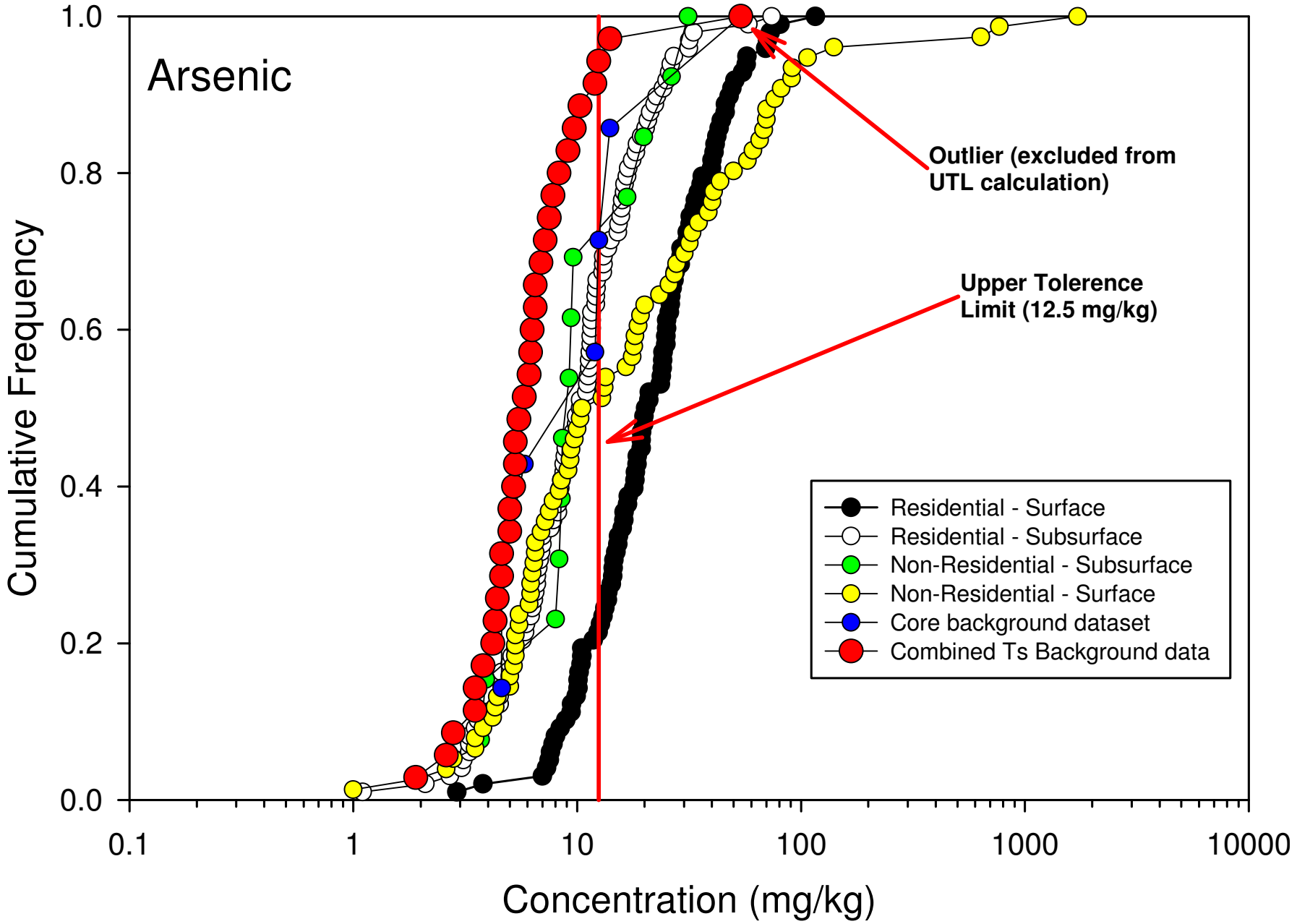
# Plot of As-Cu-Pb in non-residential Ts samples -

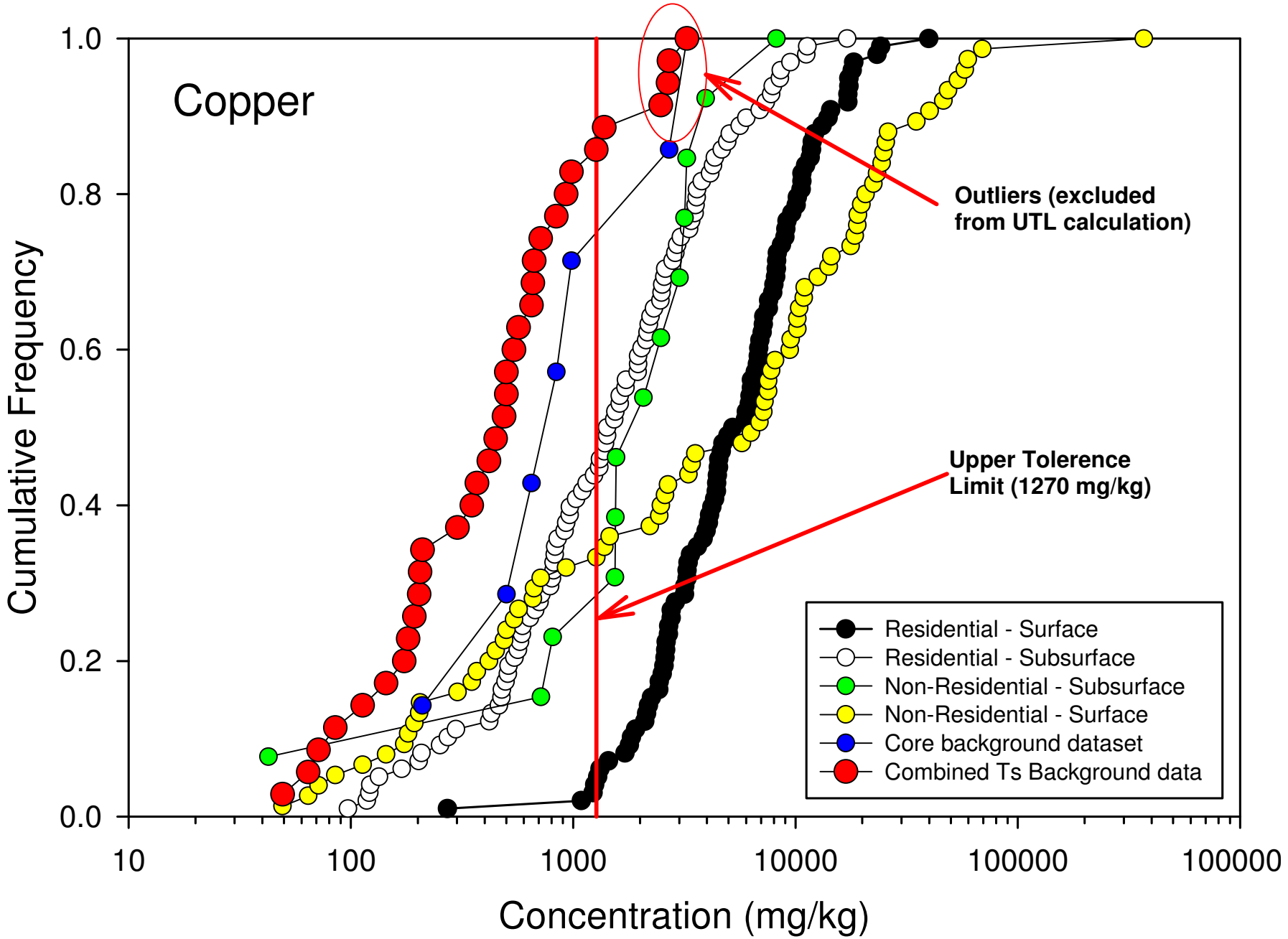


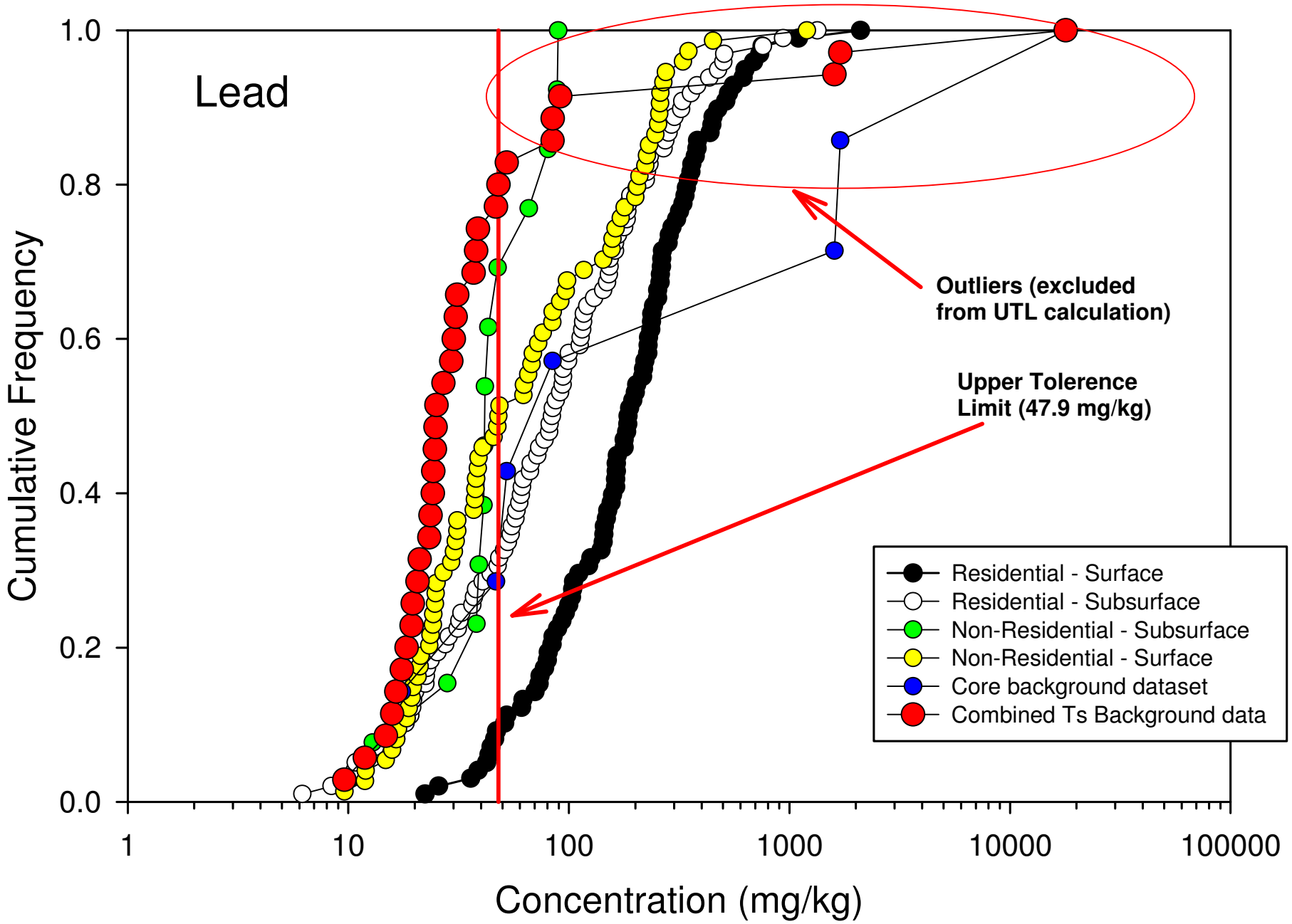

Plot of As-Cu-Pb in non-residential Ts samples -
HPUB Subsurface
UP Subsurface
HPUB Surface
KS Surface
PCON Surface
PSMT Surface
SPW Surface
UP Surface
WSCL Surface
Surface and subsurface at same location
Lead (mg/kg)
10000
1000
100
10
1
Copper (mg/kg)
1000000
100000
10000
1000
100
10
Arsenic (mg/kg)
10000
1000
100
10
1
0.1


Plot of As-Cu-Pb in non-residential Ts samples -
Exclude as outliers?
Lead (mg/kg)
10000
1000
100
10
1
Arsenic (mg/kg)
1000
100
10
1
0.1
1000000
100000
10000
1000
100
10
Copper (mg/kg)
HPUB Subsurface
UP Subsurface
HPUB Surface
KS Surface
PCON Surface
PSMT Surface
SPW Surface
UP Surface
WSCL Surface
Surface and subsurface at same location
Background?

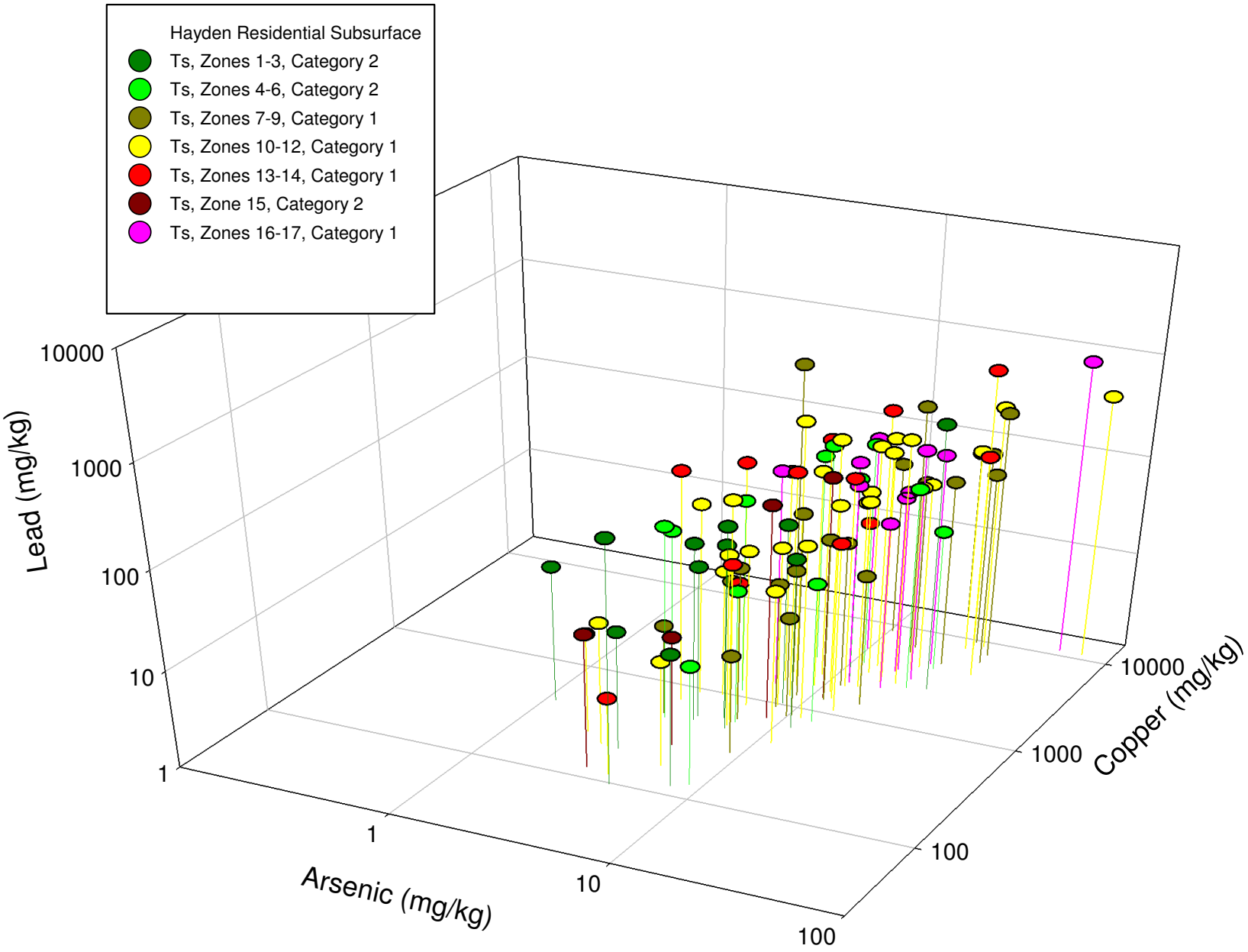
# Attachment B – Cumulative Frequency Diagrams for Selected Ts Data


Arsenic
Cumulative Frequency
1.0
0.8
0.6
0.4
0.2
0.0
0.1
1
10
100
1000
10000
Concentration (mg/kg)
Outlier (excluded from UTL calculation)
Upper Tolerence Limit (12.5 mg/kg)
Residential - Surface
Residential - Subsurface
Non-Residential - Subsurface
Non-Residential - Surface
Core background dataset
Combined Ts Background data

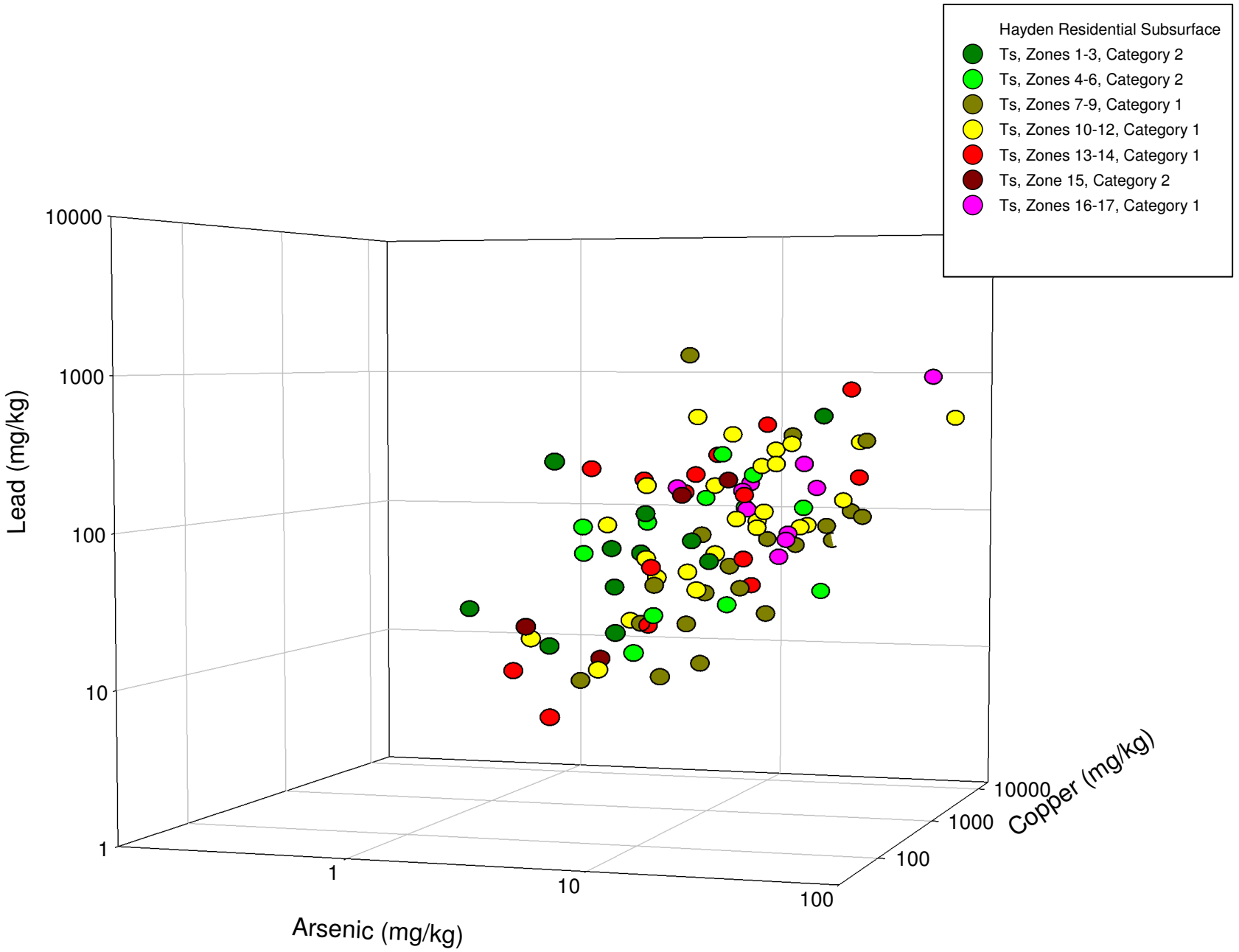

Copper
Cumulative Frequency
1.0
0.8
0.6
0.4
0.2
0.0
10
100
1000
10000
100000
100000
Concentration (mg/kg)
Outliers (excluded from UTL calculation)
Upper Tolerence Limit (1270 mg/kg)
Residential - Surface
Residential - Subsurface
Non-Residential - Subsurface
Non-Residential - Surface
Core background dataset
Combined Ts Background data


Lead
Cumulative Frequency
1.0
0.8
0.6
0.4
0.2
0.0
1
10
100
1000
10000
100000
Concentration (mg/kg)
Outliers (excluded from UTL calculation)
Upper Tolerence Limit (47.9 mg/kg)
Residential - Surface
Residential - Subsurface
Non-Residential - Subsurface
Non-Residential - Surface
Core background dataset
Combined Ts Background data

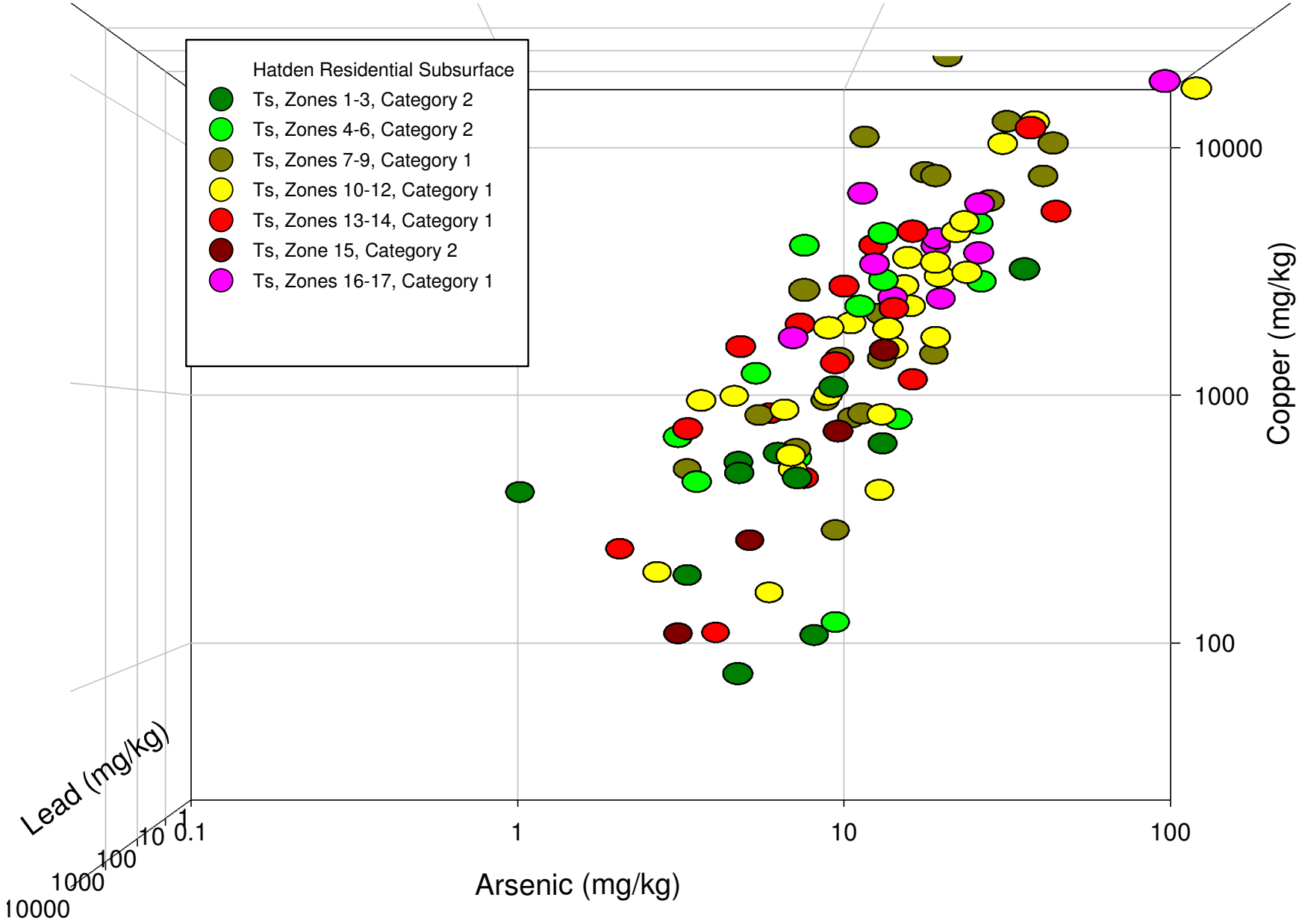
# Attachment C – Three-Dimensional Scatterplots of Selected Residential Ts Data



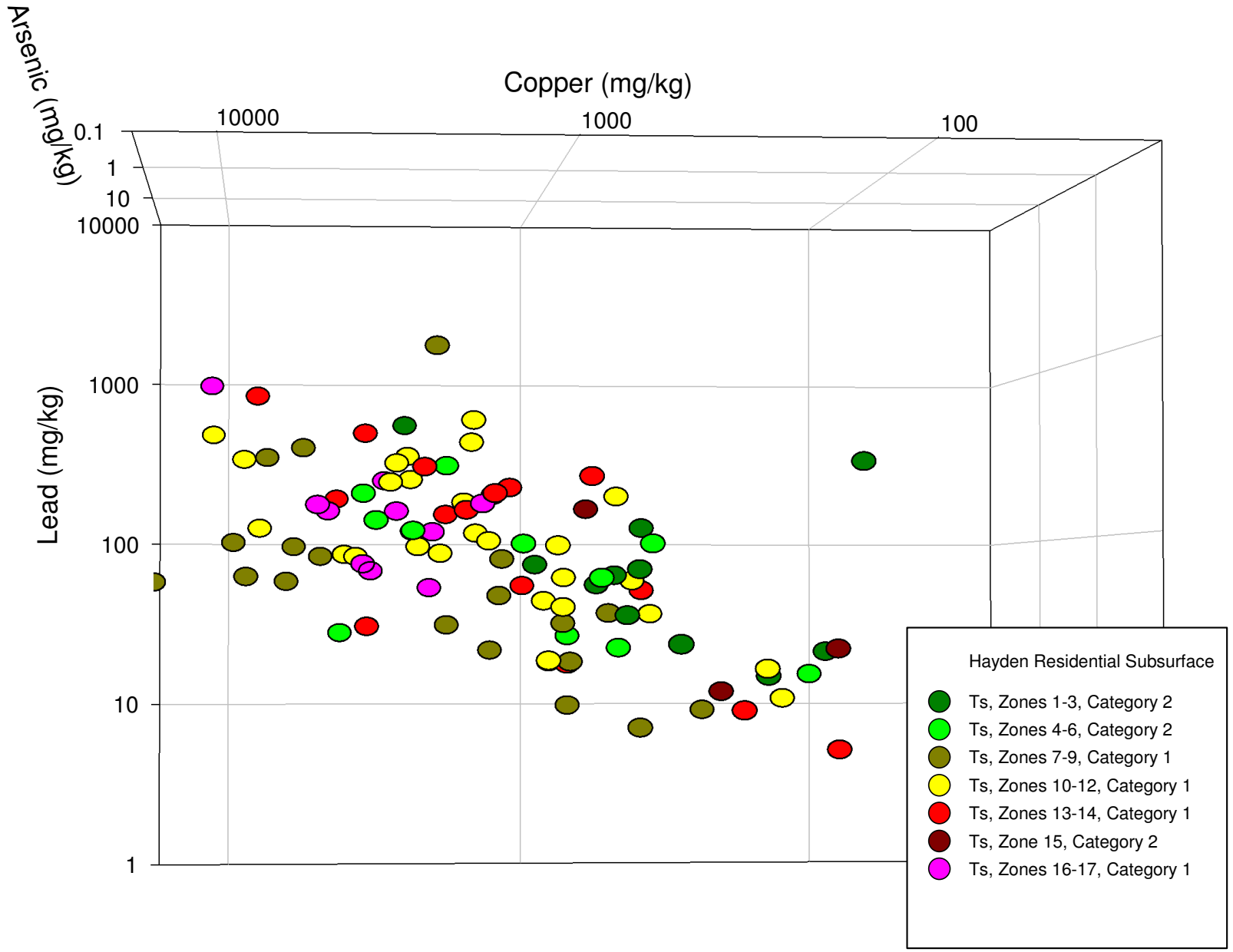

Plot of As-Cu-Pb in Hayden Residential Subsurface Samples, by zone



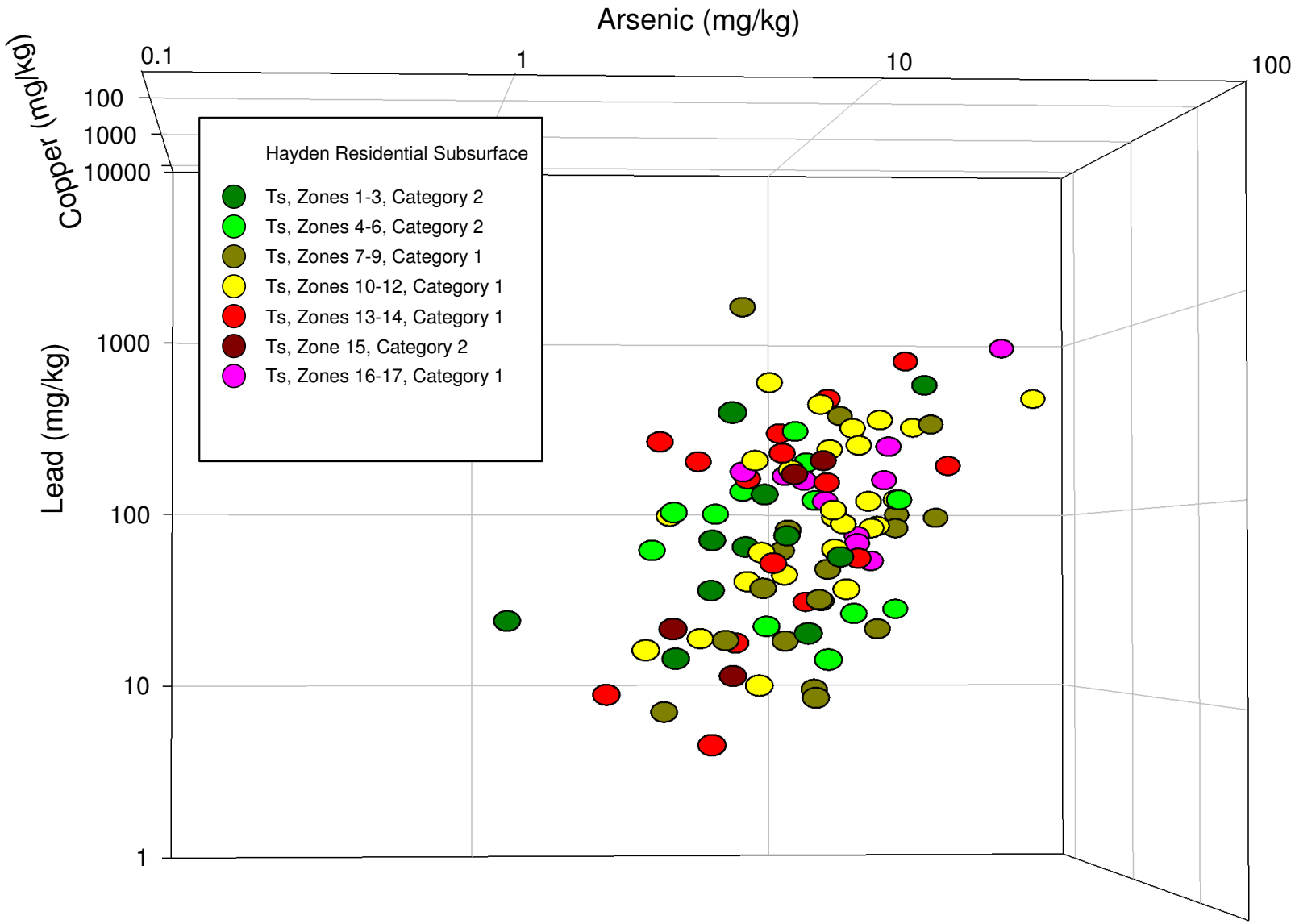

Plot of As-Cu-Pb in Hayden Residential Subsurface Samples, by zone




Plot of As-Cu-Pb in Hayden Residential Subsurface Samples, by zone




Plot of As-Cu-Pb in Hayden Residential Subsurface Samples, by zone




Plot of As-Cu-Pb in Hayden Residential Subsurface Samples, by zone