FINAL

OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT LAVA CAP MINE SUPERFUND SITE NEVADA CITY, CALIFORNIA

Prepared for:

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LAVA CAP MINE
OPERABLE UNIT 02 REMEDIAL INVESTIGATION REPORT

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Executive Summary

The U.S. Environmental Protection Agency (EPA), under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, is conducting a remedial investigation (RI) and feasibility study (FS) to address arsenic contamination in groundwater in Operable Unit 2 (OU-2) of the Lava Cap Mine Superfund Site (Site).

The Site is located southeast of Nevada City, California and includes the mine property and downgradient areas to the confluence of Clipper Creek (CC) and Little Greenhorn Creek (LGC) that are affected by contamination from the mine. The Site is divided into the following four operable units:

- Operable Unit 1 (OU-1), the terrestrial portion of the former active mining area, includes surficial features upstream, from Greenhorn Road to Little Clipper Creek (LCC). The OU-1 remedial action (RA) began in May 2006 and is still underway.
- OU-2 includes groundwater at the Site and is the focus of this report.
- Operable Unit 3 (OU-3) includes surficial features downstream from Greenhorn Road and the Lost Lake/Deposition Area. An RI data gaps investigation is planned for OU-3, which will lead to the development of the OU-3 FS.
- Operable Unit 4 (OU-4) is a subset of OU-1 and was delineated to account for the accelerated RA implemented at residences located on the mine property. The OU-4 RA was completed in early 2006.

Mine-related contaminants have adversely impacted portions of the Site, including downgradient areas along LCC and CC and extending through Lost Lake to LGC. Arsenic concentrations exceeding the maximum concentration level (MCL) have been detected in groundwater and surface water at the Site and pose a threat to human health. The OU-1 and OU-3 RAs will address surficial arsenic contamination concerns for soil, sediment, and surface water. The OU-2 RI/FS process will address arsenic contamination concerns in groundwater. This RI report documents the results of data collection efforts conducted to characterize Site groundwater conditions, estimate the nature and extent of groundwater contamination, support informed risk management decisions regarding human health risks from groundwater arsenic contamination, and support preparation of the OU-2 FS to identify a remedy. The process will lead to a Record of Decision for OU-2, which will describe the actions necessary to mitigate risks to human health from arsenic contamination in groundwater.

The Site is divided into in the following areas:

- **Background Areas**. These areas include (1) the LCC watershed upstream from the Mine Area and (2) CC upstream from its confluence with LCC. Water samples from the Background Areas were compared with water samples from areas having known mine-related impacts.

- **Source Area.** This area includes portions of the mine property where tailings and waste rock from historical mining operations are located and areas where mine-related water discharge occurs.
- **Mine Area.** This area includes portions of the mine property that are adjacent to and upstream from the Source Area.
- **Downgradient Area.** This area is downstream from Lava Cap Mine, where mine tailings were transported by creeks, including the following:
  - Portions of LCC downstream from the Source Area
  - CC, from the confluence with LCC to the confluence with LGC
  - Portions of land adjacent to these creek sections
- **Lost Lake/Deposition Area**. This area includes Lost Lake and the Deposition Area immediately upstream from Lost Lake where mine tailings have been deposited.

Previous Investigations

Routine and periodic sampling of various environmental media were part of the sitewide RI/FS process, which is still in progress. A sitewide RI report (EPA, 2001a) summarized soil, sediment, surface water, and groundwater data collected in 1999 and 2000. As part of the RI, human health and ecological risk assessments were conducted and documented. The risk assessments established arsenic as the primary risk driver in groundwater. An OU-1 FS (EPA, 2004a) addressed the mitigation of risks associated with arsenic contamination in Source Area and Mine Area surface water and soil.

Following the RI report, a data gap investigation was conducted in 2001, which included the installation of three new monitoring wells, three new piezometers, and the addition of several new residential well and surface water monitoring locations. Routine surface water and groundwater monitoring occurred from October 2001 through March 2007 to support the OU-2 RI/FS. Monitoring was performed to evaluate seasonal and long-term trends in arsenic and general chemistry parameters, develop an understanding of the extent of arsenic contamination in groundwater, track groundwater elevation changes over time, and provide a dataset to support human health risk management decisions.

Remedial Investigation Data Collection

Groundwater and surface water data from 1999 through 2004 were reviewed to identify data gaps and determine the need for additional OU-2 RI-related fieldwork. The data gap identification work included the following:

- A records search of Nevada County files and a Site residential well canvass. The objective of the records search was to determine the availability of pertinent residential well information that could assist in evaluating groundwater flow and groundwater quality at the Site. Approximately 100 of the 300 residential wells identified during the records search were targeted for additional data gathering. Mailings and phone calls

yielded approximately 16 well owners who were interested in participating in the sampling program. Where possible, those wells were visited, and the well location, condition, and construction; the depth to water; pumping rate; pump manufacturer; drilling contractor; and water use were recorded. The well canvass work led to the addition of five residential wells (Wells 11AY, 11AZ, 11A1, 11A2, and 11A3) to the sampling program.

- Continued collection of groundwater and surface water monitoring samples. Routine monitoring included sampling and analysis for arsenic, cations (calcium, iron, magnesium, manganese, potassium, and sodium), anions (chloride, phosphate, and sulfate), total dissolved solids (TDS), alkalinity, and field parameters (dissolved oxygen [DO], oxidation reduction potential [ORP], pH, specific conductance, temperature, and turbidity). Special investigations, including arsenic speciation sampling and stable isotope sampling, were also performed to help determine water types at the Site and the origin of elevated arsenic concentrations in groundwater downgradient from the Source Area and Mine Area.
- Installation of five additional monitoring wells and a staff gauge. Two shallow/deep well pairs (Well Pairs 5K-S/5K-D and 5L-S/5L-D) were installed upgradient from residential wells that had elevated arsenic concentrations (Wells 11AL, 11AS, and 11AV). Also, a deep monitoring well (Well 13T) and CC Staff Gauge 14E were paired with existing shallow Well 13R to evaluate vertical hydraulic gradients, vertical arsenic distributions, and groundwater/surface water interactions in the Deposition Area.
- Short-term aquifer testing to refine estimates of hydraulic properties for the Site. This included flow rate and water level measurements during routine groundwater sampling events and after well development to calculate specific capacity and for use with analytical modeling to estimate aquifer transmissivity.
- Monitoring stream discharge, including manual flow measurements and automated, continuous datalogging of stream stages at engineered structures (stream gauges).
- Updating the Lava Cap Mine Groundwater Flow Model.

The OU-1 RA affected the OU-2 RI effort. Several monitoring wells and piezometers were abandoned and four stream gauges were installed in the Source Area and Mine Area as part of the OU-1 RA. The Log Dam was replaced with a Rock Buttress. Surface water patterns in the Source Area and Mine Area were also altered and the waste rock/tailings pile was capped. These OU-1 RAs likely affect the groundwater flow patterns and arsenic distributions in the Source Area and Mine Area.

Site Physical Characteristics

The Site physical characteristics are summarized as follows:

- Annual precipitation is approximately 52 inches and average temperatures range from approximately 30 degrees Fahrenheit in winter to 98 degrees Fahrenheit in summer.
- LCC is the main surface-water drainage leading south, away from the mine. The upper reaches of LCC are seasonally dry; the creek becomes perennial at the base of the Rock

Buttress with flows ranging from 0.1 to 155 cubic feet per second (ft^3/sec) (45 to 70,000 gallons per minute [gpm]). LCC flows downstream from the Rock Buttress and merges with CC approximately 1 mile south of the Rock Buttress. CC flows into Lost Lake, which is contained by Lost Lake Dam. CC continues below Lost Lake to LGC, which joins GC and flows into Rollins Reservoir.

- The Site contains five main rock types, including mine deposits (waste rock and tailings overlaying basal gravel), Tertiary volcanic breccias (Tvb unit), Cretaceous igneous intrusive rocks, Jurassic to Triassic metamorphosed volcanic rocks, and Paleozoic to Upper Jurassic metamorphic rocks (Pms unit). Groundwater occurs in primary pore spaces in the saturated overburden throughout the Site and in secondary openings (e.g., fissures, faults, and joints) of the consolidated and crystalline rocks of the Pms unit, which has a low hydraulic conductivity (10^{-5} to 10^{-6} centimeters per second). Groundwater also occurs in the more permeable Tvb unit that overlies the Pms unit north of the mine. Springs occur at the contact between the Tvb and Pms units.

- Groundwater flow is primarily from high topographic elevations (e.g., ridges) toward deep drainages, including LCC, CC, and LGC to the south-southeast. The regional groundwater table is a subtle expression of the land surface. Groundwater in the waste rock/tailings pile likely seeps beneath the Rock Buttress into the Pms unit and flows toward the LCC drainage. Groundwater flow also occurs in the basal gravel and fractured metasediment present at the contact between overburden material and bedrock throughout the Site, potentially creating a preferential flowpath along the contact. Groundwater flowing from northwest of Lost Lake likely discharges into the lake on the northwest shore of the northern lobe of the lake and seeps beneath Lost Lake Dam on the southern shore of the southern lobe of the lake.

- No long-term increasing or decreasing trends were observed in groundwater levels at the Site, suggesting that the system is in a state of dynamic equilibrium.

- Vertical hydraulic gradients are generally downward in the waste rock/tailings pile (according to pre-OU-1 RA water levels) and the Deposition Area. In the Mine Area, vertical hydraulic gradients on the ridge above LCC alternate downward and upward at Well Pair 5K-S/5K-D and are consistently upward at Well Pair 5L-S/5L-D. Initial data indicate that CC seasonally alternates as a gaining or losing stream at Staff Gauge 14E. These observations and groundwater flow modeling results suggest that the groundwater table is located very near the bottom of the CC channel near Staff Gauge 14E.

- Surface water discharge was estimated by using crest gauges, manual flow measurements, and stream gauges. Surface water discharge is summarized as follows:

  - LCC upgradient from the mine (Locations 1J and 1U) typically goes dry by the end of June and flows again by early winter. A maximum flow of 45 ft^3/sec (20,200 gpm) was observed during a large winter storm.

  - The perennial adit flow (Location 3A) ranges from 0.1 to 4 ft^3/sec (45 to 1,800 gpm); however flows are typically less than 0.5 ft^3/sec (225 gpm). The peak discharges were likely not coming from the adit but were the result of surface runoff directed to the pond at the adit discharge.

- Perennial LCC flow downgradient from the Rock Buttress and upgradient from the confluence with CC (Locations 4A/4A2, 12B, and 12J) ranges from 0.1 to 155 ft^3/sec (45 to 70,000 gpm).
- CC flow (Locations 2G, 14E, 19A, and 19B) ranges from less than 0.01 to 22 ft^3/sec (5 to 9,900 gpm). This range does not include any winter storm events.
- LGC flow (Location 19M) ranges from 0.2 to 30 ft^3/sec (90 to 13,500 gpm). This range does not include any large winter storm events.

Nature and Extent of Contamination

The nature and extent of arsenic concentrations in Site water are summarized as follows:

- Exceedances of the arsenic MCL (10 micrograms per liter [µg/L]) occurred in the following locations:
  - Source Area and Mine Area groundwater and surface water (Wells 10G, 10H, 10I, 10J, 10N, 5A, 5D, 5E, 5I, 5J, 5K-S, 5L-S, and 5L-D; Piezometers 5PZ-2 and 5PZ-3; and surface water monitoring Locations 3A, 3B, and 4A/4A2)
  - Downgradient Area residential Wells 11AL, 11AS, and 11AV (between the mine and Greenhorn Road) and LCC surface water (Location 125)
  - Deposition Area Wells 13Q and 13R (completed in tailings)
  - Bedrock Well 13T (additional samples are needed to confirm this exceedance)
  - LCC and CC surface water (Locations 12J and 14E)
  - Lost Lake and at the base of Lost Lake Dam (Locations 16B, 16C, and 19B)
- Background arsenic concentrations were low in surface water and groundwater (within the areas sampled), except in areas within the footprint of the mine workings. No discernible, steadily increasing or decreasing trend in arsenic concentrations is apparent in the data during the period of record.
- Surface water and groundwater arsenic concentrations in the Source Area and Mine Area are significantly higher than background concentrations and were usually above the MCL at Wells 10G, 10H, 10I, 10J, 10N, 5A, 5D, 5E, 5I, 5J, 5K-S, 5L-S, and 5L-D; Piezometers 5PZ-2 and 5PZ-3; and surface water monitoring Locations 3A, 3B, 4A/4A2. The highest arsenic concentrations (greater than 100 µg/L) occurred in water discharging from the mine adit and in groundwater samples from wells screened within waste rock, tailings, or mine workings. Arsenic concentrations were typically lower in wells screened in bedrock on the ridges to the northwest, west, and southwest of the waste rock/tailings pile (less than 100 µg/L). Arsenic concentrations detected in the different geologic units in and below the waste rock/tailings pile (e.g., waste rock, tailings, basal gravel, and underlying bedrock) typically were similar to each other.
- Within the Downgradient Area, elevated arsenic concentrations (above the MCL) are detected in LCC surface water downstream from the mine and in groundwater samples

from downgradient Wells 11AL, 11AS, and 11AV. Except for these locations, concentrations of arsenic in surface water and groundwater of the Downgradient Area were less than the MCL, similar to background concentrations.

- Elevated arsenic concentrations (above the MCL) in the Lost Lake/Deposition Area were limited to bedrock Well 13T and locations directly impacted by the tailings deposits. Additional samples are needed to confirm MCL exceedances at Well 13T. The locations directly impacted by the tailings deposits included the surface water in CC (Location 14E), groundwater within the tailings pile (Wells 13Q and 13R), surface water in Lost Lake (Locations 16B and 16C), and surface water at the base of Lost Lake Dam (Location 19B). Groundwater from residential wells and monitoring Well 13S, which are screened in the bedrock, had low arsenic concentrations (less than 6 µg/L).

Fate and Transport

The following sections summarize sources, transport, and fate of arsenic in the study area.

Arsenic Sources

The OU-1 RA minimized the likelihood of further tailings migration from the Source Area by the construction of the Rock Buttress, surface water diversions, and the waste rock/tailings pile cap. As part of the OU-1 RA, tailings deposits in LCC (south of the Rock Buttress and north of Greenhorn Road) were removed. The remaining known or suspected sources of arsenic contamination to groundwater include the following:

- Subsurface mine workings beneath the Mine Area.
- Waste rock and tailings in the Source Area. As part of the ongoing OU-1 RA, surface water from the adit and Rock Buttress drain will be treated, significantly reducing arsenic loading from this source.
- Tailings in the Deposition Area.
- Tailings deposits in LCC, CC, and Lost Lake. Future RAs in OU-3 will mitigate adverse impacts of tailings in these areas.
- Naturally occurring arsenic not associated with mining activities (from natural ore bodies).

Groundwater Flowpath Evaluation

The Lava Cap Mine Groundwater Flow Model was used to estimate groundwater flowpaths from mine-related sources. Groundwater particles were started from three sets of locations as follows:

- Flowpath Set 1 – Surficial mine waste areas (tailings and waste rock piles in the Source Area and adjacent Mine Area, Lost Lake/Deposition Area, and along LCC and CC)
- Flowpath Set 2 – Shallow mine workings (600 Drift Level and above)
- Flowpath Set 3 – Deep mine workings (700 Drift Level and below)

The flowpath analysis did not predict arsenic concentrations at specific points along the groundwater flowpaths. Groundwater flow along localized fracture zones, groundwater use (pumping), potential subsurface ore bodies containing arsenic, geochemical reactions, adsorption, dilution, and travel times can affect arsenic concentrations along the groundwater flowpaths.

Results from the Flowpath Set 1 analysis (see Figure ES-1) suggest that shallow groundwater flow from beneath areas that have mine waste and tailings is confined to the Source Area; Mine Area; LCC, downstream from the mine; CC, downstream from the confluence with LCC; and the Lost Lake/Deposition Area. Shallow groundwater flow converges toward drainage channels. Shallow groundwater in the Source Area and Mine Area converges toward LCC; shallow groundwater in the Deposition Area converges toward LGC. The convergence of shallow groundwater flow limits the flowpath area from these source areas. Flowpaths from surficial mine waste areas are shallow and discharge to springs or directly to stream channels after short travel distances. Only a few residential wells in the Mine Area (10-series wells), Downgradient Area (Wells 11AL and 11AU), and Lost Lake/Deposition Area (Wells 11AI and 11AE) appear to be within the potential area of Flowpath Set 1.

Results from the Flowpath Set 2 analysis (see Figure ES-1) suggest that groundwater from shallow mine workings (600 Drift Level and above) flows through portions of the subsurface beneath the Source Area, Mine Area, LCC, and a larger area west of these locations. Groundwater from the shallow mine workings is predicted to eventually discharge to LCC, CC, and LGC, exiting the CC watershed primarily as stream outflow in LGC. The potential area of Flowpath Set 2 includes two additional Downgradient Area residential wells that have elevated arsenic concentrations (Wells 11AS and 11AV) but also includes many wells that have very low arsenic concentrations. Groundwater samples collected from Monitoring Well Pairs 5K-S/5K-D and 5L-S/5L-D, located upgradient from residential Wells 11AS and 11AV, had detected arsenic concentrations above the MCL.

Results from the Flowpath Set 3 analysis (see Figure ES-2) suggest that groundwater from deep mine workings (700 Drift Level and below) flows through portions of the subsurface beneath the Source Area, Mine Area, LCC, and CC. Groundwater from the deep mine workings is predicted to eventually discharge to LGC and exit the CC watershed primarily as stream outflow. The potential area of Flowpath Set 3 includes the same residential wells with elevated arsenic concentrations as Flowpath Set 2 plus several additional residential wells where low arsenic concentrations were detected. Most of the flowpaths from the deep mine workings would be much deeper than the residential wells in the area.

The combination of these three groundwater flowpath areas provides a conservative estimated geographic footprint of where groundwater could be flowing from known or potential mine-related arsenic sources. Uncertainty in these geographic areas increases with depth (i.e., the extent of the Flowpath Set 2 area has greater uncertainty than the Flowpath Set 1 area, and the Flowpath Set 3 area has greater uncertainty than the Flowpath Set 2 area) because the influence of topography on groundwater flow patterns lessens with increasing depth. Limited data are available regarding the characteristics of the deep bedrock aquifer system. Additionally, geochemical processes that impact arsenic concentrations along flowpaths are not known; therefore, the uncertainty regarding arsenic concentrations along flowpaths from source areas increases with increasing travel distance from the source areas.

Arsenic Geochemistry

Conclusions from the geochemistry analysis (e.g., general chemistry, trace metals, natural tracers, arsenic speciation, and stable isotopes) do not provide a clear indication of the influence of mine-related contamination on groundwater in the area. Other conclusions include the following:

- Groundwater in the area generally is a calcium-bicarbonate type with low TDS.
- Water samples from the Source Area have a more pronounced sulfate presence than most of the surrounding Site wells. This sulfate signature persists in downstream samples from LCC but does not appear to persist in groundwater away from the mine. This suggests the possibility that the effect of mine-related contamination on local groundwater is limited.
- Stable hydrogen and oxygen isotope signatures form a very tight range for all samples analyzed. This geochemical tool was not useful for identifying effects of mine-related contamination on groundwater in residential wells.
- Arsenic speciation results show that elevated arsenic exists predominantly in the As(III) state, with a few exceptions. Initial speciation sampling results suggested a possible link between mine-related contamination and residential wells, but sampling in 2006 showed that speciation is variable and does not clearly indicate such a link.
- Groundwater chemical conditions downgradient from the Site generally indicate oxidizing conditions that favor the less mobile forms of arsenic. The abundance of iron oxide minerals in the aquifer matrix suggests a high capacity for adsorption of arsenic, potentially limiting arsenic mobility in the aquifer.

Groundwater Arsenic Loading to Little Clipper Creek

After the arsenic concentration in water discharging from the mine adit and Rock Buttress drain is treated and reduced to 10 µg/L (as specified in the OU-1 Record of Decision [EPA, 2004b]), other groundwater contributions of arsenic to LCC and arsenic-related chemical reactions in the creek (adsorption or precipitation) could increase or decrease downstream arsenic concentrations. Available data are insufficient to accurately forecast the effect of these processes on arsenic concentrations in LCC. If groundwater contributing to LCC has average arsenic concentrations higher than 10 µg/L, and if chemical reactions do not decrease the overall arsenic concentration in LCC, arsenic concentrations could increase downstream from the Rock Buttress because of the additional arsenic loading from groundwater discharge. However, if groundwater contributing to LCC has an average arsenic concentration less than 10 µg/L, arsenic concentrations in LCC surface water would be expected to remain below the MCL, assuming that all of the arsenic-contaminated tailings in and near the stream channel have been removed. After the OU-1 and OU-3 RAs, continued monitoring of LCC surface water arsenic concentrations and flow will be required to assess the impacts of these processes.

Human Health Risk Assessment

An update of the groundwater HHRA was prepared that compared residential well data to the arsenic MCL (10 µg/L). None of the groundwater samples from residential wells in the Background Areas and the Lost Lake/Deposition Area exceeded the MCL for arsenic. Groundwater samples from three residential wells (Wells 11AL, 11AS, and 11AV) in the Downgradient Area (along LCC, below the mine and above Greenhorn Road) exceeded the arsenic MCL. Groundwater samples from all of the residential wells in the Source Area and Mine Area (Wells 10G, 10H, 10I, 10J, and 10N) exceeded the MCL.

Recommendations

This report describes an evaluation of the groundwater system at and near the Site by using available data and a groundwater flow model that attempts to balance a reasonable level-of-effort scientific analysis with uncertainty in results. The Lava Cap Mine Groundwater Flow Model was constructed as a reconnaissance-level, steady-state numerical tool capable of simulating large-scale features and processes of the hydrologic system. The spatial distribution of aquifer properties and precipitation recharge simulated in the model are based on the results from past geologic and hydrologic studies, aquifer tests, local climate data, and professional judgment. Any numerical representation of an aquifer system is a simplification of the actual Site conditions. Some features of the hydrologic system and patterns of water use are not explicitly represented in the model. These features could be incorporated into future versions of the model to reduce the uncertainty associated with the model output. However, because of the complex nature of the bedrock aquifer system in the area, incorporation of additional complexity into the Lava Cap Mine Groundwater Flow Model might not significantly reduce uncertainty in the evaluations of remedial alternatives that will take place during the OU-2 FS. Despite this limitation, output from the current version of the Lava Cap Mine Groundwater Flow Model provides useful insights into long-term patterns of groundwater flow and arsenic pathways on a watershed and subwatershed scale.

Recommendations for additional data collection attempt to balance Site access, cost, and value for reducing uncertainty in future groundwater evaluations. The following are higher priority recommendations:

- Continue routine monitoring of all active residential wells that exceed the arsenic MCL (Wells 10G, 10H, 10N, 11AL, 11AS, and 11AV).
- Continue semiannual monitoring and maintenance of existing EPA-maintained residential well head treatment systems.
- Install stream weirs at (1) Location 12J on LCC, immediately upstream from the confluence with CC, (2) Location 19A, upstream from LGC, and (3) LGC, where it exits the watershed. Stream discharge measurements from these weirs would provide insights into the groundwater/surface-water interactions and water budget calculations for the watershed. These data would also provide additional constraints on aquifer property estimates for the Pms unit and improve the CSM and predictive capabilities of the Lava Cap Mine Groundwater Flow Model. Surface water samples should be

collected at least quarterly from the new weir locations and from stream gauge Location 12B; the samples should be analyzed for total and dissolved arsenic for use in the mass load calculations.

- Collect at least two additional groundwater samples for dissolved arsenic from Well 13T to determine if the arsenic concentration in this well will stabilize below the MCL.
- Collect a surface water sample for total arsenic analysis from LGC, within the area projected to potentially have mine-impacted groundwater discharge (near elevation 2,350 feet msl). The travel times from the mine area to this LGC discharge location are likely extremely long (i.e., many hundreds of years).
- Continue bimonthly water level measurements through December 2008 in Site monitoring wells, piezometers, and staff gauges.
- Continue stream discharge monitoring through December 2008 to complete an annual cycle and to validate and correct existing streamflow data.

The following are lower priority recommendations:

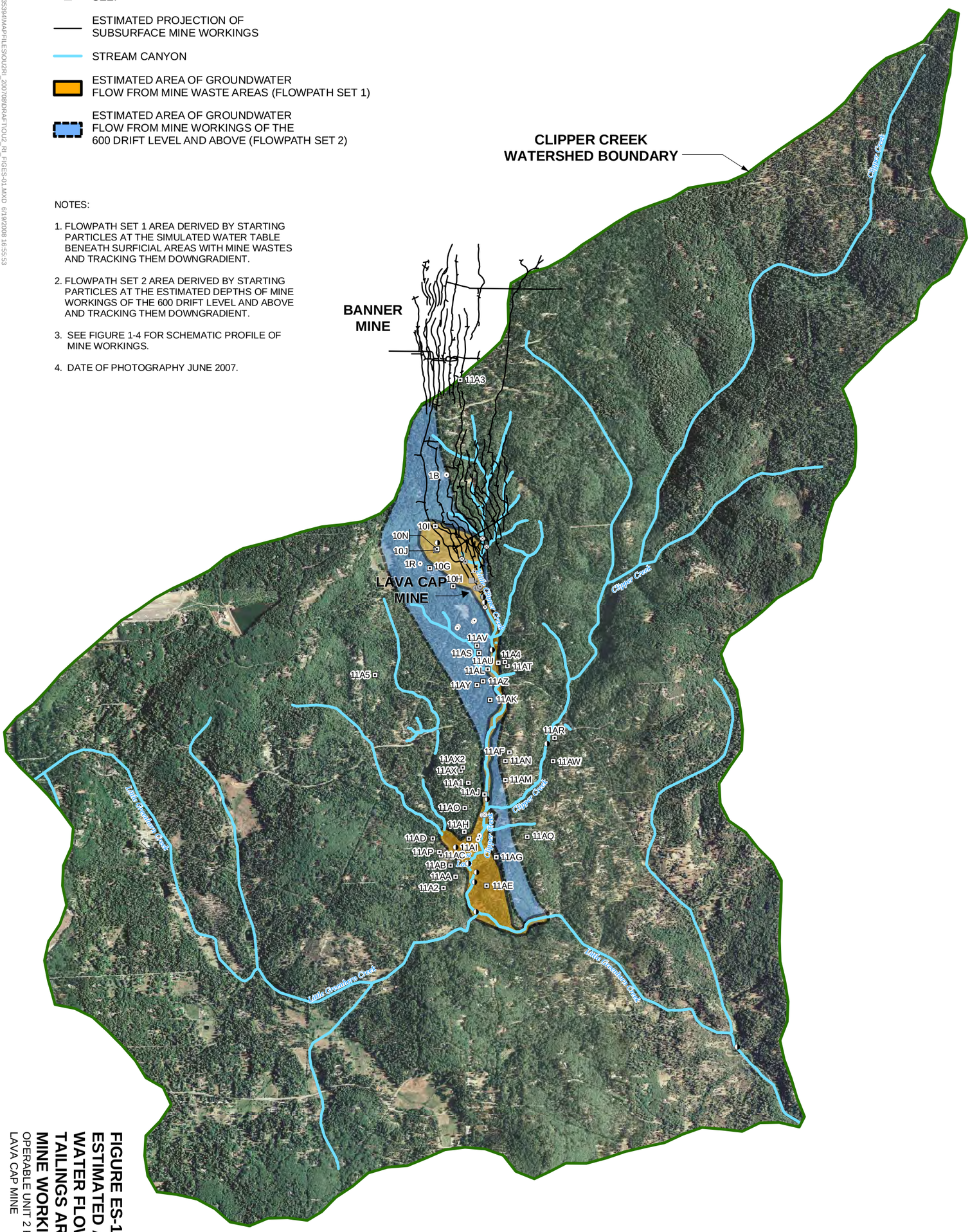
- Resample the wells sampled in October 2006 for arsenic speciation to evaluate whether arsenic speciation trends are a result of field or laboratory quality control problems, seasonal fluctuations, or a combination of both.
- Install new monitoring wells in the Source Area to help evaluate how groundwater elevations and arsenic concentrations have changed as a result of the OU-1 RA.
- Perform depth-discrete groundwater sampling in Well 5L-D to determine at what depth the greatest arsenic concentrations are present. This information could aid in the placement of new monitoring wells as part of the OU-2 FS.
- Collect surface water samples from tributaries upstream from Lost Lake, LGC upstream from the confluence of CC, and LGC to verify the assumption of low arsenic concentrations in these waters.
- Perform a reach-specific stream discharge analysis in LCC between the Rock Buttress and Lost Lake (collect accurate stream discharge measurements with a current meter in LCC at several distances from the Rock Buttress). This should include sampling and analysis for total and dissolved arsenic in surface water at each discharge measurement location to help evaluate arsenic concentrations and groundwater/surface water interactions along LCC.
- Incorporate any new information into the Lava Cap Mine Groundwater Flow Model.

LEGEND

- MONITORING WELL
- PIEZOMETER
- RESIDENTIAL WELL
- SURFACE WATER SAMPLE LOCATION
- STREAM GAGE AND SURFACE WATER SAMPLE LOCATION
- STAFF GAGE
- SEEP
- ESTIMATED PROJECTION OF SUBSURFACE MINE WORKINGS
- STREAM CANYON
- ESTIMATED AREA OF GROUNDWATER FLOW FROM MINE WASTE AREAS (FLOWPATH SET 1)
- ESTIMATED AREA OF GROUNDWATER FLOW FROM MINE WORKINGS OF THE 600 DRIFT LEVEL AND ABOVE (FLOWPATH SET 2)

NOTES:

1. FLOWPATH SET 1 AREA DERIVED BY STARTING PARTICLES AT THE SIMULATED WATER TABLE BENEATH SURFICIAL AREAS WITH MINE WASTES AND TRACKING THEM DOWNGRADIENT.
2. FLOWPATH SET 2 AREA DERIVED BY STARTING PARTICLES AT THE ESTIMATED DEPTHS OF MINE WORKINGS OF THE 600 DRIFT LEVEL AND ABOVE AND TRACKING THEM DOWNGRADIENT.
3. SEE FIGURE 1-4 FOR SCHEMATIC PROFILE OF MINE WORKINGS.
4. DATE OF PHOTOGRAPHY JUNE 2007.



N

0 2,400 4,800 FEET

FIGURE ES-1
ESTIMATED AREA OF GROUND-WATER FLOW FROM SURFICIAL TAILINGS AREAS AND SHALLOW MINE WORKINGS
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LAVA CAP MINE

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LEGEND

- MONITORING WELL
- PIEZOMETER
- RESIDENTIAL WELL
- SURFACE WATER SAMPLE LOCATION
- STREAM GAGE AND SURFACE WATER SAMPLE LOCATION
- STAFF GAGE
- SEEP
- ESTIMATED PROJECTION OF SUBSURFACE MINE WORKINGS
- STREAM CANYON
- ESTIMATED AREA OF GROUNDWATER FLOW FROM MINE WORKINGS OF THE 700 DRIFT LEVEL AND BELOW (FLOWPATH SET 3)

NOTES:

1. FLOWPATH SET 3 AREA DERIVED BY STARTING PARTICLES AT THE ESTIMATED DEPTHS OF MINE WORKINGS OF THE 700 DRIFT LEVEL AND BELOW AND TRACKING THEM DOWNGRADIENT.
2. SEE FIGURE 1-4 FOR SCHEMATIC PROFILE OF MINE WORKINGS.
3. DATE OF PHOTOGRAPHY JUNE 2007.

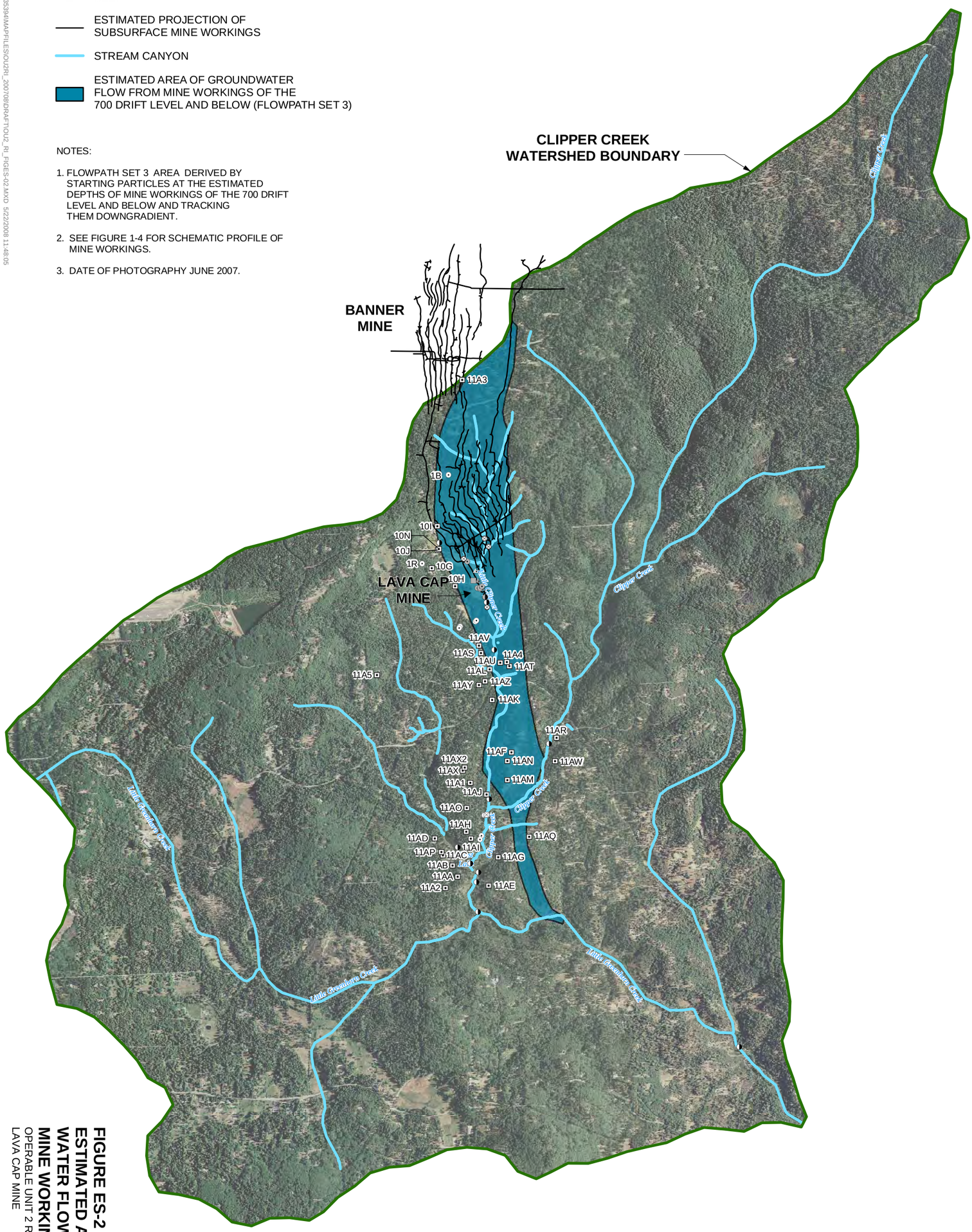

FIGURE ES-2
ESTIMATED AREA OF GROUND-WATER FLOW FROM DEEP MINE WORKINGS
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LAVA CAP MINE

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Acronyms and Abbreviations

°F	degrees Fahrenheit
µg/L	micrograms per liter
As(III)	trivalent arsenic
As(V)	pentavalent arsenic
CC	Clipper Creek
CSM	conceptual site model
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
FS	feasibility study
ft^2/day	square feet per day
ft^3/sec	cubic feet per second
GC	Greenhorn Creek
GMWL	global meteoric water line
gpm	gallons per minute
gpm/ft	gallons per minute per foot
HI	hazard index
JT_Rv	Jurassic to Triassic metamorphosed volcanic rock
K_h	horizontal hydraulic conductivity
LGC	Little Greenhorn Creek
LMWL	local meteoric water line
MCL	maximum contaminant level
Md	mine deposits
mg/L	milligrams per liter
msl	mean sea level
N/A	not applicable
NA	not accessible

NPL	National Priorities List
NS	not sampled
OU-1	Operable Unit 1
OU-2 FSP Addendum	*Sampling and Analysis Plan Addendum for Operable Unit 2 Remedial Investigation/Feasibility Study*
OU-2 FSP	*Field Sampling Plan for the Operable Unit 2 Remedial Investigation/ Feasibility Study*
OU-2	Operable Unit 2
Pms	Paleozoic to Upper Jurassic metamorphic rock
ppt	parts per thousand
RA	remedial action
RI	remedial investigation
ROD	Record of Decision
SAP Addendum	*Sampling and Analysis Plan Addendum for Operable Unit 2 Remedial Investigation/Feasibility Study*
Site	Lava Cap Mine Superfund Site
TDS	total dissolved solids
Tvb	Tertiary volcanic breccia

SECTION 1.0

Introduction

The U.S. Environmental Protection Agency (EPA), under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, is conducting a remedial investigation (RI) and feasibility study (FS) to address contamination in Operable Unit 2 (OU-2) of the Lava Cap Mine Superfund Site (Site). The Site was listed on the National Priorities List (NPL) in January 1999.

The Site is located southeast of Nevada City, California and includes the mine property and downgradient areas to the confluence of Clipper Creek (CC) and Little Greenhorn Creek (LGC) that are affected by contamination from the mine. The Site is divided into the following four operable units:

- Operable Unit 1 (OU-1), the terrestrial portion of the former active mining area, includes surficial features upstream, from Greenhorn Road to Little Clipper Creek (LCC). The OU-1 remedial action (RA) began in May 2006 and is still underway.
- OU-2 includes groundwater at the Site and is the focus of this report.
- Operable Unit 3 (OU-3) includes surficial features downstream from Greenhorn Road and the Lost Lake/Deposition Area. An RI data gaps investigation is planned for OU-3, which will lead to the development of the OU-3 FS.
- Operable Unit 4 (OU-4) is a subset of OU-1 and was delineated to account for the accelerated RA implemented at residences located on the mine property. The OU-4 RA was completed in early 2006.

1.1 Purpose of Report

Mine-related contaminants have adversely impacted portions of the Site, including downgradient areas along LCC and CC and extending through Lost Lake to LGC. Arsenic, the Site contaminant of concern, occurs in groundwater and surface water in concentrations that pose a threat to human and ecological receptors at the mine and in areas downgradient from the mine. Arsenic concentrations in soil, sediment, and surface water are highest in the source areas at the mine and along LCC, CC, and at Lost Lake, where tailings have been deposited. Continued migration of dissolved and suspended arsenic from the mine is occurring through perennial adit discharges and tailings pile seepage from the newly constructed Rock Buttress. OU-1 and OU-3 remedial activities will address these surficial arsenic contamination concerns for soil, sediment, and surface water.

Elevated arsenic concentrations also occur in groundwater at some monitoring and residential well locations. In general, locations with elevated arsenic concentrations in groundwater coincide with areas having elevated arsenic concentrations in soils, sediments, and surface water. However, this is not the case for all monitoring and residential well locations. The lack of information on three-dimensional groundwater flow directions and rates has limited

the understanding of how arsenic moves through the groundwater system. The following OU-2 RI groundwater investigations were necessary to better understand the groundwater system:

- A groundwater system conceptual site model (CSM), including primary features of the groundwater system, groundwater fate and transport, areas of groundwater recharge and discharge, and the groundwater budget components
- Potential sources of elevated arsenic in groundwater in some residential wells, including water affected by past mining operations, the continued presence of Lava Cap Mine, or from naturally occurring processes

This RI report documents the results of data collection efforts conducted to characterize Site conditions, estimate the nature and extent of groundwater contamination, support informed risk management decisions regarding human health from groundwater arsenic contamination, and support preparation of the OU-2 FS to identify a remedy. This RI report was developed in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988). Geologic and hydrogeologic investigations that involved collection of groundwater and surface water samples at the Site to provide a groundwater CSM are summarized herein.

After evaluation of the information gathered during the OU-2 RI, potential RA alternatives will be evaluated in the OU-2 FS. The OU-2 RI/FS process will lead to a Record of Decision (ROD) for OU-2, which will describe the environmental cleanup actions necessary to mitigate risks to human health from arsenic contamination in groundwater.

1.2 Site Background

The following sections provide a brief description and history of the Site and a summary of previous investigations. Detailed information is provided in the *Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada County, California* (EPA, 2001a), the *Mine Area Feasibility Study for the Lava Cap Mine Superfund Site, Nevada County, California* (EPA, 2004a), and the *Field Sampling Plan for the Operable Unit 2 Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (CH2M HILL, 2006b).

1.2.1 Site Description

The Site occupies approximately 30 acres in a rural residential area in the foothills of the Sierra Nevada Mountains. The mine is located approximately 5 miles southeast of Nevada City and 6 miles east of Grass Valley (see Figure 1-1), at 14501 Lava Cap Mine Road. The geographical coordinates are latitude 39°13’41.0” north and longitude 120°58’11.5” west, Township 16 North, Range 9 East, Section 28 of the Mount Diablo baseline and meridian. The mine property is bordered on all sides by forest and low-density residential areas.

Figure 1-2 shows features of the Source Area and Mine Area prior to the OU-1 RA, which began in May 2006. Currently, there are several structures at the mine, including the former mill building, the former cyanide treatment building, several other old mine buildings, and two residences. As part of the OU-1 RA, two residential buildings were removed, the surface water drainage patterns were altered, the waste rock/tailings pile was covered,

some waste rock and tailings were removed, and the Log Dam was replaced with the Rock Buttress. The OU-1 RA is described in the *Mine Area OU-1 Phase 1 Primary Mine Area Remedial Design* (CH2M HILL, 2006a). The OU-1 RA report (in preparation) will provide details of the final remedial design and implementation.

The Site is divided into in the following areas (see Figure 1-3):

- **Background Areas.** These areas include (1) the LCC watershed upstream from the Mine Area and (2) CC upstream from its confluence with LCC. Water samples from the Background Areas are compared with water samples from areas having known mine-related impacts.
- **Source Area.** This area includes portions of the mine property where tailings and waste rock from historical mining operations are located and areas where mine-related water discharge occurs.
- **Mine Area.** This area includes portions of the mine property that are adjacent to and upstream from the Source Area.
- **Downgradient Area.** This area is downstream from Lava Cap Mine where mine tailings were transported by creeks, including the following:
  - Portions of LCC downstream from the Source Area
  - CC, from the confluence with LCC to the confluence with LGC
  - Portions of land adjacent to these creek sections
- **Lost Lake/Deposition Area.** This area includes Lost Lake and the area immediately upstream from Lost Lake where tailings from the mine site have been deposited in the CC drainage.

1.2.2 Site History

Gold and silver mining activities started at Lava Cap Mine (formerly the Central Mine) in 1861. Banner Mine, which is located approximately 1.5 miles north of Lava Cap Mine, began operation in 1860. Sometime after 1934, the Banner and Lava Cap Mines were connected underground by a 5,000-foot drift. The subsurface workings of the mines are depicted schematically on Figure 1-4. Various entities intermittently operated the mines between 1860 and 1943; a history of operations during that period is provided in the *Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada County, California* (EPA, 2001a) and the *Mine Area Feasibility Study for the Lava Cap Mine Superfund Site, Nevada County, California* (EPA, 2004a); a brief overview is provided in this section.

From 1860 to 1918, an amalgamation process was employed that used mercury to recover silver and gold from ore. The process was not highly effective on Central Mine ore because of its high sulfide content. A flotation plant (the Lava Cap mill) was built to process the ore. The mill consisted of crushing and grinding circuits to reduce the particle size of the ore. The crushed ore was then subjected to flotation to separate the ore into a concentrate that contained gold, silver, and tailings.

In 1940, a cyanide plant was built onsite to recover gold from the concentrates, but the operation was ineffective. From 1941 to 1943, the cyanide plant processed only the

middlings and tailings from the flotation plant and did not process the higher-grade flotation concentrates. The middlings and tailings were crushed to a very fine size and then vat-leached with cyanide to remove residual gold and silver by using the Merrill-Crowe zinc-precipitation process.

Tailings from flotation and cyanidation processes were deposited in a ravine on the mine property. The Log Dam (removed as part of the OU-1 RA and replaced by the Rock Buttress), which was approximately 30 feet high, held the tailings in place where the ravine steepened and narrowed. The construction date of the Log Dam is unknown, but it likely occurred shortly after mining operations resumed in 1934. The waste rock and overburden were deposited in two piles between the mine shaft and tailings pond that formed north of the Log Dam. As of 1941, the primary mining method was cut and fill, whereby the open stope formed by mining was filled with waste rock after the ore was removed. This provided a more stable method than leaving the stope open under weak rock conditions.

Lost Lake Dam, located on CC approximately 1.25 miles downstream from Lava Cap Mine, was constructed as a mine tailings impoundment. The dam created Lost Lake, which is now a 5-acre private lake (see Figure 1-5).

In 1943, Lava Cap Mine closed because the federal government prohibited the production of nonstrategic metals during World War II. There was an attempt to reopen the mine in the mid-1980s, but community opposition prevented the opening.

The adit at Lava Cap Mine collapsed sometime between 1978 and 1984. Additionally, the main shaft into the mine has been at least partially filled with debris; no access to the underground workings of the mine now exists. The condition of the underground workings is not known.

During a major winter storm in January 1997, the upper half of the Log Dam collapsed, releasing over 10,000 cubic yards of tailings into LCC. Extensive deposits of tailings were observed in LCC, in CC below the confluence with LCC, in Lost Lake, and in associated wetlands. This prompted the California Department of Toxic Substance Control to issue warning in June 1997 for potential hazards from contact with Lost Lake sediments. In October 1997, the EPA Region 9 Emergency Response Office determined that conditions associated with the tailings release from Lava Cap Mine met the National Contingency Plan, Section 300.415(b)(2) criteria for a removal action. The primary concern was the potential for additional releases of tailings from the mine's waste rock/tailings piles. This concern was based on the high arsenic concentrations and the mobility of the extremely fine-grain tailings, which are easily suspended and transported in surface water (EPA, 1997).

During October and November 1997, 4,000 cubic yards of tailings were removed upstream from the damaged Log Dam and stockpiled (lined and capped) on the waste rock pile immediately north of the tailings pile. Stream diversions were also constructed around the waste rock and tailings piles. In February 1998, EPA conducted additional work to stabilize another smaller tailings release and further improve drainage. All work related to the emergency RA took place on the Lava Cap Mine property, at or north of the Log Dam, in summer 1998.

In 1998, EPA evaluated potential risks to human health and the environment to determine if Lava Cap Mine warranted listing on the NPL as a Superfund site. In January 1999, the Site was listed on the NPL, which provided funding for investigations and cleanup activities.

1.2.3 Previous Investigations

1.2.3.1 California Department of Toxic Substance Control Investigations

After the Log Dam collapse in January 1997, the Department of Toxic Substances Control sampled surface water, sediment, and surface soil periodically from 1997 through 1999. Sampling results indicated the presence of arsenic in the surface water of Lost Lake at concentrations of up to 28.4 micrograms per liter (µg/L) and in shoreline soils at concentrations of up to 1,130 milligrams per kilogram. Surface water arsenic concentrations in LCC remained steady between 1997 and 1999; however, concentrations in Lost Lake fluctuated between events. There was one small pond near the confluence of LCC and CC that had high arsenic concentrations ranging from 706 to 2,070 µg/L. Analysis of soil samples collected on private property at Lost Lake indicated a decrease in arsenic concentrations with increasing distance from the shore.

1.2.3.2 Routine Sampling Associated with the Sitewide Remedial Investigation/Feasibility Study

Routine and periodic sampling of various environmental media were part of the sitewide RI/FS process, which is still in progress. A sitewide RI report (EPA, 2001a) summarized soil, sediment, surface water, and groundwater data collected in 1999 and 2000. As part of the RI, human health and ecological risk assessments were conducted and documented (EPA, 2001a, Appendices E and F). The risk assessments established arsenic as the primary risk driver in groundwater; an FS (EPA, 2004a) addressed the mitigation of risks associated with arsenic contamination in surface water and soil in the Mine Area.

1.2.3.3 2001 Data Gaps Investigation

A data gap investigation was conducted in 2001, as outlined in the *Addendum No. 3 to the Field Sampling Plan for the Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (EPA, 2001b), which included the following:

- Installation of three new monitoring wells:
  - Well 1R – an upgradient well in one of the Background Areas (November 2001)
  - Well 5J – a deep well in the bedrock beneath the Source Area waste rock/tailings piles (August 2001)
  - Well 13S – a deep bedrock well in the Lost Lake/Deposition Area, which was paired with shallow Well 13Q (September 2001)
- Installation of three new piezometers (Piezometers 5PZ-1, 5PZ-2, and 5PZ-3) in the waste rock/tailings piles to measure water levels
- Monitoring of four Downgradient Area residential wells (Wells 11AS, 11AT, 11AU, and 11AV), located along the LCC drainage near a well with elevated arsenic concentrations (Well 11AL)

- Addition of a new surface water sampling location (Location 19M) on LGC, approximately 1.5 miles downstream from the confluence with CC, to aid in evaluating downstream mine-related impacts
- Sampling and analysis of selected groundwater and mine discharge areas for arsenic speciation
- A special sampling event in November 2001; select water and soil samples from the Source Area and Mine Area were analyzed for volatile and semivolatile organic compounds
- Sampling of waste rock, tailings, soil, sediment, and dust at the Source Area, Mine Area, and Lost Lake Dam to support OU-1 and OU-3 FS work
- Geotechnical exploration of the waste rock/tailings piles and the Log Dam in August 2001 in support of the OU-1 FS work

The results of the 2001 data gap investigation are presented in the *Field Monitoring Report for RI/FS Field Activities, August through November 2001, Lava Cap Mine Superfund Site* (CH2M HILL, 2002a).

1.2.3.4 Routine Sampling Associated with the OU-2 Remedial Investigation/Feasibility Study

Routine surface water and groundwater monitoring occurred from October 2001 through March 2007 to support the OU-2 RI/FS. The monitoring was performed to evaluate seasonal and long-term trends in arsenic and general chemistry parameters, develop an understanding of the extent of arsenic contamination in groundwater, track groundwater elevation changes over time, and provide a dataset to support human health risk management decisions. Groundwater and surface water sampling locations are shown on Figures 1-6 though 1-9. The sampling program was established to address data gaps relating to subsurface flow and the nature and extent of contamination at the Site identified after the 2001 RI work. Results from routine monitoring performed from 2001 to 2004, as outlined in *Addendum No. 3 to the Field Sampling Plan for the Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (EPA, 2001b) are presented in the following reports:

- *Field Monitoring Report for RI/FS Field Activities, August through November 2001, Lava Cap Mine Superfund Site* (CH2M HILL, 2002a)
- *Field Monitoring Report, Quarterly Monitoring Activities, February and May 2002, Lava Cap Mine Superfund Site* (CH2M HILL, 2002b)
- *Field Monitoring Report, Quarterly Monitoring Activities, August 2002, Lava Cap Mine Superfund Site* (CH2M HILL, 2003a)
- *Field Monitoring Report, Quarterly Monitoring Activities, November 2002, Lava Cap Mine Superfund Site* (CH2M HILL, 2003b)
- *Field Monitoring Report, Quarterly Monitoring Activities, February and May 2003, Lava Cap Mine Superfund Site* (CH2M HILL, 2003c)
- *Field Monitoring Report, Quarterly Monitoring Activities, August and December 2003, Lava Cap Mine Superfund Site* (CH2M HILL, 2004a)

- *Field Monitoring Report, Quarterly Monitoring Activities, March and June 2004, Lava Cap Mine Superfund Site* (CH2M HILL, 2004b)
- *Field Monitoring Report, Quarterly Monitoring Activities, September/October and December 2004, Lava Cap Mine Superfund Site* (CH2M HILL, 2005a)

Groundwater and surface water data from 1999 through 2004 were used to identify data gaps and determine the need for additional OU-2 RI-related fieldwork. The planned work was outlined in the *Field Sampling Plan for the Operable Unit 2 Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (OU-2 FSP) (CH2M HILL, 2005b) and the *Quality Assurance Project Plan for the Operable Unit 2 Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (CH2M HILL, 2005c). Fieldwork performed between 2004 and 2005 included the following:

- Routine groundwater and surface water monitoring
- A record search of Nevada County files in 2004 to evaluate the availability of pertinent groundwater quantity and quality data from existing local residential wells
- A residential well canvass that led to the addition of five new residential wells to the sampling program (Wells 11AY, 11AZ, 11A1, 11A2, and 11A3)
- Hydraulic testing of selected monitoring wells at the Site and nearby residential wells
- Installing, developing, and aquifer testing of a shallow/deep monitoring well pair (Well Pair 5K-S/5K-D) between the mine and arsenic-impacted residential Wells 11AL and 11AS
- Incorporating hydraulic data into an existing three-dimensional numerical groundwater flow model of the Site (the Lava Cap Mine Groundwater Flow Model)
- Performing a metal sample filtration study to explore the effect of colloid particles on metal concentration results in groundwater and surface water samples
- Conducting an arsenic speciation and stable-isotope analyses study
- Installing four stream gauges (Locations 1U, 1J, 3A, and 12B) in the Source Area and Mine Area to provide data to refine local water budget estimates and improve understanding of the seasonal quantity of surface water that flows near or through the waste rock/tailings piles in Source Area and Mine Area (for the OU-1 remedial design work)

These activities are documented in Section 2.0 and in the *Lava Cap Mine, Field Monitoring Activities, April through October 2005, Nevada City, California* (CH2M HILL, 2005d). Additional fieldwork was conducted in 2006 and 2007 to fill data gaps identified in the *Sampling and Analysis Plan Addendum for Operable Unit 2 Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (OU-2 FSP Addendum) (CH2M HILL, 2006b). The additional fieldwork included the following:

- Routine groundwater and surface water monitoring

- Installation, development, and aquifer testing of a new shallow/deep monitoring well pair (Wells 5L-S/5L-D) between the mine and arsenic-impacted residential Wells 11AL and 11AS
- Installation, development, and aquifer testing of a new, deep monitoring well (Well 13T) and LCC Staff Gauge 14E, which are paired with existing shallow Well 13R
- Incorporation of hydraulic data into the Lava Cap Mine Groundwater Flow Model
- Additional arsenic speciation sampling and analysis

These activities are documented in Section 2.0 and in the L*ava Cap Mine, Routine Groundwater and Surface Water Monitoring Activities, April 2006 through May 2007, Lava Cap Mine Superfund Site, Nevada City, California* (CH2M HILL, 2007b).

1.2.3.5 Operable Unit 1 Remedial Action Work

In May 2006, the RA for OU-1 began in accordance with the *Mine Area OU-1 Phase 1 Primary Mine Area Remedial Design* (CH2M HILL, 2006a). The RA included the following activities:

- Excavating arsenic-contaminated soil along LCC, downstream from the mine near Tensy Lane, and placing the material beneath the waste rock/tailings pile cap
- Constructing the Rock Buttress at the downstream end of the waste rock/tailings piles to replace the Log Dam
- Constructing an LCC channel and several smaller channels to control drainage in the Source Area and Mine Area
- Regrading the waste rock pile and constructing an 18-inch-deep vegetative soil cover by using soil from an onsite borrow source
- Removing contaminated soil and water from within the mine buildings and surrounding appurtenances and disposing of the material offsite
- Excavating contaminated soil from areas surrounding the mine buildings, placing it under the waste rock/tailings pile cap, and backfilling excavated areas with clean soil
- Constructing a waste rock/tailings pile cap with geotextile and geomembrane layers and placing 18 inches of vegetative soil cover from an onsite borrow source over the contaminated materials
- Covering contaminated soil near the southernmost residence with an 18-inch-deep vegetative soil cover (near the residence) or a layer of rock mulch (on the steeper surrounding slopes)
- Hydroseeding all covered, capped, and disturbed areas
- Armoring the primary mine access road and other access roads with imported aggregate base and asphalt concrete

These activities caused the following impacts to the surface water and groundwater sampling program for the OU-2 RI/FS:

- Wells 5A, 5D, 5E, 5I, and 5J and Piezometers 5PZ-2 and 5PZ-3 were abandoned in June 2006 during the buttress excavation and grading of the waste rock/tailings piles. Piezometer 5PZ-1 was damaged during the excavation work, but it was repaired and resurveyed.
- Stream gauges and data loggers were installed in fall 2005 at the Lava Cap Mine adit (Location 3A), upper LCC side channel (Location 1U), and upper and lower reaches of LCC (Locations 1J and 12B, respectively). The instruments were taken offline from June to December 2006 because of the OU-1 RA construction activities.
- Surface water was temporarily diverted from the Lava Cap Mine adit (Location 3A), the former waste rock/tailings pile seep (Location 3B), and LCC at the base of the waste rock/tailings pile (the former Log Dam) in July 2006. The water was diverted to a reach of LCC near Tensy Lane and later (in early August) to a reach north of Greenhorn Road. This work might have affected well yields in some residential wells near Tensy Lane (see Section 2.0).
- The waste rock/tailings pile seep (Location 3B) at the west side of the waste rock/ tailings pile no longer exists and cannot be sampled. The infiltrating water (from the adit, from LCC north of the mine, and from precipitation on the waste rock/tailings pile) that fed the seep at Location 3B was diverted or minimized; the tailings were capped as part of the OU-1 RA. The former sampling location was also buried.
- Location 4A, at the base of the former Log Dam on LCC, was covered by the construction of the Rock Buttress at the downstream end of the waste rock/tailings pile. The sampling location was moved to the base of the Rock Buttress (but upstream from where the diverted adit water discharges to LCC) and designated as Location 4A2.
- New residential wells (Wells 11A4 and 11A5) were identified for groundwater sampling.

1.3 Report Organization

This RI report is organized as follows:

- **Section 1.0 – Introduction.** The section describes the purpose, Site background, and report organization.
- **Section 2.0 – Remedial Investigation Data Collection.** This section provides a summary of recent RI-related field activities.
- **Section 3.0 – Site Physical Characteristics.** This section provides information on the climate and hydrogeologic framework near the Site.
- **Section 4.0 – Nature and Extent of Contamination.** This section provides information regarding nature and extent of arsenic contamination in groundwater and surface water at the Site.

- **Section 5.0 – Contaminant Fate and Transport.** This section provides a summary of the groundwater CSM and geochemical evaluation.
- **Section 6.0 – Human Health Risk Assessment.** This section describes the risk assessment approach and human health risk evaluation for arsenic in residential drinking water wells.
- **Section 7.0 – Summary and Conclusions.** This section provides a summary and the conclusions regarding the site physical characteristics, the nature and extent of contamination, contaminant fate and transport, human health risk assessment, and recommendations.
- **Section 8.0 – Works Cited.** This section provides a list of documents cited in this report.
- **Appendix A – Analytical Data Summary.**
- **Appendix B – Field Parameter Data Summary.**
- **Appendix C – 2005 and 2007 Monitoring Well Installations and Aquifer Testing.**
- **Appendix D – Soil Boring Logs.**
- **Appendix E – Well Construction Diagrams.**
- **Appendix F – Sampling Location Information.**
- **Appendix G – Groundwater Flow Model Documentation.**
- **Appendix H – Arsenic Concentration Tables.**
- **Appendix I – Data Quality Summary**.

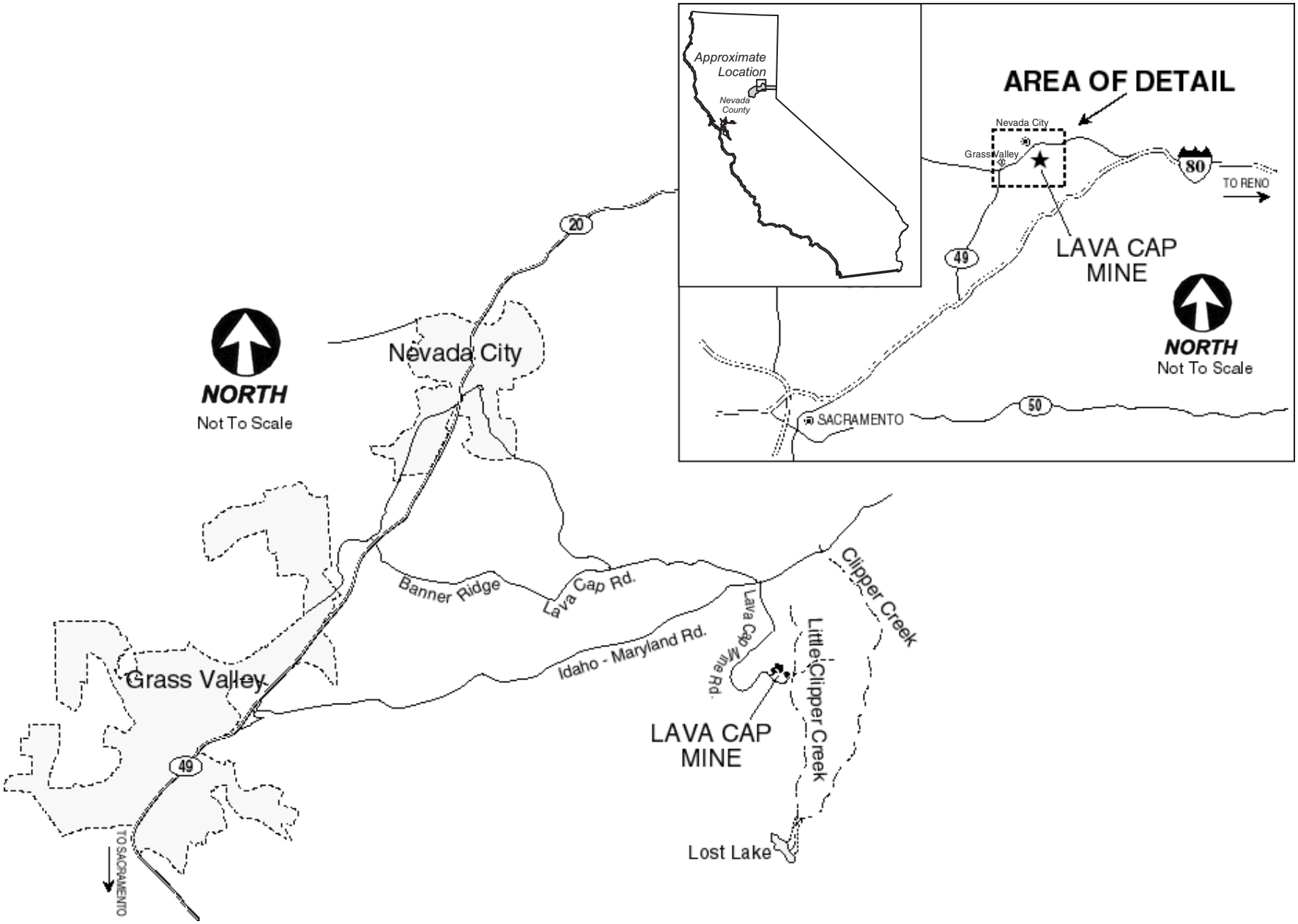
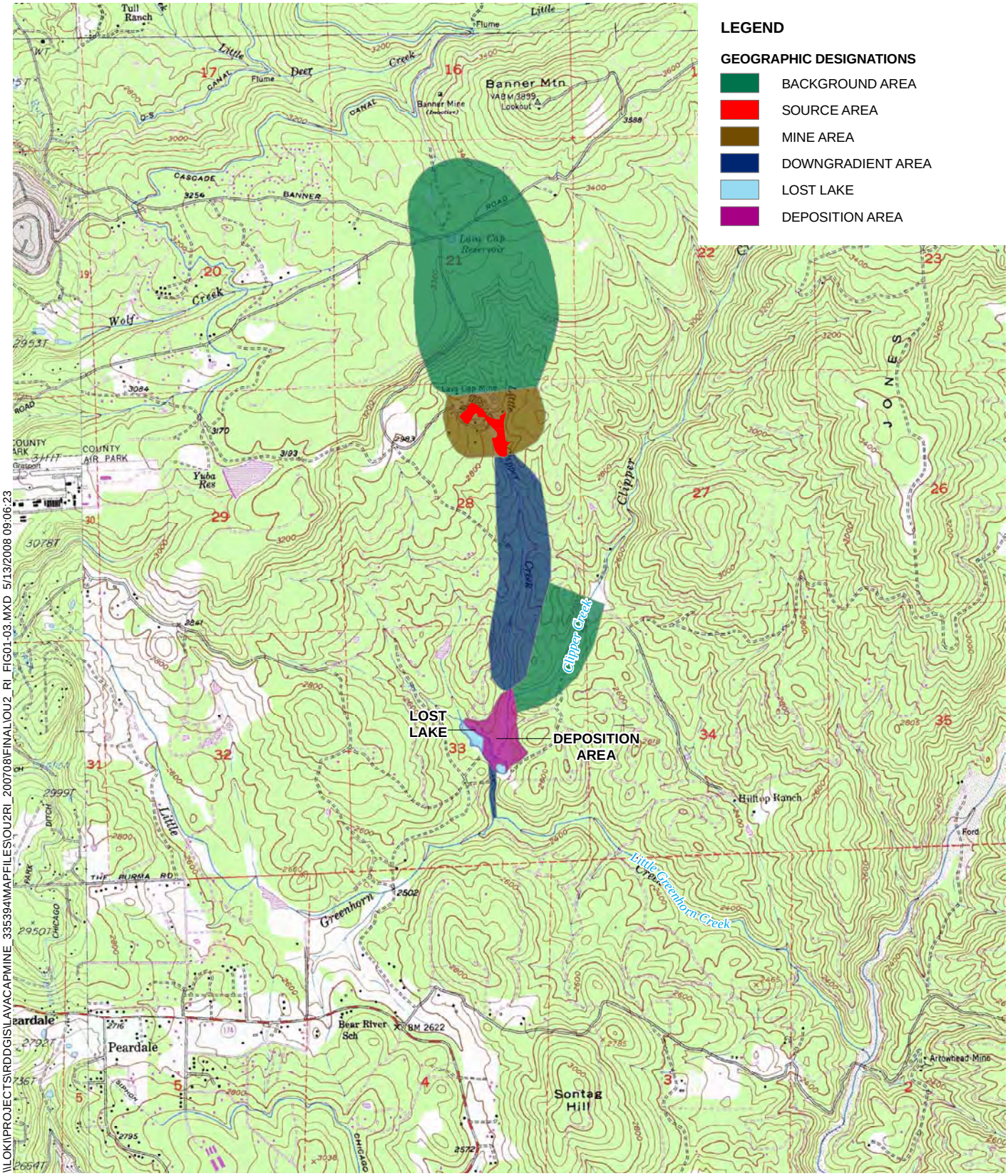


FIGURE 1-1
LOCATION OF LAVA CAP MINE SITE
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ES022008009RDD_03 (7/3/08)

FIGURE 1-2
MINE SITE FEATURES
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\LOKI\PROJECTS\RDDGIS\LAVACAPMINE_335394\MAPFILES\OU2RI_200708\DRAFT\OU2_RI_FIG01-02.MXD 6/30/2008 15:20:03



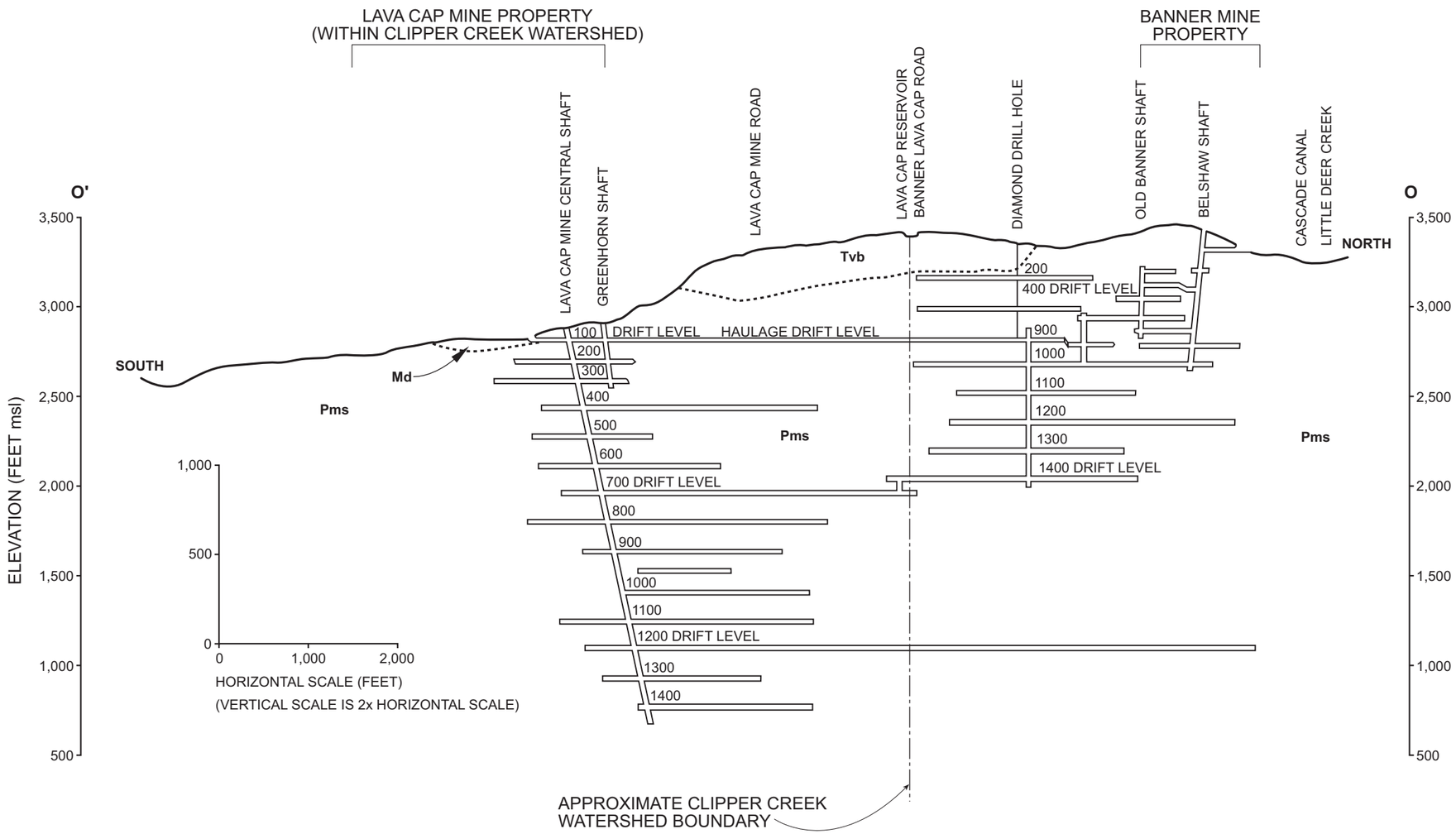
\\LOK\PROJECTS\RDDGIS\LAVACAPMINE_335394\MAPFILES\OU2RI_200708\FINAL\OU2_RI_FIG01-03.MXD 5/13/2008 09:06:23

N

FEET

0 3,000 6,000

FIGURE 1-3
GEOGRAPHIC DESIGNATIONS IN THE LAVA CAP MINE AREA
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE



LEGEND

Md	MINE DEPOSITS (WASTE ROCK AND TAILINGS)
Tvb	VOLCANIC FLOW BRECCIA (LAVA CAP)
Pms	METASEDIMENTARY ROCK
600	MINE WORKINGS AND DRIFT LEVEL IDENTIFICATION
	APPROXIMATE GEOLOGIC CONTACT

NOTES:

1. PROFILE LOCATION SHOWN ON FIGURE 3-3.
2. GROUND SURFACE ELEVATIONS REFLECT CONDITIONS PRIOR TO THE OU-1 REMEDIAL ACTION (STARTED IN MAY 2006).
3. THE DRIFT LEVEL IDENTIFICATION DOES NOT INDICATE AN ACTUAL DEPTH OR ELEVATION (e.g., THE 700 DRIFT LEVEL IS NOT NECESSARILY LOCATED AT 700 FEET bgs OR 700 FEET msl)

SOURCE: COLE/MILLS ASSOCIATES, 1985.

FIGURE 1-4
SCHEMATIC PROFILE OF SUBSURFACE MINE WORKINGS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ES022008009RDD_02 (2/15/07)

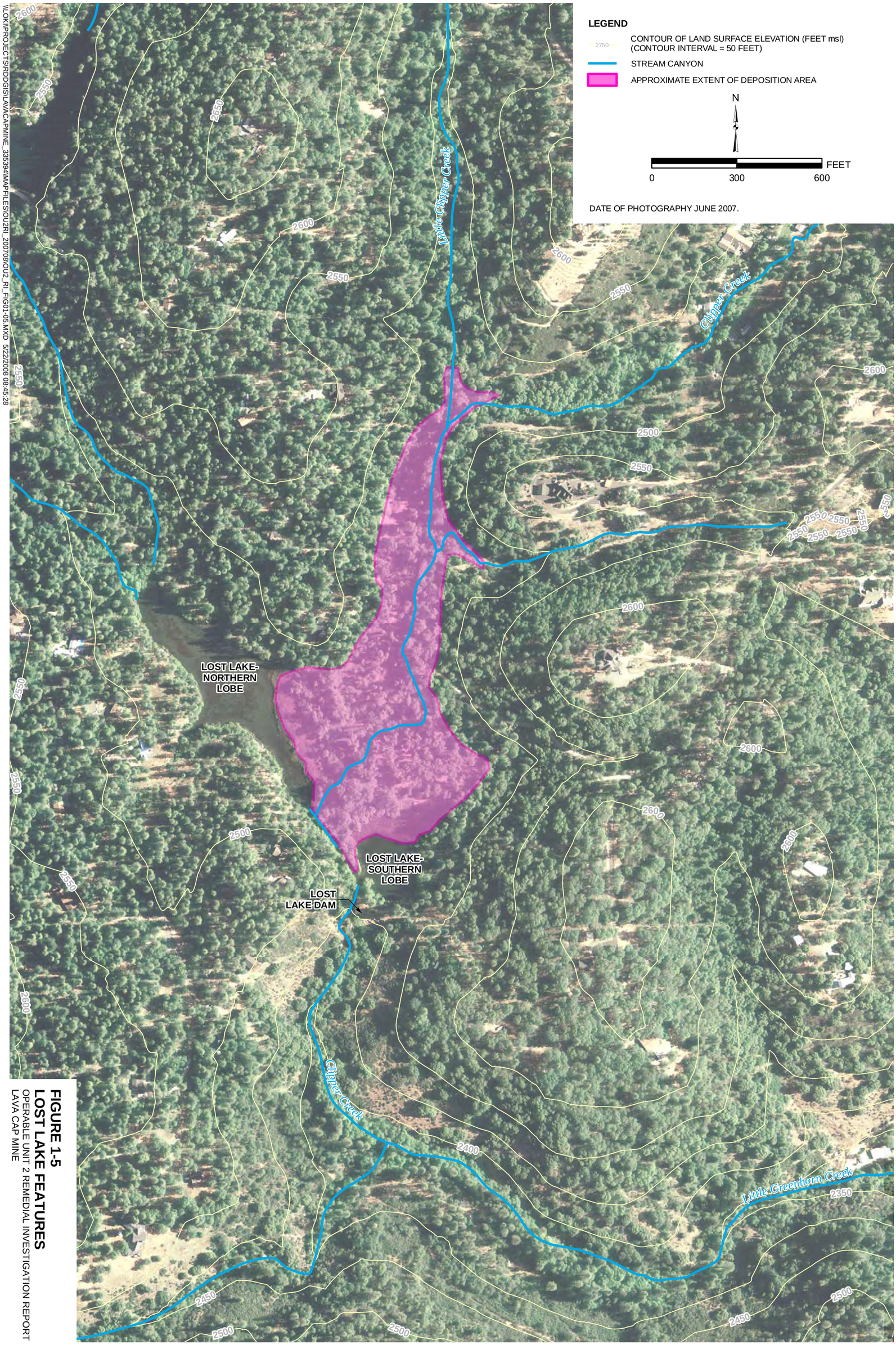


FIGURE 1-5
LOST LAKE FEATURES
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ILOKI:\PROJECTS\RDGIS\LAVACAPMINE_335394\MAPFILES\OU2\RI_200708\OU2_RI_FIG01-05.MXD 5/22/2008 08:45:28

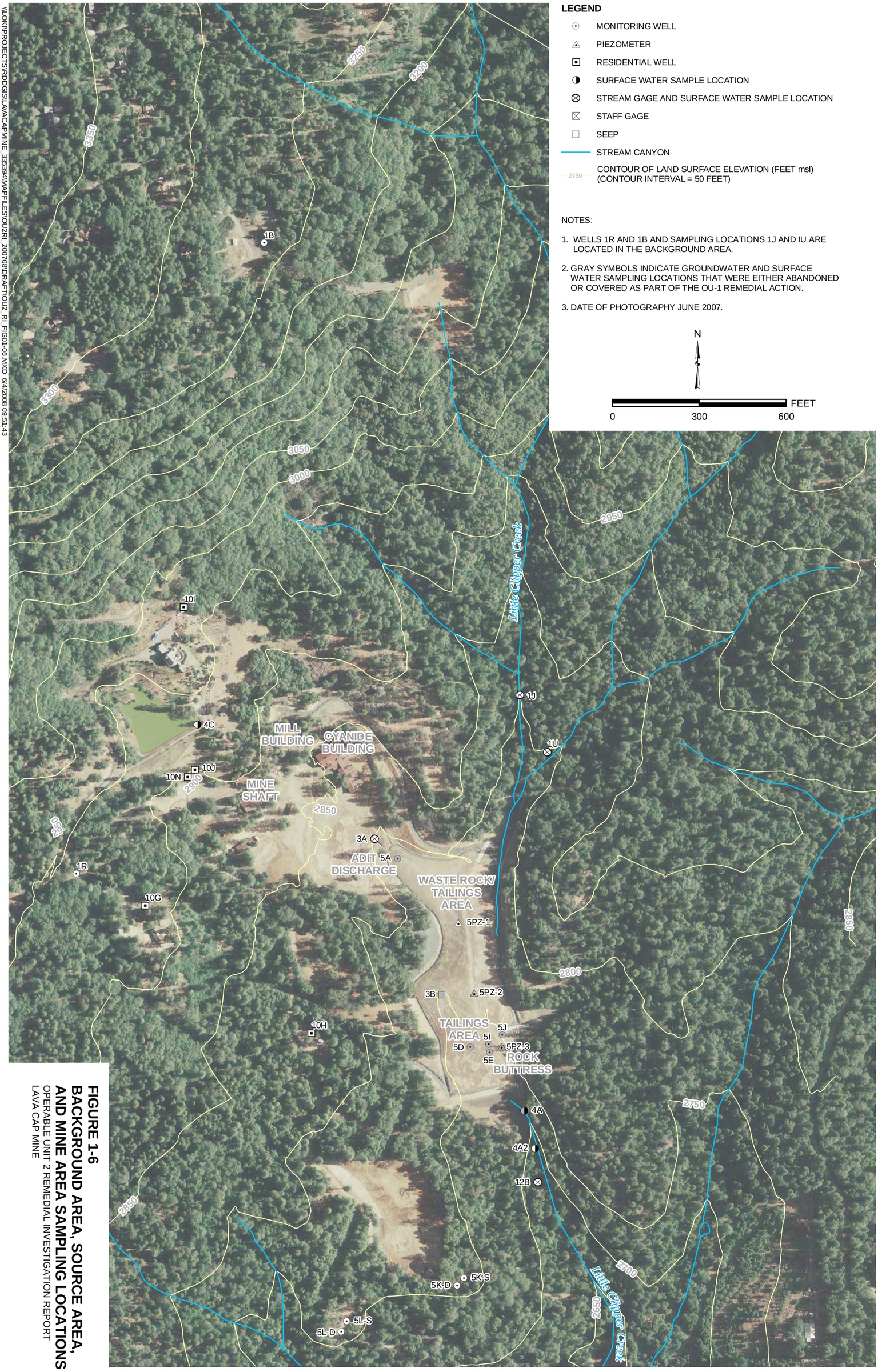
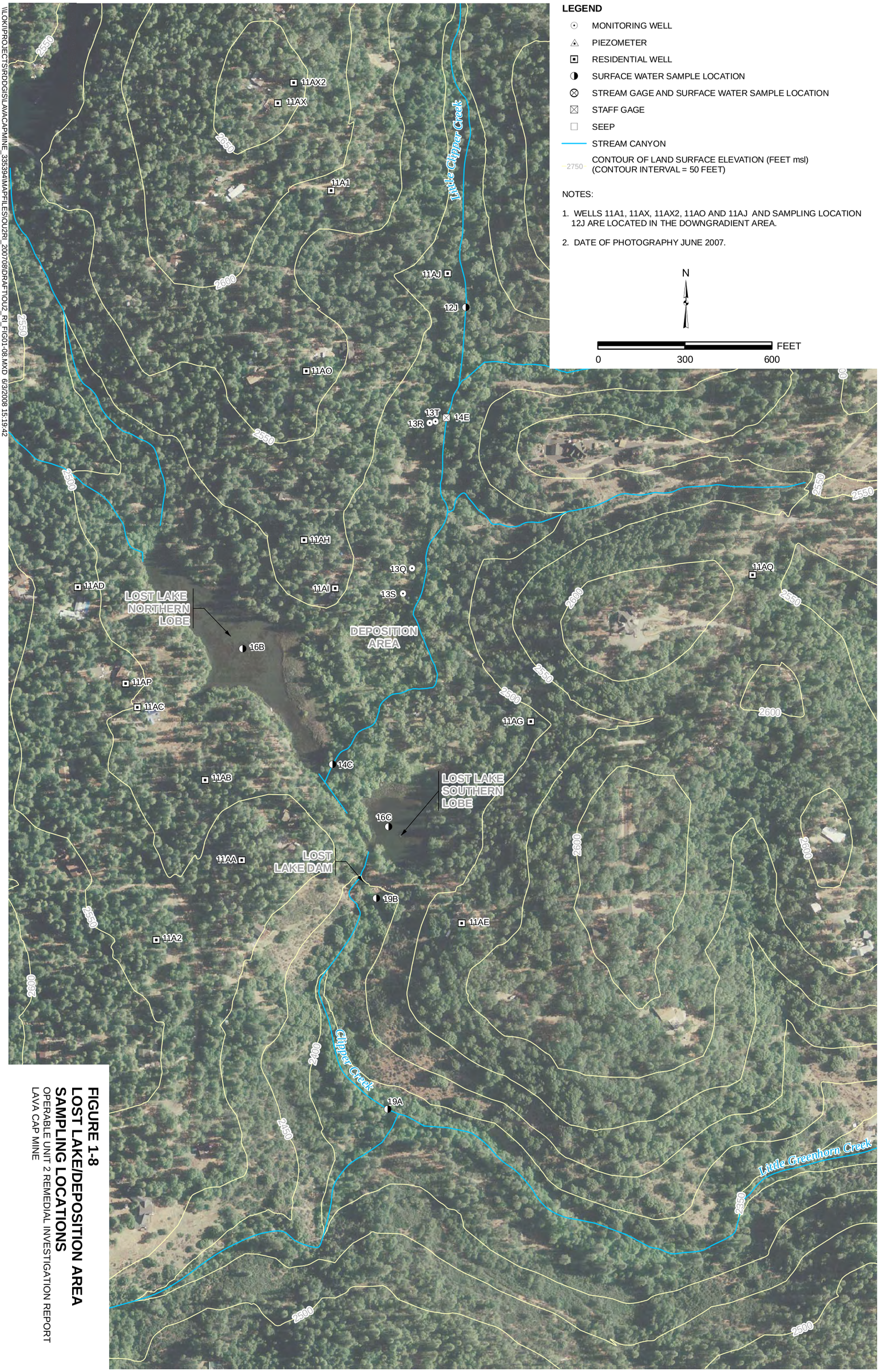


FIGURE 1-6
BACKGROUND AREA, SOURCE AREA, AND MINE AREA SAMPLING LOCATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\LOKI\PROJECTS\RDDGIS\LAVACAPMINE_3353941\MAPFILES\OU2RI_2007\08\DRAFT\OU2_RI_FIG01-06.MXD 6/4/2008 09:51:43

FIGURE 1-7
DOWNGRADIENT AREA
SAMPLING LOCATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\LOKI\PROJECTS\RDDGIS\LAVACAPMINE_335394\MAPFILES\OU2RI_200708\OU2_RI_FIG01-07.MXD 5/22/2008 08:50:41



\\LOKI\PROJECTS\RDGIS\LAVACAPMINE_3353941\MAPFILES\OU2\RI_2007\08\DRAFT\OU2_RI_FIG01-08.MXD 6/3/2008 15:19:42

FIGURE 1-8
LOST LAKE/DEPOSITION AREA SAMPLING LOCATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

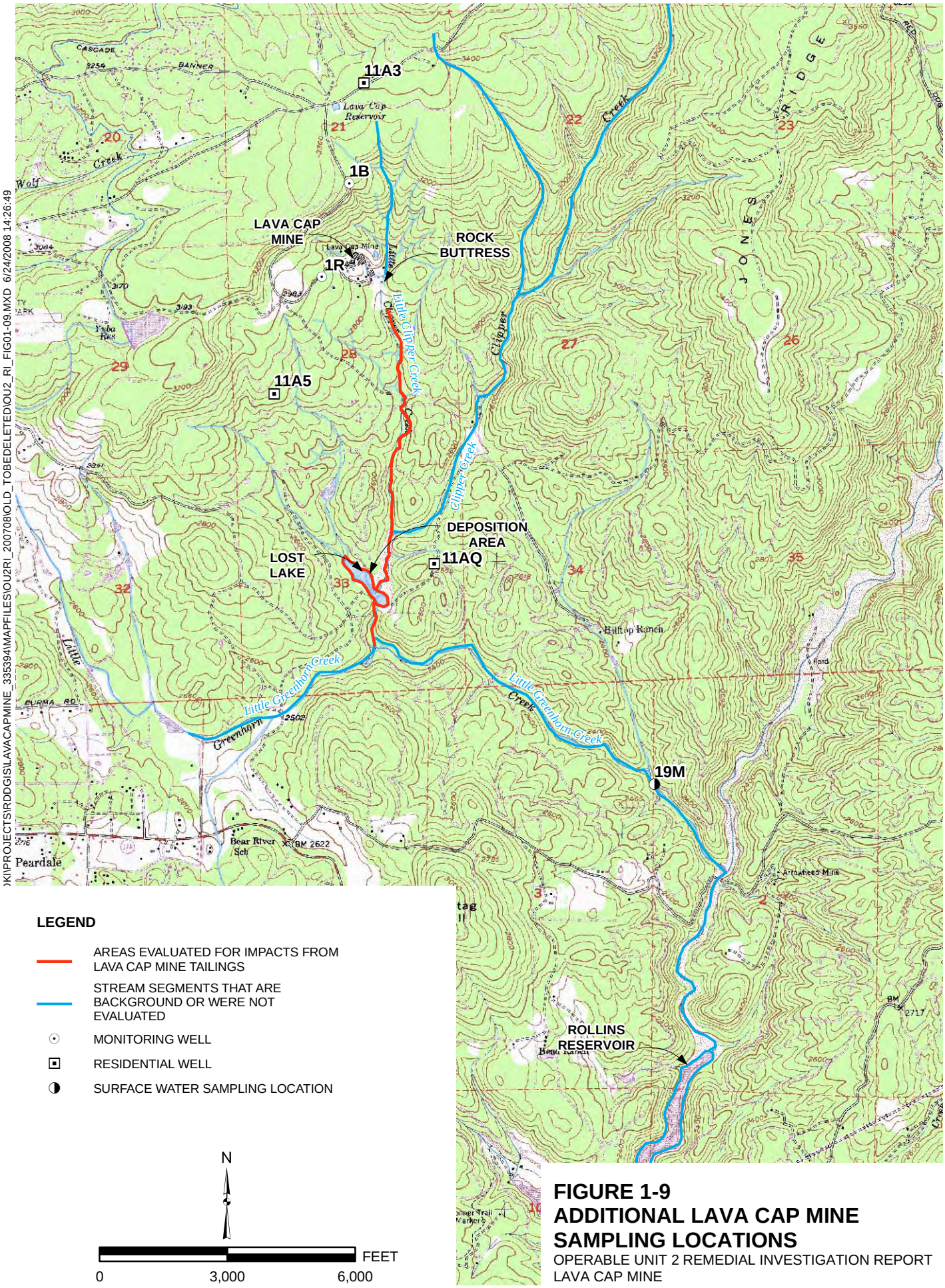


FIGURE 1-9
ADDITIONAL LAVA CAP MINE SAMPLING LOCATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

OKI\PROJECTS\RDDGIS\LAVACAPMINE_335394\MAPFILES\OU2RI_200708\OLD_TOBEDELETED\OU2_RI_FIG01-09.MXD 6/24/2008 14:26:49

SECTION 2.0

Remedial Investigation Data Collection

This section presents the objectives of the OU-2 RI field effort and describes some of the fieldwork conducted during the RI. This section focuses on OU-2 RI data gap investigation fieldwork performed between 2004 and 2007, which is not documented elsewhere. Data gap investigation fieldwork performed in 2001 is documented in the *Field Monitoring Report for RI/FS Field Activities, August through November 2001, Lava Cap Mine Superfund Site* (CH2M HILL, 2002a); the fieldwork is summarized in Section 1.2.3. Data applicable to the OU-2 RI fieldwork from 1999 through 2007 were used to describe the site physical characteristics (see Section 3.0), characterize the nature and extent of arsenic contamination in groundwater and surface water (see Section 4.0), evaluate the fate and transport of arsenic in groundwater (see Section 5.0), and evaluate human health risk (see Section 6.0).

A phased approach was employed to ensure that the OU-2 RI data collection efforts were cost effective and focused. Data collection was focused on filling the data gaps identified in the groundwater CSM, where possible, and gathering information to support risk management decisions and future evaluations of remedial alternatives in the OU-2 FS. The description of the data collection investigations is separated into the following tasks:

- Well canvass survey
- Groundwater and surface water monitoring
- New groundwater monitoring well installation
- Aquifer testing
- Stream discharge monitoring
- Surveying
- Ongoing fieldwork

2.1 Well Canvass Survey

A records search of Nevada County files was performed in 2004. The objective of the search was to determine the availability of pertinent residential well information that could assist in evaluations of groundwater flow and groundwater quality at the Site. Existing residential well data were considered a potentially less expensive source of information on groundwater conditions throughout the area of interest, as compared with installing additional monitoring wells.

As part of the records search, the Hydro-Search, Inc., report (1984), a map of the mine workings, and records for approximately 300 residential wells were obtained. The well locations for which easting and northing coordinates were either provided or could be estimated are shown on Figures 2-1 and 2-2. Approximately two-thirds of the wells identified had construction data (see Figure 2-1). Approximately one-half of the wells identified had records of pumping rates (see Figure 2-2), lithology, or location information. Data necessary for specific capacity calculations were only available for three wells in the CC

watershed; values ranged from 0.01 to 8.25 gallons per minute per foot (gpm/ft) of drawdown.

Approximately 100 of the 300 residential wells identified during the records search were targeted for additional data gathering. Mailings and phone calls yielded approximately 16 well owners who were interested in participating in the sampling program. Those wells were visited, and where possible, the well location, condition, and construction; the depth to water; pumping rate; pump manufacturer; drilling contractor; and water use were recorded when available. The well canvass work led to the addition of five residential wells (Wells 11AY, 11AZ, 11A1, 11A2, and 11A3) to the sampling program. The well locations are shown on Figures 1-7 through 1-9, and available well details are provided in Appendix F.

2.2 Groundwater and Surface Water Monitoring

The routine monitoring program is a component of EPA's ongoing OU-2 RI/FS at the Site. The monitoring program is discussed further in *Addendum No. 3 to the Field Sampling Plan for the Remedial Investigation/Feasibility Study, Lava Cap Mine Superfund Site* (EPA, 2001b), the OU-2 FSP (CH2M HILL, 2005b) and the OU-2 FSP Addendum (CH2M HILL, 2006b). The routine monitoring program includes the following:

- Collection of water samples from monitoring wells, piezometers, residential wells, and surface water for analysis for arsenic, cations (calcium, iron, magnesium, manganese, potassium, and sodium), anions (chloride, phosphate, and sulfate), total dissolved solids (TDS), alkalinity, and field parameters (DO, oxidation reduction potential [ORP], pH, specific conductance, temperature, and turbidity)
- Measurement of groundwater levels in Site monitoring wells, piezometers, and residential wells (where accessible)
- Measurement of streamflow
- Semiannual collection of water samples and maintenance (by EPA) of residential wellhead arsenic treatment systems at Wells 10G, 10H, and 11AL (Well 10H has not been in use since fall 2004)

Details of the groundwater and surface water monitoring are included in the sitewide RI report (EPA, 2001a) and periodic groundwater monitoring reports (CH2M HILL, 2002a, 2002b, 2003a, 2003b, 2003c, 2004a, 2004b, 2005a, 2005d, and 2007b). Table 2-1 provides a summary of the routine monitoring program sampling locations. Water elevation data are discussed in Section 3.0. Analytical results from the sampling program are presented in Appendix A; field parameter data are presented in Appendix B. Additional, nonroutine activities of the monitoring program include the following:

- Arsenic speciation analysis in August 2001 (third quarter 2001 [3Q01]), April 2005 (2Q05), April 2006 (2Q06), and October 2006 (4Q06) for samples collected from selected monitoring well, piezometer, residential well, and surface water sampling locations. A subset of these sampling locations was included in a 1Q05 comparison of arsenic speciation procedures by using either a field-separation method or a laboratory-separation method (the 2001 speciation results used a different laboratory-speciation

TABLE 2-1
Summary of Monitoring Locations and Events
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Sampling Event	Sample Type	Background Areas	Source Area	Mine Area	Lost Lake/ Deposition Area	Downgradient Area (south of mine, north of Greenhorn Road)	Downgradient Area (between Greenhorn Road and Deposition Area)	Downgradient Area (south of Lost Lake)
Groundwater Monitoring Locations								
4Q99	Monitoring wells/ piezometers	1B	5A, 5D, 5E					
	Residential wells			10G, 10H, 10I	11AA, 11AB, 11AC, 11AD, 11AE, 11AG, 11AH, 11AI, 11AP	11AL	11AF, 11AJ, 11AK, 11AM, 11AN, 11AO, 11AQ	
1Q00	Monitoring wells/ piezometers	1B	5A, 5D, 5E					
	Residential wells			10I, 10J		11AL		
2Q00	Monitoring wells/ piezometers	1B	5A, 5D, 5E, 5I		13Q, 13R			
	Residential wells	11AR		10G, 10J	11AA, 11AB, 11AC, 11AD, 11AE, 11AG, 11AH, 11AI, 11AP	11AL	11AF, 11AJ, 11AK, 11AM, 11AN, 11AO, 11AQ	
3Q00	Monitoring wells/ piezometers	1B	5A, 5D, 5E, 5I		13Q, 13R			
	Residential wells							
3Q01	Monitoring wells/ piezometers	1B	5A, 5D, 5E, 5I		13Q, 13R			
	Residential wells			10G, 10H, 10J	11AA, 11AE, 11AI, 11AP	11AL, 11AS, 11AT, 11AU, 11AV	11AF, 11AN	
4Q01	Monitoring wells/ piezometers	1B	5D, 5E, 5I, 5J		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10J	11AA, 11AE	11AL, 11AS, 11AT, 11AU, 11AV	11AF, 11AJ	

TABLE 2-1
Summary of Monitoring Locations and Events
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Sampling Event	Sample Type	Background Areas	Source Area	Mine Area	Lost Lake/ Deposition Area	Downgradient Area (south of mine, north of Greenhorn Road)	Downgradient Area (between Greenhorn Road and Deposition Area)	Downgradient Area (south of Lost Lake)
1Q02	Monitoring wells/ piezometers	1B, 1R	5A, 5D, 5E, 5I, 5J		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10J		11AL, 11AS, 11AU, 11AV		
2Q02	Monitoring wells/ piezometers	1B, 1R	5D, 5I, 5J		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10J		11AL, 11AS, 11AU, 11AV		
3Q02	Monitoring wells/ piezometers	1B, 1R	5A, 5D, 5E, 5I, 5J		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10J	11AB, 11AE, 11AG, 11AI	11AL, 11AS, 11AU, 11AV	11AF, 11AO	
4Q02	Monitoring wells/ piezometers	1B, 1R	5D, 5E, 5I, 5J		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10N	11AA, 11AB, 11AD, 11AE, 11AG, 11AI, 11AP	11AL, 11AS, 11AU, 11AV	11AF, 11AJ, 11AM, 11AN, 11AO	
	Residential wells			10G, 10H, 10N	11AB, 11AD, 11AP	11AL, 11AS, 11AU, 11AV	11AF, 11AJ	
1Q03	Monitoring wells/ piezometers	1B, 1R	5A, 5D, 5E, 5I, 5J		13Q, 13R, 13S			
2Q03	Monitoring wells/ piezometers	1B, 1R	5D, 5E, 5I, 5J		13Q, 13R, 13S			
	Residential wells	11AW		10G, 10H, 10N	11AD, 11AE, 11AG, 11AH, 11AI	11AL, 11AU	11AF, 11AN, 11AO,11AQ	

TABLE 2-1
Summary of Monitoring Locations and Events
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Sampling Event	Sample Type	Background Areas	Source Area	Mine Area	Lost Lake/ Deposition Area	Downgradient Area (south of mine, north of Greenhorn Road)	Downgradient Area (between Greenhorn Road and Deposition Area)	Downgradient Area (south of Lost Lake)
3Q03	Monitoring wells/ piezometers	1B, 1R						
	Residential wells	11AW		10G		11AL, 11AV	11AQ	
4Q03	Monitoring wells/ piezometers							
	Residential wells			10G, 10H		11AL		
1Q04	Monitoring wells/ piezometers	1B, 1R	5A, 5D, 5E, 5I, 5J		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10N	11AB, 11AD, 11AP	11AL, 11AS, 11AU, 11AV	11AJ, 11AN, 11AX/11AX2	
2Q04	Monitoring wells/ piezometers		5E, 5I					
	Residential wells			10G, 10H, 10N	11AA, 11AE, 11AH	11AL, 11AS, 11AT, 11AU, 11AV	11AF, 11AM, 11AN, 11AO, 11AX/11AX2	
3Q04	Monitoring wells/ piezometers	1B, 1R	5A, 5D, 5E, 5I, 5J, 5PZ-2, 5PZ-3		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10N	11AD, 11AG, 11AI	11AL, 11AS, 11AU, 11AV	11AJ, 11AN, 11AO	
4Q04	Monitoring wells/ piezometers		5A, 5D, 5E, 5I, 5J, 5PZ-1, 5PZ-2, 5PZ-3		13S			
	Residential wells			10G, 10H, 10N	11AA, 11AB, 11AH, 11AP	11AL, 11AS, 11AU, 11AV	11AF, 11AM, 11AQ, 11AX/11AX2	
1Q05	Monitoring wells/ piezometers	1R	5A, 5D, 5E, 5I, 5J, 5PZ-1, 5PZ-2, 5PZ-3		13Q, 13R, 13S			
	Residential wells			10G, 10H, 10N	11AG, 11AI	11AL, 11AS, 11AU, 11AV	11AJ, 11AN, 11AO	

TABLE 2-1
Summary of Monitoring Locations and Events
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Sampling Event	Sample Type	Background Areas	Source Area	Mine Area	Lost Lake/ Deposition Area	Downgradient Area (south of mine, north of Greenhorn Road)	Downgradient Area (between Greenhorn Road and Deposition Area)	Downgradient Area (south of Lost Lake)
2Q05	Monitoring wells/ piezometers		5A, 5D, 5E, 5I, 5J, 5PZ1, 5PZ2, 5PZ3	5K-S, 5K-D	13S			
	Residential wells	11A3		10G, 10N	11A2	11AY, 11AZ	11A1	
3Q05	Monitoring wells/ piezometers	1B, 1R	5A, 5D, 5E, 5I, 5J, 5PZ1, 5PZ2, 5PZ3	5K-S, 5K-D	13Q, 13R, 13S			
	Residential wells	11A3		10G, 10H, 10N	11AA, 11AE, 11AG, 11AI, 11A2	11AL, 11AS, 11AU, 11AV, 11AY, 11AZ	11AJ, 11AN, 11AO, 11A1	
2Q06	Monitoring wells/ piezometers	1B, 1R	5A, 5E, 5I, 5J, 5PZ-3	5K-S, 5K-D	13Q, 13R, 13S			
	Residential wells	11A3, 11AW		10G, 10H, 10N	11AB, 11AD, 11A2	11AL, 11AS, 11AT, 11AU, 11AV, 11AY, 11AZ	11AF, 11AM, 11AX, 11A1	
3Q06	Residential wells					11A4, 11AL, 11AS, 11AT, 11AU, 11AV		
4Q06	Monitoring wells/ piezometers	1B, 1R		5K-S, 5K-D	13Q, 13R, 13S			
	Residential wells	11A3, 11AW, 11A5		10G, 10H, 10N	11AB, 11AD, 11A2	11AL, 11AS, 11AT, 11AU, 11AV, 11AY, 11AZ, 11A4	11AF, 11AM, 11AX, 11AX2, 11A1	
1Q07	Monitoring wells/ piezometers		5PZ-1	5K-S, 5K-D, 5L-S, 5L-D	13Q, 13R, 13S, 13T			
	Residential wells					11AL, 11AS, 11AT, 11AU, 11AV, 11A4	11AX2	
2Q07	Monitoring wells/ piezometers			5K-S, 5K-D, 5L-S, 5L-D	13R, 13T			
	Residential wells					11A4	11AX2	

TABLE 2-1
Summary of Monitoring Locations and Events
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Sampling Event	Sample Type	Background Areas	Source Area	Mine Area	Lost Lake/ Deposition Area	Downgradient Area (south of mine, north of Greenhorn Road)	Downgradient Area (between Greenhorn Road and Deposition Area)	Downgradient Area (south of Lost Lake)
Surface Water Monitoring Locations								
4Q99	Surface water		3A, 4A		16B, 16C, 19B		12J	
1Q00	Surface water	1J	3A, 3B, 4A		16B, 16C, 19B		12J	
2Q00	Surface water	1J, 2G	3A, 3B, 4A		16B, 16C, 19B		12J	
3Q00	Surface water		3A, 4A					
3Q01	Surface water	2G	3A, 4A		16B, 16C, 19B		12J	19M
4Q01	Surface water	2G	3A, 4A		16B, 16C, 19B		12J	19M
1Q02	Surface water	1J, 2G	3A, 3B, 4A		16B, 16C, 19B		12J	19M
2Q02	Surface water	1J, 2G	3A, 3B, 4A		16B, 16C, 19B		12J	19M
3Q02	Surface water	2G	3A, 4A		16B, 16C, 19B		12J	19M
4Q02	Surface water	2G	3A, 4A		16B, 16C, 19B		12J	19M
1Q03	Surface water	1J, 2G	3A, 4A		16B, 16C, 19B		12J	19M
2Q03	Surface water	1J, 2G	3A, 3B, 4A		16B, 16C, 19B		12J	19M
3Q03	Surface water		3A, 4A		16B, 16C, 19B			19M
4Q03	Surface water		3A, 4A		16B, 16C, 19B		12J	19M
1Q04	Surface water	1J, 2G	3A, 3B, 4A		16B, 16C, 19B		12J	19M
2Q04	Surface water	2G	3A, 4A		16B, 16C, 19B			19M
3Q04	Surface water		3A, 4A		16B, 16C, 19B		12J	19M
4Q04	Surface water		3A, 3B, 4A		16B, 16C, 19B		12J	19M
1Q05	Surface water	1J, 2G	3A, 3B, 4A		16B, 16C, 19B		12J	19M
2Q05	Surface water		3A, 4A		16B, 16C, 19B			
3Q05	Surface water	2G	3A, 3B, 4A		16B, 16C, 19B		12J	19M
2Q06	Surface water	1J, 2G	3A, 4A				12J	19M
3Q06	Surface water							
4Q06	Surface water	2G	3A, 4A2		16B, 16C, 19B		12J	19M
1Q07	Surface water	1J, 1U	3A, 4A2		19B		12J	
2Q07	Surface water		3A, 4A2		14E			

method). As a result of this comparison, the field-separation method was used for all subsequent samples. The results of the arsenic speciation sampling are discussed in Section 5.0.

- Analysis of groundwater samples collected at all monitoring wells and at selected residential wells and surface water sampling locations for stable isotopes (oxygen-18 [^{18}O] and deuterium [^{2}H]) in 1Q05 and 3Q05. The results of this effort are discussed in Section 5.0.
- A metal sample filtration study to evaluate the effect of colloid particles on analytical results in groundwater and surface water samples collected in 1Q05 (comparison study of 0.1- versus 0.45-micrometer filters). No statistical difference was observed between the filter samples (CH2M HILL, 2005d); therefore, 0.45-micrometer filters were used during subsequent sampling events.
- Beginning in September 2004 (3Q04), groundwater samples were collected from the Site piezometers (they were previously used for groundwater level measurements only). Prior to the December 2004 (4Q04) sampling event, both total and dissolved arsenic and cation samples were collected from the Site monitoring wells. After 4Q04, monitoring wells and piezometers were sampled for dissolved arsenic and cations; residential wells and surface water were sampled for total arsenic and cations (CH2M HILL, 2005d).

Quality assurance/quality control procedures followed QAPP (CH2M HILL, 2005c) guidelines and included the following:

- Collection of field duplicates, matrix spike/matrix spike duplicates, equipment blanks, temperature blanks, and trip blanks
- Chain-of-custody protocols
- Use of method blanks, laboratory control samples, matrix spikes, and laboratory duplicates (internal laboratory quality assurance/quality control checks)

Arsenic and metal data, speciated arsenic data, and isotope data were validated in accordance with the QAPP. Analytes that are not compounds of concern, such as alkalinity, TDS, and anions (chloride, orthophosphate, and sulfate) underwent a completeness review to verify that all analyses requested were performed and that current analyte concentrations agreed with historical data. These analytes underwent additional review only if anomalies were identified. A data quality summary report is included in Appendix I.

2.3 New Groundwater Monitoring Well Installation

To fill data gaps identified in the OU-2 FSP and the OU-2 FSP Addendum, five new groundwater monitoring wells were installed at the Site. Appendix C provides details of the fieldwork at these new monitoring wells. Activities included the following:

- Installation, development, and aquifer testing of a shallow/deep monitoring well pair (Well Pair 5K-S/5K-D) (see Figures 1-6 and 1-7). Work was performed between May 25, 2005, and June 22, 2005.

- Installation, development, and aquifer testing of a shallow/deep monitoring well pair (Well Pair 5L-S/5L-D) (see Figure 1-7). Work was performed between February 5, 2007, and March 15, 2007.
- Installation, development, and aquifer testing of a deep monitoring well (Well 13T) and LCC Staff Gauge 14E (see Figure 1-8). These monitoring locations are paired with existing shallow monitoring Well 13R to evaluate vertical hydraulic gradients, groundwater/surface water interactions in this area, and the vertical distribution of arsenic contamination. Well 13T was installed between February 5, 2007 and March 15, 2007; Staff Gauge 14E was installed in December 2006.

The wells were installed in spring 2005 and winter 2007 in accordance with the procedures described in the OU-2 FSP and the OU-2 FSP Addendum. The purpose of installing and monitoring wells located between the Source Area and Tensy Lane (Well Pairs 5K-S/5K-D and 5L-S/5L-D) was to help gain insights into the source of the elevated arsenic concentrations present in Wells 11AL, 11AS, and 11AV. The deep well installed in the Lost Lake/ Deposition Area (Well 13T) was co-located with existing shallow monitoring Well 13R and the new Staff Gauge 14E.

Soil boring logs from the monitoring wells are presented in Appendix D (all Site boring logs are also included in Appendix D). A summary of well construction details is presented in Table 2-2. Well completion diagrams are provided in Appendix E (all well completion diagrams for the Site monitoring wells and piezometers are also included in Appendix E). Location information for all Site monitoring wells, piezometers, residential wells, and surface water sampling locations are provided in Appendix F.

2.4 Aquifer Testing

As described in Appendix C, short-term aquifer tests (pumping tests) were conducted at selected residential and monitoring wells to refine estimates of hydraulic properties for the Site. The types of aquifer testing performed at the Site include the following:

- Short-term aquifer testing during well sampling. Hydraulic data, including flow rates and water level measurements, were collected from residential and monitoring wells during the quarterly groundwater monitoring event in September 2004. These data were used to estimate aquifer transmissivity near the wells.
- Short-term aquifer testing at the end of well development. Constant-rate pumping tests were performed during the final stages of well development at Wells 5K-S, 5K-D, 5L-D, and 13T, as described in Appendix C. Data from these tests were used to estimate the horizontal and vertical aquifer properties near the shallow/deep well pairs.
- Short-term aquifer testing at Wells 11A4, 11AT, and 11AU. During the remedial construction activities at the Site in 2006, surface water was diverted around the Mine Area. Additionally, LCC was lined with fine-grained materials in June 2006. During this time, residents along Tensy Lane began reporting diminished yields from Wells 11A4, 11AT, and 11AU. To evaluate whether the decrease in well yields was caused by decreased streamflow (as a result of construction activities), short-term aquifer tests

TABLE 2-2
Well Drilling and Construction Summary
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Well Name	Year Installed	Easting (feet)	Northing (feet)	Ground Surface Elevation (feet msl)	Top of Casing Elevation (feet msl)	Total Borehole Depth (feet bgs)	Borehole Diameter (inches)	Total Well Depth (feet bgs)	Casing Diameter (inches)	Casing Type	Screen Type	Screen Interval (feet bgs)
5K-S	2005	6853751.689	2208791.362	2,757.63	2,759.58	120.6	11	116	4	PVC-40	PVC-40	95.5 – 115.5
5K-D	2005	6853728.874	2208765.284	2,757.25	2,758.87	220	11	220	6	0.25-inch-thick mild steel	Open hole	170 – 220.7
5L-S	2007	6853346.748	2208641.974	2,755.48	2,758.37	70	10	60.5	4	PVC-40	PVC-40	30 – 60
5L-D	2007	6853327.383	2208606.006	2,755.45	2,758.27	220	11.75	220	6	0.25-inch-thick mild steel	Open hole	143 – 220
13T	2007	6853954.608	2203994.672	2,467.81	2,469.19	76	8	75.5	4	PVC-40	PVC-40	65 – 75

Notes:

Easting and northing data in California State Plane Coordinate System, NAD83, Zone 2
The vertical datum used is NAVD88
msl = mean sea level
bgs = below ground surface
PVC-40 = schedule 40 polyvinyl chloride

were performed at the impacted wells in August 2006 and again in March 2007, after water to LCC had been restored. The testing provided inconclusive results (see Appendix C).

Hydraulic data from the pumping tests were used to estimate specific capacity and transmissivity near the wells by using the graphical methods described in Appendix C. Aquifer properties were calculated by using the MLU analytical method computer program (Hemker and de Boer, 2002). Results from aquifer testing (see Appendix C) were incorporated into the Lava Cap Mine Groundwater Flow Model (see Appendix G).

2.5 Stream Discharge Monitoring

Stream discharge measurements at the Site have been recorded over time. Two methods have been used to record stream discharge: manual flow estimates and automated, continuous datalogging of stream stages at engineered structures. Manual streamflow rates have been visually estimated during routine sampling events by determining the stream velocity per unit area. Stream velocity (in units of feet per second) was estimated by recording the time necessary for a float to travel a specified distance downstream. Velocity was then multiplied by the wetted cross-sectional area (in units of square feet) of the stream at the sampling location to estimate stream discharge in cubic feet per second (ft^3/sec). Streamflow estimates are discussed further in Section 3.0.

Figure 1-6 shows the location of four stream gauges (Locations 1J, 1U, 3A, and 12B) installed in fall 2005 during the OU-1 RA, as described in the *Draft Lava Cap Mine Water Balance Weir Installation and Operation Manual* (Clear Creek Hydrology, Inc., 2006). The gauges are v-notch weirs; the type and dimensions of each weir is different, depending on the anticipated average and maximum discharge rates at each location. Two-stage, compound v-notch weirs were installed on the upper LCC (Location 1J) and the upper LCC side channel (Location 1U). A three-stage, compound v-notch weir was constructed at the lower LCC location (Location 12B), downstream from the Rock Buttress. Compound v-notch weirs are designed to contain most of the discharge within the v-notch but have one or two rectangular sections (2- and 3-stage, respectively) that allow flow volume to be measured when it is above the normal range of discharge. A simple, 90-degree, v-notch weir was first constructed at the adit (Location 3A) but was demolished during the OU-1 RA in summer 2006. This gauge was replaced in June 2007 with a 3-inch Parshall flume (from Free-Flow, Inc.) with an automated stage recorder.

The weirs were equipped with dataloggers to record the stream stage in the pool behind the weir every 15 minutes. The stream stage can be related to streamflow via an analytical solution. When possible, visual gauge readings and manual flow measurements (by using a graduated bucket and stopwatch) were estimated during field visits when data were downloaded. Collection of automated streamflow data were disrupted because of flow diversions associated with the OU-1 RA between July and December 2006. The automated streamflow data are discussed further in Section 3.0. Data from December 2006 to present are still undergoing evaluation and correction and will be presented in the OU-2 FS; streamflow data continue to be collected on a routine basis.

2.6 Surveying

Surveying with a global positioning system and real-time kinematic surveying instruments was conducted to provide horizontal and vertical positions for monitoring facilities (i.e., wells, stream gauges, and staff gauges) that were installed or added to the OU-2 RI monitoring program. The horizontal datum used was the California State Plane Coordinate System, 1983 North American Datum (NAD83), Zone 2. The vertical datum used was the North American Vertical Datum of 1988 (NAVD88). The survey originated from a previously established benchmark in the area. Appendix F presents the survey data for monitoring facilities at the Site. Wells that were not professionally surveyed were located by using a hand-held global positioning system. Survey information for groundwater and surface water sampling locations are tabulated in Appendix F.

2.7 Ongoing Fieldwork

Ongoing OU-2 fieldwork includes the following:

- Stream discharge data collection (between 15-minute and 2-hour intervals) with bimonthly datalogger downloads and stream gauge maintenance
- Bimonthly manual stream discharge estimates at surface water locations
- Bimonthly groundwater elevation measurements
- Semiannual sampling and maintenance of EPA-maintained, undersink, arsenic treatment units at Wells 10G and 11AL

Evaluation of these data will provide additional insights for development of the CSM during the OU-2 FS and design work for the OU-1 and OU-3 RAs. Any additional monitoring needs will be outlined in the OU-2 FS.

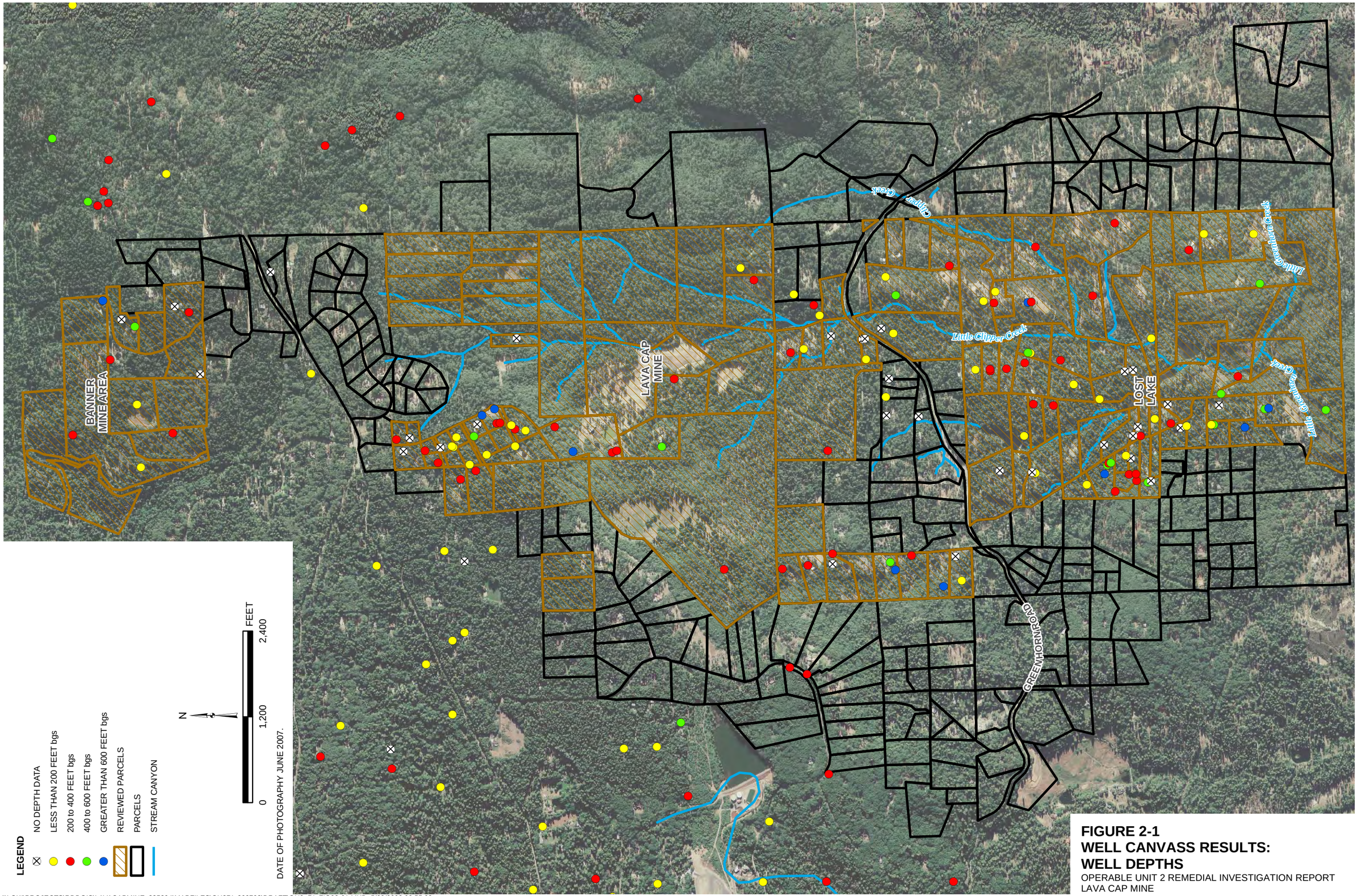


FIGURE 2-1
WELL CANVASS RESULTS:
WELL DEPTHS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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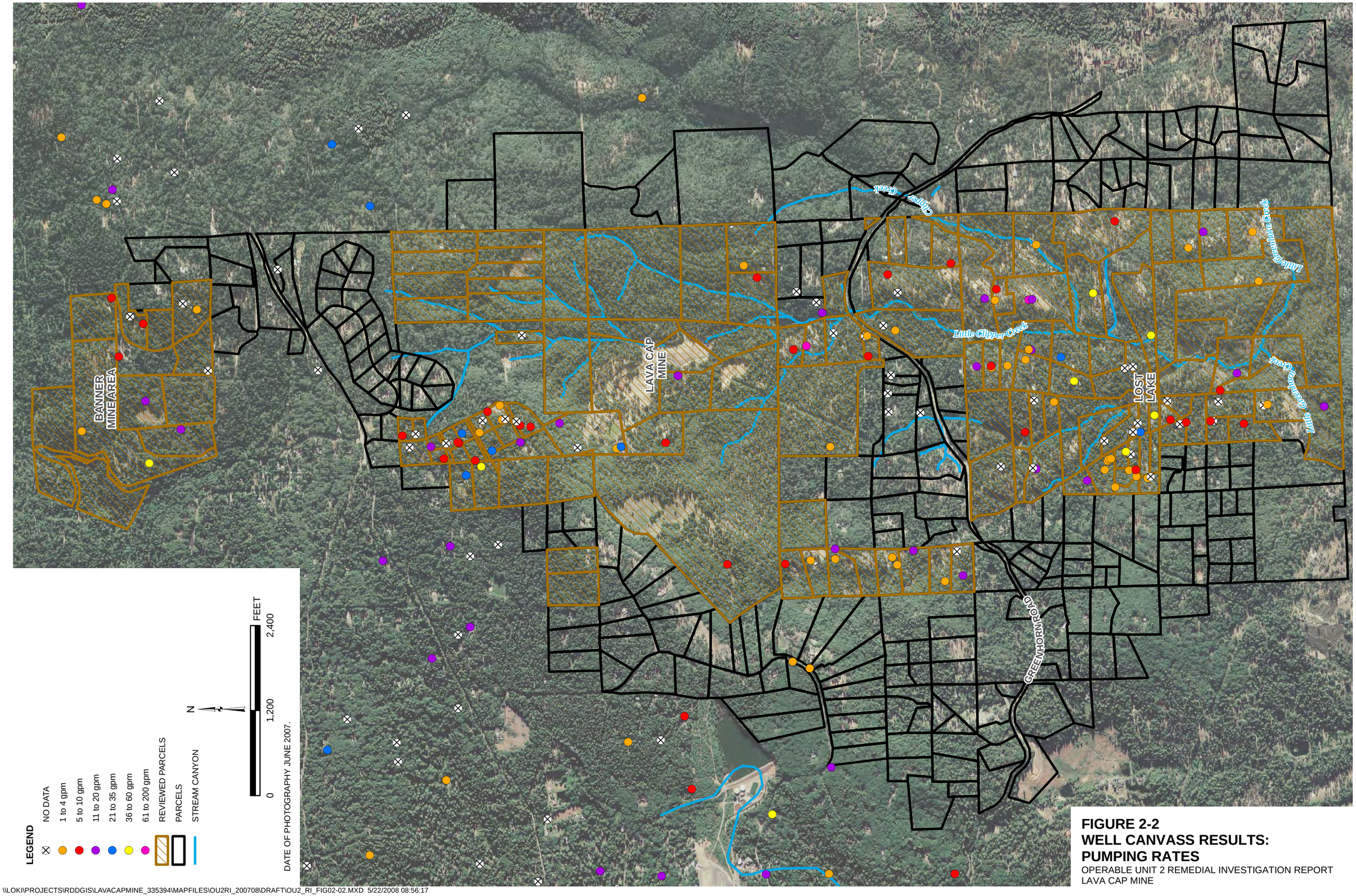

FIGURE 2-2
WELL CANVASS RESULTS: PUMPING RATES
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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SECTION 3.0

Site Physical Characteristics

This section builds on information provided in the sitewide RI report (EPA, 2001a), and includes a summary of the climate and hydrologic framework at the Site.

3.1 Climate

3.1.1 Precipitation

Figure 3-1 presents annual precipitation data recorded at Grass Valley, California, which is located in Nevada County, approximately 5 miles west of the Site. Generally, the area has warm, dry summers and mild, wet winters; most of the precipitation falls from November through April. Precipitation at the Grass Valley rain gauge ranged from 15 to 95 inches per year between 1967 and 2006; the average precipitation is 52 inches per year. Precipitation at the Site is estimated to be approximately 10 percent greater than at the Grass Valley rain gauge because of orographic (i.e., elevation) effects.

3.1.2 Air Temperature and Relative Humidity

The average temperatures in the eastern part of Nevada County ranges from 60 degrees Fahrenheit (°F) at the lower elevations to 55°F at higher elevations. Minimum temperatures are affected by local variations in the terrain. The January average minimum temperature ranges from 36°F at the lower elevations to 30°F at 4,500 feet above mean sea level (msl). Average maximum temperatures in July range from 98°F at the lower elevations to 92°F at the higher elevations.

The relative humidity during winter in Nevada County ranges from 90 percent at night to 70 percent in the day. In summer, average relative humidity ranges from 80 percent at night to 25 percent during the day (Natural Resources Conservation Service, 1993).

3.1.3 Prevailing Wind Direction

Prevailing winds in Nevada County are from a southwesterly direction most of the year, with an average wind speed of nearly 10 miles per hour. Thundershowers typically come from a south or southwesterly direction during summer and winter; at times they are accompanied by high winds.

Winds from the north and east occasionally blow over the lower western slopes of the Sierra Nevada Mountains. In winter, these winds bring cold, dry weather; in spring and summer these winds are warm and dry. As a result, the wind quickly removes moisture from the soil surface and dries out vegetation.

3.1.4 Evapotranspiration

Evapotranspiration (ET) is the vaporization of water to the atmosphere through evaporation (from plant, soil, and water surfaces) and transpiration (water uptake by plant roots). ET

depends on the availability of water and energy to convert the water into vapor. The rate of ET varies spatially and temporally and depends on the weather (e.g., air temperature, relative humidity, and wind speed), solar radiation, vegetation (e.g., plant type, root depth, plant density, plant height, and stage of growth), and soil (e.g., soil moisture, texture, density, structure, and soil chemistry). Historical average monthly reference ET rates recorded in Grass Valley range from 0.64 inches in December to 6.34 inches in July, with an annual average of 3.16 feet per year (Goldhamer and Snyder, 1989).

3.2 Hydrogeologic Framework

This section describes the characteristics of the hydrogeologic setting (framework) at the Site, including the following:

- Physical characteristics of the surface and subsurface
  - Topography and vegetation
  - Hydrology
  - Geology, including local rock types and geologic structures
  - Aquifers, including the extent, occurrence (geometry) and hydraulic properties
- Flow characteristics
  - Groundwater elevations and flow patterns
  - Surface water discharge

3.2.1 Topography and Vegetation Cover

Lava Cap Mine is located on the southern slope of Banner Ridge at an elevation of approximately 2,840 feet msl. The elevation drops from approximately 2,870 feet msl at the historical mine buildings to approximately 2,700 feet msl at the base of the Rock Buttress, which is approximately 1,400 feet to the south. The waste rock/tailings pile area has been extensively reworked as part of the OU-1 RA. The altered topography of this area will be discussed in the OU-1 RA report. The LCC drainage between the Rock Buttress and the confluence of LCC and CC has a 230-foot elevation change over a distance of 1 mile. The elevation at the confluence of LCC and CC is approximately 2,468 feet msl. The Deposition Area ranges in elevation from 2,464 to 2,470 feet msl; the elevation at Lost Lake is 2,461 feet msl.

The area surrounding the Site is covered with dense trees of the Sierra Nevada Transition Zone, with the predominant vegetation consisting of ponderosa pine. Numerous areas within the LCC and CC watersheds have undergone logging or land clearing activities.

3.2.2 Hydrology

Lava Cap Mine is located within the CC watershed, which is drained by CC and its tributaries. LCC is the dominant surface water drainage leading south, away from the mine. The upper reaches of LCC are seasonally dry (ephemeral), and the creek becomes perennial about halfway across the mine property, where it is fed by continuous groundwater discharge from the diverted adit water and flow from the base of the Rock Buttress.

Historically, subsurface access to Lava Cap Mine during mining operations was possible through an adit connected to a horizontal tunnel that bisected the central mine shaft (see 100 Drift Level on Figure 1-4). After the mine ceased operations the adit caved in, and it is no longer usable for mine access. The discharge of groundwater into the mine during mining operations was reported to have been approximately 0.078 ft^3/sec (35 gallons per minute [gpm]) (Cole/Mills Associates, 1985). Currently, water discharges continuously from the mine at the caved-in adit in the waste rock pile area. Discharge rates are discussed in Section 3.2.5.

Stream diversions were constructed around the waste rock/tailings piles in 1997 to reduce water flow through the pile. Additional stream and adit diversions were constructed, and the tailings pile was capped as part of the OU-1 RA (beginning in May 2006) to reduce the infiltration of rainfall and mine drainage into the waste rock/tailings piles. LCC flows downstream from the Rock Buttress for approximately 1 mile to the confluence with CC in the Deposition Area, north of Lost Lake. The combined LCC and CC flows continue downstream (in CC) through the Deposition Area and into Lost Lake. Deposition of arsenic-laden sediment in the CC channel formed the Deposition Area, which separates Lost Lake into northern and southern lobes. The total area of the lake is approximately 5 acres (3.6 acres in the northern lobe and 1.3 acres in the southern lobe). Lost Lake is contained by Lost Lake Dam, which is approximately 50 feet high; the dam has a concrete spillway. CC continues south from Lost Lake Dam for less than 0.25 mile before it enters LGC, which joins Greenhorn Creek (GC) at the CC watershed boundary after approximately 2 miles. GC flows into Rollins Reservoir, which discharges to Bear River; the river flows into Lake Combie, approximately 11 miles downstream from Rollins Reservoir. The CC watershed is depicted on Figure 3-2.

3.2.3 Geology

Lava Cap Mine is located on the western slope of the northern Sierra Nevada Mountains. The Site is located within the Sierra Nevada Physiographic Province, which is characterized by intrusive and volcanic igneous rocks and metamorphosed sedimentary rocks that have been faulted and fractured. In general, these rocks are highly weathered at the surface and have a well developed soil profile.

The Site overlays the following five types of rock units (in order of increasing age) (Cole/Mills Associates, 1985):

- Mine deposits (Md unit), including waste rock and tailings (up to approximately 75 feet thick)
- Tertiary volcanic breccia (Tvb unit), commonly referred to as lava, with zones of conglomerates or gravels (up to 400 feet thick)
- Cretaceous igneous intrusive rocks, including diorite and granodiorite
- Jurassic to Triassic metamorphosed volcanic (metavolcanic) rocks (JT_Rv unit)
- Paleozoic to Upper Jurassic metamorphic rocks (Pms unit), including argillite, slate, conglomerates, thin-bedded cherts, and other metasedimentary rock (metasediment)

Overlying these rocks are discontinuous stream alluvium, slope colluvium, and surface soils. Between the mine and Lost Lake along LCC, the surficial geology is dominated by alluvium and recent mine deposits, which are underlaid by the Pms unit. The other rock units listed occur at the surface, north of the mine. Figure 3-3 shows a generalized plan-view geologic map of the Mine Area. A schematic profile that includes the locations of geologic contacts and mine workings is presented on Figure 1-4.

The mine was developed exclusively in the Pms unit (composed primarily of Paleozoic argillite, slightly metamorphosed claystone, and slate). Gold-bearing quartz veins averaging 5 feet in width and a maximum width of 20 feet occur along inactive reverse faults. The strike of the quartz veins ranges from N5°W to N35°W in the Lava Cap Mine area, with a 51-degree dip to the east (Cole/Mills Associates, 1985). The host rock for the quartz veins is argillite. The argillite and the other metasediments in the Pms unit are part of the Calaveras Formation (Cole/Mills Associates, 1985).

Rocks found near the surface in areas surrounding the mine include Pms, JT_Rv, and Tvb units that are 200 feet or more in thickness and Cretaceous and Jurassic granitic rocks that are mainly quartz diorite to granodioritic in composition. Road cuts leading to Lava Cap Mine show the Tvb unit consists of poorly sorted angular to subangular pebbles and cobbles in a volcanic ash matrix (Cole/Mills Associates, 1985).

Near the historical mining areas, the surface is covered by waste rock, underlaid by tailings (observed to be up to 75 feet thick in places) at the southern end of the mining area. The waste rock is a gravel mixture consisting of Pms unit rocks, igneous intrusives, and JT_Rv unit rocks. The tailings range from fine sand to (more commonly) clay, which is dark gray when wet and unoxidized. In the soil borings drilled for the 2001 RI, the underlying Pms unit was observed to be a greenish-gray argillite with evidence of quartz, feldspar, and sulfide minerals present in small amounts (EPA, 2001a). A map showing the soil boring locations and a cross section line for the Source Area and Mine Area (Cross Section A-A′) are included on Figure 3-4. Cross Section A-A′ (see Figure 3-5) runs through the waste rock/tailings pile and is representative of conditions prior to the OU-1 RA that began in May 2006. The upper layer shown in Cross Section A-A′ is mainly waste rock and tailings. This layer is thickest at the northern end of the cross section and thins toward the south as the ground surface elevation decreases. The waste rock is typically underlaid by fine-grained soils of variable thickness and discontinuous gravel layers. The deeper layers shown in this cross section generally are Pms unit metasediments and igneous intrusive rock.

Three additional cross sections are shown on Figures 3-6 through 3-8; cross section locations are shown on Figure 3-4. Cross Section B-B′ (see Figure 3-6) is located within the Downgradient Area and runs subparallel to LCC. The upper layer of this cross section is primarily clay and overburden material. Pms unit rock and igneous intrusive rock make up the lower layers along Cross Section B-B′. Cross section C-C′ (see Figure 3-7) starts in the Downgradient Area, runs through the Lost Lake/Deposition Area, and continues downgradient. Fine-grained material exists on the surface within this area; however, the predominant lithology consists of Pms unit metasediments. Cross Section D-D′ (see Figure 3-8) depicts the geology near the new shallow/deep monitoring well pairs (Well Pairs 5K-S/5K-D and 5L-S/5L-D) on the ridge upgradient from arsenic-contaminated Wells 11AL, 11AS, and 11AV. Silts and clays comprise the upper layers of Cross

Section D-D'. Coarser-grained soils are typically found between the upper layers and the lowermost Pms unit metasediments. The contact between the overburden and Pms unit metasediments is deeper at the northeast end of Cross Section D-D', near Wells 5K-S/5K-D.

3.2.3.1 Geologic Structure and Seismicity

Lava Cap Mine lies within an area characterized by numerous ancient fractures, joints, and inactive faults of the Foothills Fault System (Cole/Mills Associates, 1985). No known active faults are present on the mine property. Ancient fractures in the mine workings were reported by Chandler and Siegfried (1952). The main walls of the mine workings have reportedly been weakened by fracturing. Four miles to the east, the northeast-trending Cement Hill Fault might have had Late Cenozoic movement of more than 5 vertical feet. Four miles to the west, a 1.5-mile-long, north-trending GC lineament (with no observed displacement noted) is present near the major Pre-Cenozoic Northern Melones Fault (Cole/Mills Associates, 1985). The prevalence, interconnectivity, and orientation of fracturing in the subsurface metasedimentary rocks is poorly understood.

No systematic joint analysis is available for the Site; however, joints were mapped in drifts at the Empire and North Star Mines, approximately 4.5 miles to the southwest. Trends ranged from N20ºE to N55ºE (Johnston, 1940).

There are no earthquake epicenters reported at the Site; however, seismicity data within a 30-mile radius indicate moderate earthquakes occurred in 1867, 1888, and 1909. In the Foothills Fault System, calculations for the Cement Hills Fault indicate the maximum earthquake magnitude would be 5.5, with a maximum surface displacement of 4 inches. Similarly, a maximum earthquake magnitude of 5.6 could occur near the GC lineament, with a maximum surface displacement of 6 inches. The active Little Grass Valley Fault Zone, 40 miles north of Lava Cap Mine, is capable of generating the maximum credible earthquake for the area, resulting in a magnitude of 6 to 6.5 and a ground acceleration at the earth's surface of 0.02 to 0.1g at Lava Cap Mine (Cole/Mills Associates, 1985).

3.2.3.2 Soils

Within the LCC subwatershed, the primary soil unit mapped is the Josephine-Mariposa Complex. This unit is mapped over most of the Site; it extends north and south of the mine on either side of LCC. It is present on the slopes of CC in the lower half of the CC watershed, near the CC/LCC confluence. The Josephine-Mariposa Complex has a moderate to high water erosion hazard rating (National Resource Conservation Service, 1993).

3.2.4 Aquifers

The residential groundwater supply throughout the Site is stored in primary pore spaces in the saturated overburden and in secondary openings (e.g., fissures, faults, and joints) in the consolidated and crystalline rocks of the Pms unit, which is hundreds to thousands of feet thick (see Figure 1-4). Inactive thrust faults and associated lineaments trend north-south to slightly northwest-southeast (Cole/Mills Associates, 1985), which matches the generally southward groundwater flow between Lava Cap Mine and Lost Lake.

Groundwater also occurs in the Tvb unit, which overlies the Pms unit north of the mine. The hydraulic conductivity of the Tvb unit is relatively high compared to the underlying Pms

unit. Groundwater is distributed throughout the Tvb unit, in contrast to the Pms unit, where most of the groundwater likely occurs primarily in joints and fractures. This is evident by physical characteristics of the units and the difference in yield from wells completed in each unit. Groundwater in the Tvb unit is likely to be seasonally perched, with limited hydraulic interaction between the Tvb and the Pms units. Several springs are identified at the lithologic contact between the Tvb and Pms units (see Figure 3-3).

Previous studies (Hydro-Search, Inc., 1984 and Cole/Mills Associates, 1985) found that shallow domestic wells in the area that are less than 200 feet deep have an average yield of 4 to 18 gpm. In the early to mid 1980s, the reported median yield in 13 local residential wells in the Pms unit was 4 gpm (Hydro-Search, Inc., 1984). Deep domestic wells in the area penetrate 300 to 570 feet, producing from 0.25 to 140 gpm, with an average yield of 18 gpm (Cole/Mills Associates, 1985).

The availability of groundwater level data from wells (under pumping or nonpumping conditions) is very limited for the area around Lava Cap Mine; however, suitable information to estimate specific capacity from three residential wells was available at the Nevada County Planning Department. Specific capacity is a measure of a well's ability to yield water and is expressed in units of gpm/ft of drawdown during pumping. Specific capacities at the three wells were estimated to range from less than 0.05 to 8 gpm/ft. According to these estimated specific capacities, the horizontal hydraulic conductivity (K_h) of the Pms unit near these wells ranges from 10^{-6} to 10^{-2} centimeters per second (cm/sec). The upper range of specific capacity and K_h were estimated by using data for a well that is likely partially screened in the more permeable Tvb unit, north of Lava Cap Mine; therefore, a K_h of approximately 10^{-6} cm/sec is likely to be representative of most of the Pms unit.

To improve estimates of subsurface hydraulic properties, short-term aquifer tests were conducted at selected residential and monitoring wells in 2004, 2005, and 2007 (see Appendix C). Approximate specific capacities ranged from 0.03 to 1 gpm/ft at wells screened in the Md unit, and from 0.01 to 16 gpm/ft at wells screened in the Pms unit. The range of specific capacity estimates indicate an approximate transmissivity range from 3 to 300 square feet per day (ft^2/day) for the Md unit, and 0.2 to 4,000 ft^2/day for the Pms unit (see Appendix C). These values have a considerable range; however, they are based on data from short-term aquifer testing and use simplified calculations that assume ideal conditions (see Appendix C) that tend to overestimate actual aquifer properties.

The transmissivity estimates calculated from specific capacity data were used as starting points for a more robust method of aquifer parameter analysis that employed MLU analytical modeling software (see Appendix C). Analytical modeling techniques provide an estimated transmissivity for the Pms unit ranging from 2 to 50 ft^2/day, with most values being less than 9 ft^2/day. This equates to K_h values in the 10^{-5} to 10^{-6} cm/sec range. The estimated K_h to vertical hydraulic conductivity (K_v) ratio ranges from 0.9 to more than 400, with most values being less than 2.5 in the overburden and Pms unit rock. Local Pms unit aquifer properties are highly dependent on the prevalence and interconnection of subsurface fractures.

The K_h values estimated from the specific capacity data and analytical modeling and the typically low residential well yields suggest the Pms unit has low hydraulic conductivity (10^{-5} to 10^{-6} cm/sec). Additional evidence of the low permeability of the Pms unit is the

reported discharge rate (35 gpm) required to keep the mine dewatered during past operations (Siegfried, 1952).

3.2.5 Groundwater Elevations and Flow

Groundwater migrates from locations of recharge to locations of discharge. Precipitation recharges the groundwater system in the uplands, and groundwater discharges into the drainages at lower elevations and at springs and seeps along its course. Groundwater flow is primarily from the ridges toward the deep drainages in the area, including LCC, CC, and LGC. In general, groundwater levels rise seasonally during winter and spring because of winter rainfall and decline in summer and fall.

Groundwater flow is primarily to the south-southeast according to available groundwater level data and previous investigations (Cole/Mills Associates, 1985 and Hydro-Search, Inc., 1984). It can be expected that the regional groundwater table in the CC watershed is a subtle expression of the topography. Groundwater flow is a function of the hydraulic gradient and hydraulic conductivity. A map showing simulated groundwater elevation contours is provided on Figure 3-9, which was derived from output from the Lava Cap Mine Groundwater Flow Model (see Appendix G). These groundwater elevations represent steady-state, average conditions. Also shown on Figure 3-9 are areas where the Lava Cap Mine Groundwater Flow Model simulates groundwater discharge to the land surface (dark blue areas). These areas correspond to topographic lowlands within stream channels.

Hydrographs from Site monitoring wells and piezometers are shown on Figure 3-10 and water levels are tabulated in Table 3-1. Locations where groundwater levels are measured are north of the mine (Background Area Wells 1B and 1R) (see Figure 1-6), within the Source Area (Wells 5A, 5D, 5E, 5I, 5J, and Piezometers 5PZ-1, 5PZ-2, and 5PZ-3) (see Figure 1-6), and the Lost Lake/Deposition Area (Wells 13Q, 13R, 13S, and 13T) (see Figure 1-8). Recently, two residential wells (Wells 11T and 11AU) (see Figure 1-7) in the Downgradient Area were added to the water level monitoring network.

3.2.5.1 Background Areas

Figure 3-10 includes hydrographs for the two monitoring wells located in one of the Background Areas. The hydrograph for Background Area Well 1B (screened at the base of the Tvb unit) shows that the groundwater levels in this well have varied slightly over the last 7 years. However, the hydrograph for Background Area Well 1R (screened in the Pms unit) shows more than a 20-foot variation during an annual cycle. Groundwater tends to perch on the contact between the Pms and Tvb units, inducing lateral flow that discharges as springs near the contact between these units (observed north of the mine). Flow from the Tvb unit to the underlying Pms unit could occur through openings in the Pms unit that intersect the Tvb unit.

3.2.5.2 Source Area and Mine Area

Figure 3-10 includes the hydrographs for the five monitoring wells and three piezometers located in the Source Area. Most of these wells were abandoned in June and July 2006 as part of the OU-1 RA; only Piezometer 5PZ-1 remains. The groundwater levels in the Source Area show seasonal variability, decreasing by several feet between the spring and fall monitoring events and increasing by several feet between the fall and spring monitoring

events. Overall, groundwater levels in the Source Area do not indicate a long-term increasing or decreasing trend during the last 7 years.

In the Source Area, shallow saturated zones occur in the Md unit, which generally is porous and permeable. Shallow saturated zones are also present in the upper portions of the Pms unit beneath the Md unit, and are likely hydraulically connected with the Md unit through joints. The water levels measured in deeper bedrock monitoring wells (Wells 5I and 5J) prior to the OU-1 RA were consistently lower than those in the shallow wells in the Md unit. This indicates a downward vertical hydraulic gradient from the Md unit into the bedrock. Groundwater flow also occurs in the basal gravel layer at the contact between the overburden material and the fractured Pms unit metasediment. Groundwater that has infiltrated the Md unit either discharges at the base of the Rock Buttress, or flows into the Pms unit. Source Area groundwater in the Pms unit flows south, with some discharge to LCC, CC, and Lost Lake. Installation of new monitoring wells in the Source Area and continuous monitoring of new and existing wells would be needed to evaluate any changes to Source Area groundwater flow patterns resulting from the OU-1 RA.

Groundwater levels from Well Pair 5K-S/5K-D (in the Mine Area) usually indicate a downward vertical hydraulic gradient. This is expected in groundwater recharge areas in the topographic uplands; however, the groundwater levels measured during March and August 2007 indicate a slight upward vertical hydraulic gradient at this well pair. Groundwater levels are more than 5 feet higher in recently installed Well 5L-D compared with the associated shallow-paired Well 5L-S, indicating strong upward flow in this area. The upward vertical hydraulic gradient is unexpected for this location and might be associated with fracture flow characteristics at that location. Groundwater level monitoring is being performed bimonthly to allow for continued evaluation of groundwater levels and hydraulic gradients.

3.2.5.3 Downgradient Area

Very few groundwater elevation measurements are available for the Downgradient Area. Since October 2006, two residential wells (Wells 11AT and 11AU) have been included in the water level monitoring network (see Table 3-1). These locations have groundwater elevations of approximately 2,600 feet msl. Groundwater in the Downgradient Area flows from the uplands toward CC, LCC, and their tributaries; the overall flow is southerly, toward Lost Lake.

3.2.5.4 Lost Lake/Deposition Area

Figure 3-10 includes hydrographs for the four monitoring wells and the staff gauge in the Lost Lake/Deposition Area. These wells show seasonal groundwater level trends that are similar to those in the Source Area and Mine Area. Generally, the groundwater levels in Well 13S (in bedrock) are slightly lower than those in Well 13Q, which is located within the tailings deposits above the native materials. This indicates a downward vertical hydraulic gradient; however, a slight upward gradient was estimated between these wells in February and May 2007. Groundwater levels in Well 13R are slightly higher than in newly installed Well 13T (in bedrock), indicating a downward vertical hydraulic gradient. Water levels from

TABLE 3-1

Water Level Elevations

OU-2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

		1B	1R	5PZ-1	5PZ-2	5PZ-3	5A	5D	5E	5I	5J	13Q	13R	13S	13T	14E	5K-S	5K-D	5L-S	5L-D	11AT	11AU
Top of Casing Elevation		**3269.08**	**2943.89**	**2795.80 (2784.90; 7/06)**	**2756.30**	**2751.30**	**2791.23**	**2750.45**	**2743.69**	**2744.00**	**2751.10**	**2468.62 (2466.7; 2/07)**	**2469.50 (2467.61; 2/07)**	**2468.81**	**2469.19**	**2465.86[a]**	**2759.58**	**2758.87**	**2758.37**	**2758.27**	**2662.65**	**2630.87**
Screen Interval (feet bgs)		**130-150**	**115-135**	**20-30**	**19-29**	**15.5-25.5**	**8-28**	**32-42**	**31-41**	**65-85**	**131-151**	**18-28**	**12.5-22.5**	**60-70**	**65-75**	**Staff Gauge**	**95-115**	**170-220**	**30-60**	**143-220**	**UKN**	**61-160**
Event	**Date**	**Water Level Elevations (feet msl)**																				
4Q99	09-Nov-99						2780.81	2736.85	2736.55													
1Q00	28-Jan-00	3163.23					2782.21	2746.63	2743.69													
2Q00	04-May-00	3165.33					2781.29	2743.94	2743.09													
2Q00	23-May-00	NM					NM	NM	NM	2737.71		2459.79	2461.14									
3Q00	14-Sep-00	3164.60					2779.69	2737.01	2736.70	2731.79		2460.75	2463.35									
3Q01	01-Aug-01	3164.45					2779.81	2735.97	2735.64	2730.74		2458.71	2462.03									
4Q01	01-Nov-01	3166.68		Dry	2739.00	2739.32	2780.14	2733.01	2732.10	2727.48	2720.70	2458.27	2463.21	2456.84								
1Q02	01-Feb-02	3165.13	2873.06	2755.06	2748.14	2744.64	2781.92	2744.36	2742.60	2736.09	2732.80	2465.58	2465.90	2464.91								
2Q02	01-May-02	3165.14	2877.25	2754.41	2746.89	2743.72	NM	2741.97	2741.23	2734.20	2734.22	2461.89	2463.95	2461.33								
3Q02	01-Aug-02	3164.67	2863.25	2752.71	2742.26	2741.01	2779.87	2735.64	2735.14	2729.68	2731.11	2460.01	2463.35	2459.32								
4Q02	01-Nov-02	3164.64	2861.76	2753.05	2743.19	2741.85	NM	2736.33	2735.84	2729.95	2728.84	2461.12	2463.42	2460.61								
1Q03	01-Feb-03	3165.28	2891.22	2754.97	2748.03	2744.45	2782.18	2744.43	2742.26	2735.99	2736.72	2462.41	2464.14	2461.89								
2Q03	01-May-03	3165.53	2893.54	2755.26	2748.74	2744.61	NM	2744.89	2742.56	2737.20	2736.85	2462.18	2463.85	2461.62								
3Q03	01-Aug-03	3165.00	2876.29	2752.72	2744.24	2742.39	2780.29	2738.17	2737.61	2732.06	2733.10	2460.78	2463.14	2460.25								
4Q03	10-Dec-03	3165.00	2874.03	2754.31	2746.50	2744.55	2781.69	2740.82	2740.15	2734.20	2730.79	2462.06	2463.74	2461.48								
1Q04	24-Mar-04	3165.73	2894.84	2755.17	2748.45	2744.43	2782.01	2744.71	2742.84	2737.34	2737.39	2462.12	2463.94	2461.63								
2Q04	24-Jun-04	3164.98	2879.77	2752.98	2745.08	2742.75	2780.93	2738.72	2738.26	2733.09	2732.53	2460.97	2463.06	2460.50								
3Q04	28-Sep-04	3165.70	2873.29	2752.72	2741.03	2740.31	2780.76	2734.20	2733.87	2729.56	2729.62	2457.06	2460.29	2456.38								
4Q04	13-Dec-04	3164.35	2873.50	2754.29	2746.94	2744.34	2782.02	2741.97	2741.48	2735.68	2735.56	2461.88	2463.54	2461.31								
1Q05	14-Apr-05	NM	2896.17	2755.79	2749.64	2745.44	2783.55	2746.74	>2743.69	2739.00	2738.31	2463.54	2464.47	2462.93								
2Q05	27-Jun-05	NM	NM	2754.42	2747.16	2743.41	2782.19	2742.24	2741.51	2735.47	2734.79	2466.70	2467.61	2461.13			2694.89	2694.71				
3Q05	26-Sep-05	3164.97	2875.73	2754.00	2745.14	2743.04	2782.87	2738.43	2737.93	2732.69	2731.62	2461.05	2463.11	2460.51			2692.59	2692.46				
1Q06	09-Feb-06	3169.87	2895.17	2755.38	2749.54	2746.33	2784.14	2747.55	>2743.69	2739.77	2737.62	2463.96	2465.20	2463.36			2698.55	2698.34				
2Q06	13-Apr-06	3174.55	2897.39	2755.83	2750.18	2746.82	2784.56	2748.27	>2743.69	2740.30	2739.01	2465.96	2466.01	2465.17			2707.29	2699.69				
2Q06	03-Jun-06	3166.20	2890.81	2754.58	2748.14	2745.18	2783.12	2745.12	2742.47	2737.39	2736.40	2461.88	2463.79	2461.38			2695.38	2695.07				
2Q06	23-Jun-06	3165.16	2885.33	NA	2746.13	2744.25	2782.14	2740.64	2739.89	2733.09	2733.45	2461.37	2463.56	2460.85			2693.85	2693.68				
3Q06	17-Jul-06	3164.76	2879.39	NA	AB	AB	AB	AB	AB	2723.66	AB	2461.15	2463.38	2460.68			2693.46	2693.26				
3Q06	19-Aug-06	NM	NM	NA	AB	AB	AB	AB	AB	AB	AB	NM	NM	2460.44			2692.65	2692.42				
3Q06	26-Aug-06	3164.81	2875.64	NA	AB	AB	AB	AB	AB	AB	AB	2460.87	2463.20	2460.36			2692.53	2692.16				
4Q06	23-Oct-06	3164.88	2873.28	2759.69	AB	AB	AB	AB	AB	AB	AB	2461.25	2463.48	2460.74			2692.54	2690.76			2593.61	2596.25
4Q06	19-Dec-06	3164.92	2874.08	2754.03	AB	AB	AB	AB	AB	AB	AB	2462.17	2463.91	2461.60		2463.74	2692.02	2691.32			2599.75	2605.04
1Q07	10-Feb-07	3166.19	2874.80	2754.26	AB	AB	AB	AB	AB	AB	AB	2464.92	2465.48	2465.81		2465.10	2692.17	2691.43			NM	2605.96
1Q07	21-Mar-07	3166.15	2887.44	2755.40	AB	AB	AB	AB	AB	AB	AB	2461.72	2463.86	2461.63	2463.65	2463.96	2692.90	2693.08	2718.43	2724.89	2600.23	2603.98
2Q07	10-May-07	3165.91	2887.66	2754.12	AB	AB	AB	AB	AB	AB	AB	2460.96	2463.58	2461.26	2463.33	2463.82	2693.29	2692.62	2717.15	2724.24	NM	2603.27
2Q07	18-Jun-07	NM	NM	2753.75	AB	AB	AB	AB	AB	AB	AB	2460.83	NM	2460.74	NM	NM[b]	2693.09	2692.11	2715.87	2722.70	NM	NM
3Q07	30-Aug-07	3165.12	2874.34	2753.17	AB	AB	AB	AB	AB	AB	AB	2459.01	2462.74	2458.73	2462.27	NM[b]	2690.89	2691.06	2710.52	2714.87	NM	2601.67

[a]Staff gauge reads 3.20 feet at this elevation.

[b]Creek level below staff gauge graduation marks.

Notes:

NM = not measured.

NA = well not accessible.

AB = well abandoned.

UKN = unknown.

>2743.69 = Groundwater was discharging from well casing (flowing under artesian conditions) at time of measurement

the adjacent LCC Staff Gauge 14E were lower than the water level in Well 13R in December 2006 and January 2007 and higher than the water levels in Wells 13R/13T since March 2007. This suggests that at this location, LCC gains water in winter and loses water in late spring and summer. Additional data are being collected bimonthly to further assess these preliminary observations. However, available groundwater level data and steady-state groundwater flow modeling results suggest that the groundwater table occurs very near the LCC channel elevation downstream from the Mine Area (see simulated groundwater discharge areas on Figure 3-9).

3.2.6 Surface Water Discharge

Streamflow monitoring at the Site has occurred at only a few locations. Table 3-2 summarizes those data. Streamflow measurements were obtained from the following sources:

- Previous investigations (Cole/Mills Associates, 1985 and Hydro-Search, Inc., 1984).
- Manual readings from crest gauges installed as part of the sitewide RI work to aid in estimating peak stream discharges at four locations (EPA, 2001a).
- Manual streamflow estimates at the adit and along LCC, CC, and LGC starting in November 2002. Details of the estimating technique are presented in Section 2.5.
- Continuous stream monitoring with dataloggers at weirs in the following four Source Area locations, starting in December 2005 (descriptions are provided in Section 2.5, and locations are shown on Figure 1-6):
  - Upper LCC (Location 1J)
  - The upper LCC side channel (Location 1U)
  - Adit discharge (Location 3A)
  - LCC downgradient from the Rock Buttress (Location 12B)

In 1984, measured streamflow rates were as follows:

- LCC flow upgradient from the mine was up to 0.21 ft^3/sec (95 gpm) in spring; LCC was dry from May to August 1984, (Hydro-Search, Inc., 1984).
- Adit flow (Location 3A) was between 0.11 ft^3/sec (50 gpm) in August 1984 and 0.29 ft^3/sec (130 gpm) in April 1984 (Cole/Mills Associates, 1985). The flow decreased to approximately 0.05 ft^3/sec (20 gpm) by the end of the dry season (September and October) (Hydro-Search, Inc., 1984).

During the sitewide RI fieldwork (EPA, 2001a), crest gauges were installed and monitored to aid in evaluating peak stream discharges at four locations, including the adit discharge (Location 3A), LCC at the base of the former Log Dam (Location 4A); LCC, upstream from the confluence with CC (Location 12J); and CC, upstream from the confluence with LCC (Location 2G). Peak streamflow discharges were as follows:

- LCC and CC mostly ranged between 5 and 15 ft^3/sec (2,240 to 6,730 gpm), with significant flow increases during winter storm events (more than 300 ft^3/sec [134,650 gpm] in winter 2000).

- The adit (Location 3A) had a peak flow of approximately 4 ft^3/sec (1,800 gpm) in February 2000. Much of the peak discharge was likely not coming from the adit but was likely surface runoff directed to the pond at the adit discharge. As part of EPA's drainage improvements during the OU-1 RA, one of the drainages near the mine buildings was modified and now enters a drainage channel downstream from the adit.

Visual observations of streamflow have also been recorded during sampling events at the Site and are presented in Table 3-2. Generally, the discharge peaks at all locations between January and March, which corresponds to the timing of winter storm events. Visually estimated streamflows were as follows (locations are shown on Figures 1-6 through 1-9):

- LCC, upgradient from the mine (Locations 1J and 1U), is dry by June and flows again by early winter, with maximum flows of 45 ft^3/sec (20,200 gpm).
- The perennial adit flow at Location 3A ranges from 0.1 to 2.6 ft^3/sec (45 to 1,200 gpm); however, flows are typically less than 0.5 ft^3/sec (225 gpm).
- The perennial LCC flow, downgradient from the Rock Buttress and upgradient from the confluence with CC (Locations 4A/4A2, 12B, and 12J), ranges from 0.1 to 155 ft^3/sec (45 to 70,000 gpm).
- CC flow (Locations 2G, 14E, 19A, and 19B) ranges from less than 0.01 to 22 ft^3/sec (less than 5 to 9,900 gpm).
- LGC flow (Location 19M) ranges from 0.2 to 30 ft^3/sec (90 to 13,500 gpm).

Dataloggers began recording data in late 2005 at weirs installed at Locations 1J, 1U, 3A, and 12B in the Source Area (see Figure 1-6). However, collection of streamflow data on a daily basis did not begin until 2006. Daily streamflow data (through June 2006) from the four permanent gauging stations are shown on Figure 3-11. Manual measurements from these four locations are also shown on the graphs for comparison. The daily data show a peak in streamflow in April 2006, corresponding to a larger spring rainfall event. A significant rainfall event was also recorded (manual measurement) in late December 2005. The collection of automated streamflow data was disrupted because of flow diversions associated with the OU-1 RA work between July and December 2006. Continuous, automated streamflow data recorded after December 2006 are currently under review. The automated streamflow data are preliminary and are subject to revision as further investigations and corrections are made.

TABLE 3-2
Field Estimates of Surface Water Discharge
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Location	Creek	Nov-02 4Q02	Feb-03 1Q03	May-03 2Q03	Sep-04 3Q04	Dec-04 4Q04	Apr-05 1Q05	Jun/Jul-05 2Q05	Sep/Oct-05 3Q05	Dec-05 4Q05	Jan-06 1Q06	Feb-06 1Q06	Mar-06 1Q06	Apr-06 2Q06	Oct-06 4Q06	Dec-06 4Q06	Feb-07 1Q07	Mar-07 1Q07	Apr-07 2Q07	May-07 2Q07	Jun-07 2Q07	Jul-07 3Q07	Aug-07 3Q07
1J	LCC	Dry	1	2	Dry	Dry	NM	NM	Dry	1 to 45	3	1.7	NM	6	Dry	0.03	3.4	0.4 to 0.9	NM	0.09	Dry	Dry	Dry
1U	LCC side channel	NM	NM	NM	NM	NM	NM	NM	NM	0.6 to 0.8	NM	NM	NM	NM	Dry	0.05	1.5	0.01 to 0.15	NM	NM	Dry	Dry	Dry
3A	Adit	1	1	2	0.4	0.1	0.5	0.5	1.4	0.6 to 2.6	NM	NM	NM	NM	NM	NM	NM	0.5	0.17	0.18	0.05	0.08	0.1
4A	LCC	0.3	2	3	0.3	0.8	3	0.7	0.1	NM	NM	NM	NM	17	–	–	–	–	–	–	–	–	–
4A2	LCC	–	–	–	–	–	–	–	–	–	–	–	–	–	NM	NM	NM	4	NM	1.9	NM	NM	NM
4A – Pipe[a]	LCC	–	–	–	–	–	–	–	–	–	–	–	–	–	0.01	NM	0.002	0.1	NM	0.08	0.05	NM	0.02
12B	LCC	–	–	–	–	–	–	–	–	8.4 to 155	4.5 to 12.6	2.5 to 3.4	5.7	NM	Dry[b]	0.6	9.7	0.9 to 2.1	NM	0.67	0.24	0.2	0.12 to 0.24
12J	LCC	2	6	4	0.1	1	6	3	0.9	NM	NM	NM	NM	12	NM	NM	NM	2	NM	5.3	1.93	NM	0.19
14E	CC	–	–	–	–	–	–	–	–	–	–	–	–	–	–	NM	NM	7	NM	7.5	1.52	NM	<0.01
2G	CC	0.4	12	22	Dry	3	13	NM	0.8	NM	NM	NM	NM	NM	NM	NM	NM	21	NM	3.5	NM	NM	Dry
19A	CC	3	18	15	NM	5	NM	NM	2	NM	NM	18	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
19B	CC	0.8	0.6	1	0.1	0.4	NM	NM	0.1	NM	NM	0.6	NM	NM	0.4	NM	NM	0.04	NM	NM	NM	NM	NM
19M	LGC	5	30	18	1	6	NM	NM	0.2	NM	NM	30	NM	NM	1	NM	NM	NM	NM	NM	NM	NM	NM

[a]Flow from Rock Buttress drain pipe.

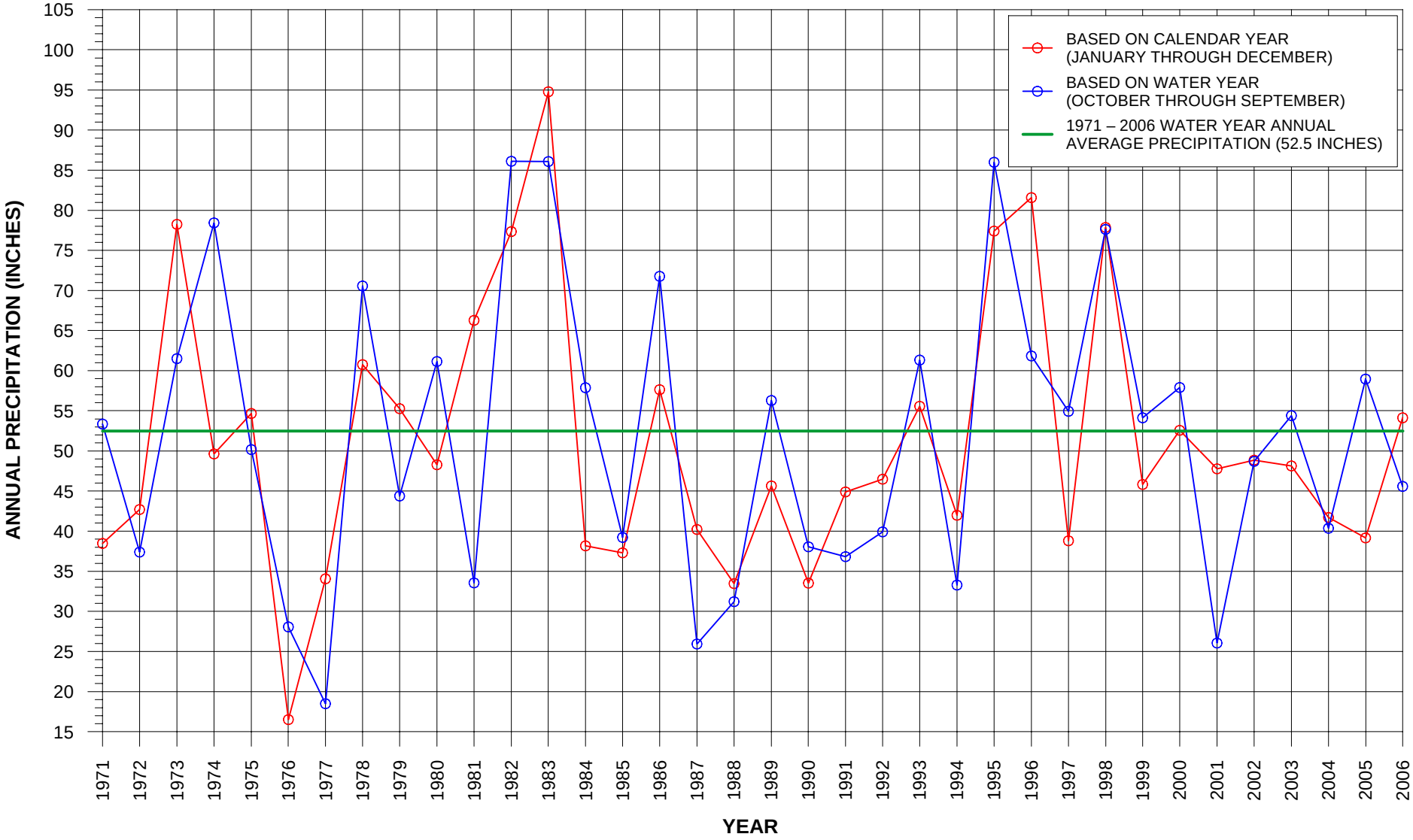
[b]LCC water diverted because of OU-1 construction activities.

Notes:

Values are reported in ft^3/sec.

NM = not measured

– = location does not exist



SOURCE: http://www.ipm.ucdavis.edu:/calludt.cgi/WXSTATIONDATA?MAP=&STN=GRASSVLY.C&GETALL=1&BACKUP=NONE

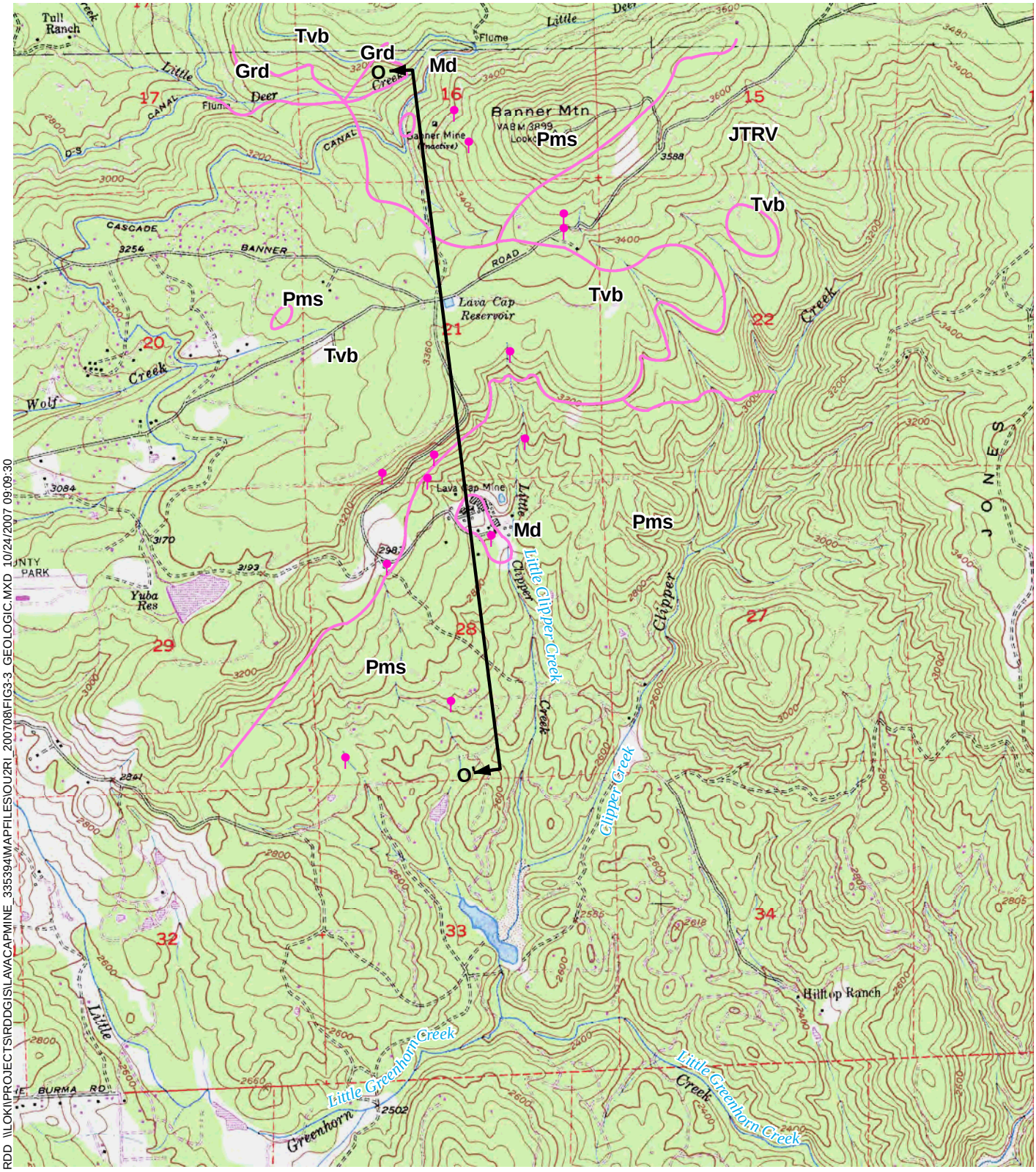
FIGURE 3-1
ANNUAL PRECIPITATION AT GRASS VALLEY
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\Odin\proj\USEPA\184646LC02RIFS\Figures\Grapher\OU2_RI\OU2_RI_FIG03-01.GRF

AREA OF CLIPPER CREEK WATERSHED = 8,178 ACRES (12.8 SQUARE MILES)

FIGURE 3-2
CLIPPER CREEK WATERSHED
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\LOKI\PROJECTS\RDDGIS\LAVACAPMINE_335394\MAPFILES\OU2RI_200708\FINAL\OU2_RI_FIG03-02.MXD 5/9/2008 16:41:02



RDD \\LOK\PROJECTS\RDDG\SLAVACAPMINE_335394\MAPFILES\OU2RI_200708\FIG3-3_GEOLOGIC.MXD 10/24/2007 09:09:30

LEGEND

Grd	DIORITE AND GRANODIORITE
JTRV	METAVOLCANICS
Md	MINE DEPOSITS (WASTE ROCKS AND TAILINGS)
Pms	METASEDIMENTARY ROCK
Tvb	VOLCANIC FLOW BRECCIA (LAVA CAP)

GEOLOGIC CONTACT

LOCATION OF GEOLOGIC CROSS SECTION

SPRING LOCATION

NOTES:
1. BASE MAP IS DERIVED FROM 7.5-MINUTE SERIES TOPOGRAPHIC MAPS FOR CHICAGO PARK AND BLOOMFIELD QUADRANGLE.

2. CROSS SECTION O-O' SHOWN ON FIGURE 1-4.

SOURCE:
COLE/MILLS ASSOCIATES, 1985

0 2,500 FEET

N

FIGURE 3-3
GEOLOGIC MAP
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

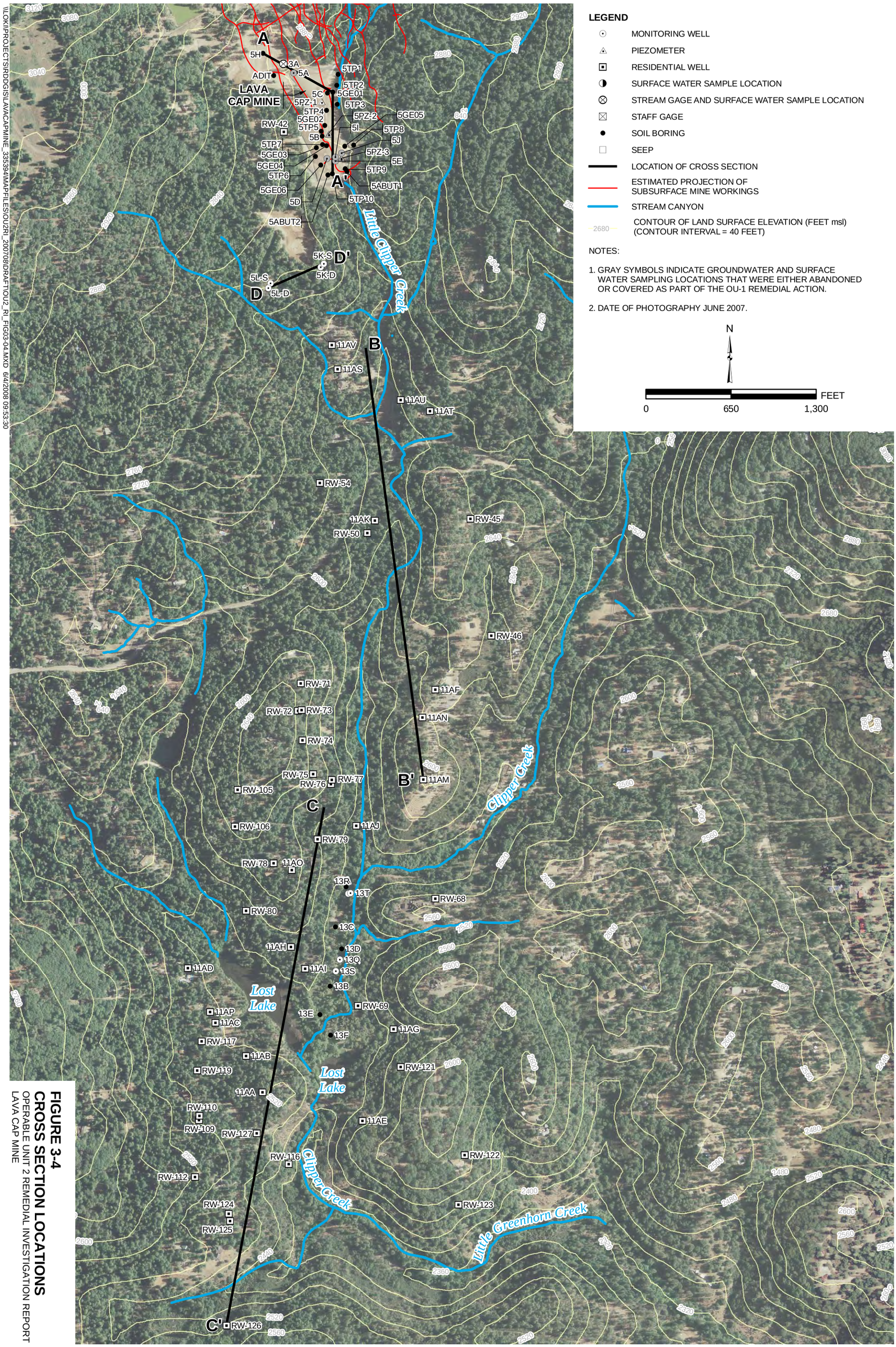
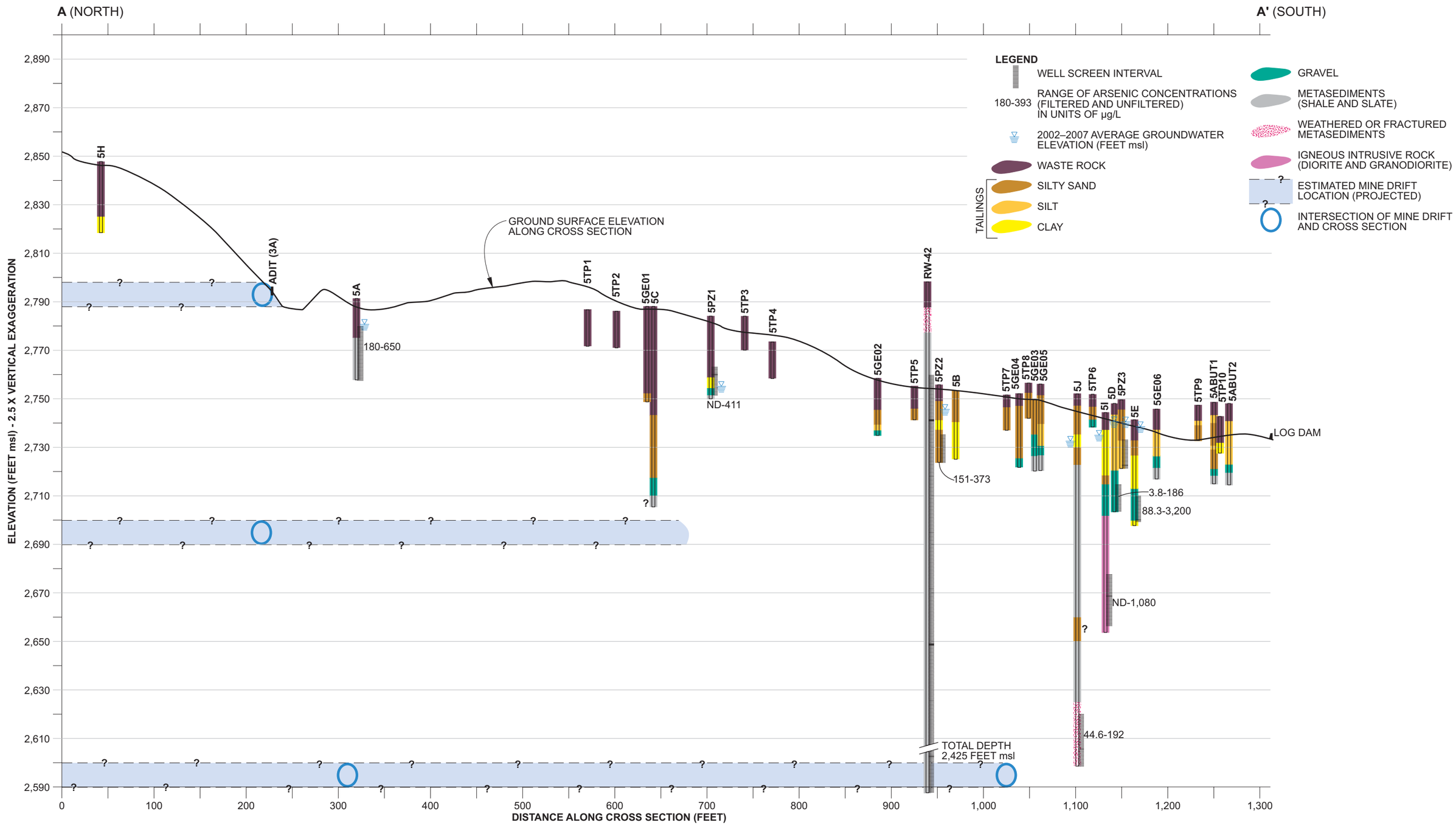


FIGURE 3-4
CROSS SECTION LOCATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\LOKI\PROJECTS\RDDG\SLAVACAPMINE_335394\MAPFILES\OU2\RI_200708\DRAFT\OU2_RI_FIG03-04.MXD 6/4/2008 09:53:30



NOTES:

1. ND = ARSENIC CONCENTRATION BELOW DETECTION LIMIT.
2. PROJECTED LOCATIONS ARE WITHIN 350 FEET FROM THE CROSS SECTION LINE.

FIGURE 3-5
CROSS SECTION A-A'
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ES072007012RDD_02 (10/25/07)

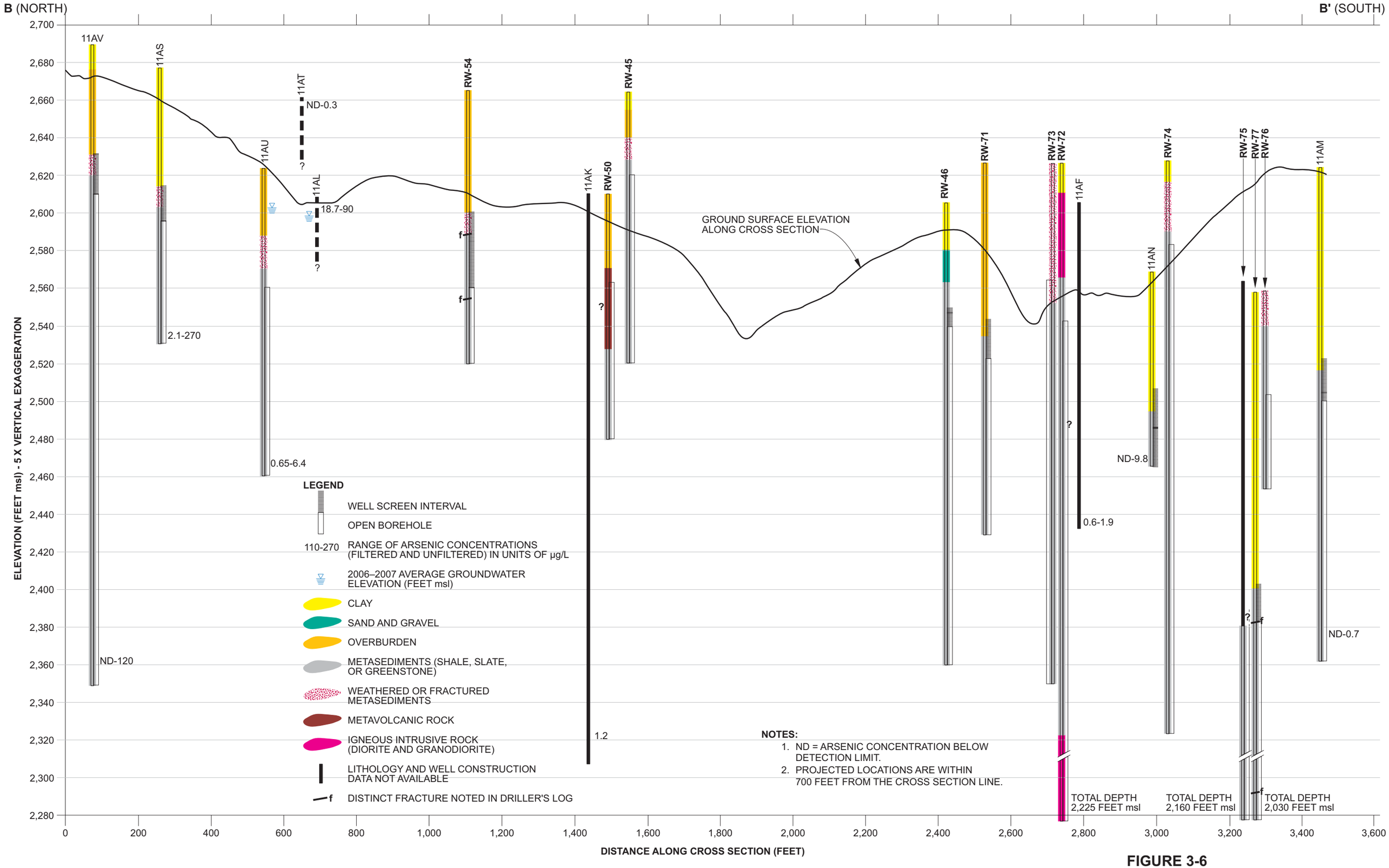


FIGURE 3-6
CROSS SECTION B-B'
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ES072007012RDD_03 (10/30/07)

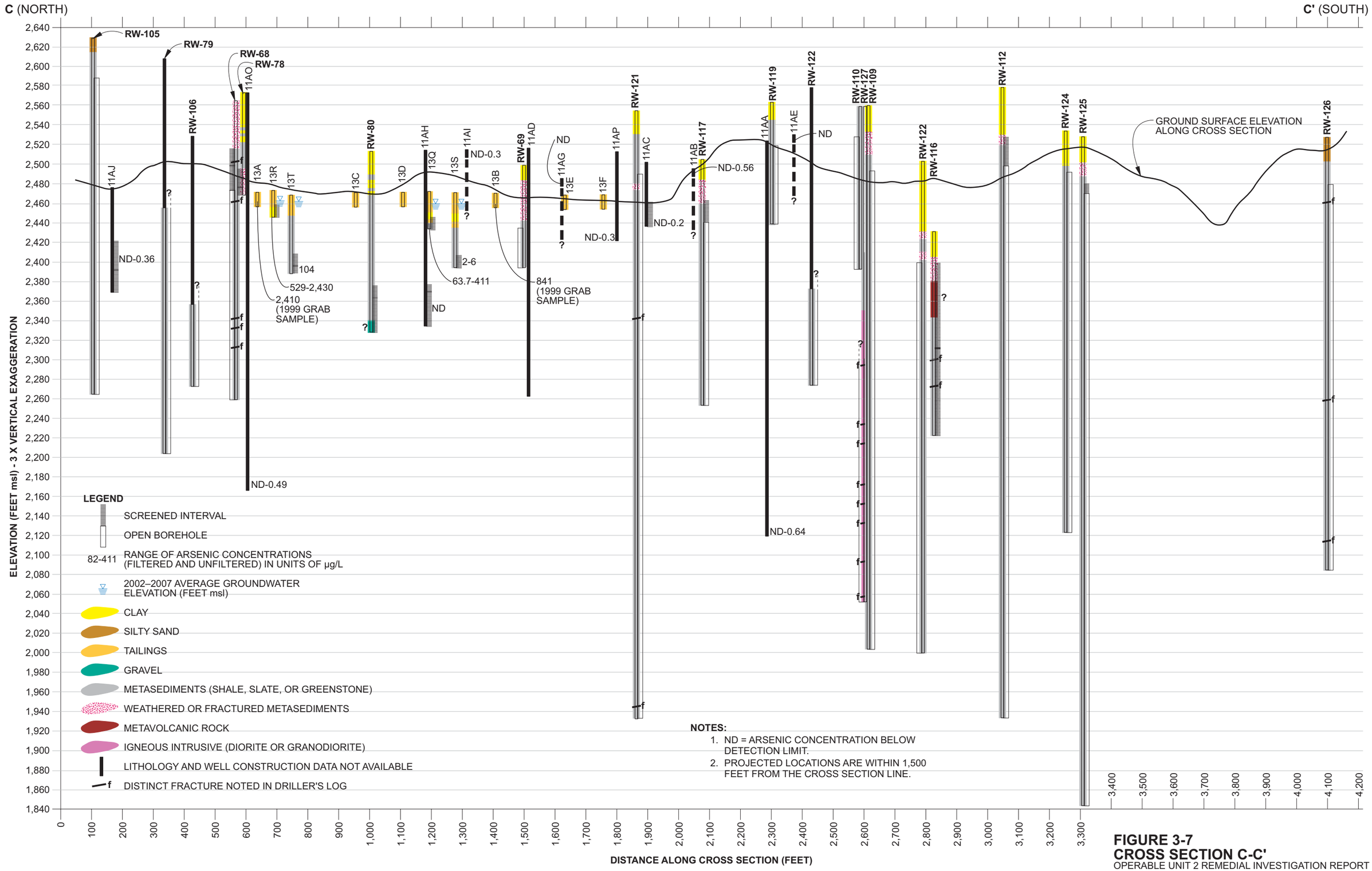


FIGURE 3-7
CROSS SECTION C-C'
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ES072007012RDD_04 (10/3/07)

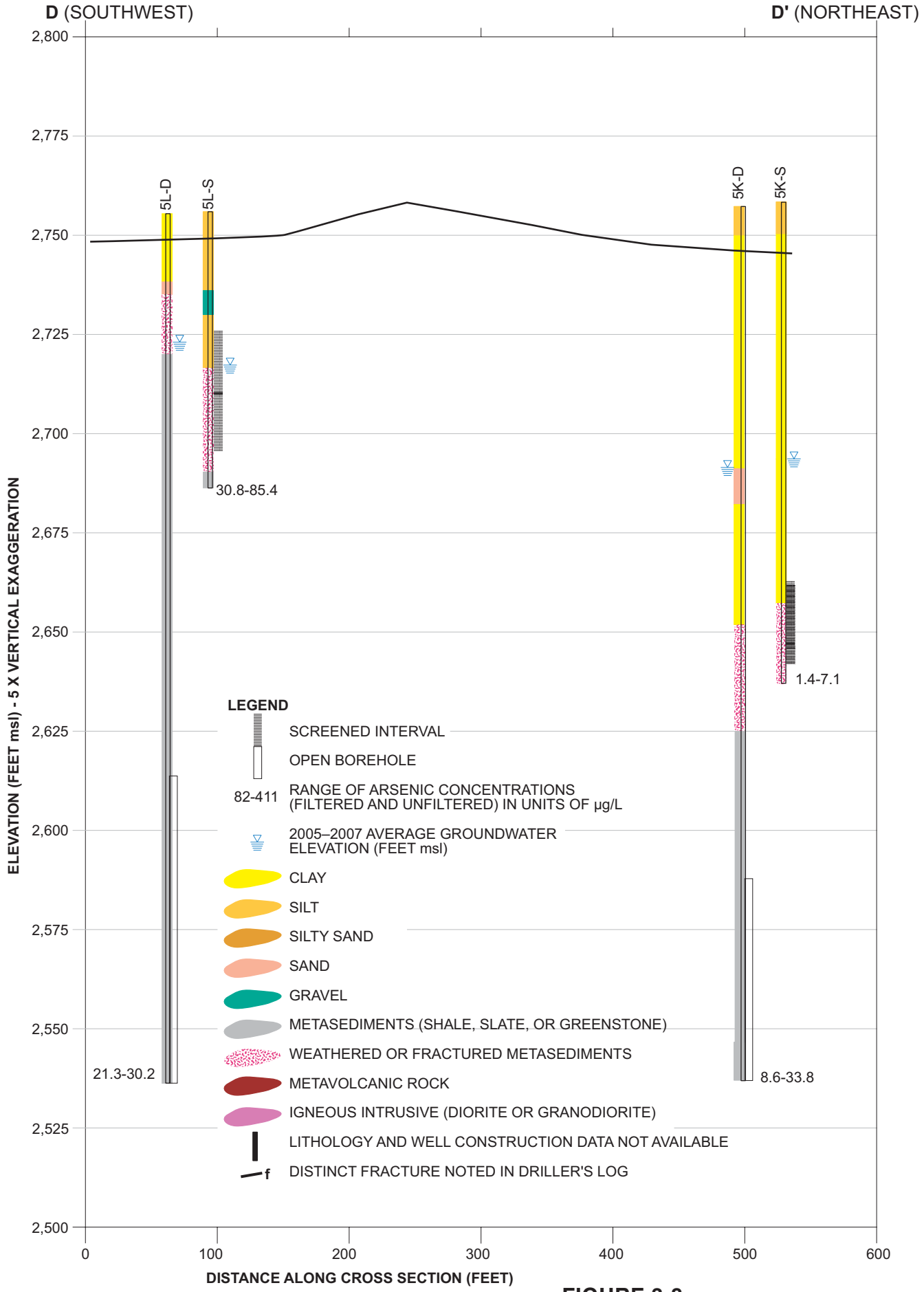


FIGURE 3-8
CROSS SECTION D-D'
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

ES072007012RDD_05 (10/25/07)

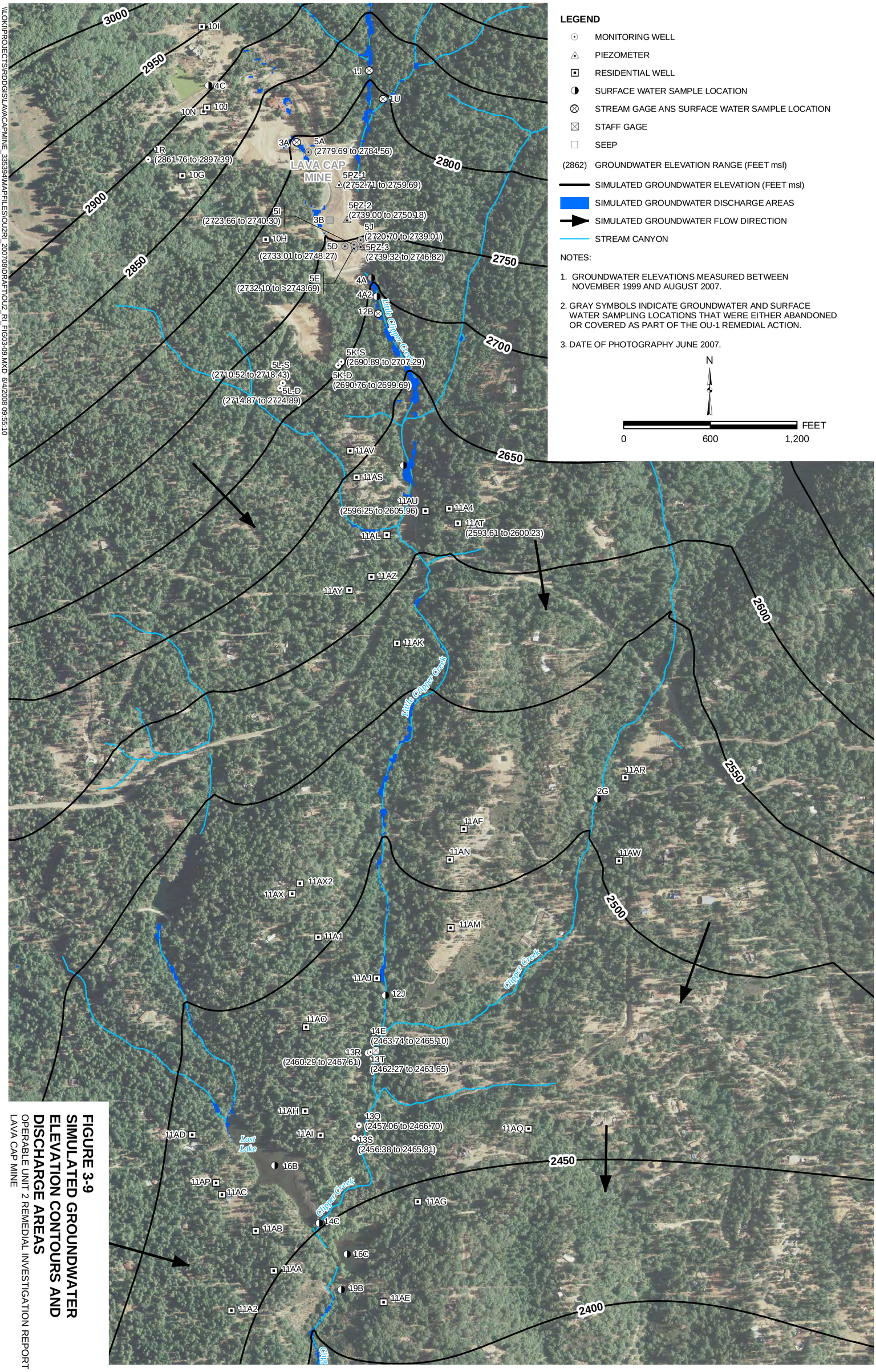


FIGURE 3-9
SIMULATED GROUNDWATER ELEVATION CONTOURS AND DISCHARGE AREAS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\LOKI\PROJECTS\RDGIS\LAVACAPMINE_3353941\MAPFILES\OU2RI_2007\08\DRAFT\OU2_RI_FIG03-09.MXD 6/4/2008 09:55:10

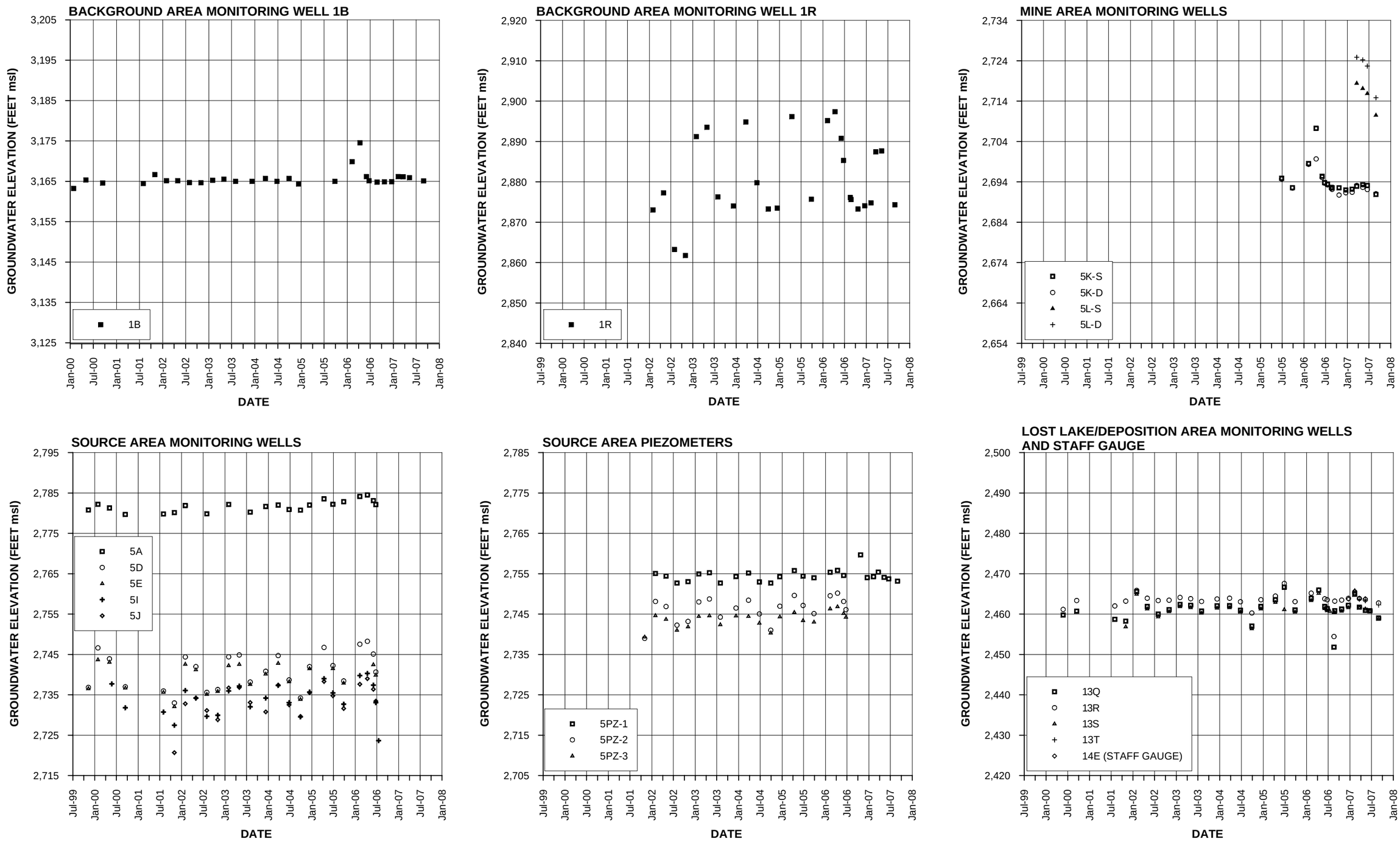
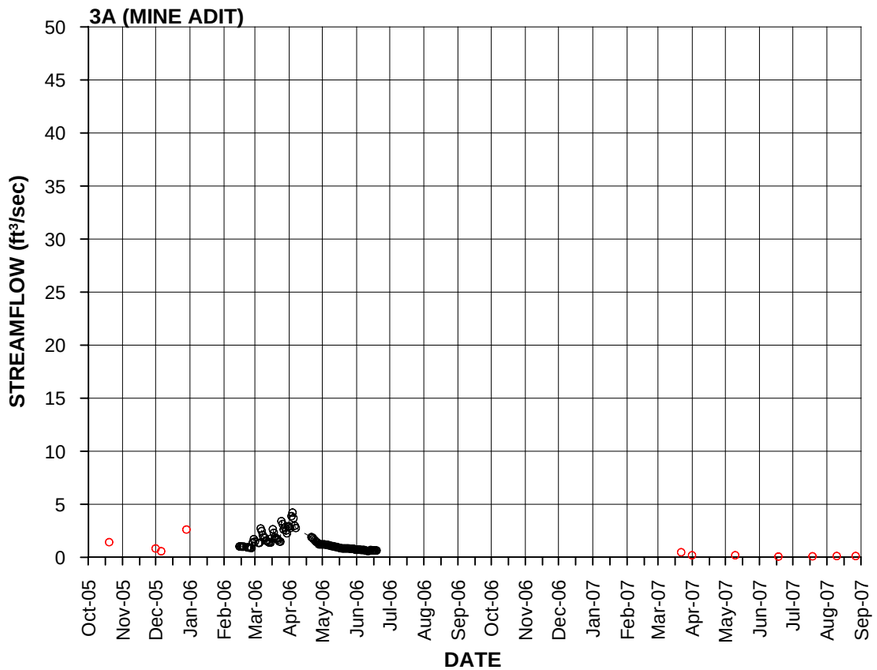
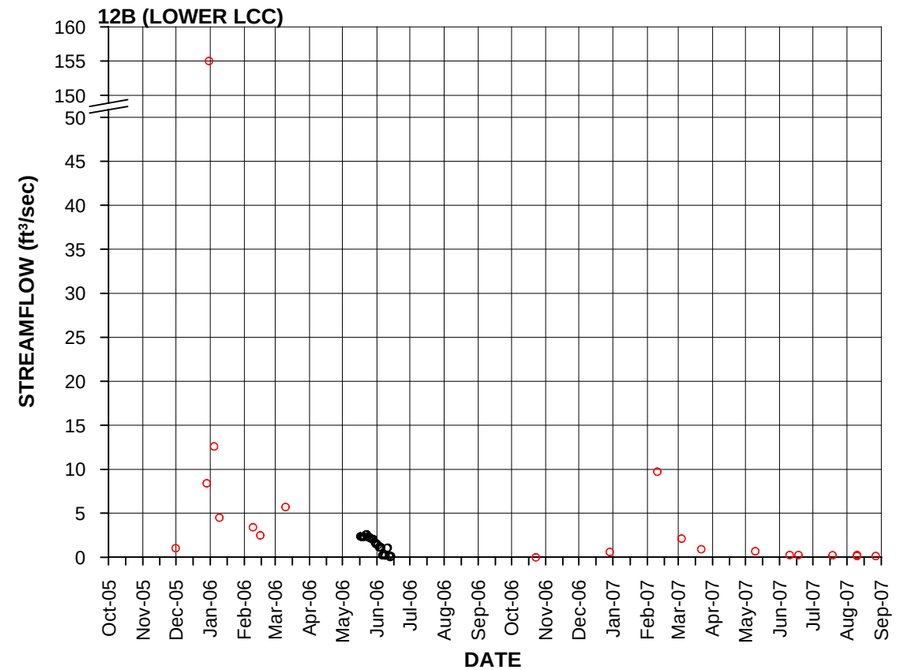


FIGURE 3-10
HYDROGRAPHS OF BACKGROUND AREA, SOURCE AREA, MINE AREA, AND LOST LAKE/ DEPOSITION AREA MONITORING WELLS

OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

\\Odin\proj\USEPA\184646LC02RIFS\Figures\Grapher\OU2_RI\OU2_RI_FIG03-10.GRF



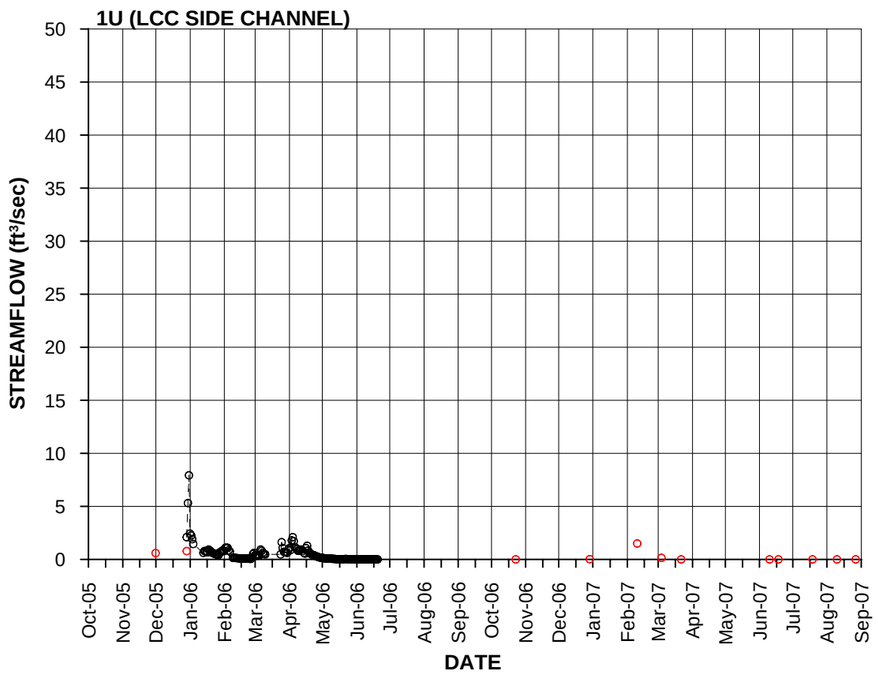


STREAM GAUGE DATA (DAILY MEAN STREAMFLOW)

MANUAL FLOW MEASUREMENT (INSTANTANEOUS STREAMFLOW)

NOTES:

1. MANUAL FLOW MEASURMENTS ARE INSTANTANEOUS READINGS
2. STREAM GAUGE DATA ARE DAILY MEAN STREAMFLOWS



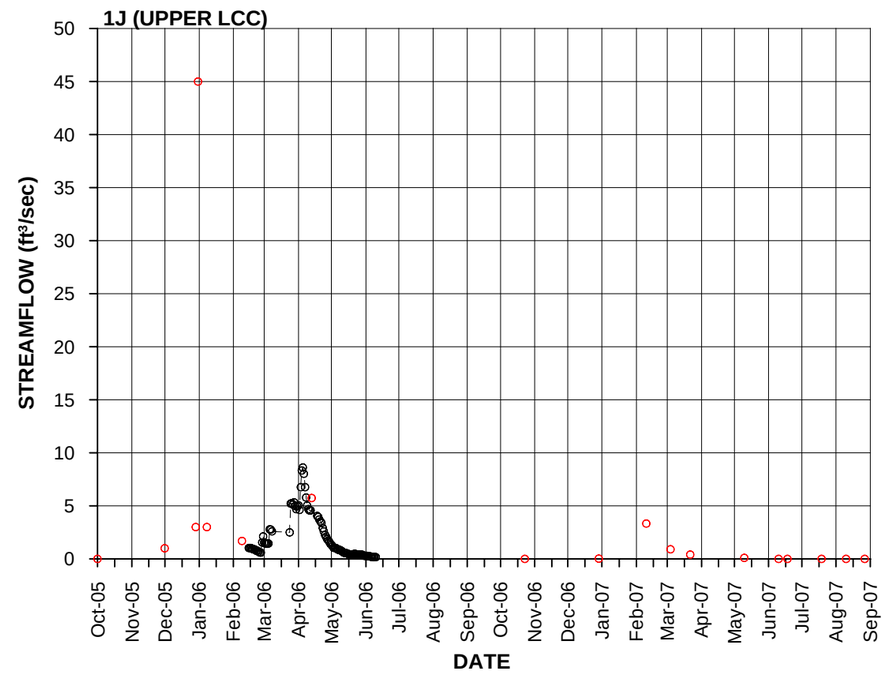


FIGURE 3-11
STREAM DISCHARGE MEASURED AT PERMANENT GAUGING STATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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SECTION 4.0

Nature and Extent of Contamination

This section describes the nature and extent of arsenic contamination associated with the Site in surface water and groundwater. Arsenic is the only identified contaminant of concern in Site groundwater. Water samples at the Site were collected from the following:

- Surface water sampling locations, including the adit, LCC, CC, LGC, and Lost Lake (total arsenic concentrations were preferentially used from these locations)
- Site monitoring wells and piezometers (dissolved arsenic concentrations were preferentially used from these locations)
- Site residential wells (total arsenic concentrations were preferentially used from these locations)

Surface water and groundwater samples have been periodically collected and analyzed from creeks, lakes, monitoring wells, piezometers, and residential wells located in the Background Areas, Source Area, Mine Area, Downgradient Area, and Lost Lake/ Deposition Area from October 1999 through June 2007 (see Section 2.0). In this section, the discussion is divided into the following geographic areas: Background Areas, Source Area and Mine Area, Downgradient Area, and Lost Lake/Deposition Area. Summary information for arsenic concentrations in Site surface water and groundwater are presented in Table 4-1 and concentration versus time plots are presented on Figures 4-1 through 4-4.

Figures 4-5 through 4-10 provide a summary of the most recent and the maximum arsenic concentrations detected in groundwater and surface water at the Site. The date of the most recent sampling result is posted for each location on Figures 4-5 through 4-7. The highest arsenic concentrations in groundwater and surface water were detected in areas that had direct impacts from waste rock, mine tailings, and mine workings.

A complete list of available total and dissolved arsenic concentrations detected in groundwater and surface water samples by geographic area is presented in Appendix H. Dissolved arsenic results from filtered surface water samples and filtered groundwater samples from wells screened in tailings were typically less (in many cases substantially less) than the associated total arsenic concentration (see Appendix H). Generally, there is agreement between the filtered and unfiltered arsenic concentrations in other groundwater samples, indicating that most arsenic in Site groundwater occurs in the dissolved form.

There was an inverse correlation between stream discharge rates and arsenic concentrations in LCC surface water. Surface water arsenic concentrations were lower in winter, when there was significant storm water runoff. Arsenic concentrations were higher during the rest of year when runoff diminishes and discharge from the adit, which contains significant concentrations of arsenic, dominated streamflow. There did not appear to be a significant correlation with seasonal groundwater elevations and arsenic concentrations in groundwater sampled from monitoring wells, piezometers, and residential wells.

TABLE 4-1
Arsenic Concentration Summary Data
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Location	Location Type	Minimum Arsenic Concentration (µg/L)	Maximum Arsenic Concentration (µg/L)	Median Arsenic Concentration (µg/L)	Average Arsenic Concentration (µg/L)	Standard Deviation	Number of Samples	Percent Detects
Background Areas								
1J	SW	0.22J	0.9	0.30	0.39	0.27	10	80
1U	SW	0.5U	0.5U	NA	NA	NA	1	0
2G	SW	0.08J	3.8	0.20	0.52	0.94	15	47
1B	MW	1.2	24.2	13	13.4	6.05	15	100
1R	MW	8.7	24	19.1	18.9	4.30	15	100
11AR	RW	0.1J	0.1J	NA	NA	NA	1	100
11AW	RW	0.21J	0.41J	0.21	0.24	0.12	4	75
11A3	RW	1U	1U	NA	NA	NA	4	0
11A5	RW	1	1	NA	NA	NA	1	100
Summary		0.08J	24.2J	1.00	7.85	8.92	66	77
Source Area and Mine Area								
3A	SW	199	910	510	510	146	31	100
3B	SW	27.2	383	50.6	95.4	101	14	100
4A/4A2	SW	16.5	532	130	168	114	30	100
5A	MW	190	610	230	284	115	13	100
5D	MW	3.5	29.3	13.3	15.5	10.3	16	100
5E	MW	88.3	470	380	344	113	18	100
5I	MW	11.8	181J	40.0	53.6	45.8	17	100
5J	MW	44.6	192	86.5	99	48.2	14	100
5PZ-1	PZ	0.43J	9.4	1.70	4.27	4.67	5	80
5PZ-2	PZ	151	373J	270	264	79.6	5	100
5PZ-3	PZ	501	871	764	725	147	6	100

TABLE 4-1
Arsenic Concentration Summary Data
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Location	Location Type	Minimum Arsenic Concentration (µg/L)	Maximum Arsenic Concentration (µg/L)	Median Arsenic Concentration (µg/L)	Average Arsenic Concentration (µg/L)	Standard Deviation	Number of Samples	Percent Detects
5K-S	MW	1.4	7.1	5.25	4.83	2.18	6	100
5K-D	MW	8.2	33.8	15.2	18.1	10.7	6	100
5L-S	MW	30.8	85.4	58.1	58.1	38.6	2	100
5L-D	MW	21.3	30.2	25.8	25.8	6.29	2	100
10G	RW	7.1	41.0	28.9	24.6	11.2	21	100
10H	RW	2.5	31.7	20.4	19.0	8.85	19	95
10I	RW	377	528	453	453	107	2	100
10J	RW	41.9	56.8	49.0	49.1	6.9	5	100
10N	RW	28.9	54.7	41.4	41.2	8.23	12	100
Summary		0.43J	910	73.0	178.0	207	244	99
Downgradient Area								
12J	SW	21.9	274	65.6	84.0	55.4	20	100
19M	SW	1.8	11	4.40	5.38	2.71	18	100
11AL	RW	18.7	90	33.6	37.0	13.4	22	100
11AS	RW	2.1	270	105	110	61.3	16	100
11AT	RW	0.2J	1U	0.20	0.24	0.12	7	43
11AU	RW	1.4	5.7	2.85	2.98	1.02	16	100
11AV	RW	3.5	890	28.7	87.9	216	16	100
11AY	RW	0.98J	1.5	1.15	1.20	0.22	4	100
11AZ	RW	1.4	2.4	2.20	2.05	0.45	4	100
11A4	RW	0.84U	2.1	2.00	1.63	0.80	4	75
11AF	RW	0.89J	1.9J	1.45	1.47	0.34	12	100
11AJ	RW	0.1J	1UJ	0.25	0.25	0.14	9	56

TABLE 4-1
Arsenic Concentration Summary Data
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Location	Location Type	Minimum Arsenic Concentration (µg/L)	Maximum Arsenic Concentration (µg/L)	Median Arsenic Concentration (µg/L)	Average Arsenic Concentration (µg/L)	Standard Deviation	Number of Samples	Percent Detects
11AK	RW	1.2	1.2	1.20	1.20	0.00	2	100
11AM	RW	0.2U	2U	0.37	0.46	0.29	7	71
11AN	RW	0.2U	9.8	0.50	1.32	2.99	10	50
11AO	RW	0.28	1UJ	0.37	0.36	0.10	9	67
11AQ	RW	0.25U	1U	0.35	0.33	0.18	5	40
11AX/11AX2	RW	0.54UJ	3.5[a]	0.60	1.22	1.22	7	57
11A1	RW	0.24J	1U	0.47	0.42	0.12	4	50
Summary		0.1J	890	2.90	30.6	76.8	192	86
Lost Lake/Deposition Area								
16B	SW	4.9	120	23.6	38.7	36.3	22	100
16C	SW	11	430	33.9	57.0	86.8	22	100
19B	SW	24	2200	98.5	238	450	22	100
14E	SW	12.6	65.9	39.3	39.3	37.7	2	100
13Q	MW	63.7	235	113	130	48.0	17	100
13R	MW	529	2270	1320	1338	495	18	100
13S	MW	2	6	3.70	3.92	1.05	17	100
13T	MW	35.4	104	69.7	69.7	48.5	2	100
11AA	RW	0.09U	1U	0.23	0.26	0.21	8	25
11AB	RW	0.2J	5U	0.50	0.68	0.72	9	67
11AC	RW	0.2U	0.2U	NA	NA	NA	2	0
11AD	RW	0.1U	0.6	0.30	0.27	0.16	9	78
11AE	RW	0.1U	1U	NA	NA	NA	9	0
11AG	RW	0.1U	1U	NA	NA	NA	8	0

TABLE 4-1
Arsenic Concentration Summary Data
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Location	Location Type	Minimum Arsenic Concentration (µg/L)	Maximum Arsenic Concentration (µg/L)	Median Arsenic Concentration (µg/L)	Average Arsenic Concentration (µg/L)	Standard Deviation	Number of Samples	Percent Detects
11AH	RW	0.1U	1U	NA	NA	NA	5	0
11AI	RW	0.1U	1U	NA	NA	NA	9	0
11AP	RW	0.2U	5U	0.28	0.64	0.87	7	29
11A2	RW	1U	1U	NA	NA	NA	4	0
Summary		0.09U	2270	15.1	177	432	192	73

[a]The 16.8 µg/L value from the October 2006 11AX sample is excluded.

Notes:

Results do not include field duplicates or laboratory split samples.

For median, average, and standard deviation calculations, one-half the reporting limit is used for values below the detection limit.

J = estimated value
NA = not applicable
MW = monitoring well
PZ = piezometer
RW = residential well
SW = surface water
U = nondetect at the specified concentration, which is equal to the reporting limit
µg/L = micrograms per liter

4.1 Background Areas

Arsenic concentrations in surface water and groundwater for the Background Areas are presented on Figure 4-1; summary statistics are presented in Table 4-1. Figures 4-5 and 4-6 and Figures 4-8 and 4-9 show sampling locations and the most recent and maximum reported arsenic concentrations detected in groundwater and surface water samples from the Background Areas. Sampling locations in the Background Areas included the following:

- Surface water upstream from the Source Area and Mine Area that feed LCC (Locations 1J and 1U; see Figures 4-5 and 4-8) and the portion of CC upstream from the confluence with LCC (Location 2G; see Figures 4-6 and 4-9) – total arsenic concentrations were less than 4 µg/L, with an average concentration of approximately 0.5 µg/L.
- Monitoring wells upgradient from the mine and the waste rock/tailings pile (Wells 1B and 1R; see Figures 4-5 and 4-8) – these wells are screened in bedrock approximately 150 feet bgs, within the footprint of the Lava Cap Mine underground workings. Dissolved arsenic concentrations were between 1.2 and 24.2 µg/L. Dissolved arsenic concentrations remained above the maximum contaminant level (MCL) of 10 µg/L in samples from these wells (the average arsenic concentration was approximately 16 µg/L), except at Well 1B, where arsenic concentrations have been below 3 µg/L since 2006.
- Residential wells located on ridges above CC, upgradient from the confluence of LCC with CC (Wells 11AR and 11AW; see Figures 4-6 and 4-9), and wells located more than 2,500 feet from LCC (Wells 11A3 and 11A5; see Figure 1-9) – total arsenic concentrations were equal to or less than 1 µg/L.

Background arsenic concentrations generally were low in surface water and groundwater in the areas sampled, except in areas within the footprint of the mine workings. No discernible steadily increasing or decreasing trend in arsenic concentrations is apparent in the data during the period of record (see Figure 4-1).

4.2 Source Area and Mine Area

Source Area and Mine Area arsenic concentrations in surface water and groundwater are presented on Figure 4-2; summary statistics are presented in Table 4-1. Figures 4-5 and 4-8 show sampling locations and the most recent and maximum reported arsenic concentrations from groundwater and surface water samples. Source Area and Mine Area sampling locations included the following:

- Surface water discharging from the mine adit (Location 3A), the former tailings pile seep (Location 3B), the base of the former Log Dam (Location 4A), and the Rock Buttress (Location 4A2) in LCC – total arsenic concentrations ranged between 16.5 and 910 µg/L in Source Area surface water and exhibited seasonal concentration variations (all above the MCL of 10 µg/L). The highest total arsenic concentration was detected in a sample from the mine adit discharge. Samples from the former tailings pile seep (Location 3B) typically had the lowest arsenic concentrations in the Source Area, but were still well above the arsenic MCL. Arsenic concentrations in samples from the base of the former

Log Dam (Location 4A) and the base of the Rock Buttress (Location 4A2) were similar to adit discharge concentrations (Location 3A) in the dry season and typically were significantly lower than adit discharge concentrations in the wet season because of dilution from storm water runoff. Arsenic concentrations in samples from Location 4A2 after the OU-1 RA were initially lower than historical concentrations detected at Location 4A (base of the former Log Dam) but increased by March 2007 to previous levels.

- Source Area monitoring Wells 5A, 5D, 5E, 5I, and 5J and Piezometers 5PZ-1, 5PZ-2, and 5PZ-3). Wells 5A, 5D, and 5E were screened in the basal gravel unit beneath the tailings. Wells 5J and 5I were screened in bedrock beneath the waste rock/tailings pile. Of these wells, only Piezometer 5PZ-1 remains at the Site after the OU-1 RA. Recent arsenic concentrations at this location were similar to pre-OU-1 RA concentrations. Dissolved arsenic concentrations ranged between 0.43 and 871 µg/L. Dissolved arsenic concentrations at individual wells and piezometers fluctuated within one order of magnitude or less and were usually above the MCL, except at Piezometer 5PZ-1. Samples from Wells 5A and 5E and Piezometers 5PZ-2 and 5PZ-3 had the highest arsenic concentrations in the Source Area. Dissolved arsenic concentrations in samples from Well 5D fluctuated below and above the MCL. No steadily increasing or decreasing trend in dissolved arsenic concentrations is apparent in the data from most Source Area monitoring wells and piezometers during the period of record (see Figure 4-2) except the following:
  - Dissolved arsenic concentrations in samples from Well 5J steadily increased over the period of record until abandonment in 2006.
  - Dissolved arsenic concentrations in samples from Well 5I showed a minor decrease from 2000 through early 2002, with concentrations remaining between 11.7 and 58.5 µg/L over the remaining period of record until abandonment in 2006.
- Mine Area monitoring wells located on the ridges southwest of the waste rock/tailings pile (shallow/deep Well Pairs 5K-S/5K-D and 5L-S/5L-D) – the shallow wells (Wells 5K-S and 5L-S) are screened through the overburden and weathered bedrock contact. The deep wells (Wells 5K-D and 5L-D) are screened in the underlying competent bedrock. Dissolved arsenic concentrations range between 1.4 and 85.4 µg/L in samples from Mine Area wells. Dissolved arsenic concentrations in groundwater from these wells were usually above the MCL, except at Well 5K-S. No discernible steadily increasing or decreasing trend in dissolved arsenic concentrations is apparent in the data from the Mine Area monitoring wells during the period of record (see Figure 4-2), except for concentrations in samples from Well 5K-D, which have consistently declined since its installation in 2005 and dropped below the MCL by March 2007.
- Mine Area residential wells (Wells 10G, 10H, 10I, 10J, and 10N), which are screened in bedrock northwest and west of the waste rock/tailings pile – total arsenic concentrations ranged between 2.5 and 528 µg/L in samples from these wells. Total arsenic concentrations in samples from Wells 10G and 10H sometimes fluctuated seasonally (above and below the MCL). Total arsenic concentrations in samples from Wells 10J and 10N fluctuated very little over the period of record. Well 10I has only two recorded sample results from late 1999 (528 µg/L) and early 2000 (377 µg/L), both significantly above the

MCL. Because of the location and depth of this well and the high arsenic concentrations detected, it appears that Well 10I might be partially completed in the mine workings. Well 10I is used for irrigation but not for residential purposes.

Surface water and groundwater arsenic concentrations in the Source Area and Mine Area were typically significantly higher than background concentrations and were usually above the MCL (except at Well 5K-S and Piezometer 5PZ-1). The highest arsenic concentrations (over 100 µg/L) occurred in water discharging from the mine adit and in groundwater samples from wells screened within waste rock, tailings, or mine workings. Arsenic concentrations were typically lower (less than 100 µg/L) in wells screened in bedrock on the ridges northwest, west, and southwest of the waste rock/tailings pile. Arsenic concentrations detected in the different geologic units in and below the waste rock/tailings pile (waste rock, tailings, basal gravel, and underlying bedrock) were typically similar to each other.

4.3 Downgradient Area

Downgradient Area arsenic concentrations in surface water and groundwater are presented on Figure 4-3; summary statistics are presented in Table 4-1. Figures 4-6 and 4-9 show sampling locations and the most recent and maximum reported arsenic concentrations from groundwater and surface water samples in the Downgradient Area. Downgradient Area sampling locations included the following:

- Surface water in LCC between the mine and Lost Lake (Location 12J) – total arsenic concentrations ranged between 21.9 and 274 µg/L at Location 12J; these concentrations were typically one-half of the total arsenic concentrations in samples of LCC surface water from the base of the former Log Dam and current Rock Buttress (Location 4A/4A2) and all are above the MCL.
- Residential wells along the LCC drainage below the mine and above Greenhorn Road (Wells 11AL, 11AS through 11AV, 11AY, 11AZ, and 11A4), and south of Greenhorn Road and north of Lost Lake (Wells 11AF, 11AJ, 11AK, 11AM through 11AO, 11AQ, 11AX, 11AX2, and 11A1) – total arsenic concentrations ranged between nondetect and 890 µg/L in samples collected from Downgradient Area wells north of Greenhorn Road. Total arsenic concentrations have only been detected up to 9.8 µg/L in samples from wells south of Greenhorn Road. Total arsenic concentrations in Downgradient Area residential wells were below the MCL, except at Wells 11AL, 11AS, and 11AV. Total arsenic concentrations in samples from Downgradient Area wells are consistent over their periods of record (typically with concentrations fluctuating less than an order of magnitude at individual wells), except at Wells 11AS and 11AV. At these wells, total arsenic concentrations detected in samples varied by two orders of magnitude (mostly above the MCL, but a few samples had arsenic concentrations below the MCL). No discernible steadily increasing or decreasing trend in total arsenic concentrations is apparent in the data from Downgradient Area groundwater during the period of record (see Figure 4-3).
- Surface water in LGC approximately 1.5 miles downstream from Lost Lake (Location 19M; see Figure 1-9) – total arsenic concentrations ranged between 1.8 and 11 µg/L in LGC downstream from Lost Lake but generally are below the MCL.

Arsenic concentrations detected in LGC downstream from Lost Lake have no discernible steadily increasing or decreasing trend in total arsenic concentrations during the period of record (see Figure 4-3).

An anomalous arsenic detection (16.8 µg/L) in the October 2006 sample from Well 11AX is not included in the summary statistics, graphs, or the nature-and-extent evaluation. This sample was collected from stagnant well water because the field team was unaware that Well 11AX had not been in use for several months; the well had been replaced by a nearby, new drinking water Well 11AX2. Active Well 11AX2 was sampled in December 2006 and again in March 2007 to check if the elevated arsenic detection was reproducible. Total arsenic concentrations at Well 11AX2 were less than 1 µg/L; therefore, the 16.8 µg/L arsenic concentration is not considered to be representative of groundwater conditions in this area.

Within the Downgradient Area, elevated arsenic concentrations were detected in LCC surface water downstream from the mine and in groundwater samples from downgradient Wells 11AL, 11AS, and 11AV. Except for these locations, concentrations of arsenic in surface water and groundwater in the Downgradient Area are low (less than the MCL) and similar to background concentrations.

4.4 Lost Lake/Deposition Area

Lost Lake/Deposition Area arsenic concentrations in surface water and groundwater are presented on Figure 4-4; summary statistics are presented in Table 4-1. Figures 4-7 and 4-10 show sampling locations and the most recent and maximum reported arsenic concentrations from groundwater and surface water samples in the Lost Lake/Deposition Area. Lost Lake/Deposition Area sampling locations included the following:

- Surface water in CC, immediately south of the confluence with LCC and immediately north of Lost Lake (Location 14E) – total arsenic concentrations ranged between 12.6 and 65.9 µg/L at Location 14E, all above the MCL. These concentrations are slightly lower than concentrations detected in samples collected upstream LCC Location 12J.

- Surface water in Lost Lake (Locations 16B and 16C) and at the base of the Lost Lake Dam (Location 19B) – total arsenic concentrations ranged between 4.9 and 2,200 µg/L; most detections were above the MCL. The highest total arsenic concentration (2,200 µg/L at Location 19B) was associated with a dissolved arsenic concentration of only 13 µg/L. This large difference indicates that suspended solids contributed to the elevated total arsenic concentrations (a preliminary USGS investigation of the orange-colored iron bacteria that occur at Location 19B indicated that the bacteria is very high in arsenic and other metals). Seasonal variations occur in Lost Lake water, with concentration peaks in the wet season and concentration lows in the dry season.

- Monitoring wells in the Deposition Area screened within the tailings (Wells 13Q and 13R) and in the underlying bedrock (Wells 13S and 13T) – dissolved arsenic concentrations ranged between 2 and 2,270 µg/L in samples from these wells. Arsenic concentrations were above the MCL for all samples from these wells, except in Well 13S (a bedrock well). Dissolved arsenic concentrations within the Deposition Area tailings (Wells 13Q and 13R) remained high (between 63.7 and 2,270 µg/L), particularly in the samples from Well 13R. Dissolved arsenic concentrations in groundwater samples from

bedrock Well 13S remained less than the MCL. Samples from the newly installed bedrock well (Well 13T), which is screened at a similar depth as Well 13S, had dissolved arsenic concentrations of 104 µg/L and 35 µg/L when it was sampled in March and June 2007, respectively. Arsenic concentrations in Well 13R appear to be decreasing over time, while the concentrations at Wells 13Q and 13S remain relatively constant. There was insufficient data to determine a trend at Well 13T; however, a significant drop occurred in arsenic concentrations between March and May 2007 at this well. Additional sampling is needed to further evaluate the concentration trend at this well. Significant drops in arsenic concentrations were also detected in other bedrock monitoring wells (e.g., Wells 5I and 5K-D) during their first year of monitoring. This could indicate that arsenic concentrations at new monitoring well installations can take time to equilibrate to natural conditions after drilling.

- Residential wells north, east, and west of Lost Lake (Wells 11AA through 11AE, 11AG through 11AI, 11AP, and 11A2) – total detected arsenic concentrations were less than 1 µg/L in Lost Lake/Deposition Area residential wells. The highest detected arsenic concentration (0.64 µg/L) was in the May 2000 sample from Well 11AA. No discernible steadily increasing or decreasing trend in total arsenic concentrations is discernable at residential wells in the Lost Lake/Deposition Area during the period of record (see Figure 4-4).

Elevated arsenic concentrations in the Lost Lake/Deposition Area were limited to locations directly impacted by the tailings deposits. This includes the surface water in LCC, groundwater within the tailings pile, surface water in Lost Lake, and surface water at the base of the Lost Lake Dam. Groundwater from residential wells and Monitoring Well 13S, which is screened in the bedrock, had low arsenic concentrations (less than 6 µg/L).

4.5 In-home Treatment Unit Results

In 2003, EPA installed in-home, under-sink treatment units to remove arsenic in the water from three residential wells that had arsenic concentrations above the MCL (Wells 10G, 10H, and 11AL). Sample results from these wells and treatment units are presented in Table 4-2. Wells 10G and 11AL were actively used for domestic purposes. The residence primarily supplied by Well 10H was demolished in 2006 as part of the OU-1 RA. Two other wells with elevated arsenic concentrations (Wells 10N and 11AV) had previously been equipped with treatment units by the residents that were not maintained by EPA. Wells 10I and 11AS also contained arsenic above the MCL but were only used for irrigation. Well 10J is no longer in use because it collapsed and was subsequently replaced by Well 10N, which is the primary well serving the main residence (with Well 10H as a backup well).

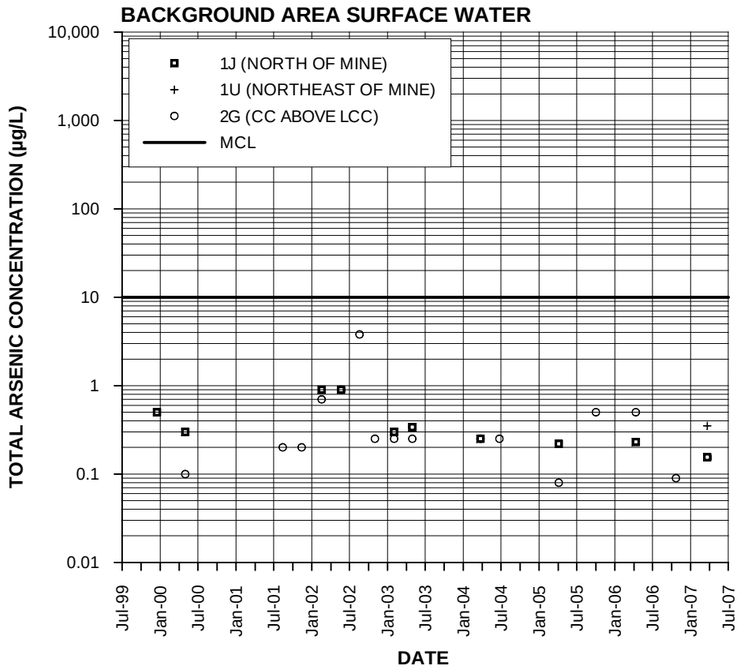
Well 10G is located on the mine property (see Figure 1-6) and Well 11AL is located down-gradient from the mine property, above Greenhorn Road (see Figure 1-7). At these wells, both untreated well water (from the wellhead) and treated water (from the treatment unit discharge) samples were collected and sampled for total arsenic. Sample results in Table 4-2 show that the treatment unit associated with Well 11AL was operating as intended at all sampling events for the guest house, but the March 2007 sample (from the main house) exceeded the MCL for the first time. This treatment unit was serviced and the filter replaced. The treatment unit associated with Well 10G was working as intended during all sampling

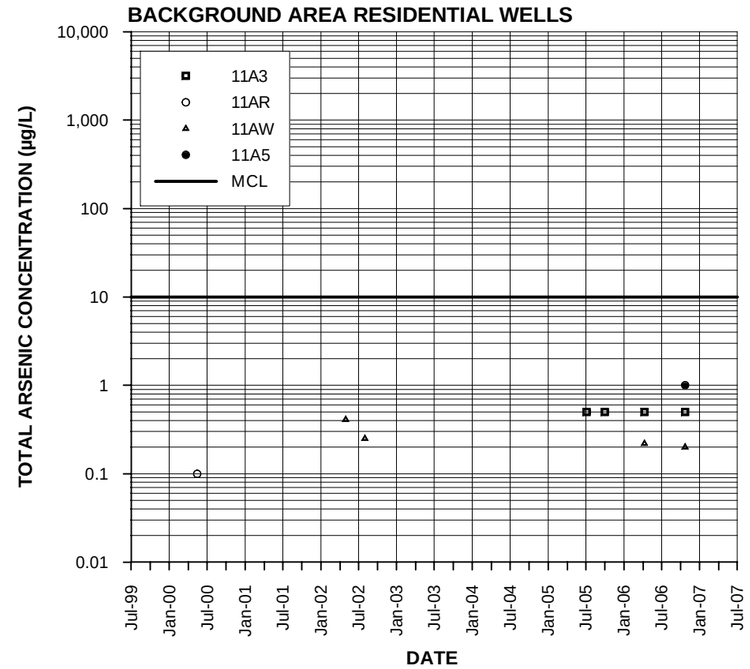
events except September 2005. The September 2005 sample from Well 10G indicated the treatment system needed maintenance. The required maintenance was performed, and arsenic concentrations in the treated water returned to less than 0.55 µg/L.

TABLE 4-2
Arsenic Concentrations in Residential Wells Equipped with Treatment Units Maintained by EPA
OU-2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Event	Date	Well 10G		Well 10H		Well 11AL		
		Wellhead	Treated	Wellhead	Treated	Wellhead	Guest House	Main House
4Q03	Dec-03	35	0.25 U	7.3	0.25 U	33		1.5
1Q04	Mar-04	13	0.5 U	22	0.41 J	90		1.3
2Q04	Jun-04	18	0.5 U	30	1.0	40		7.2
3Q04	Sep-04	30	0.5 U	22	NA	35	6.9	
4Q04	Dec-04	31.5	1.0 U	31.7		18.7	1.7	3.2
1Q05	Apr-05	13.8		23.5 (22.8)		36.2		
2Q05	Jun/Jul-05	7.1	0.2 J				0.43 J	6.5
3Q05	Sep/Oct-05	28.9 J	28.9 J	20.4 J		32.9	0.3 UJ	3.6
2Q06	Apr-06	14.6 (15.1)	1 U	2.5		30.9	3.4	2.5
4Q06	Oct-06	34.9 (32.7)	0.14 J	NA		29.1	2.0	1.9
1Q07	Mar-07	14.3	0.55 UJ			40.2	1.8	24.8

Notes:
Units are µg/L.
Results in parenthesis are field duplicates.
J = estimated value
NA = not applicable (well no longer in use)
U = nondetect at the specified concentration





NOTES:

1. MONITORING WELL RESULTS SHOWN ARE DISSOLVED ARSENIC CONCENTRATIONS
2. SURFACE WATER AND RESIDENTIAL WELL RESULTS SHOWN ARE TOTAL ARSENIC CONCENTRATIONS
3. NONDETECT CONCENTRATIONS ARE SHOWN AS ONE-HALF THE REPORTING LIMIT
4. MCL FOR ARSENIC IN DRINKING WATER (10 µg/L)

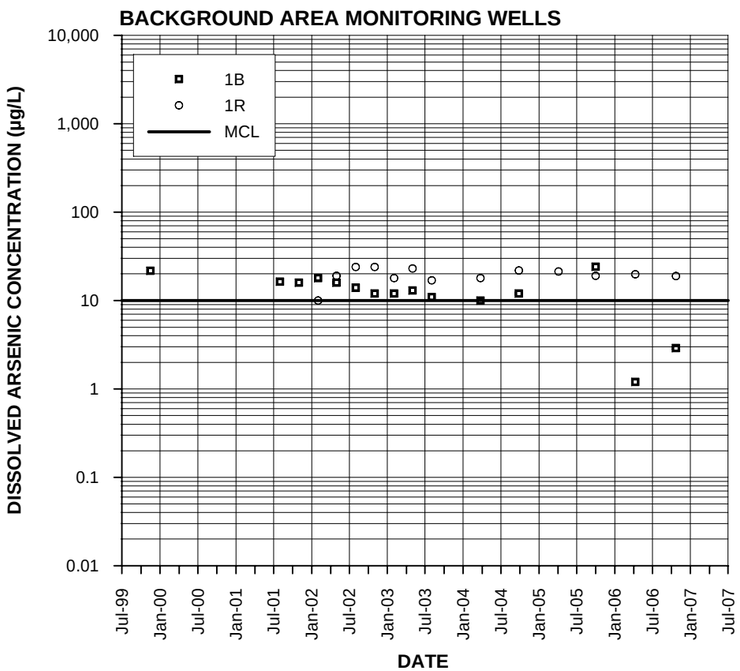
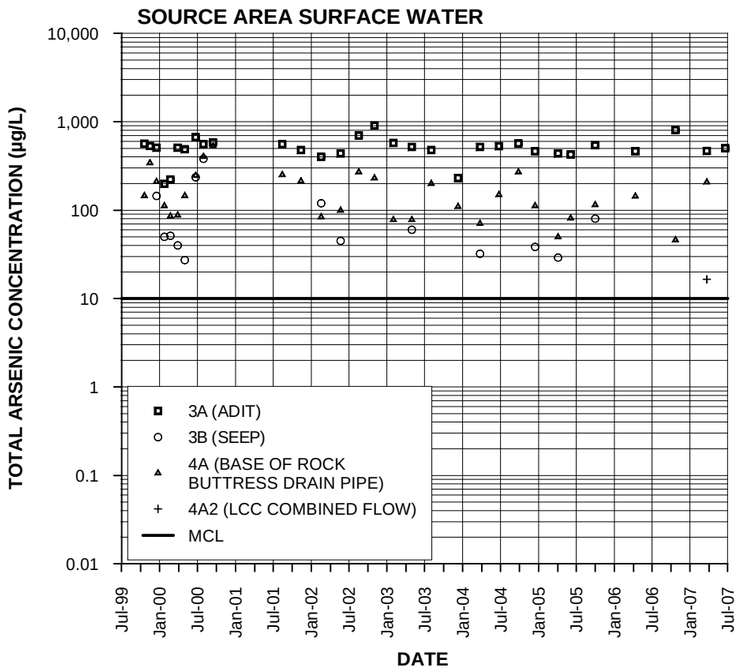
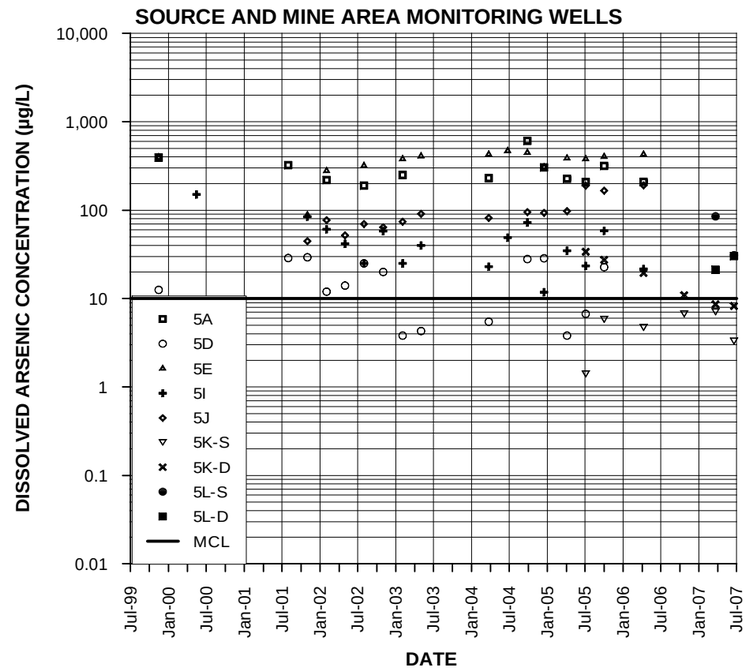


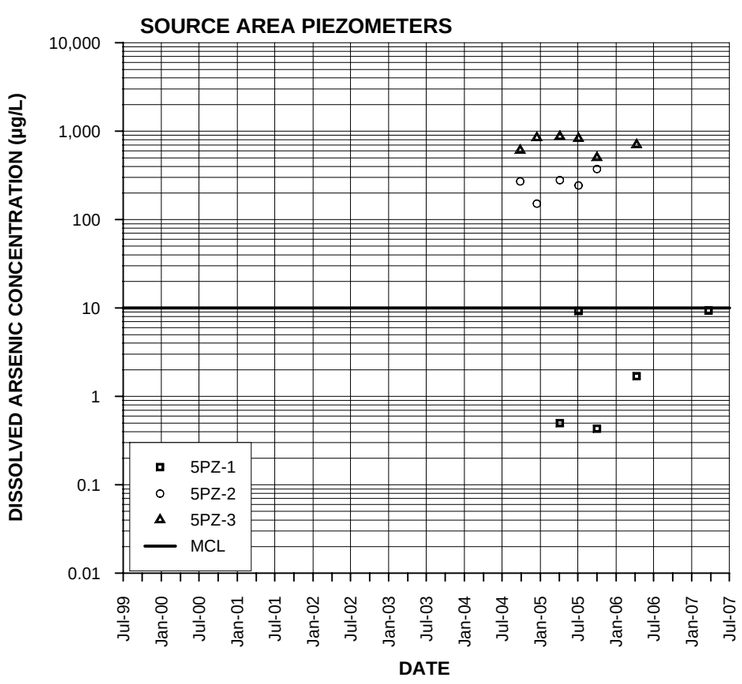
FIGURE 4-1
BACKGROUND AREA
ARSENIC CONCENTRATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE





NOTES:

1. MONITORING WELL AND PIEZOMETER RESULTS SHOWN ARE DISSOLVED ARSENIC CONCENTRATIONS
2. SURFACE WATER AND RESIDENTIAL WELL RESULTS SHOWN ARE TOTAL ARSENIC CONCENTRATIONS
3. NONDETECT CONCENTRATIONS ARE SHOWN AS ONE-HALF THE REPORTING LIMIT
4. MCL FOR ARSENIC IN DRINKING WATER (10 µg/L)
5. LL = LOST LAKE



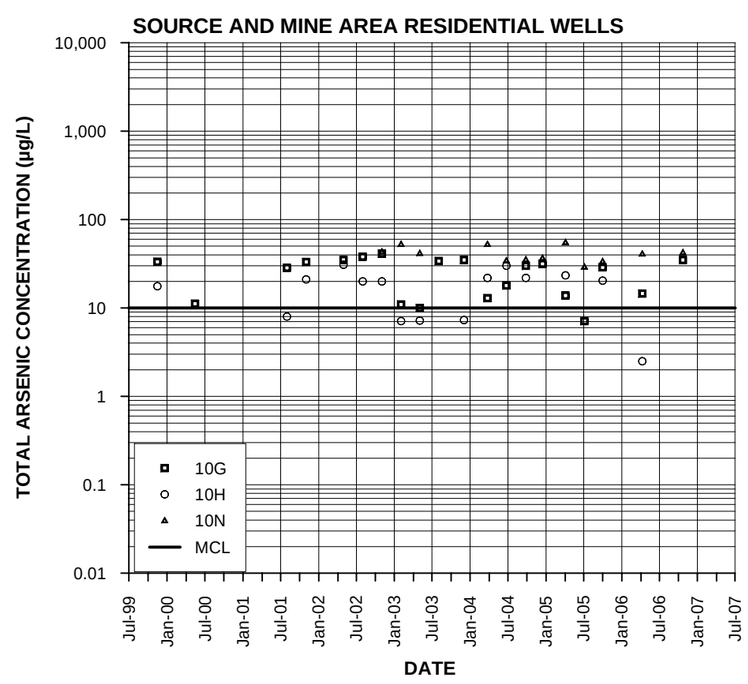
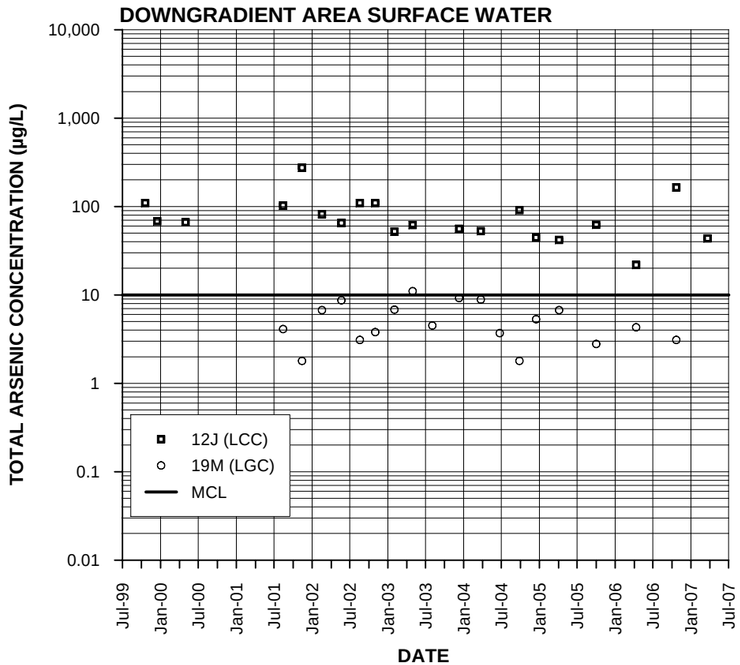
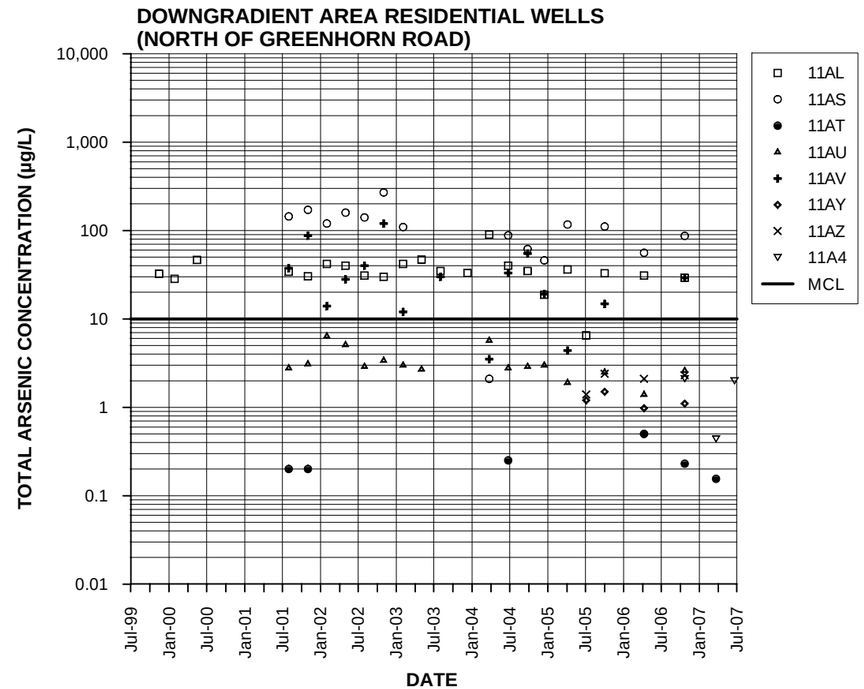


FIGURE 4-2
SOURCE AREA AND MINE AREA ARSENIC CONCENTRATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE





NOTES:

1. SURFACE WATER AND RESIDENTIAL WELL RESULTS SHOWN ARE TOTAL ARSENIC CONCENTRATIONS
2. NONDETECT CONCENTRATIONS ARE SHOWN AS ONE-HALF THE REPORTING LIMIT
3. MCL FOR ARSENIC IN DRINKING WATER (10 µg/L)

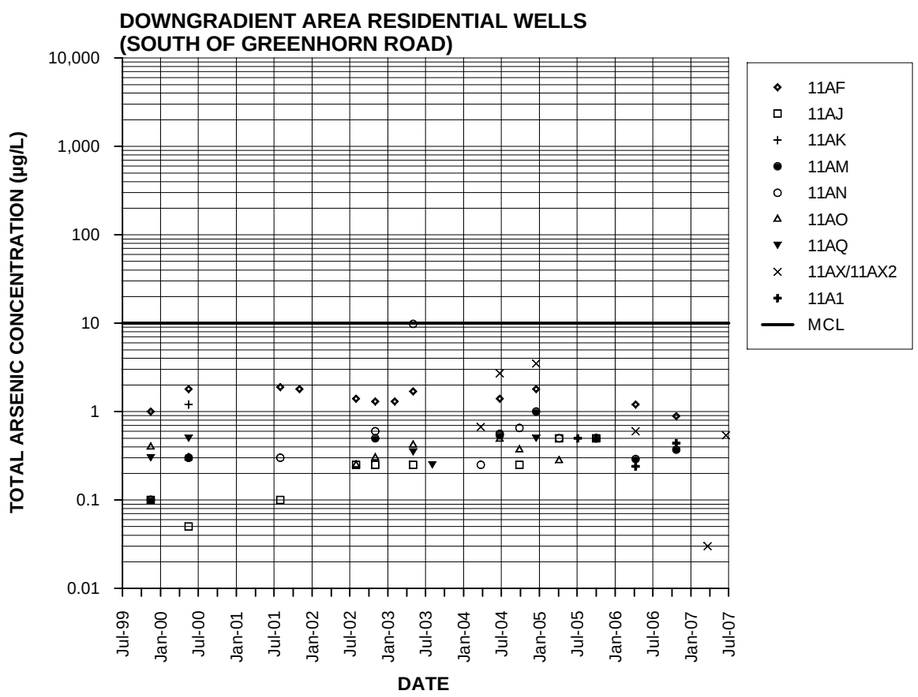


FIGURE 4-3
DOWNGRADIENT AREA
ARSENIC CONCENTRATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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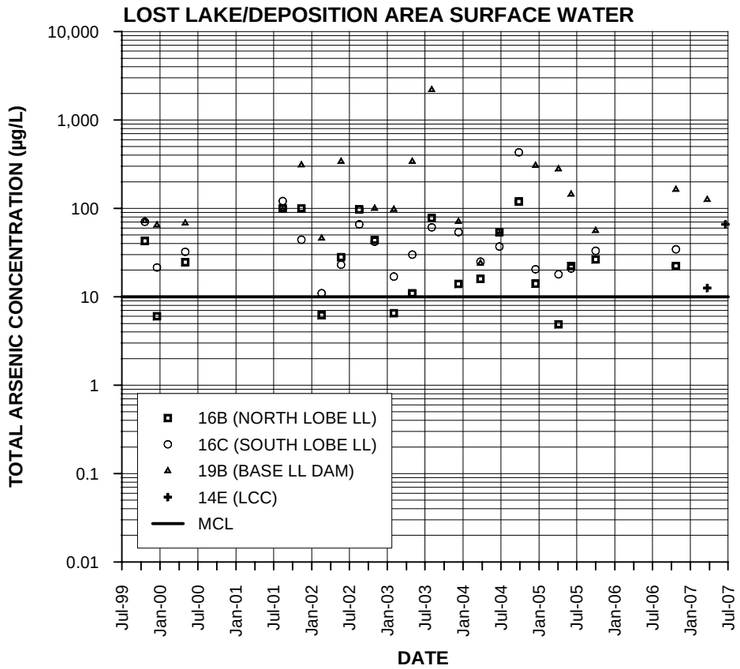

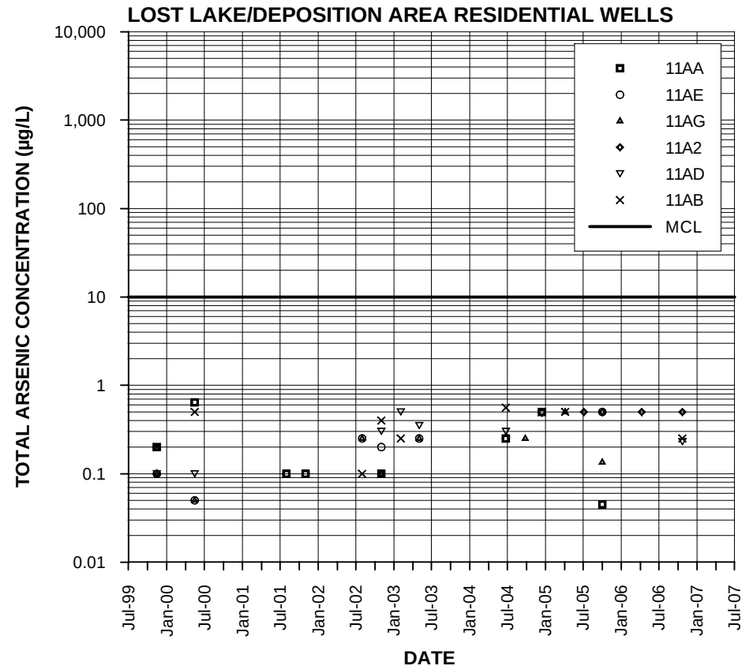

NOTES:

1. MONITORING WELL RESULTS SHOWN ARE DISSOLVED ARSENIC CONCENTRATIONS
2. SURFACE WATER AND RESIDENTIAL WELL RESULTS SHOWN ARE TOTAL ARSENIC CONCENTRATIONS
3. NONDETECT CONCENTRATIONS ARE SHOWN AS ONE-HALF THE REPORTING LIMIT
4. MCL FOR ARSENIC IN DRINKING WATER (10 µg/L)

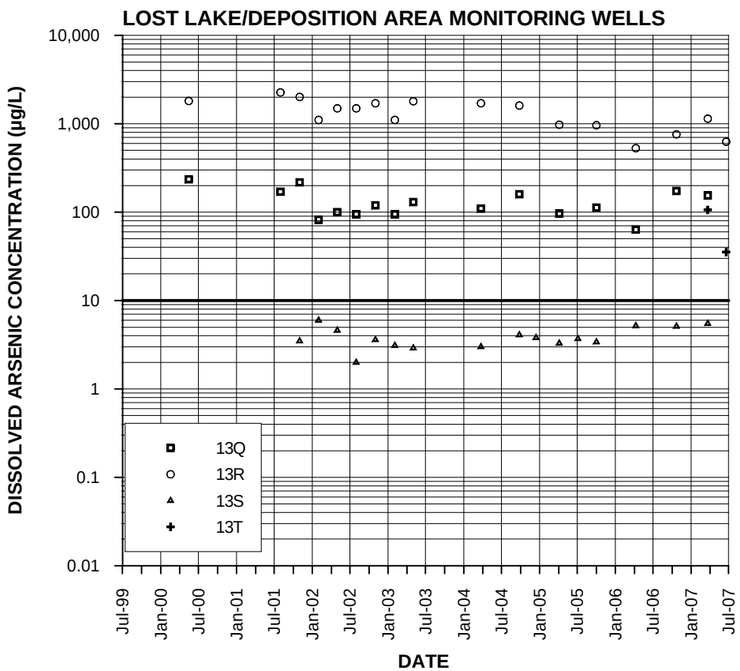

FIGURE 4-4
LOST LAKE/DEPOSITION AREA
ARSENIC CONCENTRATIONS
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

FIGURE 4-5
MOST RECENT ARSENIC CONCENTRATIONS IN BACKGROUND AREA, SOURCE AREA, AND MINE AREA

OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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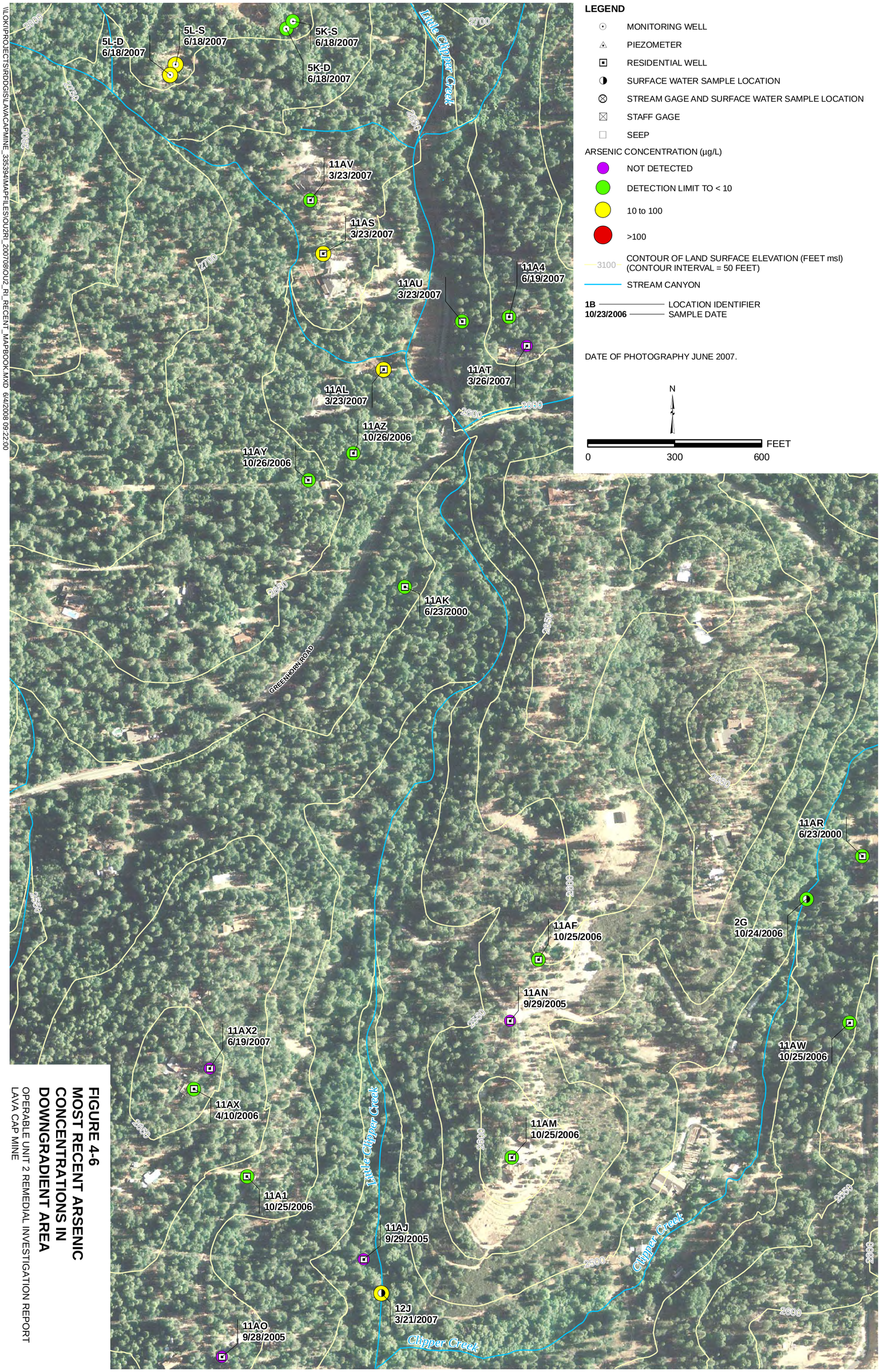

FIGURE 4-6
MOST RECENT ARSENIC CONCENTRATIONS IN DOWNGRADIENT AREA

OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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FIGURE 4-7
MOST RECENT ARSENIC CONCENTRATIONS IN LOST LAKE/DEPOSITION AREA

OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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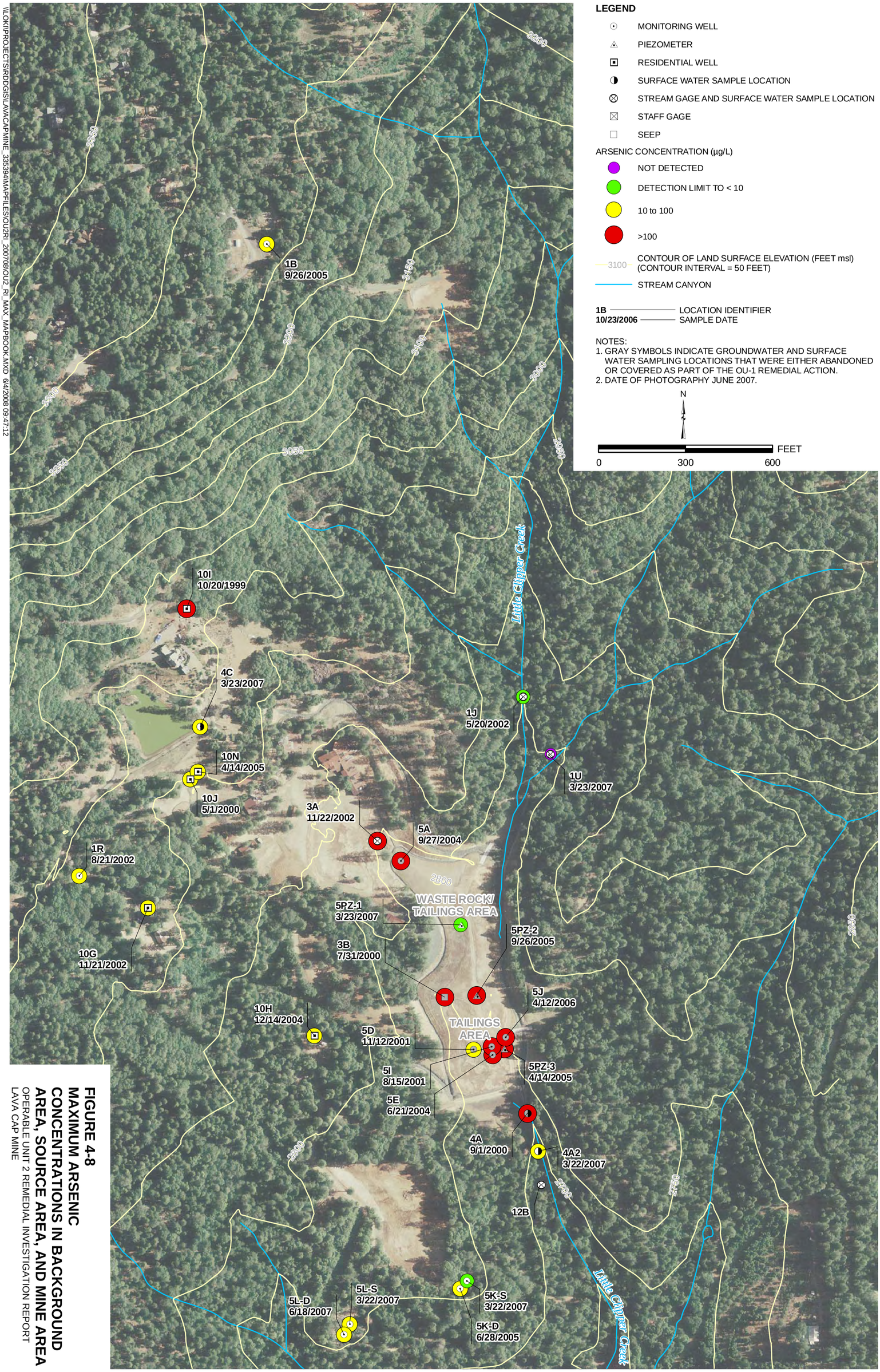

FIGURE 4-8
MAXIMUM ARSENIC CONCENTRATIONS IN BACKGROUND AREA, SOURCE AREA, AND MINE AREA
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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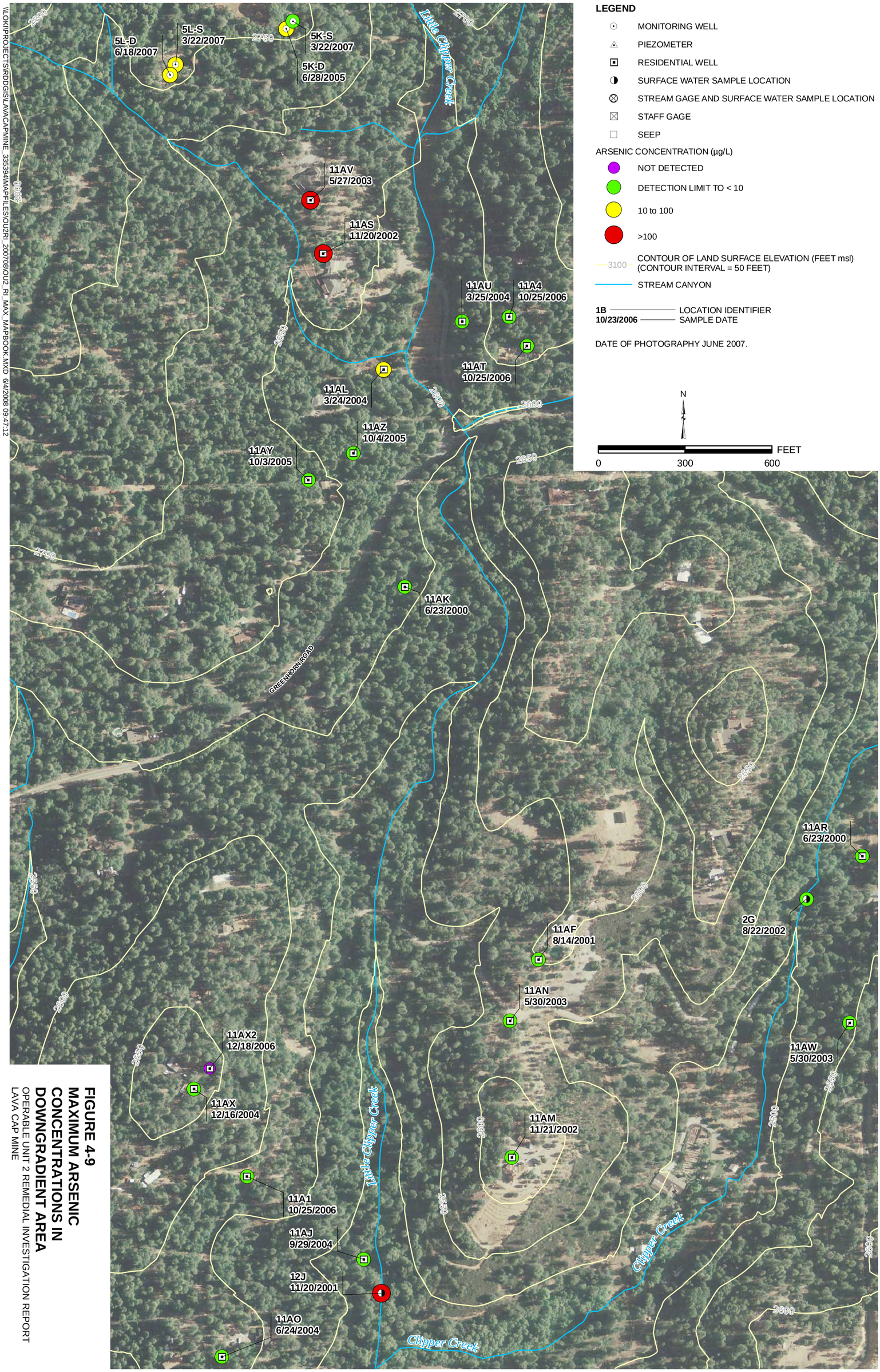

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FIGURE 4-9
MAXIMUM ARSENIC CONCENTRATIONS IN DOWNGRADIENT AREA
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

FIGURE 4-10
MAXIMUM ARSENIC CONCENTRATIONS IN LOST LAKE/DEPOSITION AREA
OPERABLE UNIT 2 REMEDIAL INVESTIGATION REPORT
LAVA CAP MINE

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SECTION 5.0

Contaminant Fate and Transport

Past mining activities and the ongoing presence of associated mine waste and tailings have impacted arsenic concentrations in groundwater at the Site and in downstream areas. The groundwater CSM and the potential for mine-related arsenic migration (leading to impacts to downgradient residential groundwater) are described in this section. This section also presents the results of analyses performed in an attempt to differentiate mine-related arsenic from naturally occurring arsenic in residential wells.

Routes of exposure have chemical and physical characteristics that could either limit or enhance arsenic migration. The potential routes of exposure of arsenic in groundwater to humans is through drinking water from residential wells and through groundwater discharge to surface waters that flow to downstream reservoirs used for municipal supply. The objectives of the contaminant fate and transport evaluation are as follows:

- Support development of CSM for groundwater flow and arsenic pathways.
- Assess the likelihood that mine-related arsenic contamination in groundwater is adversely impacting water quality at residential wells.
- Estimate arsenic contributions from groundwater discharge to LCC, between the Rock Buttress and the Deposition Area.

Both physical and geochemical techniques were used to evaluate the fate and transport of mine-related arsenic contamination in Site groundwater. This included the use of the Lava Cap Mine Groundwater Flow Model (see Appendix G) to help evaluate potential groundwater flow patterns from arsenic source areas; arsenic concentration data for groundwater and surface water; stream discharge measurements to help estimate arsenic loading; and the use of general chemistry, stable isotope tracers, and arsenic speciation analyses of Site groundwater and surface water to identify water types and possible geochemical interactions or reactions affecting arsenic.

5.1 Groundwater and Surface Water Flow

Because of the lack of information on three-dimensional groundwater flow directions and rates and the prevalence and geometry of subsurface fracture zones, groundwater flowpaths are difficult to delineate by using the available groundwater level data. In 2004 the Lava Cap Mine Groundwater Flow Model was created as a reconnaissance-level numerical tool capable of simulating large-scale features and processes of the hydrologic system. The Lava Cap Mine Groundwater Flow Model was developed by using geologic data from former reports, a county records search, field investigations, available groundwater elevation information data; aquifer testing data; water budget data; and professional judgment (see Appendix G). The Lava Cap Mine Groundwater Flow Model provided insight into groundwater flow patterns in the area. Simulated (model-derived) groundwater elevation contours for average, steady-state conditions are shown on Figure 3-9. Groundwater flow is

primarily to the south-southeast between the mine and Lost Lake. The following sections describe groundwater and surface water flow patterns near the mine.

5.1.1 Background Areas

Much of the Background Areas north of the Site occur in a groundwater recharge zone, where precipitation recharges the groundwater system. However, groundwater locally discharges to the land surface as springs upgradient from the mine along the contact between the Tvb and Pms units. This water eventually discharges with precipitation runoff to LCC, which flows southward, toward the mine. LCC is typically dry north of the mine between July and December, depending on the quantity and timing of winter precipitation. A maximum observed streamflow of up to approximately 45 ft^3/sec (20,200 gpm) has occurred during the wet season, December through May (see Figure 3-11).

5.1.2 Source Area and Mine Area

Figure 5-1 depicts a schematic cross section near Lava Cap Mine and illustrates the general pattern of groundwater and surface water flow. Water enters the Source Area and Mine Area as surface water runoff and groundwater inflow from upgradient areas north of the Site. The OU-1 RA includes diverting surface water from LCC, upstream from the Source Area, into a lined channel along the eastern edge of the waste rock/tailings pile and back to LCC immediately downstream from the Rock Buttress. The OU-1 RA also includes a diversion for the adit discharge (and adjacent surface runoff) into a lined channel on the northern and western edges of the waste rock/tailings pile; the diversion joins LCC downgradient from the Rock Buttress. Flow from the adit occurs year-round, and according to visual flow estimates, approximate adit discharges range from 0.1 to 0.5 ft^3/sec (35 to 225 gpm) (see Table 3-2). The adit discharge rate has been recorded as high as 4 ft^3/sec (1,800 gpm) (see Figure 3-11), but it was a mixture of adit flow and overland runoff from storm events. The adit discharge comprises water draining the subsurface mine workings of Lava Cap Mine and a portion of Banner Mine. Banner Mine is located north of the Site (mostly in an adjacent watershed), and the mine workings are connected to Lava Cap Mine at the 100 Drift Level (Haulage Level).

Prior to the OU-1 RA, groundwater beneath the Source Area and Mine Area had been impacted by adit discharge infiltration and surface water infiltration from the waste rock/tailings pile (indicated by elevated arsenic concentrations in shallow Wells 5A, 5D, and 5E, shallow Piezometers 5PZ-2 and 5PZ-3, and deep Wells 5I and 5J). Groundwater elevation measurements taken prior to the OU-1 RA indicated a downward vertical hydraulic gradient near the southern end of the waste rock/tailings pile (see groundwater hydrographs on Figure 3-10). The construction of the diversion channels and the partial removal and subsequent capping of the waste rock/tailings pile significantly reduced infiltration of surface water into mine-related wastes. However, as illustrated on Figure 5-1, groundwater likely continues to flow into the northern portion and out from the southern portion of the waste rock/tailings pile. Groundwater discharging from the waste rock/ tailings pile occurs as dam underflow and drain outflow from the Rock Buttress. The waste rock/tailings pile seeps (including Location 3B) were eliminated by the OU-1 RA.

Subsurface access to the mine during mining operations was possible through an adit connected to a horizontal haulage tunnel (see 100 Drift Level on Figure 5-2). The central

shaft is inclined 51 degrees toward the northeast. Fourteen drift levels were eventually tunneled from the central shaft at depths of nearly 0.5 mile below the land surface (see Figure 5-2). This set of drifts and shafts are collectively called "subsurface mine workings" in this report. These subsurface mine workings are considered sources of arsenic in the Mine Area. However, virtually no information is available to assess potential migration, if any, of arsenic away from the deeper mine workings. The hydraulic exchange of groundwater between the deep and shallow mine drifts is likely limited.

Available well construction data were reviewed to estimate the maximum residential well depth (i.e., lowest elevation) in the general area of the subsurface mine workings. The 600 Drift Level is estimated to occur approximately 200 feet below the deepest known residential well in the vicinity of the mine. Thus, groundwater above the 600 Drift Level occurs among the depth intervals of the known residential wells in the general area of the subsurface mine workings. No known residential wells are screened within the depth intervals below the 600 Drift Level.

5.1.3 Downgradient Area

Immediately south of the Rock Buttress, LCC collects the flow from the LCC diversion, the adit diversion, drain outflow from the Rock Buttress, and groundwater discharge. Visually estimated stream discharge rates downstream from the former Log Dam and the Rock Buttress (Location 4A/4A2 and 12B) have approximately ranged from 0.1 to 155 ft^3/sec (45 to 70,000 gpm) (see Table 3-2). Visual estimates of flow only from the Rock Buttress drain (Location 4A-pipe) after the OU-1 RA have approximately ranged from 0.002 to 0.1 ft^3/sec (1 to 24 gpm) (see Table 3-2). Water that discharges from the Rock Buttress drain to LCC is primarily groundwater seepage from the saturated tailings and basal gravel along the historical LCC drainage at the base of the tailings pile.

South of the Rock Buttress and north of the Lost Lake/Deposition Area, inflows to LCC and CC include the surface water from the Source Area (previously described), ephemeral surface water from tributaries to LCC and CC, and groundwater discharge (i.e., baseflow). Outflows of water from LCC along this same reach include surface water outflow to the Lost Lake/Deposition Area, stream leakage to the subsurface, and to a lesser degree, ET. As shown on Figure 3-9, groundwater discharge areas (areas where the groundwater table intersects the land surface) are not estimated to occur continuously along LCC. This pattern of groundwater discharge suggests that the groundwater table is located very near the elevation of LCC and CC between the Rock Buttress and Lost Lake/Deposition Area. In terms of groundwater/surface water interaction, LCC and CC both gain and lose surface water between the Rock Buttress and the Lost Lake/Deposition Area. The hydraulic relationship between groundwater and surface water in this area can only be estimated currently by using modeling results and professional judgment. This is because of the lack of groundwater elevation data, topographic data, and stream discharge data at regular intervals throughout these reaches of LCC and CC.

5.1.4 Lost Lake/Deposition Area

In the Lost Lake/Deposition Area, the initial water elevation data from Well Pair 13R/13T and Staff Gauge 14E indicate that CC seasonally alternates as a gaining and losing stream at this monitoring location; however, this observation is based on a limited dataset. The

vertical hydraulic gradient near Wells 13R and 13T and Wells 13Q and 13S is typically downward from the tailings to the bedrock (see Table 3-1). Continued monitoring is recommended at these locations to further assess local groundwater/surface water interactions. The available data and groundwater flow modeling results suggest that the groundwater table deepens beneath LCC and CC in the Lost Lake/Deposition Area, toward the southern lobe of Lost Lake (i.e., groundwater flow from LCC and CC in the Lost Lake/Deposition Area flows south-southeast, bypassing the northern lobe of Lost Lake). Available data and groundwater flow modeling results also suggest that groundwater flowing from northwest of Lost Lake likely (1) discharges into the northern lobe of the lake along the northwestern shoreline, near the two unnamed tributary inlets and (2) leaks water to the subsurface in a southeasterly direction, toward Lost Lake Dam. Lost Lake Dam underflow discharges from the base of the dam to CC (see groundwater discharge area near surface water sampling Location 19B on Figure 3-9).

5.1.5 Groundwater Flowpath Evaluation

Because the complexity of the hydrogeologic system, the source and subsurface migration pathways of groundwater and arsenic cannot be completely explained using the available data alone. Therefore, the Lava Cap Mine Groundwater Flow Model was used to gain insight into groundwater flowpaths that originate from historical mining areas (mine-related source areas) at the Site. This groundwater flowpath evaluation was accomplished by starting groundwater particles (i.e., flowlines) at selected areas and tracking them forward (i.e., downgradient) under steady-state flow conditions (with no restrictions on travel time; flowlines travel from the point of origin until they terminate at the groundwater table). This type of flowpath analysis provides insight into potential long-term groundwater flowpaths from mine-related source areas; however, it does not provide predictions of arsenic concentrations along the groundwater flowpaths. Groundwater flow along localized fracture zones, groundwater use, unmapped subsurface ore bodies containing arsenic, geochemical reactions, adsorption, dilution, and very long travel times can affect arsenic concentrations along the groundwater flowpaths. Less is known about the aquifer properties with depth at the site, and longer travel times allow greater opportunities for arsenic concentration changes along a flowpath (through adsorption or chemical reactions). The goal of this groundwater flowpath analysis was to identify the potential areal extent of groundwater that has flowed from areas known or suspected to be affected by past mining activities or ongoing contaminant releases. Within those areas, it is possible that elevated arsenic concentrations detected in groundwater at residential wells could be associated with historical mining operations or ongoing contaminant releases. The uncertainties in this analysis are further detailed in Appendix G.

For monitoring purposes, mine-related sources of arsenic contamination in groundwater were assumed to come from the following sources:

- Subsurface mine workings (shown in the profile view on Figure 5-2)
- Surficial tailings and waste rock (i.e., mine waste) in the Source Area
- Stream channels south of the Rock Buttress and north of the CC/LGC confluence that potentially contain tailings or adit discharge

- Lost Lake/Deposition Area

Sets of groundwater flowpath configurations were delineated with the aid of the Lava Cap Groundwater Flow Model. Flowpath sets were derived under identical steady-state flow conditions. Following is a description of each groundwater flowpath configuration (flowpath set):

- **Flowpath Set 1.** Groundwater particles were tracked downgradient from the simulated groundwater table beneath areas with mine wastes, including the following:
  - Waste rock/tailings pile in the Source Area
  - LCC channel
  - CC channel, downstream from the confluence of LCC and upstream of Lost Lake
  - Lost Lake/Deposition Area
  - CC, downstream from Lost Lake to the confluence with LGC

These areas were considered to have the greatest potential for adverse groundwater and surface water impacts resulting from mine-related waste.

- **Flowpath Set 2.** Groundwater particles were tracked from shallow mine workings, including the subsurface drifts of the 600 Drift Level and above (see Figure 5-2). Groundwater flowpaths from these drifts (600 Drift Level and above) were considered to occur among the depth intervals of the known residential wells in the mine workings area (the 600 Drift Level is approximately 200 feet deeper than the deepest known residential well). The shallow mine workings were considered to have the next greatest potential for adverse groundwater impacts compared with the areas underlying mine waste. However, the low hydraulic conductivity associated with the Palezoic to Upper Jurassic metamorphic rocks (Pms unit) could limit arsenic mobility and cause long travel times (hundreds of years) for groundwater to reach downgradient wells from this source. Groundwater flow through fractures, which was not explicitly modeled, could cause faster travel times along some flowpaths.

- **Flowpath Set 3.** Groundwater particles were tracked from deep mine workings, including the subsurface drifts from the 700 Drift Level to the 1400 Drift Level. No known residential wells are screened at these depths in the area of the mine workings. The deep mine workings are considered to have the lowest potential for adverse groundwater impacts. Furthermore, groundwater travel times from these locations might be very long because of the likely low permeability of the Pms unit at these depths and the distances to downgradient residential well locations. The least is known about the hydrogeology of the deep mine workings area.

The modeled groundwater flowpath areas for Flowpath Sets 1 and 2 are presented on Figures 5-3 and 5-4. The modeled groundwater flowpath area for Flowpath Set 3 is presented on Figure 5-5. The groundwater flowpath areas on Figures 5-3 and 5-5 were delineated by projecting the three-dimensional groundwater flowlines from the Lava Cap Mine Groundwater Flow Model (see Figure 5-4) to the land surface and drawing a geographic boundary around them. The groundwater flowlines are not shown on Figures 5-3 and 5-5 to improve visual clarity. The groundwater flowpath areas presented on these figures encompass model-derived groundwater flowpaths from known and potential source

areas; however, residential wells not impacted by arsenic exist in some of these areas. Localized groundwater flow features (e.g., fractures) could locally redirect contaminated groundwater flow, or geochemical processes could decrease arsenic concentrations in some of these areas before the groundwater reaches residential wells. The groundwater flow rates in the Pms unit are generally slow, and depending on the starting depth of the groundwater particle, impacts to downstream residential wells might not be likely. This approach for delineating the groundwater flowpath areas from known or potential arsenic source areas using the Lava Cap Mine Groundwater Flow Model is conservative and could overestimate the potentially impacted area. This approach attempts to balance a reasonable level-of-effort scientific analysis with uncertainty in results.

5.1.5.1 Flowpath Set 1 Results

Groundwater particles for Flowpath Set 1 were tracked downgradient from the simulated groundwater table beneath areas with surficial mine wastes, including the waste rock/ tailings pile in the Source Area, stream channels, and the Lost Lake/Deposition Area. These areas were considered to have the greatest potential for adverse groundwater and surface water impacts resulting from mine-related waste.

Results from the Flowpath Set 1 analysis suggest that shallow groundwater flow from beneath areas with mine waste is confined to the Source Area; Mine Area; LCC, downstream from the mine; CC, downstream from the confluence with LCC; and the Lost Lake/Deposition Area (see Figure 5-3). This is because shallow groundwater flow from recharge areas near the northern boundary of the LCC subwatershed tend to converge on LCC in a southerly direction (in some areas actually discharging to LCC), toward Lost Lake (see Figure 3-9 for groundwater elevation contours). The convergence of shallow groundwater flow limits the flowpath area from these source areas. Flowpaths from surficial mine waste areas are shallow and discharge to springs or directly to the creeks after short distances (flowpaths from these areas are not presented in cross-sectional view because they are too shallow and limited in extent to effectively view in cross section). Convergence of shallow groundwater flow toward drainage channels is a common hydrologic feature in mountainous settings. However, simulated groundwater from the LCC/CC confluence area flows south-southeast and eventually discharges into LGC south of Lost Lake, bypassing the lake on its eastern side. These modeling results are consistent with the measured downward hydraulic gradients near Wells 13Q, 13R, 13S, and 13T, as described in Section 5.1.4.

Residential wells in the Mine Area and Well 11AL, which have elevated arsenic concentrations, are located within or on the fringes of the potential area of Flowpath Set 1. Residential Wells 11AU, 11AJ, 11AI, and 11AE are also located within this groundwater flowpath area, but samples from these wells have arsenic levels less than 10 μg/L.

5.1.5.2 Flowpath Set 2 Results

Groundwater particles were tracked from shallow mine workings (100 through 600 Drift Levels) for Flowpath Set 2. The shallow mine workings coincide with the depths of known residential wells and are considered to have the next greatest potential for adverse groundwater impacts compared with the areas underlying mine waste. However, flowpaths from shallow mine workings also have greater uncertainty because of the limited hydrogeologic data at depth and the potentially longer flowpaths and travel times.

Results from the Flowpath Set 2 analysis suggest that groundwater from shallow mine workings flows through portions of the subsurface beneath the Source Area and Mine Area, LCC, and a larger area west of these locations (see Figures 5-3 and 5-4). Groundwater from the shallow mine workings is predicted to discharge to LCC, CC, and LGC, exiting the CC watershed primarily as stream outflow in LGC.

Figure 5-4 presents simulated groundwater flowpaths in plan view and in cross-sectional view for the 100 through 600 Drift Levels. Flowpaths originating from each of these drift levels are presented on separate pages of Figure 5-4.

Flowpaths from the 100 Drift Level are the most laterally extensive. These flowpaths are also simulated to flow at the greatest total depths and have longer travel distances than the other five drift levels. This is because of the long length of the 100 Drift Level, which extends north, beyond the CC watershed into the Banner Mine area (a significant groundwater recharge area for the CC watershed, with downward hydraulic gradients). The 100 Drift Level flowpaths are also the only flowpaths of Flowpath Set 2 that extend south of Greenhorn Road. The western portion of the Flowpath Set 2 area, which is significantly larger than the Flowpath Set 1 area, results from simulated groundwater particles that flow from the 100 Drift Level near the northern CC watershed boundary (see Figure 5-4, page 1 of 6). As shown on Figures 5-3 and 5-4, simulated groundwater flowpaths from the shallow mine workings also flow east of Lost Lake and eventually discharge into LGC. The flowpaths from the 400 Drift Level are the next most extensive in depth and length (see page 4 of Figure 5-4). The 400 Drift Level is the second longest of the shallow mine workings drift levels; it extends north into a significant groundwater recharge area that has downward hydraulic gradients.

The potential area of Flowpath Set 2 includes the residential wells with elevated arsenic concentrations (Mine Area wells and Wells 11AL, 11AS, and 11AV), but it also includes many wells with arsenic concentrations less than 10 µg/L.

5.1.5.3 Flowpath Set 3 Results

Groundwater particles were tracked from deep mine workings (700 through 1400 Drift Levels) for Flowpath Set 3. The deep mine workings are considered to have the lowest potential for adverse groundwater impacts. In addition, groundwater flowpaths from these depths are the most uncertain because of the limited hydrogeologic data and longer flowpaths and travel times.

Results from the Flowpath Set 3 analysis suggest that groundwater from deep mine workings (700 Drift Level and below) flows through portions of the subsurface beneath the Source Area, Mine Area, LCC, and CC (see Figure 5-5). The Flowpath Set 3 area extends farther east than the Flowpath Set 2 area because the mine workings of the 700 Drift Level and below are located farther east with increasing depth (i.e., the central shaft that bisects the subsurface drifts is inclined to the northeast [Figure 5-2]). Groundwater from the deep mine workings is predicted to eventually discharge to LGC and exit the CC watershed primarily as stream outflow (also flowing east of Lost Lake).

The potential area of Flowpath Set 3 includes the residential wells with elevated arsenic concentrations (Mine Area wells and Wells 11AL, 11AS, and 11AV), but it also includes even more wells than Flowpath Set 2 that have arsenic concentrations less than 10 µg/L. In the

Mine Area and portions of the Downgradient Area, some of the groundwater flowpaths in Flowpath Set 3 are below the depths of some residential wells.

5.1.5.4 Limitations of Groundwater Flowpath Evaluation

The combination of these three groundwater flowpath areas represents a conservative estimate of the geographic area where groundwater could be flowing from known or potential arsenic sources. Uncertainty regarding these geographic areas increases with depth (i.e., the extent of the Flowpath Set 2 area has greater uncertainty than the Flowpath Set 1 area and the Flowpath Set 3 area has greater uncertainty than the Flowpath Set 2 area) because the strong influence of topography on groundwater flow patterns at shallow depths lessens with increasing depth. Furthermore, data that could provide insight into the deep bedrock aquifer system are not available. Additionally, geochemical processes that impact arsenic concentrations along flowpaths are not known; therefore, uncertainty regarding the arsenic concentrations along flowpaths from the source areas increases with increasing travel distance from source areas.

This analysis is based on a reconnaissance-level model that does not capture the complexity of fracture flow, groundwater pumping distribution, travel times, or arsenic geochemistry. However, despite these model limitations, output from the current version of the Lava Cap Mine Groundwater Flow Model provides useful insights into possible long-term groundwater flow patterns and arsenic migration at a watershed and subwatershed scale.

5.2 Arsenic Geochemistry

Geochemical data, including general chemistry, stable isotope tracers, and arsenic speciation analyses of Site groundwater and surface water were used to assess the likelihood that arsenic impacts to downgradient residential wells resulted from mine-related contamination or from naturally occurring sources.

Arsenic exists in natural waters in two redox states: trivalent arsenic (As[III]) and pentavalent arsenic (As[V]), (the arsenic atom has a +3 and +5 state, respectively). They are present in solution as oxyions ($H_3AsO_3^0$ for As(III) and either $H_2AsO_4^-$ or $HAsO_4^{2-}$ for As(V), depending on the pH), in the pH-Eh range observed at the Site. Of the two species, As(III) is the more toxic form and is more mobile because it is in an uncharged aqueous state. With a negative charge, As(V) ions are more reactive and can adsorb to mineral surfaces, making this state less mobile.

Numerous geochemical factors affect the mobility of arsenic in groundwater. Although the solubility of arsenic minerals is not well understood, under oxidizing conditions, As(V) can form insoluble precipitates with calcium, manganese, or barium (Hem, 1989). Arsenic is also co-precipitated with iron oxides/hydroxides in environments similar to those observed at the Site (Fuller et al., 1993). Another important geochemical control in Site soil and groundwater is the adsorption of arsenic to the surface of iron oxide minerals. Adsorption or precipitation reactions can maintain dissolved concentrations of arsenic at very low levels under certain conditions, including the following:

- **pH.** As(V) is less soluble at neutral to alkaline pH, when the formation of metal arsenates or metal oxide co-precipitates is favored. At low pH (acidic), As(V) adsorbs to

mineral surfaces more strongly than at higher pH. Thus, how As(V) is limited in solution depends on the pH range. In contrast, As(III) is more likely to precipitate at low pH, forming an arsenic oxide or arsenic sulfide. Adsorption of As(III) is measurable but lower than As(V) because of its neutral charge, and this adsorption is not as influenced by pH.

- **ORP.** ORP is a general measure of the oxidizing or reducing nature of an aqueous environment. Water containing abundant DO is considered highly oxidizing, whereas water lacking DO and containing abundant dissolved iron or sulfide, for example, is considered highly reducing. Arsenic can exist at two different redox states under normal groundwater conditions, depending on ORP. Together with pH, ORP determines the favored state and, therefore, the mobility of arsenic.
- **Organic matter content.** Natural organic matter often acts as a complexing agent, keeping trace elements in solution that would adsorb or precipitate in the absence of natural organic matter. Therefore, natural organic matter can increase the mobility of arsenic. The potential for increased arsenic mobility is dependent on the properties of the natural organic matter and the mineral surface.
- **Bulk composition of the water.** Common inorganic constituents in water can, like natural organic matter, form complexes or precipitates with some trace elements. The relative amounts of iron, manganese, sulfate, calcium, and other ions help evaluate arsenic fate in the environment.

5.2.1 Site Conditions for Arsenic Mobility

Groundwater in the Pms unit, which is unaffected by mining activity, is generally of the calcium-bicarbonate type, meaning that calcium and bicarbonate are the dominant positively and negatively charged ions, respectively. TDS is typically in the 100 to 300 milligrams per liter (mg/L) range. Groundwater pH is between 5 and 8 throughout the monitored area. Sulfate concentrations are generally very low (less than 20 mg/L), but there are a few exceptions among the residential wells (Wells 11AB, 11AE, 11AT, and 11AU), where sulfate is more significant (though still less significant than bicarbonate). General water chemistry is shown on the stiff diagrams on Figures 5-6 through 5-8. These diagrams are concentration plots of cations on the left and anions on the right, with the more dominant ions forming the largest “bulges” in the plot. The resulting geometric shapes provide a visual indication of the general water chemistry. Diagrams with color fill represent water with significantly higher TDS that required a different horizontal scale.

The redox conditions in local groundwater were assessed by using a combination of redox-sensitive general chemistry parameters, including DO, ORP, dissolved manganese, dissolved iron, and sulfide. Representative redox parameters are provided for wells on Figures 5-9 through 5-11 (posted results are from the most recent results from each sampling location). ORP readings recorded in the field are often variable because field measurements (DO and ORP) can be easily impacted by oxygen exchange with air during the sample collection and measurement process. ORP readings in groundwater can vary spatially and temporally, but general tendencies can be observed from a robust data set such as this one. In areas affected by mine-related contamination (e.g., the adit area and waste rock/tailings areas), redox conditions are reducing, DO values are low, and iron and manganese

concentrations are elevated. Outside of the mine site, groundwater is generally oxidizing, containing only trace amounts of dissolved manganese and iron and no detectable sulfide. ORP values are mostly positive and DO values are typically between 2 and 8 mg/L, which indicates oxidizing conditions.

Given the general chemistry of the groundwater in the area, arsenic would be favored thermodynamically to exist predominantly in the As(V) state, as the monovalent $H_2AsO_4^-$ ion for pH below 7 or the divalent $HAsO_4^{2-}$ ion for pH greater than 7. A portion of both of these ions would be expected to adsorb onto iron oxide minerals that are prevalent in the subsurface. This would limit arsenic mobility in groundwater but not necessarily eliminate it.

In the more reducing conditions that are prevalent at the mine and in the mine waste areas, As(III) would be expected to be at a higher fraction of total arsenic, although the As(V) fraction could still be as high or higher. Arsenic speciation in these key areas was directly measured in selected wells. As previously discussed, As(III) is more mobile in groundwater than As(V), and greater concentrations of As(III) in groundwater would be expected in these areas as a consequence.

5.2.2 Chemical Tracing of Mine Site Groundwater

This section utilizes several geochemical data evaluation tools in an attempt to trace the signature of mine-affected groundwater into areas downgradient from the Source Area and Mine Area.

5.2.2.1 General Chemistry

General chemistry parameters were evaluated to help identify sources of elevated arsenic in residential wells. However, there is no obvious correlation between arsenic in groundwater from tailings pile wells and residential wells according to general chemistry data.

Wells in areas where groundwater chemistry is known to be affected by Lava Cap Mine are characterized by relatively high sulfate concentrations. Rock processed at the Source Area and Mine Area was rich in sulfide minerals such as pyrite. Water leaching through discarded tailings oxidized these minerals and became more enriched in sulfate. Arsenic concentrations in adit discharge was high (up to 910 µg/L) (see Table 4-1), and flow from the adit occurs year-round. Sulfate is significant (i.e., greater than approximately 25 percent of total anion equivalents) in the adit discharge and former seep (Locations 3A and 3B) (see Figure 5-6). Monitoring wells screened in the shallow formation immediately beneath the waste rock/tailings pile (Wells 5A, 5D, and 5E) had significant to dominant sulfate (see Figure 5-6). The notable sulfate component was also present in surface waters downstream from the Rock Buttress (Locations 4A2, 12F, 12H, and 12J) (see Figures 5-6 and 5-7). Wells screened in the Pms unit below the waste rock/tailings pile (Wells 5I and 5J) show sulfate percentages decreasing with depth (see Figure 5-6). Well 5J is unique in its sodium-bicarbonate chemistry and strongly reducing conditions, evidenced by both high sulfide and strongly negative ORP (see Figures 5-6 and 5-9). These observations indicate that tailings might impart elevated sulfate to groundwater via oxidation of sulfide minerals but only if redox conditions allow.

Groundwater from Wells 13Q and 13R, which are screened in sediment dominated by tailings in the Deposition Area, do not have elevated sulfate concentrations (see Figure 5-8) even though arsenic concentrations were as high or higher than in groundwater in and beneath the waste rock/tailings pile in the Source Area. Sulfide has been detected in historical samples from Wells 13Q and 13R, and sulfide minerals are expected to exist in the tailings sediments near these wells. Reducing conditions were clearly evident in these wells, with highly negative ORP and significant concentrations of iron and manganese.

Residential wells with more significant arsenic concentrations (Wells 10G, 10H, 10J in the Mine Area and Wells 11AL, 11AS, and 11AV in the Downgradient Area) all had similar calcium-bicarbonate chemistry with relatively low sulfate (see Figures 5-6 and 5-7). This same chemistry was observed in other Downgradient Area and some Lost Lake/Deposition Area residential well that contained little or no arsenic (Wells 11AA, 11AF, 11AG, and 11AJ) (see Figures 5-7 and 5-8). The sulfate character of the tailings piles does not appear to linger far past the Rock Buttress in groundwater, as evidenced by lower sulfate concentrations in residential wells immediately downgradient (in the Downgradient Area) (see Figure 5-7). The Background Area well in the Pms unit (Well 1R) also showed a calcium-bicarbonate chemistry, lower TDS, and a higher concentration of magnesium and sodium (see Figure 5-6).

General chemistry and arsenic concentration data from Source Area and Mine Area wells suggest that the general chemistry signature of mine-affected groundwater (elevated sulfate or sulfide) is not clearly traceable to downgradient locations, except the locations directly associated with transported tailings. Residential wells with elevated sulfate did not contain elevated arsenic, suggesting (1) that arsenic has been attenuated during groundwater flow to these areas, or (2) the sulfate concentrations represent a natural variation rather than the influence of mine-affected groundwater. Residential wells with elevated arsenic concentrations are geographically closer to the Source Area and Mine Area; however water samples from these wells do not have the elevated sulfur concentrations associated with Source Area and Mine Area wells. This suggests that arsenic concentrations in groundwater could be more closely associated with arsenic-bearing geologic materials than with past mining operations.

5.2.2.2 Trace Metals

Groundwater and surface water samples were analyzed on several occasions between 1999 and 2004 for trace metals (California Title 22), and natural groundwater tracers (boron, bromide, and fluoride). Most of these constituents were near or below the analytical detection limits in most wells, and only arsenic is considered a contaminant of concern in groundwater, according to the 2001 human health risk assessment (EPA, 2001). An attempt was made to correlate known mine-affected surface water (e.g., Locations 3A and 4A) with groundwater (Source Area and Lost Lake/Deposition Area monitoring wells) and residential wells (Wells 11AL, 11AS, and 11AV) that have elevated arsenic concentrations. Only filtered samples were considered in this effort.

The three residential wells with elevated arsenic concentrations (Wells 11AL, 11AS, and 11AV) also contained antimony concentrations that ranged between 0.29 and 1.7 µg/L. Although these concentrations are below the MCL of 6 µg/L, they are the highest antimony concentrations in residential wells. Source Area and Mine Area wells showed variable

antimony concentrations, ranging from nondetect to 3 µg/L. Detection limits also varied, so a quantitative assessment is not feasible, but generally, the highest antimony concentrations in the Source Area and Mine Area were detected at the base of the former Log Dam (Location 4A) and in Well 5J, the deepest well screened beneath the tailings pile. The data suggest a possible correlation between the Source Area and Mine Area groundwater and groundwater in residential Wells 11AL, 11AS, and 11AV. However, antimony is geochemically similar to arsenic, and the correlation could result from geochemical associations between these elements rather than mine contamination.

Barium concentrations were higher in Wells 11AL, 11AS, and 11AV (ranging from 63 to 166 µg/L) than in most of the other Downgradient Area and Lost Lake/Deposition Area residential wells. Barium concentrations were significantly higher in the Mine Area residential wells (300 to 540 µg/L), and some of the Source Area monitoring wells (Wells 5I and 5J) had barium concentrations above 100 µg/L. Barium concentrations were between 160 and 330 µg/L at background Well 1R, which is located adjacent to the Source Area. It is not clear from the available data if barium distribution exhibits natural variation or if it is linked to mine-affected groundwater.

Zinc was the only other trace metal showing notable concentrations in residential Wells 11AL, 11AS, and 11AV. Well 11AV, one of the three wells with elevated arsenic, and Source Area Wells 5A and 5D had zinc concentrations above 100 µg/L. However, the other two residential wells with elevated arsenic (Wells 11AL and 11AS) had very low zinc concentrations (less than 10 µg/L). Source Area and Mine Area wells were highly variable in their zinc concentrations, suggesting that zinc-containing colloids had passed through the filters. Although all three samples from Well 11AV had zinc concentrations of approximately 100 µg/L, there does not appear to be a consistently measurable source of zinc in mine-affected groundwater with which to correlate these results.

In summary, concentrations of most trace metals and natural tracers in groundwater were either near or below detection limits or showed no significant difference between the Source Area, the Mine Area, and residential Wells 11AL, 11AS, and 11AV. Concentrations of antimony, barium, and zinc were elevated in one or more of these three residential wells; however, only antimony, and possibly barium, appear to be related to Source Area and Mine Area groundwater. It is not clear whether this correlation is caused by similar natural geologic materials in each area or if mine-affected groundwater transported these constituents to the residential wells.

5.2.2.3 Arsenic Speciation

Arsenic speciation in groundwater was been characterized by computing the ratio of As(III) to As(V). Arsenic speciation analysis was performed on groundwater samples from selected wells to identify waters of different origin and the evolution of arsenic along groundwater flowpaths. Eight samples were collected in August 2001, followed by additional sampling events, with more sampling locations, in April 2005 and April and October 2006.

Speciation samples collected in April 2005 were analyzed by using two methods. One method included collection of unpreserved water samples in the field and performing species separation in the laboratory, similar to the method used in 2001. The other method included separating the species in the field and analyzing the two water samples for total

arsenic in the laboratory. The field-speciation method provided the best results because some of the As(III) was likely oxidized to As(V) in the unpreserved samples of the first method (CH2M HILL, 2005d). Subsequent samples were collected in April 2006 and October 2006 using the field-speciation method.

The arsenic speciation results from 2001, 2005, and 2006 are displayed in Table 5-1. In the 2001 and 2005 events, the samples that contained elevated arsenic generally were dominated by As(III), especially the wells screened immediately beneath Wells 5A and 5E or within waste rock or tailings (Wells 5A, 13Q and 13R). Two residential wells (Wells 11AL and 11AS) also had elevated As(III) to As(V) ratios. Data from these sampling events suggest a possible signature of an elevated As(III) to As(V) ratio for mine-affected groundwater that could potentially be traced downgradient. To investigate further, more wells were identified and sampled in 2006.

In 2006, both April (high runoff) and October (low runoff) arsenic speciation data were collected in groundwater and surface water in the Background Areas, Source Area, Mine Area, Downgradient Area, and Lost Lake/Deposition Area. The October 2006 data indicated that nearly all As(III) to As(V) ratios increased compared with the April event. With the exception of one well (Well 10N), all October 2006 data showed an As(III) dominance. These observations were not expected given the previous results. Samples from Wells 10G and 11AU, and surface water Locations 3A and 12J are from distinctly different areas and environments, yet samples from each showed a transition in ratio from less than 1.0 to significantly greater than 1.0 between April and October 2006. The As(III) to As(V) ratio shift could represent seasonal changes in redox conditions present at these particular sampling locations (not necessarily a particular origin of arsenic in the water) or a sampling quality control problem (e.g., the spring 2006 samples might have been oxidized before As[III] was measured). To evaluate if the As(III) to As(V) ratio shift represents a true geochemical process, arsenic speciation confirmation sampling should be performed in fall and spring at selected locations.

In summary, the oxidation state of arsenic in the samples is highly variable and, therefore, does not appear to be a reliable indicator of the source (natural or mine-related) of arsenic in the water samples.

5.2.2.4 Stable Isotopes

Concentrations of stable isotopes of hydrogen (^{2}H [deuterium]) and oxygen (^{18}O) were analyzed for selected groundwater and surface water samples in April and September 2005; results are listed in Table 5-2.

TABLE 5-1
Summary of Arsenic Speciation Results
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

		August 2001			April 2005			April 2006			October 2006		
Location	**Type**	**As(III)**	**As(V)**	**As(III) to As(V)**	**As(III)**	**As(V)**	**As(III) to As(V)**	**As(III)**	**As(V)**	**As(III) to As(V)**	**As(III)**	**As(V)**	**As(III) to As(V)**
Background Areas													
1B	MW	[14.9]	[2.26]	[7]							0.85J (1.3)	0.15 (0[a])	5.7 (N/A)
1R	MW				18.6	6.5	3	20	2	10	17	1	17
1J	SW				3 U	3 U	N/A						
2G	SW				3.9	3 U	N/A						
Source Area and Mine Area													
5A	MW				164 [83.3]	58.6 [131]	3 [0.6]	200	10	20			
5D	MW	[31]	[7.41]	[4]	3.2 [0.35]	3 U [3.1]	N/A [0.1]						
5E	MW	[409]	[103]	[4]	289 [82.1]	111 [228]	3 [0.4]	340	90	3.8			
5I	MW	[157]	[440]	[0.4]	14.6 [13.7]	18.5 [255]	0.8 [0.05]						
5J	MW				41.5 (42.4)	43.8 (40.7)	1 (1)	28 (27)	112 (93)	0.25 (0.29)			
10G	RW				3.1 [0.15]	12.4 [21.7]	0.3 [0.01]	0.92J	14	0.07	0.62J (0.64J)	0.26J (0[a])	2.4 (N/A)
10H	RW				6 J (7.4 J)	11.4 (13.3)	0.5 (0.6)	1.1	1.5	0.73	3.4	0[a]	N/A
10J	RW	[10.5]	[35.9]	[0.3]									
10N	RW				43.4	15.6	3	33	6	5.5	9.9	17	0.58
3A	SW	[142]	[467]	[0.3]	158 (139) [4.7 (6.5)]	219 (243) [559 (368)]	0.7 (0.6) [0.01 (0.02)]	180 (180)	180 (210)	1.0 (0.86)	110	20	5.5

TABLE 5-1
Summary of Arsenic Speciation Results
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

		August 2001			April 2005			April 2006			October 2006		
Location	**Type**	**As(III)**	**As(V)**	**As(III) to As(V)**	**As(III)**	**As(V)**	**As(III) to As(V)**	**As(III)**	**As(V)**	**As(III) to As(V)**	**As(III)**	**As(V)**	**As(III) to As(V)**
Downgradient Area													
11AJ	RW				3 U	3 U	N/A						
11AL	RW	[33.7]	[2.3]	[15]	14.6	16.7	0.9	24	4	6	23	0[a]	N/A
11AO	RW				3.7	3 U	N/A						
11AS	RW				61.6 [78.1]	24.8 [46.5]	2 [2]	0.51J	47	0.01	15	0[a]	N/A
11AU	RW				3 U (3 U)	3 U (3.7)	N/A (N/A)	0.50U	1.5	N/A	0.65J	0[a]	N/A
11AV	RW				4.4	3 U	N/A	0.50U	0.50U	N/A	12	1	12
12J	SW				8.4	31.8	0.3	6.1	14	0.44	48	2	24
Lost Lake/Deposition Area													
13Q	MW				74.9	17.8	4	47	6	7.8	140	0[a]	N/A
13R	MW	[2551]	[152]	[17]	720 [358]	67 [702]	11 [0.5]	330	50	6.6	490	80	6.1
13S	MW				4 J (5.9 J)	3 U (3 U)	N/A (N/A)	4	1.1	3.6	4.3	0[a]	N/A

[a]Indicates dissolved arsenic and As(III) are within acceptable relative percent difference range and 100 percent of the sample is assumed to be As(III).

Notes:

Units are in µg/L.

Results in parenthesis are field duplicates.

Results in brackets are laboratory speciation results (all others are field separation technique speciation results).

U = nondetect at the specified concentration
J = estimated value
MW = monitoring well
N/A = not applicable
RW = residential well

TABLE 5-2
Stable Isotope Results
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

	April 2005[a]		September 2005[a]	
Location	**Deuterium**	**Oxygen-18**	**Deuterium**	**Oxygen-18**
10G	-68	-9.90	-70.5	-10.34
10H	-70.1	-10.31	-71.5	-10.35
10N	-71.7	-10.35	-70.4 (-69.9)	-10.49 (-10.48)
11AJ	-67.7	-9.95	-67.7	-9.93
11AL	-66.6	-9.90	-66.5	-9.91
11AO	-67.3	-9.83	-70.2	-10.26
11AS	-68.6	-9.94	-66.9 (-67.3)	-9.96 (-9.97)
11AU	-65.3 (-65.2)	-9.95 (-9.95)	-67.7	-10.07
11AV	-68.1	-9.95	-68.1	-9.97
12J	-67.0	-10.05	-67.9 (-68.6)	-9.93 (-9.90)
13Q	-68.3	-9.84	-66.9 (-67.5)	-9.84 (-9.88)
13R	-67.8	-10.00	-68.2	-9.99
13S	-66.8	-9.89	-67.0 (-66.6)	-9.90 (-9.85)
1J	-65.5	-10.13		
1R	NA	-10.1	-68.0	-10.12
2G	-68.9	-10.22	-66.8	-9.90
3A	NA	-10.28	-68.6 (-68.9)	-10.26 (-10.25)
5A	-68.8	-10.17	-68.4 (-69.4)	-10.23 (-10.19)
5D	-67.5	-10.14	-68.9	-10.55
5E	-68.3	-10.19	-68.6	-10.12
5I	-68.3	-10.12	-68.0	-10.14
5J	NA	-10.02 (-10.08)	-68.5	-10.21
11A1	NS	NS	-66.1	-9.87
11A2	NS	NS	-66.7	-9.92
11A3	NS	NS	-69.2	-10.35
11AY	NS	NS	-67.4	-10.01
11AZ	NS	NS	-67.3	-9.98

[a]Units are in parts per thousand difference from an international standard (Vienna Standard Mean Ocean Water)

Notes:

Results in parenthesis are field duplicates

NS = not sampled

NA = not analyzed because of assumed sulfur compound interference

Stable isotope concentrations are measured as a ratio to the more common isotope of the element (^{2}H:^{1}H and ^{18}O:^{16}O). The ratios were compared to an international standard (i.e., Vienna Standard Mean Ocean Water) (National Institute of Standards and Technology, 2005), and data reported as parts per thousand (ppt) differences from the standard, expressed as $\delta^{2}H$ and $\delta^{18}O$. These values were used as conservative tracers of waters from

different sources or pathways so that a separation of sources or mixing scenarios can be inferred from the water samples collected in the hydrologic system. The combination of δ^2H and $\delta^{18}O$ constitutes an isotopic signature of the water. For the purpose of grouping water signatures, the data are best viewed on a plot of δ^2H versus $\delta^{18}O$, as shown on Figures 5-12 and 5-13. On these plots, the global meteoric water line (GMWL) is the line around which rainfall isotopic signatures cluster. Deviations from this line provide insights into the origins of the water.

The ranges of values of $\delta^{18}O$ (-10.6 to -9.8 ppt, or 0.8 ppt range) and δ^2H (-71.7 to -65.3 ppt, or 6.4 ppt range) detected at the Site are very limited compared with other groundwater systems of similar scale, which typically range greater than 8 ppt for $\delta^{18}O$ and greater than 60 ppt for δ^2H. This tight grouping demonstrates that the groundwater and surface water have similar or identical sources and that there is not a distinct signature associated with the mine adit discharge or the water that has interacted with the mining tailings. As shown on Figures 5-12 and 5-13, all the samples are above the GMWL; however, they are relatively close to the GMWL. This suggests that a local meteoric water line (LMWL) runs parallel to the GMWL and through the center of the sample distribution, as inferred on the figures.

Because no sample is significantly below the LMWL, it does not appear that any waters have been affected by evaporation or by reactions with different minerals. Groundwater samples from the Source Area (Wells 5D, 5E, 5I, and 5J) are only slightly more negative (lighter signature) than those from the Lost Lake/Deposition Area (Wells 13Q, 13R, and 13S). Residential wells located between these two areas (in the Downgradient Area) plot in the same range as water samples collected outside the influence of the tailings (Background Areas Wells 1R and 11A2, and surface water Location 2G samples from September 2005). The only trend that can be observed from the data is that the isotopic signatures appear to become heavier in the downstream/downgradient direction from the mine, which is consistent with global trends with elevation. However, the magnitude of this trend is so slight that it might be caused by a natural variation rather than elevation differences.

During spring, LCC south of the Rock Buttress, is predominantly fed by stormwater runoff. In fall, this part of the creek is fed primarily by groundwater discharge (i.e., baseflow) and adit discharge because upstream from the mine site, the creek is typically dry that time of year. The LCC surface water sample from the Downgradient Area (Location 12J) shows a small shift towards a heavier signature in the September 2005 sample compared with April 2005, which is the opposite of what would be expected given the lighter signature of the adit and tailings samples. This suggests that the shift could represent a natural variation rather than a mine-related influence. The fact that the tailings-free CC sample (Location 2G) shows a similar shift between events suggests that this is a seasonal shift rather than a shift caused by adit discharge.

There does not appear to be a relationship between arsenic concentrations and isotopic signature. Figures 5-12 and 5-13 show that samples in the arsenic concentration range of nondetect to 5 µg/L are similar in isotopic signature to samples having arsenic concentrations greater than 100 µg/L. The April 2005 samples were also analyzed for arsenic species, and the more dominant valence, As(III) or As(V), is placed adjacent to the samples on Figure 5-12. Again, there does not appear to be a relationship between the redox state of arsenic and the isotopic signature.

In summary, the data indicate very little (if any) difference in isotopic signature between the adit discharge/tailings groundwater and local residential well water. This suggests that the waters have the same sources and that mine-derived water has not caused a significant fractionation (shift) in the isotopic signature of local groundwater. As a result, isotopic data cannot be used as an effective tracer of mine-impacted water into the local groundwater system.

5.3 Groundwater Arsenic Contribution to Little Clipper Creek

Inflows of water and arsenic to LCC include surface water from the Source Area and Mine Area (adit water, seep water, Rock Buttress drain water, and diverted LCC water), ephemeral surface water inflow from tributaries to LCC, and groundwater discharge (i.e., baseflow). OU-1 RA activities have minimized the likelihood of further tailings migration from the Source Area by the construction of the Rock Buttress, surface water diversions, and waste rock/tailings pile cap. Furthermore, as part of the OU-1 RA, tailings in the LCC channel south of the Rock Buttress and north of Greenhorn Road were removed. During the final stages of the OU1-RA, water from the adit and Rock Buttress drain will be treated for arsenic. It is assumed that effluent will be discharged from the proposed treatment plant to LCC south of the Rock Buttress with an arsenic concentration of 10 µg/L. Arsenic loading to LCC from surface water inflow from the adit and the Rock Buttress drain water will be significantly reduced. Surface water inflow from tributaries to LCC is ephemeral and typically occurs during the wet season, diluting the arsenic. It is not known whether arsenic loading from groundwater discharge to LCC will continue to cause elevated arsenic concentrations in the creek after the OU-1 treatment plant is operational. To address this question, groundwater arsenic discharge to LCC was estimated for the reach between the Rock Buttress and Deposition Area by using data from Location 4A/4A2 (which includes water from the LCC diversion and the Rock Buttress drain), Location 3A (adit water that joins LCC immediately downstream from Location 4A2), and Location 12J (LCC immediately upstream from the confluence with CC). Figure 5-14 shows the locations of the monitoring locations used.

The Lost Lake/Deposition Area downstream from Location 12J is another known source of arsenic contamination to groundwater and surface water and is being addressed in a separate OU-3 RI/FS. After the OU-3 RA is identified and implemented, the remaining impacts to and from groundwater in this area can be addressed; therefore, the following discussion focuses only on groundwater impacts to LCC north of the Lost Lake/Deposition Area.

Groundwater arsenic contributions to LCC between the Rock Buttress and Deposition Area was estimated by using the relationship shown in Equation 5-1:

$$Q_{Adit}C_{Adit} + Q_{4A}C_{4A} + Q_{GW}C_{GW} = Q_{12J}C_{12J} \qquad (5\text{-}1)$$

Where:

Q_{Adit}, C_{Adit} = average surface water inflow rate from the outfall of the adit water to LCC and arsenic concentration (estimated by using Location 3A data) during summer conditions

Q_{4A}, C_{4A} = average surface water inflow rate and arsenic concentration from the upstream Rock Buttress area at Location 4A/4A2 during summer conditions

Q_{GW}, C_{GW} = average groundwater discharge rate and arsenic concentration between Location 4A/4A2 and 12J during summer conditions

Q_{12J}, C_{12J} = average stream discharge rate and arsenic concentration at Location 12J upstream from the Lost Lake/Deposition Area during summer conditions

The reason for evaluating arsenic contributions during summer (dry conditions) is because arsenic concentrations in LCC are higher in summer than in fall or winter (wet conditions) Elevated arsenic in LCC pose the greatest threat during dry conditions when there is less dilution by precipitation runoff and tributary inflows. Furthermore, estimating arsenic contributions during summer, when surface water inflow to LCC from ephemeral streams is negligible, simplifies the loading calculation by reducing the number of loading terms to only those listed in Equation 5-1. Following is a summary of key data that were used to estimate arsenic contributions to LCC downstream from Locations 4A/4A2 (and the adit discharge point) and upstream from the CC confluence (see Table 5-3):

- Available data for August show the average arsenic concentrations at Locations 4A/4A2 and 3A (inputs to LCC upstream) and 12J (input to LCC downstream) are approximately 194, 516, and 82 µg/L, respectively.
- The concentration of arsenic in groundwater discharging to LCC is not directly measurable. The range of arsenic concentrations in groundwater from Downgradient Area residential wells (screened in the Pms unit) is large, from nondetect to 890 µg/L (see Table 4-1). The average arsenic concentration in Downgradient Area residential wells within 300 feet (areally) of this reach of LCC is approximately 14 µg/L (includes data from Wells 11AL, 11AU, 11AT, 11A4, 11AZ, 11AK, and 11AJ). The median groundwater arsenic concentration from these wells is approximately 3 µg/L. For this evaluation, values of 14 and 3 µg/L were used to represent arsenic concentrations in groundwater (C_{GW}).
- During August, LCC flows at Locations 4A2 and 3A are typically 0.1 ft^3/sec (45 gpm) or less according to visually estimated flow data (see Table 3-2). At downgradient stream gauge Location 12B (i.e., stream weir location), LCC flows were estimated between 0.1 and 0.2 ft^3/sec (90 gpm) in August 2007. By using a stream discharge value of 0.15 ft^3/sec for Location 12B, 0.075 ft^3/sec was assumed for each stream discharge at Location 4A/4A2 [Q_{4A}] and the adit outfall [Q_{Adit}]) for the arsenic loading calculations. Assuming 50 percent of LCC flow at Location 12B is from the adit and 50 percent is from the base of the Rock Buttress (which includes the diverted LCC water and Rock Buttress drain water), and by using the average August concentrations for these locations, the arsenic concentration at Location 12B was estimated to be 355 µg/L.
- At downstream Location 12J, the visually estimated flow in LCC in August 2007 was approximately 0.2 ft^3/sec (90 gpm) (see Table 3-2), indicating minimal net gains to LCC streamflow between Locations 12B and 12J. However, the manual stream discharge estimates for Location 12J have the potential for a large margin of error and there are no supporting flow measurements available in this area at engineered structures

(e.g., weirs). According to Equation 5-1, the flow at Location 12J would need to be more than 0.2 ft^3/sec (90 gpm) in August to account for the decreased arsenic concentrations at this location (compared with upgradient Location 12B), assuming the arsenic concentration reduction is due to dilution.

To dilute arsenic concentrations in LCC water from 355 µg/L (at 0.15 ft^3/sec) at Location 12B to 82 µg/L at Location 12J, the groundwater would require a net discharge to LCC of approximately 0.6 ft^3/sec (270 gpm) if the groundwater concentration is 14 µg/L (average Downgradient Area groundwater concentration) during summer. A net groundwater discharge to LCC of 0.5 ft^3/sec (220 gpm) would be required if the groundwater concentration is 3 µg/L (median Downgradient Area groundwater concentration) during summer. According to these calculations (Equation 5-1), groundwater could contribute approximately 80 percent of the total LCC streamflow in this reach during the summer conditions (see Table 5-3).

TABLE 5-3
Estimates of Future Flow and Arsenic Contributions to Little Clipper Creek under Summer Conditions
Operable Unit 2 Remedial Investigation Report, Lava Cap Mine Superfund Site, Nevada City, California

Arsenic Source	Basis of Estimate	Flow (ft^3/sec)	Approximate Flow Contribution at 12J (percent)	Arsenic Concentration (µg/L)
Source 1: Rock Buttress	4A / 4A2 / 12B	0.075[a]	10	194
Source 2: Adit	3A	0.075[a]	10	516
Source 3: Groundwater	Between 12B and 12J	0.518[b] or 0.602[c]	80	3[b] or 14[c]
Sources 1, 2, and 3	12J	0.668[b] or 0.752[c]	100	82

[a]Assumes 50 percent of the estimated streamflow of 0.15 ft^3/sec at 12B.

[b]Assumes the average arsenic concentration in groundwater discharge is 3 µg/L between 12B and 12J.

[c]Assumes the average arsenic concentration in groundwater discharge is 14 µg/L between 12B and 12J.

See Figure 5-14 for monitoring locations associated with estimates summarized in this table.

Values derived from Equation 5-1.

By contrast, the Lava Cap Mine Groundwater Flow Model results predict that only approximately 0.05 ft^3/sec (22 gpm) of baseflow enters LCC (net gain) between the Rock Buttress and the Deposition Area. The required flow rate at Location 12J, approximately 0.7 ft^3/sec (310 gpm [90 gpm from the adit outfall and Location 4A/4A2, and 220 gpm from groundwater]), is much higher than the manually measured flow of 0.2 ft^3/sec (90 gpm). Therefore, there likely are other processes affecting the mass balance for arsenic in LCC, including adsorption or precipitation of arsenic in surface flows. Having more accurate stream discharge estimates along this reach would reduce the uncertainty in these estimates.

After the arsenic concentration in water discharging from the mine adit and Rock Buttress drain is treated and reduced to 10 µg/L (as specified in the OU-1 ROD [EPA, 2004b]), other groundwater contributions of arsenic to LCC and arsenic-related chemical reactions in the creek (adsorption or precipitation) could increase or decrease downstream arsenic concentrations. Available data are insufficient to accurately forecast the effect of these

processes on potential future arsenic concentrations in LCC. If groundwater contributing to LCC has average arsenic concentrations higher than 10 µg/L, and if chemical reactions do not decrease the overall arsenic concentration in LCC, arsenic concentrations could increase downstream from the Rock Buttress because of the additional dissolved arsenic in the groundwater. However, if groundwater contributing to LCC has an average arsenic concentration less than 10 µg/L, arsenic concentrations in LCC surface water would be expected to remain below the MCL, assuming that all of the arsenic-contaminated tailings in and near the stream channel have been removed. After the OU-1 RA is complete, continued monitoring of LCC surface water concentrations and flow will be required to assess the impacts of these processes.

5.4 Arsenic Fate and Transport Summary

The following sections summarize the sources, transport, and fate of arsenic in the study area.

5.4.1 Arsenic Sources

Known and suspected sources of arsenic contamination to groundwater include the following:

- Subsurface mine workings beneath the Mine Area.
- Waste rock and tailings in the Source Area and Lost Lake/Deposition Area. As part of the OU-1 RA, surface water from the adit and Rock Buttress drain will be treated, significantly reducing arsenic loading from this source.
- Remaining tailings deposits in LCC, CC, and Lost Lake. Future RAs in OU-3 will mitigate adverse impacts of tailings in these areas.
- Naturally occurring arsenic not associated with mining activities (natural ore bodies).

5.4.2 Elevated Arsenic in Residential Wells

Groundwater flowpath analysis using the Lava Cap Mine Groundwater Flow Model indicates that groundwater flowing from the surficial deposits of mine tailings and waste rock is confined to a narrow area within the Source Area, Lost Lake/Deposition Area, LCC, and CC. Groundwater in these areas travels toward the creek and typically discharges to the creeks within a relatively short distance (remaining shallow). Only a few residential wells in the Mine Area (10-series wells), Downgradient Area (Wells 11AL and 11AU), and Lost Lake/Deposition Area (Wells 11AI and 11AE) appear to be within or adjacent the flowpath area of the surficial mine deposits (Flowpath Set 1). Of these wells, potentially only the 10-series wells and Well 11AL have elevated arsenic concentrations that are likely related to releases from surficial mine waste deposits.

Two additional Downgradient Area residential wells (Wells 11AS and 11AV) have elevated arsenic concentrations and are within the flowpath area estimated from the shallow mine workings (Flowpath Set 2). Monitoring Well Pairs 5K-S/5K-D and 5L-S/5L-D, located upgradient from these residential wells, within the Flowpath Set 2 area, have had groundwater samples with arsenic concentrations above the MCL. The Flowpath Set 2 area also

encompasses several residential wells that do not have elevated arsenic concentrations. The low hydraulic conductivity of the Pms unit is likely associated with longer travel times for arsenic-impacted groundwater for this flowpath area. However, there is uncertainty in the flowpath analysis, and the uncertainty increases with depth (because less is known about the hydrogeology at depth), flowpath distance, and travel time, which provide greater opportunities for geochemical reactions along a flowpath. Several other factors also influence migration of arsenic contamination in groundwater from the Source Area and Mine Area that are not easily accounted for in the flowpath analysis, including fracture flow, groundwater use (pumping), and potential unmapped subsurface ore bodies containing arsenic. Groundwater chemical conditions downgradient from the mine generally indicate oxidizing conditions, which favor the less mobile forms of arsenic. The abundance of iron oxide minerals in the aquifer matrix suggests a significant capacity for the adsorption of arsenic, limiting its mobility in the aquifer.

Geochemical evaluations provided inconclusive results regarding water types and sources. Stable isotope signatures form a very tight range for all samples analyzed, so this geochemical tool might not be useful in identifying the effects of mine-related groundwater on residential wells. Arsenic speciation results indicated that elevated arsenic concentrations exist predominantly in the As(III) state, with a few exceptions. Initial speciation sampling results suggested a possible link between mine-related contamination and residential wells, but subsequent sampling in 2006 showed that speciation is variable and does not clearly indicate such a connection. In summary, the use of general chemistry, trace metals, natural tracers, arsenic speciation, and stable isotopes has not provided a clear indication of the influence of mine-related operations on groundwater in the area.

5.4.3 Groundwater Conceptual Site Model Summary

By using available data, groundwater flow modeling results, and professional judgment, the following observations were made. Groundwater north of the Source Area and Mine Area is perched on the contact between the Tvb and Pms units and discharges to the surface as springs upgradient from the mine. This water (with precipitation runoff and snowmelt) eventually discharges to LCC, which flows southward toward the mine. North of the mine, LCC is ephemeral and the water has low arsenic concentrations (between nondetect and 0.9 µg/L at Locations 1J and 1U) (see Table 4-1). Groundwater samples from Background Area wells that are upgradient from the mine deposits and entrance but are located within the footprint of the mine workings (Wells 1B and 1R) (see Table 4-1), have higher arsenic concentrations (between 1.2 and 24.2 µg/L) than LCC upstream from the mine.

In the Source Area and Mine Area, elevated arsenic concentrations were detected in the perennial adit discharge and seeps (up to 910 µg/L) and groundwater in the waste rock/tailings pile and underlying bedrock (up to 610 µg/L) (see Table 4-1). Samples from wells in the Source Area and along the adit discharge have a more pronounced sulfate presence than most of the surrounding wells sampled for the RI. This sulfate signature persists in downstream samples from LCC, but does not appear to persist in groundwater away from the mine, suggesting limited mine-related impacts on local groundwater. Groundwater within the waste rock/tailings pile had a downward hydraulic gradient to the underlying bedrock (according to data prior to the OU-1 RA). The OU-1 RA will significantly reduce the infiltration into the waste rock/tailings pile; however, some groundwater

will likely continue to flow along the historical LCC drainage, into the northern portion and out from the southern portion of the waste rock/tailings pile, which will leach arsenic. Groundwater discharging from the waste rock/tailings pile and the underlying Pms unit occurs as dam underflow and drain outflow from the Rock Buttress that feeds LCC. Some groundwater impacted by tailings and waste rock in the Source Area continues to flow in the aquifer to the south but is likely confined within the LCC canyon.

LCC south of the Rock Buttress collects flow from the LCC diversion (low arsenic concentrations), the adit diversion (high arsenic concentrations), and water discharged at the base of the Rock Buttress (high arsenic concentrations). Concentrations of arsenic in surface water immediately downgradient from the Rock Buttress and upgradient from the adit water outfall ranged between 16.5 and 532 µg/L (Location 4A/4A2) (see Table 4-1). Historically, tailings were transported by LCC from the mine to Lost Lake, which acted as a tailings impoundment. Naturally occurring sediments in LCC and CC are sparse; the only areas of significant sedimentation are in deposition areas upstream from Lost Lake that are dominated by tailings carried downstream during past releases from the Source Area. The OU-1 RA removed tailings in LCC south of the Rock Buttress and north of Greenhorn Road. LCC and CC both gain and lose surface water as they flow from the Rock Buttress to the Lost Lake/Deposition Area, but the relationship between LCC and CC surface water and the Pms unit groundwater is less certain because of the lack of groundwater elevation and land surface elevation data (i.e., where the groundwater table intersects land surface) or surface water flow volume and mass flux changes at regular intervals. Groundwater flow model results indicate that approximately 0.05 ft^3/sec (22 gpm) of baseflow enters LCC (net gain) between the Rock Buttress and the Deposition Area. However, because of uncertainties in the groundwater model, this number could be considerably different (visual estimates of streamflow infer that the net gain in this reach might be as much as a few hundred gpm). Arsenic concentrations in LCC currently decrease by about one-half between the Rock Buttress (Location 4A/4A2 and the adit outfall), and LCC (upstream from the confluence with CC [Location 12J]) in summer, but the total arsenic mass load increases toward the south. Arsenic in surface water is diluted south of the confluence of LCC and CC according to sampling results from Location 14E. In the Lost Lake/Deposition Area, the initial water elevation data from Well Pair 13R/13T and Staff Gauge 14E indicate that CC seasonally alternates as a gaining and losing stream at this location.

The large tailings deposit in the Lost Lake/Deposition Area contains impacted groundwater. Elevated dissolved arsenic concentrations (between 53 and 2,270 µg/L), were detected in groundwater samples from wells screened in the Deposition Area tailings (Wells 13Q and 13R). The vertical hydraulic gradient near Wells 13R and 13T and Wells 13Q and 13S is typically downward from the tailings to the bedrock. The low dissolved arsenic concentrations (between 2 and 6 µg/L) detected in bedrock Well 13S (see Table 4-1) suggest that overlying groundwater in the tailings does not significantly impact the underlying bedrock (Pms unit) water quality. However, elevated dissolved arsenic concentrations (35.4 to 104 µg/L) were detected in the new bedrock Well 13T (see Table 4-1). The arsenic concentration at Well 13T declined substantially between the first two sampling events (March and June 2007) and could continue to decline if it follows the same trend observed at Well 5K-D. At Well 5K-D, arsenic concentrations in groundwater steadily declined from 33.8 µg/L to 8.2 µg/L over 2 years. The initially high arsenic concentrations in groundwater

from these deep wells could be a result of cross contamination during drilling. Groundwater in this area is estimated to discharge to Lost Lake or to LGC, south of Lost Lake.

Groundwater flowing from northwest of Lost Lake likely discharges to Lost Lake at its northwestern shoreline and a small amount of water seeps under the dam along its southeastern shoreline. Total arsenic concentrations in Lost Lake range from 4.9 to 430 µg/L (Locations 16B and 16C) (see Table 4-1). Although some tailings deposits have been observed in CC south of Lost Lake, surface water in LGC 1.5 miles downgradient from Lost Lake (Location 19M) has relatively low arsenic concentrations (1.8 to 11 µg/L) (see Table 4-1). Mine-impacted groundwater is predicted to ultimately discharge to LGC.