



In cooperation with the Bureau of Indian Affairs

Geochemical Data from Analyses of Rock, Sediment, Water, and Solid-Phase Leaching at the Tuba City Open Dump, Tuba City, Arizona

By Raymond H. Johnson, James K. Otton, Robert J. Horton, Tanya J. Gallegos,
LaDonna M. Choate, and Jonah E. Sullivan



Open-File Report 2008–1374

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia 2008

For product and ordering information:
World Wide Web: <http://www.usgs.gov/pubprod>
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: <http://www.usgs.gov>
Telephone: 1-888-ASK-USGS

Suggested citation:
Johnson, R.H., Otton, J.K., Horton, R.J., Gallegos, T.J., Choate, L.M., and Sullivan, J.E., 2008,
Geochemical data from analyses of rock, sediment, water, and solid-phase leaching at the Tuba
City Open Dump, Tuba City, Arizona: U.S. Geological Survey Open-File Report 2008–1374,
10 p.

Any use of trade, product, or firm names is for descriptive purposes only and does not imply
endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual
copyright owners to reproduce any copyrighted material contained within this report.

Contents

Abstract	1
Introduction	1
Acknowledgments	2
Data Collection and Analytical Methods	2
Water	2
Rock and Sediment	3
Solid-Phase Leaching	4
Data Summary	4
References Cited	5

Figures

1. Location map.....	7
2. Rock sample locations	8
3. Monitoring well locations	9
4. Sediment, boring, snow, and residence sample locations.....	10

Tables

1. Well, piezometer, snow, and rock sample locations	open Excel file
2. Piezometer completion details	open Excel file
3. Water-level data	open Excel file

4. Water chemistry data from piezometers, MW-23, multiple depths in MW-15,
and one residence on Tuba City municipal water [open Excel file](#)
5. Down-hole logging data for field parameters..... [open Excel file](#)
6. Water geochemistry from split samples collected by Stantec and analyzed
by the USGS Minerals Laboratory, Denver, Colorado [open Excel file](#)
7. Water geochemistry from snow samples..... [open Excel file](#)
8. Data for tritium and geochemistry at selected wells [open Excel file](#)
9. Whole rock data [open Excel file](#)
10. Leachate data from deionized water leaching procedure
(modified EPA 1312) [open Excel file](#)
11. Leachate data from toxic characteristics leaching procedure
(modified EPA 1311) [open Excel file](#)

Abbreviations

ppm = parts per million

ppb= parts per billion

$\mu\text{S}/\text{cm}$ = microSiemens per centimeter

mg/L = milligrams per liter

$\mu\text{g}/\text{L}$ = micrograms per liter

Chemical element and constituent abbreviations are provided on a separate worksheet for each table in online files.

Conversion Factors

Temperature in degrees Celsius ($^{\circ}\text{C}$) may be converted to degrees Fahrenheit ($^{\circ}\text{F}$) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Temperature in degrees Fahrenheit ($^{\circ}\text{F}$) may be converted to degrees Celsius ($^{\circ}\text{C}$) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8$$

Horizontal coordinate information is referenced to the World Geographic System 1984 (WGS84).

Specific conductance is given in microSiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$ at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter ($\mu\text{g}/\text{L}$).

Geochemical Data from Analyses of Rock, Sediment, Water, and Solid-Phase Leaching at the Tuba City Open Dump, Tuba City, Arizona

By Raymond H. Johnson, James K. Otton, Robert J. Horton, Tanya J. Gallegos, LaDonna M. Choate, and Jonah E. Sullivan

Abstract

This report releases data collected by the U.S. Geological Survey from the Tuba City Open Dump area from January 2008 to September 2008 with cooperation from the U.S. Bureau of Indian Affairs and the Navajo and Hopi Tribes. These data were collected in support of investigations into the possible sources and resulting transport of radionuclides and other dissolved constituents in the surrounding ground water from the Tuba City Open Dump. This report provides a discussion of data collection and analytical methods with the data in a tabular format.

Introduction

The Tuba City Open Dump (TCOD) near Tuba City, in northern Arizona (fig. 1) operated as an unregulated and unsupervised waste disposal site starting in 1940. After the initiation of environmental monitoring by the U.S. Bureau of Indian Affairs (BIA) in 1995, radionuclides and other dissolved constituents were discovered in the shallow ground water in and around the TCOD at levels exceeding the U.S. Environmental Protection Agency maximum contaminant levels (<http://www.epa.gov/Region9/waste/solid/tubacity.html>). A variety of completed and on-going investigations have occurred since 1995. These investigations have focused on determining the source of radionuclides and other dissolved constituents in the TCOD and their subsequent transport in the local ground water.

Preliminary analyses of rock, sediment, and ground water from the TCOD and surrounding areas were completed by the U.S. Geological Survey (USGS) in 2006 and reported to the BIA in the form of an administrative report (Johnson and Wirt, 2006). This administrative report is currently being converted to a USGS Open-File Report (OFR), which will be available online. Additional investigations of rock, sediment, water, and solid-phase leaching from the TCOD were conducted by the USGS from January 2008 to September 2008. The purpose of this report is to release the 2008 geochemistry data. In addition, a companion report releases geologic information of the area collected by the USGS during the same time period (Otton and others, 2008). Future reports will provide more detailed discussions and interpretations of the results. These studies have been done in cooperation with the BIA and the Navajo and Hopi Tribes. Release of the 2008 geochemistry data in this report provides a discussion of data collection and analytical methods with the resulting data in a tabular format (tables 1 through 11 provided as separate Microsoft Excel files). In addition, location maps for rock samples (fig. 2), monitoring wells (fig. 3), and sediment, boring, snow, and residence samples (fig. 4) are included.

Acknowledgments

We thank the people from the Navajo and Hopi Tribes who assisted with access to tribal lands and sample collection. Without the efforts of John Krause and John Graves of the BIA, funding support for this study would not have been possible. Additional funding for this work was provided by the USGS Central Energy Resources Team. We thank Susan Hall and Margot Truini for their technical reviews of this manuscript.

Data Collection and Analytical Methods

Water

All water samples were field filtered (< 0.45 micron) and analyzed using either inductively coupled plasma–mass spectrometry (ICP–MS, Lamothe and others, 2002), and/or inductively coupled plasma–atomic emission spectrometry (ICP–AES, Briggs, 2002a), and/or ion chromatography (IC, Theodorakos and others, 2002). These analyses were completed by the USGS Minerals Program Laboratory in Denver, Colo. All water samples were collected in new plastic bottles and all samples for ICP–MS and ICP–AES were acidified to a pH < 2 with ultrapure nitric acid. Samples for IC analyses were not acidified. Alkalinity measurements were completed by titration in the field to a pH of 4.5 using sulfuric acid and a hand-held digital titrator.

In order to understand the near surface geology around the TCOB in more detail, shallow holes were hand augered into the surficial material and the weathered bedrock until competent bedrock prohibited deeper penetration (TC08B-series locations in table 1 and fig. 4). In holes that intersected the water table, shallow piezometers were installed to allow for water-level measurements and sampling for geochemistry. Completion details of these piezometers are found in table 2. Table 1 is the master location table for all water and solid samples, and sample locations are shown in figures 2 through 4. Wells that are indicated as “Monitoring Wells” (table 1 and fig. 3) were pre-existing before any USGS samples were collected from those wells. Locations of these wells were provided by the consulting firm working for the BIA (Stantec, Inc.) from professional surveying results. All other sample locations were measured using a hand-held GPS unit. The different accuracies of these two methods are reflected in the number of significant figures given in table 1.

Water levels were measured using a standard electric water-level sounding device (300-ft cable with 0.01-ft increments) that signals the completion of an electrical circuit when it contacts the water table. All water levels were measured from the top of the well/piezometer casing (below top of casing, BTOC in table 3). These water-level measurements were completed for the BIA to provide to Stantec, Inc., who are compiling data for ground-water elevation contour maps.

Water from the piezometers was sampled using a 0.25-in. polyethylene tubing placed just off the piezometer bottom (TC08B-series in table 4). New tubing was used for each sample. Water was withdrawn from the piezometer using a peristaltic pump and purged until field parameters stabilized. For all water samples, field parameters were measured at the surface in an open cup with constant water flow. Piezometer sampling often resulted in full water removal within the pipe and required continued pumping upon recovery. Monitoring wells were sampled using the same procedure (with two depths sampled for MW-15 as indicated in table 4), but did not go dry and were purged at a low flow rate until field parameters stabilized (MW-23, MW-15-24, and MW-15-27 in table 4). An additional water sample (Residence-01) was taken from tap water at a residence after it flowed through an outdoor spigot and rubber hose (10-minute purge before sampling). Field parameters included the measurement of conductivity, temperature, pH, and dissolved oxygen with standard field meters. Chloride was measured at selected sample locations using chloride-ion-specific test strips available from Hach, Inc. Water was filtered through a disposable 0.45-micron filter attached in-line with the peristaltic pump tubing. Two

field blanks were collected by running laboratory deionized water through new sample tubing and using the same sampling procedures.

Down-hole logging of temperature, conductivity, dissolved oxygen, pH, and oxygen-reduction potential (ORP) were completed in February 2008 on all existing wells using a YSI 556 MPS multiparameter meter with a 20-m cable (table 5). The down-hole logging was completed by lowering the probe to the depths indicated in table 5 and allowing the parameter values to stabilize. These data were collected to provide detailed information for in-situ measurements of field parameters with depth.

Additional water data include the analysis of split samples provided by Stantec, Inc., in March, 2008 (table 6) to cross-check laboratory precision. These samples were collected by Stantec, Inc., using a down-hole stainless-steel pump placed at the middle of the monitoring-well screen with plastic tubing to the surface. Sampling was completed using low-flow pumping to minimize drawdown. Filtering was completed in-line with the tubing (0.45-micron filter) at the surface. If the pump was not placed at the middle of the screen, the pumping depth is provided after the well identification number (for example, MW-14-31 is well MW-14 sampled at a depth of 31 ft). Split samples were sent to a Department of Energy laboratory and a commercial laboratory, but those results are not included in this report as these data will be reported by Stantec, Inc.

Snow samples were collected (locations in table 1 and on fig. 4, data in table 7) by melting snow at room temperature in 1-L plastic bottles. These samples were collected to have data on snow-melt-recharge geochemistry to the subsurface. The melt water was then analyzed for field parameters with hand-held meters (pH, conductivity, and temperature) and alkalinity. Snow-MW-18 and Snow-MW-07 were filtered using a plastic syringe and a 0.45-micron filter.

Samples for tritium were collected using the same procedures as with the peristaltic pumps discussed above with the tubing set at the depth indicated in table 8. At the same time as the tritium sample collection, field parameters and sample collection for ICP-MS, ICP-AES, and IC analyses were completed. Tritium analyses were completed by the USGS Noble Gas Laboratory in Denver, Colo., using the helium in-growth method (Clark and Fritz, 1976; Bayer and others, 1989; Demange and others, 2002). With this method, tritium is allowed to decay and produce ^3He , which is subsequently measured on a mass spectrometer. The total "in-growth" of ^3He is used to calculate the amount of tritium present in the sample at lower detection limits (0.01 tritium units) than other methods.

Rock and Sediment

Rock and sediment samples were collected in the area around the TCOD using a shovel and/or a hand auger (TC08RK and TC08SS, respectively, with locations in table 1 and on figs. 2 and 4). These samples were collected in an effort to understand the near surface geology around the TCOD. However, greater sampling density focused on the area west of the TCOD (fig. 4) because this is the down-gradient direction for ground-water flow. Rock and sediment samples were prepared by air drying and grinding to less than 150 microns (Taylor and Theodorakos, 2002) and then digested using multiple acids (Briggs and Meier, 2002; Briggs, 2002b). The digested liquid was analyzed using ICP-MS (Briggs and Meier, 2002) and/or ICP-AES (Briggs, 2002b), and elemental data is reported in parts per million (ppm) or as a percentage of the solid-phase total (Table 9). Multiple rock and sediment samples at the surface in one general location are indicated using an "A," "B," "C," "D," "E" designation. Multiple rock and sediment samples with depth are indicated using an additional numerical designation with the depths indicated in table 9. Rock/sediment samples were also analyzed from splits of core samples provided by Stantec, Inc., after the drilling of WP-01S and WP-07. These core samples were collected in the core barrel of a hollow-stem auger rig.

Solid-Phase Leaching

Rock and sediment leaching was completed to determine elemental concentrations that are readily leached from the solid phase. Samples were minimally processed by sieving to less than 2 mm to remove roots and other organic matter except for samples designated by a “cr” in table 10. These “cr” samples are splits obtained from the whole-rock sample preparation and were ground and sieved to less than 150 microns with the intention of comparing these samples to uncrushed samples. Two different leaching fluids were used for the leaching process. The first fluid was laboratory grade deionized water, which provides a leach test similar to the EPA method 1312 leaching procedure (<http://epa.gov/osw/hazard/testmethods/sw846/pdfs/1312.pdf>). The second fluid provides a leach test similar to the EPA method 1311 (<http://epa.gov/osw/hazard/testmethods/sw846/pdfs/1311.pdf>) or toxic characteristics leaching procedure (TCLP), which is intended to provide information on leachability of solids in direct contact with landfill leachate. This fluid (TCLP fluid #1) is deionized water with the addition of acetic acid and sodium hydroxide, which was obtained as a pre-made and certified fluid with a pH of 4.93 from Ricca Chemical.

For both leaching procedures, 50 g of material was placed in a 1-L plastic bottle with 1-L of deionized water (20 to 1 leaching ratio). All glassware and bottles used were acid washed in 10 percent nitric acid and triple rinsed in deionized water prior to use. The solid sample was in contact with the leaching solution and mixed end over end for 18 hours on a rotating machine. This machine allowed for daily processing of 10 samples with 1 blank sample and 1 duplicate sample (tables 10 and 11). After the rotation process, each sample was allowed to settle for an additional 6 hours; leachate was poured off into a 250-mL plastic bottle and centrifuged for 40–60 minutes at 5,000 revolutions per minute. Leachate fluid was withdrawn from the 250-mL bottle with a sterile 60-mL plastic syringe and filtered through a syringe-attached 0.7-micron glass prefilter followed in-series by a syringe-attached 0.45-micron cellulose acetate filter. Solid-phase leachate fluid samples were collected in plastic bottles after filtration, acidified to a pH < 2, and analyzed using the ICP–MS methodology discussed above for water-phase samples. Conductivity, pH, alkalinity, and chloride concentrations in the leachate were measured immediately in the laboratory after the leachate had passed only through the 0.7-micron prefilter because of the difficulty in filtering significant fluid quantities through the 0.45-micron syringe filter. Conductivity and pH were measured using standard laboratory-grade meters. Alkalinity was measured by titration to a pH of 4.5 using sulfuric acid and a hand-held digital titrator. Chloride was measured using chloride-ion specific test strips available from Hach, Inc. For chloride measurements that were less than the calibration range on the test strip, an estimated value was provided in table 10 based on a linear estimation of the calibration curve.

The intent of the EPA 1311 and 1312 leaching methods is to “determine the mobility of both organic and inorganic analytes present in liquids, soils, and wastes” from the aspect of landfill waste disposal (<http://epa.gov/osw/hazard/testmethods/sw846/pdfs/1311.pdf> and <http://epa.gov/osw/hazard/testmethods/sw846/pdfs/1312.pdf>). From a practical standpoint, these methods provide consistent leaching procedures. In addition, the large fluid to solid ratio avoids mineral solubility limits and may represent possible leaching after flushing with multiple pore volumes of ground water.

Data Summary

All of the data results are provided in tables 1 through 11, which are in separate Microsoft Excel files. Table 1 is the master location file with all of the sample locations and identification names. These identification names are kept the same in all additional tables. As such, some identification names from the original laboratory data files have been edited before inclusion of the data in these tables. The intention is for these data tables to be included in a full database for the TCOD that will be maintained by Stantec, Inc.

All water-level data collected by the USGS in 2008 at the TCOD are provided in table 3. Water chemistry data from piezometers, MW-15, MW-23, and one residence can be found in table 4. Table 5 provides the data from down-hole logging of field parameters. Water geochemistry data from split samples collected and submitted to the USGS by Stantec, Inc., are given in table 6. Table 7 provides water geochemistry of snow samples, and table 8 provides the tritium data and geochemistry from selected wells. Whole rock elemental data from rock and sediment samples are provided in table 9. Data from the deionized water leaching of rock and sediment samples is provided in table 10, and the companion TCLP leach data is provided in table 11.

References Cited

- Bayer, R., Schlosser, P., Bonisch, G., Rupp, H., Zaucker, F., and Zimmek, G., 1989, Performance and blank components of a mass spectrometric system routine measurement of helium isotopes and tritium by ^3He ingrowth method: Sitzungsberichte der Heidelberger Akademie der Wissenschaften; Mathematisch-naturwissenschaftliche Klasse: Heidelberg, Springer Verlag, p. 241–279.
- Briggs, P.H., 2002a, The determination of twenty-seven elements in aqueous samples by inductively coupled plasma–atomic emission spectrometry, *in* Taggart, J.E., ed., chap. F, Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002–223-F, 11 p. (http://pubs.usgs.gov/of/2002/ofr-02-0223/F0203ICPAES_M.pdf).
- Briggs, P.H., 2002b, The determination of forty elements in geological and botanical samples by inductively coupled plasma–atomic emission spectrometry, *in* Taggart, J.E., ed., chap. G, Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002–223-G, 18 p. (http://pubs.usgs.gov/of/2002/ofr-02-0223/G01fortyelementICP-AESsolid_M.pdf).
- Briggs, P.H., and Meier, A.L., 2002, The determination of forty-two elements in geological materials by inductively coupled plasma–mass spectrometry, *in* Taggart, J.E., ed., chap. I, Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002–223-I, 14 p. (http://pubs.usgs.gov/of/2002/ofr-02-0223/I20NAWQAPlus_M.pdf).
- Clark, I.D., and Fritz, P., 1997, Environmental isotopes in hydrogeology: New York, Lewis Publishers, 328 p.
- Demange, D., Grivet, M., Pialot, H., and Chambaudet, A., 2002, Indirect tritium determination by an original ^3He ingrowth method using a standard helium leak detector mass spectrometer: Analytical Chemistry, v. 74, p. 3,183–3,189.
- Johnson, R.H., and Wirt, L., 2006, Preliminary geochemical analyses of rock, sediment, and ground water from the Tuba City Landfill and surrounding areas: U.S. Geological Survey Administrative Report, 23 p.
- Lamothe, P.J., Meier, A.L., and Wilson, S.A., 2002, The determination of forty-four elements in aqueous samples by inductively coupled plasma–mass spectrometry, *in* Taggart, J.E., ed., chap. H, Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002–223-H, 11 p. (http://pubs.usgs.gov/of/2002/ofr-02-0223/H21&23OFR99-151_M.pdf).

Otton, J.K., Johnson, R.H., and Horton, R.J., in press, Geologic maps and cross sections of the Tuba City Open Dump site and vicinity with implications for the occurrence and flow of ground water: U.S. Geological Survey Open-File Report.

Taylor, C.D., and Theodorakos, P.M., 2002, Rock sample preparation, *in* Taggart, J.E., ed., chap. A1, Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002–223-A1, 5 p. (http://pubs.usgs.gov/of/2002/ofr-02-0223/A1RxSampPrep_M.pdf).

Theodorakos, P.M., d'Angelo, W.M., and Ficklin, W.H., 2002, Fluoride, chloride, nitrate, and sulfate in aqueous solution utilizing autosuppression chemically suppressed ion chromatography, *in* Taggart, J.E., ed., chap. V, Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002–223-V, 7p. (<http://pubs.usgs.gov/of/2002/ofr-02-0223/OFR-02-0223.pdf>).

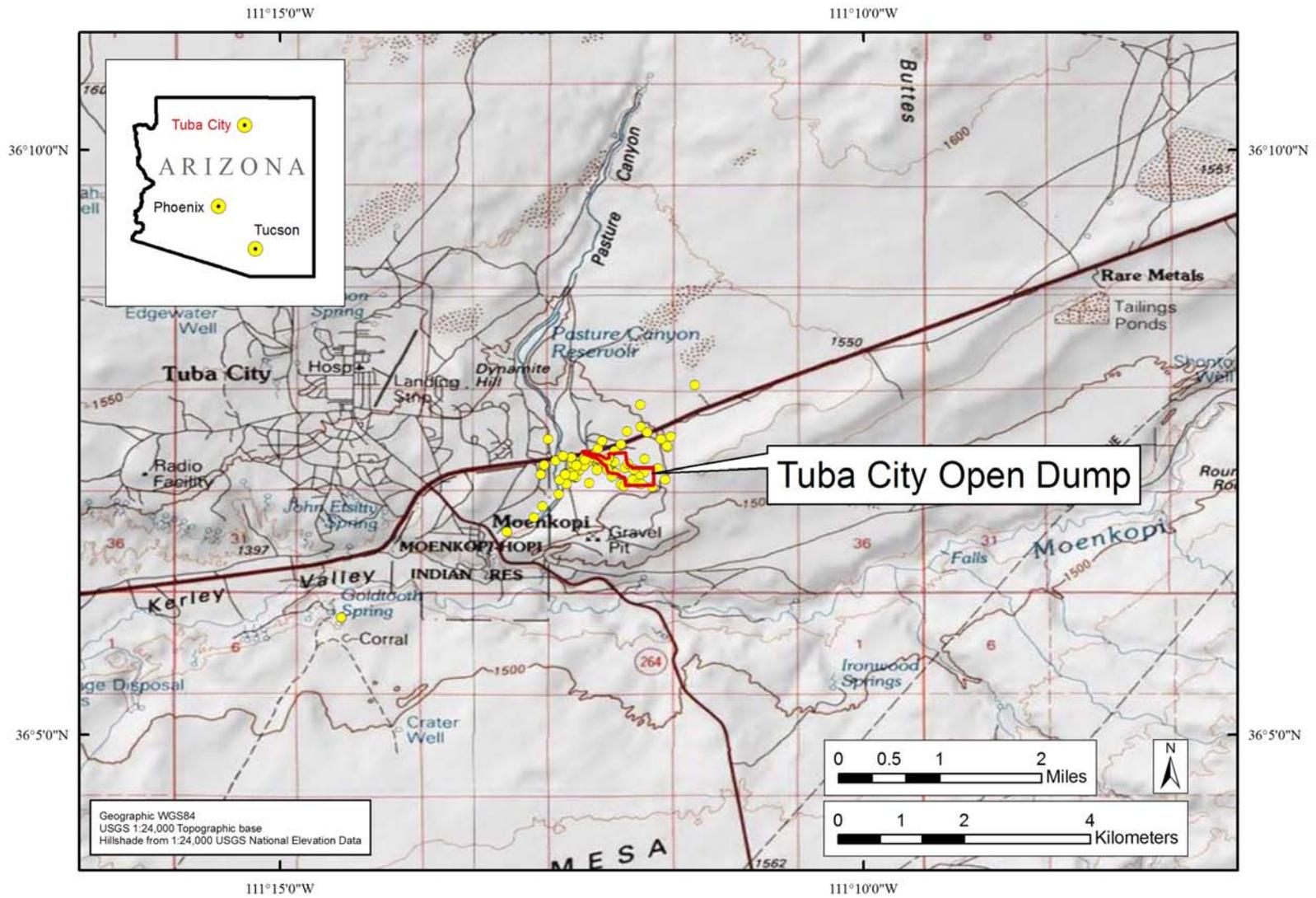


Figure 1. Location map.

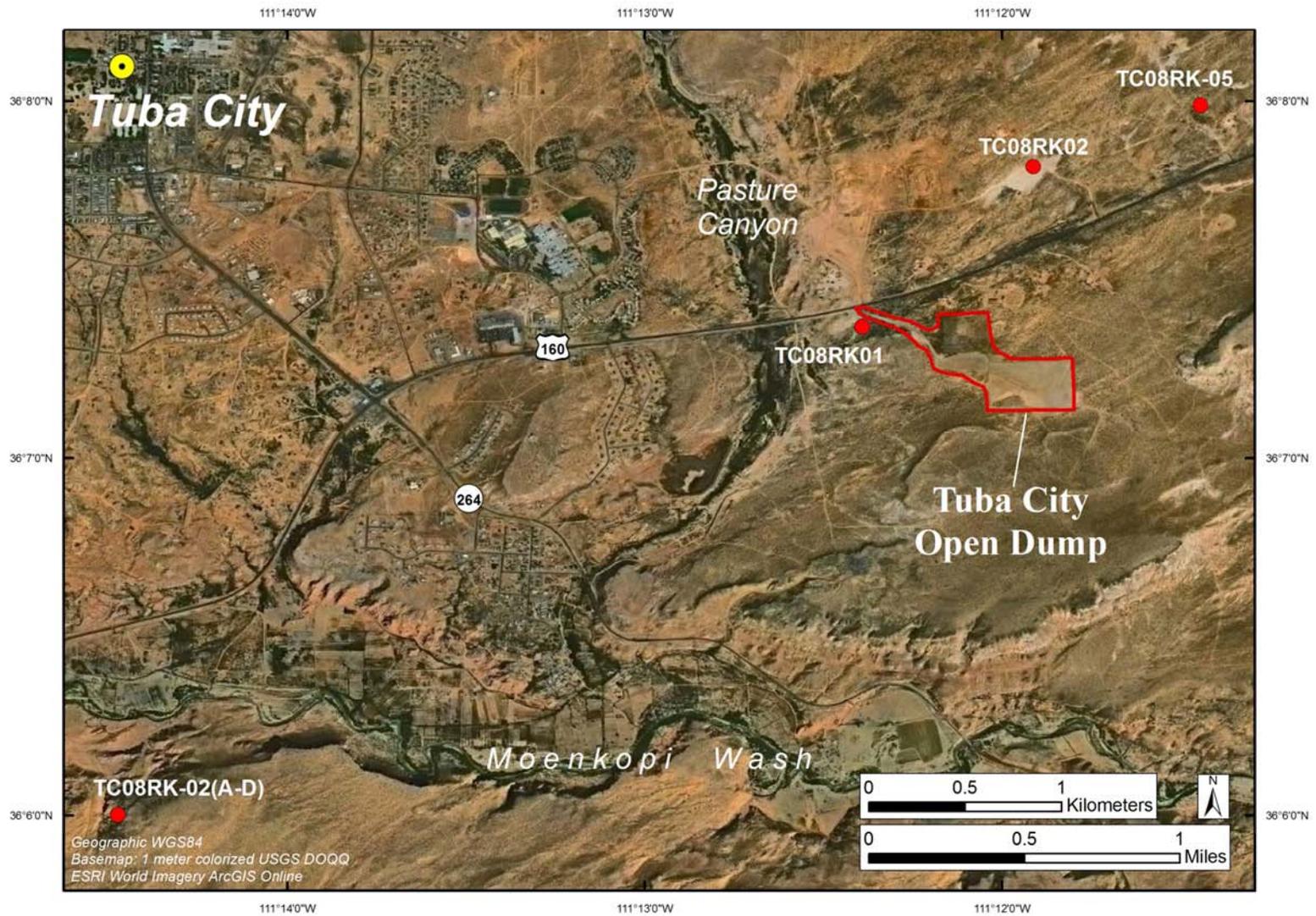


Figure 2. Rock sample locations.

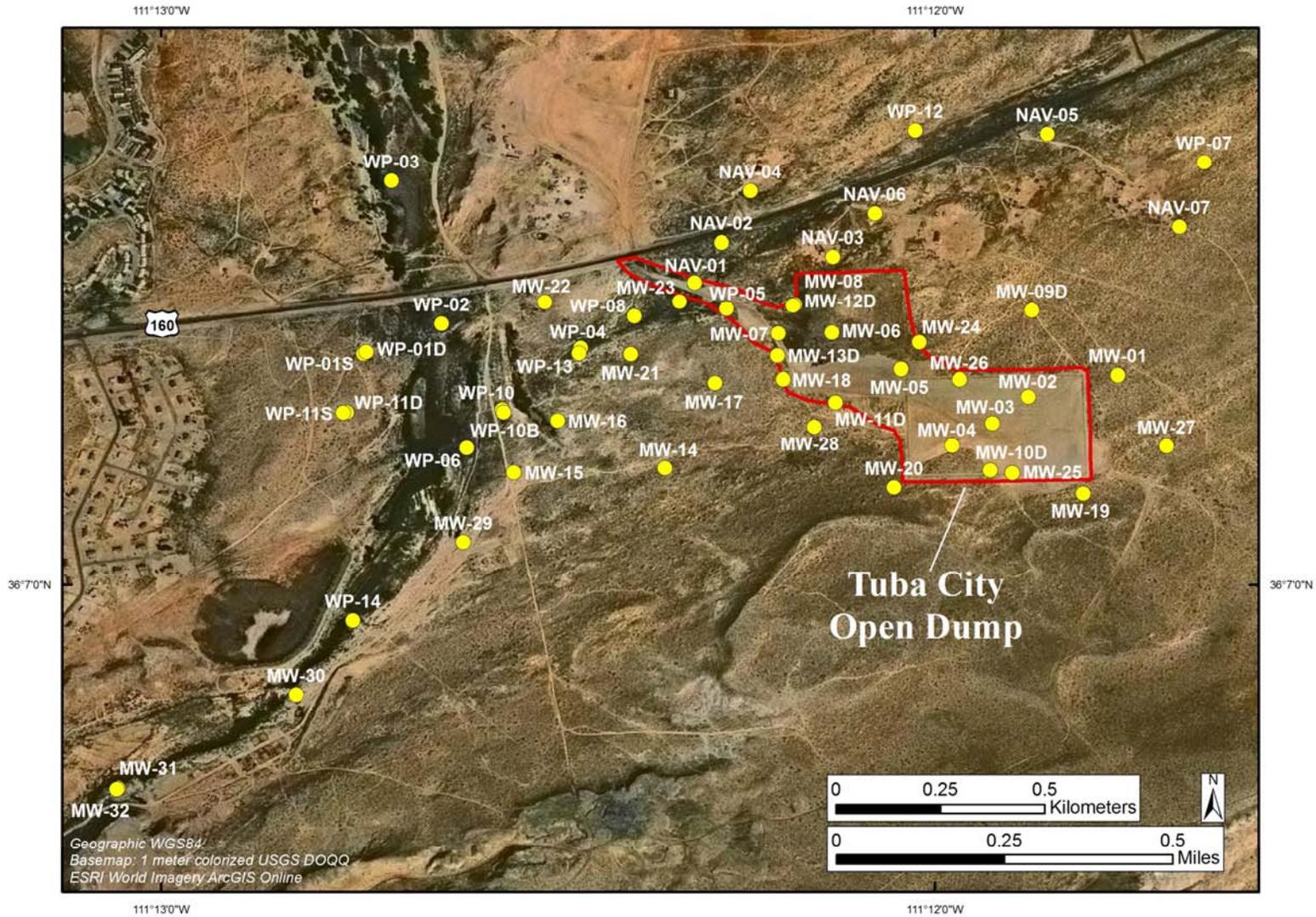


Figure 3. Monitoring well locations.

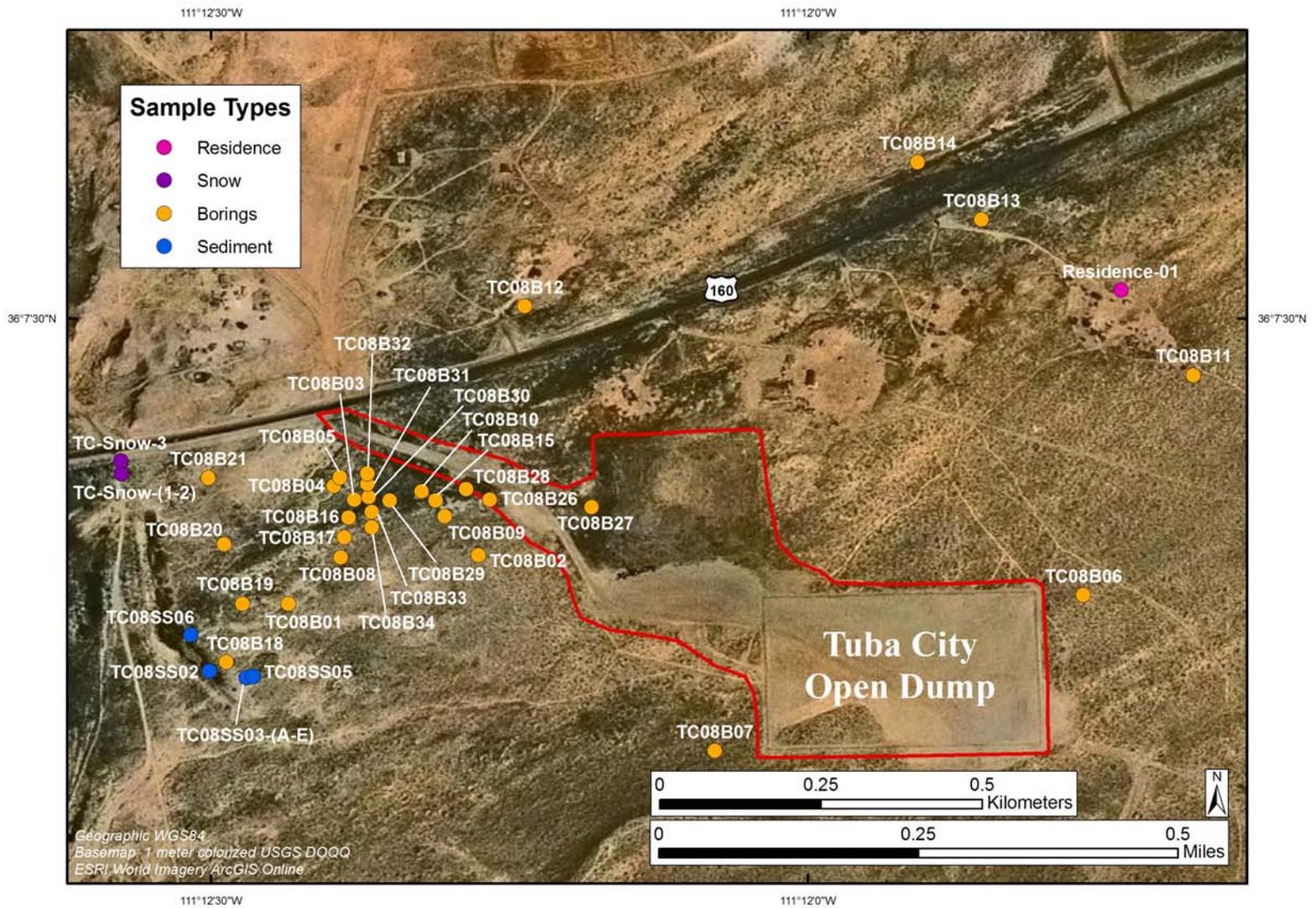


Figure 4. Sediment, boring, snow, and residence sample locations.