California's Abandoned Mines

A Report on the Magnitude and Scope of the Issue in the State
Volume II

Department of Conservation
Office of Mine Reclamation
Abandoned Mine Lands Unit

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1 Introduction

The Abandoned Mine Lands Unit (AMLU) within the Office of Mine Reclamation (OMR) was charged with determining the "magnitude and scope" of AML issues in California (i.e. on a statewide basis). Given the short time frame and limited resources to conduct the investigation, statistical modeling became a necessity. The existing sources of state-wide digital data are legacy databases, such as the Minerals Availability System / Mineral Industry Location System (MAS/MILS) (Causey 1998). Our initial evaluation of the legacy databases found them to be unsuitable for directly modeling the "magnitude and scope" of AML on a state-wide basis, lacking both sufficient information for "magnitude" parameters and accurate locations. To support this watershed effort, AMLU digitized mine symbols from the USGS 7.5-minute topographic maps. It was necessary to develop an intermediate step — the watershed-based evaluation. Detailed data on the occurrence and character of AML was gathered at the watershed level from a number of watersheds. These data were then used to develop statistical models for the watersheds which were in-turn used to develop corollary models using the legacy databases. The models utilizing the legacy databases were then used to develop state-wide estimates of the "magnitude and scope" of AML in California.

This volume presents the supporting documentation for findings and options in Volume I, presenting procedures on how data were acquired, processed, and analyzed (Methods, page 3). These procedures are iterated at the watershed-specific level in Watershed Studies (page 26). Data analysis is further discussed in Statewide Modeling (page 110).

In comparison to previous efforts in California, this investigation embodies several new concepts in characterizing abandoned mine lands (AML). They are the use of features (a single physical entity and its location) instead of "mine sites" as the point of reference; the segregation of those features into physical- and chemical hazards; the use of an environmental model to rank hazards; and the use of legacy databases for statistical modeling to characterize the "magnitude and scope" of AML on a state-wide basis.

The concept of features was developed to address the reality that a "mine" as presented in the legacy databases, can encompass a single shaft with little or no infrastructure to 50 openings with a mill and smelter. The lack of clarity associated with the term "mine" precluded conducting comparative analyses. However, by cataloguing features at a site, one then could contrast and evaluate the potential risks and impacts from a collection of features at a site versus those at another site.

Having defined the concept of features, the next logical step was to categorize the observed features, hazardous and non-hazardous, with hazardous being further subdivided into physical hazards and chemical hazards. Physical hazards are primarily acute hazards, posing an immediate threat to life and limb. Examples include unstable structures and mine openings. A hazardous mine opening was defined as an opening (shaft, adit, drift, tunnel, etc.) that is large enough and deep enough for someone to become trapped in or from which a fall could cause serious injury (i.e., a depth or length of 10 feet). Chemical hazards are those hazards which typically constitute a chronic threat to human health and the environment. The classic example is metals-laden acidic discharge from an AML site.

Comparative analyses among sites is conducted via the Preliminary Appraisal and Ranking (PAR) Model. The PAR model uses a series of weighted matrices to score features which results in a cumulative score for physical hazards and chemical hazards. In addition, in order to better evaluate the hazards by defining the context of their occurrence, the PAR model also evaluates the potential for exposure to the hazards. Thus, the final outputs of the PAR model are a *physical hazard score*, a *chemical hazard score*, a *physical exposure score* and a *chemical exposure score*. *Physical* and *chemical rankings* are found by the combination of *hazard* and *exposure* scores. This method is explained beginning on page 16.

2 Methods

In every project, resource limits must be addressed in determining how to accomplish the goals. The quandary of "good, fast, cheap; choose two" best summarizes the issue. That is, a balance needs to be struck between quality, timeliness and funding. If any of the two extremes are chosen, the third necessarily suffers. Given the small staff and short timeframe, the Abandoned Mine Lands Unit could not collect detailed information about all or even a significant portion of the abandoned mines in the state. Therefore, a sample design based on a screening level inventory was undertaken to determine "the magnitude and scope" of abandoned mines in the state. The subsections of this chapter will address the methods used. They cover the topics of:

- The Sample Design;
- Data Collection, Processing, Storage and Retrieval; and
- Analysis and Modeling.

2.1 Stratified Random Sampling Method

Before designing a sampling program, one must first refine the question being asked. For this project, DOC was asked to define the magnitude and scope of the abandoned mine problem in California.[1] Specifically, we want to provide accurate estimates on the number and extent of physical and chemical hazards caused by abandoned mines. The most common physical hazards associated with such mines are highwalls, and open shafts and adits. The most common chemical hazards from abandoned mines are residual processing chemicals, heavy metals, asbestos, and acid rock drainage. So the questions become:

- How many hazardous highwalls, shafts, and adits are there on abandoned mines in the state?
- How many incidences of chemical hazards such as residual processing chemicals, heavy metals, asbestos, and acid rock drainage are there on abandoned mines in the state?

Approximately 30,000 mineral occurrences are contained in existing state-wide AML databases (MINEFILE and MAS/MILS). The type and number of features at each of these mineral occurrences is unknown, and may be from none to hundreds. In 1994, the US Bureau of Mines and the Colorado Center for Environmental Management came to the conclusion that an inventory based solely on these legacy databases "underestimates the number [of abandoned mines], lacks detail needed for accurate estimation of [hazards], and has an overall low level of confidence" (USBOM and CCEM 1994).

California is a very large state, with difficult access and remote areas. This makes impossible an assessment of the magnitude and scope of the abandoned

[1] "The magnitude and scope of the abandoned mine problem in California" is the language in the Budget Change Proposal (BCP).

mine problem in the time allotted without the use of modeling; that is, using statistical sampling to estimate the "population" of mine features within a given area.

2.1.1 Determining the Target Watersheds

The sampling design uses watersheds and bioregions to determine the areas of interest. The bioregions provide a coarse control for variations in climate, topography, vegetation and other edaphic factors. Watersheds provide an appropriate management and analysis unit where water quality is an issue. The watersheds were prioritized with direction from the Abandoned Mine Task Force by using GIS analyses.

There are ten bioregions in the state as delineated by the Jepson Ecoregions (Hickman 1993). They are: Central Western California, Cascade Range, Mojave Desert, Sonoran Desert, Great Central Valley, Modoc Plateau, Northwestern California, Sierra Nevada, East of Sierra Nevada, and Southwestern California.

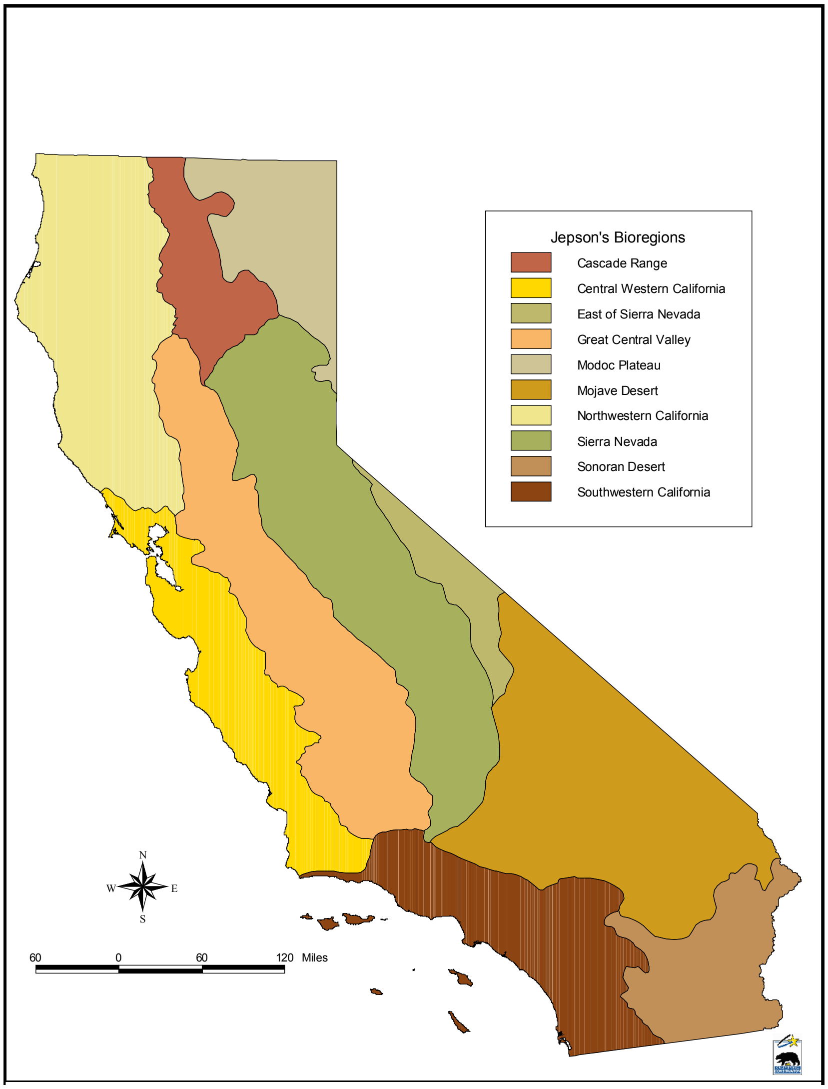


Figure 2.1: Map of Jepson Ecoregions (Bioregions).

Using the MAS/MILS data set (Causey 1998), it was determined that the Great Central Valley contained mostly sand and gravel operations. For the purposes of this project, sand and gravel operations were considered a lower priority. Therefore, the Great Central Valley bioregion was removed from consideration and all sand and gravel operations were removed from consideration in subsequent analyses for choosing target watersheds.

Figure 2.2: Map of CalWater Watersheds at the Hydrologic Area Level.

The remaining bioregions were spatially merged (unioned) with the Calwater watershed data set (ICWMP 1998 version 2.0) to produce a data set of polygons with the attribute data of both the Jepson and the Calwater coverages. The Calwater coverage has a hierarchical design such that the smallest units can be aggregated into three larger units. For the analyses, AMLU used the Hydrologic Area (HANAME) category, which is one step above the smallest unit.

Finally, to determine the priority watersheds the coverage created above was used with MAS/MILS to select two watershed units per bioregion. MAS/MILS has 29,239 records for mineral occurrences in California. Excluding the sand and gravel operations leaves 27,052 records. Intersecting MAS/MILS with the watershed-bioregion coverage produced a modified MAS/MILS data set containing the watershed and bioregion names. Two priority watersheds per bioregion were selected based on the greatest frequency of MAS/MILS mineral occurrences. They are Alameda Creek, Herlong, Lake Shasta Drainage, Lower Owens, Middle Klamath River, North Yuba, Palen, Point Buchon, Scott River, Shasta Valley, Silurian Hills, South Fork American, Susan River, Upper Owens, Ivanpah, Upper Santa Clara, Lucerne Lake, and Southern Mojave (Chemehuevis).

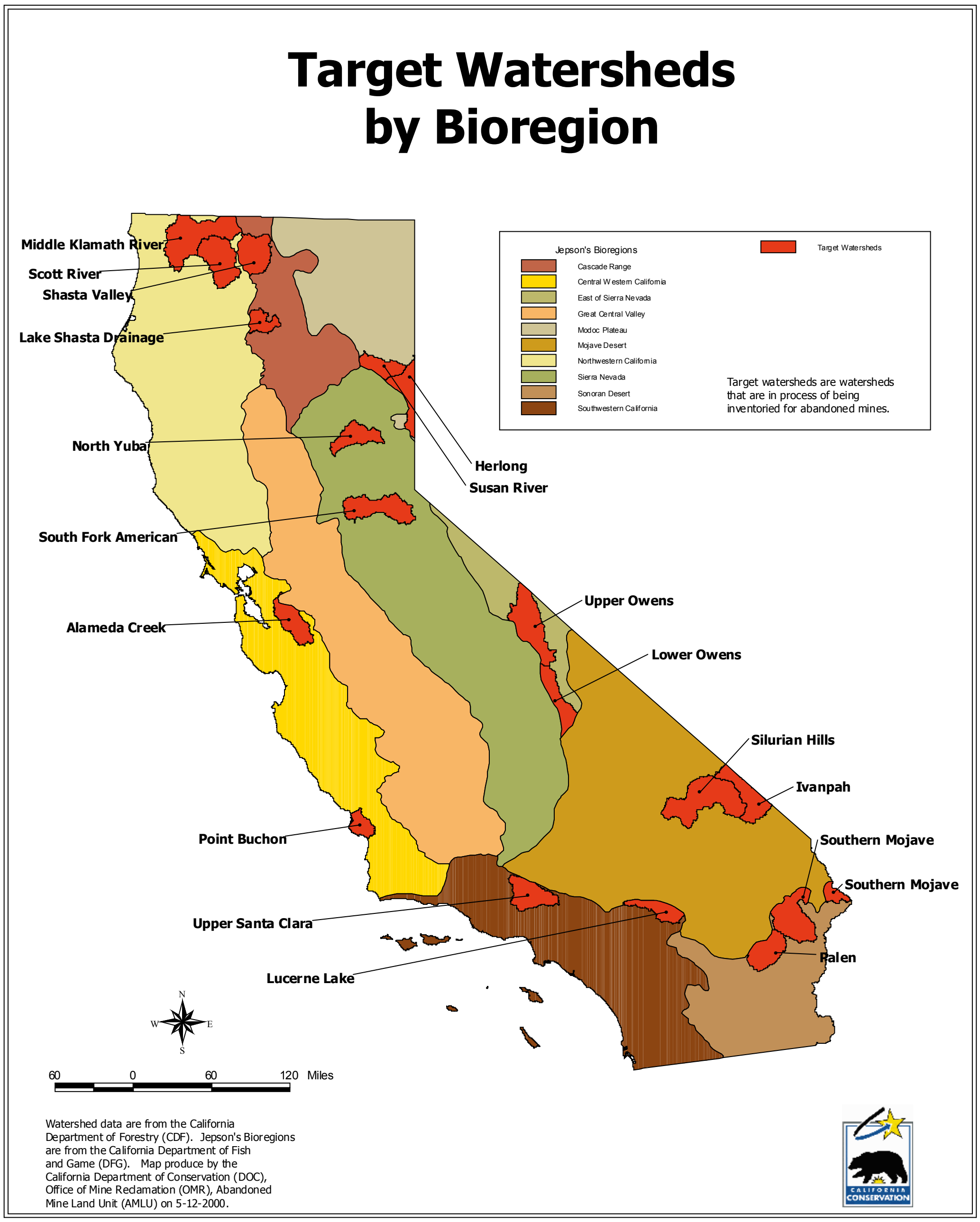


Figure 2.3: Target Watersheds for the Sample Study.

Additionally, stakeholders requested that we target Clear Creek and the Merced Watershed. In the Calwater hierarchy, the Merced Watershed is one level above the watershed level used in the priority designation and contains six such units. Due to time constraints, not all of the priority watersheds were sampled.

2.1.2 Designating Geologic Strata

One would expect that mines developed in similar geology will be similar in nature. Therefore, each Target Watershed was stratified by geology using the 1:750,000 scale state geologic map (Jennings 1977). While the mapping units are quite coarse, it is currently the only geology map of statewide extent that follows a consistent nomenclature. Because this map indicates surface geology, it was expected that there would be some error when applying it to mines. In some instances, the mine workings are located on one geology group, but the actual material being mined is significantly different. Still, it was hoped that the errors introduced by the coarseness of the data and its surficial nature, would not outweigh its utility as a means for grouping mines with similar properties.

The geology map utilizes a classification scheme based upon formations (a temporal and spatial association of rocks of varying types), and is the source of the "rocktypes" used in some analyses. The attribute data accompanying the map contains extensive information on the type and character of the rocks associated with each formation and thus provided a suitable starting point for developing another classification scheme for geologic information employed in the AML project.

Table 2.1: Rocktype, Rocktype_N, and Map Units from the DMG 1:750,000 Geology Map.

ROCKTYPE_N	**ROCKTYPE**	**MAP UNIT (PTYPE)**
1	Cenozoic Sedimentary Rocks	Tc, QPc, Qls, Mc, Qs, Oc, Qg, M+KJfs, P, M, Ep, Ec, E, E-Ep, Q, O
2	Cenozoic Volcanic Rocks	Qrv, Qrvp, Tvp, Qv, Tv, Ti, Qvp
3	Cenozoic-Precambrian Plutonic, Metavolcanic, and Mixed Rocks	mv, grCz, gb, grpC, pCc, Pzv, grPz, um, Mzv, gr, m, grMz, gr-m
4	Mesezoic-Palezoic-Precambrian Sedimentary and Metasedimentary	Kl, KJf, K, TK, ls, Pz, SO, TR, D, KJfs, C pC, Pm, J, Ku, KJfm, Ca, sch
5	Mesezoic-Palezoic-Precambrian Sedimentary and Metasedimentary/Cenozoic Sedimentary	Ku-Ep
6	water	Bay, water

In order to evaluate the relationship of mine impacts to the geologic media, a classification scheme would need to reflect the chemical nature of the geologic media. Rock type and origin (genesis), while not a direct measurement of chemical properties, proved to be a sufficiently accurate surrogate at the scale of interest, 1:750,000.

Attribute data for each of the 57 formation designations used on the geologic map were reviewed and served as the starting point for the new classification ("Reclass"). When data were not sufficiently comprehensive to permit discrimination of geologic media, secondary data sources were consulted (McFarland and Drake 1979; Armentrout, et al 1979; Ernst 1981; Ingersoll and Woodburne 1982; Staton 1972; Hyndman 1972; CDMG (Cal Geology) 1979 - 1999).

Table 2.2: Geology groupings used to define "Reclass" with the original map units and a description.

Reclass#	Map Units	Description
1	Qls, Qs, Q	Cenozoic (Holocene) unconsolidated terrestrial deposits (fluvial, aeolean, landslide, alluvium, colluvium)
2	QPc, Mc, Oc, Qg, Tc	Cenozoic (Quaternary & Tertiary) unconsolidated to semiconsolidated terrestrial deposits (glacial deposits, fluvial deposits, e.g. auriferous gravel)
3	Qvp, Tvp, Qrvp	Cenozoic (Quaternary & Tertiary) volcanic rocks (pyroclastics, mud flows (lahars)
4	Ti, mv, Qrv, Mzv, Pzv, Qv, Tv	Cenozoic through Precambrian volcanic and metavolcanic rocks
5	Ku, ls, Pz, SO, sch, D, KJfs, C, Pm, TR, J, P, M, Ep, Ec, Tk, K, Kjf, Kl, E, KJfm, E–Ep, O, pC, Ca, Ku–Ep, M+KJfs	Cenozoic through Precambrian marine sedimentary and metasedimentary rocks
6	grPz, grCz, grpC, pCc, gr, gr–m, grMz, m	Cenozoic through Precambrian granitic and associated intrusive rocks
7	um, gb	Cenozoic through Precambrian ultramafic and gabbroic rocks
8	Bay, water	Water

2.1.3 The Population to be Sampled

While MAS/MILS was used to identify our priority watersheds, it was not used to select the sites to visit. It was determined that MAS/MILS does not represent the entire population and its poor spatial accuracy would be problematic with a spatial sampling procedure. The USGS 7.5 minute topographic maps more accurately reflect the population and the spatial accuracy is excellent[2]. It is important to note that the topographic maps also underestimate the number of mines. For Example, the Arizona Mine Inspector found that 52.1 percent of the mines surveyed were not previously marked on the topographicgraphic maps.

Every digitized mine feature is represented as a point feature (linear and areal features are also digitized as arcs or polygons respectively). Within each geologic stratum of each watershed, fifteen features are selected using a pseudo-random number generator. When less than fifteen features exist, the entire subpopulation is sampled. This sample set is then augmented with at most five sites randomly selected from the Principle Areas of Mine Pollution (PAMP) database (see below). In many instances, there is a correspondence between the two.

Before the random sampling protocol is applied to this data, the points are compared to USFS and NPS data to avoid duplicating work among agencies, and they are compared to the SMARA database to eliminate active mines from the

[2] The USGS has not digitized these features and no digital data exists for California. Therefore, the Office of Mine Reclamation is in the process of digitizing the mine features for every USGS 7.5 minute quandrangle in the state. This data will be published when it is completed (estimated 2001).

sample. The results of the random sample are the sites that will actually be visited and cataloged by the field staff. These final points are compared to other databases (when possible) to gain more information that may be helpful during fieldwork, such as the name of the mine, the commodity that was mined, and the type of operation. The following databases are utilized during the pre-field work:

- The PAMP (Principal Areas of Mine Pollution) is a compilation of about 2,422 mining operations and the water-quality problems related to these operations provided by the California Department of Conservation's Division of Mines and Geology (1972) for the State Water Resources Control Board. This data set includes mining operations exceeding $100,000 in production and a few mines with lower production but with potential for high pollution.
- The SMARA (Surface Mining and Reclamation Act) database is a compilation of all mining operations (1,842 listings) that have reported to the Office of Mine Reclamation. This list includes location information of all active, idle and reclaimed mining operations after the reporting requirements of SMARA went into affect in 1991.
- The USFS (US Forest Service) and NPS (National Park Service) data is initially received in hardcopy format and entered by AMLU staff into the AMLU database. These data are similar in content to the AMLU data in regards to location, name, type of mine, type of processing, and chemical or physical hazards. Therefore, these data are considered as a valid site visitation.
- The MAS/MILS (Minerals Availability System/Mineral Industry Location System) database is a compilation of mine and mineral-related information (29,239 sites in California) compiled by the US Department of the Interior, Bureau of Mines, currently housed by the US Geological Survey. MAS/MILS provides information on name, location, type of operation (prospect, surface, underground, etc.), type of processing (leach, stamp mill, amalgamation, smelters, etc.), ownership (federal, state, private, etc.) and commodities produced. However, this database does not catalog features (shafts, adits, structures, prospect pits, etc.) or environmental information.
- The DMG MINEFILE (Division of Mines and Geology MINEFILE) is similar to MAS/MILS database and is provided by California Department of Department of Conservation's Division of Mines and Geology.
- The GNIS (Geographical Name Information System) is a database of names (2,697 sites) provided by the US Geological Survey. This database provides location information only for named mining localities that appear on USGS topographic maps.
- The MRDS (Mineral Resource Data System) is a compilation of geologic, mineralogic and petrologic data for selected mines and mining locations. MRDS was developed and is maintained by the USGS. It contains 11,578 records for California.

A literature search is also performed for each of the selected sites. The full resources of the Department of Conservation's Mines and Geology library are used, including the Reports of the State Mineralogist, USGS open file reports and professional papers, CDMG publications and bulletins, and any other sources that are discovered during this research. The purpose of this search is to gain more detailed information about the site before the field visit, including the physical extent of the operation, the type of processing that was used, detailed maps of the mine workings, and possible hazards that may exist at the site.

The information from the field verified sites within the watershed is then used to develop statistical models on both the physical and chemical hazards in the watershed as a whole.[3] The result is an estimate of the magnitude and scope of the abandoned mine problem in California by watershed. This estimate will become more accurate as more data is collected. These estimates are limited by the short-comings of the legacy databases and topographic maps as noted above. As development and population pressures dictate and budget allows, future efforts can then be put into intense surveys for abandoned mine features in the highest priority watersheds.

2.2 Collecting and Recording Data

This section describes the guidelines, protocols, and procedures used by the Abandoned Mine Lands Unit to efficiently conduct site investigations and collect data to accomplish a field inventory and hazard ranking of abandoned mine sites in California. It should be noted that, considering the limited budget and timeframe of this project, that the guidelines, protocols, and procedures described are for a field inventory at a "screening level" of detail, and are not intended to provide a complete site characterization, detailed survey, or laboratory-quality water or soil sampling. Such protocols for a more intensive site characterization are detailed in a recent publication by the Department of Toxic Substances Control entitled "Abandoned Mine Lands Preliminary Assessment Handbook," (1998).

There were three goals of the AMLU Field Inventory:

1. Find and accurately locate the features of abandoned mine sites with Differential Global Positioning Systems (DGPS), and record this information for data entry into the AMLU Database.
2. Conduct a screening-level assessment of potential risks to the public and the environment at each site visited, and assign a preliminary hazard ranking.
3. Accurately document the individual mine features found at the site by use of the AMLU Field Inventory Form and digital photography for post-field data entry into the AMLU Database.

The following sections outline and describe the field methods used to meet the goals of the AMLU Field Inventory.

2.2.1 Training

Staff received training in AMLU field procedures, protocols, hazard recognition and assessment, collection of GPS data, measurement and assessment of various mine features, photographic documentation, field mapping, and detailed field data collection and documentation. All staff were required to maintain 40-hour Hazardous Water Operations certification. Staff were also trained in the maintenance and use of the following specialized field equipment:

[3] We also include information from other sources (USFS, BLM, NPS, SWRCB) if it is deemed accurate and if it contains adequate detail.

1. Real-time, Differential , and Non-Differential Global Positioning Systems (GPS) Photographic and Digital Imaging Cameras Field Sampling
2. Meters and chemical reagents (pH, electrical conductance, temperature, acid reactivity, redox, and flow measurements)

2.2.2 Site Location

Locating abandoned mine sites can be difficult. Even with detailed location information and directions, conditions arise which cannot be anticipated, such as: using old maps, which may be inaccurate; roads, trails, and features may be mismarked; new roads and trails may obscure and change old ones; weather conditions change, causing wash outs, rock slides, and log falls; additional gates and locks may be encountered; and the right to pass may be denied. Many sites are adjacent to each other, and may have been connected by ditches, roads, trams, rail, and underground workings at some time during their history. The full extent of a "site" may be unknown, as new workings may have been developed since the last information was gathered. Even "raw prospects" have turned out to have been full scale mining operations at one time, with many diverse and scattered features when finally located. This sometimes makes it difficult to know which site the investigator has actually located, and where one begins and ends.

2.2.3 Overall Site Characterization

Staff conducting the inventory were required to characterize the overall setting and condition of each site by conducting an initial exploration of the extent of the abandoned operation, noting all of the features associated with it. Basically, staff would look for visible features which evidenced past mining activity on the site. These features would include, but not be limited to: mine openings (adits and shafts); quarries and pits; subsidence, rock falls, and erosion; buildings and structures (headframes, stamp mills, rock crushers, and sluices); waste and tailings piles; impoundments; rails or trams; haul roads; water ditches, seeps, and streams; evidence of chemicals (drums, tanks); and evidence of toxic leaks, seeps, and acid rock drainage. The information gathered from this initial exploration and site characterization would then be recorded in space provided on the AMLU Field Form (see page 123). This would include: a description of how the site was accessed (specific directions and special instructions); a description of the topography; the extent of the site and its environmental setting; the type of operation, processing used, and commodity mined, if determined; the number and type of features found; a brief statement about the geology and history of the site, if known; and the mine's current status. In addition, any information provided by local contacts would be included in this section.

2.2.3.1 Sketch Map

Materials to complete a sketch map for a mine site was provided for in the AMLU Field Inventory Form. Although not required, use of a sketch map was recommended for the larger, more complex sites. Staff completing a map would use the following procedure: estimate the shape, size, and orientation of the site boundaries; note topographic features and mine features; reference them spatially to a rough scale; and sketch them on the provided blank map grid. Measurements of the dimensions of mine features, estimates of waste and tailings volumes, and notation of GPS and photo points would also be marked and delineated. Bearings and distances between features were usually derived by using a compass, pacing distance, and rangefinder. Laser rangefinders were also used, but less frequently due to their size and weight.

2.2.3.2 AMLU Field Inventory Form

The AMLU Field Inventory Form was used to record site information and document all of the features discovered during a mine site visit. This form became the primary record used to document and complete the inventory and assessment of an abandoned mine site. Upon return from the field this form was used to enter the data collected while on-site, into the AMLU Database and GIS. The form itself also performed the function of a "checklist" for conducting a thorough mine investigation, by providing "fill in the blank" type data fields. The form provided data fields for recording: GPS point identifications (GPS IDs); feature descriptions; photograph identifications (Photo IDs); dimensional measurements for features and associated descriptors (water-quality measurements); non-GPS locational information; mine names; date; ownership and contact information; operation type and dates; on site activity; commodity mined; mining district; county; watershed; rock type; openings; waste volumes; mine status; and data sources.

Included, and incorporated with the AMLU Field Inventory Form, was the Preliminary Appraisal and Ranking (PAR) form. This section of the form was used to characterize and document: the types of hazards found on site; accessibility and exposure potential (population, proximity); current and future land use; water use; sensitive environments; vegetation disturbance; disturbed acreage; commodity group and processing location; and various surface water, soil, and groundwater descriptors used for screening-level assessments.

As the primary record used to document and complete the inventory and assessment of an abandoned mine site, it was imperative that the AMLU Field Inventory Form be thoroughly completed while on-site. This allowed for efficient data entry, and prevented errors in, or omission of information critical to the post-field hazard evaluation performed when the Preliminary Appraisal and Ranking (PAR) was calculated by the AMLU Database.

2.2.3.3 Specific Characterization of Mine Features

Each feature located at a mine site was described by using the following AML inventory identifications: Asbestos; Building(s); Carbonates; Containers, Drums; Conveyance; Embankment; Explosives; Excavation; Flume; Foundation(s); Headframe; Horizontal Opening; Highwall; Lake; Mass Wasting; Production Machinery; Mercury; Mine Waste; Ore Stockpile; Organic Matter; Production Area; Rock Sample; Salts; Sluice; Soil Sample; Spring, Seep; Stain; Stream, Creek; Subsidence; Sulphides; Tailings; Tanks; Trash; Vertical Opening; Well; and Wetlands.

These features were then characterized from the following list of conditions (descriptors): Acid Reaction; Above Ground; Below Ground; Bound; Breached; Closed; Coal; Collapsed; Dispersed; Draining; Empty; Ephemeral; Eroded; Filled; Flooded; Flowing; Free; Fresh; Intact; Lignite; Mitigated; Massive; Old; Open; Partially Collapsed; Perennial; Radioactive; Stable; and Unstable. A list of odor and color descriptors was also used to characterize mine features.

Water was sampled when found on site, and sample locations were based on the type of feature being sampled. Generally, streams crossing sites were sampled above the site, on-site, and below the site in order to obtain a range of data. Water was sampled where it seeped from tailings or waste piles, or when it emanated from adits. The instruments used to sample water were "pocket" meters. These are small, self-contained, battery-operated, hand-held units that were water resistant, and could be easily carried or packed into the field. These "pocket" meters were sufficient for the screening-level assessments conducted in the course of this inventory, and were calibrated at least weekly. Samples were measured both "ex situ" and "in situ". For example, samples were sometimes taken directly from standing and flowing water, or from balers when taken from within an adit, since underground entry was prohibited by protocol. The meters were then used to measure the condition of the sample, and the resulting measurements were recorded on the AMLU Field Inventory Form.

The following is a description of the "pocket" meters used:

- Oxygen-Reduction Potential — The meter was equipped with a platinum probe, and had a range of -999 to +999 mV with an accuracy of ±5 mV.
- PH — The pH meter had a measurement range of 0 to 14 with an accuracy of ±0.1 pH and a resolution of 0.1 pH, with automatic temperature compensation.
- Electrical Conductivity — The conductivity meter had a range of 0 to 1999 µS/cm, an accuracy of ±2% of the full scale, and a resolution of 1 µS/cm, with automatic temperature compensation.
- Thermometer — The thermometer reads in degrees fahrenheit, and had a range of -25 to 300°F, and an accuracy of ±1°F.

These same meters were used for soil sampling. Soil samples were usually only collected from suspect waste and tailings piles at mine sites. A paste was made by mixing the sample with water (1:2 ratio of soil to water by volume). The meters were then used to measure the indicator parameters from the liquid fraction, and the resulting measurements were recorded on the AMLU Field Inventory Form.

2.2.3.4 Documentary Photography

Each of the features discovered on site were documented by either film or digital photography. Usually several pictures were taken in order to show the feature from different aspects (distances, angles, or settings). Photographs and related features were associated and recorded by use of a Photo Identification (Photo ID) on the AMLU Field Inventory Form. The use of digital cameras was found to be most efficient for the field inventory for the following reasons:

- Small, lightweight, rugged, and compact. Easy to use in the field.
- Large memory capacity allows more than 100 photos to be stored at a time.
- Ability to view images taken immediately after the fact, in the field, in order to verify picture quality and exposure.

- The ability to easily post-process images and obtain recognizable images under poor lighting conditions.
- Ability to immediately download images from the camera directly to the AMLU database.

2.2.4 Location of Features by Differential Global Positioning Systems

The goals of the AMLU Field Inventory required the identification of the individual features found at an abandoned mine site as accurately as possible. This was necessary because some features were located only a few feet apart, and some means of clearly identifying them from each other was required. For the AMLU Field Inventory, it was decided that traditional map, compass, and measurement would be insufficient to accomplish accurate feature location. As a result, all of the mine feature locations documented during the AMLU Field Inventory were collected and recorded by the use of state-of-the-art GPS receivers, and in particular, by using differential and real-time GPS receivers.

Positional accuracy using the Differential GPS was usually 15 feet or better. In addition to accurately recording the GPS positions of all of the features found at each site, a "site" point was also collected at a prominent feature. This site point was taken in order to identify the site where all of the features were grouped, and could also be used to navigate back to the site on future visits. Data collected from the differential GPS receivers was recorded and stored electronically, and the site point location would also be written on the AMLU Field Inventory Form, as a precaution against equipment failure.

2.2.5 Post-Field Processing

Following field work, staff would return equipment to the office, and begin the process of downloading data from the GPS receiver and digital camera and data entry and file preparation.

- GPS Post-Processing — Differential GPS files would be downloaded to a computer with an Internet connection. Specialized software was then employed which would take GPS differential correction files downloaded separately from a GPS base station internet FTP site, perform the differential correction, and export the final corrected GPS files to a geographic information system (GIS) file format (ArcView Shapefile). These files would then be appended using ArcView GIS, with latitude and longitude[4]; and Teale Data Center's Albers equal area conic projection coordinate grid northings and eastings[5]. This file would be referenced when performing data entry on the site visited, in order to copy this information into the specific AMLU Database record for the site and it's associated features.
- Digital Image Post-Processing — Images from the digital camera would be downloaded, and any retouching and post-processing would be completed prior to the images being prepared for inclusion with the database record and electronically archived. If a film camera was used, the exposed film would be

[4] Coordinates are referenced to the North American Datum of 1927 (NAD-27, CONUS).
[5] Teale Data Center's parameters for the Albers Equal Area Projection are: Datum = NAD-27 (assumed CONUS), Ellipsoid = Clarke 1866, Latitude 1 = 34 00 00N, Latitude 2 = 40 30 00N, Latitude of Origin = 0 00 00N, Central Meridian = 120 00 00W, False Northing = -4,000,000 meters, False Easting = 0 meters.

processed into prints, which would then be digitally scanned, retouched, post-processed, and prepared for inclusion with the database and electronically archived.

- Data Entry into the AMLU Database — Data from the AMLU Field Inventory Form was entered into discrete records for each mine site visited. Data collected from any literature review or materials collected would also be entered. Photographic images would be associated with database feature records, along with differentially corrected GPS coordinates.
- Hard-Copy File Preparation — After completion of all data entry for the site visited, a hard-copy file would be created containing:
    - The AMLU Field Inventory Form;
    - Copies (or a "contact sheet'" collection) of photographic images of individual mine features;
    - A sketch map (if completed);
    - A topographic map showing the site and feature locations;
    - Additional supporting documents and literature would also be included.

2.2.6 The Relational Database Implementation

The Abandoned Mine Lands Unit Database (AMLUDB) was implemented around four goals. First, the database should be able to store the field data collected for the diverse types of mines in the state. Second, the database should be able to implement the Preliminary Appraisal and Ranking (PAR) system. Third, the database should be able to accommodate data submitted from other parties (such as the US Forest Service). Fourth, the database must have a way of linking its mine records to those in legacy databases (such as MAS/MILS and PAMP).

To accommodate the diversity of possible data, the AMLUDB was implemented as a relational database. The relational database structure allows each mine site to have zero or more of any particular thing associated with it, and allows for easy ad hoc queries on that data. For instance, each site may be referred to by one or more names. In a flat file structure (like a spreadsheet), you either must use one field for the names or you can create a specific number of fields for possible names. In the first scenario, it becomes difficult to query on the names, whereas in the second you are limited to the number of fields you originally designated for names. Now, if you add the possibility that dates of usage for the names can be included (as the AMLUDB does) then you can't use the first method at all in any reliable fashion and still have the same limitations in the second method. To take this a little further, in the AMLUDB, each site can have an arbitrary number of features associated with it. Features are any "thing" on a site that warrants mention (adits, pits, waste piles, tailings ponds, etc.). Now the flat file approach becomes untenable.

The AMLUDB currently supports locational information for the site itself as well as each of its features. Currently, it only directly supports point data. In fact, every site and feature is required to have such information. To accommodate spatial data of varying accuracy, there is a field indicating a measure of that accuracy. Having an accurate spatial component is critical because for many smaller mine sites that is the only reliable way of identifying them. Also, many of the older existing databases have extremely poor locational data, making it impossible to find a site in the field.

Being able to rank the sites is the purpose of the PAR. The database system provides the vehicle for storing the required data as well performing the calculations. Additionally, ad hoc queries and reports can be generated using the output of this data, with the knowledge that it is always up to date with the current data in the database. The actual PAR system is described in section 2.3.1 on page 16.

Being able to incorporate the work of others was an important goal. Other agencies have also expended considerable time and effort collecting data on abandoned mines. However, as is the case with the US Forest Service, this data often lives only in paper records. Staff have undertaken the effort of translating these paper documents into the AMLUDB and will return an electronic version. Other agencies, such as the National Park Service, the Bureau of Land Management, the State Water Resources Control Board, and the State Department of Toxic Substances Control have been providing AMLU with their records. In combination with historical records, and existing databases, these data can be incorporated into the AMLUDB giving a clearer picture of what is out there.

Still, the AMLUDB is far from containing a complete inventory of the abandoned mines in the state. Legacy databases such as MAS/MILS provide an important foundation for digital information on mines. However, they often contain too little information about the actual features and environmental conditions to be incorporated into the AMLUDB. Still, this data is important, so a mechanism for linking records together has been implemented. This way, it is possible to retain the old with the new, as well as easily investigate any possible discrepancies.

2.3 Analysis and Modeling

2.3.1 The Preliminary Appraisal and Ranking System (PAR)

The Preliminary Appraisal and Ranking System (PAR) is a key component of the Abandoned Mined Lands Program. It is an empirically derived system for assigning a numerical score to abandoned mine lands (AML) based on readily quantifiable measures of physical and chemical properties and associated exposure potentials. It is not intended to produce a definitive ranking of mines, but rather to produce a ranked list that can be grouped into ranked categories for initial screening. This approach is advantageous in that it provides for a rapid, uniform, and objective evaluation of AML. AML sites can then be compared and prioritized, which is useful for resource allocation (e.g. clean-up funds).

The PAR System consists of four components: *physical hazards*, *physical exposure potential*, *chemical hazards*, and *chemical exposure potential*. Each component contains criteria that describe the physical and chemical hazards at the site and their potential for environmental exposures. Each criterion has a numerical value associated with it. The numerical values form a relative ranking for each component which are then grouped into categories. Sites are then ranked into physical and chemical groups as determined by the combination of hazards and exposure. Care is taken such that a site is not elevated if exposure is high but hazards are low. Otherwise, sites where the hazards are moderate and the exposure is moderate would co-mingle with sites that present no significant problems.

The *field inventory form* is a primary source of data. It includes information on location, ownership, mine type, status, and mine features. The form also addresses physical and chemical hazards at the site, and evaluates access, vegetation, and sensitive environments.

Data acquired during the site visit consists of direct measurement and observations of physical conditions indicative of environmental and safety conditions at the site. Examples of environmental data include: pH, conductivity, reduction-oxidation potential, and temperature of waters and soils; spacing of fractures in bedrock; and the volume of tailings. Examples of safety data include locating dilapidated structures and mining equipment, mine openings, pits, high walls, and sinkholes. These types of data are easily quantified in the field, compatible with tabular data format, and suitable for GIS analysis.

2.3.1.1 Implementation

The PAR model is implemented within the AML Database (AMLUDB). There are a series of attributes for each mine which are used to rank the site. Some of these attributes are numeric and come straight from the AMLU field form. Most, however, are intervals for a specific type of attribute. For instance, a specific pH reading taken in the field for an impoundment might be 4.8. The PAR, however, is not interested in the specific value, but only wants to know which interval the surface water pH reading falls in – is it less than or equal to 5, greater than or equal to 9, or somewhere in between? All interval values are coded and saved in the database as an uppercase character (A, B, C, etc.). The users inputting the data are not aware of this. They only see the interval in question. Coded intervals were chosen to represent threshold values. Additionally, much of the input data consists of imprecise estimates. Categorical ranges clearly indicate this lack of precision.

Having a coding scheme, allows the flexibility in how the PAR is actually calculated. If it is decided later on that a particular attribute or set of attributes are either not being given enough weight or have been given too much weight, then with minimal effort, the code module "ParCalculations" can be modified to reflect those changes. All the previously calculated PAR values can be recalculated in a matter of minutes.

It must be remembered that the PAR model is empirically derived and attempts to rank a diversity of sites with a minimum of environmental data. Thus, it is to be expected that some sites will be ranked relatively lower or higher than would be anticipated. However, the system does a reasonable job of ordering sites consistent with experience and observation.

2.3.1.2 Exposure Scenarios

The principle use of exposure scenarios is to identify sensitive receptors which, in turn, provide insight on the constituents of concern. Initially it was thought that the human exposure scenario for AML would be principally one of the recreational user. However, after evaluating data on the distribution of AML with respect to high-growth areas and land development, AMLU is now of the opinion that exposure scenarios of a residential setting (dwelling, prison), a recreational use (hiker, camper, hunter, off-road vehicle user, etc.) and a commercial use (manufacturing site, warehousing, etc.) better represent the exposure potentials to California's citizens.

Examples of AML impacts within residential areas include the Mesa de Oro residential development (built on top of arsenic-laden tailings) and the recent series of mine collapses in the residential areas of Paradise, Oroville, and Grass Valley. Examples of high-use recreational exposures are Spenceville Mine, where children's footprints were observed in the mud around a water-filled mine pit, and Dairy Farm Mine where adult and children's footprints were observed within Acid Rock Drainage (ARD) generating tailings piles.

These examples strongly suggest that children are frequently exposed to the physical and chemical hazards at AML. Thus, when evaluating potential impacts to humans, children are designated as the sensitive human receptor. It is envisioned that non-human exposure would be evaluated on the basis of identified sensitive environments and associated sensitive species.

The final component of the exposure scenario is addressing institutional controls. Both Spenceville and Dairy Farm Mines are posted and surrounded by fencing, yet, as noted above, such controls are frequently subverted. Again, data such as these strongly suggest that for the evaluation of long-term exposure, institutional controls should be considered ephemeral at best.

2.3.1.3 Physical Hazard Evaluation

The *physical hazard evaluation* is comprised of two principle components, the *physical hazards inventory* which is done in the field, and the *exposure potential* which is a combination of field work and GIS analysis.

2.3.1.3.1 Hazard Scoring

The *physical hazard* score is calculated from a number of fields entered into the AMLUDB from the AMLU Field Form. It includes: the hazard level (*physApr1*) and frequency (*physApr1F*) of openings; the hazard level (*physApr2*) and frequency (*physApr2F*) of highwalls; subsidence features (*physApr3*); slope stability (*physApr4*); hazard level (*physApr5*) and frequency (*physApr5F*) of water bodies; and the hazard level (*physApr6*) and frequency (*physApr6F*) of structures and machinery. Each of these items is multiplied by a weighting factor and summed.

Openings may be given a hazard level from 0–4 (*physApr1*), with four being most dangerous. This number is then multiplied by the frequency (*physApr1F*), which is unbounded, and then multiplied by a weighting factor of 100. This subtotal is added to the *physical hazard* score.

Highwalls may be given a hazard level from 0–4 (*physApr2*), with four being the most dangerous. This number is then multiplied by the frequency (*physApr2F*), which is unbounded, and then multiplied by a weighting factor of 50. This subtotal is added to the *physical hazard* score.

Subsidence features (*physApr3*) are given a plain ranking from 0–4, with four being the most dangerous. This ranking is then multiplied by a weighting factor of 10 and added into the *physical hazard* score.

Landslide features (*physApr4*) are given a plain ranking from 0–4, with four being the greatest extent. This ranking is then multiplied by a weighting factor of 10 and added into the *physical hazard* score.

Water bodies are cummulatively given a hazard ranking (*physApr5*) from 0–4, with four being the most dangerous. This number is then multiplied by the frequency (*physApr5F*), which is unbounded, and then multiplied by a weighting factor of 20. This subtotal is added to the *physical hazard* score.

Finally, structures, machinery and trash are given a hazard ranking (*physApr6*) from 0–4, with four being the most hazardous. This number is then multiplied by the frequency (*physApr6F*), which is unbounded, and then multiplied by a weighting factor of 20. This subtotal is added to the *physical hazard* score.

After the "raw" *physical hazard* score is calculated, sites are placed into ranking categories from 0 to 5, with five being the most severe. The breaks for each category are as follows:

Table 2.3: *Physical hazard* rankings from scores.

Rank	Score
0	0
1	1 – 330
2	331 – 1,090
3	1,091 – 2,020
4	2,021 – 4,400
5	> 4,400

2.3.1.3.2 Exposure Potential

Physical exposure is calculated using the inputs of site accessibility (*access* in AMLUDB), current land use (*luCur* in AMLUDB), anticipated future land use (*luFut* in AMLUDB) and population proximity (*popProx* in AMLUDB).

Conceptually, the score is just the summation of the weighted values assigned to each of the categories. For physical hazard exposures, ease of access to the site and the land use of the site are the most important criteria. A site that is essentially in a residential area and that is easily accessed, presents the greatest potential for exposure.

Table 2.4: Access field descriptions, internal coding and corresponding values.

Description	Code	Value
Easy	A	20
Moderate	B	10
Difficult	C	5

Table 2.5: Field descriptions, internal coding and corresponding values for luCur.

Description	Code	Value
Residential	A	20
Recreational / Open Space	B	10
Commercial	C	5

Table 2.6: Field descriptions, internal coding and corresponding values for luFut.

Description	Code	Value
Residential	A	5
Recreational / Open Space	B	3
Commercial	C	1

Table 2.7: Field descriptions, internal coding and corresponding values for popProx.

Description	**Code**	**Value**
= 100,000	A	5
< 100,000 and = 10,000	B	3
< 10,000	C	1

The *physical exposure* score is simply calculated by adding the assigned values for each of the four fields above. This gives a "raw" exposure score. These scores are then categorized into rankings 1–4.

Table 2.8: *Physical exposure* rankings from scores.

Rank	**Score**
1	0 – 22
2	23 – 32
3	33 – 39
4	40 – 50

2.3.1.4 Physical Risk Category

This *physical risk category* is determined by the combination of the *physical hazard ranking* and the *physical exposure ranking*. The following matrix was used to assign the overall *physical risk category*:

Table 2.9: *Physical risk category* from hazard and exposure rankings.

		Hazard					
		0	**1**	**2**	**3**	**4**	**5**
Exposure	**1**	0	1	1	2	3	5
	2	0	1	2	3	4	5
	3	0	1	3	4	5	5
	4	0	2	4	4	5	5

2.3.1.5 Chemical Hazard Evaluation

The *chemical hazard evaluation* is comprised of two principle components, the *chemical hazards inventory* which is done in the field, and the *exposure potential* which is a combination of field work and GIS analyses.

The principle source of data on chemical conditions is the field inventory form. Examples of the type of data collected include, but are not limited to: pH, conductivity, ReDox and temperature of water and soils; extent and condition of vegetation; soil texture; and the character and quantity of mining wastes.

2.3.1.5.1 Hazard Scoring

The *chemical hazard scores* are heavily weighted toward documented cases of acid rock drainage (ARD) or heavy metals leaching. Following ARD as a driver is the volume of mill tailings on site. Mill tailings are likely to contribute to heavy metals (or other toxins) due to fine particle size and high likelihood of remnant toxins from the milling process (mercury, cynanide, etc.). If nothing else, they can still present a significant sedimentation problem. Finally, the scores take into account volumes of waste rock. Waste rock is less likely to pose a significant problem than either of the above. However, large volumes may present similar problems to mill tailings, especially if the rock is acid-generating, contains high levels of metals, or asbestos fibers.

The above is then modified by the type of commodity mined (metallic, non-metallic, aggregate) and where the processing occurred. Generally, a site with a metallic commodity and on-site processing facility is more likely to present chemical hazards than an aggregate operation where processing was done off-site.

The specific fields used from the AMLUDB to calculate the *chemical hazard score* are volume of tailings (*chemApr1*), volume of waste rock (*chemApr2*), the degree (*chemApr3*) and frequency (*chemApr3F*) of ARD or metals leaching, and the commodity/processing group (*comProc*).

The volume of mine tailings is given as a range, which is assigned a value. This value is then multiplied by 50 and added to the *chemical hazard* score.

Table 2.10: Description, internal coding and values for chemApr1.

Description	Code	Value
< 50 cu yds	A	0
50 to 250 cu yds	B	1
250 to 500 cu yds	C	3
500 to 1000 cu yds	D	4
1,000 to 10,000 cu yds	E	8
10,000 to 100,000 cu yds	F	12
> 100,000 cu yds	G	17

The volume of waste rock is given as a range, which is assigned a value. This value is then multiplied by 10 and added to the *chemical hazard* score.

Table 2.11: Description, internal coding and values for chemApr2.

Description	Code	Value
< 50 cu yds	A	0
50 to 250 cu yds	B	1
250 to 500 cu yds	C	2
500 to 1000 cu yds	D	3
1,000 to 10,000 cu yds	E	6
10,000 to 100,000 cu yds	F	10
> 100,000 cu yds	G	15

The degree of metal leaching (*chemApr3*) may be a number from 0 to 4, with four being the most significant. This value is then multiplied by the frequency of metal leaching occurences (*chemApr3F*) for the site, and then multiplied by 200 as a weighting factor. This subtotal is then added to the *chemical hazard* score.

The *chemical hazard* score is then multiplied by a modifier depending on the general type of commodity and where processing occurred. This multiplier is given with the matrix below. The processing location is given in the first row, and the commodity group is given in the first column.

Table 2.12: Commodity and Processing groups matrix.

	On-Site	Unknown	Off-Site
Metallic	10	7	5
Non-Metallic	7	5	3
Aggregate	3	2	1

This "raw" *chemical hazard* score is then grouped into rankings using the following ranges.

Table 2.13: *Chemical hazard* rankings from scores.

Rank	Score
0	0
1	1 – 100
2	101 – 2,499
3	2,500 – 11,999
4	12,000 – 23,000
5	> 23,000

2.3.1.5.2 Exposure Potential

The *chemical exposure* score is calculated using the *physical exposure* score with additional parameters to capture offsite effects. The additional parameters are mine waste in contact with surface flows (*chemApr5*), the stream class for mine waste contact (*chemApr4*), wind or water erosion evidence (*chemApr6*), distance range to surface water (*swDist*), estimated sedimentation category (*swSed*), and the percentage of vegetative cover on-site compared to off-site.

Mine waste in contact with surface flow (*chemApr5*) is given by categories in the database. These categories are given a weighting value, which is then multiplied by the stream class for mine waste contact (*chemApr4*). This score is then added to the ranking for wind or water erosion (*chemApr6*). This subtotal is then multiplied by two and added to the *chemical exposure* score. Stream classes can be, 0 for no stream (in which case the *chemApr5* score should also be the bottom range), 1 for small/intermittent, 2 for medium perennial, and 3 for large perennial. The wind or water erosion ranking (*chemApr6*) may be a value from 0 to 4, with four indicating the greatest amount of wind or water erosion.

Table 2.14: The descriptions, internal codings and weighting values given for chemApr5

Description	Code	Value
< 50 cu yds	A	0
50 to 250 cu yds	B	1
250 to 500 cu yds	C	2
500 to 1000 cu yds	D	3
1000 to 10,000 cu yds	E	6
10,000 to 100,000 cu yds	F	10
> 100,000 cu yds	G	15

The weighted values for distance to surface water and surface water sedimentation are then added to the *chemical exposure* score. Distance to surface water is given as one of four categories (< 500 ft., 500 to 1000 ft., 1000 to 2000 ft., and > 2000 ft.) which are each assigned a score (2, 1, 0, 0, respectively). Surface water sedimentation is given as a qualitative ranking (high, medium, low) which is assigned a score (2, 1, 0, respectively).

Both on-site (*vegOn*) and off-site (*vegUn*) average vegetative cover are stored as ranges of values. To be able to make a comparison between them, the midpoint for each range is taken and then a percent difference is calculated as 100 × [(off-site – on-site) / off-site]. This percent difference is then added to the *chemical exposure* score.

Finally, the "raw" *chemical exposure* score is produced by adding all of the above to the *physical exposure* "raw" score. If there are any off-site effects indicated by this score, then it will be greater than the corresponding *physical exposure* score. The score is then broken into rankings using the following ranges:

Table 2.15: *Chemical exposure* rankings from scores.

Rank	Score
1	0–19
2	20–30
3	31–50
4	51–70
5	> 70

2.3.1.5.3 Chemical Risk Category

This *chemical risk category* is determined by the combination of the *chemical hazard ranking* and the *chemical exposure ranking*. The following matrix was used to assign the overall *chemical risk category*:

Table 2.16: *Chemical risk category* from hazard and exposure rankings.

		Hazard					
		0	**1**	**2**	**3**	**4**	**5**
Exposure	**1**	0	1	1	1	2	3
	2	0	1	1	2	3	3
	3	0	1	2	3	3	4
	4	0	1	2	3	4	5
	5	0	2	3	4	5	5

2.3.2 Statistical Modeling

Since all 30,000 mineral occurrences located throughout the state could not be visited within the timeframe of the current project, statistical modeling was used to make extrapolations about the characteristics these mineral occurrences by using a small (but representative) sample of the total population of mines. A limited sample of mineral occurrences was taken, and the response of that sample to the measured parameters (PAR score, based on site characteristics) was determined, and that response was used to predict how the rest of the population (all mines) would likely respond to the same parameters. A good model explains a large portion of the variation in the data (with high r^2 values and low p values), and produces improved estimates of response probabilities (means with confidence limits).

Standard statistical methods have long employed regression analysis for continuous data (e.g., 1, 2, 3), but only recently have statistical methods for regression-type models of categorical data been refined. This advancement in statistics was lead by the social sciences, which frequently dealt with categorical data (e.g., race, sex, emotional responses). The data available for this "abandoned mine model" are largely categorical data, only occasionally continuous. The

Generalized Linear [Regression] Model (GLM), first introduced by Nelder and Wedderburn (1972), best fits this data. Based on the distribution of the random components in our data (which most often fit a Poisson distribution, occasionally normal), a Logistic or Loglinear GLM was determined to be the most appropriate (Agresti 1990). Resulting models were developed by AMLU using STATGRAPHICS (1997) software.

The data available for modeling the magnitude and scope of abandoned mines in California are those data that exist statewide, or those that can be created statewide. The following data sets are available for this model: MAS/MILS (USGS) and MINEFILE (DMG), which are very similar, therefore, only the former was used; 750K Geological GIS Layer (DMG); PAMP GIS Layer (AMLU), and USGS topographic mine symbols (AMLU). In other words, while better models may be created on a regional scale using information from other more detailed sources, the only data that are available for the final models are those data that exist in one of the aforementioned statewide databases.

For most of the analyses, coding of attribute data from the various input data sources was used. So that figures and tables will make sense, these coding systems are described here.

Three of the fields in MAS/MILS were often used in the modeling. The "TYP" field indicates the type of mine, the "COM1" field indicates the primary commodity, and the "CUR" field indicates the status of the mine. Their coding is shown below.

Table 2.17: Coding of MAS/MILS Mine Type ("TYP").

TYP_CODE	**TYP**
0	No Data
1	Placer
2	Unknown
3	Surface
4	Underground
5	Surface-Underground

Table 2.18: Groupings ("COM_GROUP") of MAS/MILS Commodity Types ("COM1").

METALLIC	**NON_METALLIC**	**STONE**	**AGGREGATE**	**OTHER**
aluminum	asbestos	abrasives	gravel	geothermal
antimony	barite	calcium	pumice	natural gas
arsenic	borax	clay	sand	nitrogen
beryllium	boron	diatomite		petroleum
chromium	bromine	feldspar		
cobalt	coal	gemstone		
copper	columbium	graphite		
gold	fluorine	gypsum		
iron	germanium	kyanite group		
lead	lithium	mica		
magnesium	phospate	perlite		
manganese	rare earth	potash		
mercury	strontium	quartz		
molybdenum	sulfur	silicon		
nickel	thorium	sodium		
platinum group	uranium	stone		

METALLIC	NON_METALLIC	STONE	AGGREGATE	OTHER
scandium	zirconium	talc		
silver		vermiculite		
tin		wollastonite		
titanium		zeolite		
tungsten				
zinc				

Table 2.19: Coding for MAS/MILS "CUR" Mine Status Attribute.

CUR_CODE	CUR
1	Raw Prospect, Mineral Location
2	Developed Deposit, Unknown, Explored Prospect
3	Past Producer, Producer

Sites used in the modeling that were also PAMP sites were given a boolean (yes/no) membership code. Topographic mine symbol features were grouped as openings, waste and prospects.

3 Watershed Studies

As described in the methods chapter, in order to estimate the number of abandoned mine sites, features and hazards, a sampling protocol was developed. Each of the following study areas contain a brief description of the area, it's mining history, summary results of analyses from data collected and models with estimates for the total number of sites, features and associated chemical and physical hazards. For each of the watersheds, unique models were developed for estimating chemical and physical hazards. As such, the models are only valid for the particular watershed. In the next chapter, an attempt is made to aggregate all of the watersheds to develop statewide models.

In addition to attempting to rank sites and cumulative scores for physical and chemical hazards, predictions of the number of hazardous openings for each watershed were made. A hazardous opening is defined as an opening (shaft, adit, drift, decline, tunnel, etc.) that is large enough and deep enough for someone to become trapped in or from which a fall could cause serious injury. For this purpose, a depth or length of 10 feet is used.

In addition to the reports listed here, staff visited a number of sites in various parts of the state. These sites generally were visited in a non-random fashion at the request of landowners or other interested parties, or because the visits predate the development of the sampling methodology. Hence, these sites could not be included in the analyses. However, they provided valuable background on the range of issues present. The Herlong watershed was sampled according to protocol and was originally designated to be a part of this study. However, access restrictions and the inability to find sites limited the resulting set to a small and fairly homogenous group. Because of this, no analyses could be performed.

A short summary of the estimated hazards for all of the watersheds is provided at the end of this chapter.

3.1 Alameda Creek

Alameda Creek Watershed is in the Diablo Range of the Central Coast Ranges, immediately south east of San Francisco Bay. The northern portion of the watershed is dominated by the Livermore Valley, which is easily accessed by Interstate Highways 80 and 680. South of the Livermore Valley, the watershed encompasses steep rugged terrain with peaks in excess of 4,000 feet (msl), is sparsely populated and is accessed by the north-south running Mines / San Antonio Valley Road. Land ownership and management is almost exclusively private, with the next largest land holder being local park districts.

Table 3.1: Land ownership summary.

Ownership	Agency	Acres	Percent
Federal	BLM	1,684	
	DOD	2,561	
Sum		4,245	1.0
State	Fish & Game	28	
	Parks & Recreation	1,309	
	Univ. Cal	3,123	
Sum		4,460	1.1
Local	Parks	5,823	
Sum		5,823	1.4
Private		390,060	
Sum		390,060	96.4
TOTALS		*404,588*	*99.9*

The Alameda Creek Watershed is approximately 404,588 acres in size, encompassing 1,102 miles of mapped streams, of which 409 miles are named. Eighty-two percent of the streams occur near or along side roads. Alameda Creek is approximately 33 miles long. The watershed contains three reservoirs, Lake Del Valle, Calaveras, and San Antonio. Precipitation averages 20.65 inches per year.

The Alameda Creek Watershed contains three streams that have been listed as impaired under section 303(d) of the Federal Clean Water Act. They are Alameda Creek, Arroyo Valle, and Arroyo Hondo (Figure 3.1). EPA has rated this watershed as a level 2 watershed, i.e. better water quality, but highly vulnerable.

The Alameda Creek Watershed includes portions of the San Francisco Bay Area (SnFrB) and San Joaquin Valley (SnJv) biological subregions, which are components of the Central Western California (CW) and Greta Central Valley (GV) bioregions, respectively, as defined in the Jepson Manual (Hickman 1993).

This watershed may provide habitat for as many as 30 threatened or endangered plants, 6 threatened or endangered animals , and 15 animal species of concern, including the Pale Big-Eared Bat.

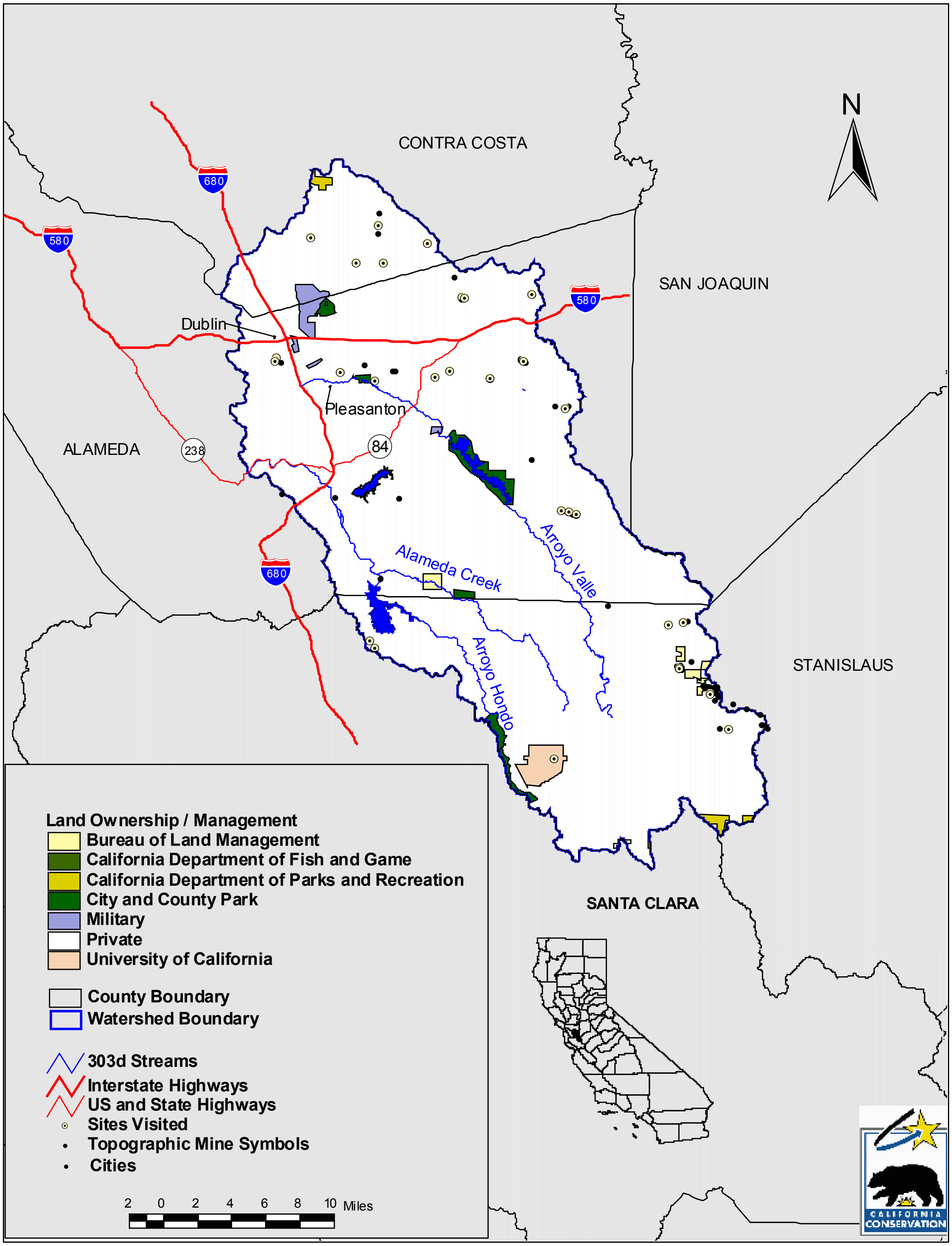


Figure 3.1: Area map for the Alameda Creek Watershed.

The Alameda Creek Watershed lies within the northern portion of the Diablo Range. Structurally, the geology is controlled by the intrusion of older Franciscan Formation complex through younger sedimentary rocks along northwest-southeast trending faults. This intrusion or piercement has resulted in a crude domal structure with older Franciscan Formation rocks exposed at its core, flanked by younger nonmarine and marine sedimentary rocks. In the Livermore Valley these rocks are overlain by several hundred feet of ice-age to recent alluvium that forms the highly productive aquifer of the Livermore Valley and the prospering construction materials industry.

The importance of this structure is that the piercement process along the faults led to serpentinization of the marine sediments and the emplacement of ultramafic rock complexes that were the source of the hard-rock minerals mined in the watershed. In addition, the forces giving rise to the intrusion of the Franciscan Formation complex, also led to localized folding and faulting that exposed the coal, glass-sands, and clays that were also mined in the watershed.

3.1.1 Short History of Mining

Mining in the watershed can be broken down into three broad categories, coal, strategic minerals, and construction materials.

Coal was, for a short time, important to the regional economy. Coal was discovered in the Corral Hollow region around 1857. These deposits were traced back into the watershed along Arroyo Seco, and production began in earnest by 1897. Production continued at a steady pace until 1902, when infrastructure development was sufficient to bring in cheaper coal from outside the region (Huguenin and Castello, 1920, Davis 1950).

The term strategic minerals is used herein for minerals of military importance, and include chromite, manganese oxides, and magnesite. These minerals are sources of chromium, manganese, and magnesium, which are key components in weapons-grade steel and light-weight alloys. The production history of these minerals reflects America's history of involvement in major conflicts. Discovery and evaluation of these minerals occurred between 1880 and 1885. By 1886 several localities were engaged in small-scale production (one or two-man operations). With the onset of World War I, strategic minerals mining experienced its first boom. However, by 1919 demand ceased and mining essentially halted (Huguenin and Castello, 1920, Bradley, 1925, Davis 1950, Trask, 1950).

There was one exception, the magnesite deposits on Red Mountain (Red Mountain District). The Red Mountain District hosted the highest-grade and most massive magnesite deposits in the region. Prior to 1919 there had been up to ten different companies working properties or leases in the Red Mountain District. By 1919 the different claims and leases had been consolidated by the Western Magnesite Company and the mine complex is now simply referred to as Western Mines. The size and quality of the deposits enabled Western Mines to continue operating even after the other mines had ceased production.

With the onset of World War II, the region once again experienced an upswing in the demand for strategic minerals. And like before, by wars end, the demand disappeared. Even the Western Mines was not immune from this downturn. The development of technology to extract magnesium from sea water made terrestrial mining of magnesium uneconomical and Western Mines closed in 1947 (Davis 1950, Trask, 1950).

However, mining in the region experienced transition and growth with the post-war population boom. The sudden influx of people to the region created an unprecedented demand for construction materials (Davis 1950). Aggregate, building stone, common clay (sewer and water pipes), and silica sand (glass and filter media) were all produced in the watershed. These materials are in even greater demand today as the region's population continues to grow.

3.1.2 Current Mining

Active mining within Upper Alameda Creek Watershed is limited to 15 operations producing various construction materials.

3.1.3 Sample Study

This evaluation of the Alameda Creek Watershed is based upon a statistical sampling of abandoned mine lands within the watershed. The sample design employs a stratified random approach in which the population, in this case abandoned mines, is subdivided into relatively homogeneous groups or strata. Geologic conditions control the type and distribution of ores, thus areas of uniform (homogeneous) geology should lead to very similar (homogeneous) types of mines. Therefore, geologic associations were used to delineate the sample strata. Mine symbols shown on United States Geologic Survey (USGS) Topographic maps were used as the "population" to be sampled. All total, 28 sites were selected for evaluation.

3.1.3.1 Watershed Summary: Results of Analysis and Modeling

The sampled sites were evaluated for chemical and physical hazards and then ranked by the severity of each type of hazard. These rankings were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see section 2).

Table 3.2: Field verified chemical hazard rankings.

Rank	**Count**	**Percent**	**Definition of Rank**
0	20	71	No probability of releasing hazards into the environment
1	0	0	Very low probability of releasing hazards into environment
2	6	22	Low probability of releasing hazards into environment
3	2	7	Moderate probability of releasing hazards into environment
4	0	0	High probability of releasing hazards into environment
5	0	0	Very high probability of releasing hazards into environment
Total	*28*	*100*	

Table 3.3: Field Verified Physical Hazard Ranking Numbers

Rank	**Count**	**Percent**	**Definition of Rank**
0	16	57	No physical hazards
1	4	14	Very few physical hazards
2	5	18	Few physical hazards
3	2	7	Moderate amount of physical hazards
4	0	0	Large amount of physical hazards
5	1	4	Very large amount of physical hazards
Total	*28*	*100*	

3.1.3.2 Predicted Chemical Hazard Rankings

The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model allowing for a combination of categorical and quantitative data to be used. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r^2=79%, $p<0.0001$) were then applied to the MAS/MILS occurrences within the watershed. The analyses utilized the field generalized commodity from the MAS/MILS database (COM1); the rock type (Rocktype#) from the state geologic map; and membership in the Principle Areas of Mine Pollution database. Results of the regression model for *chemical hazards* and its components are displayed below. The cumulative chemical hazard ranking score for this watershed is 245, which indicates a very low probability that abandoned mine sites pose a significant chemical threat to the environment.

Table 3.4: Summarized statistics for the chemical hazard GLM.

Analysis of Variance for CHEMICAL HAZARD

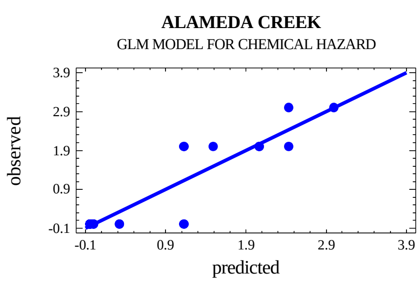
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	25.36	6	4.23	17.50	0.0000
Residual	5.072	21	0.24		
Total (Corr.)	30.43	27			

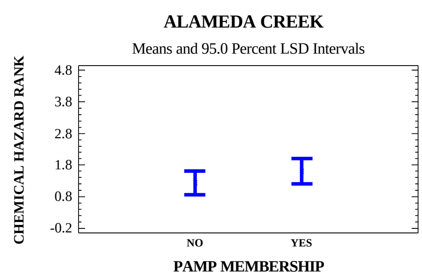
TYPE III Sums Of Squares

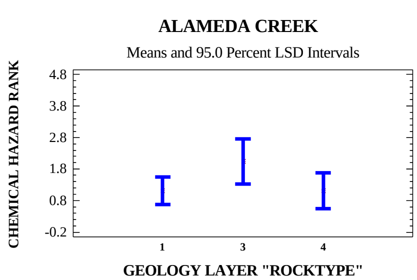
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	0.48	1	2.37	1.98	0.1740
ROCKTYPE#	1.86	2	0.93	3.84	0.0378
COMM_GROUP	7.10	3	2.37	9.79	0.0003
residual	5.07	21	0.24		
Total (Corr.)	30.43	27			

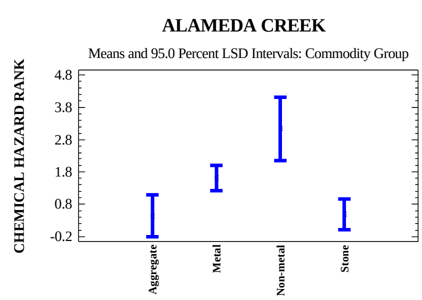
All F-ratios are based on the residual mean square error.
R-Squared = 83 percent
R-Squared (adjusted for d.f.) = 79 percent

The following graphs depict the tests among means for each component of the above GLM regression analysis.









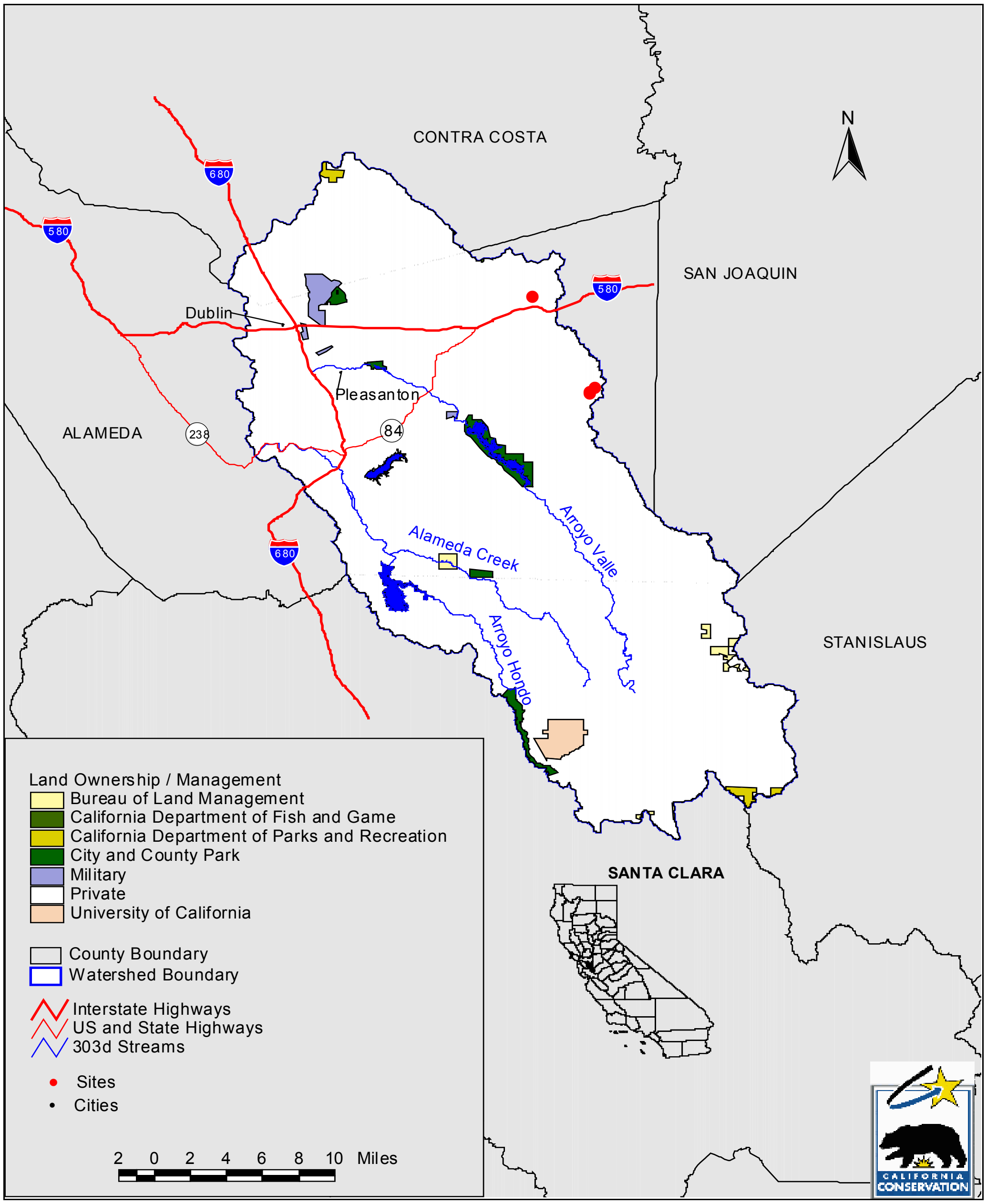


Figure 3.2: Chemical hazard predictions of rank 3 or above for MAS/MILS mineral occurrences.

Table 3.5: Chemical hazard predictions for MAS/MILS mineral occurrences.

Rank	Count	Percent	Definition of Rank
0	41	29	No probability of releasing hazards into the environment
1	80	57	Very low probability of releasing hazards into environment
2	16	11	Low probability of releasing hazards into environment
3	4	3	Moderate probability of releasing hazards into environment
4	0	0	High probability of releasing hazards into environment
5	0	0	Very high probability of releasing hazards into environment
Total	*141*	*100*	

3.1.3.3 Predicted Physical Hazard Rankings and Hazardous Openings

The *physical hazard ranking* could not be predicted. However, the number of hazardous openings were predicted by simple regression analysis. The predictive model utilizes the topographic openings from the AMLU digitized mine symbols database (r^2=93%, $p<0.0338$). The total number of hazardous openings for the Alameda Creek Watershed is estimated to be 104.

3.1.4 Summary of Findings

In this watershed there is a low probability for a site which presents a significant chemical hazard, and cumulatively, the AML sites in the watershed do not pose a significant chemical threat to the environment. We were unable to predict the physical hazards. And the watershed as a whole is estimated to have 104 hazardous openings.

Table 3.6: Summarized findings for the Alameda Creek Watershed.

Watershed Area (Acres)	404,588
Predicted Cumulative Chemical Ranking Score	245
Predicted Cumulative Chemical Ranking Score Density	0.001
Predicted Cumulative Physical Ranking	Unable to Predict
Predicted Hazardous Openings	104

3.2 Chemehuevis Watershed

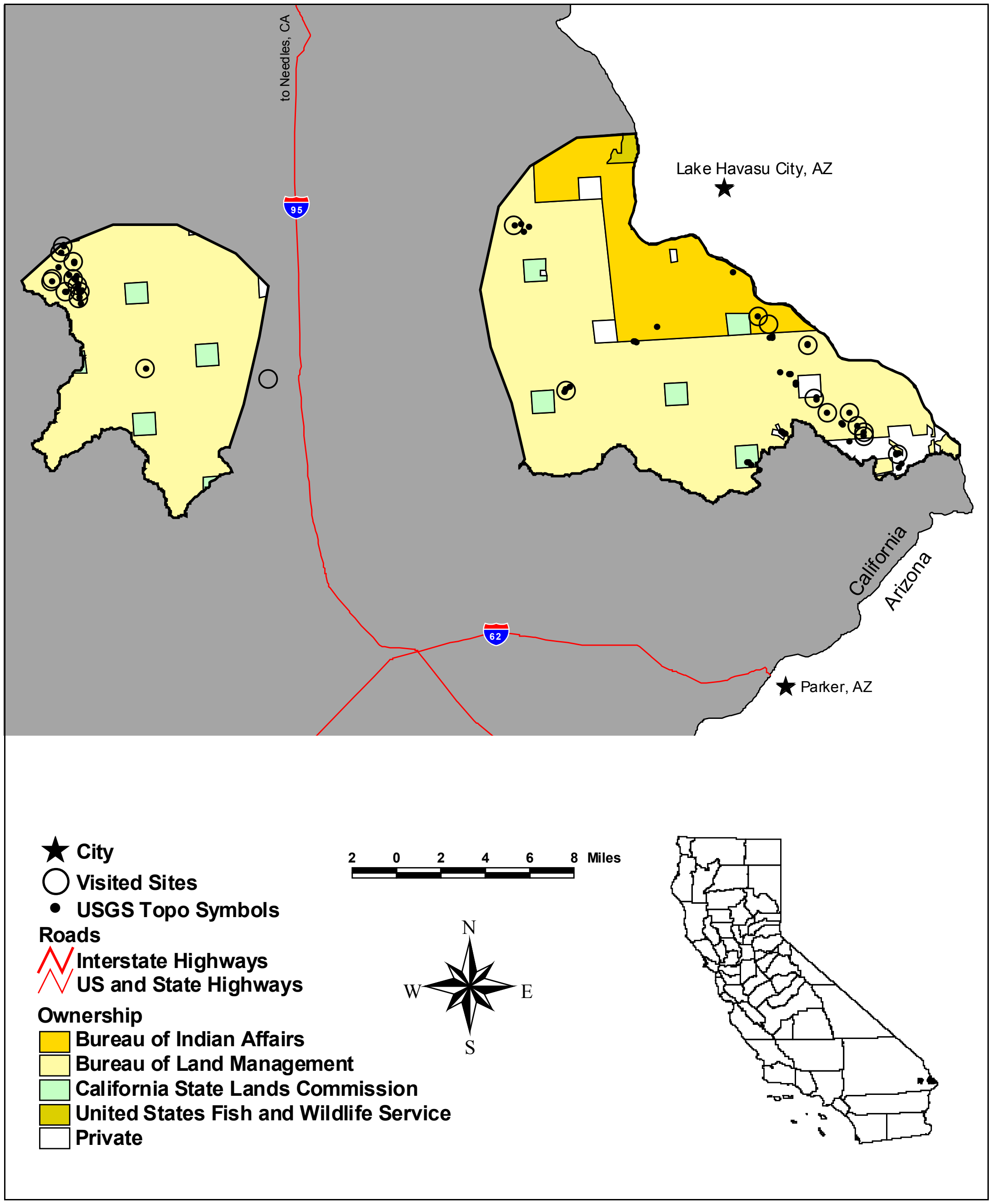


Figure 3.3: Chemehuevis Watershed Study Area Map.

The Chemehuevis Watershed (a subset of the Southern Mojave Watershed) lies along the California-Arizona border in the Sonoran Desert (Dson) bioregion, according to the Jepson Manual (Hickman 1993). The study area is divided into two parts by a strip of land designated as Mojave Desert, which was not included in this study because it is part of a different bioregion. The federal government owns the vast majority of the land with BLM ownership being greatest, followed by BIA and US Fish and Wildlife. State and private lands make up a small amount of the total ownership of the watershed. Highway 95 between Interstate 40 and Interstate 10 is fairly busy, but few people venture off the highway into the surrounding hills. However, the watershed does have a lot of OHV traffic near the Colorado River side of the watershed as well as a few small resort communities such as Havasu Palms and Black Meadow Landing.

Table 3.7: Chemehuevis Watershed Land Ownership Summary.

Government Level	Agency	Acres	Percent
Federal	BLM	138,957	78.64
	US Fish and Wildlife	746	0.42
	BIA	25,571	14.47
Sum (Federal)		165,274	93.53
State	State Land Commision	5,350	3.03
Private	Private	6,047	3.42
Sum (Total)		*176,671*	*100.00*

The climate of the watershed is very hot and arid. The mean annual precipitation is about 3 to 5 inches. Most of the precipitation falls during the winter and spring months with very little precipitation in the summer and fall months.

The watershed is bordered on the south by the Vidal Valley, on the north by the Chemehuevi Mountains and the Stepladder Mountains, on the west by the Turtle Mountains, and on the east by the Colorado River and the Arizona border. The west side of the watershed drains into the Chemehuevi Wash which ultimately drains into the Colorado River in the east. The east side of the watershed drains directly into the Colorado River. The runoff is rapid from the mountains and slower on the alluvial fans. There are no perennial streams in the watershed; most only flow after very heavy rains.

The elevation of the watershed ranges from 500 feet on the Colorado River to about 4,000 feet in the Turtle Mountains and the Whipple Mountains. The geomorphology of the area ranges from very gentle to moderately sloping alluvial fans, moderately steep hills, and steep, near-vertical mountains. The watershed is dominated by the creosote bush series with ocotillo and a few varieties of cholla throughout the area (Hickman 1993) The larger washes in the watershed support riparian woodlands, where blue palo verde, ironwood, and smoke tree thrive.

The Geology of the field area includes Cenozoic (Quaternary and Tertiary) unconsolidated to semiconsolidated non-marine deposits, Cenozoic (Holocene) unconsolidated non-marine deposits, Cenozoic through Precambrian volcanic and metavolcanic rocks, Cenozoic through Precambrian granitic and associated intrusive rocks, and Cenozoic through Precambrian marine sedimentary and metasedimentary rocks. The Cenozoic unconsolidated non-marine deposits consist of alluvial fan and fluvial system sediments. Cenozoic through Precambrian volcanic and metavolcanic rocks are basalt flows, rhyolite flows, and flow breccias containing tuffaceous sediments. The Cenozoic through Precambrian granitic and associated intrusive rocks include a metamorphic core complex exposed in the Whipple Mountains by a low-angle normal [detachment] fault. This core complex is mostly gneissic and mylonitic basement rock. Other rocks that fall into this category include granite, diorite, and monzanite, as well as a wide range of felsic and mafic dikes. Cenozoic through Precambrian marine sedimentary and metasedimentary rocks include a fanglomerate, metasedimentary gneiss, mudstone, siltstone, sandstone and limestone.

3.2.1 Short History of Mining

The first gold and copper mining was recorded in the Turtle Mountains in 1862. One report states that Mexican citizens were operating the Sablon gold mine in the Turtle Mountains in the 1880's — using mules to haul ore to the railroad. Robert A. Martin took over mining this area in the early 1900's and supported himself until the 1950's by shipping high-grade ore from the various sites he prospected in the area. Exploration in the area increased dramatically when gold prices were deregulated by the government in 1972, and several small mines were developed as a result of these investigations.

Some reports indicate that mining in the Whipple Mountains began as early as 1862, when some copper extraction occurred in the Copper Basin area. Relatively high levels of copper production continued at several mines in this area until the 1940's. Manganese production started in the area around World War I and continued into the 1950's. Silver production at the Black Metal Mine started in 1879 and spawned a thriving community in the area. This prodigious production continued until 1890, and production continued sporadically until 1942. Gold production in the Whipple Mountains got started around the turn of the century, and by 1911 the Klondike Mine was producing hundreds of tons of high-grade ore. Gold production for the region was sporadic from 1900–1950, and the only recorded production since then was at the Bessie Mine in 1979. In general, mining activity in the Whipple Mountains was highest in the first half of this century due to the discovery of several large metallic deposits and newfound manganese production driven by the war effort.

3.2.2 Current Mining

Currently there is no active mining in the area.

3.2.3 Sample Study

The Chemehuevis Watershed was chosen at random from a larger dataset of Bioregions (Jepson) for study. Topographic mining symbols were digitized from the 25 USGS 7.5 Minute topographic maps encompassing the watershed, and the geology (DMG 750k) was spatially analyzed by major "Rocktype". It was determined that with the exception of abandoned or inactive borrow pits, and sand and gravel operations, only five rocktypes occurred in conjunction with a mine symbol. These rockypes include Cenozoic (Quaternary & Tertiary) unconsolidated to semiconsolidated non-marine deposits, Cenozoic (Holocene) unconsolidated non-marine deposits, Cenozoic through Precambrian volcanic and metavolcanic rocks, and Cenozoic through Precambrian granitic and associated intrusive rocks. For each rocktype, ten topographic symbols were randomly selected for field inventory. For the rocktypes that contained less than ten symbols, all of the symbols were selected. All of the Principle Areas of Mine Pollution (PAMP) mine locations were selected since only 2 occurred in the watershed. This selection resulted in 33 symbols representing 28 sites. AMLU staff field verified 24 sites consisting of 28 of the selected symbols in the watershed. The four remaining sites (five symbols) were unable to be cataloged due to access and time constraints.

3.2.3.1 Watershed Summary: Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard.

Table 3.8: Field verified Chemical Hazard Ranking Numbers.

Rank	Count	Percent	Definition of Rank
0	14	58	No probability of releasing hazards into the environment
1	4	17	Very low probability of releasing hazards into the environment
2	6	25	Low probability of releasing hazards into the environment
Total	*24*	*100*	

Table 3.9: Field verified Physical Hazard Ranking Numbers.

Rank	Count	Percent	Definition of Rank
0	6	25	No physical hazards
1	2	8	Very few physical hazards
2	9	38	Few physical hazards
3	3	13	Moderate amount of physical hazards
4	2	8	Large amount of physical hazards
5	2	8	Very large amount of physical hazards
Total	*24*	*100*	

3.2.3.2 Predicted Chemical Hazard Rankings

These rankings were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see section 2). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model allowing a combination of categorical and quantitative data to be used. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r^2=66%, p=0.0001) were ~~are~~ then applied to the MAS/MILS records occuring within the watershed. The fields from the MAS/MILS database utilized for the modeling are current status (CUR), Mine type (TYP), and PAMP Membership. The results of the regression model for *chemical hazards* and its components are displayed below.

Table 3.10: Summarized statistics for the chemical hazard GLM.

Analysis of Variance of CHEMICAL HAZARD					
Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
Model	12.6692	5	2.53384	9.78	0.0001
Residual	4.66411	18	0.259117		
Total (Corr.)	17.3333	23			

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
CUR_CODE	1.58941	1	1.58941	6.13	0.0234
TYPE_CODE	5.47382	3	1.82461	7.04	0.0025
PAMP	1.3812	1	1.3812	5.33	0.033
Residual	4.66411	18	0.259117		
Total (Corr.)	17.3333	23			

R-Squared = 73.0917%
R-Squared (adjusted for Df) = 65.6171%
All F-Ratios are based on residual mean square error.

The following graphs depict the tests among means for each component of the above GLM regression analysis.

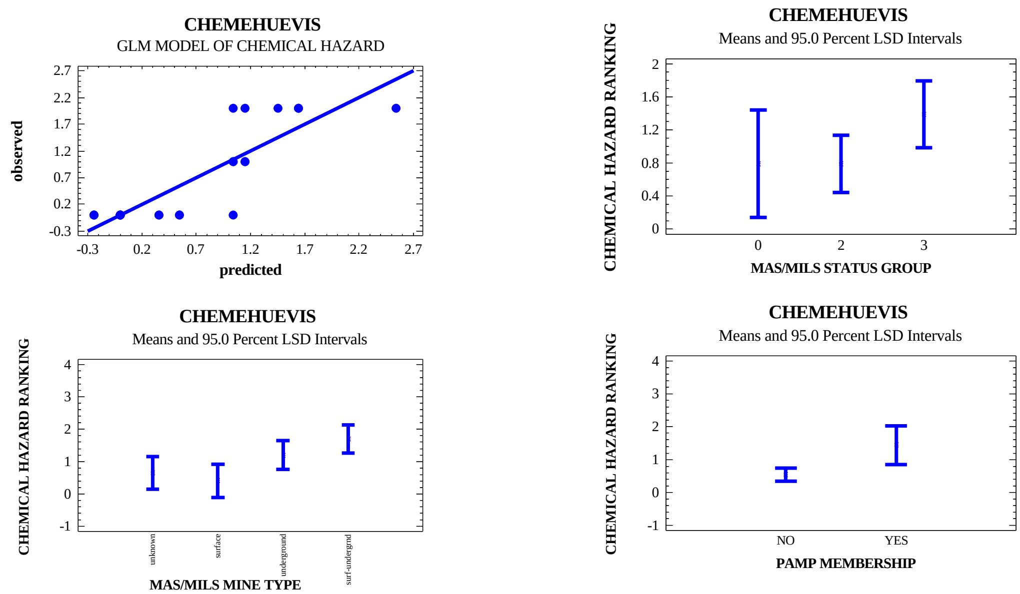


Table 3.11: Predicted Chemical Hazard Rankings for MAS/MILS Records.

Rank	Count	Percent	Definition of Rank
0	30	48	No probability of releasing hazards into the environment
1	27	43	Very low probability of releasing hazards into the environment
2	6	9	Low probability of releasing hazards into the environment
Total	63	100	

The results indicate that this watershed has a very low probability for a site, which presents a significant chemical hazard. The cumulative Chemical Hazard Ranking Score for the 176,710 acre watershed is 63, indicating that the AML sites in the watershed likely pose no cumulative chemical threat to the environment.

3.2.3.3 Predicted Physical Hazard Rankings

The *physical hazard ranking* was also predicted by regression analysis with a General Linear Model. The prediction model utilizes the field verified *physical hazards ranking*. The results of the predictive model (r^2=58%, p=0.0003) are then applied to the MAS/MILS database for the watershed using MAS/MILS database information about the mine type (TYP) and PAMP membership. The results of the regression model for *physical hazards* and its components are displayed below.

Table 3.12: Summarized statistics for the physical hazard GLM.

Analysis of Variance of PHYSICAL HAZARD

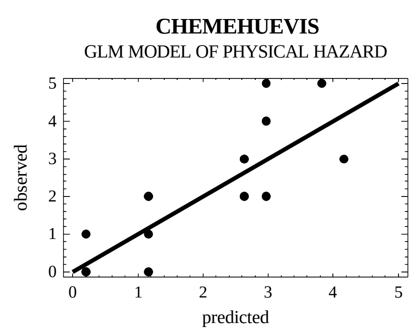
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	36.0574	4	9.01435	9.06	0.0003
Residual	18.9009	19	0.994786		
Total (Corr.)	54.9583	23			

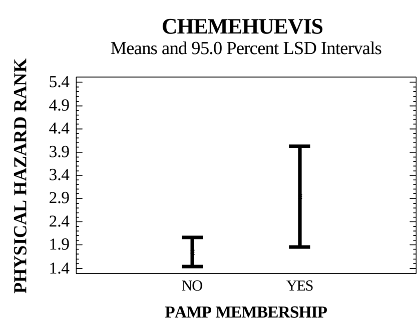
Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	2.42287	1	2.42287	2.44	0.1351
TYPE_CODE	26.9627	3	8.98757	9.03	0.0006
Residual	18.9009	19	0.994786		
Total (Corr.)	54.9583	23			

R-Squared = 65.6086%
R-Squared (adjusted for Df) = 58.3683%
All F-Ratios are based on residual mean square error.

The following graphs depict the tests among means for each component of the above GLM regression analysis.





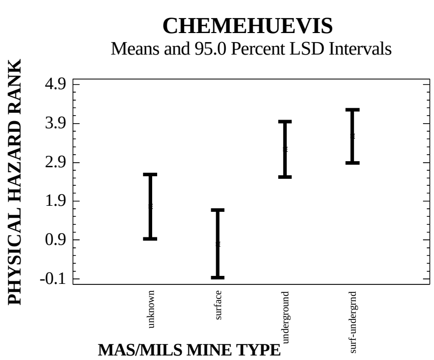


Table 3.13: Predicted Physical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent	Definition of Rank
0	21	33	No physical hazards
1	9	14	Very few physical hazards
3	33	53	Moderate amount of physical hazards
Total	*63*	*100*	

The results indicate that this watershed has a moderate probability for a site, which represents a significant physical hazard. The cumulative *physical hazard ranking* for the watershed is 1,098 — indicating that cumulatively the watershed likely poses a low threat of physical hazards.

3.2.3.4 Predicted Hazardous Openings

Twenty-one symbols indicative of an opening where shown on the topographic maps for the sampled sites and 22 prospect symbols were shown. Forty-six openings were verified in the field for these sites, and 46 (or 100%) were found to be potentially hazardous. The findings show that it is impossible to construct a predictive model for hazardous openings, but it is possible to construct a model for openings in general.

The number of opening can be predicted with an R-squared value of 71% at a $p<0.0001$ level using the number of openings shown on the topographic maps. The predicted number of openings in this watershed is 99. AMLU documented 46 openings within this sample set, of which 46 were hazardous. Using this same ratio (of hazardous to total), the estimated number of hazardous openings for this watershed is 99.

3.2.4 Summary of Findings

Table 3.14: Summarized findings for the Chemehuevis Watershed.

Total Watershed Area (Acres)	176,671
Predicted Cumulative Chemical Ranking Sore	63
Predicted Cumulative Chemical Ranking Score Density	.0004
Predicted Cumulative Physical Ranking	1,098
Predicted Cumulative Physical Ranking Score Density	.0062
Predicted Hazardous Openings	99

In this watershed there is a low probability for a site which presents a significant chemical hazard, and cumulatively, the watershed probably poses no chemical threat to the environment. Overall, in this watershed there is a low, yet significant, probability for a single site, which presents a significant physical hazard. In addition, there are many sites, each with a few hazards. The watershed as a whole does have a number of hazardous openings (estimated to be 99).

3.3 Clear Creek Watershed

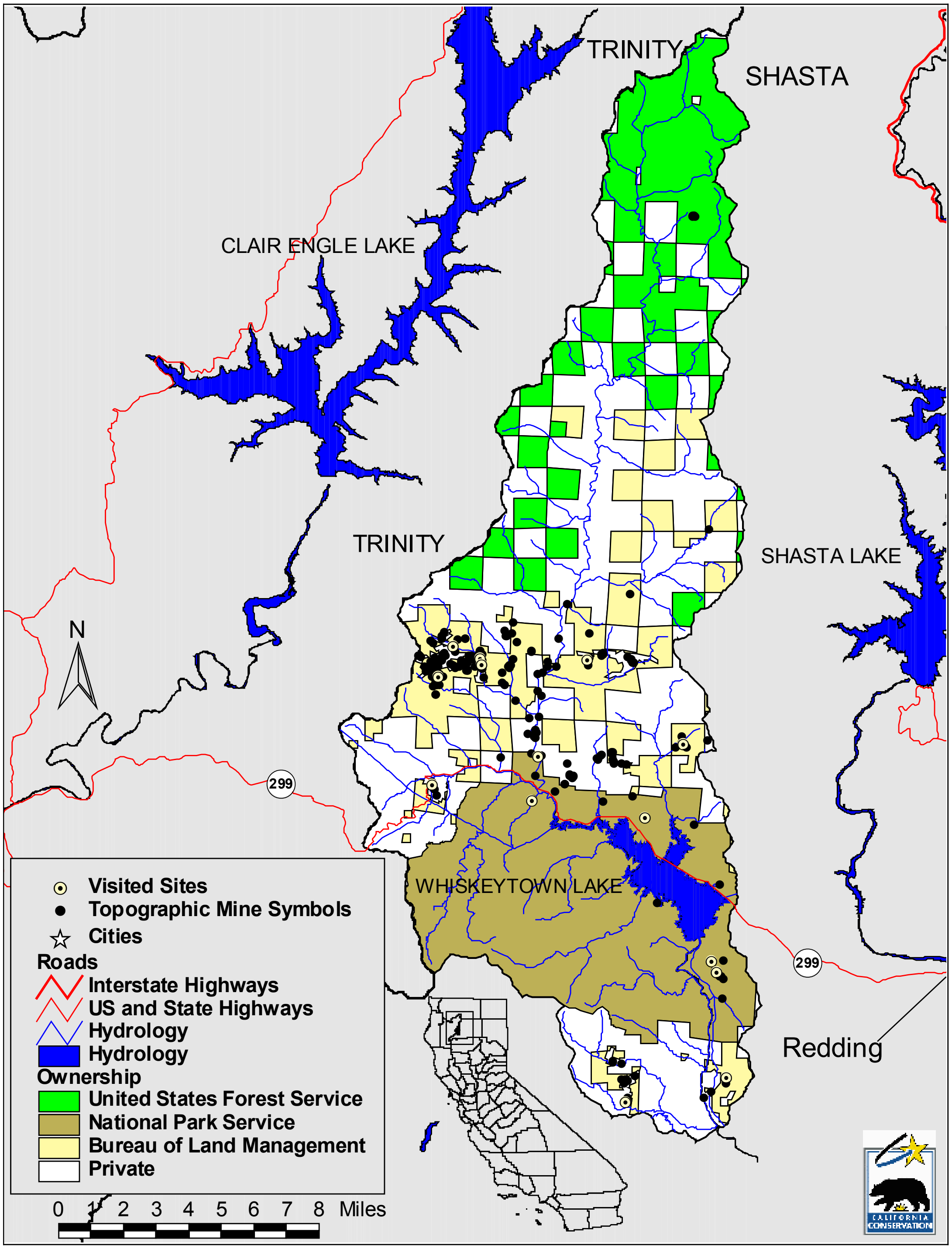


Figure 3.4: Clear Creek Watershed Area Map.

Clear Creek is a tributary to the Sacramento River located in west Shasta County. Its watershed encompasses an area bordered on the north and west by Trinity County, on the east by the Shasta Lake Watershed, and on the south by Tehema County. It is approximately 40 miles long, varies from one to ten miles wide, and is approximately 229 square miles in size. This watershed supplies Whiskytown Lake (Reservoir), and joins with the Sacramento River Watershed approximately 7 miles west of the confluence of Clear Creek and the Sacramento River. Whiskytown Lake provides water for consumption and domestic use to the city of Redding, which has a population of 78,490 (1995 estimate). It also provides water for the communities of Shasta, Keswick, Centerville, Happy Valley, and the Whiskytown National Recreation Area (WNRA). Each of these communities has a population less than 10,000, however the WNRA has reported annual park visitation of nearly a million (950,586 in 1994). In all, it is estimated that the Clear Creek Watershed may provide water to more than 100,000 residents and over a million annual visitors (Whiskytown NPS 1999).

Table 3.15: Clear Creek Watershed Land Ownership Summary

Government Level	Agency	Acres	Percent
Federal	USFS	24,724	17
	BLM	22,834	16
	Whiskytown NRA (NPS)	40,704	28
Sum (Federal)		88,262	60
State		0	0
Private	Private	58,312	40
Sum (Total)		*146,574*	*100*

The climate of this watershed varies widely as does the elevation. In the south where Lower Clear Creek joins with the Centerville and Sacramento River Watersheds, the elevation averages 700-800 feet, and the climate is characterized by hot, dry summers and mild winters. The annual average rainfall is 38 inches. In the Upper Clear Creek, the elevation ranges from 1,000 to 6,132 feet (Shasta Bally) with hot, dry summers and cool winters. The annual average rainfall within the watershed ranges from 60 to 80 inches and snowfall occurs during winter at the higher elevations (CERES 1998).

The Clear Creek Watershed encompasses an area bordered by the Cascade Range to the north and east, the Trinity Mountains to the west, Shasta Bally to the south, and the Great Central Valley to the southeast. The topography varies from gently rolling hills to steep mountains and narrow canyons. Clear Creek watercourses range from steeply graded and fast in the middle and northernmost reaches; and wide and slow near the southernmost confluence with the Sacramento River. The main tributaries to Clear Creek are: Cline Gulch, French Gulch, Sawpit Gulch, Mill Creek, Crystal Creek, Boulder Creek, Willow Creek, Brandy Creek, Whisky Creek, and Paige Boulder Creek. Clear Creek flows into Whiskytown Lake at the northwest and exits through the dam to the southeast. Colder lake water is diverted via the Spring Creek Tunnel to the Keswick Reservoir (and the Sacramento River) in an effort to enhance Salmon reproduction (Whiskytown NPS 1999). Willow Creek is listed as impaired under Section 303(d) of the Federal Clean Water Act. Clear Creek is listed as a Level 3 watershed (less serious problems, low vulnerability) by the USEPA (USEPA 2000).

The Clear Creek Watershed is comprised by the Klamath Ranges (KR) biological subregion, which is a component of the Northwest California (NW) biological region as defined in the Jepson Manual (Hickman 1992). The plant communities of this KR subregion vary by elevation across the watershed and include mixed chaparral, oak woodland, and grasslands; and mixed evergreen, oak and conifer forest as elevation increases. Ponderosa pine and white fir are the dominant conifers. Manzanita, ceanothus, toyon, and poison oak are dominate in the chaparral and oak woodland (Alden 1998). Some of the soils of this watershed are developed from granitic parent material and are highly erodable. Other soils were developed from metavolcanic and granitic rock, and vary in erodabililty depending on disturbance and slope (Whiskytown NPS 1999). Logging, wildfire, and mining activities have left surface disturbance that is characterized by moderate to severe erosion and the loss of soils favorable to re-forestation. This has allowed chaparral shrub species to proliferate in the previously forested areas. The riparian habitat is densely vegetated with pine, alder, willow, cottonwood, blackberry, sedges, rushes, ferns, and poison oak. The watershed has been severely impacted by streambed alterations caused by two dams and a large reservoir. In addition, the combinations of placer and dredging operations, and waste and tailings dumps in contact with the streambed have disturbed the natural hydrologic setting, caused sedimentation, and resulted in loss of aquatic and riparian habitat. Threatened and endangered species include Northern Spotted Owl, and Southern Bald Eagles (CERES 1998). Prior to dam construction and mining impacts, the Clear Creek Watershed supported anadromous fish (Salmon and Steelhead). Townsend's Big-Eared Bats, a species of special concern, have been reported at several abandoned mines in this watershed (Whiskytown NPS 1999).

The Clear Creek Watershed is located in the southeastern portion of the Klamath Range. The geology of the area encompasses metamorphosed silicic volcanics and pyroclastic deposits (Paleozoic Copley Greenstone, overlain by Balaklala Rhyolite); metamorphosed marine sedimentary rocks of the Paleozoic Bragdon Formation; and by the intrusions of the Mesozoic Shasta Bally batholith, which is primarily composed of biotite quartz diorite. The geologic formations within the watershed are extensively fractured and tilted due to faulting (Lydon and O'Brian 1974).

3.3.1 Short History of Mining

Gold was discovered along the banks of Clear Creek in 1848. A gold rush to the area followed as thousands of miners set up both large and small-scale placer and drift mining operations. By 1852, large quantities of lode gold were being mined in French Gulch, primarily at the Washington Mine. The Washington Mine was still active (but idle) at the time of visit. Other large gold mines in this area included the Old American, El Dorado, Gladstone, Brunswick, Niagara, Franklin and Milkmaid. Thousands of feet of underground workings were developed and an 18-stamp mill was in operation at the Niagara Mine by 1857. By 1869, the Washington Mine was operating a 22-stamp mill. Lode gold was also mined in quantity at Mad Mule and Mule Mountains, Whiskytown, and Igo. Hydraulic mining started in 1855 following construction of a mine ditch to deliver water. The major hydraulic mining sites for this watershed are located in an area south of Whiskytown. Dredging operations started in 1895 and continued until the 1950's mainly from Cline and French Gulch, and south to the lower reaches of the Clear Creek Watershed. The largest area of placer dredge tailings is just south of the watershed, at the confluence of Clear Creek with the Sacramento River. Some silver and platinum was also recovered as a by-product from the lode and placer gold mining and refining (Clark 1998). Most of the mines in the vicinity of Whiskytown were flooded when the reservoir was filled.

Mining of silver ore began at the Silver Falls-Chicago Mine in 1866. This area, known as the South Fork District, produced large quantities of silver. Other silver mines in this area were the Big Dyke, and White Star (Crystal) Group. Small amounts of silver were mined up to the 1950's; however, the majority of silver was mined prior to 1896. This was the year a copper smelter was built at Keswick. Silver was recovered in such large quantities as a by-product of refining the copper ore from Iron Mountain and other mines of the West Shasta Copper District that, combined with an already low market value, mining was no longer economical (Lydon and O'Brian 1974).

Copper, gold, silver, zinc, and lead were mined from massive sulphide and pyrite deposits at the Greenhorn Mine beginning in 1894. Over 3,400 tons of high-grade copper ore was shipped from this mine through 1930. In 1939, a mill and cyanide leaching plant were built on site to process 75,000 tons of gold and silver ore. Major production ceased following a tailings dam failure in 1941 (Lydon and O'Brian 1974).

Talc was produced in commercial quantities at the Ganim Mine from 1925 - 1946. This mine was developed for gold and silver production prior to this time, and continued to produce an unknown amount of gold until it was abandoned in the 1960's (Lydon and O'Brian 1974).

Commercial quantities of aggregate were made available from the placer and dredger tailings at French Gulch, on Clear Creek. Most of the aggregate, however, was mined from the lower reaches of Clear Creek, just south of the Watershed (Lydon and O'Brian 1974).

The Whiskytown National Recreation Area (WNRA) is actively preserving and restoring several abandoned historic sites. The El Dorado, Mt. Shasta, and Salt Creek Mines, are interpretive sites in the park, with well-marked and maintained hiking trails. One of the best preserved and restored sites is the Tower House Historic District, which is listed in the National Register of Historic Places (NRHP). This district includes the El Dorado Mine and Stamp Mill, where a restoration effort is under way (Whiskytown NPS 1999).

3.3.2 Current Mining

The Washington Mine (lode gold) was the only recently active mining operation in the Clear Creek Watershed. It was idle at the time of visit, but has since come into operation. There are several active sand and gravel producers outside the southern boundary of the watershed. These operations are located near the confluence of Clear Creek and the Sacramento River and may have the potential to impact water quality through the re-mobilization of mercury used by the numerous historical placer and dredging operations in this area.

3.3.3 Sample Study

The Clear Creek Watershed was chosen from a larger dataset of bioregions (Jepson), and included in this sample study because of stakeholder interest. Topographic mining symbols were digitized from the seven USGS 7.5 Minute topographic maps encompassing the watershed, and the geology (DMG 750k) was spatially analyzed by major reclassified rocktype ("Reclass"). The watershed was stratified into three generally homogenous units based on geology. These were Cenozoic through Precambrian marine sedimentary and metasedimentary rocks;

Cenozoic through Precambrian volcanic and metavolcanic rocks; and Cenozoic through Precambrian granitic and associated intrusive rocks. Fifteen sites were selected for field inventory. At least three mine sites for each rocktype were field visited. In addition, nine Principle Areas of Mine Pollution (PAMP) were associated with the selected sites and included in the sample study. This sample represented 40% of the PAMP in this watershed, and all nine were field visited. Of the total of 216 topographic mining symbols delineated for this watershed, approximately 6% were field visited. One site was not field visited due to access restrictions, and one was not found. However, another site not previously known was added to the sample. Thirteen "topographic symbol" sites, plus one unknown site, were field inventoried by OMR staff for this study.

3.3.3.1 Watershed Summary: Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard.

Table 3.16: Field verified Chemical Hazard Ranking Numbers

Rank	Count	Percent	Definition of Rank
0	2	14	No probability of releasing hazards into the environment
2	7	50	Low probability of releasing hazards into the environment
3	4	29	Moderate probability of releasing hazards into the environment
5	1	7	Very high probability of releasing hazards into the environment
Total	*14*	*100*	

Table 3.17: Field verified Physical Hazard Ranking Numbers.

Rank	Count	Percent	Definition of Rank
1	2	14	Very few physical hazards
2	3	21	Few physical hazards
3	2	14	Moderate amount of physical hazards
4	5	36	Large amount of physical hazards
5	2	14	Very large amount of physical hazards
Total	*14*	*99*	

3.3.3.2 Predicted Chemical Hazard Rankings

These rankings were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for details see Section 2). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data to be used. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r^2=60%, p=0.0064) are then applied to the MAS/MILS occurances within ~~for~~ the watershed using information from the MAS/MILS database about mine type (TYP), and the reclass number (derived from the 750K geologic map). The results of the regression model and its components are displayed below.

Table 3.18: Summarized statistics for the chemical hazard GLM.

Analysis of Variance of CHEMICAL HAZARD

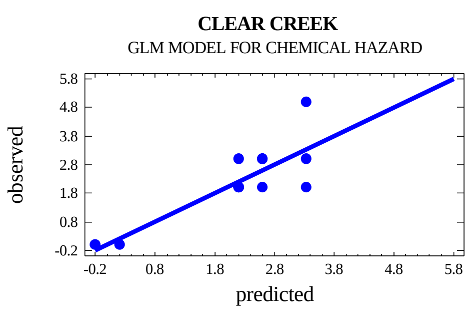
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	14.0905	3	4.69683	7.49	0.0064
Residual	6.26667	10	0.626667		
Total (Corr.)	20.3571	13			

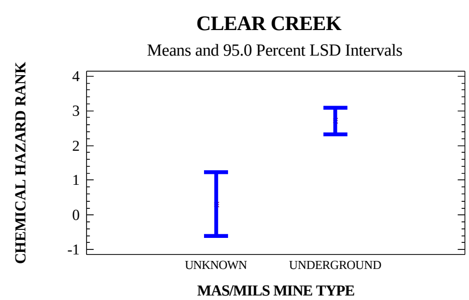
Type III Sums of Squares

Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
TYPE_CODE	9.25714	1	9.25714	14.77	0.0032
RECLASS#	2.65	2	1.325	2.11	0.1715
Residual	6.26667	10	0.626667		
Total (Corr.)	20.3571	13			

R-Squared = 69.2164%
R-Squared (adjusted for Df) = 59.9813%
All F-Ratios are based on residual mean square error.

The following graphs depict the tests among means for each component of the GLM regression analysis.





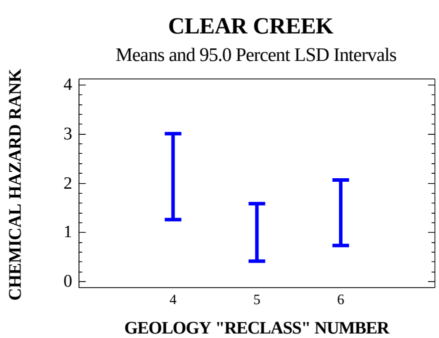


Table 3.19: Predicted Chemical Hazard Ranking Numbers for MAS/MILS Records.

Rank	**Count**	**Percent**	**Definition of Rank**
0	32	31	No probability of releasing hazards into the environment
1	12	12	Very low probability of releasing hazards into the environment
2	23	22	Low probability of releasing hazards into the environment
3	37	36	Moderate probability of releasing hazards into the environment
Total	*104*	*101*	

The results indicate that this watershed has a moderate probability for a site which presents a significant chemical hazard. The cumulative *chemical hazard ranking score* for the 146,574 acre watershed is 51,194, indicating that cumulatively AML sites in the watershed may pose a highly significant chemical threat to the environment.

3.3.3.3 Predicted Physical Hazard Rankings

The *physical hazard ranking* could be predicted by regression analysis with a General Linear Model, but only at a very low level (r^2=24%, *p*=0.08). Therefore, no further analyses were attempted with this model.

3.3.3.4 Predicted Hazardous Openings

Thirty-nine symbols indicative of an opening where shown on the topographic maps for the sampled sites and 16 prospect symbols were shown. Ninety-one openings were verified in the field for these sites, and 57 (or 63%) were found to be potentially hazardous. While it was found that a predictive model could not be constructed for hazardous openings, a model for openings in general was constructed.

The number of openings can be predicted with an R-squared value of 63% at a $p<0.0046$ level using the Reclass geology layer and the number of openings shown on the topographic maps. The predicted number of openings in this watershed is 133. AMLU staff documented 91 openings within this sample set, of which 57 were hazardous. Using this same ratio (of hazardous to total), the estimated number of hazardous openings for this watershed is 79.

3.3.4 Summary of Findings

Table 3.20: Summarized Finding for the Clear Creek Watershed

Total Watershed Area (Acres)	146,574
Predicted Cumulative Chemical Ranking Sore	51,194
Predicted Cumulative Chemical Ranking Score Density	0.3493
Predicted Cumulative Physical Ranking	Unable to Predict
Predicted Hazardous Openings	79

In this watershed there is a moderate probability for a site which presents a significant chemical hazard, and cumulatively, AML sites in the watershed likely poses a highly significant chemical threat to the environment. Physical hazards could not be predicted accurately, yet the watershed has a moderate number of hazardous openings.

Drainage from the Greenhorn Copper Mine was sampled by the DOC and CVRWQCB in a joint study in 1995, and was found to be contaminating the watershed with considerable ARD and heavy metal pollution. Concentrations of copper, cadmium, iron, and zinc sampled in this runoff were above the Water Quality Objectives for Willow Creek (Gaggini and Croyle 1995).

3.4 Ivanpah Watershed

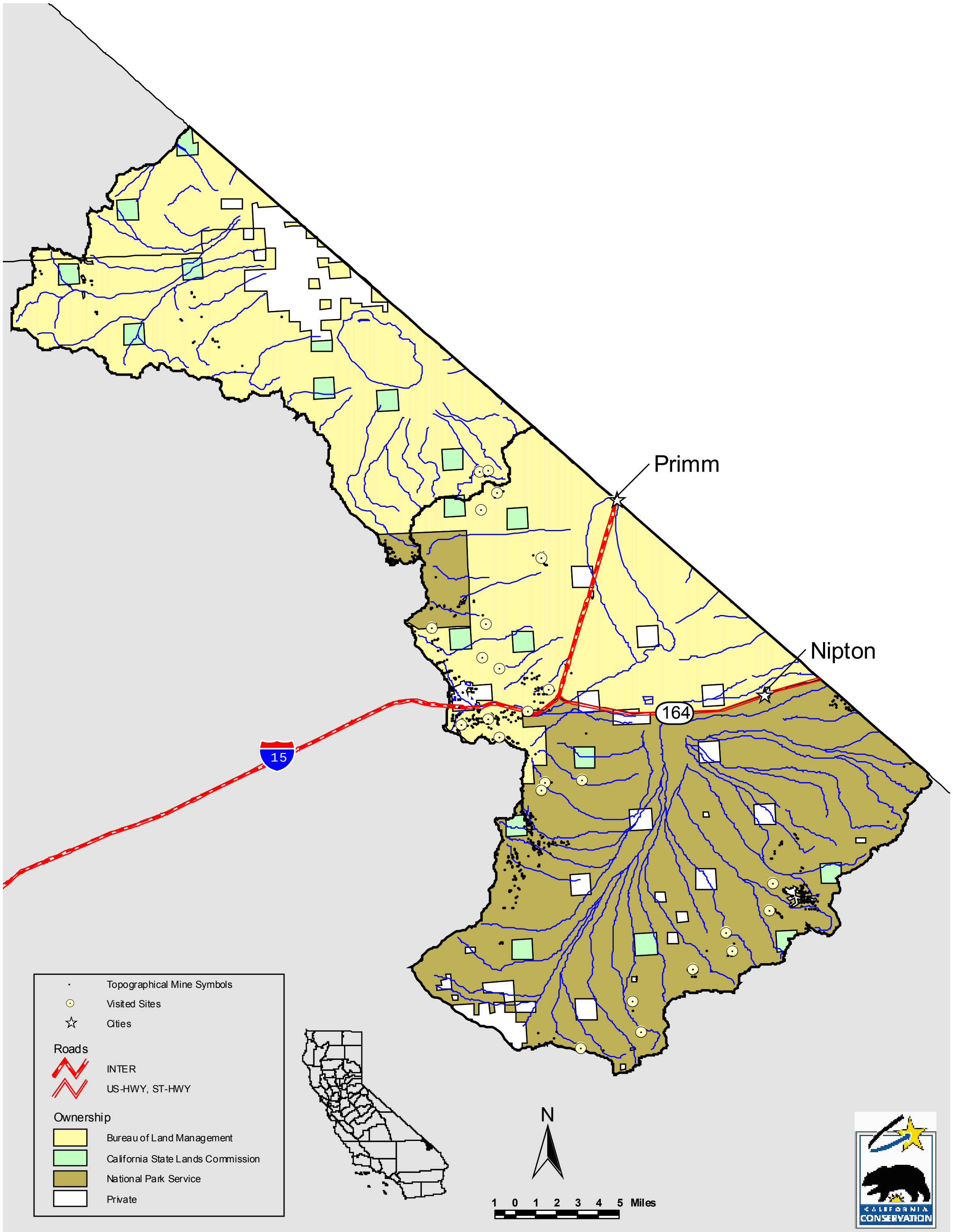


Figure 3.5: Ivanpah Watershed Area Map.

The Ivanpah Watershed lies in the Mojave Desert along the California-Nevada border with Interstate 15 splitting it laterally. The federal government owns the vast majority of the land, and this ownership is split almost equally between the Bureau of Land Management (BLM) and the National Parks Service (NPS). Interstate 15 carries a constant stream of cars between Las Vegas and the Los Angeles area, but there are relatively few travelers that venture off this major artery into the desert. The millions of Las Vegas residents are 45 minutes away, but the watershed itself houses only a few hundred residents in towns such as Nipton and Cima.

Table 3.21: Ivanpah Watershed Land Ownership Summary

Government Level	Agency	Acres	Percent
Federal	BLM	205,211	50.00
	NPS	167,728	40.87
Sum (Federal)		*372,939*	*90.87*
State	State Land Commision	11,567	2.82
Private	Private	25,919	6.32
Sum (Total)		*410,425*	*100.00*

The climate of the watershed is a dry hot desert, with a mean annual precipitation between 4 and 8 inches.

The watershed is bordered on the south by the New York Mountains and the Mid Hills. The Ivanpah Range, Clark Range, Mescal Range, and Mesquite Range comprise the western border. The northern border is the Kingston Range and the eastern border is the Nevada border. The entire watershed drains into two large enclosed basins, Ivanpah Valley in the south and Mesquite Valley in the north. The runoff ultimately either percolates down into the valley sediment or evaporates, creating a dry lakebed in the center of each valley. There are no perennial streams in this watershed; most only flow after very heavy rains.

The elevation of the watershed ranges from 2500 feet at Ivanpah Lake to over 7000 feet in the New York and Clark Mountains. Common plant types at lower elevations are creosote bush and saltbush, with iodine bush and saltgrass present on wet lacustrine deposits. Joshua trees are common on the alluvial fans and increase in density as elevation increases, and the higher elevations of the mountain ranges host singleleaf pinyon pines and white firs (Hickman 1993).

The wildlife in this field area consists mostly of reptiles, insects, and other animals typical of desert environments. There are two atypical species that strongly affect the federal government's policies toward wildlife in this area: the desert tortoise and the wild burro. The desert tortoise and its habitat are protected by federal laws under the Endangered Species Act, and much of the NPS land in the Ivanpah Watershed is designated as tortoise habitat. The watershed also has wild burros that were introduced from northeastern Africa in the 16th century. The estimated 1,100 burros living in the Mojave National Preserve consume about 6.8 million pounds of vegetation each year. This enormous appetite threatens native plant species and reduces the available food for sensitive species like the bighorn sheep and desert tortoise. Because these burros are seen as a threat to native species, they are being removed by NPS personnel and placed in adoption programs.

The Ivanpah Watershed is located in the Basin and Range Province of southeastern California. The geology of the area includes Cenozoic (Holocene) unconsolidated terrestrial deposits, Cenozoic through Precambrian granitic and associated intrusive rocks, Cenozoic through Precambrian volcanic and metavolcanic rocks and Cenozoic through Precambrian marine sedimentary and metasedimentary rocks (Ref. 750k geology map). Cenozoic (Holocene) unconsolidated terrestrial deposits consist of sand dunes, lake deposits, landslide deposits, alluvial, and colluvial deposits. The Cenozoic through Precambrian granitic and associated intrusive rocks consists of quartz monzonite, granite porphyry and gneiss. The Cenozoic through Precambrian volcanic and metavolcanic rocks consists of isolated pockets of basalt and rhyolite. Cenozoic through Precambrian marine sedimentary and metasedimentary rocks consists of mainly marine sedimentary rocks such as limestone, dolomite, sandstone and shale.

The mineral deposits in this watershed consist of gold, silver, copper, lead, zinc, iron, molybdenum, tungsten, antimony and tin. These metals commonly occur together in this watershed, therefore only a few prospectors were looking for a single commodity. In general the location of the deposits are structurally controlled. The emplacement of the quartz monzonite masses and some intrusions of rhyolite mobilized the elements, which traveled along the numerous fault planes and contact zones where they were ultimately deposited.

3.4.1 Short History of Mining

John Moss is credited with the first discovery of economic minerals in the Ivanpah Valley. He discovered silver in 1865 and quickly claimed up to 130 claims throughout the Clark Mountains, Ivanpah Mountains and the New York Mountains. On July 18, 1865 the Clark Mining district was organized. Moss formed the Piute Mining Company in 1869, founded the town of Ivanpah and shipped several tons to silver ore to San Francisco's Selby Works. The 1870's saw the height of the silver boom in this region. Most of the ore during the 1870's was running at $1000 per ton. The ore was processed by crushing in Mexican arrastras, hauled by mule teams to San Pedro where it was loaded onto steamer ships and finally shipped to Selby Works. The whole trip cost an estimated $450 per ton. Many miners left any ore below this value on the mine dumps because it was not economical to ship.

The McFarlane Brothers played a crucial role during this time forming the Ivanpah Mining Company. The McFarlane Brothers are credited with bringing the first modern processing equipment to the Ivanpah area. In 1873, they had a furnace built and began processing ore into bullion. In 1875, they built the first 5 stamp mill, which made it possible to process the low grade ore left on the dumps from earlier mining in the area. The combination of modern processing techniques and the richness of the ore helped this area see $3 million in silver production by 1883 (Nadeau 1999). However, by 1893 the price of silver dropped, affecting the production of silver until 1905 when the Union Pacific Railroad (Los Angeles to Salt Lake route) was built.

Silver was not the only profitable commodity in the Ivanpah area. By 1892, some notable deposits of lead and zinc were found, but development lagged until 1892 when the railroad was built between Goffs and Vanderbilt (Hewlet 1956). In 1893, the discovery of gold at Vanderbilt led to the extensive development and exploration of that area. The onset of World War I (1915-1918) sparked a widespread exploration for zinc, copper and lead ores in the entire region due to the increased demand for these strategic metals. Exploration for tungsten followed shortly after (1916-1918). This area also has the distinction of having the only producing antimony mine in San Bernardino County.

Despite the wealth and variety of the commodities in this area, many mines were inactive by 1930. One exception is the Desert Antimony Mine, which continued in operation (sporadically) until the 1960's.

3.4.2 Current Mining

Current mining in this watershed is limited in scope but diverse in nature. Current activities include a talc mine, an underground gold and copper mine, a large rare-earth metal operation, and a open pit gold mine.

3.4.3 Sample Study

The Ivanpah Watershed was chosen at random from a larger dataset of Bioregions (Hickman 1993) for study. Topographic mining symbols were digitized from the 25 USGS 7.5 Minute topographic maps encompassing the watershed, and the geology (DMG 750k) was spatially analyzed by major "Rocktype". It was determined that with the exception of abandoned or inactive borrow pits, and sand and gravel operations, only four rocktypes occurred in conjunction with a mine symbol. These rockypes include Cenozoic (Holocene) unconsolidated terrestrial deposits, Cenozoic through Precambrian granitic and associated intrusive rocks, Cenozoic through Precambrian volcanic and metavolcanic rocks and Cenozoic through Precambrian marine sedimentary and metasedimentary rocks. For each rocktype, ten topographic symbols were randomly selected for field inventory. In addition, five Principle Areas of Mine Pollution (PAMP) mine locations were randomly selected from the only rocktype in which they occurred. Of the total of 40 random sites selected for this watershed, 13 occurred on (NPS) land. The NPS has completed a survey of abandoned mines in the Mojave National Preserve. Therefore, data received from the NPS is treated as a field visit. AMLU staff field verified 24 sites for a total of 37 sites in the watershed. The remaining sites were not cataloged due to access and time constraints.

3.4.3.1 Watershed Summary and Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard.

Table 3.22: Field verified Chemical Hazard Rankings

Rank	Count	Percent	Definition of Rank
0	9	24	No probability of releasing hazards into the environment
1	11	29	Very low probability of releasing hazards into the environment
2	13	34	Low probability of releasing hazards into the environment
3	5	13	Moderate probability of releasing hazards into the environment
	38	*100*	

Table 3.23: Field verified Physical Hazard Rankings

Rank	Count	Percent	Definition of Rank
0	4	11	No physical hazards
1	2	5	Very few physical hazards
2	13	34	Few physical hazards
3	9	24	Moderate amount of physical hazards
4	3	8	Large amount of physical hazards
5	7	18	Very large amount of physical hazards
	38	100	

3.4.3.2 Predicted Chemical Hazard Rankings

These rankings were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see section 2). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data to be used. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r^2=44%, p=0.0002) were then applied to the MAS/MILS occurances within the watershed using information from the MAS/MILS database about generalized commodity (derived from COM1), PAMP Membership, and the potential for arsenic (derived from MRDS database). The results and components of the regression model for *chemical hazards* are displayed below.

Table 3.24: Summarized statistics for the chemical hazard GLM.

Analysis of Variance of CHEMICAL HAZARD

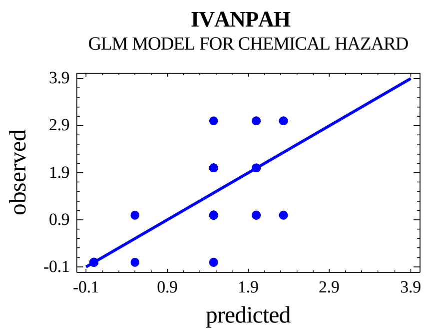
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	18.9386	5	3.78772	6.77	0.0002
Residual	17.9035	32	0.559485		
Total (Corr.)	36.8421	37			

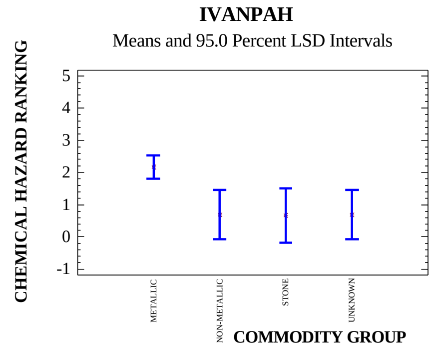
Type III Sums of Squares

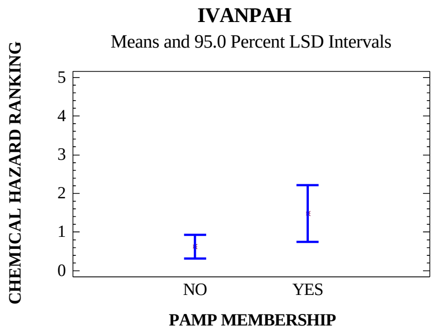
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	1.91467	1	1.91467	3.42	0.0736
COM GROUP	13.5032	3	4.50105	8.04	0.0004
ARS	1.55945	1	1.55945	2.79	0.1048
Residual	17.9035	32	0.559485		
Total (Corr.)	36.8421	37			

R-Squared = 51.4048%
R-Squared (adjusted for Df) = 43.8118%
(All F-Ratios are based on residual mean square error.)

The following graphs depict the tests among means for each component of the GLM regression analysis.







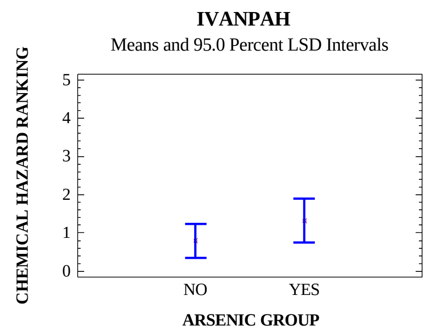


Table 3.25: Predicted Chemical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent	Definition of Rank
0	148	43	No probability of releasing hazards into the environment
1	168	49	Very low probability of releasing hazards into the environment
2	25	7	Low probability of releasing hazards into the environment
	341	*100*	

The results indicate that this watershed has a low probability for a site that presents a significant chemical hazard. The cumulative Chemical Hazard Ranking Score for the 410,425 acre watershed is 793, indicating that cumulatively, AML sites in the watershed probably pose no chemical threat to the environment.

3.4.3.3 Predicted Physical Hazard Rankings

The Physical Hazard Ranking was also predicted by regression analysis with a General Linear Model. The prediction model utilizes the field verified *physical hazards ranking*. The results of the predictive model (r^2=52%, p=0.0152) are then applied to the MAS/MILS database for the watershed using MAS/MILS database information about the mine status (CUR), generalized commodity (derived from COM1), and PAMP membership. The results and components of the regression model for *physical hazards* are displayed in below.

Table 3.26: Summarized statistics for the physical hazard GLM.

Analysis of Variance of PHYSICAL HAZARD

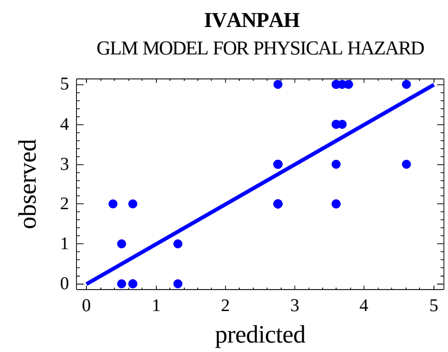
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	46.0948	5	9.21897	7.74	0.0001
Residual	38.1157	32	1.19112		
Total (Corr.)	84.2105	37			

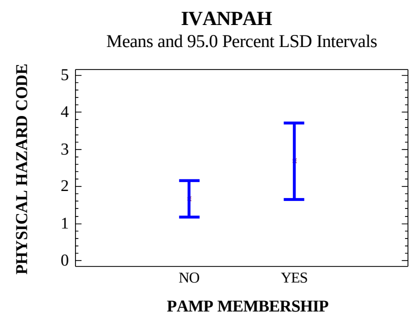
Type III Sums of Squares

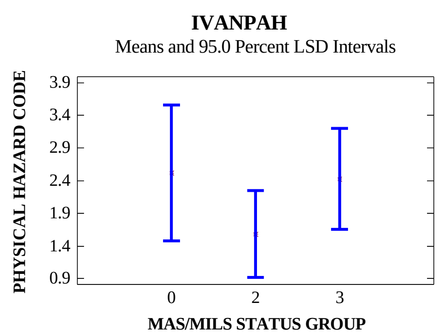
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	2.45098	1	2.45098	2.06	0.1611
COMM GROUP	25.4163	3	8.47212	7.11	0.0009
CUR_CODE	3.5695	1	3.5695	3	0.0931
Residual	38.1157	32	1.19112		
Total (Corr.)	84.2105	37			

R-Squared = 54.7376%
R-Squared (adjusted for Df) = 47.6654%
(All F-Ratios are based on residual mean square error.)

The following graphs depict the tests among means for each component of the GLM regression analysis.







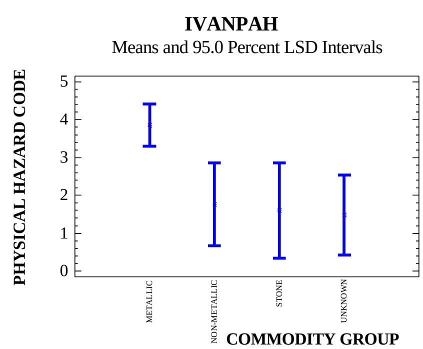


Table 3.27: Predicted Physical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent	Definition of Rank
0	56	16	No physical hazards
1	90	26	Very few physical hazards
2	6	2	Few physical hazards
3	132	39	Moderate amount of physical hazards
4	52	15	Large amount of physical hazards
5	5	2	Very large amount of physical hazards
	16	*100*	

The results indicate that this watershed has a high probability for a site which represents a significant physical hazard. The cumulative Physical Hazard Ranking for the watershed is 9,614,835, indicating that, cumulatively, AML sites in the watershed likely pose a very high threat of physical hazards.

3.4.3.4 Predicted Hazardous Openings

For the sampled sites, 110 symbols indicative of an opening where shown on the topo maps and 106 prospect symbols were shown. Of these sites, 154 openings were verified in the field and 145 (or 94%) were found to be potentially hazardous. While it was found that predictive model could not be constructed for hazardous openings, a model for openings in general was constructed.

The number of openings can be predicted with an R-squared value of 71% at a $p<0.0001$ level using the number of openings shown on the topographic maps. The predicted number of openings in this watershed is 286. AMLU staff documented 154 openings within this sample set, of which 145 were hazardous. Using this same ratio (of hazardous to total), the estimated number of hazardous openings for this watershed is 286.

3.4.4 Summary of Findings

Table 3.28: Summarized findings for the Ivanpah Watershed.

Total Watershed Area (Acres)	410,425
Predicted Cumulative Chemical Ranking Sore	793
Predicted Cumulative Chemical Ranking Score Density	.0019
Predicted Cumulative Physical Ranking	9,614,835
Predicted Cumulative Physical Ranking Score Density	23.43
Predicted Hazardous Openings	286

In this watershed there is a low probability for a site which presents a significant chemical hazard, and cumulatively, AML sites in the watershed probably pose no chemical threat to the environment. Overall, in this watershed there is high probability for a single site that presents a significant physical hazard. In addition, there are many sites, each with a few hazards, resulting in a very high cumulative physical hazard score. The watershed as a whole does have a large number of hazardous openings (estimated to be 286).

3.5 Lake Shasta Watershed

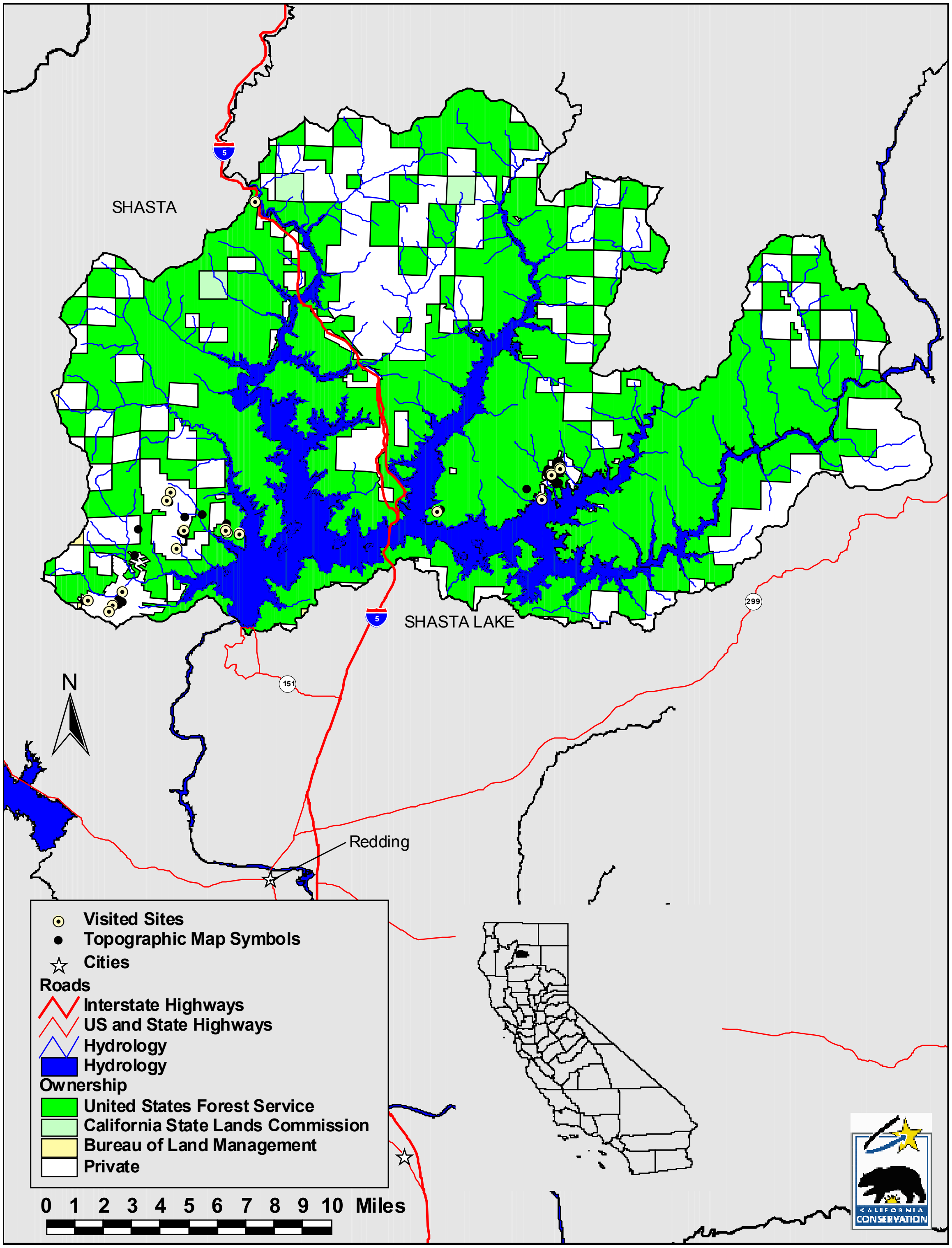


Figure 3.6: Lake Shasta Watershed, Area Map.

The most prominent features of the Lake Shasta Watershed are the 46 square mile reservoir, and Shasta Dam. This watershed has a total area of 375 square miles, and forms the headwater drainage for the Sacramento River. The Lake Shasta Watershed is located in west-central Shasta County, and is approximately 18 miles long, and 30 miles wide. It is adjacent to the Clear Creek Watershed on the west, and the Sacramento River Watershed to the south. With over 370 miles of shoreline and a capacity of 4,552,000-acre feet of water, Lake Shasta is one of the largest reservoirs in California. There are no communities located within the watershed, however there are numerous resorts, cabins, and camping areas around the lake, which is a major recreation, tourism, and sport-fishing destination. This watershed provides water for consumption and domestic use to the city of Redding, which has a population of 78,490 (1995 estimate). It also provides water for the nearby communities of Anderson, Cottonwood, Summit City, Project City, Pine Grove, and Central Valley. In addition, this watershed supplies the downstream communities of the Great Central Valley, such as Red Bluff, Corning, etc. In all, it is estimated that the Lake Shasta Watershed may provide the Sacramento River and the Central Valley Water Project with water for consumption and domestic use for populations in the hundreds of thousands, in addition to large scale industrial and agricultural (irrigation) use.

Table 3.29: Lake Shasta Watershed Land Ownership Summary

Government Level	**Agency**	**Acres**	**Percent**
Federal	USFS	173,364	72
	BLM	165	0
Sum (Federal)		*173,529*	*72*
State	DFG	7	0
	State Lands Commission	1,892	1
	Sum (State)	1,899	1
Private	Private	64,373	27
Sum (Total)		*239,801*	*101*

The climate of this watershed varies with elevation. Lake level forms the lower elevation and varies with storage requirements. The elevation of the Shasta Dam Spillway is 1,065 feet and the highest elevation in the watershed is 4,156 feet (Bohemotash Mountain). The climate at lake level is characterized by mild summers and cool, wet winters. The annual average rainfall is 60 inches. The higher elevations are characterized by mild summers and cold, wet winters with significant snowfall. (CERES 1998).

The Lake Shasta Watershed encompasses an area bordered by the Cascade Ranges to the north and east, the Klamath Ranges to the west, and the Great Central Valley to the south. The topography is generally characterized by steep mountains and narrow canyons. The creeks and streams that are tributary to Lake Shasta are generally steeply graded and fast-flowing. However, the main tributaries of the Upper Sacramento River, McCloud River, and Lower Pit River tend to be wider and slower. Other tributaries to Lake Shasta are: Backbone Creek, Little Backbone Creek, Squaw Creek, West Squaw Creek, Salt Creek, Horse Creek, Town Creek, Campbell Creek, Charlie Creek, and Sugarloaf Creek. Little Backbone Creek, West Squaw Creek, Horse Creek, Town Creek, the Lower Pit River, and Shasta Lake are listed as impaired under Section 303(d) of the Federal Clean Water

Act as a result of contamination with cadmium, copper, lead, and zinc from abandoned mines within the watershed (USEPA 2000).

The Lake Shasta Watershed is comprised of the Klamath Ranges (KR), High Cascade Ranges (CaRH), and Cascade Range Foothills (CaRF) biological subregions, which are components of the Northwest California (NW) and Cascade Range (CaR) biological regions as defined in the Jepson Manual (Hickman 1993). The plant communities of these subregion vary by elevation across the watershed and include mixed chaparral, oak woodland, and mixed evergreen, with mixed oak and conifer forest as elevation increases. Ponderosa pine, Jeffrey pine and white fir are the dominant conifers. White fir and mixed conifer forest generally characterize the highest elevations. Manzanita, ceanothus, toyon, and poison oak are dominate in the chaparral and oak woodland (Alden 1998). Logging, wildfire, and mining activities have left surface disturbance that is characterized by moderate to severe erosion and the loss of soils favorable to re-forestation. This has allowed chaparral shrub species to proliferate in the previously forested areas. The watershed has been heavily impacted by alterations caused by Shasta Dam and the Lake Shasta Reservoir. Threatened and endangered species in this watershed include the Northern Spotted Owl, Bald Eagle, and Shasta Salamander. (CERES 1998). Townsend's Big-Eared Bat, a species of special concern, have been reported at several abandoned mines in the adjoining Clear Creek Watershed (Whiskytown NPS 1999).

The Lake Shasta Watershed is located in the southeastern portion of the Klamath Range. The geology of the watershed includes metamorphosed silicic volcanics and pyroclastic deposits (Paleozoic Copley Greenstone, overlain by Balaklala Rhyolite); metamorphosed volcanic and sedimentary rocks (Bully Hill Rhyolite); metamorphosed marine sedimentary rocks of the Paleozoic Bragdon Formation; miscellaneous combined geologic units; and by the intrusions of quartz diorite along the McCloud River arm of the watershed. The area encompassing the western third of the watershed is known as the West Shasta Copper-Zinc District. This is a region where stratified formations, fractures, faults, and shear zones occurring in the Balaklala Rhyolite were found to contain massive sulphide ores which contained large deposits of copper and zinc with lesser quantities of lead, gold, silver, and cadmium. Another highly mineralized area of copper, zinc, lead, gold, and silver deposits occurs in the eastern quarter of the watershed, and is known as the East Shasta Copper-Zinc District. In this region, the sulphide ores are associated with shear zones and fault contacts in the Bully Hill Rhyolite (Lydon and O'Brian 1974).

3.5.1 Short History of Mining

Lode gold was first mined in the 1860's from gossans overlying sulphide ores in the West Shasta Copper-Zinc District. While this region was to become better known for copper and zinc production, considerable quantities of gold and silver were also produced. The most productive lode gold operation was the Uncle Sam Mine, which operated a 30-stamp mill and produced over a million dollars in gold and silver from 1886 to 1913. However, beginning in the 1890's large amounts of gold and silver were being produced as a by-product of the smelting of copper ore. It soon was no longer profitable to specifically mine for gold and silver in this region (Clark 1998).

Copper was the principal commodity mined in the Lake Shasta Watershed. Copper mined from both the West and East Shasta Copper Districts accounted for more than half of the state's total production. Copper mining began in 1862 at Copper City, which was flooded when the Lake Shasta Reservoir was filled. The lack of a smelter required shipping the ores to Europe for processing, so both production and profit were limited. In 1894, an English company acquired the Iron Mountain Mine, which is located a few miles south of the watershed. In 1896, this company built a smelter at Keswick that eliminated the need to ship ore out of the country for processing. This development led to the expansion of copper mining within the Lake Shasta Watershed. Large mines were developed in the West Shasta Copper District, and included the Mammoth and Balaklala mines. The largest mine complex in the East Shasta Copper District was the Bully Hill mine. Various sites at the Mammoth Mine complex may have been worked for gold as early as the 1880's, however records of copper production did not begin until 1905. The Mammoth complex of mines included the Friday-Louden, Sutro, Summit, Mayflower, and Golinsky sites and was itself developed by nine adits and thousands of feet of workings. A smelter was built at Kennett (later to be inundated by Lake Shasta) in 1907, which operated until 1924. More than 3 million tons of copper ore were produced from the Mammoth complex before mining ceased in 1925.

The Balaklala Mine began operations in the 1890's. By 1902, more than 20 adits and thousands of feet of workings had been developed. In 1906, a smelter was built at Coram (near what is now, Shasta Dam). A 3-mile long aerial tramway was built to transport ore from the massive workings to the smelter, which was closed in 1911 due to litigation over smoke emissions. It has been estimated that more than one million tons of ore were mined here. The mine continued production until the 1920's and shipped ore to be refined at the Mammoth smelter at Kennet. Other large copper mines in the West Shasta Copper-Zinc District included the Keystone and Shasta King mines, which operated between the 1860's and the late 1920's. The Bully Hill and Rising Star complex was the largest operation in the East Shasta Copper-Zinc District. During the years these mines were in operation, more than a half-million tons of ore was mined between 1900 and 1950. At least nine adits and thousands of feet of workings were developed at this site. A smelter was put into operation in 1901, but ceased operation in 1910 because increasing zinc content made refining more difficult, and because of litigation over emissions. In 1918, an experimental smelter was constructed at nearby Winthrop to process the zinc ores, but by 1925, ore was again being shipped to Europe for smelting. Between 1927 and 1951, activity at this site was limited to exploration and the reprocessing of smelter slag. The emissions from copper smelting severely impacted air quality and caused massive environmental degradation and the loss of forests throughout the region. By 1919, most of the smelters had been shut down due to litigation resulting from the environmental damage caused by ore refining. The cost of shipping the copper ore for refining elsewhere, combined with the high cost of grinding the ore to concentrates made further mining of copper and zinc ores in this watershed unprofitable, and most mining had ceased by the 1920's (Lydon and O'Brian 1974).

Iron was first mined in this watershed in 1902 at the Shasta Iron Mine to provide flux for the copper smelter at Bully Hill. A smelter was put into operation nearby in 1907 to produce pig iron from the mine. More than 15,000 tons of iron ore was mined from trenches and quarries between 1907-1914. The smelter was shut down following WW I, but iron ore production continued until 1925. The mine became active again in WW II, and produced quantities of iron ore for use as marine ballast. Barges were required to transport the ore across Lake Shasta, following the completion of Shasta Dam. In 1948, production ceased, and litigation arising from loss of access to the mineral deposits due to the rising lake level was settled (Lydon and O'Brian 1974).

Limestone was mined from the Holt and Gregg quarries beginning in 1894 and processed in kilns to produce lime for agricultural and construction use through 1927. Beginning in 1896, limestone from these and several other small quarries were used to provide flux material for the copper smelters located at Iron Mountain, Bully Hill, Corum, and Kennett until their operations ceased.

3.5.2 Current Mining

There is currently no active mining in the Lake Shasta Watershed. The Balaklala, Keystone, and Mammoth Complex (Friday-Louden) mines of the West Shasta Copper-Zinc Mining District, and the Bully Hill Mine of the East Shasta Copper-Zinc Mining District are undergoing active remediation attempts, but are otherwise inactive.

3.5.3 Sample Study

The Lake Shasta Watershed was chosen at random from a larger dataset of bioregions (Hickman 1993). Topographic mining symbols were digitized from the sixteen USGS 7.5 Minute topographic maps encompassing the watershed, and the geology (DMG 750k) was spatially analyzed by major reclassified rocktype ("Reclass"). The watershed was stratified into three generally homogeneous units based on geology. These were Cenozoic through Precambrian marine sedimentary and metasedimentary rocks; Cenozoic through Precambrian volcanic and metavolcanic rocks; and Cenozoic through Precambrian granitic and associated intrusive rocks. Sixteen topographic symbols were randomly selected for field inventory. All but two sites were located in the same rocktype. At least one mine site for each rocktype was field visited. In addition, eleven Principle Areas of Mine Pollution (PAMP) were associated with the randomly selected symbols and included in the sample study. This sample represents 85% of the PAMP in this watershed. Of the total of 68 topographic mining symbols delineated for this watershed, approximately 29% were field visited by AMLU staff. Three sites included in this sample were inventoried by the USFS. Thirteen "topographic symbol" sites were field inventoried by OMR staff for this study.

3.5.3.1 Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard.

Table 3.30: Field verified Chemical Hazard Ranking Numbers

Rank	Count	Percent	Definition of Rank
1	4	25	Very low probability of releasing hazards into the environment
2	7	44	Low probability of releasing hazards into the environment
3	2	12	Moderate probability of releasing hazards into the environment

Rank	Count	Percent	Definition of Rank
4	3	19	High probability of releasing hazards into the environment
Total	*16*	*100*	

Table 3.31: Field verified Physical Hazard Ranking Numbers

Rank	Count	Percent	Definition of Rank
0	2	12	No physical hazards
1	1	6	Very few physical hazards
2	3	19	Few physical hazards
3	7	44	Moderate amount of physical hazards
4	1	6	Large amount of physical hazards
5	2	12	Very large amount of physical hazards
Total	*16*	*99*	

3.5.3.2 Predicted Chemical Hazard Rankings

These rankings were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see section 2). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r^2=62%, p=0.0005) were then applied to the MAS/MILS database for the watershed using information about the PAMP Membership. The results of the regression model for *chemical hazards* and its components are displayed below.

Table 3.32: Summarized statistics for the chemical hazard GLM model.

Analysis of Variance of CHEMICAL HAZARD

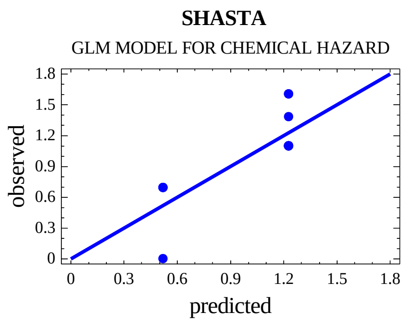
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1.43901	1	1.43901	21.76	0.0005
Residual	0.793551	12	0.0661292		
Total (Corr.)	2.23256	13			

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	1.43901	1	1.43901	21.76	0.0005
Residual	0.793551	12	0.0661292		
Total (Corr.)	2.23256	13			

R-Squared = 64.4556%
R-Squared (adjusted for Df) = 61.4935%
All F-Ratios are based on residual mean square error.

The following graphs depict the tests among means for each component of the GLM regression analysis.



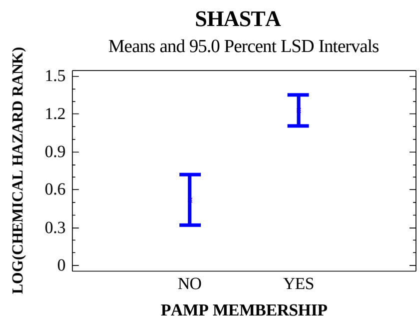


Table 3.33: Predicted Chemical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent	Definition of Rank
2	95	88	Low probability of releasing hazards into the environment
3	13	12	Moderate probability of releasing hazards into the environment
Total	108	100	

The results indicate that this watershed has a low to moderate probability for a site which presents a significant chemical hazard. The cumulative *chemical hazard ranking score* for the 239,801 acre watershed is 11,222, indicating that AML sites in the watershed likely pose a low to moderate chemical threat to the environment. These results underestimate the issues of this watershed. Further discussion is on page 66.

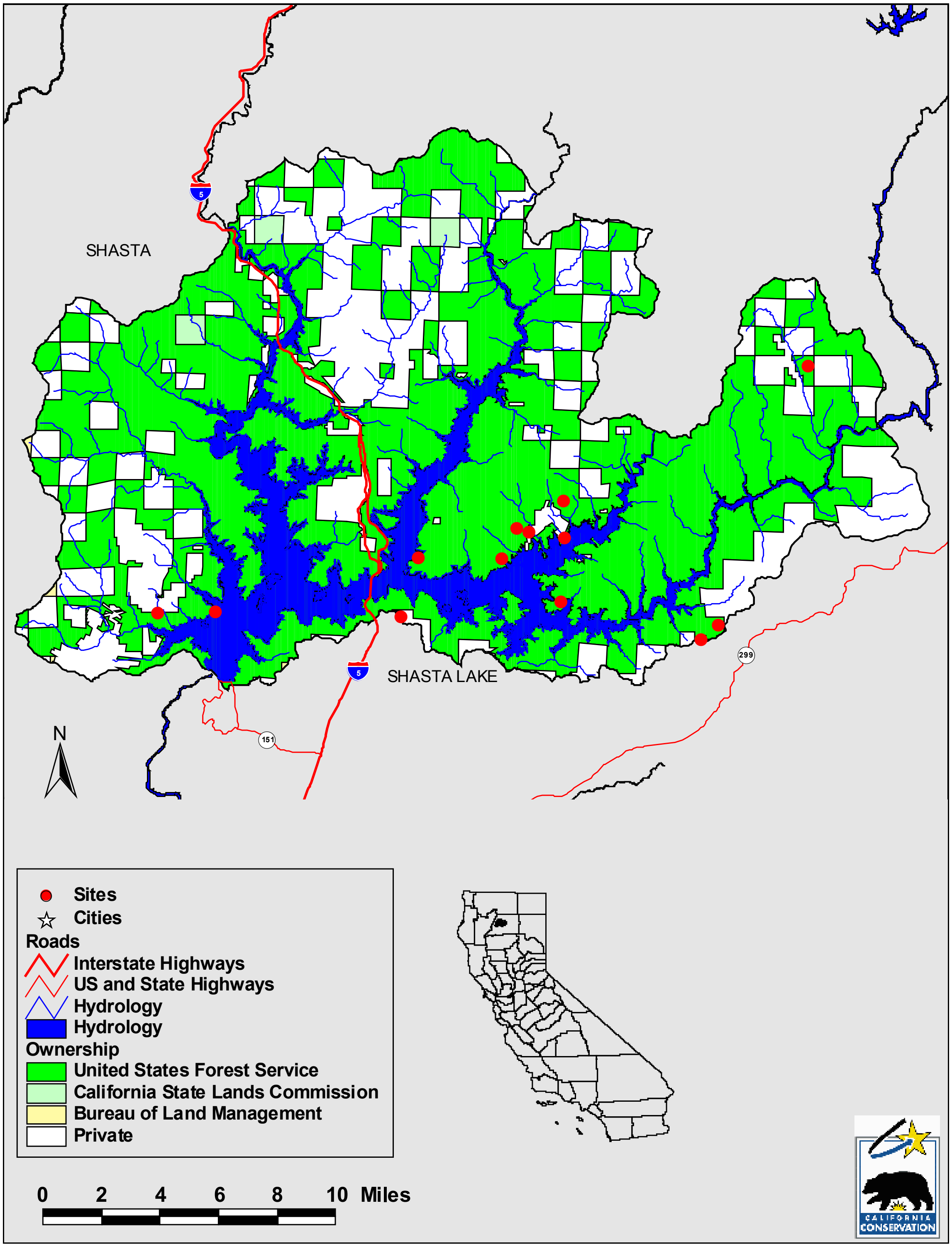


Figure 3.7: MAS/MILS sites with a chemical hazard prediction of 3 or more.

3.5.3.3 Predicted Physical Hazard Rankings

The *physical hazard ranking* could be predicted by regression analysis with a General Linear Model. The prediction model utilizes the field verified *physical hazards ranking*. The results of the predictive model (r^2=65%, p=0.0011) are then applied to the MAS/MILS database for the watershed using information about the PAMP Membership and Reclass number (derived from the geol750K). The results of the regression model for *physical hazards* and its components are displayed below.

Table 3.34: Summarized statistics for the physical hazard GLM.

Analysis of Variance of PHYS_APR_CODE

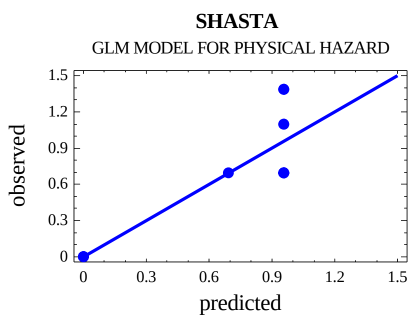
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	2.68042	3	0.893474	10.61	0.0011
Residual	1.01069	12	0.0842238		
Total (Corr.)	3.69111	15			

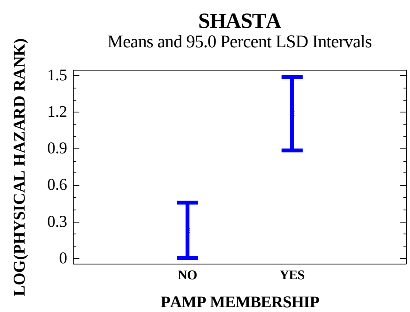
Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	2.15386	1	2.15386	25.57	0.0003
RECLASS #	0.384362	2	0.192181	2.28	0.1446
Residual	1.01069	12	842238		
Total (Corr.)	3.69111	15			

R-Squared = 72.6184%
R-Squared (adjusted for Df) = 65.773%
All F-Ratios are based on residual mean square error.

The following graphs depict the tests among means for each component of the GLM regression analysis.





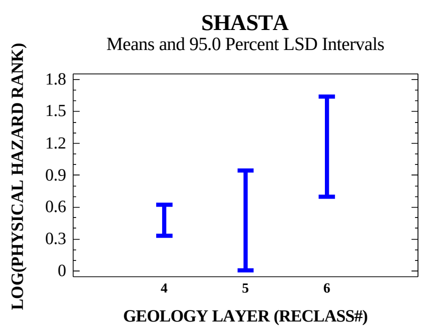


Table 3.35: Predicted Physical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent Definition of Rank
2	4	24 Few physical hazards
3	13	76 Moderate amount of physical hazards
Total	*17*	*100*

The results indicate that this watershed has a low to moderate probability for a site which presents a significant physical hazard. The cumulative *physical hazard ranking score* the watershed is 2,213, indicating the watershed is likely to pose a moderately significant threat of physical hazards.

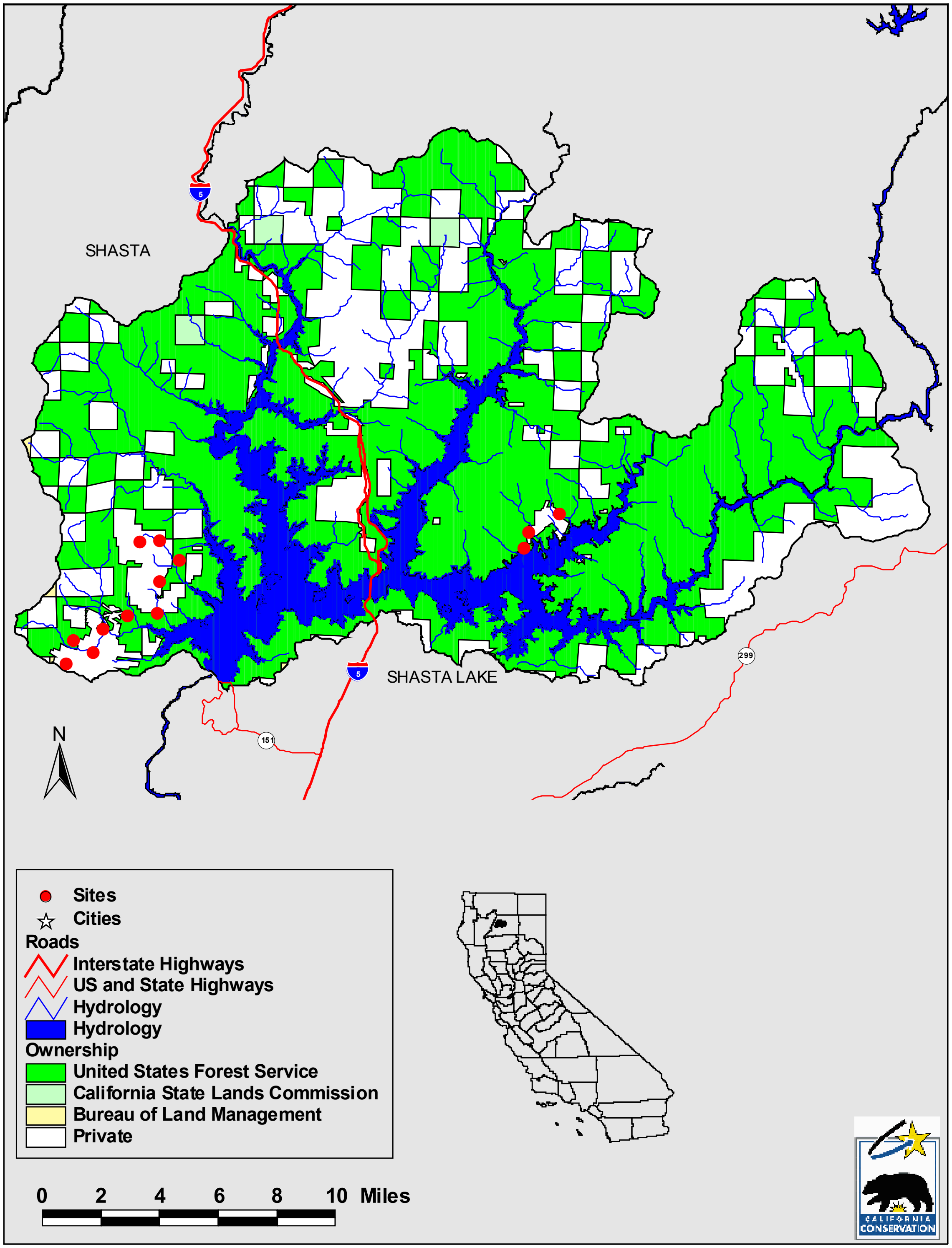


Figure 3.8: MAS/MILS sites with a physical hazard prediction of 3 or more.

3.5.3.4 Predicted Hazardous Openings

Twelve symbols indicative of an opening where shown on the topographic maps for the sampled sites and 36 prospect symbols were shown. 33 openings were verified in the field for these sites, and 28 (or 85%) were found to be potentially hazardous. While it was found that predictive model could not be constructed for hazardous openings, a model for openings in general was constructed.

The number of openings can be predicted with an R-squared value of 72% at a $p<0.0074$ level using the number of prospects and openings shown on the topographic maps. The predicted number of openings in this watershed is 42. AMLU staff documented 33 openings within this sample set, of which 28 were hazardous. Using this same ratio (of hazardous to total), the estimated number of hazardous openings for this watershed is 37.

3.5.4 Summary of Findings

Table 3.36: Summarized Findings for the Lake Shasta Watershed.

Total Watershed Area (Acres)	239,801
Predicted Cumulative Chemical Ranking Sore	11,222
Predicted Cumulative Chemical Ranking Score Density	0.0468
Predicted Cumulative Physical Ranking	2,213
Predicted Cumulative Physical Ranking Score Density	0.0092
Predicted Hazardous Openings	37

In this watershed there is a low to moderate probability for a site that presents a significant chemical hazard, and cumulatively, the model predicts that AML sites in the watershed pose a low to moderate chemical threat to the environment. This particular watershed model appears to underestimate the level of environmental hazard posed by AML sites. This is likely do to the atypical mines in the watershed; that is sites are larger than average and many generate ARD. Overall, in this watershed there is a low, yet significant, probability for a single site which represents a significant physical hazard.

ARD was observed and documented by field staff at a number of sites visited in this watershed. West Squaw Creek, a major tributary to Lake Shasta has been heavily impacted from ARD and continues to pollute the lake with acidic runoff saturated with heavy metals. Five tributaries and Lake Shasta is itself listed as impaired under Section 303(d) of the Federal Clean Water Act as a result of ARD and heavy metal contamination from abandoned copper-zinc mines within the watershed (USEPA 2000). The Central Valley Regional Water Quality Control Board has instituted waste discharge requirements and Cease and Desist Orders associated with permits issued under the National Pollutant Discharge Elimination System (NPDES) for the Mammoth, Keystone, Early Bird, Balaklala, and Shasta King mines within this watershed.

The watershed analyses suffer from two atypical situations: 1) Most of the mines are located within two planning-level watersheds within the Lake Shasta Watershed (planning-level watersheds are much smaller than the level used for analyses); 2) Mine density is low overall, except in these two planning-level watersheds — Upper Squaw and Lower Backbone. Therefore, the impact on these smaller watershed units is diluted by inclusion in the larger Lake Shasta Watershed. In circumstances such as these, perhaps the analyses should be done at the planning-level — of which there are 39 within the Lake Shasta Hydrologic Area.

3.6 Lower Owens River Valley Study Area

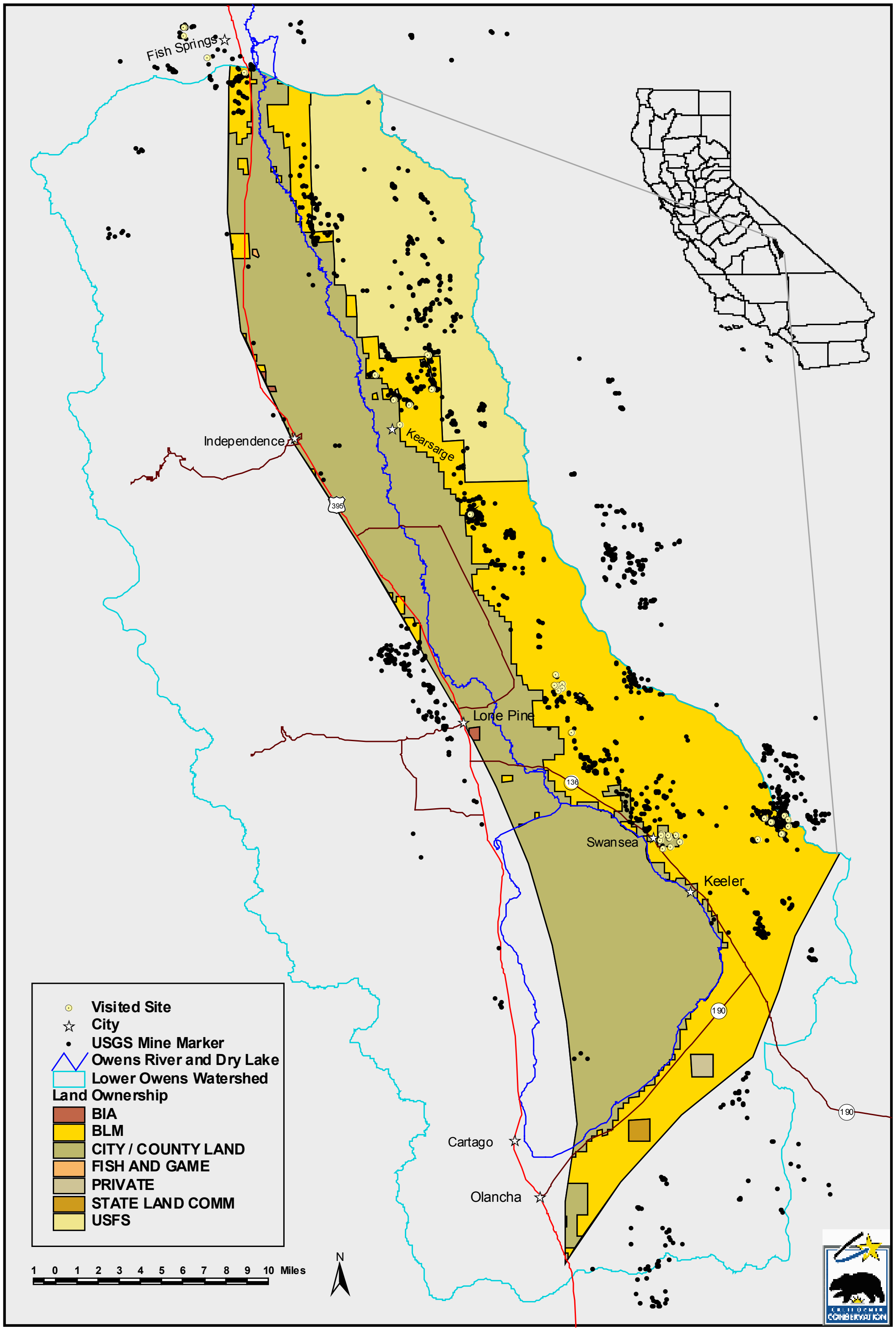


Figure 3.9: Lower Owens River Watershed, Area Map.

The study area comprises the intersection of the "Lower Owens" Watershed (ICWMP 1998) with the Jepson "East of Sierra Nevada" Region (Hickman 1993). This region is approximately bounded by the Tinemaha Resevoir to the north, Lake Owens to the south, Highway 395 to the west and the peaks of the Inyo Mountains to the east. Average annual precipitation ranges from a high of 12.5 inches, in some of the mountain areas, to a low of 5.5 inches at the valley floor (USGS et. al. 1994). Elevation ranges from a low of about 3,600 feet at Lake Owens to a high of about 11,100 feet at Mount Inyo.

The area is sparsely populated. The small towns of Lone Pine and Independence (the county seat) represent most of the people. There are probably fewer than one thousand in all. The area is highly dependent on tourist dollars. Lone Pine provides a center for visitors to Mount Whitney and the Alabama Hills (made famous by the Lone Ranger television series) as well as a stopping point for travellers heading to Mammoth Mountain.

One vegetation classification for the area (USFS 1981) shows a predominance of perennial grasses along the valley floor. Sagebrush communities are more common at higher elevations from the toe slopes of the Inyos and up. In Lake Owens, alkali scrub predominates. To the east of the lake bed, desert scrub communities dominated by creosote and blackbrush are more common than the sagebrush communities to the north. Near the ridgeline of the Inyo Mountains, gradations of pinyon-juniper and, to a lesser extent, subalpine conifer exist. Generally, the vegetative cover is low, typical of this hot and dry climate.

Land ownership in the study area is approximately 182,493 acres federal, 150,803 acres local government, 1,304 acres private, and 684 acres state. It should be noted that local government refers to all city and county entities. And in the case of the Owens River Valley, much of the valley floor is actually owned by the City of Los Angeles rather than local entities. Of the federal land, approximately 124,619 acres is BLM, 57,615 acres is USFS and 259 acres is BIA. Of the State land, approximately 640 acres is SLC and 44 acres is DFG. Local Government and Private lands are not subdivided in the data source (USFS and BLM 1999).

3.6.1 Short History of Mining

The first prospecting in the Owens Valley occurred shortly after 1859 and the large Comstock discovery in Nevada. Before that time, Anglo people had rarely ventured through the valley. As promising discoveries were reported, more Anglos began descending on the valley. The native Paiute Indians attempted to thwart the migration of unwanted settlers but were eventually subdued by the U.S Calvery. Still, skirmishes between the Paiutes and settlers effectively delayed the widespread mining between 1862 and 1865.

The original silver claims at Cerro Gordo were discovered in 1865 by the Mexican Pablo Flores and several others. Despite this promising discovery, the Cerro Gordo district did not experience a rapid growth spurt like other areas. This was largely due to its remote location high up in the Inyo Mountains. However, in 1868, this all changed with the arrival of Mortimer Belshaw. He was an experienced silver miner and a cunning businessman. He had the first road built to the mines, and began charging a toll for its use. With financial backing from partners in San Francisco, he managed to build a small empire on the hill. The Cerro Gordo mine was instrumental not only in the development of the Owens

Valley, but also to San Pedro — accounting for one third of all shipments at the port in 1874. Shortly after that year, the rich galena ores became harder to find, and by 1879 the mine had ceased operation completely. Others continued to work low grade ores and continued to prospect for several years. In 1906 the mine saw new life, first processing low grade silver ores, and then processing the high grade zinc carbonate ores from 1911 to 1919. But again, the ores gave out and the mining halted. The mine has seen little production since (Nadeau 1999).

While the history of Cerro Gordo is certainly the most well documented of any of the mines in the study area, it certainly wasn't the only mine. Ores similar to those found at Cerro Gordo were mined at many locations along the Inyo Mountains. Most were much smaller in magnitude, with the notable exceptions of the Reward and Silver Spur mines. But silver was not the only thing in those hills. A significant deposit of dolomitic limestone has been mined along the base of the Inyos northeast of Owens Lake. Copper, gold, lead and zinc have also been mined.

Historically, the silver ores were processed in smelters. Early smelters were crude vasos. Belshaw introduced a much more efficient water jacketed smelter at Cerro Gordo. The smelters created a huge demand for charcoal in the region, leading to the almost complete deforestation of the Inyo Mountains. The resulting bullion was then shipped to refining facilities such as the Selby Works in San Francisco and even as far as Wales. Amalgamation with mercury was more often used for "free-milling" gold and silver ores. However, occurrences of such ores were less frequent in this study area.

3.6.2 Current Mining

Mines that are currently active consist largely of stone and aggregate operations. The dolomitic limestones mentioned above, continue to be worked. Many of the reporting mines are small borrow pits used for road base.

The most recently active metallic mine was the Snowcaps, east of Independence. It was an open pit gold mine, with cyanide heap-leach processing. It ceased operation in 1990. A closure plan was subsequently implemented. After a five year monitoring phase, the site was signed off as reclaimed by the lead agency. Final documentation was filed in 1995.

3.6.3 Sample Study

3.6.3.1 Results Summary

The sampled sites were evaluated and ranked for chemical and physical hazards using the Preliminary Appraisal and Ranking system. Summaries of these rankings are provided below (see page 16 for details on the ranking system).

Table 3.37: Summary Chemical Hazards Ranks for Field Visited Sites.

Rank	Count	Percent	Definition of Rank
1	20	57.14	Very low probability of chemical hazards
2	7	20.00	Low probability of chemical hazards
3	8	22.86	Moderate probability of chemical hazards
4	0	0.00	High probability of chemical hazards
5	0	0.00	Very high probability of chemical hazards
	35	*100.00*	

Table 3.38: Summary Physical Hazard Ranks for Field Visited Sites.

Rank	Count	Percent	Definition of Rank
0	7	20.00	No physical hazards
1	4	11.43	Very low probability of physical hazards
2	10	28.57	Low probability of physical hazards
3	4	11.43	Moderate probability of physical hazards
4	4	11.43	High probability of physical hazards
5	6	17.14	Very high probability of physical hazards
	35	*100.00*	

3.6.3.2 Predicted Chemical Hazard Rankings

The rankings summarized above were then used to create a statistical model to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see Section 2.3 on page 16). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data. The predictive model utilized the field verified *chemical hazard rankings*. The results of the model (r^2=55%, p<0.0001) are then applied to the MAS/MILS occurances within the watershed using information from the MAS/MILS database about generalized commodity (derived from COM1), mine type (TYP), mine status (CUR), and PAMP. The results of the regression model for chemical hazards and its components are displayed below. It is interesting to note that in this model PAMP membership defines a lower ranking unlike all previous models that employed PAMP.

Table 3.39: Summarized statistics for the chemical hazards GLM.

Analysis of Variance for CHEMICAL HAZARD

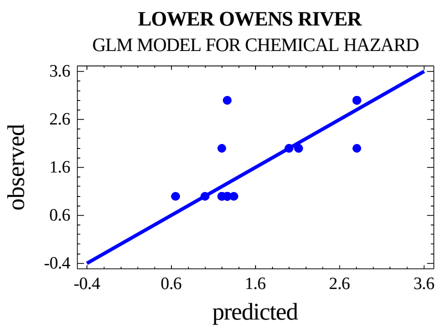
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	14.9985	6	2.49976	7.88	0.0000
Residual	8.88718	28	0.317399		
Total (Corr.)	23.8857	34			

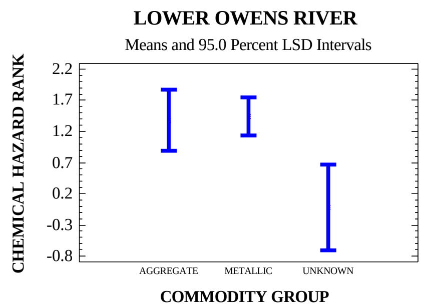
Type III Sums of Squares

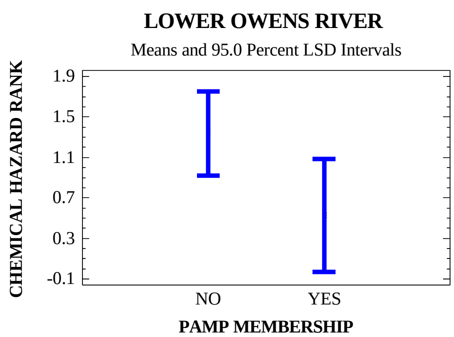
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
commod_group	3.48782	2	1.74391	5.49	0.0097
TYPE_CODE	2.69501	2	1.34751	4.25	0.0245
PAMP	1.02797	1	1.02797	3.24	0.0827
CUR_CODE	1.24615	1	1.24615	3.93	0.0574
Residual	8.88718	28	0.317399		
Total (corrected)	23.8857	34			

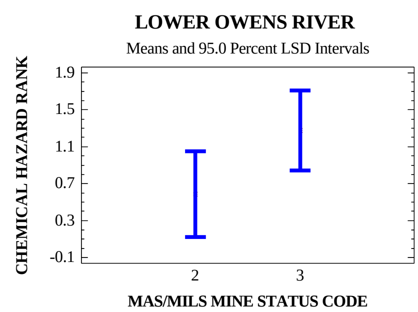
R-Squared = 62.7929 percent
R-Squared (adjusted for d.f.) = 54.82 percent
All F-ratios are based on the residual mean square error.

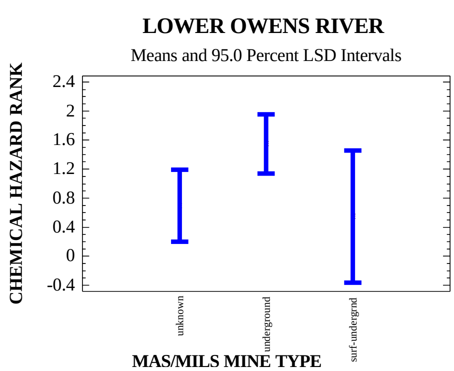
The following graphs depict the tests among means for each component of the GLM regression analysis.











The following table is a summary by rank for predicted rankings of sites in the MAS/MILS database. Within this study area, approximately 100 MAS/MILS sites could not be predicted. The excluded MAS/MILS sites included raw prospects, mineral locations, processing plants, surface or placer operations, and all non-metallic commodities. These sites could not be predicted because the sampled sites did not have sufficient correspondence with these categories.

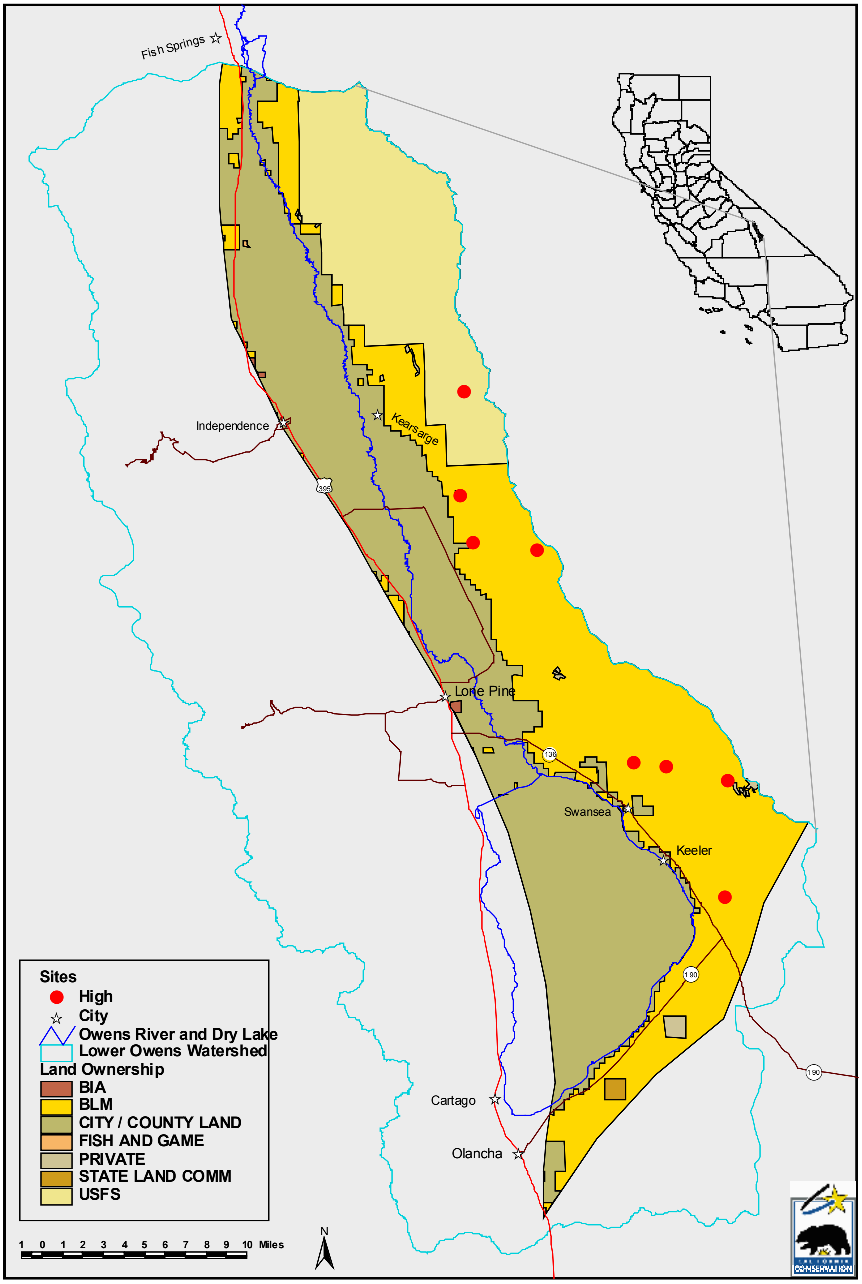


Figure 3.10: Plot of MAS/MILS mineral occurrences with a predicted chemical hazard rank of three or more.

Table 3.40: Chemical hazard predictions for MAS/MILS mineral occurrences.

Rank	Count	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
0	13	0.1130	13	0.1130
1	60	0.5217	73	0.6348
2	34	0.2957	107	0.9304
3	8	0.0696	115	1.0000

The results indicate that for this watershed there is a low to moderate probability for a site which represents a significant chemical hazard. The cumulative chemical hazard ranking score for this 331,981 acre watershed is 1728 (density 0.005205) — indicating a low cumulative chemical impact potential. It should be remembered that these results are based on metallic, stone or aggregate mines where the site is at least a developed prospect. Therefore, the contributions from non-metallic sites are not included.

3.6.3.3 Predicted Physical Hazard Rankings

The *physical hazard ranking* was also predicted by regression analysis with a General Linear Model. The prediction model utilizes the field verified *physical hazards ranking*. The results of the predictive model (r^2=57%, p<0.0001) are then applied to the MAS/MILS database for the watershed using MAS/MILS database information about the mine type (TYP), geologic rocktype group (Rocktype) and the potential for arsenic (derived from MRDS). The results of the regression model for physical hazards and its components are displayed in below.

Table 3.41: Summarized statistics for the physical hazard GLM.

Analysis of Variance for PHYSICAL HAZARD

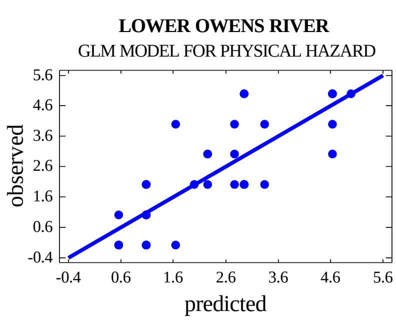
Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
Model	66.2714	6	11.0452	8.68	0.0000
Residual	35.6144	28	1.27194		
Total (Corr.)	101.886	34			

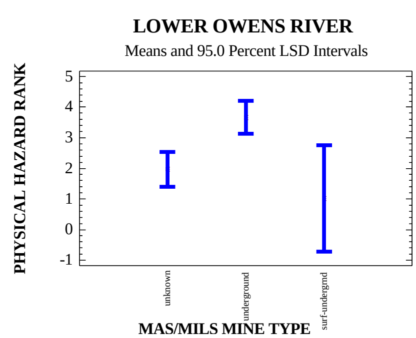
Type III Sums of Squares

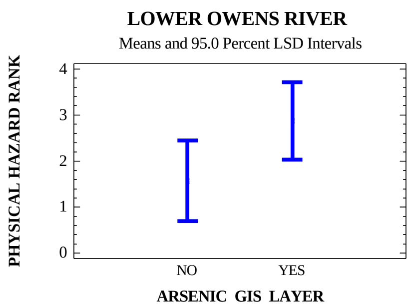
Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
TYPE_CODE	24.3597	2	12.1798	9.58	0.0007
ROCKTYPE_N	27.9151	3	9.30502	7.32	0.0009
AS	4.82857	1	4.82857	3.80	0.0615
Residual	35.6144	28	1.27194		
Total (corrected)	101.886	34			

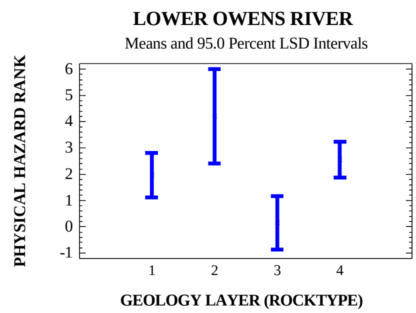
R-Squared = 65.0448 percent
R-Squared (adjusted for d.f.) = 57.5544 percent
All F-ratios are based on the residual mean square error.

The following graphs depict the tests among means for each component of the GLM regression analysis.









The following table is a summary by rank for predicted rankings of sites in the MAS/MILS database. Within this study area, approximately 100 MAS/MILS sites could not be predicted. The excluded MAS/MILS sites included raw prospects, mineral locations, processing plants, surface or placer operations, and all non-metallic commodities. These sites could not be predicted because the sampled sites did not have sufficient correspondence with these categories.

Table 3.42: Physical hazard predictions for MAS/MILS mineral occurrences.

Rank	**Count**	**Relative Frequency**	**Cumulative Frequency**	**Cum. Rel. Frequency**
0	33	0.2870	33	0.2870
1	18	0.1565	51	0.4435
2	32	0.2783	83	0.7217
3	26	0.2261	109	0.9478
5	6	0.0522	115	1.0000

The results indicate that for this watershed there is a moderate probability for a site which represents a significant physical hazard. The cumulative physical hazard ranking score for this 331,981 acre watershed is 26,394 (density 0.0795) indicating that AML sites in the watershed likely poses a moderate threat of physical hazards. It should be remembered that these results are based on metallic, stone or aggregate mines where the site is at least a developed prospect. Therefore, the contributions from non-metallic sites are not included.

3.6.3.4 Predicted Hazardous Openings

A hazardous opening is defined as an opening (shaft, adit, drift, decline, tunnel, etc.) that is large enough and deep enough for someone to become trapped in or from which a fall could cause serious injury. For this purpose, a depth or length of 10 feet is used.

There are 126 topographic symbols indicative of an opening as shown on the topographic maps for the sampled sites (The number of topographic openings is digitized by AMLU from the USGS quad.). 198 openings were verified in the field for these sites, and 143 (or 72%) were found to be potentially hazardous. Using a simple regression model, we can predict the number of openings in the field (r^2=71%, p<0.0001) based on the number of openings shown on the topographic sheet. The predicted value is 680 openings. Once again, applying a simple regression to the predicted openings, we estimate that there are 518 hazardous openings in the watershed (r^2=85%, p<0001).

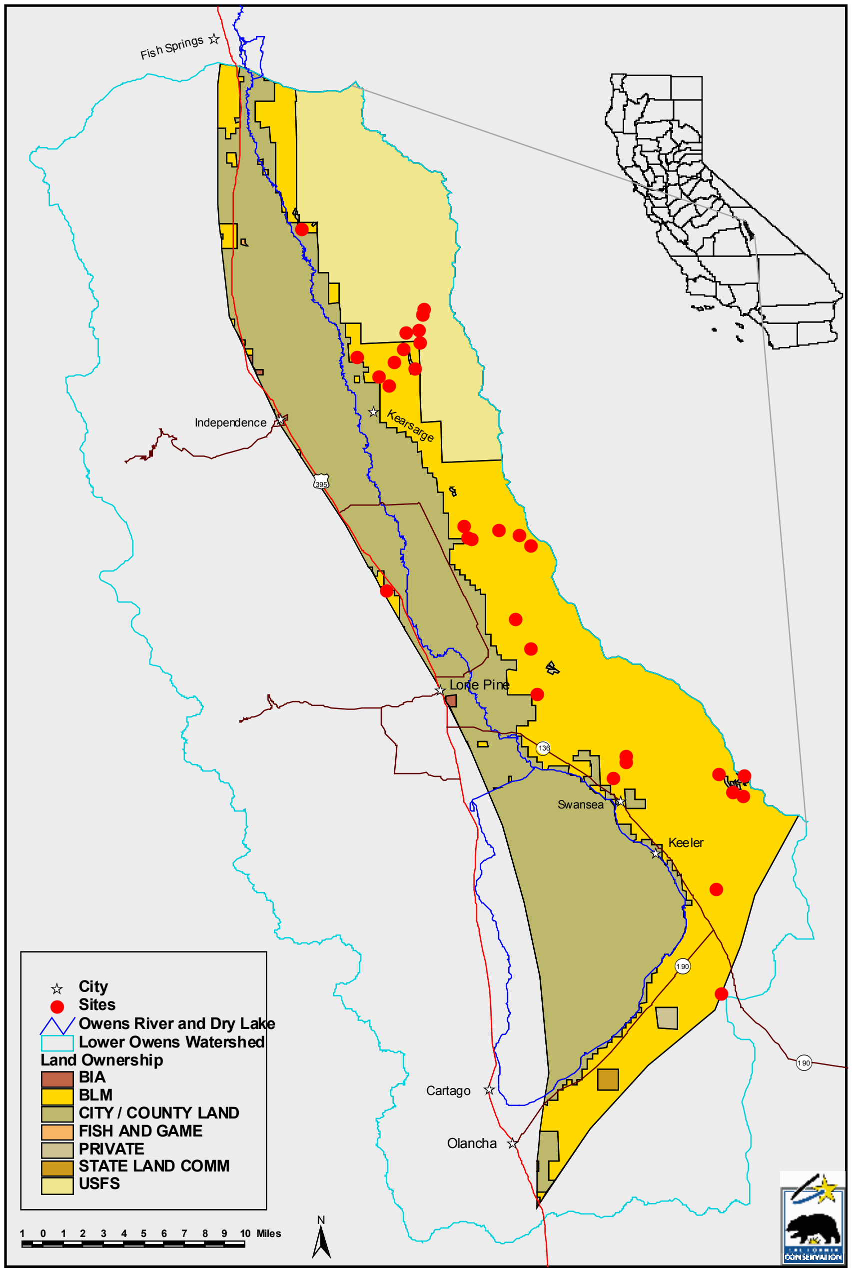


Figure 3.11: Plot of MAS/MILS mineral occurrences with a predicted physical hazard rank of three or more.

3.6.4 Summary of Findings

In this watershed, there is a low probability for a site which presents a significant chemical hazard. Cumulatively, there is a low probability for a significant impact to the environment. Individual mines in this watershed have a moderate probality of presenting a physical hazard, and cumulatively the watershed has large number of hazardous openings.

Table 3.43: Summarized findings for the Lower Owens Watershed.

Total Watershed Area (Acres)	331,981
Predicted Cumulative Chemical Ranking Score	1,728
Predicted Cumulative Chemical Ranking Score Density	0.005205
Predicted Cumulative Physical Ranking Score	26,394
Predicted Cumulative Physical Ranking Score Density	0.0795
Predicted Hazardous Openings	518

3.7 Merced River Watershed

The Merced River Watershed (Merced) lies in the Central Sierra Nevada. It lies almost entirely within Mariposa County with a small sliver of the western-most extremity of the watershed in Merced County and the southeastern extremity in Madera County.

Major, through-going roads are limited to State Highways 41, 49, and 120. While the county has been historically sparsely populated, it is now experiencing the same rapid expansion as the more northerly foothill counties. With the presence of Yosemite Park, the region experiences very high levels of tourism and outdoor recreation is a primary industry.

Land management and ownership is summarized in Table 3.44. Essentially, 80% of the Merced is public land managed by three Federal Agencies; Forest Service (USFS), Bureau of Land Management (BLM), and the National Park Service (NPS), with the remaining 20% under private ownership. Lands managed by the NPS form a single large contiguous parcel. Lands managed by the USFS essentially form a single large contiguous parcel, having only discrete private in-holdings surrounded by USFS managed public lands. However, the lands managed by the BLM are quite different. Public lands managed by BLM are highly fragmented, and at times it is difficult to discern whether one is dealing with a private inholding in public lands or a remnant of public land within private land.

Table 3.44: Land Ownership in the watershed.

Ownership	**Agency**	**Acres**	**Percent**
Federal	USFS	176,368	25.1
	BLM	70,252	10.0
	NPS	320,060	45.5
Sum		*566,680*	*80.6*
State	Lands Commission	311	0.04
	Fish & Game	121	0.02
Sum		*432*	*0.06*
Private		136,300	19.4
Totals		*703,412*	*100.06*

For the 49 sites visited, 46% of the mine features observed and catalogued occurred on private land. However, 76% of the observed and catalogued mine features occurred on lands adjacent to or within public lands. Thus presenting a significant potential for interaction with users of public lands, e.g. outdoor recreationists and tourists.

The Merced is comprised of six Hydrologic Areas, the five summarized in Table 3.45 and the Mountain Star King . Together they have a total area of 703,412 acres. However, the study was limited to the five Hydrologic Areas in which mining has been documented.

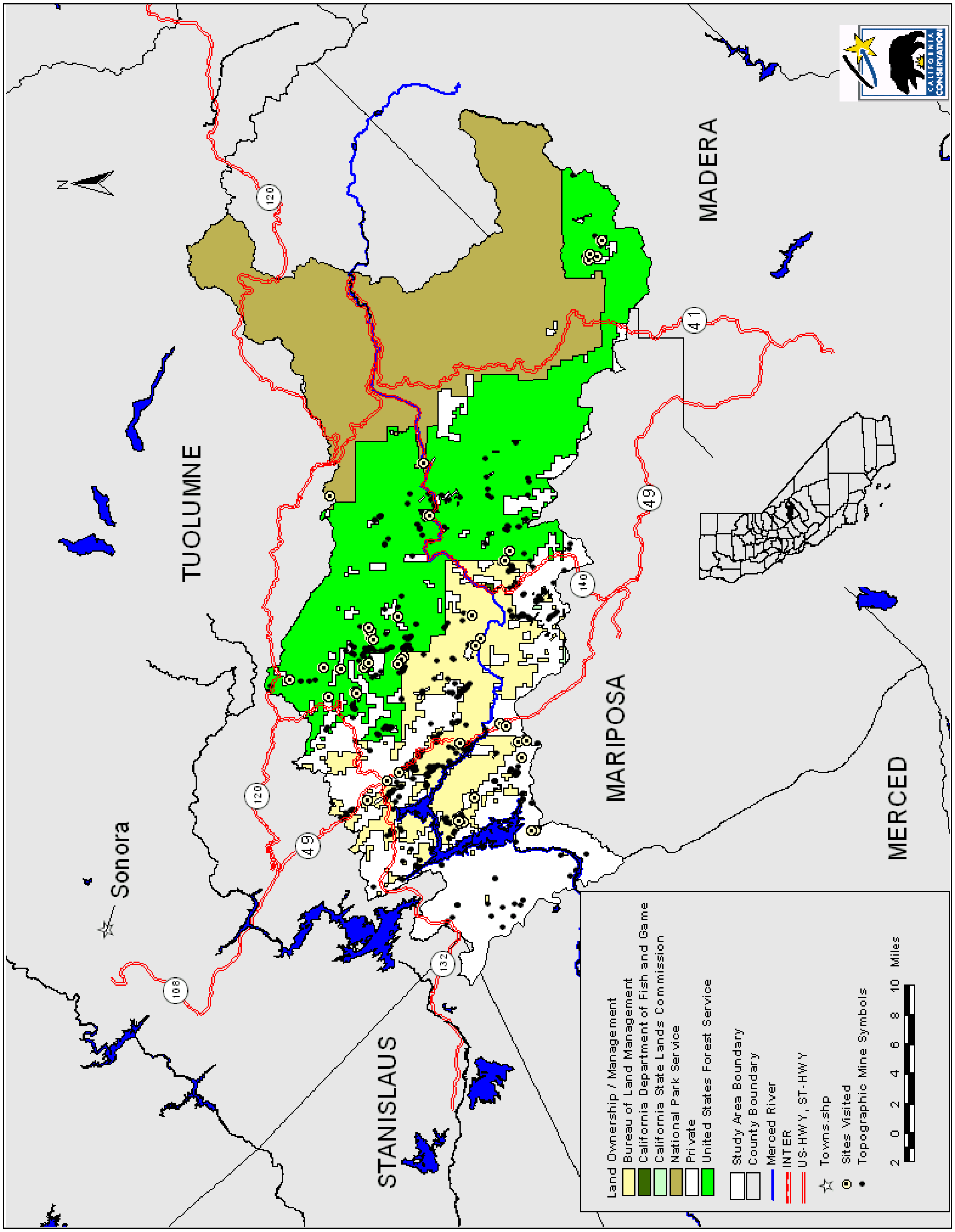


Figure 3.12: Merced River Watershed, Area Map.

The main stem of the Merced River is 164 miles long from its headwaters in eastern Yosemite National Park to its confluence with the San Joaquin River. The segment down-stream of Lake McClure has been listed as impaired under section 303(d) of the federal Clean Water Act. The California Unified Watershed

Assessment rates the Merced as a functional, but at-risk watershed. The Merced is rated 5, serious problems, low vulnerability, on the USEPA Index of Watershed Indicators.

Table 3.45: Summary of Hydrologic Areas with Mining in the Merced River Hydrologic Unit.

Area	**Acres**
Yosemite	121,867
North Fork Merced	160,856
Buckhorn Peak	80,379
Kassenbaum Flats	39,709
South Fork Merced	154,021
Total	556,832

This watershed may provide habitat for as many as 16 threatened or endangered plants, four threatened or endangered animals , and 12 animal species of concern, including two bats, and four invertebrates of concern.

The Merced encompasses the Northern High Sierra Nevada (SNH), Central Sierra Nevada Foothills (SNF), and San Joaquin Valley (SnJV) biological subregions, which are components of the Sierra Nevada (SN) and Great Central Valley (GCV) BioRegions, respectively, as defined in the Jepson Manual (Hickman 1992). The SnJV occurs on the western boundary of the watershed and encompasses approximately 1% of the watershed. It is characterized by grasslands with sparse oaks. The SNF occupies the western and west-central portion of Merced Watershed, encompassing approximately 28% of the watershed. It is characterized by a mix of scrub-oak manzanita chaparral and grasslands. The SNH occurs west-central through the eastern boundary of the Merced, encompassing approximately 71% of the watershed. This subregion is typically characterized by conifer forests interspersed with alpine valley grasslands and associated stands of mixed deciduous. However, in the western third of this region, extensive clear cuts have resulted in a setting more closely related to a manzanita dominated chaparral.

Located within the central portion of the Sierra Nevada Geomorphic Province, the Merced encompasses the southern termini of the Sierran Mother Lode and Copper Belts and the sculpted granites of Yosemite National Park. The geology of the Merced is dominated by the granitic highlands made famous by Yosemite National Park. Granites and related plutonic rocks occupy approximately 45% of the area of the Merced. They occur in the eastern half of the watershed. While they comprise the largest single geologic unit, only 10% of the mining activity occurred in granitic terrain. The mining that did occur was not in the granites themselves, but rather in exotic non-granitic blocks incorporated into the granitic terrain, during its formation. Metasedimentary and related rocks occupy approximately 30% of the area of the Merced. They occur primarily in the central and west-central portion of the watershed and define the southern extent of the "Mother Lode". This geologic setting was host to approximately 55% of the mining activity that occurred in the Merced.

The metasedimentary rocks that hosted the ore veins were typically Mesozoic marine sediments that have been altered to slates, phyllite, quartzite, and marbles. Of these, slates are by far the most abundant, being the host rock for over 50% of the gold-bearing quartz veins that typify the "lodes" of this region. Volcanic and related rocks occupy approximately 22% of the area of the Merced. They occur primarily in the western portion of the watershed and define the "Foothills Copper Belt". This geologic setting hosted approximately 33% of the mining that has occurred in the Merced. The rocks of this region are typified by volcanic and metamorphosed volcanic rocks (greenstones) of Mesozoic age that originated as undersea volcanic eruptions. These rocks are the dominant rocks of this region, with minor amounts of highly metamorphosed sedimentary rocks that where the temporal and spatial contemporaries of the volcanic rocks. The volcanic rocks and to a much lesser degree the interlaced metasedimentary rocks, host massive sulfide deposits (pyrites) that are the source of the rich copper ores.

3.7.1 Short History of Mining

The Merced shares much of the same history of mining as the main mother load to the north. Sporadic mining was carried out by Mexican miners until about 1848 when the massive influx of Anglo miners heralded the "gold rush" . By 1849 placer mining was occurring at a fevered pitch throughout the watershed. In addition to the classic small-scale placer operations, the Merced was experiencing large-scale hydraulic mining at sites such as Australian Gulch. As competition for placer claims grew, miners began looking for the source of the placer gold. Toward the end of 1849, several of the major lode gold ore bodies had been discovered and development was well under way .

However, unlike their neighbors to the north, this portion of the mother load did not possess extensive high-grade ore veins. Rather, lode gold deposits in this region consisted of "pocket gold". Typically, ore bodies consisted of extensive stringers of low-grade ore that would lead into a pocket of very high grade ore. Thus, the lode mines of the Merced experienced a significantly different economic reality than those working in the "heart" of the mother lode (Aubrey L. E. 1904, Castello 1921). This translated into mining operations that were difficult to capitalize and difficult to maintain profitability (i.e., operating). For example, one of the longest operating and most successful mines in the region, the Mountain King, when faced with diminishing availability of fuel resources for steam-power, chose to invest its limited capital reserves in conversion to electric power with the construction of a hydro-electric diversion on the Merced River, rather than upgrade their milling operations (Castello 1921). The Mountain King was still using mercury amalgamation when it closed in the early 1930's, long after the more efficient cyanization process had become the standard for the wealthier mines in the north (William Imhoff, personal communication, review of diary of Mountain King Mine superintendent 1999).

The Merced also supported extensive copper mining. Copper mining came late to this region, getting started in early 1863. A copper boom ensued, but by 1867 the demand for copper fell dramatically and copper mining essentially halted. A small resurgence began in the northern copper belt in 1875. By 1884, a few of the larger mines such as the La Victoria had resumed limited, small-scale operations. Low-level activity continued until the on-set of World War I. The war driven demand resulted in many of the mines reopening and the larger ones working at full capacity. However, shortly after the end of World War I, the demand for copper plummeted and the mines closed. This cycle repeated itself with the onset of World War II. Large operations such as the La Victoria and the Blue Moon were reopened and operated at capacity through the war years. As with the previous cycle, by 1948 the mines had closed (Bramel, H. R. et al 1948).

In addition to gold and copper, lead, zinc, barite, jade, and iron were mined. Of these, barite was the most significant. The El Portal Barite mine was the principle source of barium in the entire Sierra Nevada Region. The development of the oil industry in the adjacent Great Valley, created a large demand for barium (barite) as a weighting agent for drilling fluids used in the oil industry (Laizure C. M. 1930). The El Portal Mine and its sister the Barite Queen flourished until their closure in the late 1940's .

At the turn of the century and into the 1920's, several iron deposits underwent developmental work and some limited mining. Of those the most notable was the Hart Iron Deposit which is located adjacent to the southern boundary of Yosemite National Park (Root L. L. 1928). While the proven reserve was sufficiently large to be of economic interest, the lack of a transportation infrastructure precluded this deposit from being mined.

In the last twenty years, the Merced has seen several flurries of activity related to the "run-up" in gold prices. The vast majority of activity was exploration and re-evaluation of known ore bodies. During the gold price run-up of the mid 1980's, the major copper mines experienced extensive drilling. For example, one can today find many thousands of feet of rock cores, in boxes, and the remnants of a complete core laboratory at the Blue Moon – American Eagle site.

3.7.2 Current Mining in the Watershed

Currently, there is one active large-scale gold mine within the Merced, operated by the Colorado Quartz-Gold Corporation. Numerous small-scale placer and lode operations are currently active within the watershed. Also, some of the larger historic mines such as the Hasloe are experiencing recreational mining by mining clubs comprised of history buffs reliving the romance of a bygone era. In addition, historic dredge tailings are being mined for aggregate.

3.7.3 Sample Study

The Merced Watershed was chosen as a "target watershed" based on stakeholder priorities. The sample design employs a stratified random approach in which the population is subdivided into relatively homogeneous groups or strata based on geology. Mine symbols shown on United States Geologic Survey (USGS) Topographic maps were used as the "population" to be sampled. All total, 50 localities were selected for evaluation. However, only 49 were visited as AMLU personnel were denied access to one site in the western portion of the watershed.

3.7.3.1 Watershed Summary and Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard (Table 3.46, Table 3.47).

Table 3.46: Field Verified Chemical Hazard Rankings.

Rank	Count	Percent	Definition of Rank
0	21	43	No probability of releasing hazards into the environment
1	3	6	Very low probability of releasing hazards into environment
2	10	20	Low probability of releasing hazards into environment

Rank	Count	Percent	Definition of Rank
3	8	16	Moderate probability of releasing hazards into environment
4	6	12	High probability of releasing hazards into environment
5	1	2	Very high probability of releasing hazards into environment
Total	*49*	*99*	

Table 3.47: Field Verified Physical Hazard Rankings.

Rank	Count	Percent	Definition of Rank
0	8	16	No physical hazards
1	14	29	Very few physical hazards
2	5	10	Few physical hazards
3	10	20	Moderate amount of physical hazards
4	6	12	Large amount of physical hazards
5	6	12	Very large amount of physical hazards
Total	*16*	*99*	

3.7.3.2 Predicted Chemical Hazard Rankings

The rankings above were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see section 2). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data. The predictive model employed information from MAS/MILS on production status (CUR), overlain with "reclass" (from Geology GIS layer) and whether or not the site was a member of the Principle Areas of Mine Pollution (PAMP) database. The salient points of the model are summarized below.

Table 3.48: Summarized statistics for the chemical hazard GLM.

Analysis of Variance for CHEM_APR

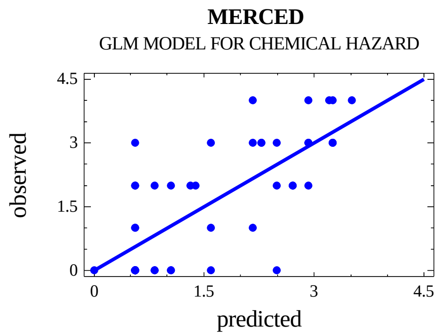
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	58.35	8	7.29	6.68	0.0000
Residual	43.65	40	1.09		
Total (Corr.)	102.0	48			

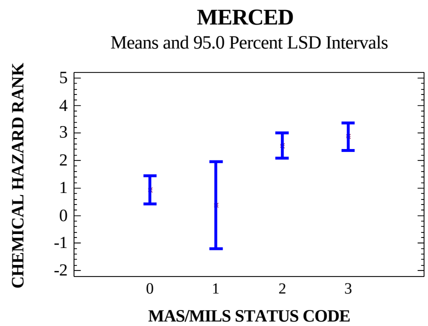
TYPE III Sums Of Squares

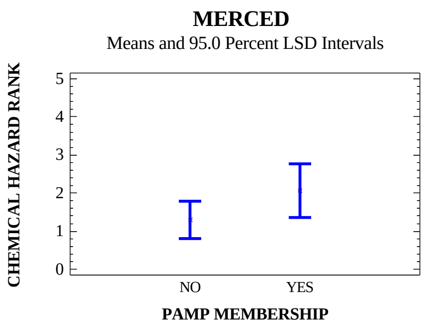
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	3.39	1	3.39	3.11	0.0854
CUR_CODE	24.76	3	8.25	7.56	0.0004
RECLASS	9.56	4	2.39	2.19	0.0875
Residual	43.65	40	1.09		
Total (Corr.)	102.0	48			

All F-ratios are based on the residual mean square error.
R-Squared = 57.21 percent
R-Squared (adjusted for d.f.) = 48.65 percent

The following graphs depict the tests among means for each component of the GLM regression analysis.







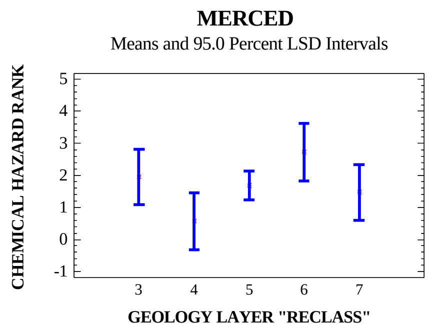


Table 3.49: Predicted chemical hazard rankings for MAS/MILS mineral occurrences.

Rank	Count	Percent	Definition of Rank
0	74	14	No probability of releasing hazards into the environment
1	149	27	Very low probability of releasing hazards into environment
2	264	49	Low probability of releasing hazards into environment
3	47	9	Moderate probability of releasing hazards into environment
4	4	1	High probability of releasing hazards into environment
5	0	0	Very high probability of releasing hazards into environment
Total	*538*	*100*	

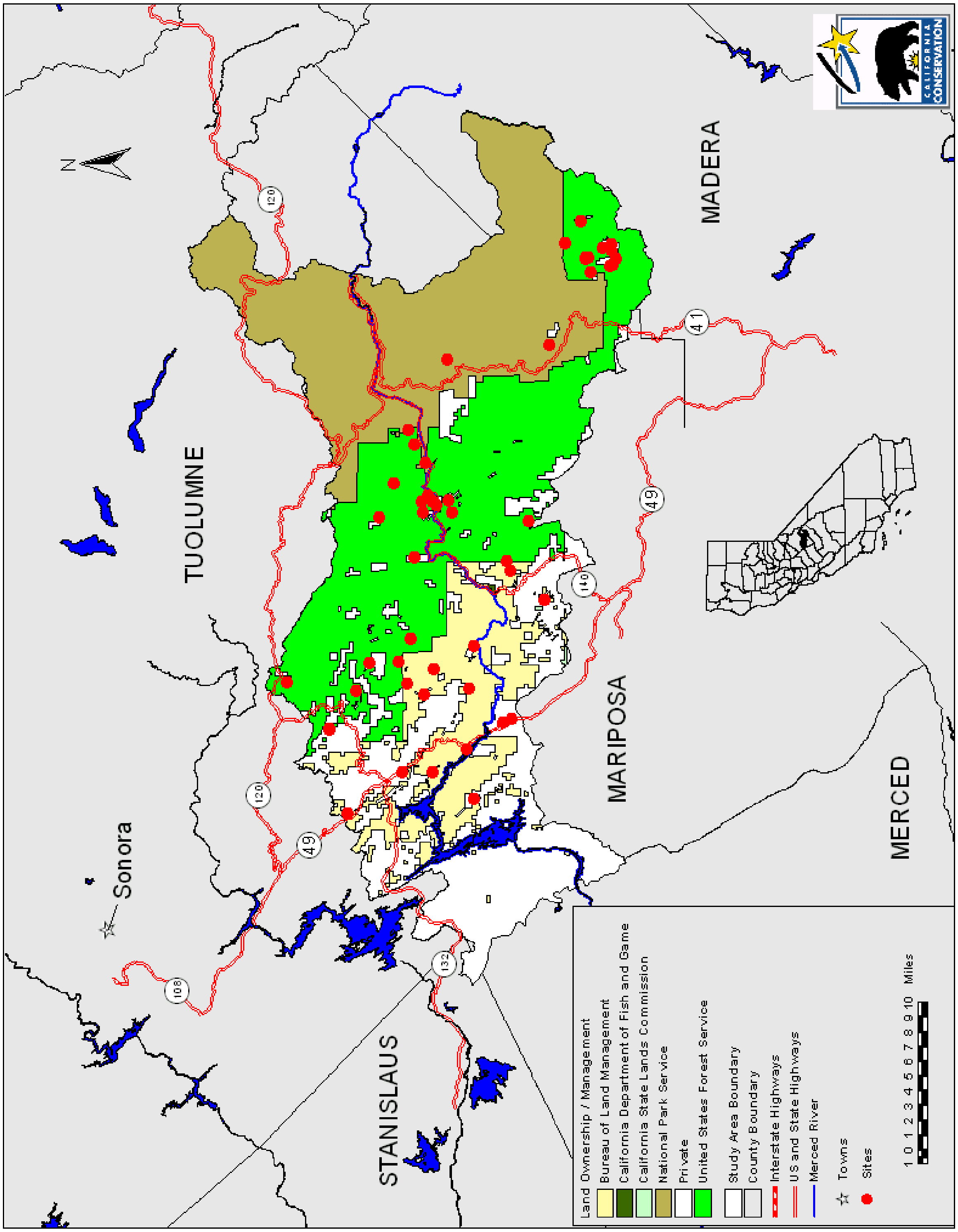


Figure 3.13: Map of MAS/MILS sites with a predicted chemical hazard ranking of 3 or above.

3.7.3.3 Predicted Physical Hazard Rankings

A reliable model for predicting *physical hazard rankings* required the use of information outside of MAS/MILS and the accessible GIS layers. In summary, either a field visit is required to consistently and accurately determine rankings, or reconciliation between the topographic symbol database and MAS/MILS is required. Therefore, we are unable to predict this score.

3.7.3.4 Predicted Hazardous Openings

Forty-three (43) topographic symbols indicative of an opening and 24 prospect symbols were shown on the topographic maps for the sampled sites. One hundred forty-four (144) openings were verified in the field for these sites, and 106 (or 74%) were found to be potentially hazardous. While it was found that we could not construct a predictive model for hazardous openings, we were able to construct a model for openings in general.

The number of openings can be predicted with an R-squared value of 62% at a $p<0.0001$ level based on the number of prospect and opening symbols shown on the topographic map, coupled with which topographic map the symbols occur on. The number of prospect and opening symbols on the USGS topographic maps are derived from digital records created by AMLU from USGS quad sheets.

The predicted number of openings for the study area is 513 (95% confidence limits are 222-819 openings). We documented 144 openings within this sample set, of which 106 were hazardous. Using this same ratio (of hazardous to total), the estimated number of hazardous openings for the study area is 378.

3.7.4 Summary of Findings

In this watershed there is a low to moderate probability for a site which presents a significant chemical hazard, and cumulatively, the AML sites in the watershed may pose a significant chemical threat to the environment. We were unable to predict *physical hazard rankings*, but the watershed as a whole has many hazardous openings (estimated to be 378).

Table 3.50: Summarized Findings for the Merced Watershed.

Watershed Area with Mining (Acres)	556,832
Predicted Cumulative Chemical Ranking Score	173,685
Predicted Cumulative Chemical Ranking Score Density	0.31
Predicted Cumulative Physical Ranking	Unable to Predict
Predicted Hazardous Openings	378

3.8 North Yuba Watershed

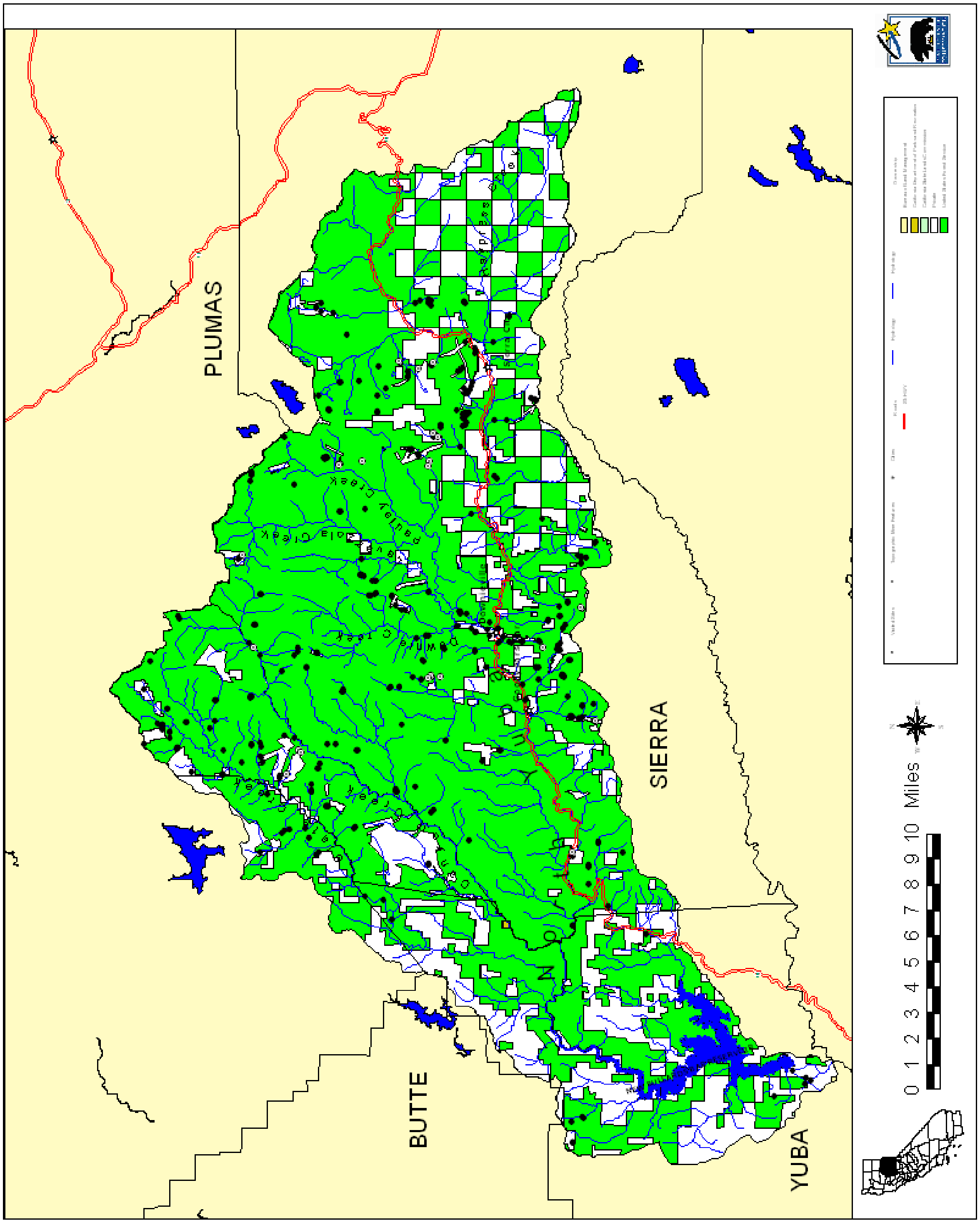


Figure 3.14 : North Yuba Watershed, Area Map.

The North Yuba Watershed is located in the Northern Sierra Nevada Mountains. This watershed is lies in parts of three counties: Yuba, Sierra, and Plumas. The size of the watershed is approximately 40 miles long and 18 miles wide with a total area of 490 square miles. The elevation ranges within this watershed ranges from a minimum of 1224 feet at New Bullards Bar dam, in the southwestern area of the watershed, to a maximum of 8107 feet at Haskell Peak in the northeastern area. The geology of the area includes Cenozoic Volcanic Rocks, Cenozoic-Precambrian Plutonic, and Mesezoic-Palezonic-Precambrian. The volcanic rocks are mostly Miocene and Pliocene lahars. This watershed lies between the towns of Nevada City to the South, Portola to the East, Quincy in the North, and Oroville to the West. This watershed is sparsely populated with less than 10,000 residents. The "Sixteen-to-One" Mine is located in this watershed and has been featured on Public Broadcasting Station (PBS) as a working tourist mine.

Table 3.51: Land Ownership Summary for the North Yuba Watershed.

Government Level	Agency	Acres	Percent
Federal	US Forest Service	241106	76.76
Federal	Bureau of Land Management	18	0.005
Sum (Federal)		241124	76.77
State	State Parks	46	0.01
State	State Lands Commission	3	0.0009
Sum (State)		49	0.016
Private	Private	72915	23.21
Sum (Private)		72915	23.21
Sum (Total)		*314088*	*100*

The climate of this watershed has cool wet winters and hot dry summers, with frequent afternoon summer thundershowers. Annual precipitation is mostly in the form of rain below 3,500 feet in elevation and ranges from 55-85 inches annually. Snow accumulates at elevations above 5,000 feet and range from 24 inches to 60 inches annually.

The topography of the area varies from west to east. That is, steep incised river channels and moderately tall mountains characterize the western region of the watershed. However, in the eastern region the watershed has steeper slopes, deeper incised river channels and higher mountains. Some of the main tributaries that make up the North Yuba River are located on the north side of the river: Canyon Creek, Slate Creek, Pauley Creek, Lavezzola Creek, Fiddle Creek and Haypress Creek.

The North Yuba watershed is contained entirely in the Northern Sierra Nevada Mountain Range Ecoregion (Hickman 1993). The plant communities are predominantly mixed-conifer series and Ponderosa Pine (at lower elevations) and white fir series (at higher elevations). Canyon Live oak series on steep canyon slopes and mixed and chaparral shrublands on steep south slopes (Miles et. al. 1997).

3.8.1 Short History of Mining

This watershed was a very important and productive gold mining region that played a central role in the California Gold Rush of 1849. One of the first parties to arrive in this region was lead by William Downie, after whom the town of

Downieville was soon named. Because of the large number of gold seekers arriving in the area, a mining district was quickly organized with fixed claims of "30 feet per man". Many rich strikes were made, and the population of the area soared to more than 5000 by 1851. In 1852, sailors began deserting their ships in San Francisco Bay to seek riches at the Forest Diggings, which later became known as the Alleghany District (Clark 1998).

Within a few years, mining districts were established throughout the watershed. All of the surface placer deposits in this watershed were mined intensively and included in-stream mining of the North Yuba River and it's tributaries. This was soon followed by extensive hydraulic operations at Howland Flat, La Porte, Poverty Hill, Port Wine, Morristown, Chip's Flat, Scales, and Minnesota. These hydraulic mines were worked intensively from the 1850's to the mid 1880's, and intermittently during the 1930's. Beginning in the 1850's, drift mining was also developed. Major drift mines in the watershed included the Bald Mountain, Live Yankee, and Ruby mines. In 1853, lode gold mining began in the watershed. The most productive lode gold districts were Allegheny, Downieville, and Sierra City. Major lode gold mines included the Sixteen-to-One, Sierra Buttes, Brush Creek, and Plumbago. Gold production in the watershed peaked in 1861, but several lode gold operations continued production of commercial quantities well into the 1960's. In 1942, War Production Board Order L-208 closed most of the mines. By the 1950's, there were only 15 lode gold mines still in operation. (DMG Vol. 52)

The North Yuba Watershed contains seven major mining districts: Port Wine, La Porte, Alleghany, Poverty Hill, Downieville, Poker Flat, and Sierra City. The most productive were the La Porte, Allegheny, Sierra City, and Poker Flat districts. The La Porte District produced more than $60 million in placer gold, mostly by hydraulic mining, from 1855 to 1871. Drift and lode gold mining remained commercially profitable and continued until 1918. The Alleghany District had an estimated production of both placer and lode gold exceeding $50 million. Drift and hydraulic operations continued until the mid 1880's, when lode mining became more prevalent. The Allegheny District remained productive following WW II, and commercially successful lode mining continued until the 1960's at the Sixteen-to-One and Brush Creek mines. The Sierra City District was extremely productive from 1870 to 1914. Estimates of gold output in this district total more than $30 million. The Sierra Buttes Mine was reported to have produced over $17 million in gold alone. The Poker Flat District was heavily mined by hydraulic operations until the 1880's. Howland Flat, one of the largest hydraulic mines in the watershed is estimated to have produced $14 million. The Downieville District is famous, not only for being the first mining district established in this watershed, but for the sheer volume and size of gold nuggets recovered from the placer deposits during the early months of the "Gold Rush". The Port Wine and Poverty Hill districts were characterized mainly by extensive hydraulic and drift mining. From the 1850's to the 1960's, the mines of the North Yuba Watershed produced over $155 million in gold, making this one of the most productive watersheds in California for lode and placer gold production. (Clark 1998)

3.8.2 Current Mining

Only three mines remain active in the watershed today. One mine is a sand and gravel operation, and another produces decomposed granite. The third is the illustrious Sixteen-to-One Mine in the Alleghany District, which is still actively producing lode gold. After closing in 1965, the mine was re-opened in the late 1980's and has been active ever since. In addition to gold production, it is also a tourist mine offering underground tours.

3.8.3 Sample Study

The North Yuba Watershed was chosen at random from a larger data set of bioregions. Topographic mining symbols were digitized from the thirteen USGS 7.5-minute topographic maps that encompass the watershed. Then the watershed was stratified by the four rocktypes that make up this area. These rocktypes types were: Cenozoic Sedimentary Rocks, Cenozoic Volcanic Rocks, Cenozoic-Precambrian Plutonic Metavolcanic and Mixed Rocks, and Cenozoic-Precambrian Plutonic Metavolcanic, and Mixed Rocks. Ten topographic mine symbols were randomly select by rocktype in addition to five Principal Areas of Mine Pollution (PAMP). This makes the total population of samples to be thirty mine sites. Due to poor location, denied access and time constraints we obtained thirty samples but the distributions among rocktypes vary. For more details on sampling techniques refer to the Methods section of this document.

3.8.3.1 Watershed Summary: Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard.

Table 3.52: Field verified Chemical Hazard Rankings.

Rank	**Count**	**Percent**	**Definition of Rank**
0	11	37	No probability of releasing hazards into the environment
1	2	7	Very low probability of releasing hazards into the environment
2	14	47	Low probability of releasing hazards into the environment
3	2	7	Moderate probability of releasing hazards into the environment
4	1	3	High probability of releasing hazards into the environment
Total	*30*	*101*	

Table 3.53: Field verified Physical Hazard Rankings.

Rank	**Count**	**Percent**	**Definition of Rank**
0	4	13	No physical hazards
1	7	23	Very few physical hazards
2	11	37	Few physical hazards
3	6	20	Moderate amount of physical hazards
4	1	3	Large amount of physical hazards
5	1	3	Very large amount of physical hazards
Total	*30*	*99*	

3.8.3.2 Predicted Chemical Hazard Rankings

These rankings were then employed in a statistical model which was used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see section 2). The *chemical ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r-squared 50%, p=0.0075) are applied to the MAS/MILS database for the watershed using the potential for native mercury (derived from the MRDS database) and the "Reclass" geology (derived from the 750K surface geology). The results of the regression model for *chemical hazards* and its' components are displayed below.

Table 3.54: Summarized Statistics for the GLM Model of Chemical Hazards.

Analysis of Variance for Chemical Hazard

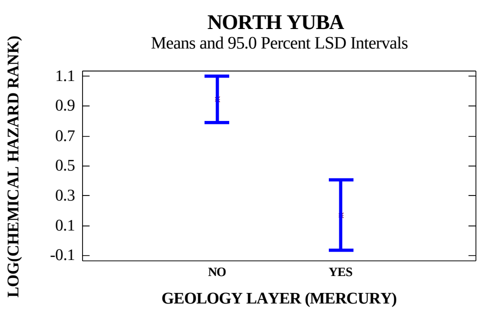
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1.27757	6	0.212929	5.19	0.0075
Residual	0.491861	120	.0409884		
Total (Corr.)	1.76943	18			

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Hg	0.49954	1	0.49954	12.19	0.0045
RECLASS#	1.15846	5	0.231692	5.65	0.0066
Residual	0.491861	12	0.0409884		
Total (corrected)	1.76943	18			

All F-ratios are based on the residual mean square error.
R-Squared = 72.2023 percent
R-Squared (adjusted for d.f.) = 58.3035 percent

The following graphs depict the tests among means for each component of the GLM regression analysis.



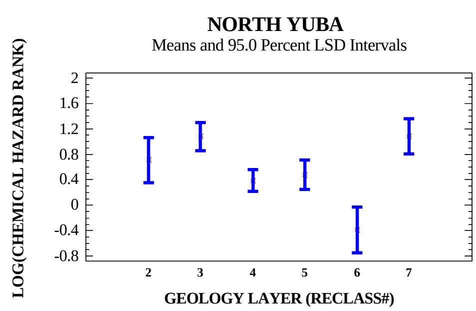


Table 3.55: Predicted Chemical Hazard Rankings Numbers for MAS/MILS Records in the North Yuba Watershed.

Rank	Count	Percent	Definition of Rank
1	76	13	very low probability of releasing hazards into the environment
2	490	83	low probability of releasing hazards into the environment
3	22	4	moderate probability of releasing hazards into the environment
Total	588	100	

The results indicate that this watershed has a low to moderate probability for a site, which presents a significant chemical hazard. The cumulative Chemical Hazard Ranking Score for the 314,088 acre watershed is 250,824, indicating that AML sites in the watershed pose a moderately significant chemical threat to the environment.

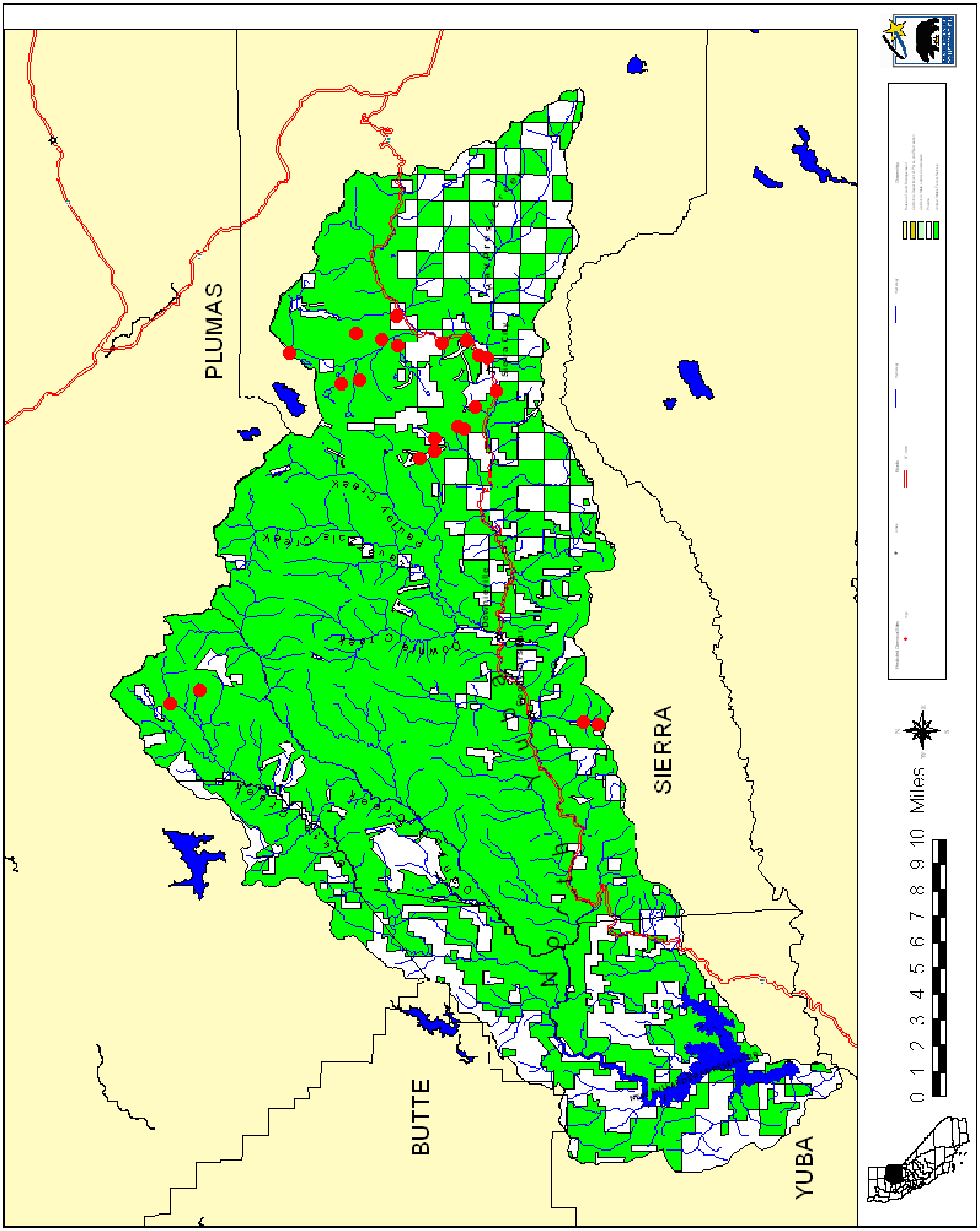


Figure 3.15: Predicted MAS/MILS sites with a Rank 3 or Greater *Chemical Hazard*.

3.8.3.3 Predicted Physical Hazard

Unable to predicted physical hazard because of the low R-squared value.

3.8.3.4 Predicted Hazardous Openings

Fifteen symbols indicative of an opening where shown on the topographic maps for the sampled sites and nine prospects were shown. Thirty-four openings were verified in the field for these sites, and twenty-four (or 71%) were found to be potentially hazardous.

The number of hazardous openings can be predicted with an R-squared value 40% at a $p<0.0054$. The predicted number of hazardous openings is 101.

3.8.4 Summary of Findings

In this watershed, there is a low to moderate probability for a site which presents a significant chemical hazard, and cumulatively, the AML sites in the watershed may pose a significant chemical threat to the environment. We were unable to predict the *physical hazard rankings*, but the watershed as a whole has many hazardous openings (estimated to be 101).

Table 3.56: Summarized Findings for the North Yuba Watershed.

Total Watershed Area (Acres)	314,088
Predicted Cumulative Chemical Ranking Sore	250,824
Predicted Cumulative Chemical Ranking Score Density	0.7986
Predicted Cumulative Physical Ranking	Unable to Predict
Predicted Hazardous Openings	101

3.9 Point Buchon Watershed

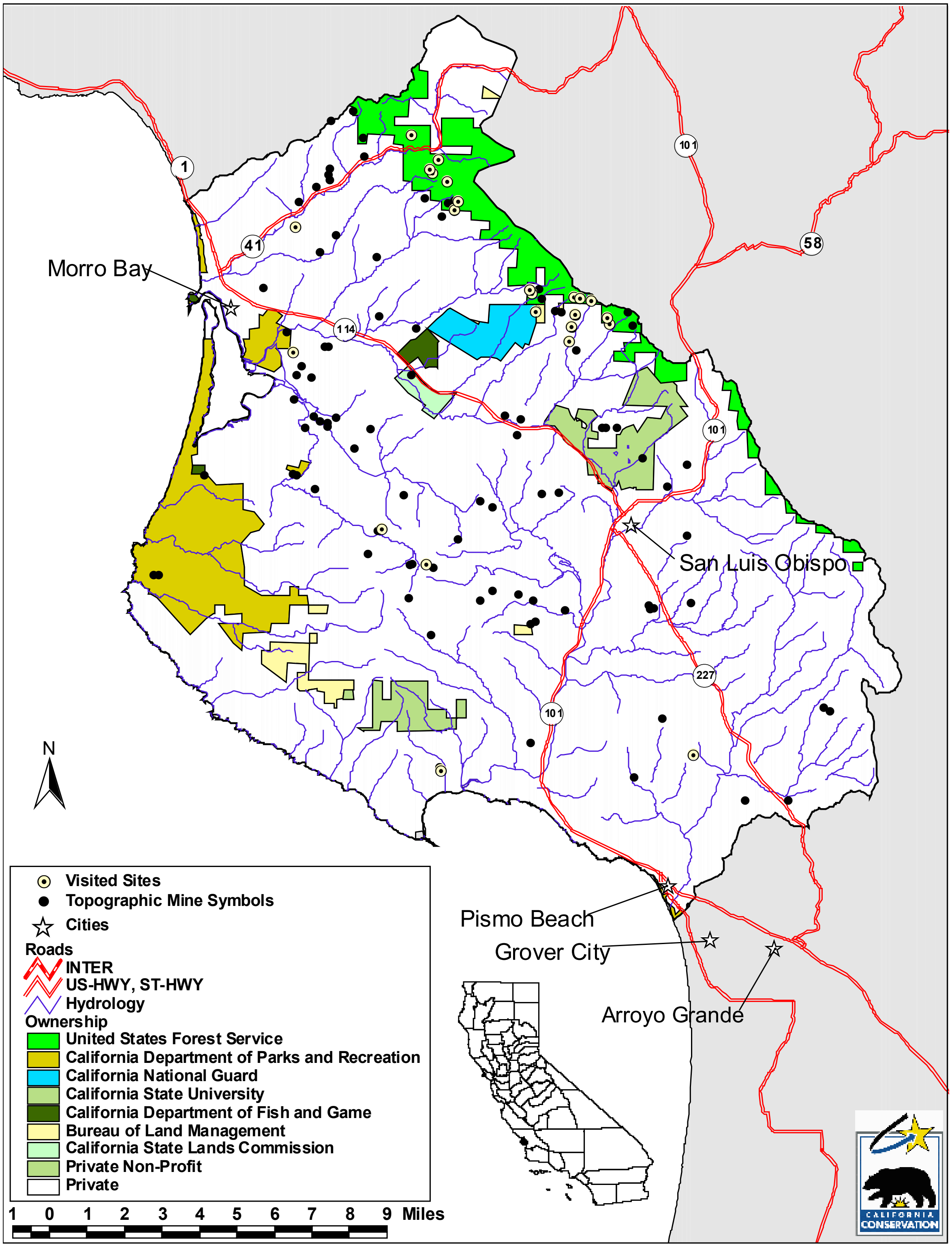


Figure 3.16: Point Buchon Watershed, Area Map.

The Point Buchon Watershed is located in the central coast region of west San Luis Obispo County and generally encompasses the area around San Luis Obispo between Morro Bay and Pismo Beach. This watershed provides freshwater to the City of San Luis Obispo, which has a population of 41,958 (1990 Census); in addition to the communities of Morro Bay, Los Osos, Avila beach, Shell Beach, Pismo Beach, the California Men's Colony, the Camp San Luis Obispo California Army National Guard Post, and the Diablo Canyon Nuclear Power Plant Facility. In all, it is estimated that the Point Buchon Watershed may provide freshwater to more than 60,000 people. The majority of land ownership throughout this watershed is private (86%), with the Los Padres National Forest (4%) and state parks and beaches (5%) making up the majority of the remaining.

Table 3.57: Point Buchon Watershed Land Ownership Summary.

Government Level	Agency	Acres	Percent
Federal	USFS	7,529	4.32
	BLM	1,297	0.74
	USCG	32	0.02
Sum (Federal)		*8,858*	*5.08*
State	Parks and Recreation	9,061	5.20
	Fish and Game	576	0.33
	National Guard	1,772	1.02
	State Land Commission	509	0.29
	State University	3,161	1.81
Sum (State)		*15,079*	*8.65*
Private	Private	109	86.21
Other	Unknown	150,399	0.06
Sum (Total)		*174,336*	*100.00*

The climate of this watershed is coastal mediterranean, with an annual (average) rainfall of 23 inches with warm, dry summers and cool, moist winters.

The watershed encompasses the western slope of the Santa Lucia Mountain Range and the Irish Hills, and is the drainage for Chorro Creek and its tributaries west to Estero Bay and the Pacific Ocean. The main tributaries to Chorro Creek (south to north) are: Dairy Creek, Pennington Creek, San Luisito Creek, and San Bernardo Creek which joins with Chorro Creek before it drains directly into Morro Bay. Other major drainages to Estero Bay in this watershed include Little Morro Creek, Islay Creek, Coon Creek, Pecho Creek, Froom Creek, Prefumo Creek, Los Osos Creek, San Luis Obispo Creek, and Pismo Creek. Chorro Creek and Morro Bay are listed as impaired under Section 303(d) of the Federal Clean Water Act. The Point Buchon Watershed is listed as a Level 3 watershed (less serious problems, low vulnerability) by the USEPA (USEPA 2000).

The Point Buchon Watershed is comprised by the Central Coast (CCo) and the Outer South Coast Ranges (SCoRO) biological subregions, which are components of the Central Western California (CW) biological region as defined in the Jepson Manual (Hickman 1993). The CCo subregion occurs along the coastal (western) boundary of the watershed and characterized by coastal sage, scrub oak, and chaparral. The SCoRO subregion occupies the eastern two-thirds of the watershed, and is characterized by coastal sage, scrub oak, chaparral; and at higher elevations, evergreen conifers.

The soils of this watershed are typically low in nutrients, so vegetation is sparse. Additional ground cover is lost during the long, dry periods typified by the climate of this region. When this loss is followed by sudden heavy rains, heavy erosion and stream sedimentation can result. The shrublands are particularly prone to wildfire, and this also contributes to the natural tendency for the region to have high erosion potential. The main agricultural use of the hillsides is open cattle grazing, and recent spreading urbanization combined with increased recreational use has contributed to even more loss of vegetation and erosion. The evidence of a massive wildfire which occurred in the mid-1990's in the Los Padres National Forest and parts of Camp San Luis Obispo was observed along with heavy erosion and sedimentation. In at least one case, this fire and the resultant erodable soils left behind, contributed to the massive wasting of millions of cubic yards of material downstream of the La Primera Chromium Mine, and extensive damage to Chorro Creek.

The Point Buchon Watershed is located in the southern portion of the Coast Ranges. The geology of the area includes Cenozoic Sedimentary Rocks, Cenozoic Volcanic Rocks, Cenozoic-Precambrian Plutonic, Metavolcanic and Mixed Rocks, and Mesozoic-Paleozoic-Precambrian Sedimentary and Metasedimentary Rocks (Jennings 1977). Cenozoic Sedimentary Rocks consist of sand dunes, various marine and non-marine rocks, large landslide deposits and alluvial deposits. Cenozoic Volcanic Rocks include basalt and dacitic volcanic plugs. Morro Rock is a famous local feature, rising approximately 600 feet at the entrance to Morro Bay, and is an example of a dacitic volcanic plug. Cenozoic-Precambrian Plutonic, Metavolcanic and Mixed Rocks consist of ultramafic rocks, granitic rocks and some volcanic rocks. Mesozoic-Paleozoic-Precambrian Sedimentary and Metasedimentary Rocks include recent marine rocks and Franciscan Complex rocks.

3.9.1 Short History of Mining

Mineral production by commodity was not recorded for this area prior to 1880, and none could be verified prior to 1850, although some references indicate that some seasonal placer gold mining had begun by 1848. Copper was reported to have been mined in small quantities in the early 1860's. However, one reference reported that over 15,000 tons of chromium ore was shipped prior to 1880. (Logan, 1917) The Santa Lucia Range, on the east boundary of the watershed, was found to have numerous, large deposits of chromite located on the main ridge between Morro Creek and Cuesta Pass, and that these and other deposits also yielded lesser quantities of copper, manganese, and nickel. Areas at the south end of the watershed yielded deposits of natural asphalt and bituminous sandstone. Areas to the west of the watershed yielded small deposits of copper, manganese, iron, chromite, and lesser deposits of gold and silver. These valleys and hills of the central and western part of the watershed contained deposits of dacite, diatomite, sand and gravel, pumice, and clay.

Because such large chromite deposits were found in this watershed, they were the first to be developed. Extensive underground operations were begun in the 1880's, and production of chromium from chromite at some mines exceeded 1000 tons annually. So much tonnage was being extracted that a concentration facility was developed at Goldtree Station, several miles north of San Luis Obispo. A narrow gauge spur rail line of the Pacific Coast Railroad was constructed to

Goldtree Station where chromium ore was stockpiled, processed, loaded, and transported by rail car to Port San Luis. At least 2000 tons of concentrates were reported to have been produced at this facility which operated through the 1940's. Total production of chromite ore in this watershed has been estimated to have exceeded 73,000 long tons (Bigley, 1993).

It was reported (Logan, 1915) that while chromite deposits were numerous, they were not uniform in size or distribution, and decreased in richness with depth. The ore was generally found in small, low-grade fragments, or high-grade "kidneys" of many tons. This may account for the fact that many of the chromite deposits were originally developed by surface quarrying. The exceptions were the Pick and Shovel, La Primera, La Trinidad, and New London Mines which utilized dozens of short tunnels to extract the high-grade ore in addition to surface quarrying and the working of shallow placer deposits. One of the largest operations, the Pick and Shovel Mine, had over 1,200 feet of underground workings. Much of the ore produced contained over 50% chromic oxide. Subsequent chromium production from these mines, which occurred during both world wars, was conducted by surface quarrying.

3.9.2 Current Mining

Active mines in this watershed currently report production of sand and gravel, diatomite, stone, rock, shale, and decomposed granite mostly for construction, roadbase, and building materials.

3.9.3 Sample Study

The Point Buchon Watershed was chosen at random from a larger dataset of Bioregions (Jepson) for study. Mining symbols were digitized from the eight USGS 7.5 minute topographic maps encompassing the watershed, and the geology (DMG 750k) was reclassified and spatially analyzed by major "rocktype". It was determined that with the exception of abandoned or inactive borrow pits, and sand and gravel operations, only one rocktype, identified as Cenozoic-Precambrian Plutonic, Metavolcanic, and Mixed Rocks occurred in conjunction with the location of mine symbols. This determination was not based entirely on the surface rocktype, but the ore containing rocktype due to the occurrence of a thin layer of surface sedimentary material which was not being mined. For the determined ore-bearing rocktype, fifteen topographic symbols were then randomly selected for field inventory. In addition, five Principle Areas of Mine Pollution (PAMP) mine locations were randomly selected to be included in the sample study. Of the total of twenty random sites selected for this watershed, sixteen mine sites were included in the final sample for this watershed. One site was not field visited due to access restrictions, one was not found, and two had been previously field inventoried by US Forest Service personnel. A total of thirteen "topographic symbol" sites, and three PAMP sites were field inventoried by OMR staff for this study.

3.9.3.1 Watershed Summary and Results of Analysis and Modeling

The sampled sites were evaluated for physical and chemical hazards and then ranked by the severity of each type of hazard.

Table 3.58: Field verified Chemical Hazard Ranking Numbers.

Rank	**Count**	**Percent**	**Definition of Rank**
0	5	31	No probability of releasing hazards into the environment
2	6	38	Low probability of releasing hazards into the environment
3	4	25	Moderate probability of releasing hazards into the environment
5	1	6	Very high probability of releasing hazards into the environment
Total	*16*	*100*	

Table 3.59: Field verified Physical Hazard Ranking Numbers.

Rank	**Count**	**Percent**	**Definition of Rank**
0	1	6	No physical hazards
1	3	19	Very few physical hazards
2	10	62	Few physical hazards
3	1	6	Moderate amount of physical hazards
4	1	6	Large amount of physical hazards
Total	*16*	*100*	

3.9.3.2 Predicted Chemical Hazard Rankings

These rankings were then used to create a statistical model which could be used to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see Section 2). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data. The predictive model utilized the field verified *chemical hazard rankings* and the results of the model (r^2=56%, p=0.0045) were then applied to the MAS/MILS occurances within the watershed using information from the MAS/MILS database about the production status (CUR) and generalized commodity (derived from COM1). The results of the regression model and its components for *chemical hazards* are displayed below.

Table 3.60: Summarized statistics for the chemical hazards GLM.

Analysis of Variance of Chemical Hazard

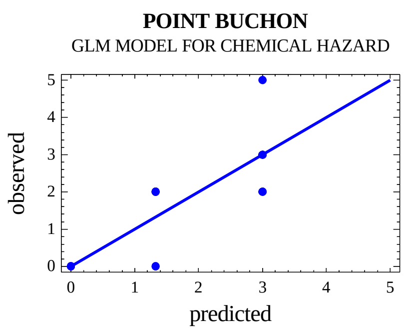
Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
Model	21.1042	3	7.03472	7.45	0.0045
Residual	11.3333	12	0.944444		
Total (Corr.)	32.4375	15			

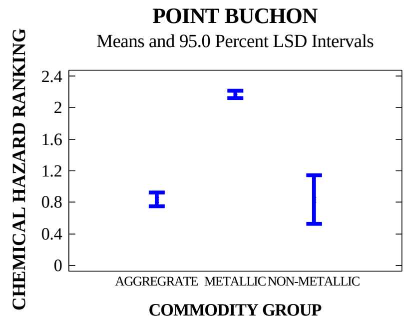
Type III Sums of Squares

Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
COMM GROUP	3.55556	2	1.77778	1.88	0.1945
CUR_CODE	8.97436	1	8.97436	9.5	0.0095
Residual	11.3333	12	0.944444		
Total (Corr.)	32.4375	15			

R-Squared = 65.061%
R-Squared (adjusted for Df) = 56.3263%
All F-Ratios are based on residual mean square error.

The following graphs depict the tests among means for each component of the GLM regression analysis.





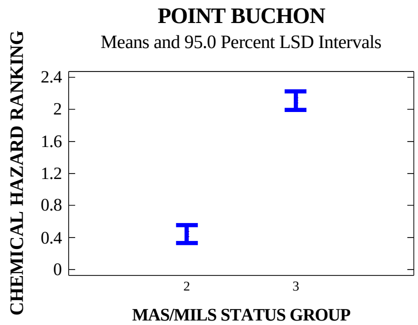


Table 3.61: Predicted Chemical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent Definition of Rank
1	47	44 Very low probability of releasing hazards into the environment
2	28	26 Low probability of releasing hazards into the environment
3	32	30 Moderate probability of releasing hazards into the environment
Total	*107*	*100*

The results indicate that this watershed has a moderate probability for a site, which presents a significant chemical hazard. The cumulative *chemical hazard ranking* score for the 174,333 acre watershed is 33,599, indicating that AML sites in the watershed likely poses a significant chemical threat to the environment**.**

3.9.3.3 Predicted Physical Hazard Rankings

The *physical hazard ranking* was also predicted by regression analysis with a General Linear Model. The prediction model utilizes the field verified *physical hazards ranking*. The results of the predictive model (r^2=52%, p=0.0152) are then applied to the MAS/MILS database for the watershed using MAS/MILS database information about the type of mine (TYP field) and PAMP membership. The results of the regression model and its components are displayed below.

Table 3.62: Summarized statistics for the physical hazard GLM.

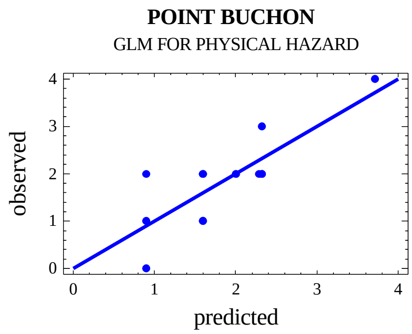
Analysis of Variance of Physical Hazard

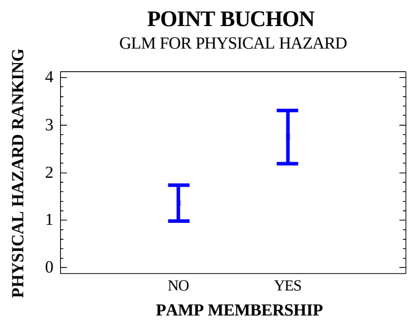
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	7.58226	4	1.89556	5	0.0152
Residual	4.16774	11	0.378886		
Total (Corr.)	11.75	15			

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
TYPE_CODE	5.49892	3	1.83297	4.84	0.022
PAMP	2.98226	1	2.98226	7.87	0.0171
Residual	4.16774	11	0.378886		
Total (Corr.)	11.75	15			

R-Squared = 64.5299%
R-Squared (adjusted for Df) = 51.6316%
All F-Ratios are based on residual mean square error.





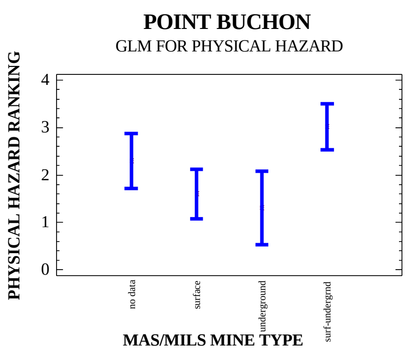


Table 3.63: Predicted Physical Hazard Ranking Numbers for MAS/MILS Records.

Rank	Count	Percent Definition of Rank
1	78	78 Very few physical hazards
2	28	26 Few physical hazards
4	1	1 Large amount of physical hazards
Total	107	100

The results indicate that this watershed has a very low probability for a site, which represents a significant physical hazard. The cumulative *physical hazard ranking* for the watershed is 866, indicating that the watershed likely poses few significant physical hazards.

3.9.3.4 Predicted Hazardous Openings

No topo symbols indicative of an opening where shown on the topo maps for the sampled sites; however, four prospect symbols were shown. Five openings were verified in the field for these sites, and 3 (or 60%) were found to be potentially hazardous. While it was found that we could not construct a predictive model for hazardous openings, we were able to construct a model for openings in general.

The number of opening can be predicted with an R-squared value of 86% at a *p<0.0001* level using the number of prospects and the area of mine waste shown on the topo maps. The predicted number of openings this watershed is 18. We documented 5 openings within this sample set, of which 3 were hazardous. Using this same ratio (of hazardous to total), the estimated number of hazardous openings for this watershed is 10.

3.9.4 Summary of Findings

The Point Buchon Watershed has a very low probability for a site, which has moderate physical hazards, and the watershed as a whole has very few hazardous openings (estimated to be 10). However, there is a low to moderate probability for a site which presents a significant chemical hazard, and cumulatively, the watershed likely poses a significant chemical threat to the environment.

Runoff from the abandoned Chromite Mines of the Chorro Creek drainage contaminates drinking water at facilities operated by the State of California and presents a potentially serious threat to human health. The Chorro Creek Reservoir is located several miles downstream from the Pick and Shovel, La Primera, La Trinidad, and New London Mines. The rainfall runoff collected in this reservoir from these abandoned chromite mines supplies drinking water to the California Men's Colony (State Dept. of Corrections), the Camp San Luis Obispo California Army National Guard Post (State Military Department), Cuesta Community College, and the County Sheriff's substation. The Central Coast Region Water Quality Control Board (CCRWQCB) reports that these mines have contaminated Chorro Creek and it's reservoir with elevated levels of chromium, iron, magnesium, and nickel. This report also states that "Maximum concentrations of total antimony, dissolved copper, total nickel, total chromium, total lead, dissolved zinc, alkalinity, electrical conductance, and boron exceeded a variety of human health, fish and wildlife, agricultural, plant and nuisance standards" (Schwartzbart, 1993). In addition to the potential impact on human health, contaminated runoff from Chorro Creek accumulates in Morro Bay, which further impacts an estuary inhabited by several threatened and endangered species.

Table 3.64: Summarized findings for the Point Buchon Watershed.

Total Watershed Area (Acres)	174,336
Predicted Cumulative Chemical Ranking Sore	33,599
Predicted Cumulative Chemical Ranking Score Density	0.193
Predicted Cumulative Physical Ranking	866
Predicted Cumulative Physical Ranking Score Density	.005
Predicted Hazardous Openings	10

3.10 Upper Santa Clara River Watershed

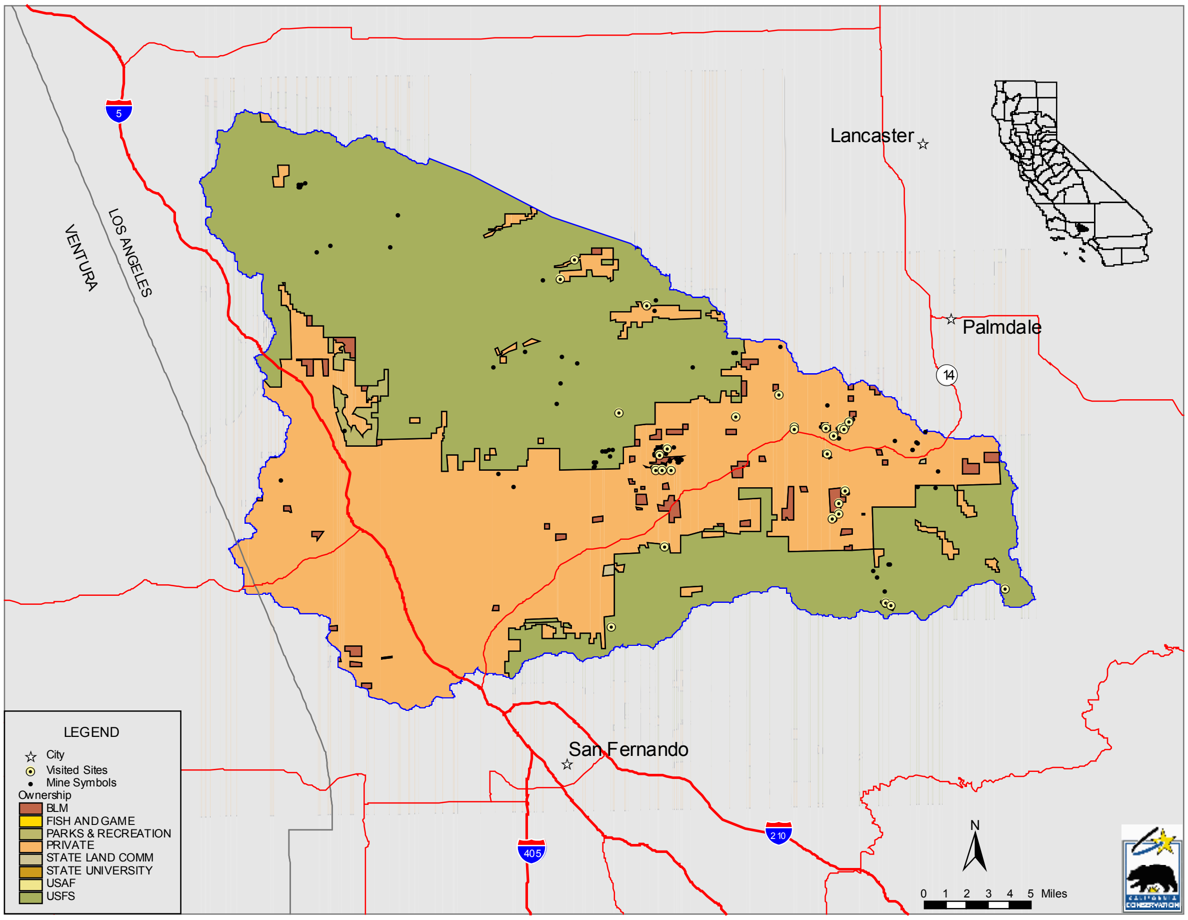


Figure 3.17: Upper Santa Clara River Watershed, Area Map.

Table 3.65: Upper Santa Clara River Watershed Land Ownership Summary

Government Level	Agency	Acres	Percent
Federal	US Forest Service	204,968	51.67
Federal	Bureau of Land Management	5748	1.45
Sum (Federal)		210,716	53.12
State	Parks and Recreation	2,989	0.75
State	State Lands Commission	190	0.05
Sum (State)		3,179	0.80
Private	Private	182,770	46.08
Sum (Total)		*396,665*	*100.00*

The Upper Santa Clara River Watershed lies between the bustling San Fernando Valley and the bedroom communities of Palmdale and Lancaster. Slightly over half of the area is owned by the Federal Government, most as part of the Angeles National Forest. The valley area is growing rapidly. State Highway 14 fills up in the morning and evening with commuters traveling between homes in Palmdale and Lancaster and workplaces in the Los Angeles Basin. The majority of the population growth in this valley has and is occurring near the I-5 corridor in towns such as Valencia and Santa Clarita.

The Upper Santa Clara River Watershed is located in the Transverse Ranges. The geology of the area includes Cenozoic Sedimentary and Volcanic Rocks — Cenezoic-Precambrian Plutonic, Metavolcanic and Mixed Rocks — and Mesezoic, Palezoic, Precambrian Sedimentary and Metasedimentary Rocks (Jennings 1977). Vasquez rocks are a famous local feature, showing up in many television shows and commercials.

The biota of this area lies within the San Gabriel Mountains and Western Transverse Ranges sub-regions of the South Western California Region as delineated by the Jepson manual (Hickman 1993). Lower elevation areas tend to be dominated by chapparals including chamise, manzanita and scrub oak types. At higher elevations in the Transverse Ranges, one is likely to find montane type chapparal as well as oak forests and evergreen conifers.

3.10.1 Short History of Mining

The first documented gold discovery occurred in Placerita Canyon in 1842, by Jose Francisco de Garcia Lopez. The mythical story has Lopez discovering gold flakes attached to the roots of an onion he dug up after napping under an oak tree. The tree has since been named "The Oak of the Golden Dream" and lies within Placerita Canyon State Park. A small gold rush ensued, and reportedly 1,300 pounds were recovered from the gravels of this canyon between 1842 and 1847 (Worden 1996 1997). However, Reports to the State Mineralogist (vols. XV and XXII) indicate Garcia Lopez was managing placer mining by priests and Native Americans from the San Fernando and San Buena Ventura Missions between 1834 and 1838. So, there are some discrepancies in the historical record. Nonetheless, it is clear gold was discovered and mined here, well before the more famous Marshall discovery at Sutter's Mill in 1848.

Lode mining for gold, silver, and copper have also occurred here with some success. Among the more successful are the Governor (named for Governor Henry T. Gage), Red Rover and Emma Group. Mining this area was quite difficult due to the rugged terrain, dense brush and lack of water. In fact, lack of water is often cited as one of the reasons this area wasn't mined more heavily. Typical processing methods for the mines include panning methods that separated placer golds by weight and stamp milling followed with mercury amalgamation for lode gold recovery. There are some instances of other chemical processing, such as cyanide leaching at the Emma Group and Red Rover Mines, though the extent of processing using those methods was apparently small. In the Cedar Mining district many mines sent their ores to one of the mills operating near Acton. This author is unaware of the history of those mills, other than their existence. One of the most successful historic mines in the area was not a metal mine. The Sterling Borax mine, which was active between 1908 and 1922 was a significant producer in its day, with over 100,000 tons of ore mined. The value of this ore has been placed at approximately $3 million in its day. However, it could not compete with the borax mines discovered in the California desert and closed soon after they began operating.

3.10.2 Current Mining

Active mining continues today, mostly for building materials. Clay has been a significant resource for the area both historically and presently. There are also several aggregate mines operating. For the most part, these mines are in or alongside the larger river channels.

3.10.3 Sample Study

Initially 50 topographic symbols were randomly selected for site visits — ten for each of the five "Rocktypes". Additionally, all 12 of the PAMP (Principle Areas of Mine Pollution) mines were included. Most of these corresponded to mines in the selected set of topographic symbols. Due to time constraints and access restrictions some of these sites were not visited. However, a total of 39 topographic symbols were checked, including six PAMP sites. This resulted in a total of 29 separate sites. Of these, 3 were field verified by USFS staff, one was field verified by both USFS and OMR staff (on separate occasions), and the remaining 25 sites were visited by OMR staff.

3.10.3.1 Results Summary

The sampled sites were evaluated and ranked for chemical and physical hazards using the Preliminary Appraisal and Ranking System. Summaries of these rankings are provided below (see page 16 for details on the ranking system).

Table 3.66: Summary Chemical Hazard Ranks for Field Visited Sites.

Rank	Count	Percent	Definition of Rank
0	12	41	No chemical hazards
1	8	28	Very low probability of chemical hazards
2	9	31	Low probability of chemical hazards

Table 3.67: Summary Physical Hazard Ranks for Field Visited Sites.

Rank	Count	Percent	Definition of Rank
0	2	7	No physical hazards
1	6	21	Very low probability of physical hazards
2	15	52	Low probability of physical hazards
3	5	17	Moderate probability of physical hazards
4	1	3	High probability of physical hazards

3.10.3.2 Predicted Chemical Hazard Rankings

The rankings summarized above were then used to create a statistical model to make predictions about the characteristics of all the abandoned mines found in the watershed (for a more detailed discussion of the modeling methodology, see Section 2.3 on page 16). The *chemical hazard ranking* was predicted by regression analysis with a General Linear Model that allows for a combination of categorical and quantitative data. The predictive model utilizes the field verified *chemical hazard rankings*. The results of the model (r^2=50%, p=0.0028) were then applied to the MAS/MILS occurances within the watershed using the MAS/MILS data fields of current status (CUR) and operation type (TYP), geologic rocktype class, and the potential for arsenic (derived from MRDS database). The results of the regression model for chemical hazards and its components are displayed below.

Table 3.68: Summarized statistics for the chemical hazard GLM.

Analysis of Variance for CHEM_APR_RANK

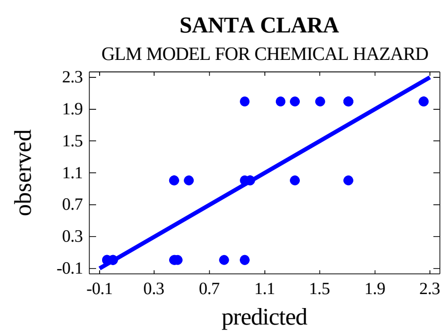
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	13.3644	8	1.67055	4.56	0.0028
Residual	7.32524	20	0.366262		
Total (Corr.)	20.6897	28			

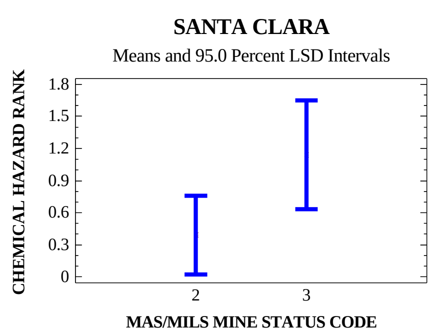
Type III Sums of Squares

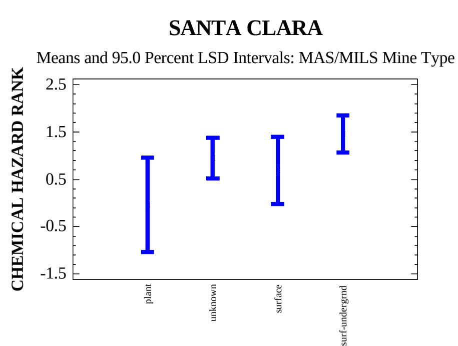
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
As	1.00872	1	1.00872	2.75	0.1126
Rocktype_N	1.76679	3	0.588929	1.61	0.2190
CUR_Code	1.98325	1	1.98325	5.41	0.0306
TYP_Code	2.85499	3	0.951664	2.60	0.0807
Residual	7.32524	20	0.366262		
Total (corrected)	20.6897	28			

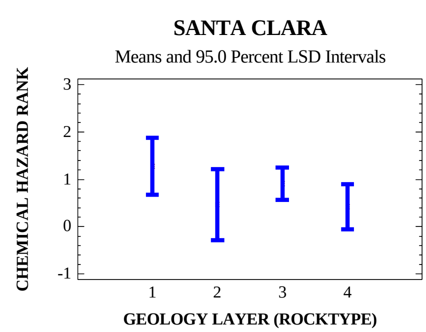
All F-ratios are based on the residual mean square error.

R-Squared = 64.5947 percent
R-Squared (adjusted for d.f.) = 50.4325 percent









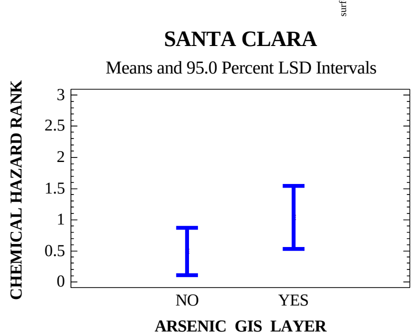


Table 3.69: Chemical hazard predictions for MAS/MILS mineral occurrences.

Rank	Count	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
0	29	0.2377	29	0.2377
1	73	0.5984	102	0.8361
2	20	0.1639	122	1.0000

The results indicate there is a very low probability for a site in this watershed that has a significant chemical hazard. The cumulative chemical hazard ranking score for this 396,665 acre watershed is 473 (density 0.00119) — indicating a very low probability for a cumulative chemical impact.

3.10.3.3 Physical Hazard Predictions

For this watershed, no combinations of parameters was sufficient to produce a model with an acceptable level of confidence. Therefore, there are no statistical predictions for physical hazards overall.

3.10.3.4 Predicted Hazardous Openings

Twenty seven topographic symbols indicative of an opening were shown on the topographic maps for the sampled sites. Sixty-one openings were verified in the field for these sites, and 50 (or 82%) were found to be potentially hazardous. While it was found that we could not construct a predictive model for hazardous openings, we were able to construct a model for openings in general.

Using the same type of regression model, we can predict the number of openings in the field (r^2=50%, p=0.0271) based on which topographic sheet and the number of openings shown on the topographic sheet. The predicted value is 174 openings. If the same relationship exists (82% hazardous) as that found in our field data, then the number of hazardous openings in this watershed is estimated to be 143.

The number of topographic openings is digitized by AMLU from the USGS quad sheets, and the topographic sheet is a number from 1 to 5 assigned to each topographic sheet for the watershed. In other words, the number of field openings is related to, the number shown on the topographic sheet, and which topographic sheet it occurs on. That is, there is some relationship between who creates the topographic sheet and the number of symbols put on the map.

3.10.4 Summary of Findings

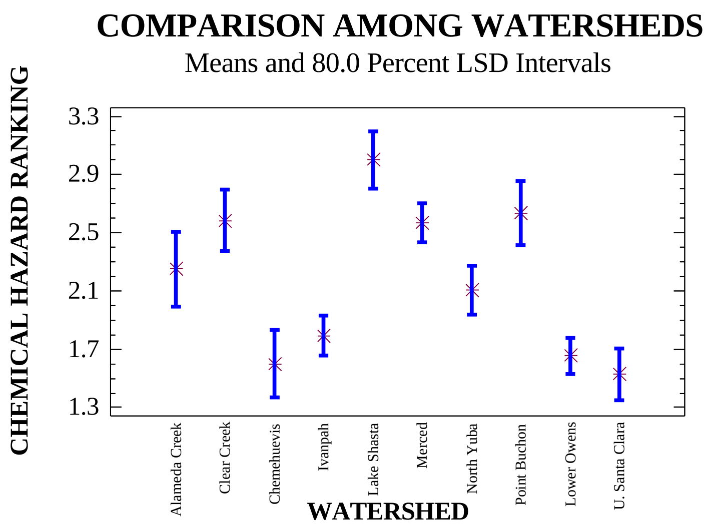
Table 3.70: Summarized findings for the Upper Santa Clara River Watershed.

Total Watershed Area (Acres)	396,665
Predicted Cumulative Chemical Ranking Score	473
Predicted Cumulative Chemical Ranking Score Density	0.00119
Predicted Cumulative Physical Ranking Score	Unable to Predict
Predicted Cumulative Physical Ranking Score Density	Unable to Predict
Predicted Hazardous Openings	143

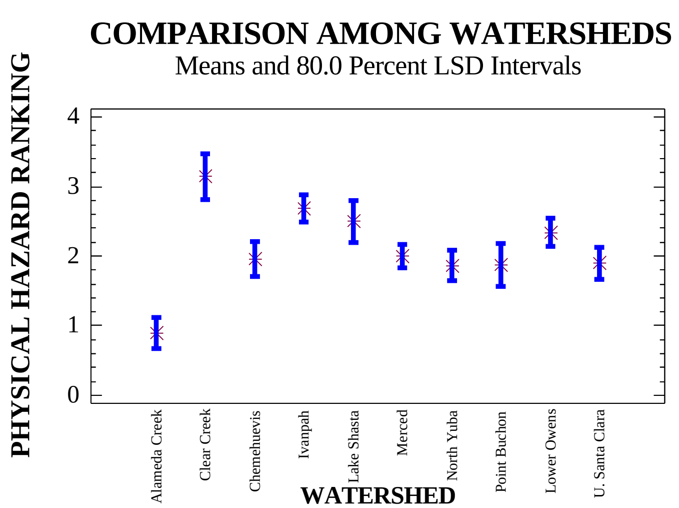
In this watershed, there is a very low probability for a site which presents a significant chemical hazard. Cumulatively, there is a very low probability for a significant impact to the environment from AML sites. Predictions could not be made about the numbers of mines with significant physical hazards. However, the number of hazardous openings was predicted as 143.

3.11 Summary for all Sampled Watersheds

When comparing the chemical hazard rankings by watershed for the sites that were field verified, a relative ranking of sampled watersheds results. Approximately four groupings are indicated by the mean rankings: 4=Lake Shasta, 3=Clear Creek, Merced, and Point Buchon, 2=Alameda Creek and North Yuba, and 1=Chemehuevis, Ivanpah, Lower Owens, and Upper Santa Clara. The Lake Shasta watershed (Group 4) has a significantly higher mean chemical hazard ranking than all watersheds except Point Buchon; and Group 1 watersheds are significantly lower than all other Groups. The following figure compares the chemical hazard rankings for all sampled sites within the sampled watersheds.



One can also discern approximately four groupings within the mean physical hazard scores among the watersheds: 4=Clear Creek, 3=Ivanpah, Lake Shasta, and Lower Owens, 2=Chemehuevis, Merced, North Yuba, Point Buchon and Upper Santa Clara, and 1=Alameda Creek. The following figure compares the physical hazard rankings for all sampled sites within the sampled watersheds.



The following table summarizes the results presented at the end of each of the preceding watershed reports. Comparisons across watersheds can be done for *predicted* chemical hazards for all *estimated* mine sites. That is, since all mine sites within a watershed were not visited, an estimation of the hazards was made based on the GLM model for the watershed and the mine site data in the MAS/MILS database. Because physical hazards could not be predicted for most of the watersheds, comparisons across watersheds are less useful for physical hazards.

Table 3.71: Summarized Results for All Watershed Studies.

Watershed	Area (acres)	Chemical Score	Chemical Density (X 100)	Physical Score	Physical Density	Predicted Hazardous Openings
Alameda Creek	404,588	245	0.10	N/A	N/A	104
Chemehuevis	176,671	63	0.04	1,098	0.0062	99
Clear Creek	146,574	51,194	34.93	N/A	N/A	79
Ivanpah	410,425	793	0.19	9,614,835	23.43	286
Lake Shasta	239,801	11,222	4.68	2,213	0.0092	37
Lower Owens	331,981	1,728	0.52	26,394	0.0795	518
Merced	556,832	173,685	31.00	N/A	N/A	378
North Yuba	314,088	250,824	79.86	N/A	N/A	101
Point Buchon	174,333	33,599	19.30	866	0.005	10
Upper Santa Clara	396,665	473	0.12	N/A	N/A	143

When comparing the potential cumulative chemical hazards, the values to be compared are the size of the watershed, the cumulative chemical score and the c*hemical density* numbers. For example, the largest sampled watershed, the Merced, has the second highest cumulative chemical score and the third highest chemical density score, indicating a high potential for cumulative chemical impacts to the watershed. The North Yuba is the sixth largest watershed, has the highest cumulative chemical score, and the highest chemical density score, indicating a very high potential for cumulative chemical impacts to the watershed. In comparison, Clear Creek is the smallest watershed, has the third highest cumulative chemical score, and a chemical density score similar to Merced's, also indicating a high potential for cumulative chemical impacts to the watershed. Point Buchon's chemical density indicates a moderate potential for cumulative chemical impacts to the watershed. The chemical density scores for Alameda Creek, Ivanpah, Lower Owens and Upper Santa Clara indicate a low potential for impacts to the watershed. The score for Chemehuevis indicates a very low potential for cumulative chemical impacts to the watershed.

Of interest, is the predicted chemical density score for the Lake Shasta watershed, which indicates a low to moderate potential for cumulative chemical impacts to the watershed. However, based on the field-sampled sites, this watershed ranked significantly higher than all other watersheds, except Point Buchon. Extensive sampling by the Regional Water Quality Control Board has documented that this watershed is highly impacted by ARD and heavy metals from abandoned mines, yet our score does not reflect this fact. The density score is low because the size of the watershed is moderately large and the number of sites is relatively low, hence the density score is moderately low. What uniquely characterizes the abandoned mines in the Lake Shasta watershed is that they are few, they tend to be larger than average, most of them produce ARD, and they are concentrated in two of the 39 planning-level watersheds within the Lake Shasta Hydrologic Area. Therefore, the high chemical densities of these watersheds — Lower Backbone and Upper Squaw — are diluted by the very low densities of the remaining 37 planning-level watersheds.

4 Statewide Modeling

The preceding section detailed chemical hazard modeling by watershed, and on occasion, physical hazard modeling. The next question should be, how well do these models work on a statewide basis. In summary, the best predictive models require the reconciliation of the MAS/MILS database with the topo symbol database; a daunting task to implement statewide and outside the scope of this report.

4.1 Chemical Hazard Predictive Model

The data fields used for each of the models for chemical hazard prediction varied among the watersheds. The most common data field for prediction of chemical hazard was membership in the PAMP database, which is not surprising. This database was compiled from historical production records, and includes those mines with at least $100,000 of production that could impact water quality. Therefore, it would be assumed that this list should contain the larger mines. Based on our random sample, the average mine size for a non-PAMP site was 4 acres (log transformation required), while the average mine size for a PAMP site was 12 acres (log transformation required). Both the means and the medians for the non-PAMP and PAMP sites were found to be highly significantly different from each other ($p<0.0001$, using Mann-Whitney U and Kolmogorov-Smirnov tests), thus confirming the prior assumption. However, it should be noted that for one watershed (Lower Owens River), the reverse was true (PAMP sites were significantly lower for *chemical hazards*).

Other data fields that were commonly used in the watershed models included the commodity group (derived by AMLU from "COM1" in MAS/MILS), mine status ("CUR" in MAS/MILS), and mine type ("TYP" in MAS/MILS). On occasion, the geology layers were of use, including "ROCKTYPE" (from the DMG geology layer), "RECLASS" (derived by AMLU from the DMG geology layer), and "As" (derived by AMLU from the USGS's MRDS database).

On a statewide basis, the best predictive model for chemical hazard has an r^2 value of 34%, and is highly significant at the $p<0.001$. This model uses PAMP membership, RECLASS, TYP, the volume of waste as shown on the topo, and the number of prospects as shown on the topo for the site. Since this model requires that each site be identified in MAS/MILS, as well as located by one or more topo symbols, this model is not easily implemented on a statewide basis. In other words, this model requires the reconciliation of two disparate databases — MAS/MILS and the AMLU topo symbols.

Table 4.1: Summarized statistics for *chemical hazard ranking*.

Analysis of Variance for *chemical hazard ranking*.					
Source	**Sum of Squares**	**Df**	**Mean Square**	**F-Ratio**	**P-Value**
Model	60.9702	14	4.35502	7.87	0.0000
Residual	94.0784	170	0.553402		
Total (Corr.)	155.049	184			

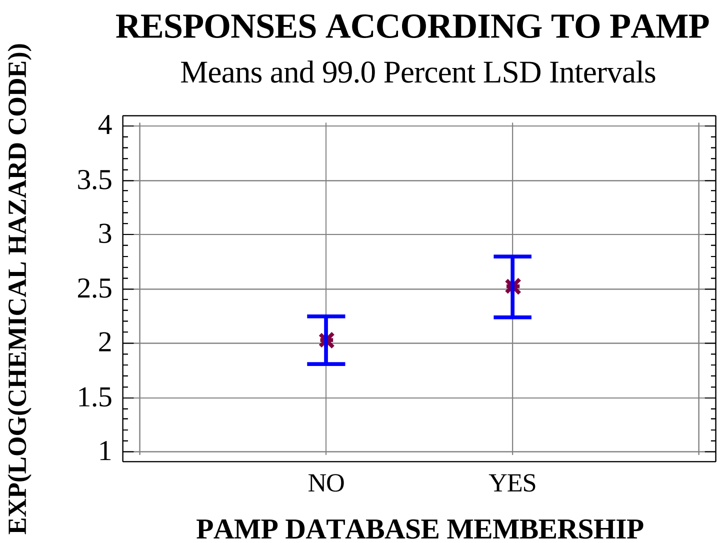
Type III Sums of Squares

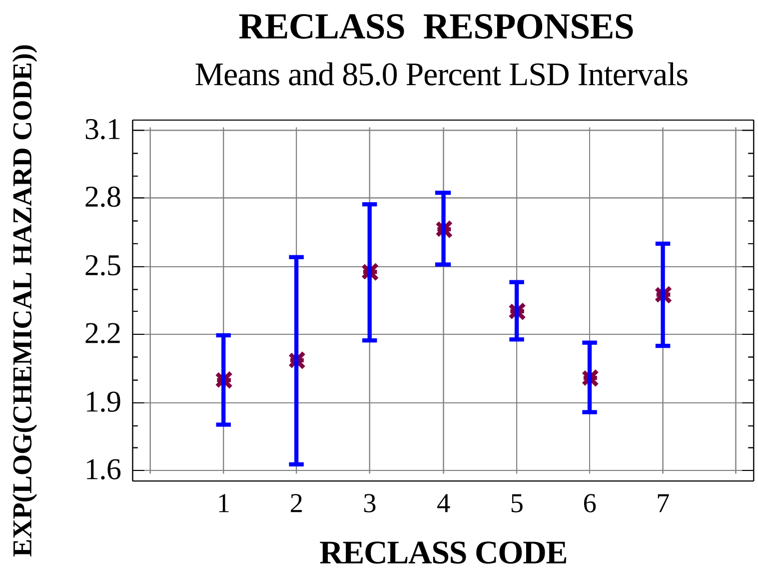
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
PAMP	7.573	1	7.573	13.68	0.0003
RECLASS#	8.24712	6	1.37452	2.48	0.0250
TYPE_CODES	8.71429	5	1.74286	3.15	0.0096
WASTE_TOPO	5.63388	1	5.63388	10.18	0.0017
PROSPECTS_TOPO	5.04769	1	5.04769	9.12	0.0029
Residual	94.0784	170	0.553402		
Total (corrected)	155.049	184			

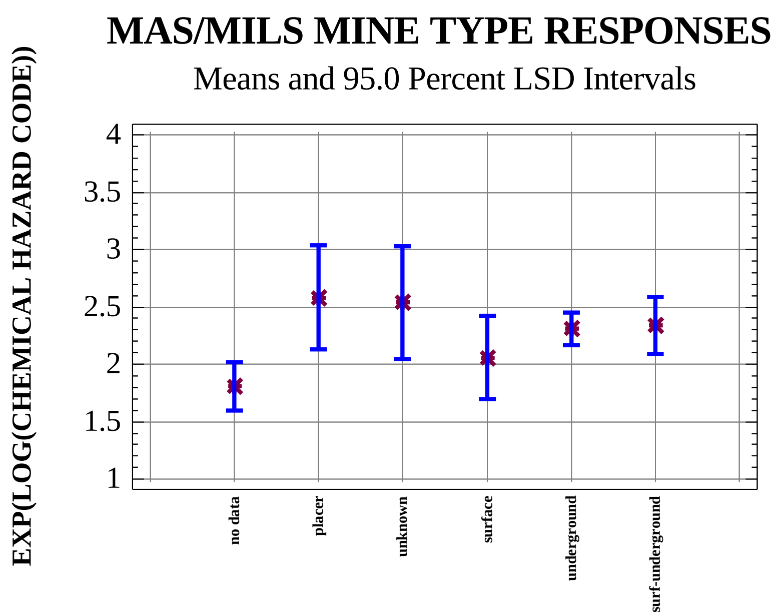
All F-ratios are based on the residual mean square error.

R-Squared = 39.3233 percent
R-Squared (adjusted for d.f.) = 34.3264 percent

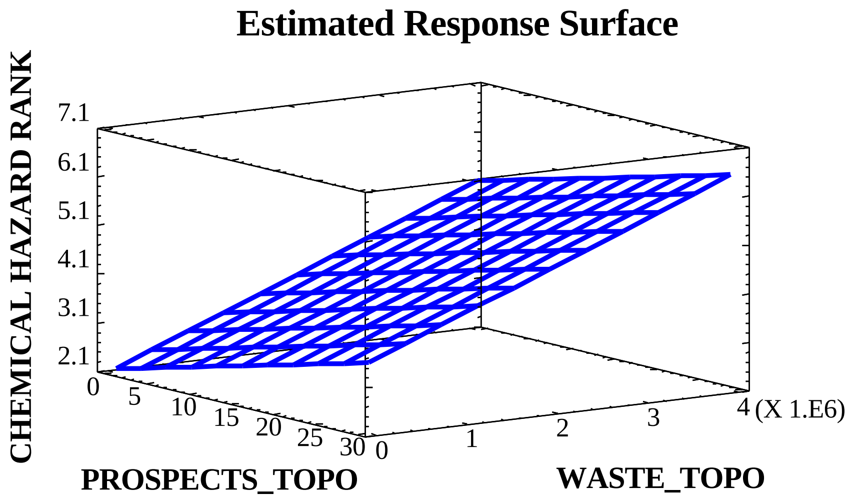
Useful information can be gained from looking at the multiple comparisons for the above model. As discussed above, those sites in the PAMP database have significantly higher chemical hazard ranking than those not in the database. Those sites not is MAS/MILS were significantly lower in chemical hazards than those in MAS/MILS, but all mine types (unknown, surface, underground, etc.) in MAS/MILS were not significantly different from each other. Sites in RECLASS number 4 were significantly higher in chemical hazards than those in numbers 1,5,and 6.







The responses of chemical hazard to waste and prospects, as shown on the topos, is displayed below. This graph shows that as the area of waste and the number of prospects increases, the chemical hazard rank also increases.



4.2 Physical Hazard Prediction

Only four of the ten watershed models were found to be significant for physical hazard prediction. In those four models, the data fields used for each of the models for physical hazard prediction varied among the watersheds. As with chemical hazard prediction, the most common data field for prediction of physical hazard was membership in the PAMP database, which is not surprising for the same reasons as cited above (largely mine size). The other data field that occurred in two watershed models was the mine type ("TYP" from MAS/MILS).

The best predictive model for physical hazard has an r^2 value of 43%, and is highly significant at the $p<0.001$. This model uses nothing more than the number of openings shown on the topo. Since this model requires that each site be identified in MAS/MILS, as well as located by one or more topo symbols, this model is not easily implemented on a statewide basis.

Table 4.2: *Physical hazard* model.

Regression Analysis - Square root-X model: Y = a + b*sqrt(X)

Dependent variable (Y): EXP(LOG(PHYS_APR_CODE))
Independent variable (X): (OPENINGS_TOPO)

Parameter	**Estimate**	**Standard Error**	**T Statistic**	**P-Value**
Intercept(a)	1.77245	0.0799860	22.1595	0.0000
Slope(b)	0.792809	0.0600948	13.1926	0.0000

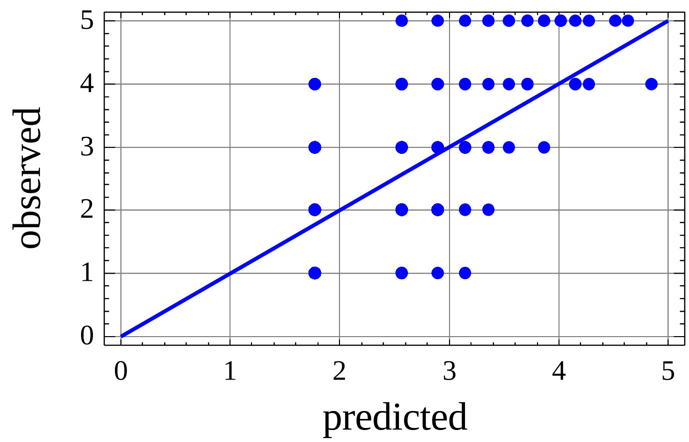
Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	136.979	1	136.979	174.05	0.0000
Residual	181.017	230	0.78703		
Total (Corr.)	317.996	231			

Correlation Coefficient = 0.656321
R-squared = 43.0757 percent

ALL RANDOM SITES

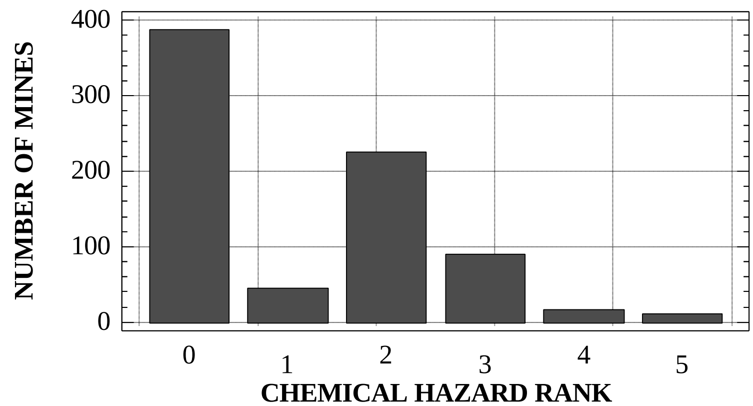
REGRESSION MODEL FOR PHYSICAL HAZARD



4.3 Distribution of Rankings

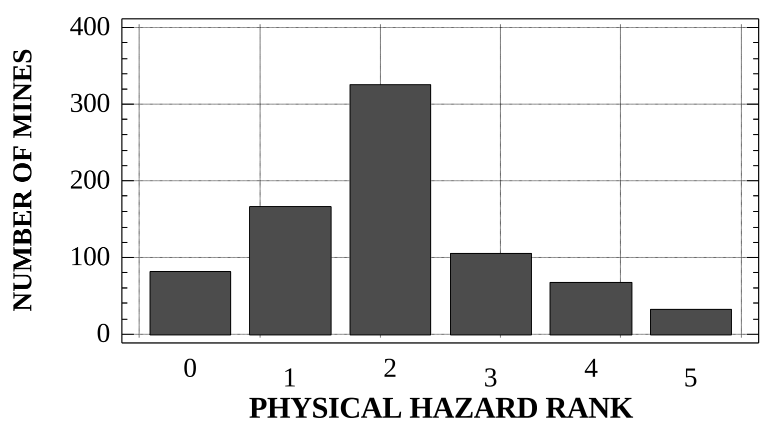
The following histogram, displays the *chemical hazard rank* for each site included in our database. These 778 sites include non-randomly selected sites, as well as the random sample used for the prior analyzes. By far the most common rank for chemical hazard is 0, i.e., most abandoned mines in the state do not pose a potential for chemical hazard. For the sites that have a rank above 0, the majority of sites have either a very low potential for a chemical hazard (rank 1), or a low potential for a chemical hazard (rank 2). Very few sites pose such serious problems as to receive a ranking of 5, and this rank is characterized by Superfund and CERCLA sites. The remaining ranks of 3 and 4 are where clean-up opprotunities are greatest. These sites are not so large as to require the high level of funds as do Superfund sites, nor to they pose the same level of contamination. Yet, cumulatively they may adversely impact a watershed. One example of a watershed that would probably benefit from such a watershed approach is the Point Buchon Watershed in San Luis Obispo. This watershed is relatively small and has a few mines in ranks 3 and 4, mines that would are not so hazardous as to gain Superfund attention. Yet, cumulatively these mines do impact the watershed (Schwartzbart 1993), and could be cleaned-up, largely for less than $500,000.

HISTOGRAM FOR CHEMICAL RANKINGS



The Figure below displays the histogram for *physical hazards ranking* for those sites in our database, randomly selected and non-random. Unlike *chemical hazard ranking* which only addressed potential, rankings for physical hazards are based on direct observation, and are therefore actual hazards. The result is only those sites with a Rank of 0 actually have no physical hazards. The difference between the Ranks (1-5) is the number of hazards. In other words, Rank 1 sites have only one small hazard such as a shallow shaft or one adit. Rank 2 sites have at least 2 features that are considered hazardous (shafts or adits deeper than 10 feet and highwalls greater than 10 feet). Rank 3 sites generally have 3-5 such features; Rank 4 sites have from 6-10 such hazards and Rank 5 greater than 10 such hazards.

HISTOGRAM FOR PHYSICAL RANKINGS



5 Summarized Findings

5.1 Size of Mines

The average mine size is 7 acres (based on a log transformation); the range is from 0 acres to 4400 acres. Because of the large amount of variation in the data, it might be more informative to use the untransformed data and report the average, median, and mode. The average is 29 acres (this number is skewed by the few large sites), median is 2 acres (median = ½ above and ½ below) and is probably the best single number to use, and mode = 1 acre (mode=most common number). In other words, the majority of the mine sites in the state are less than 2 acres in size.

Table 5.1: Percentage of visited mines in several surface area classes by total acreage and disturbed acreage.

Acreage	Percent by Total Area	Percent by Disturbed Area
0.0	2	4
0.1 — 1.0	34	45
1.1 — 5.0	28	25
5.1 — 10.0	13	12
10.1 — 20.0	11	7
20.1 — 50.0	6	3
50.1 — 100.0	4	2
100.1 +	2	2

5.2 Number of Features per MAS/MILS Record

MAS/MILS includes a field entitled "CUR" which lists the status of the mine, such as raw prospect to producer. All of the "CUR" status groups were represented in our random data set, except for mineral location. Since no mineral locations were encountered in the sample set, we assume that this status of mineral occurrence did not disturb the ground. Therefore, the number of features and mines in the state based on the MAS/MILS data set will be the total records (29,240) in that data set minus the mineral locations (4,227), i.e., 25,013 records.

The number of features based on the 25,013 records in the MAS/MILS database is estimated at 132,570, with 95% confidence intervals from 115,060-150,078. The estimate is calculated by multiplying 25,013 by the number of features at each of the randomly sampled MAS/MILS mine sites. Of the 279 random sites, 187 were also included in the MAS/MILS database. The mean number of field features per record (i.e., site) in MAS/MILS was 5.3 (required a log transformation to normalize the data); the 95% confidence interval for this mean is from 4.6 to 6.0.

5.3 Number of Features per Feature on Topographic Maps

Since AMLU has only digitized 1450 of the 2869 topos for the state, we do not have an absolute number of mine symbols for the state at this time. Based on current data, the number of symbols per topo varies from a low of 0 to a high of 454. Using a log transformation, the average number of mine symbols was calculated as 7.9, with the 95% confidence intervals for the mean from 7.2-8.7. A total of 27,812 mine features occur on the 1450 topos currently digitized. Using the calculated mean and confidence intervals for the remaining topos, the current estimate of the number of features statewide is 128,800, with 95% confidence intervals for the mean from 102,700-160,600. (Please note that this number and all subsequent numbers derived from this calculation will continue to change as more topos are digitized. Prior estimates, using fewer topos, were slightly higher and with a larger 95% confidence interval. In approximately one year, all the topos will have been digitized and the estimated number of mines based on topo symbols will then remain stable.)

5.4 Number of Mines in the State

Using the above calculation of 128,800 features (95% confidence from 102,700-160,600), and the relationship of 3.3 features in the field for every field site visited (95% confidence intervals from 2.3-3.5), it is estimated that there are 39,000 mines in the state (95% confidence interval from 29,300-69,800).

Using information in the MAS/MILS database, one would estimate the number of mines at 25,013 plus the number of mines not found in the database. Approximately 33% of the randomly chosen sites could not be linked to a MAS/MILS site. Using this relationship, the number of mine sites would be estimated to be 37,330 (no confidence interval).

Neither of these estimates are capturing the sites that do not occur in MAS/MILS nor on the topos. Approximately 6% of the sites in our database fit this criterion; however, these sites were not randomly selected, and therefore, it would not be prudent to use the 6% factor to increase the current estimates. Most of these sites were located while en route to a randomly chosen site or were the result of a public request for assistance. Obviously, both the topo data and the MAS/MILS data will underestimate the true number of mines because of this one fact. If the 6% rate remains stable with more sampling, then this figure could be used to increase the estimates.

5.5 Number of Sites with Potential Chemical Hazards

Of the randomly chosen sites, 11% pose at least a moderate potential for a chemical hazard. Based on the topo symbol data, we estimate that 4,290 mines have at least a moderate potential to present a chemical hazard (category 3,4, or 5). Based on the MAS/MILS estimate, 4,100 sites fit this same criteria. The most significant factor in the General Linear Model Regressions that addressed chemical hazard was whether or not a site was contained in the PAMP database. This report, which was compiled by DMG and digitized by AMLU, contains 2,422 sites and presents a starting point for locating the sites with moderate chemical hazard.

5.6 Number of Sites with Potential Physical Hazards

Of the randomly chosen sites, 84% pose at least a moderate physical hazard. Based on the topo symbol data, we estimate that 32,760 mines have at least a moderate potential to present a physical hazard (category 3,4, or 5). Based on the MAS/MILS estimate 31,360 mines fit this same criteria

5.7 Number of Hazardous Openings

Of the features sampled on the sites, 38% were found to be hazardous openings. Applying this rate to the predicted number of features statewide, we estimate that there are 48,944 hazardous openings in the state. Another method to calculate this number would be to increase the number of digitized openings by a factor of 1.87 (the current relationship between topo openings and hazardous openings in the random data set). A total of 8,149 openings occur on the 1450 topos currently digitized. Using the calculated mean for the remaining topos to estimate the number of openings and the 1.87 relationship cited above, another estimate of the number of hazardous openings statewide is 34,400. Yet another for calculation for the number of hazardous openings is to base it on MAS/MILS, resulting in 50,380 hazardous openings in the state.

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A AMLU Field Inventory Form

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B Project Chronology

Table 5.2 : Chronology of the Abandoned Mine Lands Unit.

TASK	START	FINISH	DESCRIPTION
Project Planning	9/1/97	6/2/98	The AML Unit was established, a manager was assigned, project scoping was completed, staff were hired, preliminary data intake forms were established, a risk analysis methodology was developed, and a health and safety plan was written. A Feasibility Study Report (FSR), required by DOC's Information Technology manager, was prepared.
Hiring of Permanent Staff	9/1/97	2/3/98	A manager was assigned, job specifications were prepared, jobs were advertised, exams and interviews were held, and three permanent staff were hired. (Two Research Program Specialists, and one Associate Engineering Geologist)
Program Scoping	9/1/97	12/2/97	It was determined that it would be impractical to expect three full-time staff and two student assistants to actually be able to field visit 20,000 abandoned mines within the time allotted. Contacts with federal and county officials and with adjoining states also indicated that the actual number of abandoned mines might be much larger. It was determined that the most practical way to accomplish this task, would be to develop a Database System (DBS) connected to a Geographical Information System (GIS) from which databases of mines, geology, ownership, bioregion, watershed, population, and other data could be collected, viewed, and analyzed spatially. This data could be sorted and grouped, a random sample of sites could be selected, which would then be inventoried in the field. Results of GIS analysis combined with field investigations could then produce statistics that could be used to determine the magnitude and scope of the AML in California. Unlike a strict field study, the use of GIS technology would allow the assessment of risk to the public and the environment, and provide the means to assign a ranking system for remediation priorities within the time and staffing limitations of the BCP.
Process and Workflow Planning. Preparation of FSR	11/3/97	2/25/98	The Department of Conservation, Office of Technology Assessment and Project Development (OTAPD) determined that a Feasibility Study Report (FSR), approved by the Department of Information Technology (DOIT)

TASK	START	FINISH	DESCRIPTION
			would be required based on the GIS system and software proposed in the scoping study.
Internal Departmental Review and Approval (FSR)	11/3/97	5/20/98	Concurrent with the DOIT FSR approval process, the Director for Conservation allowed that on January 1, 1998 the project could begin by hiring staff and purchasing equipment unrelated to the GIS.
Design of Data Intake Format	2/25/98	3/16/98	Staff designed the first drafts of the field data intake form. AML Task Force reviewed and provided comments.
Development of Risk Analysis Methodology (PAR)	4/13/98	6/2/98	PAR Model designed and reviewed by the AML Task Force.
Preparation of Health and Safety Plan	4/8/98	5/28/98	A health and safety plan was developed; All staff received training on plan.
Systems Design And Set-Up:	1/1/98	1/27/00	
Order and Delivery of Standard Complement Computers	1/1/98	2/25/98	Three moderate performance desktop computers with large monitors and Microsoft Office software were ordered for the program.
Department Installation of Standard Complement Computers	2/25/98	4/17/98	OTAPD installs Standard Complement Computers
Preparation and Submittal of FY 97-98 GIS Computer and Software Specifications	1/1/98	1/8/98	Paperwork for one high-performance GIS-capable desktop computer, including ArcView and ArcInfo GIS software was completed.
Approval, Order, and Delivery of FY 97-98 GIS Computer and Software	5/20/98	11/6/98	OTAPD approved, ordered and set-up the first GIS-capable desktop computer system. Software order was incomplete.
Department Installation of FY 97-98 GIS Computer and Software	12/15/98	2/17/99	ArcView and ArcInfo GIS software installation was completed for GIS-capable desktop computer system.
Preparation and Submittal of FY 98-99 GIS Computer and Software Specifications	4/26/99	5/6/99	Paperwork for second high-performance GIS-capable desktop computer, including ArcView and ArcInfo GIS software was completed.
Approval, Order, Delivery and	5/6/99	1/27/00	OTAPD approved, ordered and set-up the second GIS-capable desktop computer system

TASK	START	FINISH	DESCRIPTION
Installation of FY 98-99 GIS Computer and Software			and completed ArcView and ArcInfo GIS software installation.
Preliminary Database Schema Developed by AMLU	2/25/98	3/26/98	Database Schema used by other similar projects reviewed and AMLU's design completed.
OTAPD Review of Database Schema	3/26/98	3/26/98	Review denied by OTAPD Manager.
Develop and Implement Access Database Application	3/26/98	7/22/98	Integration of AMLU DBS with project and preliminary fieldwork completed.
Preparation, Approval, Order, and Receipt of Field Equipment and Vehicles	2/16/98	8/3/98	Field equipment included vehicles, GPS receivers, water-sampling meters, etc.
Approval, Contract Preparation, and Acquisition of Teale and DMG Data	7/1/98	3/8/99	Approval of Teale Data Center contract by OTAPD required. Final approval granted.
Implementation:	4/1/98	3/31/00	
Field Training, Testing of Equipment, Field Methods, and GPS protocols	4/1/98	6/24/98	All staff trained on equipment and safety protocols.
Choice of Initial Study Area Using GIS/USGS Features (GIS not installed)	4/15/98	5/1/98	It was intended that GIS technology (spatial analysis) would be used to choose an initial study area. However, the OTAPD Manager determined that a DOIT approved FSR was necessary before computers and software could be purchased. As a result, the choice of study areas had to be completed without use of this technology. In March, the OTAPD Manager determined that the FSR would only require internal DOC review. Therefore, it was re-directed,re-written, and finally approved for purchase by DOC on 4/17/98. Six months hence the necessary GIS hardware and software were finally installed.
Implementation of Inventory at Initial Field Study Areas	4/1/98	11/30/98	Field investigations of abandoned mine sites began as part of the initial pilot study to test protocols, methodology, and equipment.
Initial Study Data Entry	7/22/98	1/29/99	Concurrently, data entry of field investigation findings, and USFS data, (by contractual

TASK	START	FINISH	DESCRIPTION
			agreement) began in a Microsoft Access database developed by AMLU staff. Staff also made presentations to the media; as well as other state, federal, and local government groups. Staff collected databases and other information about abandoned mines from other state, federal, and local agencies, which was then incorporated into the AML database.
Initial Study Analysis/Results Implemented	11/30/98	1/29/99	With the GIS system in place, results of the initial study were analyzed, methodologies were refined and GIS capability was fully developed and implemented for future study areas. The Microsoft Access database was further modified to reflect the results of the pilot study. GIS coverages of mine site and feature locations collected by GPS were assembled and projected for GIS display and analysis.
Field Inventory (Using pre-field GIS analysis)	1/29/99	3/31/00	Digitized maps and other spatial databases from Teale Data center were made available by contract for GIS analysis. Sites were chosen utilizing GIS applications and analysis of existing data at the watershed level. Mine sites and features located by GPS were processed and appended to previously collected data and projected for GIS use.
Data Entry (AMLU Field Data and USFS Files)	1/29/99	3/17/00	Through this period, AML staff collected and entered data on more than 3,900 mine features (shafts, adits, waste, etc.) at approximately 800 sites statewide. The AML Access database was further refined.
Digitizing of USGS Topographic Map Features for State	7/1/99	3/31/00	A project to digitize and create a "GIS data coverage" of every USGS topographic map mine feature in the state was undertaken by AML staff and through contract with several college campuses.
Analysis and Report:	10/15/99	6/30/00	
Data Analysis	10/15/99	3/17/00	Beginning December 1, 1999, and continuing through April 3, 2000, draft reports of the previously completed watershed-level analysis were prepared and analyzed. During this same period, staff prepared draft sections of the final AML Report.
Draft Report	12/1/99	3/31/00	Staff continued to prepare reports and conduct analyses of completed field inventories.
Draft Report Review (DOC and Stakeholders)	4/1/00	7/12/00	Review and revision of the draft AML Report by the Department of Conservation with comments from stakeholders completed.
Final Draft Report Completed	7/12/00	7/14/00	Final Draft of the AML Report document completed.