Valley Fire

CA-LNU-009088

Post Fire Watershed Emergency Response Team Report

October 12, 2015

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List of Abbreviations

ALERT	Automated Local Evaluation in Real Time
BAER	Burned Area Emergency Response
BARC	Burned Area Reflectance Classification
BOF	California State Board of Forestry and Fire Protection
CAL FIRE	California Department of Forestry and Fire Protection
CalVeg	Classification and Assessment with Landsat of Visible Ecological Groupings
CEG	Certified Engineering Geologist
CFS	Cubic Feet per Second
CGS	California Geological Survey
CVRWQCB	Central Valley Regional Water Quality Control Board
DWR	California Department of Water Resources
EHR	Erosion Hazard Rating
EWP	Emergency Watershed Protection Program
FEMA	Federal Emergency Management Agency
FRAP	Fire and Resource Assessment Program
FT	Flow Transference Method
GIS	Geographic Information
GPS	Global Positioning Satellite
HEC-HMS	Hydraulic Engineering Center-Hydraulic Modeling System
HVLCSD	Hidden Valley Landowners Community Service District
LiDAR	Light Detection and Ranging
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PE	Professional Engineer
PFWERT	Post Fire Watershed Emergency Response Team
PG	Professional Geologist
PH	Professional Hydrologist (AIH)
RSAC	Remote Sensing Application Center
RI	Return Interval
RPF	Registered Professional Forester
TR-55	Technical Release-55
USDA	United States Department of Agriculture
USGS	United States Geological Survey

I. Introduction

Post wildfire emergency response work has been conducted in on non-federal lands in California in numerous ways over the past 35 years. This includes CAL FIRE Emergency Watershed Protection (EWP) evaluations in the 1980's and 1990's, which authorized the Department to conduct post burn rehabilitation work as part of its EWP program. Examples of past work included post fire seeding for erosion control in high hazard areas and channel clearance to prevent over-bank flooding in populated areas. However, since the year 2000, the use of wide spread grass seeding has been largely eliminated because numerous studies have shown that (1) the seed does not sprout and grow quickly enough to prevent most of the erosion that comes in the first winter after a fire, and (2) the planted grass competes with natural vegetation and can lead to less effective long-term cover conditions. In contrast, straw and wood mulch, which establishes cover prior to the first fall rains, has been shown to be much more effective in preventing post fire erosion (Robichaud et al. 2010). After 2000, post fire emergency response teams in southern California have emphasized the use of early warning systems (e.g., ALERT systems), and warning letters have been increasingly used to inform residents of debris flow and flooding potential, as determined by licensed geologists participating on these teams.

Prior to 2015, little post fire evaluation work has been conducted on non-federal lands in California since 2008. This has been largely due to a limited number of large fires in southern California and reduced funding for this type of work, including no direct state funding for post fire emergency protection measures (leaving that to private landowners, the counties, NRCS, and others).

In 2007, CAL FIRE staff developed a draft prioritization form to select fires that presented the highest risk to lives and property, and this form was revised in 2015. In appropriate situations, small state teams of civil engineers, geologists and CAL FIRE staff can be assembled to assess risk to lives and property from debris flows and hyper-concentrated flood flows. CAL FIRE senior staff, along with OES, determined that a post fire emergency response team was needed for the devastating Valley Incident, primarily located in Lake County. It was clearly recognized that in order to avoid duplication of efforts and make the most of funding opportunities, it was critical for the post fire response team developed for the Valley Fire to coordinate with and compliment the efforts that are underway by NRCS and other state and federal agencies. A multi-agency team comprised of individuals with expertise in geology, hydrology, forestry, GIS, and water quality was assembled on September 30, 2015 for the Valley Fire. Primary objectives for this Phase I Post Fire Watershed Emergency Response Team (PFWERT) effort were to:

- Identify on-site and downstream threats to public health or safety from landsliding, debris torrents, flooding, road hazards, and other fire related problems.
- Develop and recommend emergency protective measures needed to avoid life-safety threats.

Following this the Phase I effort, a Phase II PFWERT team will be assembled to:

- Identify threats to watershed resources, including: excessive erosion; impaired water quality; threats to wildlife, fisheries, and botanical values; and cultural resources.
- Develop and recommend emergency protective measures needed to prevent identified threats.

The phased approach is being used to streamline the initial life safety hazard detection effort completed in Phase I. The process is described as a phased approach only because the prioritized life-safety hazard effort overlaps and transitions with the evaluation of natural resource impacts.

Table 1. Phase I team members.

Main Team			
Name	**Position**	**Agency**	**Expertise-Position**
Pete Cafferata, PH #1676, RPF #2184	Team Leader	CAL FIRE	Hydrology/Forestry
Dave Longstreth, CEG #2068	Co-Leader	CGS	Engineering Geology
Patrick Brand, CEG #2542	Team Member	CGS	Engineering Geology
Griffin Perea, PG #9237	Team Member	CVRWQCB	Engineering Geology
Trevor Morgan, PE #79967	Team Member	DWR	Civil Engineer/Hydrology
Stacy Stanish, RPF #3000	Team Member	CAL FIRE	GIS/Forestry
Julia Grim	Team Member	NRCS	Geology
Adjunct Team			
Korinn Woodard	Team Member	NRCS	District Conservationist
Kelly Larvie	Team Member	CAL FIRE-FRAP	Research Analyst, GIS
Tom Smythe	Team Member	Lake County Department of Water Resources	Water Resources Engineer
Will Evans	Team Member	Lake County Department of Water Resources	Water Resources Program Coordinator

II. Valley Fire Summary Information

The Valley Fire began on September 12, 2015 and burned 76,067 acres in Lake, Sonoma, and Napa Counties, south of Clear Lake (Figure 1). Major areas impacted include Middletown, Cobb, and Hidden Valley. Tragically, the fire killed four people. Additionally, a total of 1958 structures were destroyed, including 1280 homes and 27 apartment buildings. This total makes the Valley Fire the third worst in state history in terms of the number of damaged structures. Approximately 99 percent of Boggs Mountain Demonstration State Forest rapidly burned (roughly 3460 acres of the total Forest area of 3493 acres). The Valley Fire area burned went from 400 acres in the first few hours to 40,000 acres in approximately the first 18 hours due to high wind conditions, reported up to 60 mph. Detailed information is provided at: http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=1226

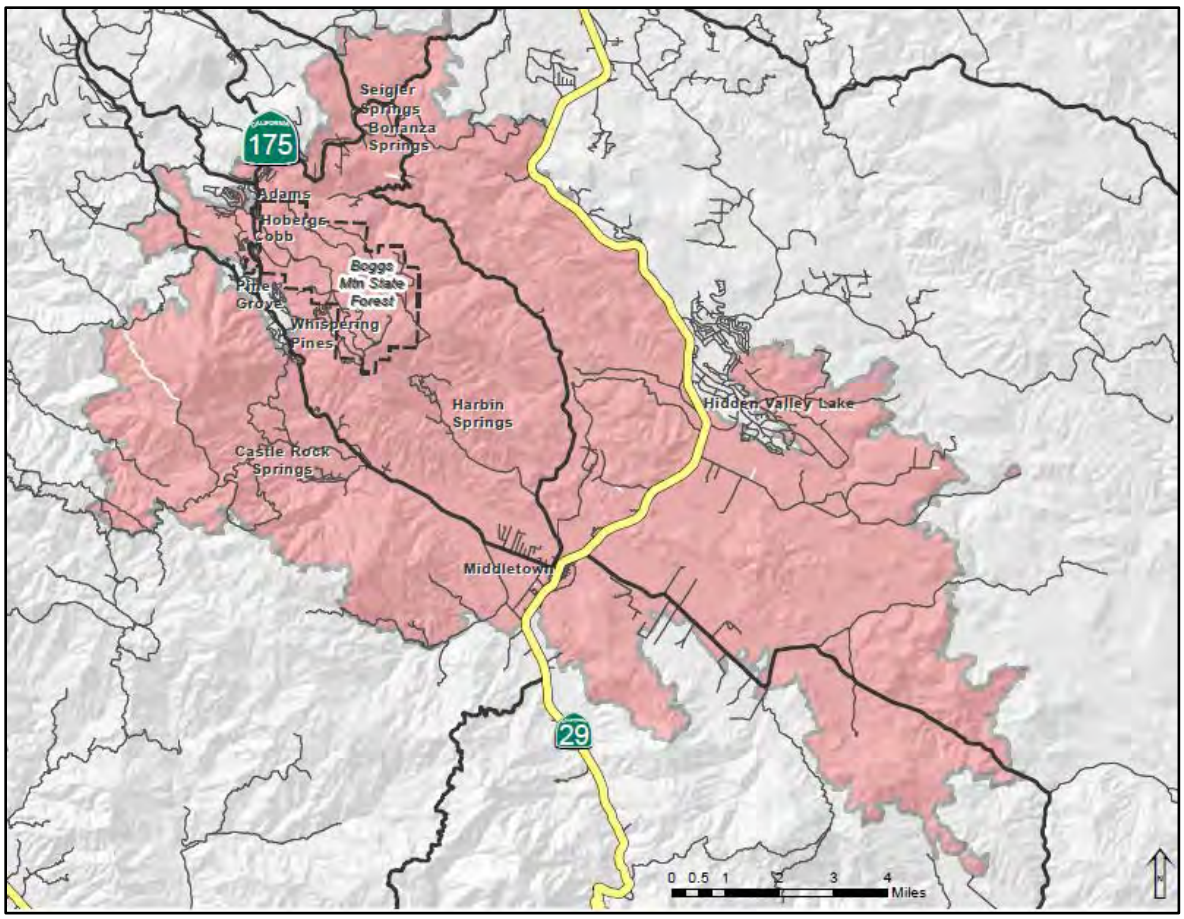

Figure 1. General Valley Fire map.

III. Physical Setting

Geographic Setting

The Valley Fire burned through an area that ranges in elevation from about 1000 feet above mean sea level near Bordeaux Lake to a high of about 4700 feet above mean sea level at Cobb Mountain. This area is home to numerous communities, wineries, agricultural centers, and resorts. Lower and mid elevation areas were comprised of mostly of gray pine and oak woodlands with areas of manzanita/ chamise fields and low lying grasslands. Upper elevation areas transition to conifer forests with numerous hardwood species in riparian zones. For specific information regarding vegetation types, including acres and percentage within the fire perimeter, see Table 2. Precipitation varies greatly from the northwest portion of the fire to the southeast portion of the fire, from 80 inches annually southeast of Anderson Springs near the fire perimeter to 30 inches annually near Bordeaux Lake. Upper elevation areas receive limited snow most years, however most of the precipitation is in the form of rain. Areas that do receive snow are within the rain-on-snow zone. The area experiences a typical Mediterranean climate, with warm dry summers and cool wet winters. Temperatures can range from highs in the 100 degree range during the summer to lows in the 30's during the winter. Topography in the area varies widely, ranging from low lying valleys in the south eastern portion of the fire perimeter to

steep sided canyons in the Highway 175 and Big Canyon corridors. Slopes can vary from less than 10% to over 75%, but generally slopes within the fire perimeter range from 10% to 30%.

Table 2. CalVeg cover types for the Valley Fire area.

CalVeg Cover Type	Acres in Valley Fire Perimeter	Percent of Valley Fire
Agriculture (AGR)	7127	9.4
Barren (BAR)	301	0.4
Conifer (CON)	11187	14.7
Hardwood (HDW)	14136	18.6
Grassland (HEB)	5757	7.6
Hardwood/Conifer Mix (MIX)	18316	24.0
Shrubland (SHB)	18316	24.0
Urban (URB)	371	0.5
Water (WAT)	574	0.8
Total	**76085**	**100.0**

Fire History

Only 21 percent of the Valley Fire area had burned since 1950 prior to the Valley Fire; 19 individual fires have occurred in the last 65 years (GIS analysis using NICS layer; Mike Wink, CAL FIRE, personal communication). Recent fires in the Valley Fire area have included the 1985 Hidden Valley Fire, which burned 1032 acres in the footprint; the 1991 Geysers Fire, which burned 1582 acres entirely within the footprint; the 2000 Hidden Fire, which included 3593 within the footprint; the 2004 Geysers Fire, with 664 acres within the footprint; and the 2014 Butts Fire, which included only 40 acres within the Valley Fire footprint (Figure 2).

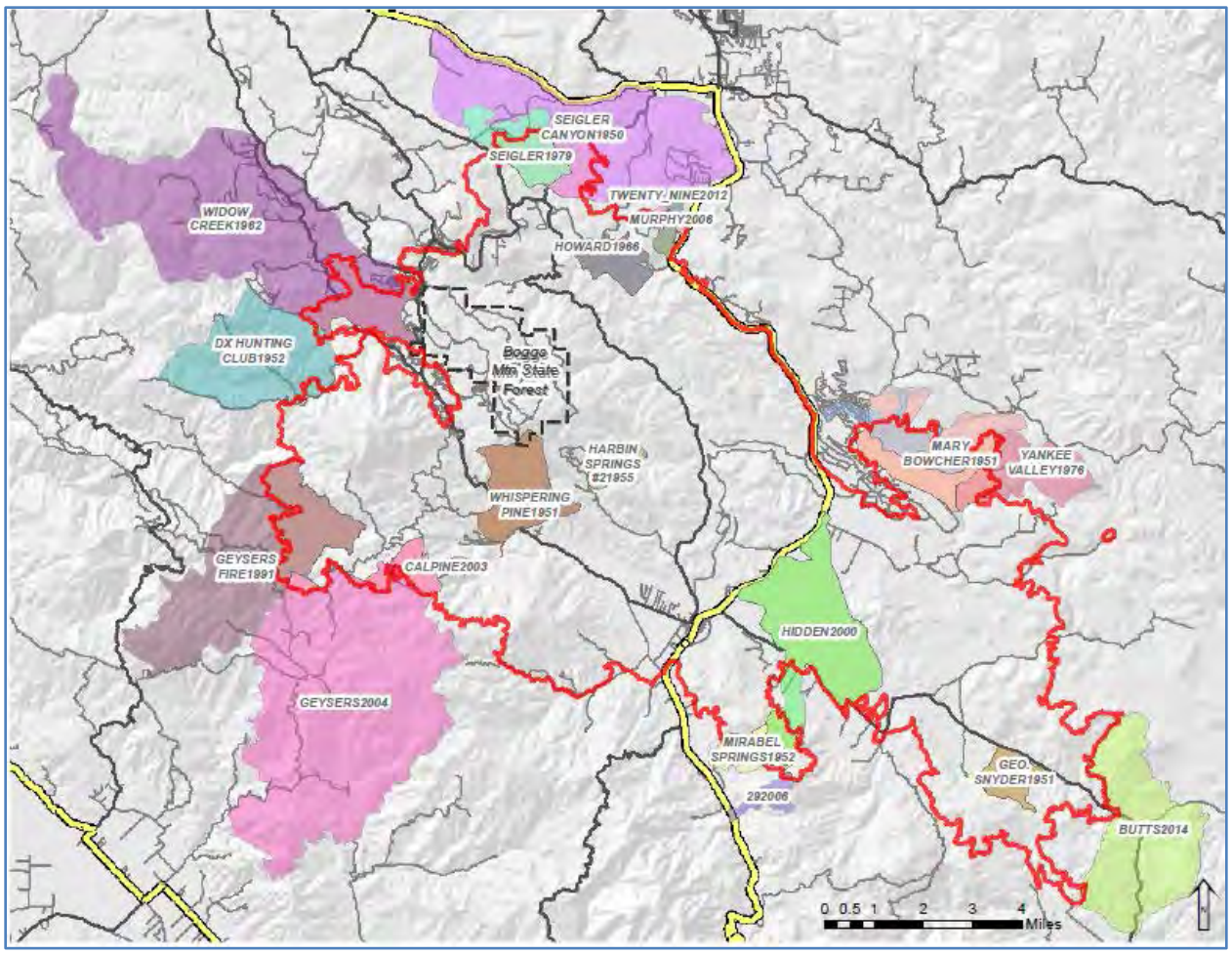

Figure 2. Fire history for the Valley Fire area.

Geologic Setting

The 2015 Valley Fire burn area is located in the north-central portion of the Coast Ranges geomorphic province. The Coast Ranges are northwest-trending mountain ranges and valleys that trend northwest, subparallel to the San Andreas Fault (CGS, Note 36). Topography in the Valley Fire area can generally be divided into three areas: (1) steep slopes drained by moderate to steep gradient watercourses in the northwest portion of the fire area in the area of Cobb and Boggs Mountain, (2) relatively gentle and flat ground that contain the Long Valley, Coyote Valley and Collayomi Valley areas in the central portion of the fire area, and (3) steep slopes drained by moderate to steep gradient watercourse in the southeast portion of the fire area in the area of Butts Canyon. Fault relationships in the area of the Valley Fire are complex, with numerous faults mapped within the burn area. A number of active faults, likely associated with the Clear Lake volcanic field are mapped immediately north of the burn area.

The Coast Ranges are composed of thick Mesozoic and Cenozoic sedimentary strata. In the Valley Fire area sedimentary rocks are overlain by volcanic cones and flows of the Clear Lake volcanic fields. Published geological mapping (Brice, 1953; Hearn and others, 1995; McNitt,

Plates 1, 2, and 3) indicates three basic types of bedrock in the fire area: (1) Mesozoic to Cenozoic marine sediments and volcanics of the Franciscan Complex and Great Valley Sequence, (2) continental sediments of Plio-Pleistocene age, and (3) Quaternary volcanic rocks (Brice, 1953; Hearn and others, 1995). The Franciscan Complex underlying portions of the Valley Fire area is described as consisting of greywacke sandstone interbedded with minor chert, shale, and conglomerate. The Great Valley Sequence rocks are described as sandstones and mudstones with shale, conglomerate and greenstone. Both units includes serpentinite (Brice, 1953; Hearn and others, 1995,) thought to be disrupted pieces of ultramafic rock representative of displaced upper mantle material (Harden, 2004). The Plio-Pleistocene Cache Formation is described as freshwater deposits of gravel, silt, and clay with marl limestone and diatomite in the upper portions (Brice, 1953). Quaternary volcanics of the Clear Lake volcanic field (https://volcanoes.usgs.gov/volcanoes/clear_lake/) that overlie portions of the sedimentary bedrocks contain rhyolitic and basaltic volcanic rocks ejected as flows and tuffs. It is thought that some of the relatively flat valley bottoms in the vicinity are due to lava flow dams and the highest topography within the burn area, including Cobb and Boggs Mountains, is formed of volcanic rock (Brice, 1953).

Brice (1953) indicates that serpentinite and the volcanics appear especially susceptible to landslide processes. Landslides are commonly found near the contact between the overlying volcanics and underlying Franciscan Complex in the western and northern portion of the burn area. Potentially hazardous naturally occurring minerals (asbestos and mercury) occur within the Valley Fire burn area. Both asbestos and mercury can be associated with ultramafic rocks, particularly serpentinite. Exploration borings for hydrothermal energy are present over most of the burn area and an active development exist in the southwest portion. A byproduct of hydrothermal processes are gases containing sulfuric compounds. Plate 4 illustrates locations of mineral hazards within the Valley Fire burn area. Information regarding naturally occurring asbestos can be found at the Lake County Air Quality Management District website: http://www.lcaqmd.net/SerpentineAsbestosChoices.htm

Soil and Erosion Information

Soils in the 2015 Valley Fire burn area are generally derived from underlying bedrock or discontinuous deposits of colluvium and alluvium that overlie the bedrock. Alluvial deposits occupy valley floors and stream channels and colluvium blankets most slopes throughout the burn area. Published soil surveys identify more than one hundred soils units within the burn area (Smith and Broderson, 1989; Miller and others, 1972; Lambert and Kashiwagi, 1978). In general, soils on gentle to moderately steep upland areas consist of loam to clay loam, with increased clay content where the parent material is volcanic or serpentinite. Soils on steeper hillsides are often gravelly loam and gravelly clay loam, while soils in lower lying areas such as valley floors, stream channels, and floodplains generally consist of loam to sandy loam.

Erosion Hazard Rating (EHR) for soils in the 2015 Valley Fire burn area was estimated by CAL FIRE (Figure 3) based on the procedure described in the California Forest Practice Rules (Board Technical Rule Addendum #1) and using an assumed post fire vegetative cover of 10 percent. The EHR results indicate that areas of High and Extreme EHR generally correlate with the areas of steep slopes, such as the southwest portion of the fire area (e.g., the Mayacamas Mountains and Geysers areas) and the southeast and east flanks of Boggs Mountain (e.g., the Harbin Springs area). The results also indicate that the very steep slopes that flank Cobb Mountain have an Extreme EHR.

Mary Ellen Miller (Michigan Technological University) and Bill Elliot (USFS Rocky Mountain Research Station) also modeled post-fire hillslope erosion in the 2015 Valley Fire burn area

(Figure 4) using GeoWEPP (Geographical interface for the Water Erosion Prediction Project). The model estimates the quantity of erosion during a ten year storm event/recurrence interval based on the field verified Soil Burn Severity map and assumed values for post-fire ground cover in areas of differing burn severity. The model results are generally consistent with the BOF Technical Rule Addendum No. 1 estimated EHR, with the highest quantities of estimated erosion in the southwest portion of the fire area (e.g., in the Mayacamas Mountains, Geysers, and Cobb Mountain areas) and the southeast and east flanks of Boggs Mountain (e.g., the Harbin Springs area). However, the results also appear to improve upon the BOF estimated EHR results by using varying ground cover estimates based on the verified Soil Burn Severity map. As such, some areas identified by the BOF EHR mapping as High or Extreme EHR have relatively low estimated quantities of erosion (such as the north face of Cobb Mountain).

The highest GeoWEPP modeling data indicates erosion rates of approximately 310 to 680 Megagrams per hectare per year (160 to 360 cubic yards per acre) within some of the basins on Cobb Mountain. These basins are shown as orange and red in the GeoWEPP modeling map (Figure 4). As such, high rates of surface erosion should be expected during high intensity rain events.

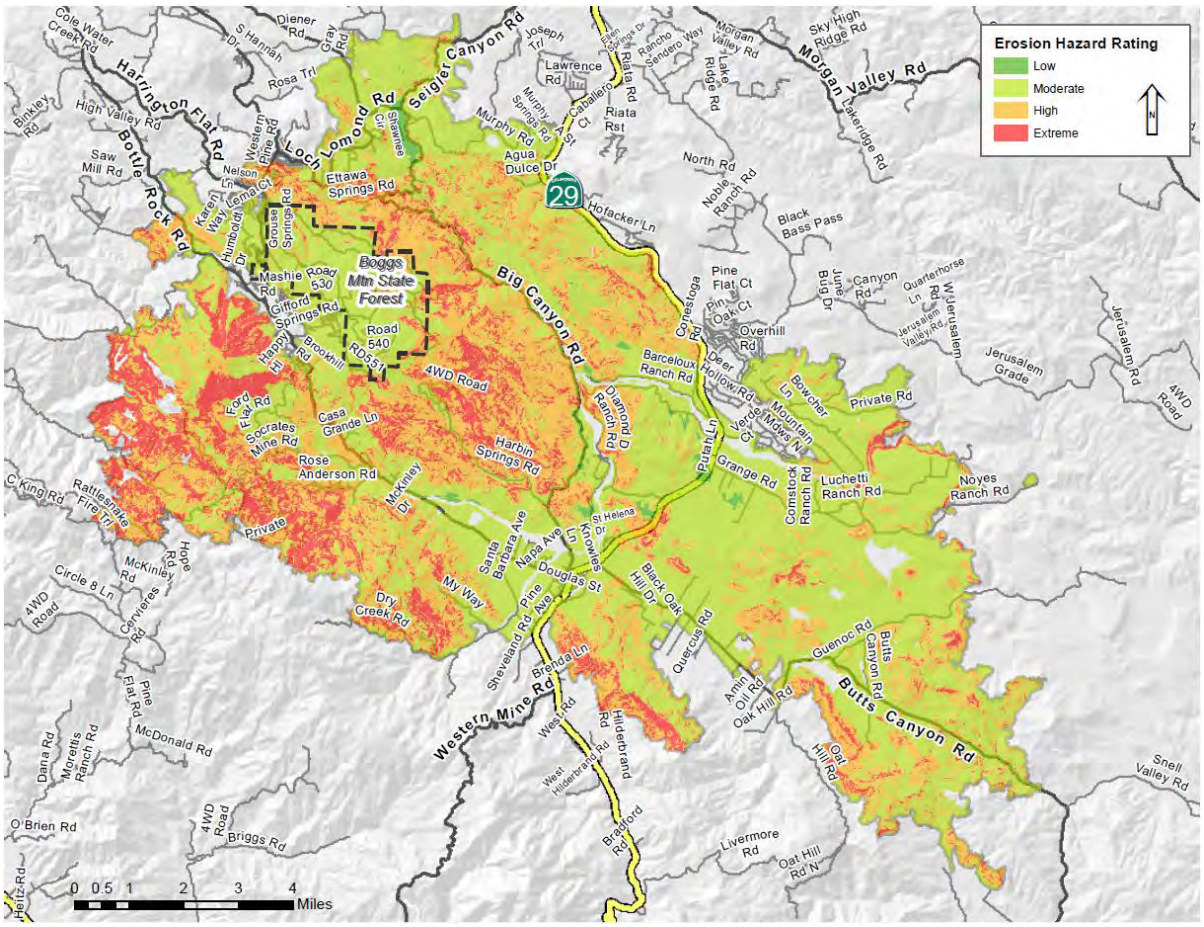

Figure 3. BOF Technical Rule Addendum No. 1 erosion hazard rating map.

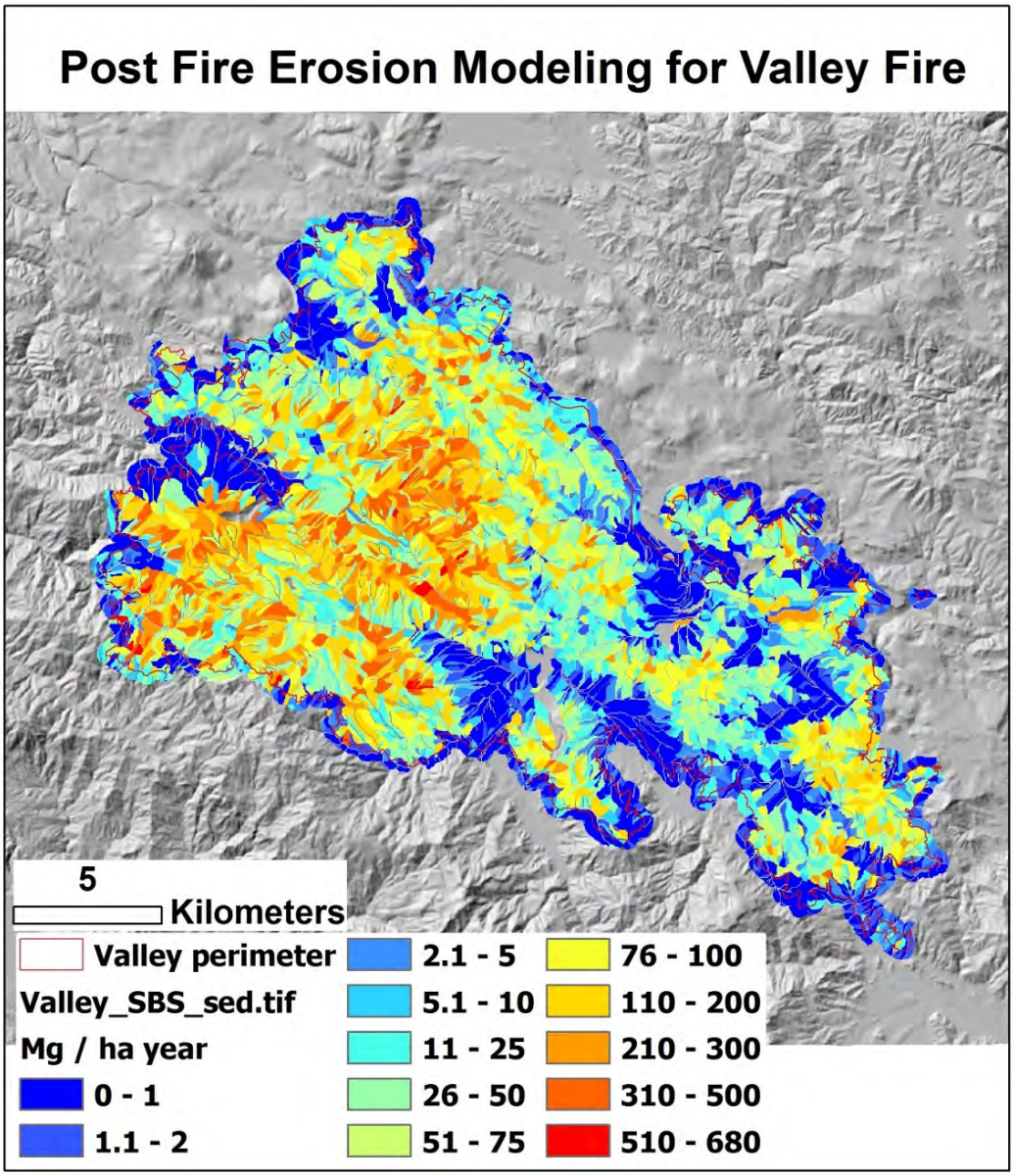

Figure 4. Post fire erosion modeling completed for the Valley Fire by Drs. Mary Ellen Miller and Bill Elliot.

Flooding Information

Incomplete flood history is available for the watersheds located within the Valley Fire area. FEMA (2011) reported that in the last 50 years, Lakeport has experienced six stream bank overflow flood events: December 1937, February 1940, December 1964, January 1970, January 1983, and February 1986. Kelsey Creek is the only unregulated watershed with a long flow record partly within the Valley Fire footprint. Beginning in 1947, flood events exceeding a 10 year recurrence interval in the Kelsey Creek watershed have occurred in water years 1954, 1965, 1983, 1995, 1997, and 2013 (Figure 5). The January 1997 flood equated to approximately a 30 year return interval event (Hunrichs et al., 1998).

Floodplain development in the upper Putah Creek area is mostly agricultural, except for the portion of Middletown subject to overflow from Putah Creek tributaries. FEMA has mapped the 100 year floodplain for Putah Creek and its tributaries in the Middletown area, as well as for the Anderson Springs, Copsey Creek, Butts Creek through Snell Valley to Putah Creek, Seigler Canyon near Lower Lake, and the Cache Creek watersheds. It has been estimated that over 1000 homes are located in the 100 year floodplain within the fire perimeter (Tom Smythe, Lake County Department of Water Resources, personal communication). FEMA flood zone maps are available at:
http://www.co.lake.ca.us/Government/Directory/Water_Resources/Department_Programs/Flood_Management/Check_Floodplain_Status.htm

Localized flooding during heavy rain events prior to the fire has been observed in multiple areas within the fire perimeter (M. Wink, CAL FIRE, personal communication). These areas include the Collayomi Valley between Santa Barbara and Napa Streets, Long Valley near Highway 29 and Butts Canyon Road and between Loconomi and Eureka streets, the Coyote Valley at Hartman Road including the south east end of the Hidden Valley Lake subdivision behind the levee, Spruce Grove Extension, and Seigler Valley along the Seigler Canyon Road. A resident in the Seigler Valley area reported that during heavy rain events, the bridges along Seigler Canyon Road would often overtop.

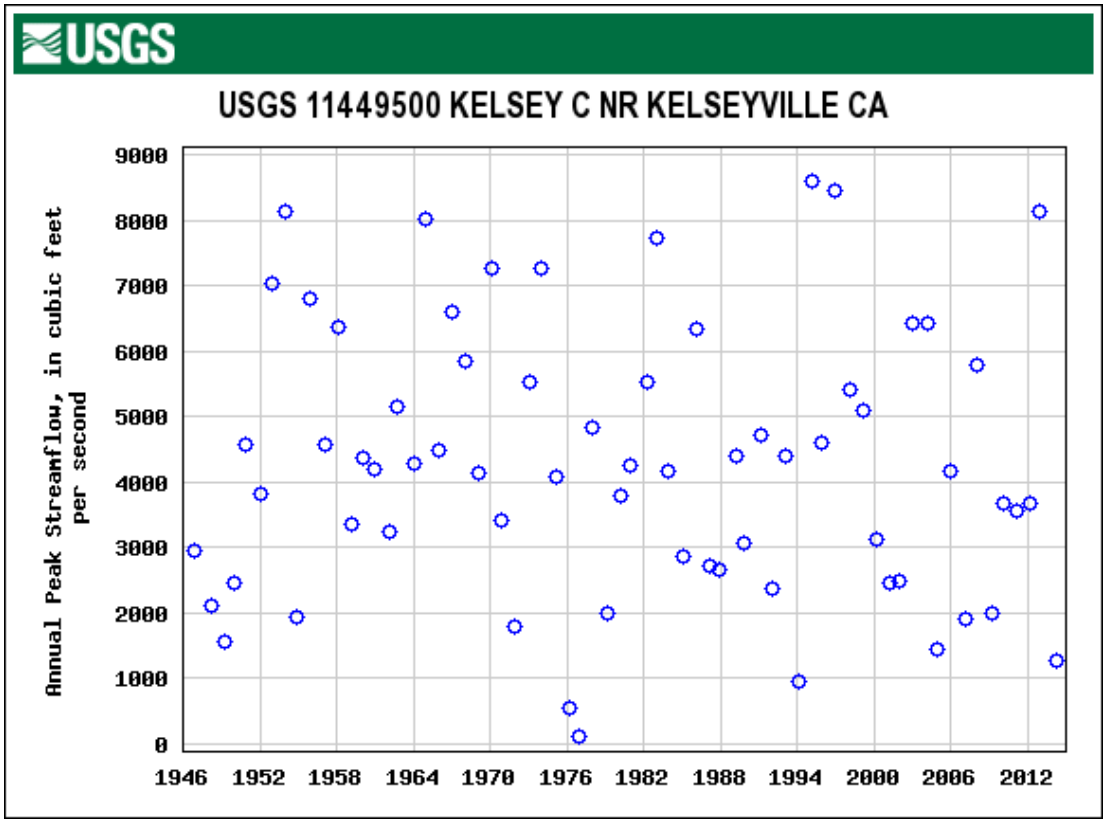

Figure 5. Annual peak discharges for the Kelsey Creek watershed, USGS Station 11449500.

IV. Field Observations

The Post Fire Watershed Emergency Response Team (PFWERT) was initially provided a preliminary Burned Area Reflectance Classification (BARC) map of the Valley Fire burn area prior to initiation of field work. Satellite data for the BARC map was produced by the USFS and the initial map was produced by CAL FIRE-FRAP. PFWERT field observations can be broken into two general sections: (1) verification and ground truthing of BARC map provided by the USGS, and (2) site specific observations of post-fire conditions that pose a risk to life and property.

Compilation of GIS Data and Maps (conducted on October 1 and 2, 2015): In order to compare field observations with map data, geo-referenced pdf maps were produced for team member use. Raster data from the Valley Fire BARC map was layered onto a topographic base layer using ArcGIS. Road layers and culvert/bridge location data provided by Lake County were added to the ArcGIS maps that were converted to geo-referenced pdf files. The geo-pdf files were uploaded to team member smart phones and one iPad. Team members used an application named “PDF Maps” (Avenza, Inc.) to track their locations on the ground relative to mapped GIS features. An Esri application named “Collector” was used on an iPad to easily compare aerial imagery with respect to GIS data. This was particularly useful in tracking map location when conducting an aerial helicopter reconnaissance.

BARC Map Verification (conducted October 2 and 3, 2015): A BARC map is composed of satellite-derived data layers of post-fire vegetation conditions. The BARC has four classes: high, moderate, low, and unburned. Typically the higher the burn severity, the more susceptible the area is to rapid runoff and erosion. The Valley Fire BARC map was used by the PFWERT as a guide to discover areas of probable erosion and debris flows that may occur during storm events and threaten impacts to downslope structures and infrastructure.

CAL FIRE requested that a Burned Area Reflectance Classification (BARC) map be created. The United States Forest Service (USFS) Remote Sensing Application Center (RSAC) gathered the satellite imagery and provided this imagery to CAL FIRE’s Fire and Resource Assessment Program (FRAP). The BARC map was created on 22 September 2015 and displayed the Valley Fire perimeter and the burn severities (unburned, low, moderate, high) within the Valley Fire, based on post fire vegetation conditions as of 22 September 2015. To verify the accuracy of the BARC map, members of PFWERT conducted field tests, mostly within the moderate and high burn severity areas, and compared the results to the BARC map soil burn severity classification.

In order to have confidence in the BARC map data the PFWERT divided into two teams and conducted soil hydrophobicity testing and vegetation burn severity observations at points within the burn area (Figure 6) consistent with guidelines provided by Parsons et al., 2010. Testing was conducted at 28 sites within the Valley Fire perimeter. Soil water repellency testing was conducted on both the soil surface and at depth. Surface water repellency testing was completed by scraping away the ash layer to expose bare mineral soil at the surface and then timing how long it took for a drop of water to infiltrate the soil. Subsurface water repellency testing was completed in the same fashion as surface testing, however a small trench was dug approximately ½ inch to 1 inch below the soil surface to test for water repellency. At nearly every site, surface water repellency was observed, however subsurface water repellency was highly variable.

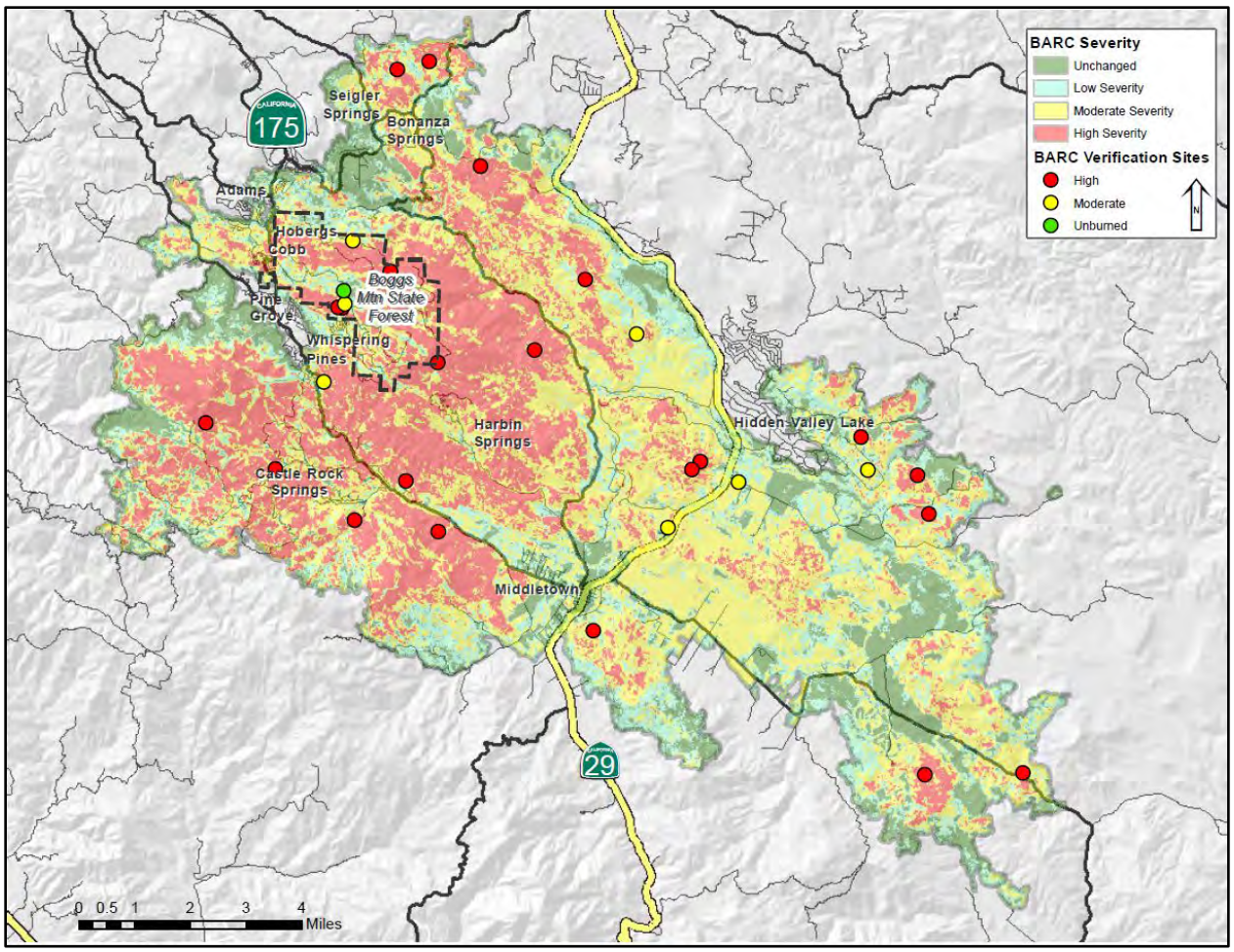

Figure 6. BARC map with field verification sites.

Throughout the testing it became apparent that soil water repellency was not necessarily a good sole indicator for burn severity, as water repellant conditions persisted throughout various BARC burn severities and was highly variable. Therefore, to validate the BARC map, additional information on ash thickness, ash color, pre-fire vegetation density, ground cover, and vegetation type was collected in conjunction with soil water repellency to determine the overall soil burn severity for comparison with the BARC map. Field data gathered during the BARC map verification is summarized in Appendix A.

In general the PFWERT found the Valley Fire BARC map to be highly accurate, with only one minor revision from moderate to high burn severity near the Hidden Valley Lake Area, south of Guenoc Lane. The corrected BARC map was provided to the USGS, who then conducted debris flow modeling. Overall for the entire Valley Fire area, approximately 14% was unchanged, 18% low, 40% moderate, and 27% high. Individual HUC 12 planning watershed percentages are displayed in Table 4.

<u>USGS Debris Flow Modeling</u>: The USGS uses empirical models to estimate the probability and volume of debris flows for selected basins in response to a design storm. The characteristics of basins affected by the Valley fire were calculated using a geographic information system (GIS). Debris-flow probability, volume, and combined hazard were estimated for each basin outlet as

well as along the upstream drainage networks for a 2, 5, 10, 25, 50, and 100 year design storm event. The combined hazard line segments for the 100-year design event and locations downslope or downstream of the line segments were used by the PFWERT as a guide to possible locations of concern. The USGS modeling data was provided to the PFWERT on October 5, 2015.

Aerial Helicopter Reconnaissance (conducted October 4, 2015): An aerial reconnaissance of the Valley Fire Burn area was conducted via a helicopter on the morning of October 4, 2015. The aerial reconnaissance enabled team members to visually assess potential areas of concern to be evaluated on the ground. As a potential area of concern was observed during then flight a GIS point was taken on the PFWERT iPad. These point locations were then added to the geo-pdf data maps so that they could be visited on the ground by team members.

Site Specific Observations (conducted October 4, 5, 6, and 7, 2015):

An initial training was conducted by the PFWERT within the Anderson Springs area. The purpose of the training was to provide consistency in team member observations and recording of potential hazard locations. An Excel spreadsheet titled “Burn Site Evaluation Summary” (Appendix B) was printed and used to compile notes during site specific observations. The summary sheet logs the type of at-risk feature (e.g., a house or bridge), the address, the GPS location (NAD 83 datum), the type of hazard (for example flooding, debris flow, culvert plugging), the likelihood of hazard occurrence, whether the hazard poses a risk to life and/or property, possible emergency protection measures, and the responsible agency.

After the site specific training, the PFWERT broke into two teams and began assessing areas of concern within the Valley Fire footprint. Site specific observations were conducted October 4, 5, 6, and 7, 2015. Locations and areas of concern were based on the USGS debris flow modeling data for the 100 year design event (combined hazard), FEMA 100 year flood plain mapping, BARC data, topography, aerial imagery from Google Earth, and information gathered from knowledgeable individuals who have lived in the area for several years. Where possible, team members noted preliminary or possible emergency protective measures. Data were collected every night and entered into an Excel spreadsheet (Appendix B).

V. Debris Flow Modeling and Results

The USGS conducted a post-fire debris flow hazard evaluation for the 2015 Valley Fire using empirical models to estimate the probability and volume of debris flows for selected basins in response to a design storm. The empirical models are based upon historical debris-flow occurrence and magnitude data, rainfall storm conditions, terrain and soils information, and the field verified Soil Burn Severity map. Post-fire debris-flow probability, volume, and combined hazards are estimated at both the drainage-basin scale and in a spatially distributed manner along the drainage network within each basin. The characteristics of basins affected by the fire were calculated using a geographic information system (GIS). Debris flow probability and volume in response to a design storm were estimated for each basin outlet, as well as along the upstream drainage networks. The combined debris flow hazard is considered to be the combination of both the estimated probability and volume. For example, the most hazardous basins or segments will show both a high probability of occurrence and a large estimated volume of material. Slightly less hazardous areas would be basins or segments that show a combination of either relatively low probabilities and larger volume estimates or high

probabilities and smaller volume estimates. The lowest relative hazard would be for basins and segments that show both low probabilities and the smallest volumes.

USGS Valley Fire Debris Flow Results

Results of the USGS debris flow results can be viewed as an interactive map at the following link: http://landslides.usgs.gov/hazards/postfire_debrisflow/2015/20150912valley/.

The interactive map displays estimates of the probability of debris flow in percent, potential volume of debris flow in cubic meters, and as a combined relative debris flow hazard. These predictions are made at the scale of the drainage basin, and at the scale of the individual stream segment. Estimates of probability, volume, and combined hazard are based upon a design storm with 25-year recurrence interval (i.e., a 1 in 25 chance of a storm of that magnitude occurring in any given year). The PFWERT used the 100-year recurrence interval (i.e., a 1 in 100 chance of a storm of that magnitude occurring in any given year) and this is what is shown on the identified values at risk map (Plates 5). The 100-year recurrence interval debris flow modeling shows more or higher ranked segments of potential debris flows (particularly in the high burn severity areas in the northwest portion of the Valley Fire burn area) when compared to the 25-year interval. All the recurrence intervals indicate Anderson Creek and Bear Creek (Anderson Springs area) as high potential for debris flow.

Figures 7 and 8 show USGS modeling results for combined debris flow hazard and probability of volumes. Estimates of combined hazard and volume are based upon a design storm with 25-year recurrence interval (i.e., a 1 in 25 chance of a storm of that magnitude occurring in any given year).

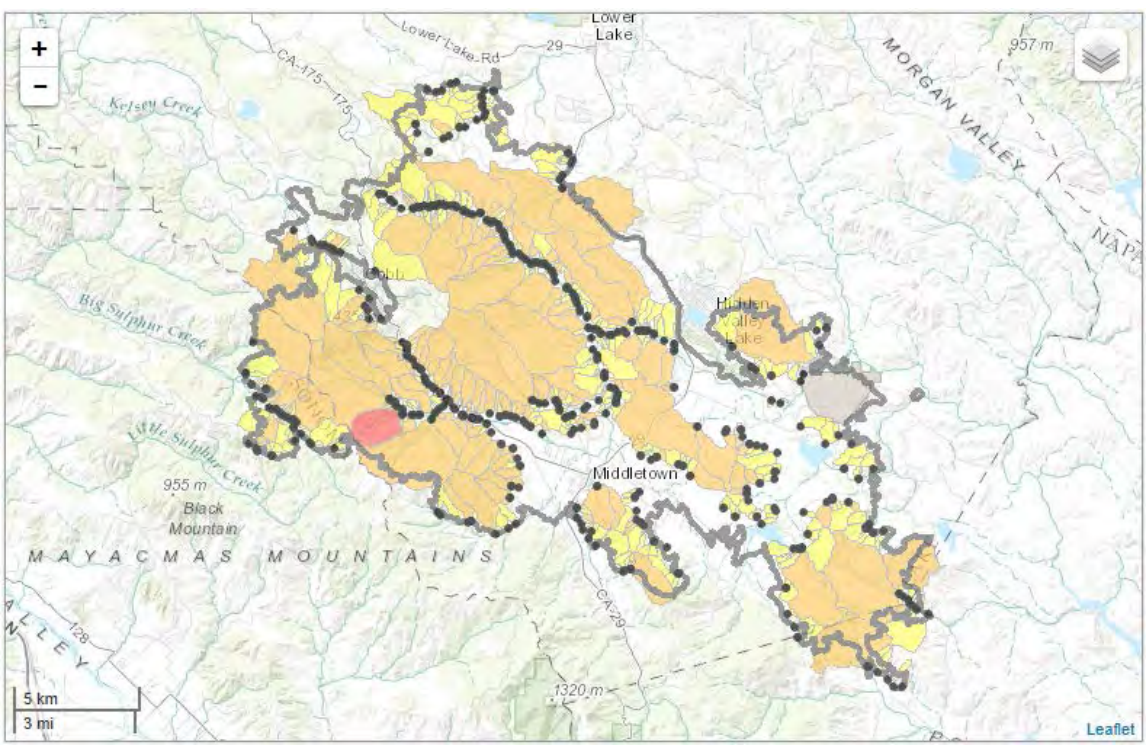

Figure 7. USGS modeling results for combined debris flow hazard for a 25 year return interval storm event.

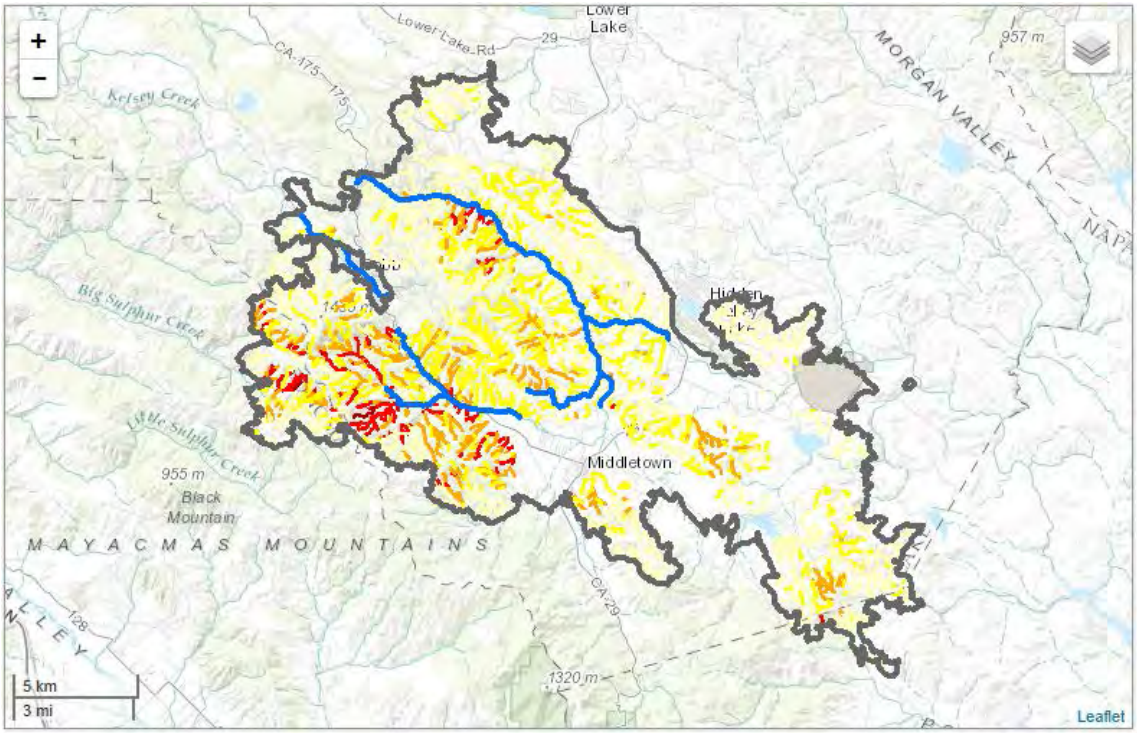

Figure 8. USGS modeling results for probability of stream segment volumes based on a 25 year return interval storm event.

VI. Flood Flow Modeling and Results

Flood Modeling Methods

Several different approaches are available for estimating pre and post-fire stream flows for the watersheds affected by wildfire (Mai 2003, Foltz et al. 2009, Kinoshita et al. 2014). These include:

- The Rational Method (limited to watersheds < 200 ac),
- USGS regional regression equations (Gotvald et al., 2012),
- Stream gauging station data with flood frequency analysis and flow transference (area adjustment) to nearby hydrologically similar watersheds (Waananen and Crippen, 1977),
- Flow estimates provided in Rowe et al. 1949 for southern California watersheds,
- NRCS Curve Number methods (Foltz et al., 2009), and
- Computer programs using the unit hydrograph approach (programs such as TR-55, HEC-HMS) (Kinoshita et al., 2014).

Kinoshita et al. (2014) compared several of these methods for pre and post wildfire flow estimates. They reported inconsistency between model predictions for events across the sites and less confidence with larger return periods (25- and 50-year events) and for post-fire predictions. Therefore, we only estimated the 10 year return interval pre and post fire flood flows for the HUC 12 watersheds associated with the Valley Fire (see map in Appendix C).

For pre-fire flow evaluation, we determined that the local stream gauging data would provide reasonable estimates of flood flows. Stream gauging data with flow transference were used for the 14 HUC 12 watersheds analyzed for the Valley Fire (Cafferata et al. 2004). Peak flow calculations were based on the data collected from 1947 to the present at USGS stream gauging station No. Station - 11449500 Kelsey Creek near Kelseyville, CA. This unregulated gauging station is located below the fire perimeter, but the upper part of the basin was burned as part of this incident and the drainage area is generally similar to those of the HUC 12 basins analyzed. A flood frequency analysis for this station was produced using the USGS PeakFQ software program (Figure 9 and Appendix C).

In addition to using Kelsey Creek flow data, FEMA's (2011) analysis of flooding conditions in the upper Putah Creek watershed provides a valid methodology to predict pre-fire flood flows within the general fire area. FEMA utilized a unit hydrograph approach to generate drainage area-peak discharge relationships for upper Putah Creek (Figure 10), as well as other drainages in Lake County.

To determine the impact of the wildfire on first year post-fire peak flows, the total acres and acres burned at high, moderate, and low soil burn severity for each HUC 12 watershed was determined (Tables 3 and 4). Then a simple equation included in Foltz et al. (2009) was used to predict first year increases following the fire:

$$\textit{Modifier} = 1 + \frac{\textit{Percent Runoff Increase}}{100\%} \times \frac{(A_h + A_m)}{A_T}$$

where:

A_H = high burn severity area within the watershed (acre or mi^2)
A_M = moderate burn severity area within the watershed (acre or mi^2)
A_T = total watershed area (acre or mi^2)

Limited studies and guidelines exist to determine the appropriate modifier or percent runoff increase for high and moderate soil burn severity. As stated in Foltz et al. (2009), US Forest Service BAER specialists have used a 100% runoff increase (double the runoff amount) for high/moderate soil burn severity areas in the first year after a severe wildfire. This simple approach appears reasonable for the Valley Fire and was used for post fire flood analysis. It is generally consistent with information included in a review of changes in peak flows following wildfire conducted by Moody and Martin (2001). They state that Rowe et al. (1949) has been used for post-fire flow modification evaluation in southern California for decades, and that for the first year after the wildfire, the ratio of post fire flow to pre-fire flow increases from 2 to 3 fold for less frequent, large magnitude storms (5 to 100 year recurrence intervals).

The GeoWEPP erosion modeling (Figure 4) indicates relatively high rates of erosion in those sub-basins that received high burn intensity (approximately 310 to 680 megagrams per hectare per year). As such, the high flows anticipated from the effects of moderate to high burn severity will likely result in high rates of surface runoff and erosion during moderate to high intensity rainfall events.

Flood Flow Modeling Results

Estimates for pre and post-fire flood flows for the 14 modeled watersheds draining the Valley Fire are provided in Table 5. The 10-year return interval flood flow in the Big Canyon Creek-Putah Creek watershed is projected to increase 1.7 times. The estimate for the Dry

Creek-Putah Creek watershed is only slightly less, at 1.6 times. All of the remaining HUC 12 watersheds are projected to increase less than or equal to 1.3 times for 10 year return interval flood events. Note that the pre- and post-wildfire flow transference values for Kelsey Creek are lower than those derived from the FEMA graph. Using the more conservative FEMA graph estimates will provide a greater factor of safety.

It is important to note that watershed area affects the size of estimated post-fire flood flows. In general, Neary et al. (2005) and Foltz et al. (2009) state that post-fire changes in peak flows are greatest in smaller sized watersheds less than 0.4 mi^2 (~250 ac). The HUC 12 watersheds used in this analysis are approximately 13 to 54 square miles, so higher increases are expected for the Valley Fire in much smaller sub-watersheds that are intensely burned.

Additionally, no bulking factor was included in our analysis, but bulking by sediment can be extremely important during the first post winter. Estimates of projected flood flow volumes are commonly doubled due to bulking, or entrainment of sediment from mass wasting processes, in southern California watersheds (LACDPW 2006). It may be less for northern California watersheds, but this is currently unknown.

Even without bulking, in the Big Canyon Creek-Putah Creek HUC 12 watershed for the first winter, it is significant to understand that the Valley Fire is projected to change a 10 year return interval event (10,500 cfs) to approximately a 100 year event (18,000 cfs), using the FEMA graph for upper Putah Creek (Figure 10, Table 5).

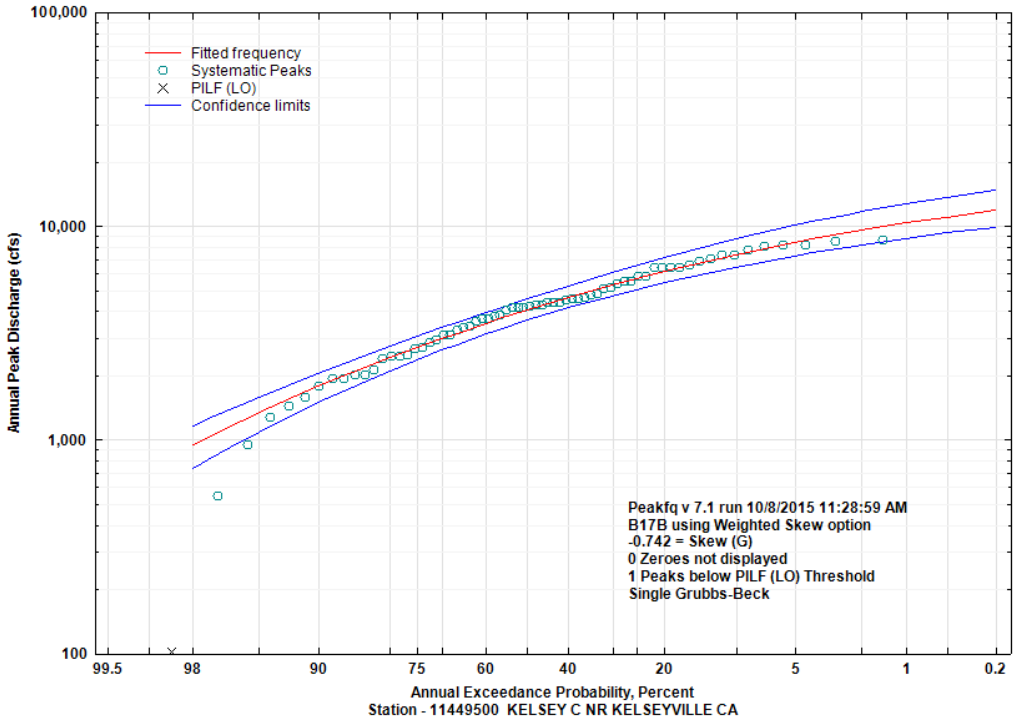

Figure 9. Flood frequency plot for the Kelsey Creek watershed (using USGS PeakFQ program).

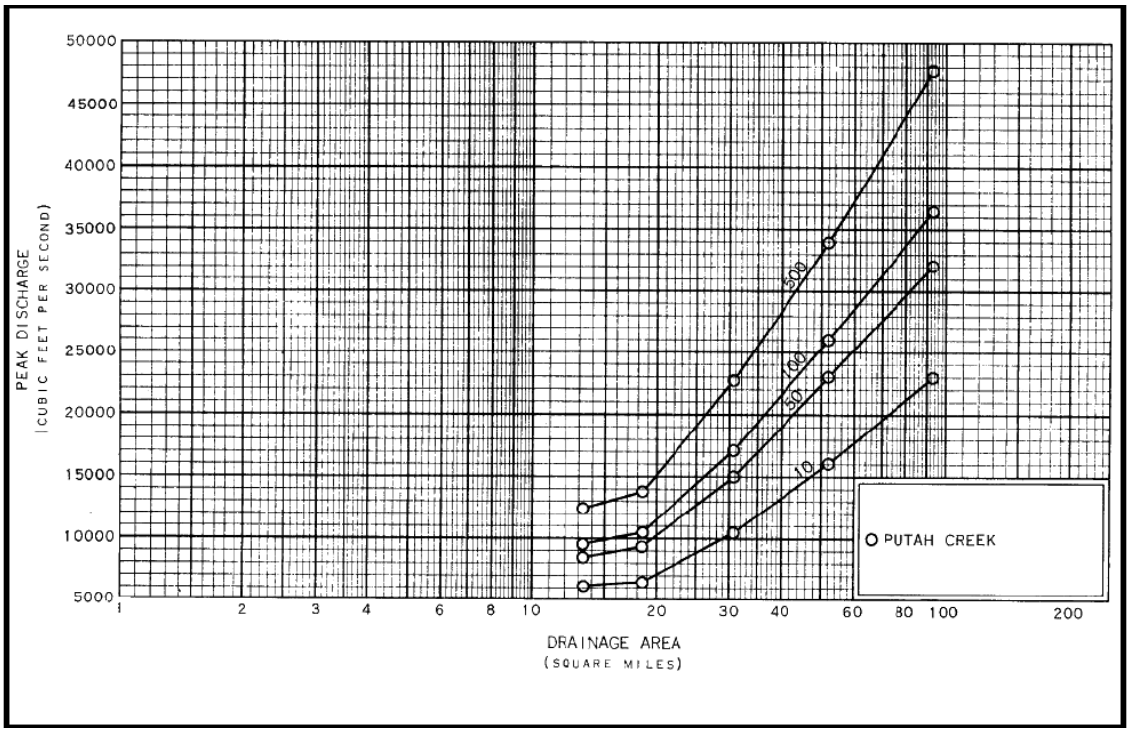

Figure 10. Peak discharge-drainage area relationships for varying return intervals for the upper Putah Creek watershed (from FEMA 2011).

Table 3. Valley Fire HUC 12 watershed areas, area burned, and areas unburned (note that total acres on September 22, 2015).

Watershed Name	Area	Area	Area Burned	Area Burned	Area Burned	Area Burned	% Area
	(ac)	(sq mi)	(in fire perimeter)	(in fire perimeter) %	(ac)	(%)	Unburned
Alder Creek-Big Sulfer Creek	34372	53.7	3493.0	10	2783	8.0	92.0
Big Canyon Creek-Putah Creek	20862	32.6	19055.0	91	17548	70.1	29.9
Bucknort Creek	16818	26.3	8575.0	51	6205	35.0	65.0
Butts Creek-Putah Creek	35276	55.1	2524.0	7	1990	5.6	94.4
Cole Creek	18613	29.1	6.0	0	1	0.0	100.0
Copsey Creek	11132	17.4	2458.0	22	2226	14.6	85.4
Crazy Creek-Putah Creek	25327	39.6	13998.0	55	12039	45.7	54.3
Dry Creek-Putah Creek	20483	32.0	15025.0	73	13973	54.3	45.7
Kelsey Creek	28480	44.5	4700.0	17	3519	11.6	88.4
Little Sulphur Creek	20359	31.8	199.0	1	141	0.6	99.4
Saint Helena Creek	13649	21.3	1809.0	13	1543	10.5	89.5
Seigler Canyon Creek (revised)	8072	12.6	3094.0	38	2362	23.6	76.4
Soda Creek	20811	32.5	275.0	1	214	0.9	99.1
Upper Pope Creek	13956	21.8	830.0	6	526	3.5	96.5
Total			76041.0		65070		

Table 4. Soil burn severity for the HUC 12 watersheds, as well as flow modifier values.

Watershed Name	Burn Severity HIGH (ac)	Burn Severity HIGH (%)	Burn Severity MOD (ac)	Burn Severity MOD (%)	Burn Severity LOW (ac)	Burn Severity LOW (%)	Flow Modifier
Alder Creek-Big Sulfer Creek	1254	3.6	964	2.8	565	1.6	1.065
Big Canyon Creek-Putah Creek	7262	20.8	8146	39.0	2140	10.3	1.739
Bucknort Creek	612	1.8	3329	19.8	2264	13.5	1.234
Butts Creek-Putah Creek	281	0.8	1218	3.5	491	1.4	1.042
Cole Creek	0	0.0	0	0.0	1	0.0	1.000
Copsey Creek	888	2.5	889	8.0	449	4.0	1.160
Crazy Creek-Putah Creek	1690	4.8	7120	28.1	3229	12.7	1.348
Dry Creek-Putah Creek	6876	19.7	5071	24.8	2026	9.9	1.583
Kelsey Creek	1106	3.2	1464	5.1	949	3.3	1.090
Little Sulphur Creek	21	0.1	80	0.4	40	0.2	1.005
Saint Helena Creek	173	0.5	758	5.6	612	4.5	1.068
Seigler Canyon Creek (revised)	598	1.7	1117	13.8	647	8.0	1.212
Soda Creek	58	0.2	73	0.4	83	0.4	1.006
Upper Pope Creek	53	0.2	208	1.5	265	1.9	1.019

Table 5. Valley Fire 10 year return interval pre-fire and post-fire flood predictions (FT = flow transference method).

	Pre-Fire 10 Year RI		Post-Fire 10 Year RI		10 Year RI
Wateshed Name	Kelsey Cr FT (cfs)	FEMA Graph (cfs)	Kelsey Cr FT (cfs)	FEMA Graph (cfs)	Times Normal
Alder Creek-Big Sulfer Creek	10302	16500	10966	17565	1.1
Big Canyon Creek-Putah Creek	6639	10500	11542	18255	1.7
Bucknort Creek	5492	9200	6779	11356	1.2
Butts Creek-Putah Creek	10540	17000	10988	17722	1.0
Cole Creek	6005	10000	6005	10000	1.0
Copsey Creek	3820	6200	4429	7190	1.2
Crazy Creek-Putah Creek	7874	13000	10613	17522	1.3
Dry Creek-Putah Creek	6532	11000	10342	17416	1.6
Kelsey Creek	8731	14500	9518	15808	1.1
Little Sulphur Creek	6498	11000	6530	11055	1.0
Saint Helena Creek	4570	7500	4882	8012	1.1
Seigler Canyon Creek (revised)	7198	12000	8728	14550	1.2
Soda Creek	6624	11000	6666	11069	1.0
Upper Pope Creek	4661	8000	4748	8150	1.0

VII. General Observations of Values at Risk

1) Soils Susceptible to Erosion. Some of the Valley Fire burn area is underlain by Franciscan formation sedimentary rock (Bric, 1953). It appears that the on-site soils in these areas are loose and susceptible to erosion, whether they are affected by wildland fire or not.

2) Hazardous Minerals. Portions of the Valley Fire burn area are underlain by naturally occurring hazardous minerals (particularly asbestos). Information regarding these hazardous minerals can be found at the Lake County Air Quality Management District website: http://www.lcaqmd.net/SerpentineAsbestosChoices.htm

3) Development of Water Repellent Soils. Our evaluation of soils within the burn area indicate that water repellent soils have developed in areas where the BARC map indicates moderate to high burn classifications. The presence of water repellent soils is anticipated to

decrease infiltration of water resulting in an increase of surface flow during storm events, particularly during the first winter after the fire. The increased flows can result in increased erosion of hillsides, scouring of watercourse channels, bulking of sediment, and development of in-channel debris flows. Because the burn area contains loose soils that in some areas are susceptible to erosion, the potential for flooding, erosion, and debris sliding is exacerbated by the effects of the wildfire and development of water repellent soils.

4) Road System. The residential communities within and downstream of the Valley Fire burn area are serviced via a network of roads and highways. Caltrans maintains Highways 29 and 175 and Lake County controls the municipal road system. Roads within the geothermal field on the northwest side of the burn area are controlled by the Calpine Corporation. Many of the roads are located near or cross the drainages that flow within or downstream of the fire area. The road system is drained via numerous culverts and bridges that discharge into what appear to be natural and man-made drainage swales. Many of the roads are insloped and carry water to the culverts along inside ditches. Because water repellent soils developed from the fire, increased flows on slopes and onto the road system can be expected. Loose and erodible soils that mantle the slopes could wash down, inundate, and plug the drainage system. Flows could be diverted down roads and cause erosion and possible blockage and/or loss of portions of the road infrastructure and structures along roads.

The PFWERT did not evaluate every culvert, bridge or other type of crossing within or downstream of the burn area. **Only observed areas that appeared at risk to obvious debris flow impact or flooding were noted. The observations documented in this report are intended to be used as a preliminary indication of some of the most obvious areas of potential concern for follow-up work and more detailed evaluations. The observations are not intended to be comprehensive and conclusive, but rather to serve as a preliminary tool to assist emergency response agencies (for example CAL FIRE, Lake County, Caltrans, Office of Emergency Services, Natural Resource Conservation Service, Calpine, utility companies, and other responsible agencies) in development of more detailed post-fire emergency response plans.** Along bridges and other types of crossings identified as high risk to flooding and hyper concentrated (bulked) flows, the PFWERT suggests responsible agencies consider installing gates, warning signs, or other measures (such as evacuation warnings) to control traffic and keep people out of identified risk areas during large storm events. It will be very important to utilize scheduled storm patrols during large, intense storm events to ensure that identified high risk watercourse crossings are functioning properly.

5) Mobile Homes on Burnt House Footprints. The PFWERT's observations did not record locations where structures were destroyed by the Valley Fire (empty lots). It is understood that mobile homes may be moved onto burnt house footprints. Because many of the foot prints are located low in the watershed, they may be subject to impacts from flooding or debris flows. Mobile homes should not be located low in a watershed or drainage, particularly in watersheds identified in the USGS debris flow modeling as being at high to moderate risk from debris flow hazard from the 100 year design storm event or in areas with an identified high flood risk.

6) Homes Located in the FEMA 100 Year Floodplain. The PFWERT noted several areas of homes that are located within the FEMA 100 year floodplain (shown on Plate 5), supplemented with information obtained from anecdotal discussions with landowners. The most obvious areas of flooding are noted in Specific Observation (Appendix B).An early

warning system should be developed to notify home owners and/or communities prior to onset of large storm events. Information and methodology critical to this process is provided for by the USGS Open File Report OF10-1039 that can be accessed at: http://pubs.usgs.gov/of/2010/1039/pdf/OF10-1039.pdf

7) Campgrounds and Trailer Parks. Several campgrounds and mobile home parks were noted within and downstream of the Valley Fire burn area. These locations are located along flat areas along stream sides susceptible to flooding and debris flows. The PFERT observed campgrounds at Hidden Valley Lake along Gallager Creek, within Boggs Demonstration State Forest, Jellystone Park along Kelsey Creek, and the Pine Grove Resort (these are reported in specific observations). These areas should be closed to the public during the winter months the first years following the fire. Additionally, an early warning system should be developed to notify communities prior to onset of large storm events. Information and methodology critical to this process is provided for by the USGS Open File Report OF10-1039 that can be accessed at: http://pubs.usgs.gov/of/2010/1039/pdf/OF10-1039.pdf

8) Early Warning Systems. First Responder Agencies should coordinate with affected communities. Local community meetings should be conducted to inform landowners of potential post-fire hazards. Letters should be used to notify businesses and residents in the susceptible downstream areas that flooding and debris flows may occur during the first winter period following the fire. Residents should be informed that they may install structure protection measures where appropriate. For example this could involve installing K-rails (large cement highway barriers), muscle wall (http://www.musclewall.com/), and sand bags to prevent water and debris from reaching high value areas (i.e., deflect water away from roads and homes). Residents should be provided with information on how to obtain these protection measures. Available stream gages and/or rainfall stations with telemetry should be used (or installed quickly) to monitor real-time river stages and/or precipitation. Precipitation and river gage sensors can be event driven and transmit data collected to base station computers at National Weather Service offices and NOAA River Forecast Centers. Residents should be encouraged within and downstream of the burn area to download the NIXLE application for cell phone notification of emergency situations, such as flood forecasts (http://www.nixle.com/). **Specifically, we strongly recommend that Lake County follow through with the installation of a real time stream flow station on Putah Creek approximately two miles east of Anderson Springs above Middletown. This station can serve as an excellent early warning system trigger to help evacuate people in flood prone areas identified in this report.**

9) Municipal Water Supplies. A large portion of the Valley Fire burn area (approximately 80 percent) drains into Putah Creek, which ultimately drains to Lake Berryessa, which is utilized as a municipal water supply. Other portions of the may burn area drain to other domestic water supplies. **The PFWERT did not evaluate impacts to water supplies, but it is anticipated that this will occur during the Phase II effort.** It is expected that runoff from the burn area will contain chemical contaminants in addition to ash and fire-related sediment that may pose adverse environmental impacts to the water supply. Additional study of impacts to downstream water supplies should be undertaken. Water supply agencies should be notified of this threat to public health.

10) Western Burn Area/Calpine Area. The PFWERT did not evaluate potential for flooding or debris flow hazards in the Calpine Geothermal area or downstream from the western portion of the burn area. The PFWERT contacted Calpine Senior Engineering Geologist Mark Walters (707 431-6101), who indicated that Calpine would be conducting its own

evaluation. Information from this report, particularly the BARC data and USGS debris flow modeling, should be shared with Calpine. The Division of Oil, Gas, and Geothermal Resources (DOGGR) performed a preliminary evaluation of the Calpine facilities. For convenience, the DOGGR report is included as Appendix D.

A search of the well sites (http://maps.conservation.ca.gov/doggr/#close) within the Calpine geothermal field that is within the Valley burn area indicates that approximately 8 wells may be located in close proximity or downstream of the modeled debris flow locations. A map showing these locations is shown in Appendix D. Calpine engineers and geologists should evaluate these locations with regard to development of protective measures, including diversion or deflection walls.

11) Highways 175 and 29/ Caltrans. The PFWERT did not evaluate the potential for flooding or debris flow hazards at all crossings along the highway corridors. The PFWERT contacted Caltrans Engineering Geologist Charlie Norwold (707 498-1631), who indicated that Caltrans would be conducting its own evaluation. Information from this report, including the BARC data, USGS debris flow modeling, and GeoWEPP erosion modeling should be shared with Caltrans.

12) LiDAR. We understand that FEMA is in the process of acquiring LiDAR-based detailed topographic information of the fire area. Once these data become available, they should be transmitted as soon as possible to the relevant response and implementation agencies so that they can be used in their more detailed plans, evaluations, and designs.

VIII. Specific Observations

Specific observations are summarized in the attached spread sheet (Appendix B). The observations are intended to be used as a preliminary indication of some of the most obvious areas of potential concern for follow-up work and more detailed evaluations. Most of the specific observations are reported as points, however seven areas of potential flooding or debris flow depositions are reported as polygons. Overall, 107 specific values at risk were identified, including 53 homes, 26 bridges, 12 culverts, and 16 miscellaneous structures (e.g., campgrounds, water treatment facilities, businesses). Key areas are Anderson Springs, Cobb Valley, Ettawa Springs, Middletown, and Hidden Valley.

The objective of this report is to present observations made during a limited and general evaluation of downstream areas in a position that could be affected by flooding and/or debris flows generated from basins burned by the 2015 Valley Fire. **The observations are not intended to be comprehensive and conclusive**, but rather to serve as a preliminary tool to assist emergency response agencies (for example CAL FIRE, Lake County, Caltrans, Office of Emergency Services, Natural Resource Conservation Service, utility companies, and other responsible agencies) in development of more detailed post-fire emergency response plans. **This report does not provide emergency response plans**. **It is intended that the emergency response agencies will use the information presented in this report as a preliminary guide to complete their own more detailed evaluations and develop detailed emergency response plans and measures.**

IX. Emergency Response Planning

Several agencies control infrastructure that is listed or discussed in this report. It is intended that the information in this report be relayed to all responsible agencies. **The agencies that produced this report do not assume the responsibility of relaying this information. It is incumbent on representatives of Lake County to determine who the responsible agencies are and how to notify them.** Possible responsible agencies may consist of:

- CAL FIRE
- Various Lake County, Sonoma County, and Napa County Departments (fire, enforcement, roads, engineering, Air Quality Management District)
- Caltrans
- FEMA
- Office of Emergency Services
- Calpine
- Hidden Valley Lake Homeowners Association
- Natural Resource Conservation Service
- Utility companies, and water supply companies and municipalities

The Natural Resources Conservation Service (NRCS) is an agency that can provide funding for emergency watershed restoration. They may be contacted through the following links:

http://www.nrcs.usda.gov/wps/portal/nrcs/main/ca/programs/financial/ewp/

http://offices.sc.egov.usda.gov/locator/app?service=page/CountyMap&state=CA2&stateName=Southern%20California&stateCode=06

Emergency-response and public-safety agencies are often faced with making decisions and deploying resources both well in advance of each coming winter storm and during storms themselves. Information and methodology critical to this process is provided by the USGS in Open File Report OF10-1039 that can be accessed at:
http://pubs.usgs.gov/of/2010/1039/pdf/OF10-1039.pdf

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Appendices

Appendix A - BARC Verification Spreadsheet

Valley Fire BARC Map Field Verification

Datum: NAD 83

Site Number	Date	BARC Map Classification	GPS location		Ground Cover %	Surface Color	Ash Depth (mm)	Soil Water Repellancy				Site Description					
			Latitude (N)	Longitude (W)				Test type	Surface Repellancy Time	Surface Repellancy (% positive repellant tests)	Subsurface Repellancy (Depth, % positive repellant layer, time)	Slope (%)	Surface Rock %	Veg Type	Pre-Fire Veg Density	Observed Soil Burn Severity Class	Comments
AB-1	10/2/2015	Moderate	38.82566	-122.69745	20-50	Black	2	WD	>40	Not Recorded	0.5-1 in	0-10	30	Forest	High	Moderate	Boggs Mtn DSF training
AB-2	10/2/2015	High	38.82465	-122.69836	<20	Black	2	WD	>40	100	Not Found	0-10	30	Forest	High	High	Boggs Mtn DSF training
AB-3	10/2/2015	Moderate	38.82467	-122.69951	20-50	Black	2	WD	>40	100	Not Found	0-10	30	Forest	High	Moderate	Boggs Mtn DSF training
AB-4	10/2/2015	Unburned	38.82901	-122.69779	100	Litter	100	WD	Not Recorded	Variable Repellency	Variable at depth	0-10	Unknown	Forest	High	Unburned	Boggs Campground
B-1	10/2/2015	Moderate	38.84208	-122.69523	20-50	Black	2	WD	>40	75	33 to 50% >40 sec	Missing	30	Forest	High	Moderate	Needle cast
B-2	10/2/2015	High	38.83447	-122.6826	<20	Black	1	WD	>40	25-100	Variable at depth, generally <10 sec	35	30-40	Forest	High	High	No needle cast
B-3	10/2/2015	High	38.79478	-122.52455	<20	Black	1	WD	>40	50-75	Generally <40 sec at 1/2 to 1 inch depth	<10	50	Chaparral	High	High	Very rocky; highly variable not wettable conditions
B-4	10/2/2015	Moderate	38.78625	-122.52205	<20	Black	1	WD	>40	30-100	<10 sec at depth	10	40-50	Chaparral	High	Moderate	Looks similar to high but less hydrophobic and thin ash layer
B-5	10/2/2015	Moderate	38.81994	-122.60018	<20	Black	1	WD	>40	75-100	Generally not repellent at depth	10	Not recorded	Oak Grass Woodland	Low	Moderate	Little cover before the Valley Fire
B-6	10/2/2015	High	38.83375	-122.61762	<20	White and Black	1	WD	>40	50-75	Generally not repellent at depth	30	15	Chaparral	High	High	Only chaparral stobs remaining
B-7	10/3/2015	High	38.8869	-122.68212	<20	White and Black	12	WD	>40	67-100	90-100% repellent >40 sec	<10	Not recorded	Oak Woodland	High	High	Mix of oak species near PG&E line
B-8	10/3/2015	High	38.88926	-122.6717	<20	White and Black	6	WD	>40	67-100	Subsurface <10 sec	10	10	Chaparral	High	High	Manzanita and Chamise; hard soil
B-9	10/3/2015	High	38.86241	-122.65361	<20	Black	2	WD	>40	100	100% <10 sec	25	30	Chaparral	High	High	Only chaparral stobs remaining
B-10	10/3/2015	High	38.81511	-122.6339	<20	Black	1	WD	>40	100	100% < 40 sec	20	10	Chaparral	High	High	Mixed chaparral and pine
B-11	10/3/2015	High	38.81112	-122.66596	<20	Black	1	WD	>40	20-75	10% >40 sec	20	20	Chaparral	Moderate	High	Only chaparral stobs remaining
A-1	10/2/2015	High	38.8052	-122.7036	<20	Black	2	WD	>40	50	Subsurface <10 sec	Not Recorded	Not recorded	not recorded	not recorded	High	
A-2	10/2/2015	High	38..7802	-122.7036	<20	Black	2	WD	>40	100	100% <40sec	Not Recorded	Not recorded	not recorded	not recorded	High	small patchers of burn and grass resprouting
A-3	10/2/2015	High	38.7672	-122.6641	<20	Black	1	WD	>40	33	Variable at depth, generally <10 sec	not Recorded	not recorded	not recorded	low	High	Very shallow soils, likely little no veg pre fire
A-4	10/2/2015	High	38.7696	-1,226,920	<5	.Black	1	WD	>40	67	.variable	Not Recorded	Not recorded	not recorded	not recorded	High	
A-5	10/2/2015	High	38.7822	-122.7188	>2.0.	Black	2	WD	>40	100	.>40 to sub surface	Not Recorded	Not recorded	not recorded	not recorded	High	
A-6	10/2/2015	High	38..7937	-122.7423	>10	Black	2	WD	>40	100	near surface	Not Recorded	Not recorded	not recorded	not recorded	High	
A-7	10/2/2015	High	38.7426	-122.6117	>10	Black	1	WD	>40	100	near surface	Not Recorded	Not recorded	not recorded	not recorded	High	
A-8	10/2/2015	High	38.7086	-122.468	>10	not recorded	2	WD	>40	100	near surface	Not Recorded	Not recorded	not recorded	not recorded	High	dry ravel observed on slopes above
A-9	10/3/2015	High	38.7873	-122.5778	>10	not recorded	1	WD	>40	100	near surface	Not Recorded	Not recorded	Chaparral	high	High	
A-10	10/3/2015	High	38.7851	-122.5806	>10	Black	2	WD	>40	100	near surface	Not Recorded	Not recorded	Chaparral	High	High	
A-11	10/3/2015	High	38.7853	-122.5055	>10	Black	1	WD	>40	100	near surface	Not Recorded	Not recorded	Chaparral	High	High	
A-12	10/3/2015	Moderate	38.7822	-122.5648	none	Black	1	WD	10 to 40	100	not recorded	Not Recorded	Not recorded	Grassland	low	Moderate	Pasture
A-13	10/3/2015	High	38.7075	-122.5003	>10	Black	1	WD	>40	100	near surface	Not Recorded	Not recorded	Forest/Chaparral	high	High	Mixed Forest

Appendix B - Specific Observation/Values at Risk Map

Burn Site Evaluation Summary
Fire Name : 2015 Valley Fire, Lake County, CA
Datum: NAD83

* H = High; M = Moderate; L = Low; 0 = Not located on an identified stream segment
(Upstream basins and tributaries with identified hazards noted)

Site#	Community	At-risk Feature	Category	General Street Address	GPS location Latitude N	Longitude W	Hazard/Field Observations	Located in FEMA 100Y Flood Zone?	USGS Debris Flow Hazard Results for Adjacent Stream Segment or Nearby/Upstream Basin(s) (100y)*	Likelihood	Potential Risk to life	Potential risk to property	Responsible Agency?	Preliminary or Possible Emergency Protective Measures
102	Anderson Springs	Bridge	Bridge	Foard Road Bridge at Anderson Creek	38.77438	-122.68942	Bridge and attached domestic water pipeline with ~9' clearance and center pier plugging, washing out bridge and threatening nearby homes. Note undercut left abutment (looking downstream; originally slated for replacement by county.	Y	0 (Upstream Basin = H)	H	L	H	Lake County	Early-warning system;storm patrol
106	Anderson Springs	Bridge	Bridge	Van Dorn Reservoir Rd Bridge at Anderson Cr	38.77623	-122.70312	Bridge has good clearance and no center pier, but large boulders instream above bridge suggest large debris flows have passed down Anderson Creek historically.	Y	Upstream Basin = H	H	L	H	Lake County	Early-warning system;storm patrol
110	Anderson Springs	Bridge	Bridge	Anderson Springs Rd Bridge at Anderson Cr (near #11611)	38.77432	-122.69274	Debris impact, dam	Y	0 (Upstream Basin = H)	H	L	H	Lake County	Early-warning system;storm patrol
100	Anderson Springs	Single family dwelling	Home	Anderson Springs Road	38.77456	-122.69003	Debris-laden flooding or debris flow down Anderson Creek rising to an elevation that will impact the home.	Y?	0 (Upstream Basin = H)	H	M	H	Lake County	Early warning
101	Anderson Springs	Single family dwelling	Home	Foard Rd	38.77462	-122.68904	Debris-laden flooding or debris flow down Anderson and Bear Canyon Creeks rising to an elevation that will impact the home.	Y?	0 (Upstream Basin = H)	H	H	H	Lake County	Early warning
105	Anderson Springs	Single family dwelling	Home	Van Dorn Reservoir Rd	38.776	-122.703	Overflows from 24" plugged culvert draining steep small drainage and from road spreading across road and into home. Plugged culvert could also wash out private access drive to #11010 Van Dorn Reservoir Rd	N	L	H	L	M	Lake County	Diversion along edge of road and across driveway. Clear and monitor culvert inlet
107	Anderson Springs	Single family dwelling	Home	Anderson Springs Rd	38.77684	-122.68563	Debris from steep tributary plugging 24" culvert beneath Anderson Springs road, forcing overflow onto downslope property. Note shotgun culvert and 6-ft headcut in gully above road	N	M	M	M	M	Lake County	Early warning system; Diversion near house. Clear landscape materials from lower channel.
111	Anderson Springs	Single family dwelling	Home	Anderson Springs Rd	38.77813	-122.68079	Flooding to home; near Anderson Cr confluence with Putah Cr	Y	0 (Upstream tribs = M)	H	H	H	Lake County	Early warning; storm patrol
103	Anderson Springs	Burned out septic tank	Misc	Foard Road	38.77424	-122.69003	Burned out septic tank with waste is a safety hazard and could impact Anderson Creek water quality	Y	Upstream Basin = H	H	L	L	Lake County	
104	Anderson Springs	Public recreation facility	Misc	Rose Anderson Rd (Homeowners Assoc. Pools)	38.77469	-122.69970	Debris flow down Anderson Creek filling in pools, damaging gazebo, and washing out walkway bridge	Y	Upstream Basin = H	H	H	H	Lake County / HOA	Seasonal closure. Signage Early warning
540	Big Canyon (Ettawa Springs to Putah)	Bridge	Bridge	Big Canyon Rd Bridge at Big Canyon Cr (near #14220)	38.84961	-122.67442	Debris flow may cause damage to existing structure	N	0 (Upstream trib = H)	M	L	L		Early-warning system;storm patrol
542	Big Canyon (Ettawa Springs to Putah)	Bridge	Bridge	Private driveway access to #14315 at Big Canyon Cr	38.84895	-122.66862	Debris flow	N	0 (Upstream trib = M)	M	L	L		Early-warning system;storm patrol
545	Big Canyon (Ettawa Springs to Putah)	Bridge	Bridge	Big Canyon Cr Rd Bridge at Big Canyon Cr (near #14410)	38.84619	-122.66416	Flooding; minor debris observed in steel beams. Debris flow potential from tributary leading to bridge inlet	N	0 (Upstream tribs = M & H)	H	L	L		Early-warning system;storm patrol
546	Big Canyon (Ettawa Springs to Putah)	Bridge	Bridge	Big Canyon Rd Bridge at Big Canyon Cr (near #14490)	38.84511	-122.65937	Flooding	N	0 (Upstream trib = M)	M	L	L		Early-warning system;storm patrol
555	Big Canyon (Ettawa Springs to Putah)	Bridge	Bridge	Big Canyon Road bridge across Malo Creek (near #15622)	38.83173	-122.64526	Debris flow	N	M	H	L	M		Early-warning system;storm patrol
556	Big Canyon (Ettawa Springs to Putah)	Bridge	Bridge	Big Canyon Rd across unnamed tributary (near #16412)	38.82377	-122.63148	Debris flow	N	M	H	L	H		Early-warning system;storm patrol
543	Big Canyon (Ettawa Springs to Putah)	3-pipe culvert	Culvert	Bad Cr through Big Canyon Rd (near #14380)	38.84885	-122.66627	Debris flow plugging	N	M	M	L	M		Early-warning system;storm patrol

PRELIMINARY DATA
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Dimensions are estimated.

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557	Big Canyon (Ettawa Springs to Putah)	Culvert	Culvert	Unnamed tributary through Big Canyon Rd near confluence with Putah	38.80665	-122.61617	Debris flow. Double-barrel culverts (~30" and 24"). Evidence of previous overtopping	Y	M	M	L	M		Early-warning system;storm patrol
520	Big Canyon (Ettawa Springs to Putah)	Single family dwelling	Home	Ettawa Springs Rd (per parcel layer)	38.85015	-122.69913	Flooding (confluence of Mill and Big Canyon). Burned out access bridge	N	M	L	M	M		Early warning
521	Big Canyon (Ettawa Springs to Putah)	Single family dwelling	Home	Ettawa Springs Rd (per parcel layer)	38.85089	-122.69658	Flooding and debris flow down Big Canyon (downstream of Mill Cr). Burned out access bridge	N	L	M	H	H		Early warning
522	Big Canyon (Ettawa Springs to Putah)	Single family dwelling	Home	Ettawa Springs Rd	38.85122	-122.69420	Flooding and debris flow	N	L	M	M	H		Early warning
537	Big Canyon (Ettawa Springs to Putah)	Home, buildings, bridge	Home	Big Canyon (Big Canyon Rd)	38.8521	-122.68395	Debris flow and flooding to home, bridge, and structures	N	L	M	M	M		Early warning; storm patrol
538	Big Canyon (Ettawa Springs to Putah)	Single family dwelling	Home	Big Canyon Rd	38.8491	-122.67421	Debris flow and flooding; home on bank. Burned out access bridge	N	0 (Upstream trib = H)	H	H	H		Early warning
539	Big Canyon (Ettawa Springs to Putah)	Single family dwelling	Home	Big Canyon Rd	38.84953	-122.67482	Debris flow and flooding; home on bank	N	0 (Upstream trib = M)	H	H	H		Early warning. Possible diversion structures
541	Big Canyon (Ettawa Springs to Putah)	2 single family dwellings	Home	Big Canyon Rd	38.84871	-122.66909	Debris flow and flooding	N	0 (Upstream trib = M)	H	H	H		Early warning
544	Big Canyon (Ettawa Springs to Putah)	Single family dwelling	Home	Big Canyon Rd	38.84929	-122.66646	Debris flow	N	M	M	M	M		Early warning
523	Big Canyon (Ettawa Springs to Putah)	Resort cabins	Misc	Ettawa Springs Resort	38.85142	-122.69241	Flooding and debris flow; >4 creekside cabins	N	0 (Upstream tribs = L)	M	H	H		Early warning
560	Big Canyon (Ettawa Springs to Putah)	2 unknown structures	Misc	Big Canyon Cr Rd	38.84851	-122.66692	Mapped structure close to Big Canyon Cr at base of tributary with identified debris flow hazard. Structures identified in Google Earth-probable outbuildings.	N	H	H	?	H		
139	Butts Canyon	Culvert	Culvert	Unnamed tributary through Butts Canyon Rd , ~400' south of Napa County line	38.70519	-122.46407	Debris flow hazard (100y modelling)	N	M	M	L	M	Napa County	Storm patrol
140	Butts Canyon	Culvert	Culvert	Butts Canyon Cr through Butts Canyon Rd , downslope from mapped pond on #23351	38.71024	-122.47591	12-foot diameter. Debris flow/Med debris flow hazard (100y). Alignment askew to channel	N	M	M	L	M		Storm patrol
141	Butts Canyon	Culvert	Culvert	Unnamed tributary through Butts Canyon Rd near #22725	38.71401	-122.48257	36" culvert covered with 60' of fill. Inlet below watercourse level; high potential for plugging. Med debris flow hazard (100y)	N	M	M	L	M	Lake County	Remove colluvial deposits from ~20' of the channel upstream from the inlet. Install flared metal inlet or culvert riser. Storm patrol
142	Butts Canyon	Culverts	Culvert	Confluence of two Butts Canyon Cr headwater tributaries through Butts Canyon Rd near #22880	38.7178	-122.49262	Two 48-inch culverts; alignment askew to channel. Plugging/Moderate debris flow hazard. Outlet almost completely plugged	N	M	M	L	M	Lake County	Remove debris and sediment that is plugging the inlet; lay back grade. Storm patrol. [Accessible by back-hoe]
143	Butts Canyon	Culvert	Culvert	Butts Canyon Cr. Headwater tributary through Butts Canyon Rd near #22110	38.71824	-122.49591	48" culvert. Debris flow hazard. Alignment askew to channel.	N	L	M	L	M	Lake County	Fence at outlet. Maintenance

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126	Gallagher Cr/ Hidden Valley	Bridge	Bridge	Hartmann Rd Bridge at Gallagher Cr (near #19456)	38.80014	-122.54394	Debris blocking channel at bridge and overtopping road; note center pier, vegetation in channel from upstream to ~100' downstream reducing capacity	Y	0 (Upstream basin = M)	H	L	M		Channel clearance. Early-warning system; storm patrol.
130	Gallagher Cr/ Hidden Valley	Culvert beneath paved public road	Culvert	Gallagher Cr throuugh Stinson Rd near # 19780	38.80104	-122.54195	Three 60" culverts (one blocked on upstream end by ~18" dia oak) at risk of blocking and overtopping. Landowner reports previous blocking/overtopping incident, which sent water to barn. Culverts receive water from slopes behind house and adjacent parcels, as well as from Gallagher Cr (ref #131)	N	M	H	L	M	HVLCSD or Lake County	Remove large oak at culvert inlet. Early-warning system;storm patrol
134	Gallagher Cr/ Hidden Valley	Culvert	Culvert	Unnamed drainage through Sandy Rd near Dallas Ct	38.80605	-122.55147	Debris flow blocking 48" culvert and overtopping	N	L	M	L	L	HVLCSD or Lake County	Storm patrol
128	Gallagher Cr/ Hidden Valley	Culvert and single family dwelling	Home	Hartmann Rd	38.80014	-122.54394	Gallagher Cr passes under private drive through 3 culverts (~36"-48") that are at risk of blocking/overtopping. Base of home is <5' above shallow section of channel invert downstream of culverts. Note veg/trees in channel that reduce capacity	N	M	H	M	H	HVLCSD or Lake County	Early warning. Possible diversion structures.
129	Gallagher Cr/ Hidden Valley	2 single family dwellings	Home	Hartmann Rd	38.80037	-122.54012	Flooding and debris flow from Gallagher Cr	N	M	H	M	H	HVLCSD or Lake County	Early warning
131	Gallagher Cr/ Hidden Valley	Single family dwelling	Home	Stinson Rd	38.80197	-122.54121	Runoff and sediment from burned slope behind home and adjacent parcel. Landowner reports runoff/ponding occurs annually but doesn't reach house. Maintains a small gravelled interceptor ditch above home. Runoff ultimately drains towards culverts across Gallagher Cr (ref #130)	N	0	H	L	M	Lake County (not a member of HV HOA)	Possible diversions
132	Gallagher Cr/ Hidden Valley	Single family dwelling	Home	Stinson Rd	38.80172	-122.54339	Runoff and sediment from slope behind home	N	0	L	L	L	HVLCSD or Lake County	Early warning
133	Gallagher Cr/ Hidden Valley	Single family dwelling	Home	Stinson Rd	38.80201	-122.54454	Debris flow potential	N	L	L	L	M	HVLCSD or Lake County	
127	Gallagher Cr/ Hidden Valley	Campground	Misc	Hidden Valley Lake Campground on Hartmann Rd	38.79904	-122.55145	Debris and flooding from Gallagher Cr into campground (USGS=moderate hazard). Tent sites 1-12 are streamside. Gallagher Cr capacity is reduced due to in-channel vegetation along entire length of campground. Rec. clearing channel	N	0	M	H	H	Hidden Valley Lake Association	Seasonal closure. Signage. Early warning
116	Harbin Creek/Springs	Bridge	Bridge	Big Canyon Road bridge across Harbin Creek (near #19682 Big Canyon Rd)	38.77676	-122.61748	Flooding and debris flow; gate blocks outlet. Bridge is low; could be a choke point. X-sec ~7' x 20'	N	M	M	L	L	Lake County	Remove fence that is suspended from bridge. Early-warning system; storm patrol.
559	Harbin Creek/Springs	Culvert	Culvert	Big Canyon Rd	38.78092	-122.61427	Debris flow. Box culvert 5' high x 4' wide; fencing on outlet	N	M	M	L	H		Remove fence from outlet. Early-warning system;storm patrol
114	Harbin Creek/Springs	Water tank and treatment facility	Misc	Harbin Springs Rd (Heart Consciousness Church)	38.79453	-122.66614	Debris flow	N	M	L	L	H	Harbin	Diversion measures. Early warning
115	Harbin Creek/Springs	Recreation facility (tent cabin, pools, rental units)	Misc	Harbin Springs Rd (Heart Consciousness Church)	38.79110	-122.65312	Debris flow	N	0 (flanking trib = M)	M	M	H	Harbin	Seasonal closure. Signage. Early warning
505	Kelsey Cr (Cobb Valley to Whispering Pines)	2 single family dwellings	Home	Parnassus Dr	38.80953	-122.71228	Flooding and debris; homes located within swale	N	0 (Upstream basin = M)	L	L	M		Early warning
506	Kelsey Cr (Cobb Valley to Whispering Pines)	2 Single family dwelling2	Home	Maple Shadows	38.81098	-122.71249	Debris flow and flooding. Home directly adjacent to watercourse	N	M	M	M	M		Early warning

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507	Kelsey Cr (Cobb Valley to Whispering Pines)	Single family dwelling	Home	17339 Maple Shadows	38.81086	-122.71020	Debris flow. Home directly adjacent to watercourse	N	0 (Upstream basin = M)	M	M	M		Early warning
509	Kelsey Cr (Cobb Valley to Whispering Pines)	Single family dwellilng and private bridge	Home	16440 Cobb Blvd	38.82199	-122.71492	Jones Cr flooding; overtopping towards home.	N	0	M	L	L		Early warning
511	Kelsey Cr (Cobb Valley to Whispering Pines)	Multiple single family dwellings	Home	Twin Oaks Dr	38.82172	-122.71304	Jones Cr flooding; overtopping towards home.	N	0 (Upstream basin = M)	M	L	M		Early warning
512	Kelsey Cr (Cobb Valley to Whispering Pines)	Multiple single family dwellings	Home	Reed Road (Reed Rd polygon)	38.82077	-122.72399	Debris flow risk from steep (45-50%) slopes to downslope neighborhood, located on alluvial fan (Donation center at 16340 High Rd)	N	L	M	M	M		Early warning
514	Kelsey Cr (Cobb Valley to Whispering Pines)	>1 single family dwellings	Home	Bottle Rock Rd	38.82421	-122.72352	Homes on both sides of Kelsey Cr at risk of flooding along ~1,500' downstream from property	Y	0 (Upstream tribs = L/M)	M	M	M		Early warning
515	Kelsey Cr (Cobb Valley to Whispering Pines)	2 single family dwellings (2 waypoints)	Home	Rainbow Dr	38.82742	-122.72665	Two homes near floodplain	N	0 (Upstream trib = M)	M	M	M		Early warning. Possible diversion structures.
563	Kelsey Cr (Cobb Valley to Whispering Pines)	2 single family dwellings	Home	Maple Shadows and neighbor (adjacent to Bay Leaf intersection)	38.81025	-122.71142	Debris flow and flooding	N	0 (Upstream basin = M)	M	M	M		Early warning
564	Kelsey Cr (Cobb Valley to Whispering Pines)	Single family dwelling	Home	Hwy 175	38.81023	-122.71013	Debris flow and flooding; culvert drains tributary and passes beneath house	N	0 (Upstream basin = M)	M	M	M		Early warning
135	Kelsey Cr (Cobb Valley to Whispering Pines)	Campground	Misc	Yogi Bear's Jellystone Park Cobb Mtn	38.85387	-122.75888	Flooding and debris flow impact to campground; low-lying sites include P-17, P-3, P-4	N	0	H	H	H	Lake County	Early warning system; warning signs advising to stay away from channel; close facility during large storms
136	Kelsey Cr (Cobb Valley to Whispering Pines)	Campground, cabins	Misc	Pine Grove Resort (15960 Bottle Rock Rd)	38.83104	-122.72789	Flooding and debris flows may be risk to resort and structures: cabin units 1-5. Built in 1923. Pool on outside edge of meander. Eastern edge in FEMA floodplain	Y	0 (Upstream tribs = L/M)	H	H	H		Seasonal closure. Signage. Early warning
508	Kelsey Cr (Cobb Valley to Whispering Pines)	Recreation hall & outdoor chapel	Misc	16671 Forest Lake Dr	38.81702	-122.71568	Buildings directly adjacent to Kelsey Cr.	N	0 (Upstream basin = L)	M	L	M		Diversion measures. Early warning
510	Kelsey Cr (Cobb Valley to Whispering Pines)	Clubhouse and golf course	Misc	Golf Rd (multiple homes on parcel)	38.82201	-122.71598	Flooding of clubhouse/restaurant on Jones Cr.	N	0	M	L	M		Diversion measures. Early warning
513	Kelsey Cr (Cobb Valley to Whispering Pines)	Business' and homes; bridge	Misc	Cobb Village Center (Hwy 175), Pub, Resort cabins	38.82403	-122.72139	Flooding along Kelsey Cr; overtopping of bridge on Hwy 175	Y	0 (Upstream basin = L)	M	M	M		Diversion measures. Early warning
562	Kelsey Cr (Cobb Valley to Whispering Pines)	Instream and patio area	Misc	Maple Shadows	38.81114	-122.7137	Debris flow and flooding	N	0 (Upstream basin = M)	M	M	H		Early warning
120	Middletown/Long Valley	Bridge	Bridge	St Helena Cr bridge (constructed in 1908)	38.75372	-122.61069	Flooding	Y	0 (Upstream trib = M)	H	L	M	Lake County	Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
117	Middletown/Long Valley	Multiple single family dwellings	Home	Santa Barbara to Napa Streets (Polygon west of Middletown)	38.76307	-122.62952	Flooding to be exascerbated.	Y	0 (Upstream trib = M)	H	M	H	Lake County (Middletown?)	Early warning

PRELIMINARY DATA
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Dimensions are estimated.

Burn Site Evaluation Summary
Fire Name : 2015 Valley Fire, Lake County, CA
Datum: NAD83

* H = High; M = Moderate; L = Low; 0 = Not located on an identified stream segment
(Upstream basins and tributaries with identified hazards noted)

Site#	Community	At-risk Feature	Category	General Street Address	GPS location Latitude N	Longitude W	Hazard/Field Observations	Located in FEMA 100Y Flood Zone?	USGS Debris Flow Hazard Results for Adjacent Stream Segment or Nearby/Upstream Basin(s) (100y)*	Likelihood	Potential Risk to life	Potential risk to property	Responsible Agency?	Preliminary or Possible Emergency Protective Measures
119	Middletown/Long Valley	Multiple single family dwellings	Home	Main St in Middletown	38.25062	-122.61407	Flooding	N	0 (flanking trib = M)	H	M	H	Lake County	Early warning
121	Middletown/Long Valley	Single family dwelling	Home	Hwy 29 (St Helena Lane)	38.76261	-122.60133	Flooding to house	Y	0	H	L	H	Lake County	Early warning
122	Middletown/Long Valley	Single family dwelling	Home	Hwy 29	38.7581	-122.60319	Flooding to house	Y	0	H	L	H	Lake County	Early warning
137	Middletown/Long Valley	Multiple single family dwellings	Home	Loconomi (Long Valley polygon)	38.74824	-122.57774	Flooding	Y	0 (Upstream basin = M)	H	L	H	Lake County	Early warning
123	Putah -Coyote Valley	Single family dwelling	Home	S. State Hwy 29	38.79333	-122.56658	Flooding to house	Y	0 (Upstream trib = M)	H	L	H	Lake County	Early warning
124	Putah -Coyote Valley	4 single family dwellings and 3 business'	Home	Spruce Road Extension. Businesses: Vallauris Body Shop, Auto Body; Amerigas Propane Storage on Spruce Rd (2 waypoints id upper->lower end of road)	38.7985	-122.57366	Flooding along Putah Cr. Located in FEMA 100y flood zone. *One point of 2 defining extent of homes*	Y	0 (flanking trib = M)	H	L	H	Lake County (Middletown?)	Early warning
124	Putah -Coyote Valley	4 single family dwellings and 3 business'	Home	Spruce Road Extension. Businesses: Vallauris Body Shop, Auto Body; Amerigas Propane Storage on Spruce Rd (2 waypoints id upper->lower end of road)	38.79516	-122.56831	Flooding along Putah Cr. Located in FEMA 100y flood zone. *One point of 2 defining extent of homes*	Y	0 (Upstream trib = M)	H	L	H	Lake County (Middletown?)	Early warning
125	Putah -Coyote Valley	Pump Station	Misc	Last house at end of levee on Gold Flat Ct	38.78448	-122.54229	Pump used to drain subdivision runoff from behind levee into Putah Cr. burned and is inoperable; increased risk of flooding of homes	Y	0	H	L	H	Hidden Valley Lake Community Services District	Replace pump. Stage emergency backup
146	Putah -Hidden Valley	218 single family dwellings	Home	(Hidden Valley polygon) Homes on Gold Flat Ct, Oak Flat, Mountain Meadow, Horseshoe, Gooselake, Glencove Ct, Magnolia Ct, Dove Ct, Old Creek , Maple Leaf, Fairway Pt, Powder Horn Rd	38.78463	-122.53917	Flood hazard- Putah Creek flows overtopping subdivision levee	Y	0	M	M	H	Lake County	Levee protection. Early warning
517	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Seigler Canyon Rd Bridge across Seigler Canyon Cr (near #13940)	38.89533	-122.65088	High burn severity upslope may increase flooding and debris risk, compromising an already compromised bridge	N	0	M	L	M		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
518	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Private bridge	Bridge	13750 Seigler Canyon Rd (13850 per parcel layer)	38.89415	-122.65332	High burn severity upslope may increase flooding and debris risk, compromising an already compromised bridge	N	0 (Upstream tribs = L-M)	M	L	M		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
519	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Seigler Canyon Rd Bridge across Seigler Canyon Cr (near #12610)	38.87958	-122.67556	Plugging/overtopping of bridge on main road	N	0 (Upstream basin = L)	M	L	L		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
524	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Private road bridge at Harris Cr near #14641 Hwy 29	38.84562	-122.60915	Debris flow and flooding at bridge and Hwy 29	N	M	M	L	M		Early-warning system;storm patrol
525	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge and barn	Bridge	Private road bridge at Harris Cr near #14331 Hwy 29	38.84745	-122.61152	Debris flow and flooding at bridge and Hwy 29	N	M	M	L	M		Early-warning system;storm patrol

PRELIMINARY DATA
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Burn Site Evaluation Summary
Fire Name : 2015 Valley Fire, Lake County, CA
Datum: NAD83

* H = High; M = Moderate; L = Low; 0 = Not located on an identified stream segment
(Upstream basins and tributaries with identified hazards noted)

Site#	Community	At-risk Feature	Category	General Street Address	GPS location Latitude N	Longitude W	Hazard/Field Observations	Located in FEMA 100Y Flood Zone?	USGS Debris Flow Hazard Results for Adjacent Stream Segment or Nearby/Upstream Basin(s) (100y)*	Likelihood	Potential Risk to life	Potential risk to property	Responsible Agency?	Preliminary or Possible Emergency Protective Measures
526	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Private road bridge at private road near #14721 Hwy 29	38.84131	-122.61196	Debris flow and flooding at bridge and Hwy 29	N	M	M	L	M		Early-warning system;storm patrol
530	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge w/ center pier	Bridge	Riata Rd Bridge at Copsey Cr near #11978 Riata	38.8828	-122.60618	Flooding and accumulation of debris	Y	0 (Upstream basin = M)	M	L	M		Early-warning system;storm patrol
532	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Perini Rd Bridge at Seigler Canyon Creek (near confluence with Perini Cr)	38.90324	-122.63936	Plugging of debris and flooding of bridge; evidence of past flooding	N	0	H	L	L		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
536	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Siegler Canyon Rd Bridge at Seigler Canyon Cr (near #10850)	38.89875	-122.64356	Flooding and accumulation of debris; ~4' clearance	N	0 (Upstream tribs = L-M)	M	L	M		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
550	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Jesse St bridge at Seigler Canyon	38.91372	-122.61006	Flooding. Bridge with 2 midspan piers	Y	0	M	L	L		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
554	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Bridge	Bridge	Copsey Cr. Way Bridge at Copsey Cr.	38.91424	-122.59355	Flooding	Y	0	L	L	L		Vegetation clearance- 200' upstream and downstream of bridge. Early-warning system;storm patrol
527	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	2+ single family dwellings	Home	Big Canyon; Agua Dulce	38.85837	-122.62817	Debris flow and flooding to two homes along Copsey Cr. Located at confluence with Sweet Springs Cr	N	M	M	M	M		Early warning
528	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	House and winery	Home	Hwy 29	38.86505	-122.62446	Flooding to winery, tasting room, and house	Y	0 (Upstream basin = M)	M	M	M		Early warning
529	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	House and structures	Home	Hwy 29	38.88235	-122.60846	Unknown flood hazard to multiple structures	Y	0 (Upstream basin = M)	M	M	M		Early warning
531	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Mobile home and house	Home	Ellen Springs Ct	38.8943	-122.59821	Flood hazard- mobile home located in FEMA 100y flood zone	Y	0	M	L	L		Early warning
534	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Mobile home	Home	Downstream of Bell Park Bridge across Seigler	38.90919	-122.61626	Flooding posing risk to bank and mobile home. Possible other structures along Seigler Canyon Cr.	Y	0	M	L	M		Channel clearance. Early-warning
535	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Single family dwellings (>1?)	Home	Morgan Valley Rd	38.90805	-122.595	Flooding of homes downstream of arch culvert	Y	0	M	M	H		Early warning
547	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Multiple single family dwellings	Home	Lower Lake near Seigler Canyon and Cache Creeks (547 polygon)	38.92499	-122.6089	Flooding	Y	0	M	M	H	Lake County	Early warning
548	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	4-6 single family dweliings and structures	Home	End of Cache Cr Lane	38.92044	-122.59792	Flooding	Y	0	M	M	H	Lake County	Early warning
549	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	4-6 single family dwellings and structures	Home	End of Dam Rd @ confluence of Copsey and Cache Creeks	38.9226	-122.5953	Flooding	Y	0	M	M	H	Lake County	Early warning
551	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Multiple single family dwellings	Home	(Polygon 551) North bank of Cache Cr to Main St, between Hwy 53 and Lake St.	38.91735	-122.6111	Flooding	Y	0	M	L	M	Lake County	Early warning

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Site#	Community	At-risk Feature	Category	General Street Address	GPS location Latitude N	GPS location Longitude W	Hazard/Field Observations	Located in FEMA 100Y Flood Zone?	USGS Debris Flow Hazard Results for Adjacent Stream Segment or Nearby/Upstream Basin(s) (100y)*	Likelihood	Potential Risk to life	Potential risk to property	Responsible Agency?	Preliminary or Possible Emergency Protective Measures
553	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Multiple single family dwellings	Home	End of Quarterhorse Lane	38.92161	-122.59393	Flooding	Y	0	M	M	H	Lake County	Early warning
552	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Multiple single family dwellings	House	(Polygon 552). East side Copsey Cr along Pinto Place, Bronco Lane, and Quarterhorse Lane. West side Copsey Cr near bridge and Stagecoach Lane	38.91648	-122.59528	Flooding: Numerous homes on east side of Copsey Cr. Few homes west side Copsey Cr near bridge. Few homes along Stagecoach	Y	0	M	M	M	Lake County	Early warning
533	Seigler Canyon/Copsey Cr/Lower Lake (Cache)	Unknown structures	Unknown	Seigler Canyon Rd	38.90731	-122.63621	Locked gate: unknown structures along channel may be prone to debris flow and flooding	N	0	?	?	?		
118	Upper Putah (Casa Grande to Collayomi Valley)	Bridge	Bridge	Hwy 175 at Putah Cr	38.77223	-122.66386	Large oak in Putah Cr channel, in area of past flooding	Y	0 (flanking tribs = M)	M	N	L	Caltrans	Buck up oak tree in channel (no need to remove bole)
502	Upper Putah (Casa Grande to Collayomi Valley)	Bridge	Bridge	Casa Grande Lane Bridge across Putah Cr (near #11655)	38.78788	-122.69284	Bridge failure due to plugging from debris as well as legacy piers from previous bridge. Leads to one standing home and two burned residences w/ trailers	N	0 (Upstream trib = H)	L	L	L		Vegetation clearance- 200' upstream and downstream of bridge. Remove legacy piers. Early-warning system;storm patrol
558	Upper Putah (Casa Grande to Collayomi Valley)	Bridge	Bridge	Big Canyon Rd bridge at Cockerell Canyon Cr. (near confluence with Putah)	38.80252	-122.61459	Debris flow. Downstream footings are undermined, not founded on bedrock. Evidence the channel can transport 2-3' boulders. Channel constricted by bridge.	Y	H	H	L	H		Signage. Early-warning system;storm patrol
500	Upper Putah (Casa Grande to Collayomi Valley)	2 Culverts in series	Culvert	Casa Grande	38.78982	-122.68872	Increased flows and debris from #11850 plugging 18" culvert located adjacent to #11755. (ref #501)	N	0 (flanking trib = M)	M	L	L		Storm patrol
504	Upper Putah (Casa Grande to Collayomi Valley)	Culvert	Culvert	Hwy 175 culvert on unnamed drainage near private road (18649 Hwy 175)	38.79133	-122.70031	4-ft culvert. History of plugging and flooding. Reportedly not regularly maintained.	N	M	H	L	M	Caltrans	Storm patrol
112	Upper Putah (Casa Grande to Collayomi Valley)	Single family dwelling	Home	Hwy 175	38.77775	-122.67647	15" plastic culvert next to house (east); outlet melted (inlet okay).	N	0 (Flanking tribs = M)	H	H	H	Lake County	Early warning; storm patrol
113	Upper Putah (Casa Grande to Collayomi Valley)	Single family dwelling, barn	Home	Monte Vista Court	38.77714	-122.66990	Possible debris flow impact to house	N	0 (Flanking tribs = M)	L	L	M	Lake County	Early warning; storm patrol
501	Upper Putah (Casa Grande to Collayomi Valley)	Single family dwelling	House	Casa Grande	38.78431	-122.68903	Flooding (ref #500)	N	0 (Flanking trib = M)	M	L	M		Early warning; storm patrol
503	Upper Putah (Casa Grande to Collayomi Valley)	Wine storage and future home	Misc	State Hwy 175	38.78438	-122.68629	Debris flow: New construction- outbuilding, driveway, instream concrete structure. (No home yet)	N	M	H	M	H		Early warning
561	Upper Putah (Casa Grande to Collayomi Valley)	Business	Misc	State Hwy 175	38.79141	-122.70125	Flooding from unnamed tributary (ref #504)	N	M	H	M	H		Early warning; storm patrol

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Appendix C - Valley Fire HUC 12 Watershed Map and Kelsey Creek Annual Peak Flow Data

1
Program PeakFq U. S. GEOLOGICAL SURVEY Seq.002.000
Version 7.1 Annual peak flow frequency analysis Run Date / Time
3/14/2014 09/22/2015 08:49

--- PROCESSING OPTIONS ---

Plot option = None
Basin char output = None
Print option = Yes
Debug print = No
Input peaks listing = Long
Input peaks format = WATSTORE peak file

Input files used:
peaks (ascii) - C:\Users\pcaffera\Documents\Peak Flow INFO\KELSEY CREEK PEAK.TXT
specifications - C:\Users\pcaffera\Documents\Peak Flow INFO\PKFQWPSF.TMP
Output file(s):
main - C:\Users\pcaffera\Documents\Peak Flow INFO\KELSEY CREEK PEAK.PRT

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.001
Version 7.1 Annual peak flow frequency analysis Run Date / Time
3/14/2014 09/22/2015 08:49

Station - 11449500 KELSEY C NR KELSEYVILLE CA

I N P U T D A T A S U M M A R Y

Number of peaks in record = 68
Peaks not used in analysis = 0
Systematic peaks in analysis = 68
Historic peaks in analysis = 0
Beginning Year = 1947
Ending Year = 2014
Historical Period Length = 0
Generalized skew = -0.278
Standard error = 0.550
Mean Square error = 0.303
Skew option = WEIGHTED
Gage base discharge = 0.0
User supplied high outlier threshold = --
User supplied PILF (LO) criterion = --
Plotting position parameter = 0.00
Type of analysis BULL.17B
PILF (LO) Test Method GBT
Perception Thresholds = Not Applicable
Interval Data = Not Applicable

********* NOTICE -- Preliminary machine computations. *********
********* User responsible for assessment and interpretation. *********

WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE. 0.0
WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED. 1 473.1
WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE. 18913.4

Kendall's Tau Parameters

	TAU	P-VALUE	MEDIAN SLOPE	No. of PEAKS
SYSTEMATIC RECORD	-0.050	0.546	-8.730	68

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.002
Version 7.1 Annual peak flow frequency analysis Run Date / Time
3/14/2014 09/22/2015 08:49

Station - 11449500 KELSEY C NR KELSEYVILLE CA

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE DISCHARGE	EXCEEDANCE PROBABILITY	LOGARITHMIC MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	3.5590	0.3066	-2.331
BULL.17B ESTIMATE	473.1	0.9853	3.5766	0.2463	-0.742

BULL.17B ESTIMATE OF MSE OF AT-SITE SKEW 0.1617

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	<-- FOR BULLETIN 17B ESTIMATES --> VARIANCE OF EST.	95% CONFIDENCE INTERVALS LOWER	UPPER
0.9950	147.3	--	--	--	
0.9900	253.3	--	--	--	
0.9500	1338.	876.4	----	1084.0	1582.0
0.9000	1770.	1477.	----	1487.0	2041.0
0.8000	2416.	2457.	----	2099.0	2730.0
0.6667	3147.	3523.	----	2788.0	3525.0
0.5000	4044.	4618.	----	3611.0	4542.0

0.4292	4453.	5020.	----	3975.0	5022.0
0.2000	6133.	6085.	----	5416.0	7085.0
0.1000	7351.	6426.	----	6416.0	8657.0
0.0400	8693.	6578.	----	7487.0	10450.0
0.0200	9560.	6616.	----	8165.0	11630.0
0.0100	10330.	6631.	----	8758.0	12690.0
0.0050	11010.	6636.	----	9281.0	13650.0
0.0020	11800.	6639.	----	9882.0	14780.0

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.003
Version 7.1 Annual peak flow frequency analysis Run Date / Time
3/14/2014 09/22/2015 08:49

Station - 11449500 KELSEY C NR KELSEYVILLE CA

I N P U T D A T A L I S T I N G

WATER YEAR	PEAK VALUE	PEAKFQ CODES	REMARKS
1947	2940.0		
1948	2110.0		
1949	1570.0		
1950	2450.0		
1951	4560.0		
1952	3820.0		
1953	7040.0		
1954	8150.0		
1955	1940.0		
1956	6800.0		
1957	4580.0		
1958	6380.0		
1959	3350.0		
1960	4370.0		
1961	4210.0		
1962	3250.0		
1963	5150.0		
1964	4280.0		
1965	8020.0		
1966	4490.0		
1967	6600.0		
1968	5840.0		
1969	4140.0		
1970	7270.0		
1971	3400.0		
1972	1790.0		
1973	5520.0		
1974	7270.0		
1975	4070.0		
1976	543.0		
1977	101.0		

1978	4820.0
1979	2000.0
1980	3790.0
1981	4260.0
1982	5520.0
1983	7730.0
1984	4180.0
1985	2850.0
1986	6350.0
1987	2710.0
1988	2660.0
1989	4390.0
1990	3080.0
1991	4730.0
1992	2380.0
1993	4410.0
1994	941.0
1995	8600.0
1996	4610.0
1997	8450.0
1998	5400.0
1999	5100.0
2000	3110.0
2001	2470.0
2002	2490.0
2003	6420.0
2004	6420.0
2005	1440.0
2006	4180.0
2007	1920.0
2008	5800.0
2009	2000.0
2010	3680.0
2011	3560.0
2012	3660.0
2013	8140.0
2014	1280.0

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.004
Version 7.1 Annual peak flow frequency analysis Run Date / Time
3/14/2014 09/22/2015 08:49

Station - 11449500 KELSEY C NR KELSEYVILLE CA

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	B17B ESTIMATE
1995	8600.0	0.0145	0.0145
1997	8450.0	0.0290	0.0290
1954	8150.0	0.0435	0.0435
2013	8140.0	0.0580	0.0580
1965	8020.0	0.0725	0.0725
1983	7730.0	0.0870	0.0870
1970	7270.0	0.1014	0.1014
1974	7270.0	0.1159	0.1159
1953	7040.0	0.1304	0.1304
1956	6800.0	0.1449	0.1449
1967	6600.0	0.1594	0.1594
2003	6420.0	0.1739	0.1739
2004	6420.0	0.1884	0.1884
1958	6380.0	0.2029	0.2029
1986	6350.0	0.2174	0.2174
1968	5840.0	0.2319	0.2319
2008	5800.0	0.2464	0.2464
1973	5520.0	0.2609	0.2609
1982	5520.0	0.2754	0.2754
1998	5400.0	0.2899	0.2899
1963	5150.0	0.3043	0.3043
1999	5100.0	0.3188	0.3188
1978	4820.0	0.3333	0.3333
1991	4730.0	0.3478	0.3478
1996	4610.0	0.3623	0.3623
1957	4580.0	0.3768	0.3768
1951	4560.0	0.3913	0.3913
1966	4490.0	0.4058	0.4058
1993	4410.0	0.4203	0.4203
1989	4390.0	0.4348	0.4348
1960	4370.0	0.4493	0.4493
1964	4280.0	0.4638	0.4638
1981	4260.0	0.4783	0.4783
1961	4210.0	0.4928	0.4928
1984	4180.0	0.5072	0.5072
2006	4180.0	0.5217	0.5217
1969	4140.0	0.5362	0.5362

1975	4070.0	0.5507	0.5507
1952	3820.0	0.5652	0.5652
1980	3790.0	0.5797	0.5797
2010	3680.0	0.5942	0.5942
2012	3660.0	0.6087	0.6087
2011	3560.0	0.6232	0.6232
1971	3400.0	0.6377	0.6377
1959	3350.0	0.6522	0.6522
1962	3250.0	0.6667	0.6667
2000	3110.0	0.6812	0.6812
1990	3080.0	0.6957	0.6957
1947	2940.0	0.7101	0.7101
1985	2850.0	0.7246	0.7246
1987	2710.0	0.7391	0.7391
1988	2660.0	0.7536	0.7536
2002	2490.0	0.7681	0.7681
2001	2470.0	0.7826	0.7826
1950	2450.0	0.7971	0.7971
1992	2380.0	0.8116	0.8116
1948	2110.0	0.8261	0.8261
1979	2000.0	0.8406	0.8406
2009	2000.0	0.8551	0.8551
1955	1940.0	0.8696	0.8696
2007	1920.0	0.8841	0.8841
1972	1790.0	0.8986	0.8986
1949	1570.0	0.9130	0.9130
2005	1440.0	0.9275	0.9275
2014	1280.0	0.9420	0.9420
1994	941.0	0.9565	0.9565
1976	543.0	0.9710	0.9710
1977	101.0	0.9855	0.9855

1

End PeakFQ analysis.
Stations processed : 1
Number of errors : 0
Stations skipped : 0
Station years : 68

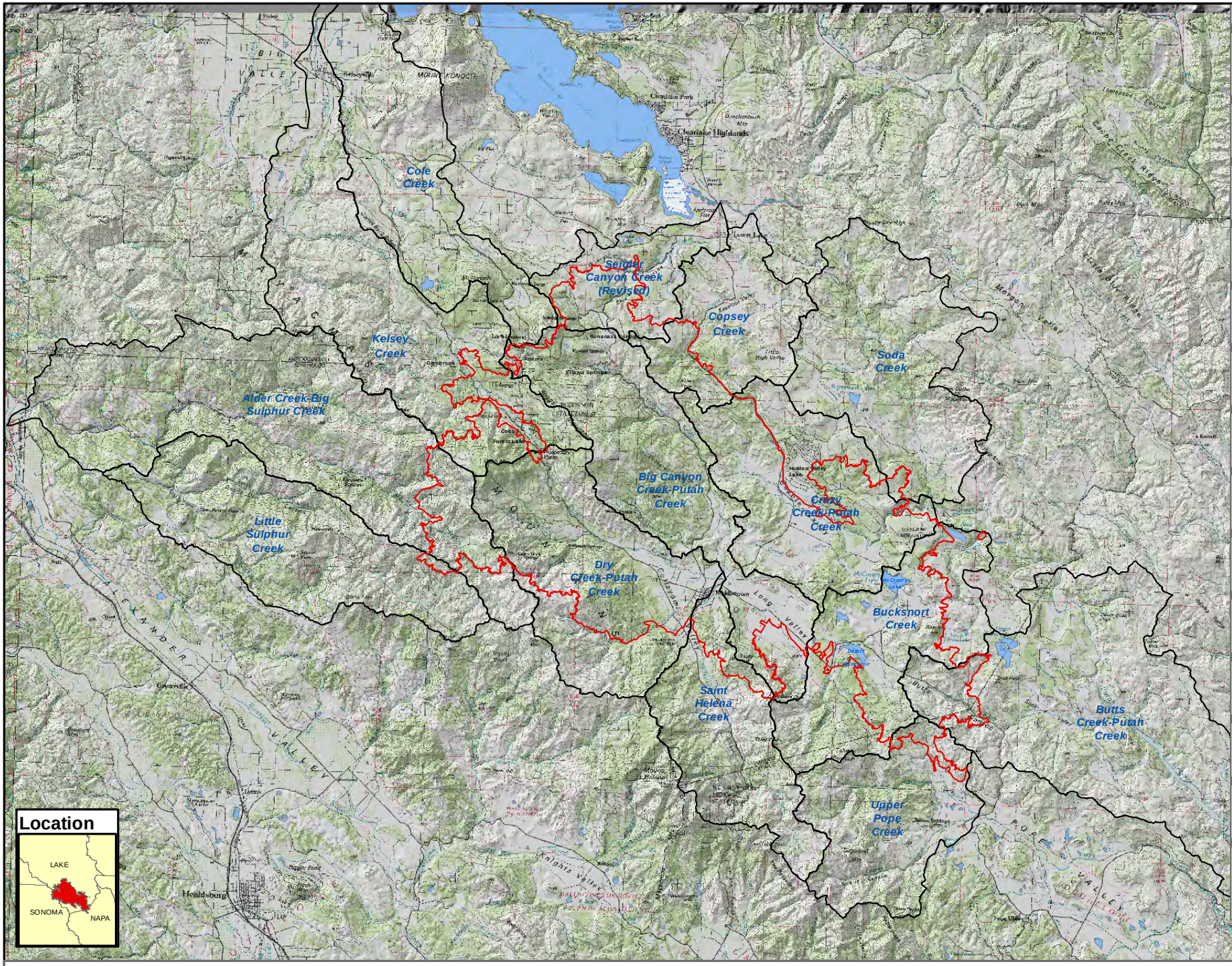
Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4, or *.)
(2, 4, and * records are ignored.)

For the station below, the following records were ignored:

FINISHED PROCESSING STATION: 11449500 USGS KELSEY C NR KELSEYVILLE CA

For the station below, the following records were ignored:

FINISHED PROCESSING STATION:



HUC 12	Watershed Acres	Acres Burned	Percent of Watershed Burned
Alder Creek-Big Sulphur Creek			
TOTAL	**34,372**	**3,493**	**10**
Unchanged		710	2
Low		565	2
Moderate		964	3
High		1,254	4
Big Canyon Creek-Putah Creek			
TOTAL	**20,862**	**19,055**	**91**
Unchanged		1,506	7
Low		2,140	10
Moderate		8,146	39
High		7,262	35
Bucksnort Creek			
TOTAL	**16,818**	**8,575**	**51**
Unchanged		2,364	14
Low		2,264	13
Moderate		3,329	20
High		612	4
Butts Creek-Putah Creek			
TOTAL	**35,276**	**2,524**	**7**
Unchanged		534	2
Low		491	1
Moderate		1,218	3
High		281	1
Cole Creek			
TOTAL	**18,613**	**6**	**0.03**
Unchanged		5	0.03
Low		1	0.01
Moderate			
High			
Copsey Creek			
TOTAL	**11,132**	**2,458**	**22**
Unchanged		233	2
Low		449	4
Moderate		889	8
High		888	8
Crazy Creek-Putah Creek			
TOTAL	**25,327**	**13,998**	**55**
Unchanged		1,957	8
Low		3,229	13
Moderate		7,120	28
High		1,690	7
Dry Creek-Putah Creek			
TOTAL	**20,483**	**15,025**	**73**
Unchanged		1,050	5
Low		2,026	10
Moderate		5,071	25
High		6,876	34
Kelsey Creek			
TOTAL	**28,480**	**4,700**	**17**
Unchanged		1,180	4
Low		949	3
Moderate		1,464	5
High		1,106	4
Little Sulphur Creek			
TOTAL	**20,359**	**199**	**0.98**
Unchanged		58	0.28
Low		40	0.20
Moderate		80	0.39
High		21	0.10
Saint Helena Creek			
TOTAL	**13,649**	**1,809**	**13**
Unchanged		266	2
Low		612	4
Moderate		758	6
High		173	1
Seigler Canyon Creek (Revised)*			
TOTAL	**8,072**	**3,094**	**38**
Unchanged		731	9
Low		647	8
Moderate		1,117	14
High		598	7
Soda Creek			
TOTAL	**20,811**	**275**	**1**
Unchanged		61	0.29
Low		83	0.40
Moderate		73	0.35
High		58	0.28
Upper Pope Creek			
TOTAL	**13,956**	**830**	**6**
Unchanged		304	2
Low		265	2
Moderate		208	1
High		53	0.38

Seigler Creek is the only portion of Seigler Creek - Cachi Creek that was in the fire. The HUC was truncated to reflect this.

0 45 90 180 Km

0 37.5 75 150 Mi

N W E S

California Teale Albers, NAD 1983
Scale 1: 250,000
at 8.5x11
October 5, 2015

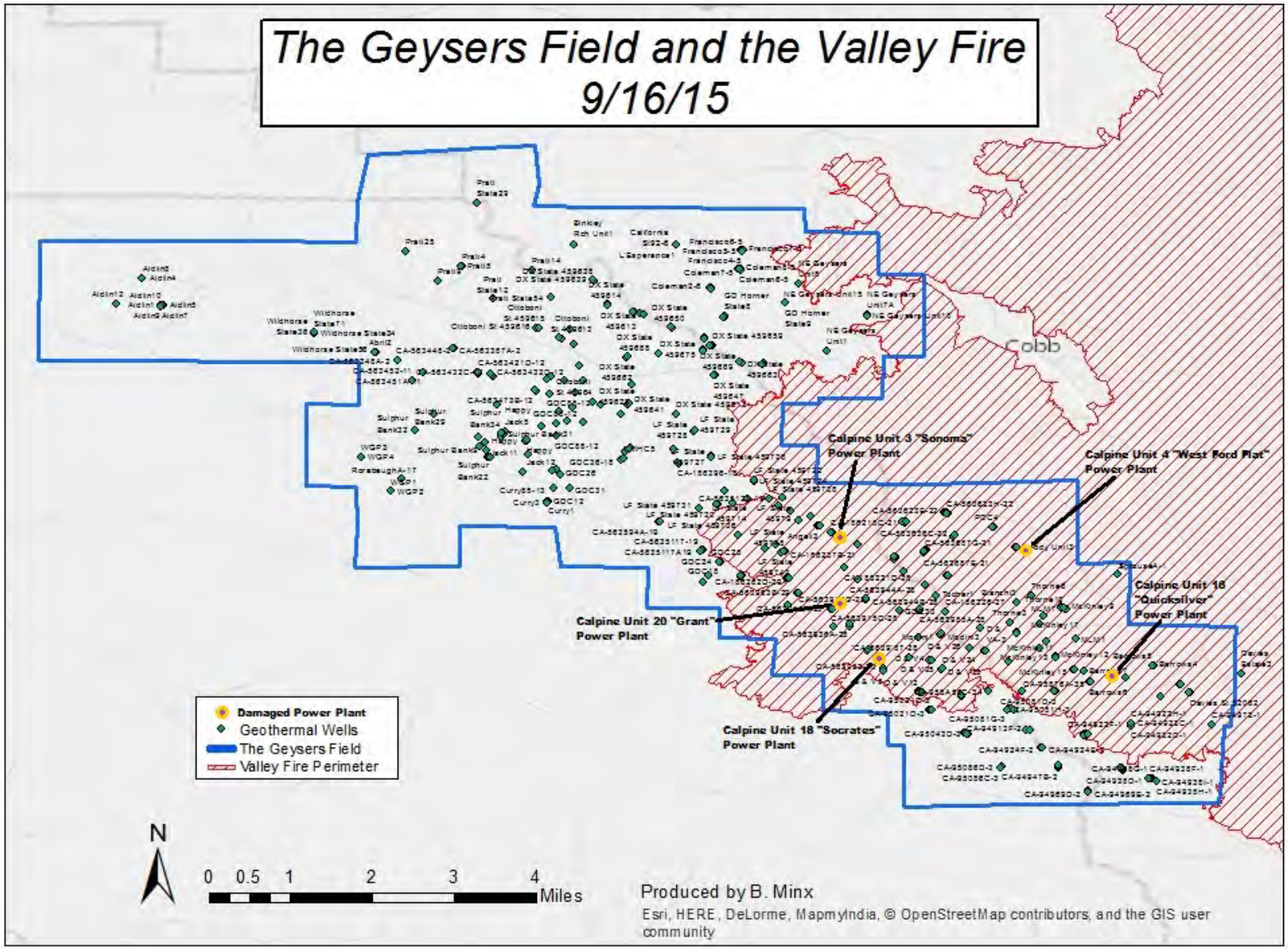
Streams
- Perennial
- Intermittent
- Ephemeral

HUC 12 Watersheds

Fire Perimeter 9-22-2015

Appendix D -` Calpine Damage Evaluation, DOGGR

The Valley Fire & Damages
at The Geysers - Sept. 2015
Calpine Unit 18 "Socrates"
Power Plant
Calpine Unit 20 "Grant"
Power Plant


The Geysers Field and the Valley Fire
9/16/15
Calpine Unit 3 "Sonoma" Power Plant
Calpine Unit 4 "West Ford Flat" Power Plant
Calpine Unit 18 "Quicksilver" Power Plant
Calpine Unit 20 "Grant" Power Plant
Calpine Unit 18 "Socrates" Power Plant
Cobb
Damaged Power Plant
Geothermal Wells
The Geysers Field
Valley Fire Perimeter
N
0 0.5 1 2 3 4 Miles
Produced by B. Minx
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Detail of destroyed cooling towers on Unit 18 “Socrates” Power Plant.

Additional view of destroyed cooling towers at Calpine Unit 20 “Grant” Power Plant.

Damaged flowline insulation on the “LF State 4597” lease. In the background are wells 1, 41, and 42.

Damaged production metering equipment on the “CA-1862” Federal lease.

Melted high density polyethylene injection flowline adjacent to Calpine Unit 20 “Grant” Power Plant.

A cross-bar & transformer hang from wires after their power pole burned – on Big Sulphur Creek Road below Calpine Unit 18 “Socrates” Power Plant.

SCBA tanks and fire extinguishers were reportedly stored in this shipping container adjacent to The Geysers Administrative Complex. Note the explosion damage.

A damaged vehicle adjacent to The Geysers Administrative Complex.

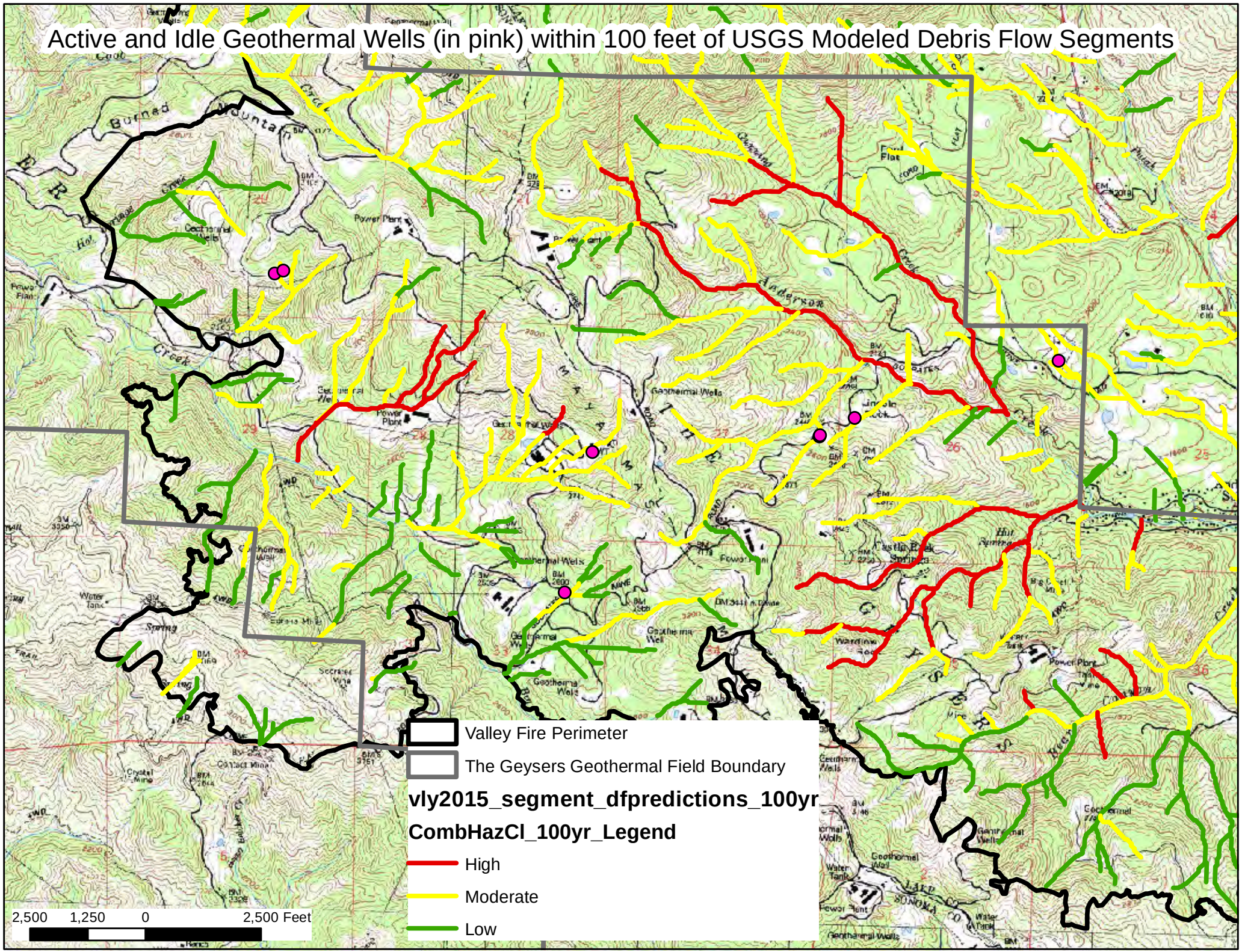
Despite sustaining damage to half of its cooling tower array, the Calpine Unit 3 “Sonoma” Power Plant is back in operation.

The photos contained herein are not a complete assessment of damages to The Geysers geothermal field, but represent typical damages to facilities that were accessible to us on September 28, 2015.

Cooling towers to five of Calpine’s power plants have been damaged or destroyed by the Valley Fire. Calpine’s normal output of 725 megawatts has reportedly been reduced to 540 megawatts. Repairs are expected to take 6 to 12 months.

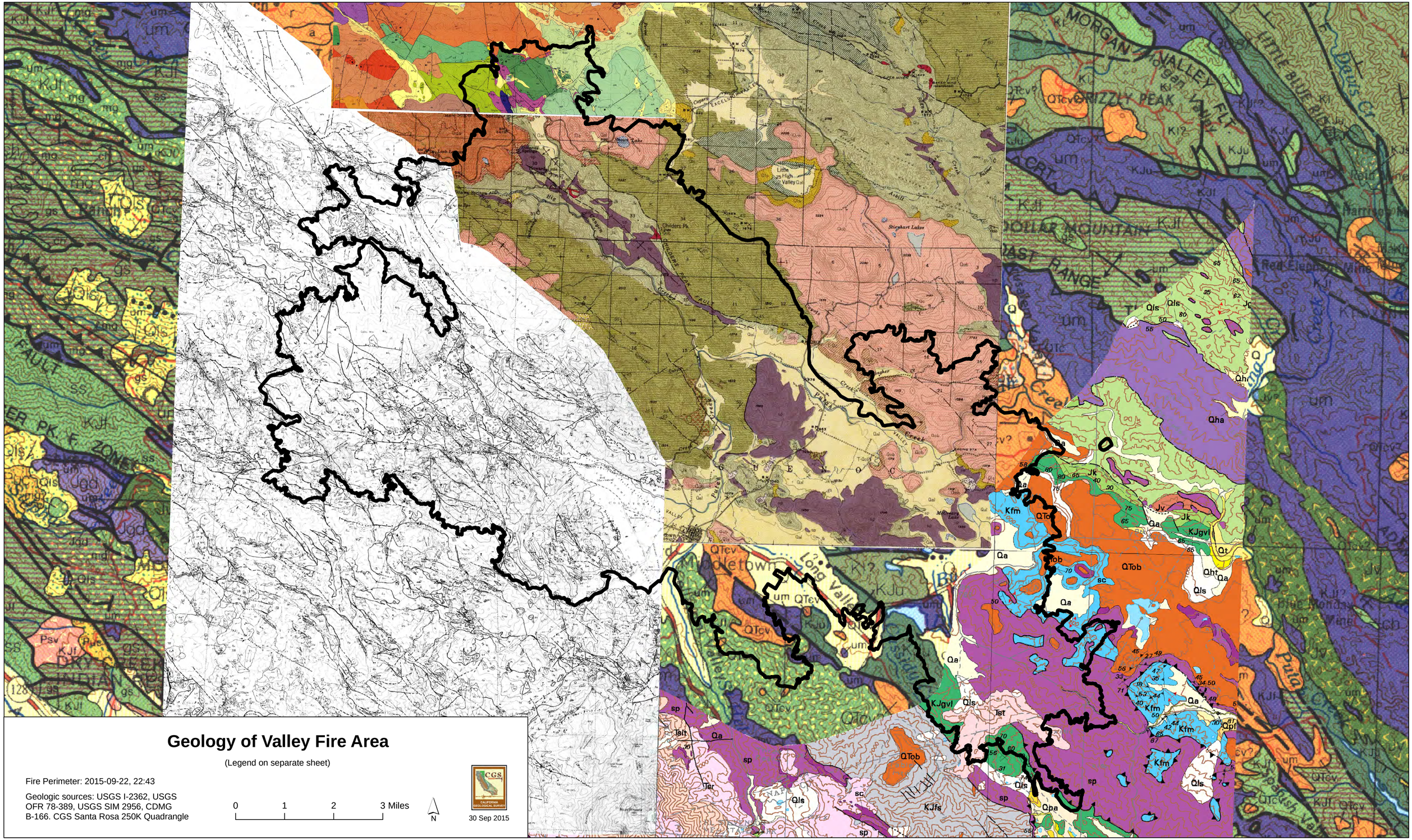
NCPA’s two power plants, and the Bottle Rock power plant were undamaged.

Map and photos by DOGGR / J. A. Austin and B. A. Minx.


Active and Idle Geothermal Wells (in pink) within 100 feet of USGS Modeled Debris Flow Segments
Valley Fire Perimeter
The Geysers Geothermal Field Boundary
vly2015_segment_dfpredictions_100yr
CombHazCl_100yr_Legend
High
Moderate
Low
2,500 1,250 0 2,500 Feet

Plates 1, 2, and 3

Map and Explanations of Geology Underlying 2015 Valley Fire



Geology of Valley Fire Area

(Legend on separate sheet)

Fire Perimeter: 2015-09-22, 22:43

Geologic sources: USGS I-2362, USGS OFR 78-389, USGS SIM 2956, CDMG B-166. CGS Santa Rosa 250K Quadrangle

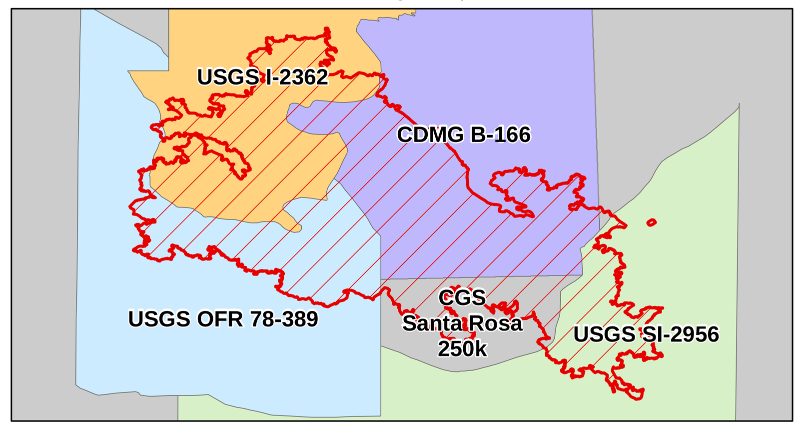
0 1 2 3 Miles

N

30 Sep 2015

Geology of Valley Fire - Explanations

Index to Geologic Map Sources

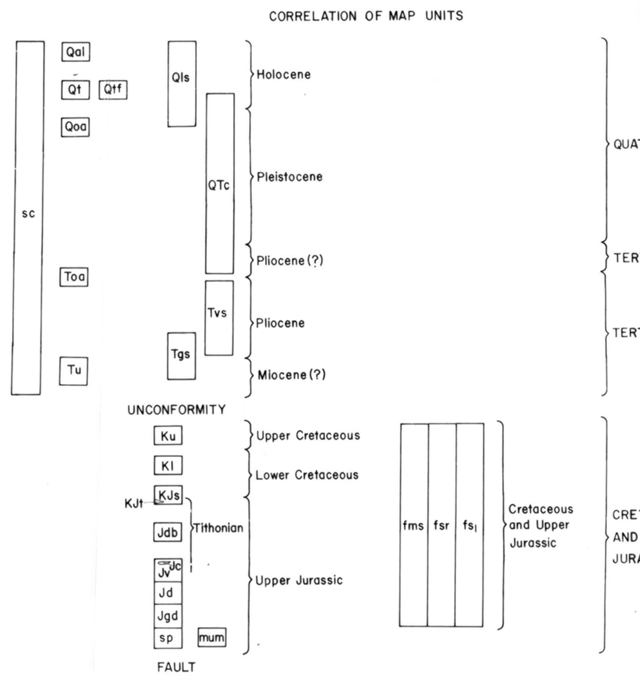


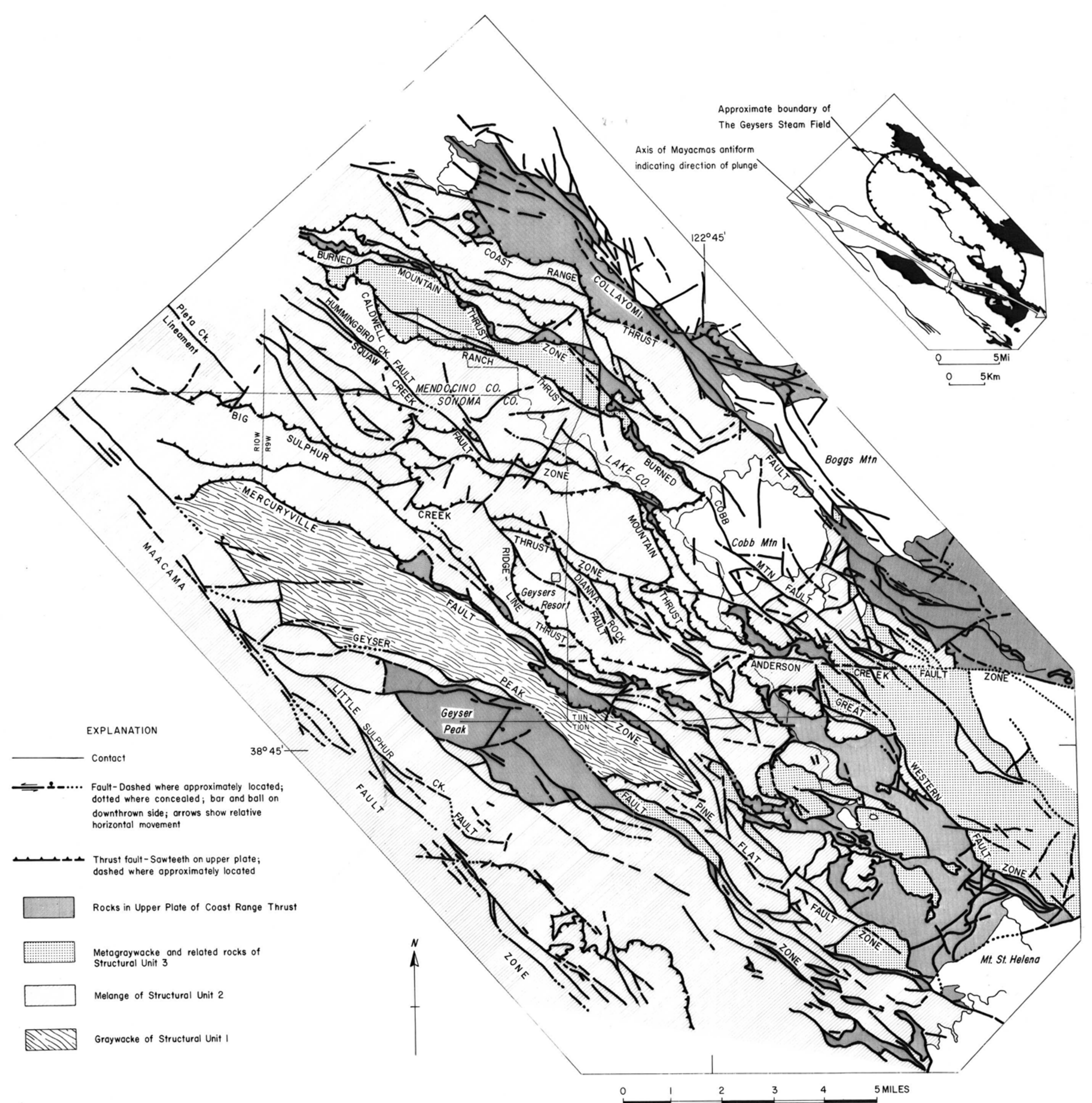
USGS I-2362 (1:24,000)

Please see Sheet 2 of 2

USGS OFR 78-389 (1:24,000)

CORRELATION OF MAP UNITS





Generalized geologic map showing the major faults and structural units in Late Mesozoic rocks of the central Mayacmas Mountains, the approximate boundary of The Geysers steam field and the axis of the Mayacmas antiform.

INTRODUCTION

This preliminary geologic map and accompanying structural sections, prepared as part of the geothermal research efforts of the U.S. Geological Survey in The Geysers-Clear Lake area, supercedes previous open file maps 76-221 (Goff and McLaughlin, 1976), 75-198 (McLaughlin, 1975), and 74-238 (McLaughlin, 1974). The map depicts previously undetermined complex bedrock structures in this region, and encompasses the probable extent of the vapor-dominated part of The Geysers geothermal system and the main area of present geothermal development. The Clear Lake Volcanics is partly compiled from Hearn, Donnelly, and Goff, 1976.

Rocks stratigraphically below the Great Valley sequence are correlated with a deformed sheet of ophiolitic rocks (Coast Range ophiolite) that forms the upper plate of the Coast Range Thrust along the west side of the Sacramento Valley (Bailey and others, 1970). The fragmentation and age relations of rocks above and below this ophiolite succession in the map area, and its correlation with the Coast Range ophiolite are discussed elsewhere by McLaughlin and Pessagno (in press). The localities of fossil collections referred to herein, are also discussed in more detail by McLaughlin and Pessagno (in press), and paleontologic data from two localities of conglomerate in the Franciscan assemblage containing Jurassic radiolaria and Triassic conodonts were obtained from V. Seiders (unpublished data).

The Franciscan and Great Valley sequence are here divided into a series of fault bounded structural units based on lithologic differences and upon the scheme of textural zonation devised for progressively metamorphosed Franciscan sandstone terranes north of Clear Lake by Blake and others (1967). In the area studied by Blake and others (1967), the gradational textural change from a weak metamorphic fabric (textural zone 1) in structurally low Franciscan sandstones, to a moderate to highly foliate metamorphic fabric (textural zones 2 and 3) in structurally higher sandstones was demonstrated to occur gradually over several kilometers within structurally unbroken Franciscan rocks. However, in the central Mayacmas Mountains these gradational textural changes are locally abrupt and out of sequence due to late Tertiary and Quaternary thrusting and strike-slip faulting, probably associated with the San Andreas fault system.

DESCRIPTION OF MAP UNITS

Qal ALLUVIAL AND LACUSTRINE DEPOSITS (Quaternary)--Unconsolidated gravel, sand, silt, and clay, deposited as fan, lacustrine, and fluvial sediments, locally hydrothermally altered and cemented by spring deposits.

Qt, Qtf TERRACE DEPOSITS (Quaternary)--Unconsolidated to semiconsolidated dissected alluvium deposited by fluvial processes; several undifferentiated terrace deposit levels recognized in Cobb, Collayomi, and Big Valley areas; deposits on southwest side of Putah Creek in Collayomi Valley (Qtf) include undifferentiated complexly related fan and terrace deposits.

Qoa, Qvt, Qos OLDER ALLUVIAL AND LACUSTRINE DEPOSITS (Quaternary)--Unconsolidated to semiconsolidated, dissected and uplifted alluvium (Qoa) consisting of undifferentiated terrace, fluvial, lacustrine, and fan deposits, containing clasts of older Clear Lake volcanics, and locally with coarse water-laid tuff in lower part (Qvt), laminated lacustrine silts (Qos) differentiated locally; consists in part of uplifted fluvial and lacustrine deposits of Kelseyville area, of Late Pleistocene (younger than about one-half million years) age (Hearn and others, 1976).

Qls LANDSLIDE DEPOSITS (Quaternary)--Unconsolidated rock and soil debris that has moved downslope by surface creep, rotational slumping, flowage, or by combinations thereof; headwall zones characteristically have closed depressions; some very large, deeply dissected landslides involving very large intact blocks of rock formed in pre-Holocene (Early to Late Pleistocene?) time; wood from bottom of closed depression at the head of block landslide 93 m north, 24 m east of SW cor. sec. 9, T. 11 N., R. 8 W. at Union-Phelps #1 drill site northwest of Cobb Mountain, yielded a radiocarbon age of 13,200±160 y.b.p. (S. Robinson, oral commun., 1977), which probably postdates earliest landslide movement; some large block landslides on north side of Big Sulphur Creek and elsewhere may have resulted in large part from extensive hydrothermal alteration and frequent shallow earthquakes

sc SILICA CARBONATE ROCK (Tertiary and Quaternary)--Hydrothermal alteration product of serpentinization, composed largely of magnesium carbonate, quartz, chalcedony, and opal; locally associated with mercury mineralization, and minor liquid hydrocarbons.

QTc CLEAR LAKE VOLCANICS of Hearn and others, 1976 (Pliocene? to Holocene)--Includes quartz basalt, andesite, dacite, rhyolite, and minor olivine basalt ranging in age from about 0.03 to 2.04 million years.

Toa OLDER ALLUVIUM BENEATH CLEAR LAKE VOLCANICS (late Tertiary?)--Includes gravel with abundant subrounded to rounded cobbles and boulders of chert, foliate metagraywacke and blueschist, derived from the Franciscan assemblage; relation to alluvium beneath Sonoma Volcanics uncertain.

Tvs SONOMA VOLCANICS (Miocene and Pliocene)--Largely silicic tuffs, breccias, welded tuffs, associated dikes, and flows ranging in composition from rhyolite to basalt, about 2.9 to 5.3 million years old (Mankinen, 1972)

Tgs OLDER FLUVIAL DEPOSITS (Miocene? and Pliocene)--Conglomerate, sandstone, and siltstone, underlies Sonoma Volcanics of Miller and Gird Creek area; and consists largely of detritus locally derived from Franciscan assemblage, ophiolite, Great Valley sequence, and rarely, as along Red Winery road, minor detritus from older part of Sonoma Volcanics; unit is steeply tilted and deformed along southwest side of Maacama fault zone; presence of minor silica carbonate detritus suggests unit post-dates ancestral hydrothermal systems related to Sonoma volcanism.

Tu OLDER FLUVIAL AND LACUSTRINE DEPOSITS OF LITTLE SULPHUR CREEK (Miocene? and Pliocene?)--Conglomerate, sandstone, and siltstone, deposited in local northwest trending extensional basin and truncated on southwest by Maacama fault zone, probably pre-dates Sonoma Volcanics; relationship to Tgs uncertain; locally contains abundant petrified wood, fresh water mollusks, and ostracodes; conglomerate moderately to poorly sorted, with subangular to well-rounded clasts derived from underlying Franciscan, ophiolite, and Great Valley sequence; locally with basal breccia composed of angular melange-derived blocks up to tens of meters in maximum dimension; intertongues of brackish or marine strata reported by McNitt (1968) and by Gealey (1951) were not recognized in this investigation

GREAT VALLEY SEQUENCE (Late Cretaceous to Late Jurassic)

Ku SANDSTONE AND MUDSTONE (Upper Cretaceous)--Greenish-gray, thin to thick-bedded, silty, micaceous marine sandstone and mudstone, locally with abundant carbonate concretions (Unit IV of Swe and Dickinson, 1970); mudstone northwest of Hobergs Resort contains Late Cretaceous (Campanian) foraminifers (W. Sliter, oral commun., 1976).

Kl SANDSTONE AND MUDSTONE (Lower Cretaceous)--Gray to gray-green, thin-bedded quartzose marine sandstone and interbedded mudstone, with scattered white-weathering limestone concretions (Unit II of Swe and Dickinson, 1970)

KJs, KJt MUDSTONE AND SANDSTONE (Upper Jurassic (early Tithonian) and Lower Cretaceous (Valanginian))--Olive-gray to black, marine mudstone alternating with thin interbeds of hard, dark-green siltstone and graywacke sandstone composed largely of basaltic detritus (Units Ia and Ib of Swe and Dickinson, 1970); mudstone is interbedded with sporadic hard gray-weathering impure concretionary carbonate beds that locally contain Tithonian to Valanginian Buchia sp., belemnites, palynomorphs, and Radiolaria; lower beds locally with three or more 10 m -thick intervals of hard, gray siliceous tuff (KJt); base of unit locally contains sedimentary breccias composed chiefly of diabase and basalt clasts.

Jdb DIABASE AND DIABASE-BASALT BRECCIA (Upper Jurassic (lower Tithonian))--Coarse breccia composed largely of angular fragments of diabase and basalt, and rare chert, locally cut by diabase dikes.

COAST RANGE OPHIOLITE (Late Jurassic)

Jv, Jc BASALTS FLOWS AND FLOW BRECCIAS OF GEYSER PEAK (Upper Jurassic (Upper Kimmeridgian or lower Tithonian))--Undifferentiated, deeply weathered and altered basaltic rocks, consisting of pillow flows, pillow breccia, tuff, minor diabase, and minor intercalated tuffaceous chert (Jc); basalts contain prominent epidote, and locally contain laumontite and prehnite; tuffaceous chert contains late Kimmeridgian or early Tithonian Radiolarian fauna.

Jd, rd DIABASE OF GEYSER PEAK (Upper Jurassic)--Fine- to medium-grained, equigranular to porphyritic, intrusive diabase sills; diabase contains prominent secondary brown to green amphibole after pyroxene; locally altered to rodingite mineral assemblages (rd) along contacts with serpentinite.

Jgd GABBRO AND DIABASE (Upper Jurassic)--Fine- to medium-grained, layered olivine and orthopyroxene-bearing gabbro displaying cumulate texture, cut by diabase dikes which increase in abundance in upper part of gabbro; locally cut by abundant dikelets of hornblende-albite pegmatite and rarely, by biotite-bearing plagiogranite.

sp SERPENTINITE (Upper Jurassic)--Pervasively sheared chromite-streaked dunite and harzburgite peridotite, partly to completely altered to chrysotile ± lizardite ± clinochrysotile; where present below gabbro on northeast side of Collayomi Valley, and at Mt. Saint Helena on the southeast, and Geyser Peak on the southwest, serpentinized ultramafic rocks together with overlying mafic rocks are considered to compose a once continuous Late Jurassic ophiolite complex; elsewhere the serpentinite occurs along major faults, shear zones, and in the cores of diapiric structures as the result of plastic remobilization during Tertiary and Quaternary time.

FRANCISCAN ASSEMBLAGE (Upper Jurassic and Cretaceous)

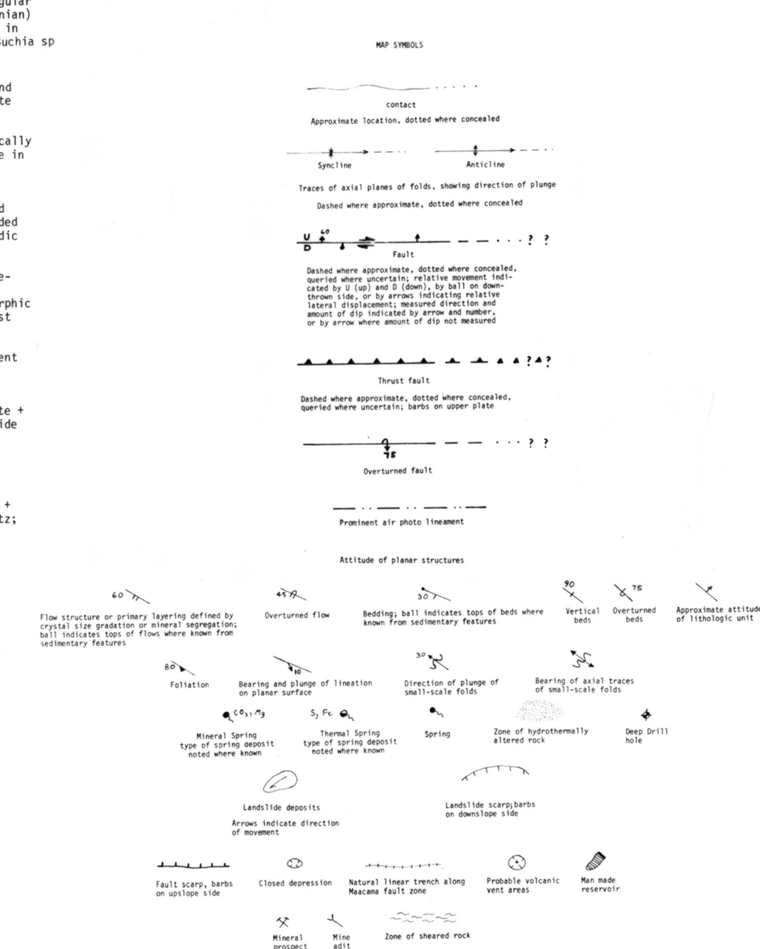
fms, fmc, fm, fmsr, fmg METAGRAYWACKE (structural unit 3)--Fine to coarse-grained, locally conglomeratic metagraywacke (fms) metamorphosed to quartz ± lawsonite ± jadeite ± albite ± pumpellyite ± glaucophane, highly reconstituted texturally (textural zone 2 to 3 of Blake and others, 1967), with minor interbeds of low blueschist grade metachert (fmc) and greenstone (fmg), locally is a melange (fmsr) with blocks of high-grade blueschist or amphibolite (fm) in a matrix of fms; overlies and is in part incorporated into underlying melanges in structural unit 2; is in thrust contact with overlying Coast Range ophiolite in southeast part of area; in northeast part of area unit overlain along a thrust fault by serpentinite and rocks of structural unit 2.

fsr MELANGE UNDIFFERENTIATED (structural unit 2)--Elements of melange include extensive intact, imbricated slabs of broken formation several kilometers in lateral extent, in addition to blocks that are as small as a meter in diameter, immersed in a penetratively sheared matrix of shale; where mapped, individual elements are differentiated as follows:

- fs_2 Lithic graywacke, thin bedded to massive, and minor interbedded black shale; graywacke with less than one precent potash feldspar, and metamorphosed to quartz + albite + white mica + pumpellyite ± lawsonite, with slight to moderate metamorphic fabric (textural zone 1 to 2 of Blake and others, 1967); locally interbedded with chert and greenstone
- fs Lithic graywacke, thin bedded to massive, and minor interbedded black shale; graywacke with up to 5 percent detrital potash feldspar, and metamorphosed to quartz + K-feldspar + albite + white mica ± pumpellyite ± prehnite, with slight metamorphic fabric (textural zone 1 of Blake and others, 1967); locally interbedded with chert and greenstone; present only in melange south of Geyser Peak fault zone
- fsb Sedimentary breccia and conglomerate, present locally as lenticular bodies locally up to several hundreds of feet thick, within fms, fs_2, fs, and basaltic volcanic rocks (fg), and also as blocks within melange matrix (fsr); contains detritus ranging in size and roundness from angular blocks up to several meters in maximum length, to well rounded pebbles less than one centimeter in diameter, enclosed in a matrix ranging in texture from penetratively sheared shale in pebbly mudstones, to graywacke; well rounded clasts are of pebble to boulder size and are composed of silicic porphyritic volcanic and hypabyssal plutonic rocks, dark chert, and vein quartz; angular and subrounded clasts are composed of radiolarian chert, basaltic volcanics, talc schist, graywacke, serpentinite, gabbro, and rare blueschist grade metamorphic rocks; rounded to angular chert clasts have yielded Late Jurassic (Lower Tithonian) and Late Cretaceous (lower Cenomanian) Radiolarians and Middle or Late Triassic conodonts; graywacke matrix of conglomerate blocks in melange south of Geyser Peak fault zone locally contains Late Jurassic or Early Cretaceous Buchia sp
- fg Altered basaltic rocks (greenstone); locally pillowed basalt flows, flow breccias, tuffs, and diabase, slightly to extensively sheared, slightly to moderately metamorphosed to pumpellyite grade, and locally hydrothermally altered.
- fc Red, green, and white thin bedded chert, and minor interbedded siliceous shale and tuff, locally hydrothermally altered, interbedded with fs_2, fs, and fg, containing Radiolarians that range in age from Late Jurassic (early Tithonian) to Late Cretaceous (early Cenomanian)
- fm High-grade glaucophane schist, amphibolite, and eclogite; foliated phyllitic to gneissose metamorphic rocks, including Type II to Type IV basaltic rocks of Coleman and Lee, 1963, and rocks with more siliceous protoliths; eclogite and amphibolite grade rocks in part retrograded to blueschist; blueschist metamorphic mineral assemblages include fine to coarse-grained sodic amphibole, jadeitic pyroxene, lawsonite, aragonite, fuchsite, and stilpnomelane.
- fsm Metasandstone of the Douglas Ranch area; highly folded, foliated, and crenulated glaucophane-muscovite-quartz schist, with relict sedimentary texture, indicating protolith probably was thin bedded sandstone and shale; contains prominent accessory fuchsite, and displays metamorphic mineral orientation; may be correlative with similar, more extensive schist exposed southwest of Skaggs Springs along Warm Springs Creek, northwest of Healdsburg.
- fl Limestone; gray to white, fine- to coarse-grained, massive, and highly recrystallized, present as blocks in melange only south of Geyser Peak fault zone.
- mum Metamorphosed ultramafic rock; serpentinite metamorphosed to greenschist or amphibolite grade, composed of serpentine and calcium magnesium amphibole mineral assemblages (antigorite + actinolite ± tremolite ± talc ± chlorite), present largely in major thrust sheet on north side of Big Sulphur Creek, and locally as minor isolated blocks in melange.

fs_1 GRAYWACKE OF LITTLE SULPHUR CREEK (structural unit 1)--Fine- to medium-grained, massive to thin bedded graywacke and minor interbedded black shale with slight metamorphic fabric (textural zone 1 of Blake and others, 1967); graywacke contains metamorphic mineral assemblage quartz + albite + white mica + pumpellyite; locally with grit-sized grains of shale, chert, and quartz; in places displays tangential cross bedding, rip-up structures, sole marks, and inverse and normal grading; shale locally contains hard, oblate siliceous and calcareous concretions

MAP SYMBOLS



Acknowledgments

The map area encompasses large tracts of private property, much of which is under lease to companies engaged in geothermal exploration and development. The author appreciates the cooperation of the following industry geologists who provided access to company lease holdings and contributed background and subsurface data. D. McMurdie, R. Dondanville, and J. Vantine, of Union Oil Co.; Ian Jamiesson and William Ehni of Thermogenics Corp.; D. Lindsey and L. Garrett of Shell Oil Co., and T. Box and R. Wall, of Aminoil Co.; C. F. Isselhardt, of Republic Geothermal Co.; R. Chandler of McCulloch Oil Co.; G. Taggert, and M. Dwyer, of Cooper Clark and Associates; and E. V. Ciancanelli, private consultant.

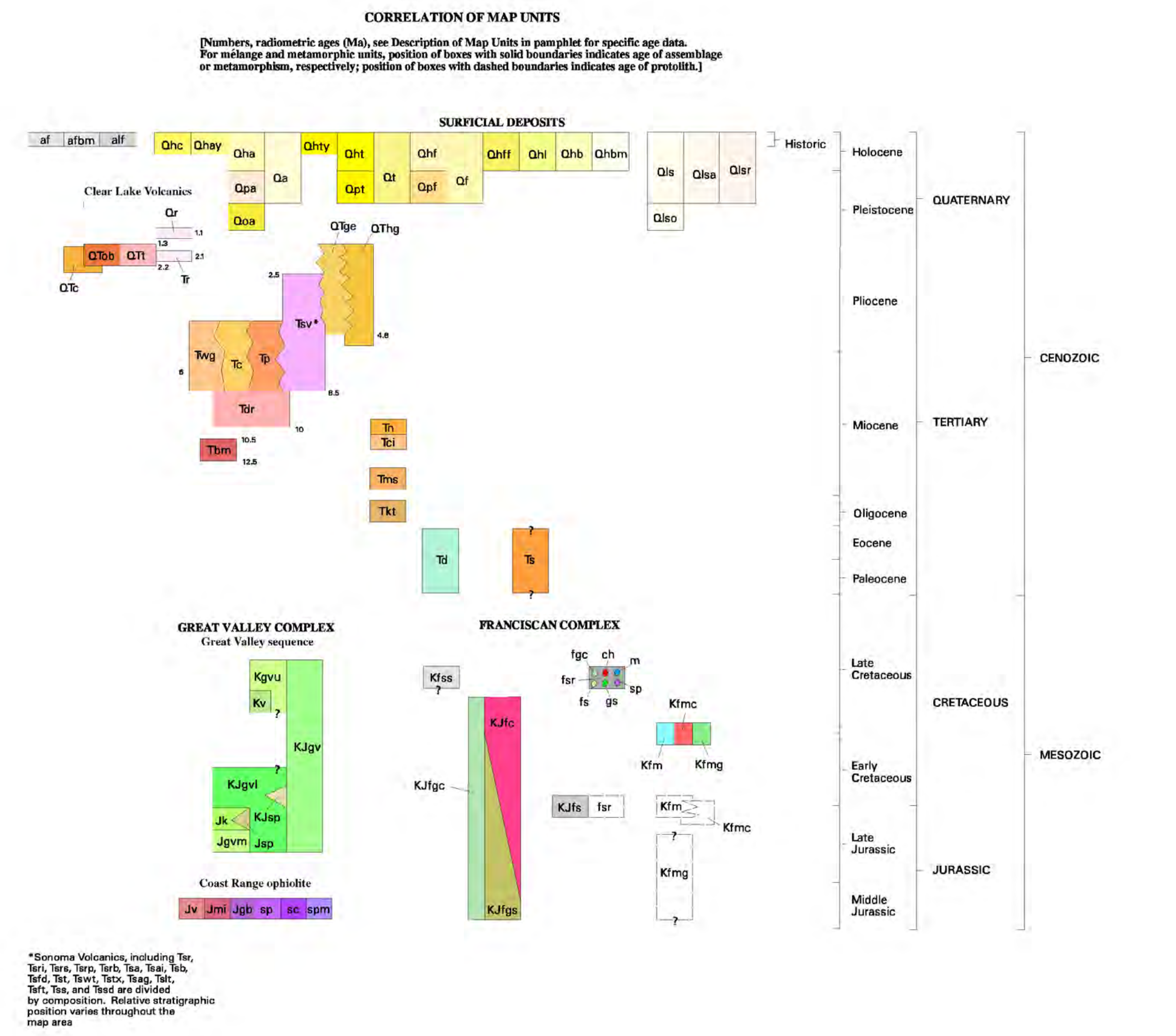
Land owners and local residents whose cooperation was most helpful include: Mr. and Mrs. J. Pedroncelli (Ridge Ranch); Mr. M. Martinez (D-Bar-M Ranch); Mr. F. C. Hock; Mr. E. Prati (Caldwell Ranch); Mr. J. Domenichelli; Mr. T. Furtado and the hands of the Circle G Ranch; Mr. and Mrs. P. Crespi; Mr. G. Smith, Mr. H. Mitchell, and Mr. C. Heater (Pocket Ranch area); and Mr. R. Meyer and Mr. C. Meyer (Black Mountain area).

Many colleagues of the U.S. Geological Survey working in adjacent areas have provided valuable data in the course of this mapping. The author was also assisted in various stages of the field work by D. H. Sorg and H. N. Ohlin. D. L. Jones, W. Sliter, W. Evitt, and E. A. Pessagno, Jr. provided valuable paleontologic support for the project, and C. A. Hopson has provided helpful insights in the mapping of ophiolitic rocks of The Geyser-Clear Lake area.

USGS SIM 2956 (1:100,000)

CORRELATION OF MAP UNITS

[Numbers, radiometric ages (Ma), see Description of Map Units in pamphlet for specific age data. For mélange and metamorphic units, position of boxes with solid boundaries indicates age of assemblage or metamorphism, respectively; position of boxes with dashed boundaries indicates age of protolith.]



LIST OF MAP UNITS

[Some unit exposures on the map are too small to distinguish the color for unit identification. These units are labeled where possible, and unlabeled units are attributed in the database.]

SURFICIAL DEPOSITS

- af — Artificial fill (Historic)
- afbm — Artificial fill over Bay mud (Historic)
- alf — Artificial levee fill (Historic)
- Qhc — Stream channel deposits (late Holocene)
- Qhay — Younger alluvium (late Holocene)
- Qhty — Terrace deposits (late Holocene)
- Qha — Alluvium (Holocene)
- Qht — Terrace deposits (Holocene)
- Qhf — Alluvial fan deposits (Holocene)
- Qhff — Fine-grained alluvial fan deposits (Holocene)
- Qhl — Natural levee deposits (Holocene)
- Qhb — Basin deposits (Holocene)
- Qhbm — Bay mud (Holocene)
- Qa — Alluvium (Holocene and late Pleistocene)
- Qt — Terrace deposits (Holocene and late Pleistocene)
- Qf — Alluvial fan deposits (Holocene and late Pleistocene)
- Qls — Landslide deposits (Holocene and late Pleistocene)
- Qlsa — Andesitic composition
- Qlsr — Rhyolitic composition
- Qpa — Alluvium (late Pleistocene)
- Qpt — Terrace deposit (late Pleistocene)
- Qpf — Alluvial fan deposits (late Pleistocene)
- Qoa — Alluvium (late and early Pleistocene)
- Qlso — Landslide deposits (late and early Pleistocene)

Clear Lake Volcanics

- Qr — Rhyolite (Pleistocene)
- QTob — Olivine basalt (Pleistocene and Pliocene)
- QTt — Tuff (Pleistocene and(or) Pliocene)
- Tr — Rhyolite (Pliocene)
- QTc — Cache Formation (Pleistocene and(or) Pliocene)
- QTge — Glen Ellen Formation (early Pleistocene? and Pliocene)
- QThg — Huichica and Glen Ellen Formations, undivided (early Pleistocene? and Pliocene)

Sonoma Volcanics

- Tsv — Sonoma Volcanics, undivided (Pliocene and late Miocene)
- Tsr — Rhyolite flows
- Tsri — Rhyolite plugs
- Tsrs — Soda rhyolite flows
- Tsrp — Perlitic rhyolite
- Tsrb — Rhyolite breccia
- Tsa — Andesite to basalt lava flows
- Tsai — Andesite to dacite plugs
- Tsb — Basalt flows
- Tsfd — Basalt or andesite lava flows and sediments
- Tst — Pumiceous ash-flow tuff
- Tswt — Welded ash-flow tuff
- Tstx — Tuff(?)
- Tsag — Agglomerate
- Tslt — Tuff breccia
- Tsft — Tuff
- Tss — Volcanic sand and gravel
- Tssd — Diatomite
- Twg — Wilson Grove Formation (late Pliocene to late Miocene)
- Tc — Sand and gravel of Cotati (Pliocene and late Miocene)
- Tp — Petaluma Formation (early Pliocene and late Miocene)
- Tdr — Donnell Ranch Volcanics (late Miocene)
- Tn — Neroly Sandstone (late Miocene)
- Tci — Cierbo Sandstone (late Miocene)
- Tbm — Burdell Mountain volcanics (late and middle? Miocene)
- Tms — Unnamed sandstone (middle Miocene)
- Tkt — Kirker Tuff (early Miocene and(or) Oligocene)
- Td — Unnamed sandstone (Eocene and Paleocene)
- Ts — Unnamed sandstone (Eocene? or Paleocene?)

GREAT VALLEY COMPLEX

Great Valley sequence

- KJgv — Sandstone, shale, and conglomerate (Late Cretaceous to Late Jurassic)
- Kgvu — Sandstone, shale, and conglomerate (Late Cretaceous)
- Kv — Venado Formation (Late Cretaceous)
- KJgvl — Sandstone and shale (Early Cretaceous and Late Jurassic)
- KJsp — Sedimentary serpentinite member
- Jk — Knoxville Formation (Late Jurassic)
- Jsp — Sedimentary serpentinite member
- Jgvm — Mélange

Coast Range ophiolite

- Jv — Basaltic pillow lava and breccia (Jurassic)
- Jmi — Mafic intrusive complex (Jurassic)
- Jgb — Gabbro (Jurassic)
- sp — Serpentinite (Jurassic)
- sc — Silica-carbonate rock
- spm — Serpentinite-matrix mélange

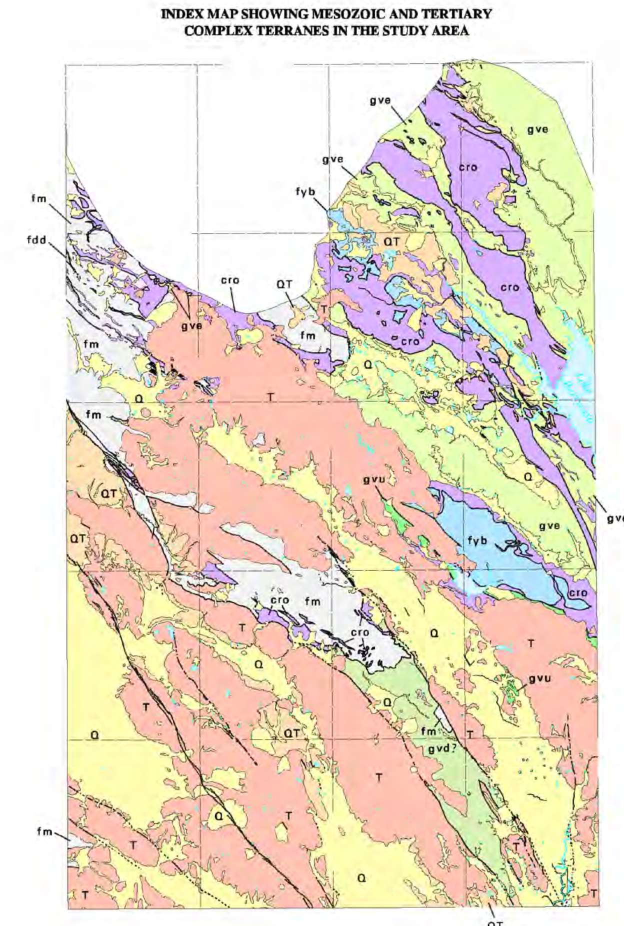
FRANCISCAN COMPLEX

- fsr — Mélange, including blocks, mapped locally, of:
- sp — Serpentinite
- fs — Graywacke
- ch — Chert
- fgc — Greenstone and chert
- gs — Greenstone
- m — High-grade metamorphic rocks
- Kfss — Sandstone (Late Cretaceous, Turonian?)
- Kfm — Metagraywacke (Late and Early Cretaceous)
- Kfmc — Metachert (Late and Early Cretaceous)
- Kfmg — Metagreenstone (Late and Early Cretaceous)
- KJfs — Graywacke and melange (Early Cretaceous and Late Jurassic)
- KJfc — Chert (Cretaceous to Jurassic)
- KJfgc — Greenstone and chert (Cretaceous to Jurassic)
- KJfgs — Greenstone (Cretaceous to Jurassic)

MAP SYMBOLS

- **Contact**—Depositional or intrusive contact, dashed where approximately located, dotted where concealed
- **Fault**—Dashed where approximately located, small dashes where inferred, dotted where concealed, queried where location is uncertain, orange denotes Quaternary-active fault, magenta denotes Holocene active-fault
- **Reverse or thrust fault**—Dashed where approximately located, small dashes where inferred, dotted where concealed, queried where location is uncertain; sawteeth on upper plate
- **Anticline**—Dashed where approximately located, dotted where concealed
- **Syncline**—Dashed where approximately located, dotted where concealed
- 36 Strike and dip of bedding
- 48 Strike and dip of bedding, top indicator observed
- 20 Strike and dip of bedding, approximate
- 83 Overturned bedding
- 79 Overturned bedding, top indicator observed
- 45 Crumpled bedding
- 26 Air photo attitude
- Vertical bedding
- Horizontal bedding
- 35 Strike and dip of foliation
- 73 Strike and dip of foliation and bedding
- Vertical foliation
- Strike and dip of joint

INDEX MAP SHOWING MESOZOIC AND TERTIARY COMPLEX TERRANES IN THE STUDY AREA



EXPLANATION OF TERRANE MAP

- Q — Quaternary surficial deposits
- QT — Quaternary-Tertiary gravels
- T — Tertiary volcanic and sedimentary rocks

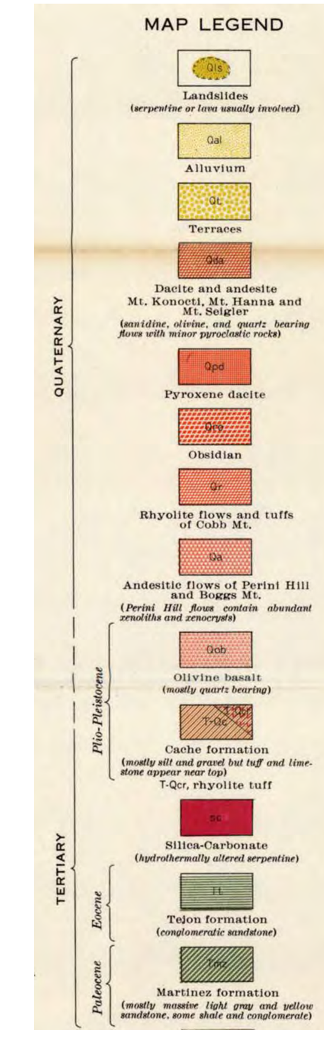
GREAT VALLEY COMPLEX

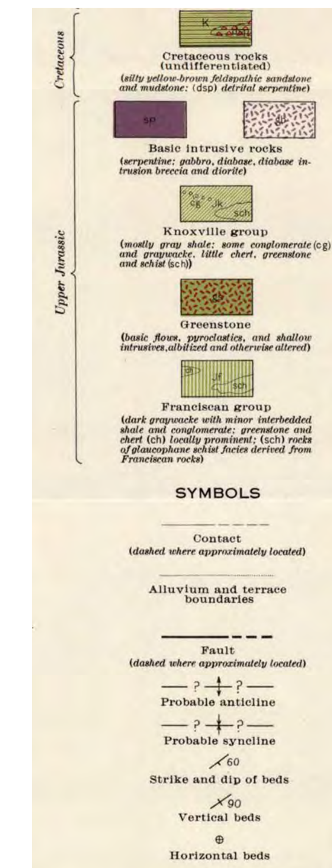
- gve — Elder Creek terrane
- gvd — Del Puerto terrane
- gvu — Great Valley complex, undivided
- cro — Coast Range ophiolite

FRANCISCAN COMPLEX

- fdd — Devils Den terrane
- fyb — Yolla Bolly terrane
- fm — Mélange
- Depositional or intrusive contact
- Fault –Dashed where approximated, dotted where concealed

CDMG B-166 (1:62,500)





CGS Santa Rosa Sheet (1:250,000)

ABBREVIATED EXPLANATION

Approximate stratigraphic relationships only; see Geologic Map Explanation for more accurate stratigraphic relationships and unit descriptions.

CENOZOIC — QUATERNARY — Holocene

- Q — Alluvium
- Ql — Natural levee and channel deposits
- Qb — Basin deposits *(Alluvium)*
- Qls — Landslide deposits
- Qs — Dune and beach sand
- Qi — Intertidal deposits *(Peaty-mud)*

Pleistocene

- Qo — Older alluvium
- Qmr — Modesto-Riverbank Formations *(Arkosic alluvium)*
- Qt — Terrace deposits
- Qml — Millerton Formation *(Marine and nonmarine clay, silt, sand and conglomerate)*
- Qrb — Red Bluff Formation *(Gravel in reddish silty or sandy matrix)*
- QT — Huichica and Glen Ellen Formations; Includes undifferentiated continental deposits. *(Fluvial gravel, silt, sand, and clay)*
- QTc — "Cache Formation" *(Pebbly sandstone, conglomerate, siltstone and tuff)*

TERTIARY — Pliocene

- Pt, Ppt — Tehama Formation *(Sand, silt, and volcaniclastic rocks)*; Putah Tuff Member *(Ppt)*
- Por — Ohlson Ranch Formation *(Marine sandstone, siltstone, and conglomerate)*
- Pwg — Wilson Grove Formation *(Marine sandstone, conglomerate, and tuff)*
- Puc — Unnamed continental deposits *(Poorly sorted sandstone and conglomerate)*
- Pp — Petaluma Formation *(Claystone, siltstone, mudstone; mostly nonmarine)*
- Mo? — Orinda (?) Formation *(Pebbly sandstone and conglomerate)*

Miocene

- Mdb — Drakes Bay Formation *Marine siltstone and mudstone)*
- Msp — San Pablo Group *(Marine sandstone and shale)*
- Mmy — Monterey Group *(Marine sandstone and shale)*
- Mgs — Gallaway - Skooner Gulch Formations *(Marine sandstone and mudstone)*
- Ml — Laird Sandstone *(Marine quartzose feldspathic sandstone)*

Eocene

- Emk — Markley Sandstone *(Marine)*
- En — Nortonville Shale *(Marine)*
- Ed — Domengine Sandstone *(Marine)*
- Ec — Capay Formation *(Marine sandstone)*
- Eum — Unnamed Eocene marine rocks

Paleocene

- Pgr — German Rancho Formation *(Marine sandstone and mudstone)*
- Pmz — Martinez Formation *(Marine quartzose sandstone)*
- Ppr — Point Reyes Formation *(Marine conglomerate and sandstone)*
- TKcb — Coastal Belt Franciscan *(Marine sandstone, shale, and conglomerate)*

MESOZOIC — CRETACEOUS

- Kga — Gualala Formation *(Marine sandstone, mudstone, and conglomerate)*
- Ku — Upper Cretaceous *(Undifferentiated marine rocks)*
- Kfo — Forbes Formation *(Marine shale and siltstone)*
- Kg — Guinda Formation *(Marine sandstone and mudstone)*
- Kf — Funks Formation *(Marine shale and sandstone)*
- Ks — Sites Formation *(Marine sandstone)*
- Ky — Yolo Formation *(Marine shale and sandstone)*
- Kv — Venado Formation *(Marine sandstone and conglomerate)*

(Upper Cretaceous Great Valley Sequence)

- Kl, Klsp — Lower Cretaceous Great Valley Sequence *(Marine mudstone, sandstone, and conglomerate) (Klsp - detrital serpentine)*
- KJ, KJsp — Lower Cretaceous-Upper Jurassic Great Valley Sequence *(Marine mudstone, siltstone, sandstone, and conglomerate) (KJsp - detrital serpentine)*

JURASSIC

- KJf (ss, ch, gs, mg) — Franciscan Complex * *(ss-sandstone, shale, conglomerate; ch-chert; gs-greenstone; mg-metagraywacke)*
- um — Serpentinized ultramafic rocks *

PALEOZOIC

- PzMz, ls — Metamorphic rocks of uncertain age. ls - limestone and marble *(Biotite schist and quartzite)*

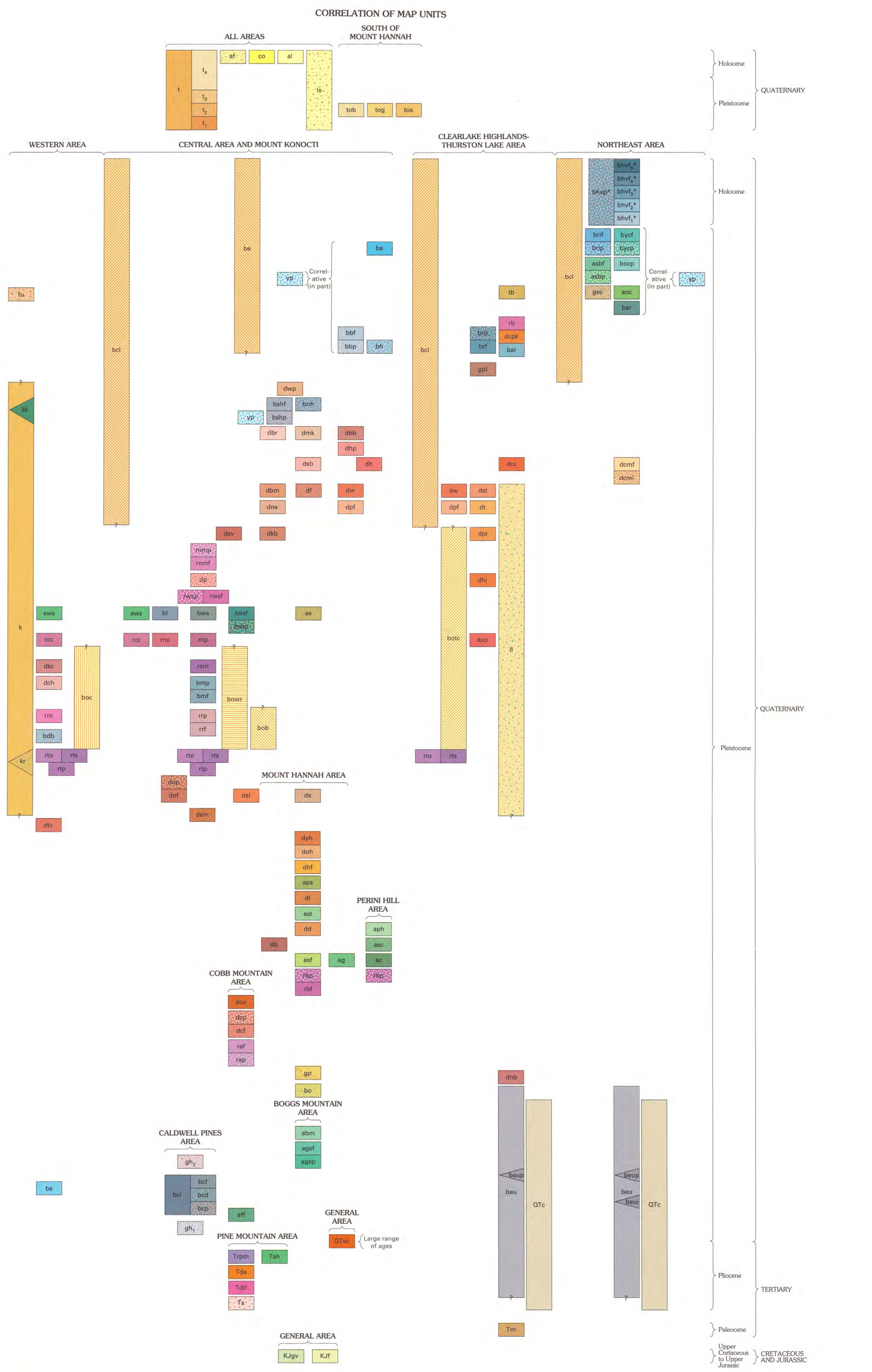
- QTcv — Clear Lake Volcanics *(d-dacite; a-andesite to basaltic rock; b-basalt; r-rhyolite; t-tuff and other pyroclastic rocks)* ✲ Quaternary cinder cone or volcano.
- Psv — Sonoma Volcanics *(b-basalt; a-andesite; r-rhyolite; t-tuff and other pyroclastic rocks)*
- Mpt — Pinole Tuff
- Mbm — Volcanic rocks of Burdell Mtn. *(Andesitic mudflow breccias and flows)*
- Mpp — Putnam Peak Basalt
- Mib — Iversen Basalt
- Kgr — Granitic rocks
- sbp — Spilite near Black Point

Coast Range Ophiolite

- Jv — Volcanic rocks, mainly basalt
- Jgd — Gabbro and diabase
- um — Ultramafic rocks (Peridotite)-partly to completely serpentinized

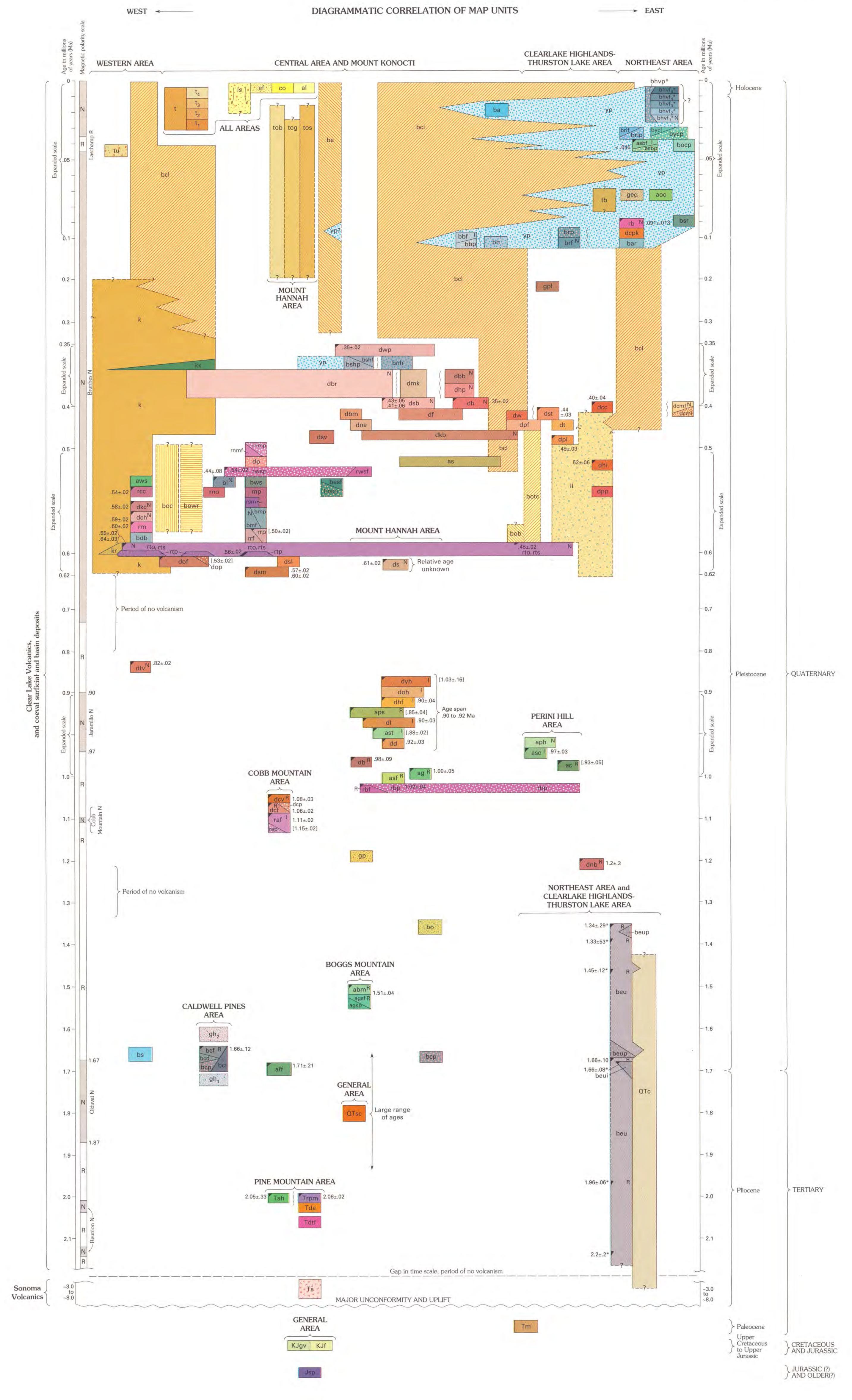
* Horizontal pattern denotes melange terrane

CORRELATION OF MAP UNITS



* See DESCRIPTION OF MAP UNITS for age assignment

DIAGRAMMATIC CORRELATION OF MAP UNITS



Notes: Diagrammatic correlation chart is organized generally by geographic areas (see index) from western areas on the left to eastern areas on the right. In addition, because volcanism decreases in age northward, geographic distribution of units is south to north from bottom to top of chart. Surficial map units al, af, co, ls, t, and bcl at the top, and bedrock units QTsc, KJgv, KJf, and Jsp at the bottom are widespread. Size of box is not proportional to volume of unit. Units bcl, bo, bcp, rbf, and as are shown only in cross section. Units dated by potassium-argon or carbon-14 are indicated by shading in upper left corner of box. Asterisk indicates dated sample is from site outside of map area; see description of map units for age assignment. Brackets enclose age that does not fit stratigraphic sequence, magnetic polarity, or other ages on the same unit. Magnetic polarity scale is from Mankinen and Dalrymple (1979), Mankinen and Grommé (1982), and Gillot and others (1979). Time scale is that of U.S. Geological Survey. Vertical wavy line separates units of unknown relative age.

DESCRIPTION OF MAP UNITS

[This map supersedes U.S. Geological Survey Open-File Report 76–751 (Hearn and others, 1976). Descriptions of map units are grouped by geographic area in approximate increasing age. Summaries of the evolution, chemistry, structure, and tectonic setting of the Clear Lake Volcanics are given in Hearn and others (1981) and Donnelly-Nolan and others (1981). The geology of parts of the area underlain by the Cache Formation is based on mapping by Rymer (1981); the geology of parts of the areas underlain by the Sonoma Volcanics, Franciscan assemblage, and Great Valley sequence is based on mapping by McLaughlin (1978). Units are named primarily on the basis of SiO_2 content: basalt less than 53, basaltic andesite 53–59, andesite 59–63.5, dacite 63.5–68, rhyodacite 68–72, and rhyolite greater than 72 percent SiO_2. A few units that have a range of SiO_2 content are named for the dominant SiO_2 value, or are named according to petrographic criteria that suggest affinity to other units of the same petrologic group. Percentages of minerals are for phenocrysts and are estimated mainly from hand specimens. Size of minerals is maximum dimension. Size of clasts in sedimentary and pyroclastic deposits is maximum dimension. Where vent locations for volcanic units are not shown on the map or discussed, the vent area is assumed to be within or near present outcrops. Known or inferred sequence of units is shown in the correlation chart, in the cross sections, or can be determined from the map. For some key units, position in the sequence is given in the description. Most ages are potassium-argon (K/Ar) ages determined for whole-rock samples by Donnelly-Nolan and others (1981), unless otherwise noted. A few ages are carbon-14 ages or were estimated from geologic relationships. Magnetic polarities are from Mankinen and others (1978, 1981) or were determined in the field by B.C. Hearn, Jr., using a portable fluxgate magnetometer. Maximum thickness of units is unknown unless specified. Thickness for most units is estimated from topographic relief except where drill-hole data was available]

GENERAL AREA

Surficial Deposits

al — **Alluvium (Holocene)**—Flood-plain, channel, and lake deposits of clay, silt, sand, and gravel. Locally may include youngest part of the basin deposits of Clear Lake (bcl)

co — **Colluvium (Holocene)**—Slope deposits of silt, sand, and coarser angular clasts. Mapped only where extensive or where covers critical contact of bedrock units

af — **Alluvial-fan deposits (Holocene)**—Coarse deposits of sand and generally angular pebbles and boulders derived from nearby upslope sources

ls — **Landslide deposits (Holocene and Pleistocene)**—Unsorted angular blocks and soil. Largest landslide deposit is on the west side of Mount Konocti; consists of the dacite of Benson Ridge (dbr) and rhyodacite of Soda Bay (dsb) and has an inferred maximum thickness of at least 250 m. Contact between adjacent landslide deposits on map separates landslides of different age or direction of movement

t — **Terrace deposits, undivided (Holocene and Pleistocene)**—Dominantly pebble to boulder gravel and minor sand. Four terrace levels mapped in the lower parts of the Kelsey Creek, Sweetwater Creek, Cole Creek, McIntire Creek, and North Fork Cache Creek drainages; terrace levels probably are correlative between adjacent drainages. In the Cole and McIntire Creek drainages, gravel is a mixture of clasts of volcanic rock and resistant components of gravel recycled from the Kelseyville Formation. Maximum thickness about 5 m. Terrace levels differentiated from youngest (lowest) to oldest (highest)

t_4 — Unit 4 (Holocene and Pleistocene)

t_3 — Unit 3 (Pleistocene)

t_2 — Unit 2 (Pleistocene)

t_1 — Unit 1 (Pleistocene)

SOUTH OF MOUNT HANNAH

Older terrace deposits of upper Kelsey Creek area (Pleistocene)

tos — Terrace deposits of Sulphur Creek—Pebble to small boulder-size gravel. Contains clasts of the andesite of Boggs Mountain (abm), rhyodacite of Diener Drive (dd), obsidian from the rhyolite of Bonanza Springs (rbp), andesite of Split Top Ridge (ast), rhyodacite of Loch Lomond (dl), and abundant clasts of sandstone and shale of the Great Valley sequence (KJgv). Source local and to east; deposited by an ancestral west-flowing Sulphur Creek whose drainage basin extended farther east than at present. Maximum thickness 1 m

tob — Terrace deposits of Bottle Rock Road—Interbedded fluvial sand and pebble-boulder gravel. Contains abundant clasts derived from the Franciscan assemblage (KJf), and subordinate clasts of the andesite of Boggs Mountain (abm), rhyodacite of Cobb Mountain (dcf, dcp), dacite of Cobb Valley (dcv), and rhyolite of Alder Creek (raf, rap) that locally are up to 3 m diameter. Source to east and southeast; deposited in an ancestral Kelsey Creek drainage. Maximum thickness 20 m

tog — Terrace deposits of Glenbrook—Fluvial sand, silt, and gravel of pebble-size to rare small boulder-size clasts. Gravel forms up to 40 percent of some outcrops; gravel consists of 80 percent chert and greenstone clasts of the Franciscan assemblage (KJf), as well as pebbles reworked from Franciscan assemblage conglomerates, 15 percent clasts of the rhyodacite of Cobb Mountain (dcf, dcp), and 5 percent clasts of the rhyolite of Alder Creek (raf, rap). Locally contains a 20- to 30-cm-thick bed of altered tuff or lacustrine diatomite. Similar gravels occur in sec. 5, T. 11 N., R. 8 W. Source to south and southeast; deposited in an ancestral Alder Creek drainage. Maximum thickness 25 m

WESTERN AREA

bcl — **Basin deposits of Clear Lake (Holocene and Pleistocene)**—See description under central area and Mount Konocti. Shown only in cross section

tu — **Upland terrace deposits (named by Soil Mechanics and Foundation Engineers, Inc., 1967; termed older alluvium by Rymer, 1978, 1981) (Pleistocene)**—Poorly stratified sand, gravel, gravelly clay, and clayey sand. Occurs in Big Valley in a down-faulted block bounded on the south by the Wight Way fault and on the north by an unnamed fault; fault boundaries in part from Soil Mechanics and Foundation Engineers, Inc. (1967). Extent and age poorly known; apparently overlies the Kelseyville Formation (k) and is older than the high terrace deposits (t_1). Thickness 34 to 44 m (Rymer, 1978, p. 85)

k — **Kelseyville Formation, undivided (named by Rymer, 1981; includes pyroclastic and lake deposits of Shaul Valley area of Hearn and others, 1976) (Pleistocene)**—Well-bedded, lacustrine, deltaic, and fluvial deposits consisting of pebble-cobble conglomerate, pebbly sand, sand, silt, diatomaceous siltstone, claystone, pumiceous sandstone, and lapilli tuff. Clasts in conglomerates are 80–95 percent Franciscan assemblage rocks (chert, greenstone, graywacke of KJf) and serpentinite (Jsp), and 5–20 percent volcanic rocks from the dacite of Cobb Valley(?) (dcv), rhyolite of Alder Creek (raf, rap), andesite of Boggs Mountain (abm), and obsidian (rto) from the rhyolite of Thurston Creek. Clasts are derived from terrain to the south, southeast, or southwest. The formation was deposited in an ancestral Clear Lake basin. The Kelseyville Formation is probably co-extensive with similar deposits concealed at depth in Big Valley and beneath Clear Lake. Wood (sample number W-3420, U.S. Geological Survey Radiocarbon Laboratory, Reston, Va.) and a conifer cone (dated by Teledyne Isotopes, M.J. Rymer, oral commun., 1975) found 45 and 3 m below the base of the Kelsey Tuff Member in sec. 26 and sec. 27, T. 13 N., R. 9 W., respectively, are both older than 38,000 yr by the carbon-14 method. Age of the exposed base of the Kelseyville Formation is approximately 0.60 Ma, based on the average age of the rhyolite of Thurston Creek (Donnelly-Nolan and others, 1981); age of exposed top of the Kelseyville Formation is estimated to be 0.13 Ma by Rymer (1981), but is more likely 0.35 to 0.45 Ma based on ages of probable sources of the Kelsey Tuff Member on or south of Mount Konocti. Upper part of the Kelseyville Formation is eroded and lowest part is unexposed; thickness in map area about 390 m; minimum total thickness about 500 m (Rymer, 1981)

kk — Kelsey Tuff Member (named by Rymer, 1981; formerly aquifer ash of Hearn and others, 1976)—Upper part consists of 40–170 cm of poorly bedded, unsorted, gray to light-tan ash, lapilli, lapilli tuff, and tuff of crystal-poor, slightly vesicular basaltic andesite; lower part consists of 10–40 cm of interbedded tuff, claystone, and siltstone. Upper part is composed of 95 percent basaltic andesite fragments, and 5 percent lithic fragments (dacite, greenstone, chert, graywacke, and, rarely, diabasic-textured mafic fragments); average basaltic andesite fragment 0.5 cm diameter, maximum generally 6 cm diameter; basaltic andesite fragments contain about 1 percent small Franciscan assemblage inclusions. Lower part typically contains several gray to rusty 2–15-cm-thick beds of 1–3-mm-diameter basaltic andesite fragments; in Shaul Valley, lower part contains angular to rounded blocks up to 0.3 m diameter of several varieties of dacite. The Kelsey Tuff Member was deposited subaqueously from airfall into lake basin. Locally shows features of soft-sediment slump or redeposition, causing variable thickness. Source vent was probably one of the cinder cones on, beneath, or south of Mount Konocti. Kelsey Tuff Member occurs 30–40 m below eroded top of the Kelseyville Formation (Rymer, 1981), and it is a major aquifer as deep as 70 m beneath much of southern Big Valley (Soil Mechanics and Foundation Engineers, Inc., 1967). Beneath northern Big Valley, it is known to be as deep as 120 m and probably is present at greater depth. Total thickness 40–190 cm in outcrop, generally decreasing away from Mount Konocti

kr — Rhyolite-rich facies—Local facies occurring in secs. 2, 10, and 11, T. 12 N., R. 9 W. Present either at the base or as much as 25 m above the base of the Kelseyville Formation; consists of as much as 40 m of pumice-rich sandstone and conglomerate. Lies immediately above, or is laterally close to a section as much as 5 m thick of mudflow-deposited, massive, rhyolitic pumice conglomerate and lapilli tuff (rtp) of the rhyolite of Thurston Creek

dkc — **Rhyodacite of Kelsey Creek (Pleistocene)**—Flows and minor pyroclastic deposits of biotite rhyodacite. Thickness in Kelsey Creek gorge about 130 m

dch — **Rhyodacite of Camels Hump (Pleistocene)**—Flows, domes, and shallow intrusions of moderately porphyritic biotite-hornblende rhyodacite. Intrudes the rhyolite of Thurston Creek, intrudes and overlies the basaltic andesite diatreme breccia (bdb) and the rhyolite of Milky Creek (rm), and is overlain by the rhyodacite of Kelsey Creek (dkc) and Kelseyville Formation (k). Biotite-hornblende dacite of normal magnetic polarity in S1/2 sec. 26, T. 13 N., R. 9 W. tentatively correlated with this unit. Age of 0.59±0.02 Ma on sanidine. Maximum exposed thickness 80 m

rm — **Rhyolite of Milky Creek (Pleistocene)**—Flow or flows, coarse blocks and bombs, coarse pumice breccia, nonbedded and poorly bedded pyroclastic breccia, minor lapilli tuff, and minor mudflow deposits of commonly perlitic, crystal-rich biotite rhyolite; locally, massive pyroclastic breccia consists of mainly biotite-free crystal-rich pumice; locally pyroclastic breccia is rich in brown scoria derived from the basaltic andesite diatreme breccia (bdb), fragments of glassy dacite, fragments of chert, greenstone, and graywacke derived from the Franciscan assemblage (KJf), and fragments of serpentinite (Jsp). Intrudes and contains inclusions of the basaltic andesite diatreme breccia (bdb); contains inclusions of, and probably overlies, the rhyolite of Thurston Creek; intruded by, and overlain by, the rhyodacite of Camels Hump (dch). Closely resembles the rhyolite of Cole Creek (rcc), but the rhyolite of Milky Creek is apparently older based on a K/Ar age of 0.60±0.02 Ma on sanidine. Maximum exposed thickness 60 m

bdb — **Basaltic andesite diatreme breccia (Pleistocene)**—Altered, coarse, nonbedded to poorly bedded diatreme breccia and derivative pyroclastic breccia of gray-to-brown basaltic andesite scoria. Breccia contains blocks up to 30 cm diameter of black, glassy, crystal-poor dacite and serpentinite, as well as blocks up to several m diameter of conglomerate containing clasts of chert, graywacke, and serpentinite. Breccia also contains rounded chert pebbles; angular fragments of obsidian (rto) from the rhyolite of Thurston Creek; angular fragments of chert, graywacke, and shale from the Franciscan assemblage (KJf); and a 2-m-diameter block of schistose amphibolite. Unit in part hydrothermally altered in SW corner sec. 36, T. 13 N., R. 9 W. Maximum exposed thickness about 35 m

Rhyolite of Thurston Creek (Pleistocene)—See description under central area and Mount Konocti. Subdivided into three map units

rto — Obsidian

rts — Stony rhyolite

rtp — Pyroclastic deposits

dtv — **Dacite of Tyler Valley (Pleistocene)**—Isolated, irregular to dikelike shallow intrusions of sparsely porphyritic dacite west of the main Clear Lake volcanic field. Intrudes the Franciscan assemblage (KJf). Ages of 0.86±0.02 Ma and 0.82±0.02 Ma on sanidine do not fit normal magnetic polarity; however, age of 0.711±0.011 Ma on sanidine by the 40/39 argon method (J.D. Obradovich, oral commun., 1994) fits normal magnetic polarity. Exposed vertical extent about 60 m

bs — **Olivine basalt north of Sweetwater Creek (Pleistocene)**—Poorly exposed small diatreme composed of light-brown, partly weathered tuff and lapilli tuff of olivine basalt and sparsely porphyritic andesite. Consists of 80–100 percent of 1–25-mm-diameter subrounded fragments of vesicular olivine-rich basalt that, in part, have cores of olivine phenocrysts, and 0–20 percent of separate olivine crystals and fragments of vesicular or solid, phenocryst-poor andesite of unknown derivation that become more abundant at top of exposure. Overlain by basal part of the Kelseyville Formation (k). Possibly similar in age to the olivine basalt of Caldwell Pines (bcf, bci, bcd, bcp) based on similar abundance of olivine. Exposed thickness 10 m

CENTRAL AREA AND MOUNT KONOCTI

Younger basin deposits (Holocene and Pleistocene)

bcl — Basin deposits of Clear Lake—Shown only in cross section. Deltaic, lacustrine, marsh, and marginal fluvial deposits composed of gravel, sand, silt, clay, mud, peat, and volcanic ash (Sims, Adam, and Rymer, 1981). Age ranges from present to greater than 0.175 Ma based on paleomagnetic and preliminary pollen analyses (core CL-80–1, Sims, Rymer, and Perkins, 1981). Lower part may overlie or grade into the Kelseyville (k) and Lower Lake (ll) Formations. Maximum thickness greater than 177 m

be — Basin deposits of Ely Flat—Lacustrine, fluvial, and coarse alluvial deposits composed of clay, silt, sand, and gravel in subsidence basin surrounding Sugarloaf. Contains fragments of the dacite of Plum Flat (dpf) and various dacites from the Mount Konocti volcanic edifice. Deposits derived from surrounding slopes and ancestral upper drainage basin of Thurston Creek. Age ranges from present to probably less than 0.5 Ma. Exposed thickness about 25 m; drilled thickness about 120 m

yp — **Young pyroclastic deposits (Holocene and Pleistocene)**—Well-bedded coarse ash and tuff, lapilli tephra, and lapilli tuff; blocks and bombs are locally abundant; commonly weathered to dark-orange soil. Typically exhibits alternating coarse-grained (0.5–15 cm) and fine-grained (<2 mm) layers that are 1–15 cm thick and show graded bedding or, rarely, reverse-graded bedding. Dominant fragments are white, yellow, and brown hydrothermally altered scoria, or gray-to-black fresh scoria mainly of andesite and basaltic andesite and, rarely, of dacite. Unit contains 1–20 percent of 1–100-cm-diameter fragments of older units of the Clear Lake Volcanics, and fragments of chert, serpentine, greenstone, graywacke, and shale from the Franciscan assemblage (KJf) and Great Valley sequence (KJgv). Unit consists dominantly of airfall deposits (rarely reworked by water or by slumping) and contains lesser amounts of maar deposits from underwater or phreatic eruptions (based on presence of mud-armored lapilli and distinct bomb sags) and base-surge deposits. Sources are: (1) inferred vents suggested by arcuate segments of the Clear Lake shoreline, by lake-bottom topography, and by localized, bedded pyroclastic deposits along the lake shore; (2) vent beneath Little Borax Lake maar; (3) inferred vent north-northwest of the Bell Mine; and (4) cinder cones east of Clearlake Oaks. Wide age range; probably correlates in part with ash beds in sediments beneath Clear Lake; youngest ash bed beneath Clear Lake is in core 7 taken midway between Fraser Point and Pirates Cove and is about 11,000 years old (Sims, Adam, and Rymer, 1981); oldest part is near Bell Mine, is apparently overlain by the basaltic andesite south of Howard Peak (bshf, bshp), and is about 0.35 Ma. Maximum exposed thickness about 60 m

ba — **Basaltic andesite of Anderson Island (Pleistocene)**—Flow(?) of blocks up to 1.7 m diameter of slightly vesicular olivine basaltic andesite; contains 1–2 percent black, cuspate, partially melted inclusions of the phenocryst-rich rhyodacite of Horseshoe Bay (dh). Covers area 10x10 m above lake level; source close to outcrop on north shore of Anderson Island. Exposed thickness 2 m

Basaltic andesite of Buckingham Peak (Pleistocene)—Olivine basaltic andesite. Unit is partly removed by landslide that may be related to eruptions which produced the maar at Little Borax Lake; fragments of this unit are common in young pyroclastic deposits (yp) northwest, north, and east of Buckingham Peak

bbf — Flow—Maximum thickness 10 m

bbp — Pyroclastic deposits—Eroded cinder cone composed of bomb, block, and lapilli tephra. Maximum thickness 50 m

bh — **Basaltic andesite of Horseshoe Bend (Pleistocene)**—Blocky flow, bombs, and scoria of porphyritic olivine basaltic andesite. Deposited on flank of its cinder-cone source that was subsequently destroyed by the explosive eruption that shaped Horseshoe Bay. Maximum thickness of flow 5 m and of pyroclastic deposits about 80 m

dwp — **Rhyodacite of Wright Peak (Pleistocene)**—Flows and dome of coarsely and abundantly porphyritic biotite rhyodacite. Contains 1–5 percent of 3–10-mm pyroxene-plagioclase mafic inclusions having a granular texture. Surfaces of flows on east slope of Wright Peak show arcuate flow ridges, which are known locally as the upper "lava rings" (Mauldin, 1960). Overlies the basaltic andesites south of Howard Peak (bshf, bshp) and north of Howard Peak (bnh). Youngest of the rhyodacite and dacite units on Mount Konocti; age of 0.35±0.02 Ma on sanidine. Maximum thickness 150 m

Basaltic andesite south of Howard Peak (Pleistocene)—Olivine-clinopyroxene basaltic andesite. Contains 0–0.25 percent of inclusions of 1–5-mm-diameter potassium feldspar, plagioclase, and quartz and 0–1 percent of 2–40-mm-diameter inclusions of solid, or frothy, partially melted dacite and biotite rhyolite. Forms eroded pyroclastic blanket on high south slope of Mount Konocti. Overlies the dacites of Benson Ridge (dbr) and Mount Konocti (dmk); may be interbedded with or grade into the young pyroclastic deposits (yp) 1 km west of Bell Mine. Maximum exposed thickness about 50 m

bshf — Flow—Subordinate part of unit; forms ledge. Maximum thickness 5 m

bshp — Pyroclastic deposits—Dominant part of unit; bomb, block, and lapilli tephra

bnh — **Basaltic andesite north of Howard Peak (Pleistocene)**—Phenocryst-poor basaltic andesite. Coarse bomb, block, and lapilli tephra, and thin vesicular flow covering a 50x20 m area. Contains rare inclusions of 1–2-mm-diameter plagioclase, potassium feldspar, and quartz and 0.5–1 percent of 2-mm- to 30-cm-diameter solid or frothy, partially melted inclusions of dacite and biotite rhyolite. Forms pair of eroded ridges that are subdued remnants of low cinder cone. Probably contemporaneous with the basaltic andesite south of Howard Peak (bshf, bshp); overlain by the rhyodacite of Wright Peak (dwp) and probably overlain by the basaltic andesite of Buckingham Peak (bbf, bbp). Maximum exposed thickness about 130 m

dmk — **Dacite of Mount Konocti (Pleistocene)**—Flows of medium-grained, moderately porphyritic dacite, commonly spherulitic. Most feldspar and quartz phenocrysts are 1–3 mm in size, in contrast with the larger phenocrysts in other dacite and rhyodacite units high on Mount Konocti. Probable source is 0.2 km west-northwest of Wright Peak, at or close to the vent symbol; vent is a partially caved, near-vertical passage reported to be of great vertical extent (Mauldin, 1960, p. 53–55) and is surrounded by blocks of oxidized dacite and welded dacite spatter. Maximum thickness less than 60 m

dbr — **Dacite of Benson Ridge (Pleistocene)**—Flows and domes of coarsely and abundantly porphyritic biotite dacite. Contains 1–2 percent of diabasic-textured pyroxene-plagioclase mafic inclusions as much as 1.2 m diameter. Main source on South Peak and possible additional vents on Benson Ridge and east of Shaul Valley. Maximum exposed thickness 300 m

dbb — **Dacite of Buckingham Bluffs (Pleistocene)**—Flow of moderately porphyritic dacite. Contains 0.5 percent of granular-textured pyroxene-plagioclase mafic inclusions. Source vent concealed near present summit of Buckingham Peak. Youngest dacite unit on Buckingham Peak. Maximum thickness 150 m

dhp — **Dacite of Henderson Point (Pleistocene)**—Flows of coarsely porphyritic biotite dacite. Similar in appearance to the rhyodacite of Soda Bay (dsb), but dacite of Henderson Point contains fewer large sanidine phenocrysts. Probable vent area just south of present summit of Buckingham Peak. Maximum exposed thickness 200 m

dsb — **Rhyodacite of Soda Bay (Pleistocene)**—Flows and domes of coarsely and abundantly porphyritic biotite rhyodacite. Additional extent concealed beneath Big Valley and Clear Lake. Unit may represent more than one eruption; source vents lie beneath Wright Peak and possibly 0.8 km north-northwest of Howard Peak. Major flow moved west and north forming Clark Peak and Dali-Dona; smaller flow shows prominent arcuate flow ridges, known locally as lower "lava rings" (Mauldin, 1960) on the east slope of Wright Peak. Average of 2 ages is 0.42 Ma; probably younger than the dacite north of Ely Flat (dne) and older than the rhyodacite of Wright Peak (dwp), which is dated at 0.35 Ma. Maximum thickness about 400 m

dh — **Rhyodacite of Horseshoe Bay (Pleistocene)**—Flow of coarsely porphyritic rhyodacite; perlitic on Anderson Island and shore of Horseshoe Bay, probably caused from flowing into water. On Anderson Island, this rhyodacite was formerly the biotite dacite of Kamdot of Hearn and others (1976). Contains abundant diabasic-textured mafic inclusions, up to 0.5 m diameter, that make up as much as 25 percent of flow on Anderson Island; contains sparse 5–25-cm-diameter inclusions of the dacite of Fraser Point (df). Source concealed above 3,300-ft elevation on Buckingham Peak. Age of 0.35±0.02 Ma on sanidine. Maximum exposed thickness 230 m

df — **Dacite of Fraser Point (Pleistocene)**—Flows of sparsely porphyritic dacite. Source vent located near western limit of unit's outcrop area, at about 3,300-ft elevation on east side of ridge that joins Howard Peak and Buckingham Peak. Probably overlain by the rhyodacite of Horseshoe Bay (dh). Exposed thickness 200–300 m

dbm — **Dacite of Bell Mine (Pleistocene)**—Flow of moderately porphyritic dacite; altered to white opalized dacite at Bell Mine. Source vent now mostly buried at about 3,300-ft elevation southeast of South Peak. Maximum exposed thickness 120 m

dne — **Dacite north of Ely Flat (formerly older hornblende dacite of Mt. Konocti of Hearn and others, 1976) (Pleistocene)**—Flows of moderately porphyritic hornblende dacite. Probable source vent concealed near 3,000-ft elevation on Mount Konocti in NE1/4 sec. 20, T. 13 N., R. 8 W. Maximum exposed thickness about 300 m

dkb — **Dacite of Konocti Bay (Pleistocene)**—Flows and domes of moderately porphyritic dacite. Source vent concealed, probably located north of Ely Flat, in sec. 21, T. 13 N., R. 8 W. Exposed thickness about 200 m

dsv — **Dacite of Shaul Valley (Pleistocene)**—Domal flows of sparsely porphyritic hornblende-biotite dacite. Probably overlies the basaltic andesite east of Shaul Valley (besf, besp); overlain by the dacite of Benson Ridge (dbr). Maximum thickness at least 130 m

as — **Speckled andesite (Pleistocene)**—Shown only in cross section A-A'. Andesite has distinctive speckled texture due to the presence of 10–15 percent of 0.25–2-mm plagioclase phenocrysts. No outcrops of the speckled andesite are known, but occurs as inclusions in the young pyroclastic deposits (yp) between Soda Bay and Fraser Point and at 120-m depth in a water well in NE1/4SE1/4 sec. 9, T. 13 N., R. 8 W. Inferred to underlie much of the low part of the eastern flank of Mount Konocti. Probably older than the rhyodacites of Horseshoe Bay (dh) and Soda Bay (dsb) and the dacites of Fraser Point (df) and Henderson Point (dhp). Thickness unknown

Older basin deposits (Pleistocene)

boc — Basin deposits southeast of Camel Back Ridge—Poorly exposed lacustrine, alluvial, and minor pyroclastic deposits in small local basin. Consists of silty claystone, diatomaceous siltstone, and lapilli tuff of rhyolitic pumice. Unit contains fragments of black obsidian and of pink and gray dacite, sparse 1–3-cm-diameter pebbles of vesicular gray dacite, abundant 1–3-mm-diameter quartz, and sparse 1-mm-diameter biotite flakes. Lapilli tuff of crystal-rich biotite rhyolite pumice is locally cemented by siliceous sinter. Probably overlies obsidian (rto) of the rhyolite of Thurston Creek and steeply tilted beds of the Kelseyville Formation (k) on the north side of basin. Exposed thickness about 2 m; maximum thickness probably about 20 m

bowr — Basin deposits of Wildcat Road—Poorly exposed claystone, siltstone, diatomaceous siltstone, pumiceous sandstone, and conglomerate. Conglomerate contains pebbles of obsidian, andesite or dacite, and chert. Overlies obsidian (rto) of the rhyolite of Thurston Creek, andesites of Split Top Ridge (ast) and Glenview (ag), rhyodacite of Diener Drive (dd), and older dacite of Mount Hannah (doh). Exposed thickness about 15 m

botc — Basin deposits of lower Thurston Creek—Well-bedded lacustrine and deltaic deposits composed of clay, silt, diatomaceous siltstone, pumiceous sandstone, and pyroclastic tuff and lapilli tuff. Rarely contains gastropod molds, and some beds are rich in silicified plant debris, or are locally rich in iron oxide, causing them to weather orange or red. Locally contains pebbles of chert, greenstone, graywacke, shale, and the glassy rhyodacite of Diener Drive (dd). North of Manning Flat, basal part contains locally derived boulder conglomerate of obsidian (rto) and pumice (rtp) from the rhyolite of Thurston Creek in tuffaceous matrix; boulder conglomerate is overlain by 30–60 cm of evenly bedded, light-gray dacitic(?) pumice of 0.25–1.5 cm diameter. Exposed thickness about 30 m

bob — Basin deposits of Bonfield Flat (formerly basin deposits of Konocti Conservation Camp of Hearn and others, 1976)—Poorly exposed, white, rhythmically layered beds of diatomaceous claystone and siltstone, fine-grained tuffaceous sandstone, and a few beds of tuffaceous sandstone containing pebbles and cobbles of obsidian and dacite. Overlies the rhyodacite of Diener Drive (dd) and obsidian (rto) of the rhyolite of Thurston Creek; may be contemporaneous with the basin deposits of lower Thurston Creek (botc) and upper part of the Lower Lake Formation (ll). Thickness at least 40 m

Rhyolite north of McIntire Creek (formerly dacite of Cleft Hill of Hearn and others, 1976) (Pleistocene) —Moderately crystal-rich, locally perlitic, biotite rhyolite. Youngest unit in complex sequence east of Mount Olive; overlies flows (bmf) of the basaltic andesite of McIntire Creek, pyroclastic deposits (rwsp) of the rhyolite west of Sugarloaf, obsidian (rto) of the rhyolite of Thurston Creek, and rhyolite northeast of Mount Olive (rno). Maximum thickness about 25–40 m

rnmp — Pyroclastic deposits—Coarse bomb and block tephra and lapilli tuff. Contain sparse obsidian fragments and, close to source vent, contain blocks of vesicular biotite rhyolite up to 1.5 m in diameter

rnmf — Flows—Small lateral extent

dp — **Dacitic pyroclastic deposit north of McIntire Creek (Pleistocene)**—Light-tan pyroclastic breccia. Contains blocks of biotite dacite and biotite-hornblende dacite up to 60 cm diameter, sparsely porphyritic obsidian fragments up to 5 cm diameter derived from the rhyolite of Thurston Creek (rto) or the rhyolite south of McIntire Creek (rsm), and rare small fragments of chert; blocks of biotite rhyolite absent. Overlies the rhyolite west of Sugarloaf (rwsp), basaltic andesite west of Sulphur Mound Mine (bws), mixed pyroclastic deposit west of Sulphur Mound Mine (mp), and obsidian (rto) of the rhyolite of Thurston Creek. Maximum thickness about 20 m

Rhyolite west of Sugarloaf (formerly biotite rhyolite pyroclastic deposits west of Sugarloaf of Hearn and others, 1976) (Pleistocene)—Crystal-rich biotite rhyolite. Exposed area is 1 km^2, but concealed extent may exceed 3 km^2; present in both Magma 1 Watson and in Getty 1 Kettenhofen drill holes. Source probably near present outcrops northwest or west of Sugarloaf. Scattered fragments of this rhyolite occur on top of the obsidian (rto) of the rhyolite of Thurston Creek as much as 3 km east-southeast of Ely Flat. Overlain by the dacites of Konocti Bay (dkb) and north of Ely Flat (dne). Age of 0.54±0.02 Ma on sanidine. Maximum exposed thickness 65 m

rwsf — Flow—Perlitic glassy crystal-rich biotite rhyolite. West of Ely Flat

rwsp — Pyroclastic deposits—Pyroclastic breccia and lapilli tuff; mostly nonbedded to poorly bedded, only locally well bedded. Biotite rhyolite pumice lapilli and blocks of pumice and lithic biotite rhyolite, both up to 1 m diameter, make up 90–95 percent of deposit. Also contains lithic fragments and blocks up to 70 cm diameter of biotite-hornblende dacite resembling the rhyodacites of Sugarloaf (dsl) or Mount Olive (dof, dop), diabasic-textured mafic inclusions up to 40 cm diameter, fragments of basaltic andesite, and rare fragments and blocks up to 15 cm diameter of the black glassy rhyodacite of Diener Drive (dd); obsidian fragments absent. Mainly airfall deposits, locally reworked by water; local well-bedded airfall layers 1–15 cm thick contain pumice fragments up to 12 cm diameter, fragments of chert and graywacke averaging 6 mm diameter, and abundant clear quartz grains of 1–3 mm diameter

bl — **Basaltic andesite of Lower Lake Road (Pleistocene)**—Flows, coarse blocks and bombs, and pyroclastic breccia of sparsely porphyritic basaltic andesite. Overlies and contains partially melted inclusions of the rhyodacite of Mount Olive (dop, dof) and rhyolite northeast of Mount Olive (rno). Maximum exposed thickness 50 m

Basaltic andesite east of Shaul Valley (Pleistocene)—Basaltic andesite. Contains vesicular, partially melted blocks of crystal-rich dacite that lack visible biotite or hornblende. Source near main exposure. Overlain by the dacites of Benson Ridge (dbr) and Shaul Valley (dsv); possibly contemporaneous with the basaltic andesite of Lower Lake Road (bl). Exposed thickness about 50 m

besf — Flows

besp — Pyroclastic deposits—Bomb, block, and lapilli tephra

bws — **Basaltic andesite west of Sulphur Mound Mine (Pleistocene)**—Porphyritic plagioclase-olivine basaltic andesite. Small flow, vent plug(?), and pyroclastic deposits of bomb, block, and lapilli tephra containing coarse scoriaceous bombs and blocks up to 3 m diameter. Contains partially fused inclusions of the rhyodacite of Sulphur Mound Mine (dsm) up to 30 cm diameter. Small area of oxidized basalt and massive fresh basalt in SW1/4SE1/4 sec. 32, T. 13 N., R. 8 W. may be a small flow and vent plug. Overlies the mixed pyroclastic deposit west of Sulphur Mound Mine (mp), apparently overlies obsidian (rto) of the rhyolite of Thurston Creek and rhyodacite of Sulphur Mound Mine (dsm); overlain by the rhyolite west of Sugarloaf (rwsp) and dacitic pyroclastic deposit north of McIntire Creek (dp). Maximum thickness about 10 m

aws — **Andesite west of Shaul Valley (formerly basalt west of Shaul Valley of Hearn and others, 1976) (Pleistocene)**—Bomb and block tephra, small flow(?), and dikes of sparsely porphyritic andesite. Vented from dikes that cut the rhyolite of Cole Creek (rcc) and rhyodacite of Mount Olive (dof, dop). Also vesicular blocks of this andesite up to 30 cm diameter (containing partially melted inclusions of the biotite rhyolite of Cole Creek (rcc)) are 5–10 percent of a mudflow(?) deposit of mixed biotite rhyolite and andesite that overlies the rhyolite of Cole Creek (rcc) in center N1/2 sec. 26, T. 13 N., R. 9 W. Maximum thickness about 5 m

rcc — **Rhyolite of Cole Creek (Pleistocene)**—Lapilli tuff, pumice breccia, and flows of predominantly perlitic, crystal-rich biotite rhyolite. Area of unit in center of N1/2 sec. 26, T. 13 N., R. 9 W. includes an overlying mudflow(?) deposit 1–3 m thick, composed of 90–95 percent biotite rhyolite fragments up to 30 cm diameter and 5–10 percent scoria from the andesite west of Shaul Valley (aws). Biotite rhyolite occurs in drill holes beneath Gunn Flat and at 123-m depth in NE1/4 sec. 15, T. 13 N., R. 9 W. in Big Valley. Apparently overlies the rhyodacite of Mount Olive (dof, dop); overlain by the Kelseyville Formation (k) and dacite of Benson Ridge (dbr); cut by dikes of the andesite west of Shaul Valley (aws). Age of 0.54±0.02 Ma on sanidine. Maximum exposed thickness 80 m

rno — **Rhyolite northeast of Mount Olive (Pleistocene)**—Bomb, block, and lapilli tephra, pyroclastic breccia, lapilli tuff, and tuff of crystal-rich biotite rhyolite. Poorly exposed, mostly nonbedded. Consists of pumice lapilli, pumice blocks, and lithic blocks up to 70 cm diameter; locally contains biotite-free rhyolitic pumice, blocks of crystal-poor biotite dacite up to 50 cm diameter, and fragments of chert up to 2 cm diameter; obsidian fragments absent. Closely similar to the rhyolites west of Sugarloaf (rwsp), of Milky Creek (rm), and of Cole Creek (rcc). Occurs as inclusions in, and is overlain by, the basaltic andesite of Lower Lake Road (bl). Maximum exposed thickness 25 m

mp — **Mixed pyroclastic deposit west of Sulphur Mound Mine (Pleistocene)**—Bomb, block, and lapilli tephra, pyroclastic breccia, and lapilli tuff composed of mixed fragments of rhyolite, dacite, Franciscan assemblage (KJf), and Great Valley sequence (KJgv) in variable proportions in a clayey matrix. Poorly bedded; deposited mainly by airfall from explosive rhyolitic eruption. Contains beds rich in biotite-free, sparsely porphyritic rhyolitic pumice of average diameter 10 mm; largest blocks or bombs of that pumice, up to about 1 m diameter, occur in beds in western part of unit. Unit contains abundant 1–3-mm-diameter quartz grains. Unit also contains blocks of biotite-hornblende dacite and biotite dacite up to 25 cm diameter, sparsely porphyritic obsidian fragments up to 5 cm diameter, abundant light-gray altered fragments, rare black glassy fragments possibly of the rhyodacite of Diener Drive (dd), and abundant angular 2–10-mm-diameter fragments of shale, siltstone, sandstone, and chert from the Franciscan assemblage (KJf) and the Great Valley sequence (KJgv). Erupted either from the vent for the rhyolite south of McIntire Creek (rsm) or another nearby source. Maximum thickness about 65 m

rsm — **Rhyolite south of McIntire Creek (formerly rhyolite of Hildebrand Springs of Hearn and others, 1976) (Pleistocene)**—Vent breccia of pumice lapilli, pumice blocks, fused pumice breccia, and obsidian composed of sparsely porphyritic rhyolite. Fused pumice breccia outlines part of border of vent. Obsidian closely resembles obsidian (rto) of the rhyolite of Thurston Creek. Cuts flow (bmf) of the basaltic andesite of McIntire Creek. Exposed thickness 25 m

Basaltic andesite of McIntire Creek (Pleistocene)—Sparsely porphyritic basaltic andesite. Maximum thickness about 80 m in eastern part of unit, about 10 m in western part of unit

bmp — Pyroclastic deposits—Bomb, block, and lapilli tephra forming subdued, eroded cinder cone; basaltic andesite in cinder cone is slightly more olivine rich than in flows

bmf — Flows

Rhyolite of Red Hill Road (Pleistocene)—Porphyritic biotite-feldspar rhyolite. Age of 0.50±0.02 Ma on sanidine

rrp — Pyroclastic deposits—Coarse bomb and block tephra composed of pumice and perlitic blocks as much as 1.5 m diameter and diabasic-textured andesitic inclusions as much as 0.5 m diameter (Stimac and others, 1991). Unit contains more abundant phenocrysts than flow and is slightly younger(?) than flow. Exposed thickness 40 m

rrf — Flow—Biotite- and feldspar-bearing obsidian. Exposed thickness 20 m

Rhyolite of Thurston Creek (Pleistocene)—Sparsely porphyritic rhyolite. Contains less than 1 percent of andesitic inclusions, most of which are less than 10 mm diameter (Stimac and others, 1991). Pyroclastic deposits (rtp), obsidian (rto), and stony rhyolite (rts) mapped separately in most of area. Dominant exposed lithology is obsidian; however, stony rhyolite is dominant in total thickness of flows. Pumiceous carapace largely eroded from surface of flows, but locally preserved where initially thicker or where previously covered by younger deposits. Rhyolite in Camel Back Ridge area may be separate flow erupted from local vents, but probably is contemporaneous with rhyolite farther east. Ages on obsidian samples are 0.479±0.015 Ma north of Manning Flat, 0.56±0.02 Ma in unit rtp at Sulphur Mound Mine, 0.551±0.016 Ma in Bottle Rock Road road cut on Camel Back Ridge, and 0.64±0.03 Ma in SW1/4NE1/4 sec. 12, T. 12 N., R. 9 W. on Camel Back Ridge; estimated actual age of about 0.60 Ma is on the basis of ages on underlying and overlying units. Maximum exposed thickness 130 m; thickness in Republic 77–1 Boggs drill hole northwest of Mount Hannah is 300 m

rto — Obsidian—Outer part of flow(s)

rts — Stony rhyolite—Devitrified inner part of flow(s)

rtp — Pyroclastic deposits—Bomb, block, and lapilli tephra, pyroclastic breccia, lapilli tuff, and tuff, locally present beneath flow(s). Near-vent deposits at Sulphur Mound Mine contain pumice, obsidian, and altered fragments of the rhyodacite of Sulphur Mound Mine (dsm) up to 30 cm diameter

dsl — **Rhyodacite of Sugarloaf (Pleistocene)**—Dome and flows(?) of abundantly and coarsely porphyritic biotite-hornblende rhyodacite. Probable source vent is faulted dome at Sugarloaf. Maximum exposed thickness 100 m

dsm — **Rhyodacite of Sulphur Mound Mine (Pleistocene)**—Flow or dome of moderately porphyritic biotite rhyodacite, mostly altered to opalized white dacite. Oldest unit in Sulphur Mound Mine area; ages of 0.60±0.02 Ma on sanidine from altered rock sample and 0.57±0.02 Ma on sanidine from fresh rock sample. Minimum thickness 100 m

Rhyodacite of Mount Olive (Pleistocene)—Abundantly porphyritic biotite-hornblende rhyodacite. Overlain by obsidian (rto) and stony rhyolite (rts) of the rhyolite of Thurston Creek, Kelseyville Formation (k), basaltic andesite of Lower Lake Road (bl), pyroclastic deposits (rwsp) of the rhyolite west of Sugarloaf, and rhyolite northeast of Mount Olive (rno); probably overlain by the rhyolite of Cole Creek (rcc) and dacite of Benson Ridge (dbr); cut by dikes of the andesite west of Shaul Valley (aws). Age of 0.53±0.02 Ma on sanidine is too young; true age must be older than the overlying rhyolite of Thurston Creek dated at about 0.60 Ma. Maximum exposed thickness 180 m

dop — Pyroclastic deposits—Block tephra, lapilli tephra, and pyroclastic breccia

dof — Flows and domes

CLEARLAKE HIGHLANDS—THURSTON LAKE AREA

bcl — **Basin deposits of Clear Lake (Holocene and Pleistocene)**—See description under central area and Mount Konocti. Shown only in cross section

rb — **Rhyolite of Borax Lake (Pleistocene)**—Flow of sparsely porphyritic to nonporphyritic obsidian and perlite and locally preserved carapace of coarse pumice blocks. Contains sparse mafic lithic inclusions that were derived from the underlying dacite of Clearlake Park (dcpk) and basaltic andesite of Arrowhead Road (bar) or that represent quenched magmas of intermediate to mafic composition. Age of 0.091±0.013 Ma on obsidian. Exposed thickness about 20 m

dcpk — **Dacite of Clearlake Park (Pleistocene)**—Blocky flow of glassy olivine-bearing dacite. Contains inclusions of baked sandstone of Franciscan assemblage (KJf) or Great Valley sequence (KJgv) and of the basaltic andesite of Arrowhead Road (bar). Exposed thickness 10–15 m

bar — **Basaltic andesite of Arrowhead Road (Pleistocene)**—Subdued cinder cone and small satellitic areas of bomb and block tephra of olivine basaltic andesite. Overlain by the rhyolite of Borax Lake (rb) and dacite of Clearlake Park (dcpk). Well data indicate that flank of cinder cone is overlain by 60 m of alluvium (al) and lacustrine sediments (bcl?) in SW1/4SE1/4 sec. 16, T. 13 N., R. 7 W. Exposed thickness 10 m

Basaltic andesite of Roundtop Mountain (Pleistocene)—Olivine basaltic andesite. Flow erupted from breached cinder cone and probably from fissures indicated by east-west vertically sheeted ribs between the cinder cone and a small area of coarse tephra 1.8 km to the east

brp — Pyroclastic deposits—Bomb, block, and lapilli tephra. Cinder cone 200 m high and smaller isolated deposit to east

brf — Flow—Thickness 20 m

tb — **Terrace deposits of Burns Valley (Pleistocene)**—Sand and gravel predominantly composed of chert and greenstone clasts reworked from the Cache Formation (QTc) and rare cobbles of early basaltic rocks (beu, beup, beui). Contains thin fine-grained basaltic tuffs (yp?) in road cuts along State Route 53 on west edge sec. 14, T. 13 N., R. 7 W. Forms subdued flat-topped topography that is less dissected than that underlain by the Cache Formation (QTc). Extensive distribution indicates deposition by a larger ancestral drainage system that was possibly related to a former outlet of Clear Lake east of Clearlake Oaks and through Ogelene Canyon. Maximum thickness probably less than 100 m

gpl — **Gravel deposit east of Pinkeye Lake (Pleistocene)**—Stream gravel composed of pebbles and small cobbles in an orange sandy matrix. Contains clasts of obsidian (rto) from the rhyolite of Thurston Creek, dacite from nearby dacite units, and chert from the Franciscan assemblage (KJf). Derived from Manning Flat area and deposited in a former eastward drainage through Pinkeye Lake. Maximum thickness 2–3 m

dcc — **Dacite of Cache Creek (Pleistocene)**—Dome and rubbly flows of sparsely porphyritic dacite. Overlies the Lower Lake Formation (ll) and dacite of Clearlake Highlands (dhi). Age of 0.40±0.04 Ma. Maximum exposed thickness 60 m

dw — **Dacite of Wheeler Point (Pleistocene)**—Domes and flows of moderately porphyritic, quartz-rich dacite. Contains 3–5 percent of 1–5-mm-diameter quartz that is commonly rimmed by clinopyroxene. Shows steep flow fronts along shore of Clear Lake. Flows north of Thurston Lake probably fed by vents or fissures aligned west-northwest in present outcrop area; other sources at south end of Konocti Bay. Probably overlies the dacite of Konocti Bay (dkb). Maximum exposed thickness 200 m

dst — **Dacite south of Thurston Lake (formerly dacite of Vulture Rock of Hearn and others, 1976) (Pleistocene)**—Flows and domes of moderately porphyritic dacite. Age of 0.44±0.03 Ma. Maximum thickness about 150 m

dpf — **Dacite of Plum Flat (Pleistocene)**—Flows and domes of abundantly porphyritic, hornblende-biotite dacite. Maximum exposed thickness 130 m

dt — **Dacite of Thurston Lake (Pleistocene)**—Two or possibly three coalesced flows, domes, and minor pyroclastic deposits of moderately porphyritic dacite. Most specimens contain one or more 1-cm-diameter or larger phenocrysts of feldspar and diabasic-textured mafic inclusions. Exposed thickness about 250 m

dpl — **Dacite of Pinkeye Lake (Pleistocene)**—Flows and domes of moderately porphyritic dacite. Base of unit along south margin shows patches of black glassy porphyritic dacite. Age of 0.48±0.03 Ma. Maximum thickness about 200 m

dhi — **Dacite of Clearlake Highlands (Pleistocene)**—Flows of moderately porphyritic dacite; lacks diabasic-textured mafic inclusions. Interbedded with and overlain by the Lower Lake Formation (ll). Age of 0.52±0.06 Ma. Maximum exposed thickness 50 m

dpp — **Rhyodacite of Peacock Point (Pleistocene)**—Flow or domes of moderately porphyritic rhyodacite. Probably older than the dacite of Clearlake Highlands (dhi). Exposed thickness about 20 m

Older basin deposits (Pleistocene)

botc — Basin deposits of lower Thurston Creek—See description under central area and Mount Konocti

Rhyolite of Thurston Creek (Pleistocene) —See description under central area and Mount Konocti

rto — Obsidian

ll — **Lower Lake Formation (named by Rymer, 1981; includes basin deposits of Wildcat Canyon of Hearn and others, 1976) (Pleistocene)**—Lacustrine, marsh, fluvial, pyroclastic, and volcaniclastic deposits in an ancestral Clear Lake basin. West of and at Lower Lake, composed of dominantly sandstone and siltstone and lesser amounts of claystone, diatomaceous siltstone, conglomerate, and tuff; conglomerate contains pebbles and cobbles of chert, andesite, dacite, the rhyodacite of Diener Drive (dd), and, rarely, obsidian. Near Lower Lake, unit contains beds of pebbly fossiliferous limestone up to 1 m thick and numerous beds of tuff and lapilli tuff of mafic to silicic composition up to 1.3 m thick (Rymer, 1981). North of Lower Lake, unit contains siliceous siltstone and mudstone, which commonly have root casts and diatom and gastropod fossils, and also contains 0.3–3-m-thick beds of orange limonitic mudstone that are especially prominent within Redbank Gorge, 0.5–2-m-thick beds of tan to gray, surgelike lapilli tuff of basaltic andesite, and rare beds of carbonaceous mudstone. Unconformably overlies the Cache Formation (QTc); adjacent to and overlies the rhyodacite of Diener Drive (dd); interbedded with and overlies the dacite of Clearlake Highlands (dhi); overlain by the dacites of Thurston Lake (dt), Pinkeye Lake (dpl), and Cache Creek (dcc), and flow (brf) of the basaltic andesite of Roundtop Mountain. Probable age range from 0.4 to 0.65 Ma. Thickness 0–25 m in upper Wildcat Canyon, thickness of tilted sequence at Lower Lake at least 200 m, exposed thickness in Redbank Gorge 20 m

dnb — **Rhyodacite north of Bald Mountain (formerly biotite-hornblende dacite of Rockledge of Hearn and others, 1976) (Pleistocene)**—Small plug of closely sheeted and foliated biotite-hornblende rhyodacite. Biotite and hornblende both produce the foliation, which tends to parallel contact near border of plug. Outcrop is labeled "Rockledge" on atlas sheet 4 of Becker (1888). Intrudes the Franciscan assemblage (KJf). K/Ar age of 1.2±0.3 Ma on biotite; reversed magnetic polarity. Exposed vertical extent 50 m

beu — **Early basaltic rocks, undivided (Pleistocene and Pliocene)**—See description under northeast area

QTc — **Cache Formation (Pleistocene and Pliocene)**—See description under northeast area

Tm — **Martinez Formation (Paleocene)**—Marine sandstone and lesser amounts of mudstone and conglomerate; see Brice (1953) and Swe and Dickinson (1970) for further description

NORTHEAST AREA

bcl — **Basin deposits of Clear Lake (Holocene and Pleistocene)**—See description under central area and Mount Konocti. Shown only in cross section

Basaltic andesite of High Valley (Holocene?)—Quartz-bearing olivine-plagioclase-pyroxene basaltic andesite, comprising cinder cone and five aa flows mapped separately. Lava flows emerged at the southwest base of the cone. Major volume of lava blocked the preexisting drainage of High Valley into North Fork Cache Creek and poured eastward 5.5 km, where oldest flow ($bhvf_1$) overlies highest terrace deposit (t_1); lesser volume flowed westward and is partly overlain by alluvium (al) and colluvium (co) in High Valley. A young age for this unit, probably less than 10,000 yr B.P., is suggested by young morphology of the cone, its 15-m-deep summit crater, and chaotic blocky flow surfaces. Aggregate thickness of flows could be as great as 100 m in NW1/4 sec. 25, T. 14 N., R. 7 W.

bhvp — Pyroclastic deposits—100-m-high cinder cone of Round Mountain and nearby deposits of bomb, block, and lapilli tephra

$bhvf_5$ — Flow 5

$bhvf_4$ — Flow 4

$bhvf_3$ — Flow 3

$bhvf_2$ — Flow 2

$bhvf_1$ — Flow 1

yp — **Young pyroclastic deposits (Holocene and Pleistocene)**—See description under central area and Mount Konocti

Younger basaltic andesite of Clearlake Oaks (Pleistocene)—Sparsely porphyritic olivine-pyroxene-plagioclase basaltic andesite. Probably overlies the andesite of Sulphur Bank (asbf, asbp); overlain by alluvium (al) and the basin deposits of Clear Lake (bcl)

bycp — Pyroclastic deposits—180-m-high cinder cone of bomb, block, and lapilli tephra. Called "north crater" by Becker (1888, p. 246). Extensively modified by quarrying

bycf — Flow—Exposed thickness 10 m; small areal extent

bocp — **Older basaltic andesite of Clearlake Oaks (Pleistocene)**—Cinder cone, eroded and partly buried, of bomb, block, and lapilli tephra of plagioclase-olivine-clinopyroxene basaltic andesite. Partly concealed by the young pyroclastic deposits (yp). More eroded and distinctly older than cinder cone of the younger basaltic andesite of Clearlake Oaks (bycp). Exposed thickness about 130 m

Basaltic andesite of Rattlesnake Island (Pleistocene)—Sparsely porphyritic olivine basaltic andesite. Contains 1 percent inclusions of milky quartz and Franciscan assemblage rock fragments (KJf) that contain milky quartz. Unit is probably younger than the andesite of Sulphur Bank (asbf, asbp) because tephra of the basaltic andesite of Rattlesnake Island is absent beneath the andesite of Sulphur Bank (asbf) in the Sulphur Bank Mine. Exposed thickness above lake level is 20 m

brip — Pyroclastic deposits—Cinder cone and associated deposits of bomb, block, and lapilli tephra and agglutinate. Low cone at south end of island is source of flow to northeast and northwest

brif — Flow—Scoriaceous aa flow erupted above lake level

Andesite of Sulphur Bank (Pleistocene)—Sparsely porphyritic andesite and basaltic andesite. Variable abundance of plagioclase phenocrysts: less than 1 percent near the cinder cone, up to 2 percent near Sulphur Bank Mine. Cinder cone (called "south crater" by Becker, 1888, p. 246) is main source of flow(s); small satellitic crater 100 m in diameter on south flank of main cone. Isolated outcrops of bombs and welded spatter, such as in NW1/4NW1/4 sec. 5, T. 13 N., R. 7 W. and sec. 32, T. 14 N., R. 7 W., may represent secondary source vents or interaction with lake water or wet sediments. Total areal extent of 4 km^2 is now partly buried by the basin deposits of Clear Lake (bcl). Age is younger than the 44,500±800 yr B.P. carbon-14 age (Donnelly-Nolan and others, 1981) of a log found in landslide(?) deposits 1.7 m beneath the flow

asbf — Flow(s)—In part hydrothermally altered at Sulphur Bank Mine (White and Roberson, 1962). Exposed thickness of flow about 20 m, maximum thickness 30 m

asbp — Pyroclastic deposits—Cinder cone, 200 m high, and associated deposits of bomb, block, and lapilli tephra

gec — **Gravel deposit east of Clearlake Oaks (Pleistocene)**—Pebble-cobble gravel consisting predominantly of chert and subordinate amounts of greenstone and graywacke, derived from the Franciscan assemblage (KJf), and scoriaceous basaltic andesite. Occurs at low elevation in valley east of Clearlake Oaks. Possibly deposited in ancestral eastward outlet of Clear Lake (Hodges, 1966, p. 135). Overlain by the younger basaltic andesite of Clearlake Oaks (bycp, bycf) and the basaltic andesite of Sulphur Bank (asbf, asbp). May correlate with part of the terrace deposits of Burns Valley (tb). Thickness about 5 m

aoc — **Andesite of old cinder cone (Pleistocene)**—Bomb, block, and lapilli tephra composed of plagioclase andesite and lesser amounts of olivine basalt; dominant rock type is sparsely porphyritic andesite. Contains sparse blocks of a distinctive, relatively porphyritic olivine basalt. Exposure is limited to small area 15x35 m along State Route 20 east of Clearlake Oaks. Remnant of buried cinder cone of unknown extent. Exposed thickness 7 m

bsr — **Basaltic andesite south of Round Mountain (Pleistocene)**—Eroded remnant of cinder cone of block, bomb, and lapilli tephra of olivine-plagioclase-pyroxene basaltic andesite. Contains up to 10 percent of 2–20-mm-diameter inclusions of Franciscan assemblage rocks (KJf). Low semicircular ridge is vestige of breached cone that is the oldest cinder cone east of Clearlake Oaks evidenced by its deeply eroded condition. Maximum thickness 50 m

Dacite of Chalk Mountain (Pleistocene)—Slightly vesicular hypersthene dacite and soft white opalized dacite; sugary to trachytic groundmass. Dacite intrudes contorted graywacke and shale of the Franciscan assemblage (KJf) on south side of Chalk Mountain. Groundmass texture and lack of oxidized basal breccia suggest that all dacite at Chalk Mountain could be a shallow intrusive mass. At Chalk Mountain, dacite is extensively altered by recent and current H_2S fumarolic activity. Source vents located at Chalk Mountain and at Stony Top. Horizontal flow foliation indicates that part of Stony Top may be a flow remnant, similar to other isolated dacite outcrops east, west, and northwest of Stony Top. Normal magnetic polarity and extensive erosion suggest age of unit is equivalent to older part of the Brunhes Normal-Polarity Chron (0–0.7 Ma) or to the Jaramillo Normal-Polarity Subchron (0.90–0.97 Ma) (of the Matuyama Reversed-Polarity Chron). Maximum thickness 60 m

dcmf — Flow(s)—Erosional remnants

dcmi — Intrusion—In part hydrothermally altered

Early basaltic rocks (Pleistocene and Pliocene)—Olivine basalt and olivine basaltic andesite. Abundance and size of phenocrysts vary in some individual exposures. Most occurrences contain very sparse (less than 0.1 percent) of 1–3-mm-diameter quartz inclusions. Flows are dominant and appear to be erosional remnants. Interbedded with and overlie upper part of the Cache Formation (QTc) near Clearlake Highlands; interbedded with and intrusive into middle or lower part of the Cache Formation near Bartlett Springs fault zone. Unit correlates in part with intrusions and more extensive flows of olivine basalt and basaltic andesite outside map area, such as southeast of Lower Lake 5–12 km near Spruce Grove Road and 17 km at Hell's Half Acre (Brice, 1953); east-southeast of Lower Lake 21 km at Manhattan Mine-McLaughlin Mine; southeast of Middletown 3 km at Snelly Peak, 6 km at Maguire Peak, and 10 km at Table Mountain; and east of Clearlake Oaks 23 km at Coyote Peak. Erupted from many vents scattered to the northeast, east, southeast and south of the main outcrop area of the Clear Lake Volcanics. In the map area, age of 1.66±0.10 Ma at Schoolteacher Hill; outside map area, ages of 1.33±0.53 Ma and 1.34±0.29 Ma along Spruce Grove Road, 1.66±0.08 Ma at Coyote Peak (McLaughlin and others, 1990), 1.45±0.12 Ma at Hell's Half Acre, 2.2±0.2 Ma at Manhattan Mine-McLaughlin Mine (D.H. Sorg, oral commun., 1984), and 1.96±0.06 Ma at Table Mountain. Part of this unit near the Bartlett Springs fault zone may be older on the basis of interbedded occurrence in the middle or lower part of the Cache Formation (QTc). Most flows have reversed magnetic polarity; Snelly Peak and one flow at Hell's Half Acre have normal magnetic polarity; and Maguire Peak and basalt 5.9 km southeast of Chalk Mountain have intermediate(?) magnetic polarity. Maximum thickness about 60 m

beu — Undivided—Dominantly flows; lesser pyroclastic deposits and intrusive rocks

beup — Pyroclastic deposits—Bomb, block, and lapilli tephra, pyroclastic breccia, lapilli tuff

beui — Intrusive rocks—Dikes and plugs

QTc — **Cache Formation (revised by Rymer, 1981) (Pleistocene and Pliocene)**—Siltstone, sandstone, conglomeratic sandstone, and tuff. Fluvial and locally lacustrine origin; deposited in fault-bounded basin that is older than and separate from the Clear Lake basin. In map area, contains 5–15 percent of 1–5-cm-diameter pebbles mainly of chert, vein quartz, and greenstone, and contains 1 percent or less of pebbles of graywacke, shale, and serpentinite. Contains late Pliocene mammalian fossils (Rymer, 1981). Blackeye Canyon section (Rymer, 1981) contains rhyolitic(?) tuff as much as 3.5 m thick and lapilli tuff and pyroclastic breccia (beup) of the early basaltic rocks unit as much as 2.7 m thick. Generally lacks pebbles of the Clear Lake Volcanics, except from the early basaltic rocks units (beu, beup) from nearby sources. See Anderson (1936), Brice (1953), and Rymer (1981) for more detailed descriptions of this unit. Forms dissected topography with grass-covered slopes and lag gravel on the surface. Probably derived mainly from the north and east. As mapped here, the upper part contains interbedded early basaltic rocks (beu) near Clearlake Highlands, and the lower or middle part contains interbedded and intrusive early basaltic rocks (beui, beu) near the Bartlett Springs fault zone; also intruded by and overlain by the early basaltic rocks (beu, beup, beui). Age of unit is late Pliocene and early Pleistocene (Rymer, 1981). Maximum thickness unknown, but minimum thickness is 1,600 m (Rymer, 1981)

MOUNT HANNAH AREA

ds — **Rhyodacite of Seigler Mountain (Pleistocene)**—Domes and flows of abundantly porphyritic hornblende-biotite-quartz-feldspar rhyodacite. Both size and abundance of hornblende phenocrysts distinguish this unit from all other feldspar-phyric dacite and rhyodacite units in the Clear Lake volcanic field. Age of 0.61±0.02 Ma on sanidine; normal magnetic polarity. Maximum thickness about 350 m

dyh — **Younger dacite of Mount Hannah (Pleistocene)**—Flows of moderately porphyritic dacite containing medium-size plagioclase phenocrysts. Mainly vented near summit of the edifice built by the older dacite of Mount Hannah (doh); may be partly intrusive where exposed northwest of summit. Age of 1.03±0.16 Ma is too old; true age of about 0.90 Ma, in the Jaramillo Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron), is suggested by intermediate magnetic polarity of this unit and ages of underlying units. Maximum exposed thickness about 50 m

doh — **Older dacite of Mount Hannah (Pleistocene)**—Flows and domes of moderately porphyritic dacite containing coarse plagioclase phenocrysts, which distinguish this dacite unit from the overlying younger dacite of Mount Hannah (dyh). Intermediate magnetic polarity. Maximum exposed thickness of 420 m, plus an additional 280 m observed in drill hole USGS 1 Mt. Hannah on the northern flank of Mount Hannah, indicate a total thickness of at least 700 m for this unit close to its source vent

dhf — **Dacite of Harrington Flat (Pleistocene)**—Flows of moderately porphyritic dacite. Vents concealed beneath Mount Hannah. Average age is 0.90±0.04 Ma. Maximum exposed thickness about 70 m; drilled 60 m without reaching base of unit on northern flank of Mount Hannah

aps — **Andesite of Poison Smith Spring (Pleistocene)**—Flows of pyroxene andesite that has a distinctive texture of abundant (15–20 percent) clots of clinopyroxene and orthopyroxene. Ages of 0.84±0.05 and 0.86±0.04 Ma determined for unit are too young, because age by stratigraphic position is 0.90±0.03 Ma; reversed magnetic polarity indicates age is probably younger than the Jaramillo Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron). Maximum thickness about 80 m

dl — **Rhyodacite of Loch Lomond (Pleistocene)**—Flows and domes of moderately porphyritic rhyodacite containing coarse feldspar phenocrysts. Probable vent west of Loch Lomond; other vents are concealed beneath Mount Hannah. Age is 0.90±0.03 Ma. Intermediate magnetic polarity. Maximum exposed thickness 150 m

ast — **Andesite of Split Top Ridge (Pleistocene)**—Flows of andesite that has a distinctive texture of sparse large (15-mm-long) phenocrysts and abundant small (0.25–1-mm-long) phenocrysts of plagioclase. Widespread unit that has been correlated by texture and mineralogy. Ages of 0.88±0.06 Ma at Split Top Ridge, 0.88±0.02 Ma 0.3 km south of Loch Lomond, and 0.86±0.03 Ma on northwest side of Boggs Lake are all slightly too young. Age from stratigraphic position and intermediate magnetic polarities is about 0.90 Ma. Small differences in polarity may imply small age difference between exposures east and west of Mount Hannah. Maximum exposed thickness southeast of Boggs Lake 80 m; maximum thickness at Split Top Ridge about 150 m

dd — **Rhyodacite of Diener Drive (Pleistocene)**—Extensive flow or flows of sparsely porphyritic pyroxene rhyodacite that is locally spherulitic. Groundmass rich in subparallel 0.2-mm-long plagioclase and pyroxene. Similar to the dacite of Boggs Lake (db) but less porphyritic. Age is 0.92±0.03 Ma. Minimum thickness on Split Top Ridge 50 m

db — **Dacite of Boggs Lake (Pleistocene)**—Flows of sparsely porphyritic dacite. Groundmass rich in subparallel 0.2-mm-long plagioclase and pyroxene. Age is 0.98±0.09 Ma. Reversed magnetic polarity. Maximum exposed thickness 20 m

ag — **Andesite of Glenview (Pleistocene)**—Flow and scoriaceous bombs of andesite that has a distinctive speckled appearance due to presence of 25–30 percent of 1–2-mm-long single crystals and 1–2-mm-diameter clots of plagioclase. Partly covered by the older (doh) and younger (dyh) dacites of Mount Hannah. Age is 1.00±0.05 Ma. Reversed magnetic polarity. Maximum exposed thickness about 200 m

asf — **Andesite of Salmina Flat (Pleistocene)**—Flows of ilmenite-bearing andesite. Contains 0.25 percent of conspicuous 0.25–0.5-mm-diameter steel-gray ilmenite in a sugary to aphanitic groundmass. Reversed magnetic polarity. Maximum thickness about 250 m

Rhyolite of Bonanza Springs (Pleistocene)—Very sparsely porphyritic rhyolite. Age is 1.02±0.04 Ma. Reversed magnetic polarity in drill-core sample of flow. Maximum exposed thickness 70 m near Seigler Springs; thickness 1–2 m west of Mount Hannah; drilled thickness 110 m in Republic 77–1 Boggs northwest of Mount Hannah

rbp — Pyroclastic deposits—White pumiceous tuff, lapilli tuff, and, locally, coarse pyroclastic breccia; upper 3–4 m in road cut of State Route 175 in W1/2 sec. 26, T. 12 N., R. 8 W. is reworked and contains boulders of the andesite of Salmina Flat (asf). Shows rhythmic layering of coarse and fine layers of widely varying thickness. Mainly deposited by airfall, locally in quiet water and, in places, reworked by water. Grades into chaotic pyroclastic breccia near a concealed vent northwest of Seigler Springs; another probable vent is concealed northwest of Mount Hannah

rbf — Flows—Not exposed; shown only in cross section A-A'. Three rhyolitic obsidian flows, which are 29, 17, and 15 m thick, are present in the Republic 77–1 Boggs drill hole northwest of Mount Hannah

gp — **Gravel deposit east of Poison Smith Spring (Pleistocene)**—Eroded remnant of coarse pebble-boulder fluvial gravel in light-yellow soil and lag gravel. Contains clasts of the andesite of Boggs Mountain (abm) up to 20 cm diameter and smaller clasts of graywacke, blueschist, and chert from the Great Valley sequence (KJgv) and the Franciscan assemblage (KJf); lacks clasts of the andesite of Poison Smith Spring (aps). Overlies graywacke and shale that are probably of the Great Valley sequence (KJgv); overlain by the andesite of Poison Smith Spring. Thickness 1–2 m

bo — **Old basin deposits (Pleistocene)**—Shown only in cross section. Conglomerate, sandstone, and silty claystone. Contains clasts of graywacke and serpentinite; in part rich in detrital serpentinite(?). Known only from Republic 77–1 Boggs drill hole northwest of Mount Hannah. Occurs beneath the rhyolite of Bonanza Springs (rbp, rbf); overlies lapilli tuff (bcp) of olivine-rich basalt probably derived from the olivine basalt of Caldwell Pines. Possibly deposited in a graben. Thickness 60 m

PERINI HILL AREA

aph — **Andesite of Perini Hill (Pleistocene)**—Flows and minor pyroclastic deposits of porphyritic quartz- and cordierite-bearing andesite. Contains rare 1–2-mm-diameter lavender cordierite. Rich in 1-mm to 15-cm-diameter rounded to tabular inclusions of metasedimentary rocks that have high-grade mineral assemblages (garnet+spinel+cordierite and plagioclase +quartz+orthopyroxene±biotite). Also rich in inclusions of clear to amethyst quartz, known locally as "Clear Lake diamonds," that are up to 15 cm in diameter and have an irregular to rounded shape, resorbed margins, and an elongate splintery fracture. Normal magnetic polarity. Maximum thickness about 200 m

asc — **Andesite of Seigler Canyon (Pleistocene)**—Dome and surrounding flow of andesite. Resembles the andesite of Split Top Ridge (ast), but contains smaller feldspar phenocrysts and more pyroxene phenocrysts. Ages of 1.03±0.04 Ma and 0.97±0.03 Ma; latter age fits intermediate magnetic polarity at beginning of the Jaramillo Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron). Maximum thickness about 120 m

ac — **Andesite of Childers Peak (Pleistocene)**—Flow remnant of andesite and diatreme composed of fragments of vesicular, gray to light-yellow andesite, rhyolitic pumice (rbp) from the rhyolite of Bonanza Springs, and sparse fragments of chert, graywacke, and serpentinite. Flow probably tilted down to south; diatreme is a possible source vent. Dated at 0.93±0.05 Ma, but true age is probably greater than 0.97 Ma (predating the Jaramillo Normal-Polarity Subchron of the Matuyama Reversed-Polarity Chron) to fit tilt-corrected reversed magnetic polarity and to preserve the easily eroded pyroclastic deposits (rbp) of the rhyolite of Bonanza Springs that underlie the andesite of Childers Peak. Maximum thickness of flow 30 m

Rhyolite of Bonanza Springs (Pleistocene)—See description under Mount Hannah area

rbp — Pyroclastic deposits

COBB MOUNTAIN AREA

dcv — **Dacite of Cobb Valley (Pleistocene)**—Flow and minor coarse pyroclastic deposits of sparsely porphyritic dacite. Source is probably near spinelike outcrop of vesicular dacite at highest altitude of flow on north flank of Cobb Mountain. Average of three ages is 1.08±0.03 Ma. Magnetic polarity reversed, but 40 degrees from axial dipole. Maximum thickness about 100 m

Rhyodacite of Cobb Mountain (Pleistocene)—Coarsely porphyritic biotite rhyodacite. Ages of 1.05±0.02 and 1.06±0.02 Ma on sanidine. Reversed magnetic polarity. Maximum thickness about 400 m

dcp — Pyroclastic deposits—Coarse blocks of pumiceous, oxidized biotite rhyodacite close to vent

dcf — Flows and domes

Rhyolite of Alder Creek (Pleistocene)—Crystal-rich biotite rhyolite. Three ages of 1.15±0.02, 1.11±0.02, and 1.11±0.02 Ma on sanidine; average age is 1.12±0.02 Ma. Intermediate magnetic polarity in the Cobb Mountain Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron) (Mankinen and others, 1978; Mankinen and Grommé, 1982). Maximum exposed thickness about 400 m in the southeastern cliffs of Cobb Mountain; thickness as much as 150 m in down-faulted blocks southeast of Cobb Mountain (Goff and McLaughlin, 1976)

raf — Flows—Thick, mostly devitrified, stony. Vesicular vitric blocks occur locally at top and base of unit

rap — Pyroclastic and volcaniclastic deposits—Pyroclastic breccia, lapilli tuff, tuff, and tuffaceous sedimentary rocks. Minor extent, occurs on top of and beneath the main group of flows (raf). In the extreme SW corner sec. 14, T. 11 N., R. 8 W., tuffaceous sedimentary rocks are 5 m thick, contain biotite rhyolite pumice, blocks of the andesite of Ford Flat (aff), and Franciscan assemblage rocks (KJf); rap unit represents an early pyroclastic eruption

aff — **Andesite of Ford Flat (Pleistocene)**—Isolated remnants of fragmental deposits of olivine andesite. Most occurrences consist of bombs, spatter, and cinders, plus 5 percent or less of fragments of Franciscan assemblage rocks (KJf). Includes interbedded lake sediments in the NE1/4NE1/4 sec. 22, T. 11 N., R. 8 W. Olivine andesite below the southeastern cliffs of Cobb Mountain appears to have filled gullies in an erosion surface. In sec. 24, T. 11 N., R. 8 W., a 35-m-thick mudflow deposit consists of 90–95 percent of poorly sorted lapilli and scoriaceous blocks of olivine andesite of Ford Flat and 5–10 percent of blocks of Franciscan assemblage (KJf) graywacke; this mudflow has lobate tongues about 5 m long and 1 m thick, which suggest that the mudflow moved toward the southeast. Olivine andesite cinders are locally abundant beneath the rhyolite of Alder Creek (raf, rap) in exposures too small to map at this scale. Source vent probably concealed beneath Cobb Mountain. Age is 1.71±0.21 Ma. Maximum exposed thickness 35 m

BOGGS MOUNTAIN AREA

abm — **Andesite of Boggs Mountain (Pleistocene)**—Flows, 10–15 m thick, and rare dikes(?) of andesite that has a distinctive speckled appearance due to abundant small plagioclase phenocrysts. Contains about 10 percent of 1–3-mm-diameter clots of clinopyroxene and orthopyroxene. Flows are typically sheeted near base and margins. Two probable dikes in sec. 2, T. 11 N., R. 8 W. are close to one vent. Ages are 1.47±0.06 and 1.51±0.04 Ma; latter age from longer fusion of sample is more accurate. Reversed magnetic polarity. Maximum thickness about 150 m

Andesite of Grouse Spring (Pleistocene)—Hornblende-bearing andesite. Typically contains 5–10 percent of 0.1–10-cm-diameter inclusions of metasedimentary rocks and sparse 0.5–1-cm-diameter inclusions of sieve-textured plagioclase that contains altered hornblende needles. Reversed magnetic polarity

agsf — Flow—Thickness about 50 m

agsp — Pyroclastic deposits—Small patches of lapilli tuff and pyroclastic breccia of hornblende-bearing andesite scoria. Maximum exposed thickness 5 m

CALDWELL PINES AREA

Olivine basalt of Caldwell Pines (Pleistocene)—Olivine basalt that is particularly rich in olivine (7–15 percent). Least evolved of the Clear Lake volcanic rocks. Lacks quartz inclusions found in most occurrences of the early basaltic rock units (beu, beup, beui). Diatreme (bcd) is probable source of flow. Steeply sheeted exposures (bci) in NW1/4NW 1/4 sec. 36, T. 12 N., R. 9 W. are probable dikes. Age is 1.66±0.12 Ma. Maximum thickness about 50 m

bcf — Flow and minor amount of underlying bomb and lapilli tephra

bci — Intrusive rocks—Dikes and irregular small bodies

bcd — Diatreme breccia—Nonbedded, in part well-cemented. Average diameter of fragments is 0.5–2 cm. Contains 40–60 percent of altered fragments of vesicular and massive olivine basalt and 40–60 percent of fragments of Franciscan assemblage (KJf) rocks that are up to 1 m diameter, are predominantly graywacke and argillite, and are only about 1 percent each of red chert, greenstone, and serpentinite

bcp — Pyroclastic deposits—Lapilli tuff beneath flow and in Republic 77–1 Boggs drill hole. Shown only in cross sections A–A' and B–B'

High-level gravels (Pleistocene)—Coarse deposits

gh_2 — Unit 2—Younger deposit; composite waterlaid and lag deposit of resistant, rounded, pebble- to boulder-size clasts of Franciscan assemblage (KJf) graywacke, chert, and blueschist mainly derived from unit 1 (gh_1), as well as angular fragments derived from the olivine basalt of Caldwell Pines (bcf, bci, bcd). Maximum thickness 2 m

gh_1 — Unit 1—Older deposit; waterlaid deposit of rounded pebbles, cobbles and boulders up to 1 m in diameter of Franciscan assemblage (KJf) graywacke, chert, and blueschist; lacks clasts of the Clear Lake Volcanics or Sonoma Volcanics; cut by intrusive rocks (bci) and overlain by flows (bcf) of the olivine basalt of Caldwell Pines. Maximum thickness about 10 m

PINE MOUNTAIN AREA

Tah — **Andesite of Helen Mine (Pliocene)**—Small flow(?) and dikelike and irregular intrusions of sparsely porphyritic olivine andesite. Occurs at the Helen Mine as four small remnants totalling 1,000 m^2 at the surface and as several small underground masses. Intruded near and along a fault that separates Franciscan assemblage mélange from serpentinite (Yates and Hilpert, 1946, pl. 46 and 47). Three of the four surface exposures are extensively altered by hydrothermal activity. Mercury mineralization post-dates andesite according to Yates and Hilpert (1946). Average age of andesite is 2.05±0.33 Ma. Vertical extent at least 100 m

Trpm — **Rhyolite of Pine Mountain (Pliocene)**—Dome and flow of white, hydrothermally altered, crystal-rich rhyolite and rare blocks of black glassy biotite rhyolite. In most samples, groundmass and feldspar phenocrysts are pervasively altered, possibly due to proximity of mercury mineralization in the Helen Mine area to the north. Overlies the rhyodacite of Appletree Creek (Tda). Age of 2.06±0.02 Ma on sanidine. Thickness about 110 m in summit area

Tda — **Rhyodacite of Appletree Creek (Pliocene)**—Eroded small flow of hydrothermally altered, moderately porphyritic rhyodacite. Eroded condition, small phenocryst size, and lack of quartz phenocrysts indicate possible affinity of this unit with the Sonoma Volcanics. Maximum thickness about 60 m

Tdtf — **Rhyodacite of Turner Flat (Pliocene)**—Eroded pluglike remnant, 30 m in diameter, of rhyodacite. Contains fewer sanidine and plagioclase phenocrysts than the rhyodacite of Appletree Creek (Tda). Probably older than the rhyolite of Pine Mountain (Trpm) and rhyodacite of Appletree Creek (Tda). Eroded condition and paucity of quartz phenocrysts indicate possible affinity of this unit with the Sonoma Volcanics. Exposed thickness 15 m

Ts — **Sonoma Volcanics (Pliocene)**—Flow(?) of silicified dacite(?) that contains 5–10 percent feldspar phenocrysts in SW1/4 sec. 18 and NW1/4 sec. 19, T. 10 N., R. 7 W. Erosional remnants of dacitic(?) welded ash-flow tuff that contains 5 percent feldspar phenocrysts in sec. 13, T. 10 N., R. 8 W. Source of welded tuff probably at Mount St. Helena 6.5 km to the southeast. Map contacts taken in part from McLaughlin (1978). Remnants of Sonoma Volcanics in map area probably are part of youngest member, the rhyolite of Calistoga (Fox and others, 1985). The only K/Ar age for the rhyolite of Calistoga is 3.0±0.2 Ma (Mankinen, 1972) for sample collected at the summit of Mount St. Helena. Fission-track age of 2.6±0.3 Ma on zircon from the lowermost part of the rhyolite of Calistoga (Fox and others, 1985) is probably too young. Overall age range for the Sonoma Volcanics is late Miocene to late Pliocene; however, age in area of this report is considered Pliocene only. Maximum thickness in map area about 25 m

GENERAL AREA

Bedrock Units

QTsc — **Silica-carbonate rock (Quaternary? and late Tertiary)**—White, tan, red-brown to dark-gray, locally porous, resistant rocks composed of quartz, chalcedony, opal, and magnesium carbonate minerals. Formed by hydrothermal alteration of serpentinite. Associated with thermal springs and altered zones along faults. Common host rock for mercury deposits

KJgv — **Great Valley sequence (Upper Cretaceous to Upper Jurassic)**—Shale, siltstone, graywacke, conglomerate, greenstone, and chert. See Brice (1953), Swe and Dickinson (1970), and McLaughlin and others (1990) for more detailed descriptions and subdivisions of this unit

KJf — **Franciscan assemblage (Upper Cretaceous to Upper Jurassic)**—Structurally complex assemblage of varied rock types, such as chert, greenstone, graywacke, shale, and metamorphic rocks of blueschist grade. See Brice (1953), McNitt (1968a, b, c), McLaughlin (1978, 1981), and McLaughlin and others (1990) for detailed descriptions and subdivisions of this unit

Jsp — **Serpentinite (Jurassic? and older?)**—Serpentinized mafic and ultramafic rocks. Locally has tectonically intruded the Clear Lake Volcanics along major fault zones

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1995

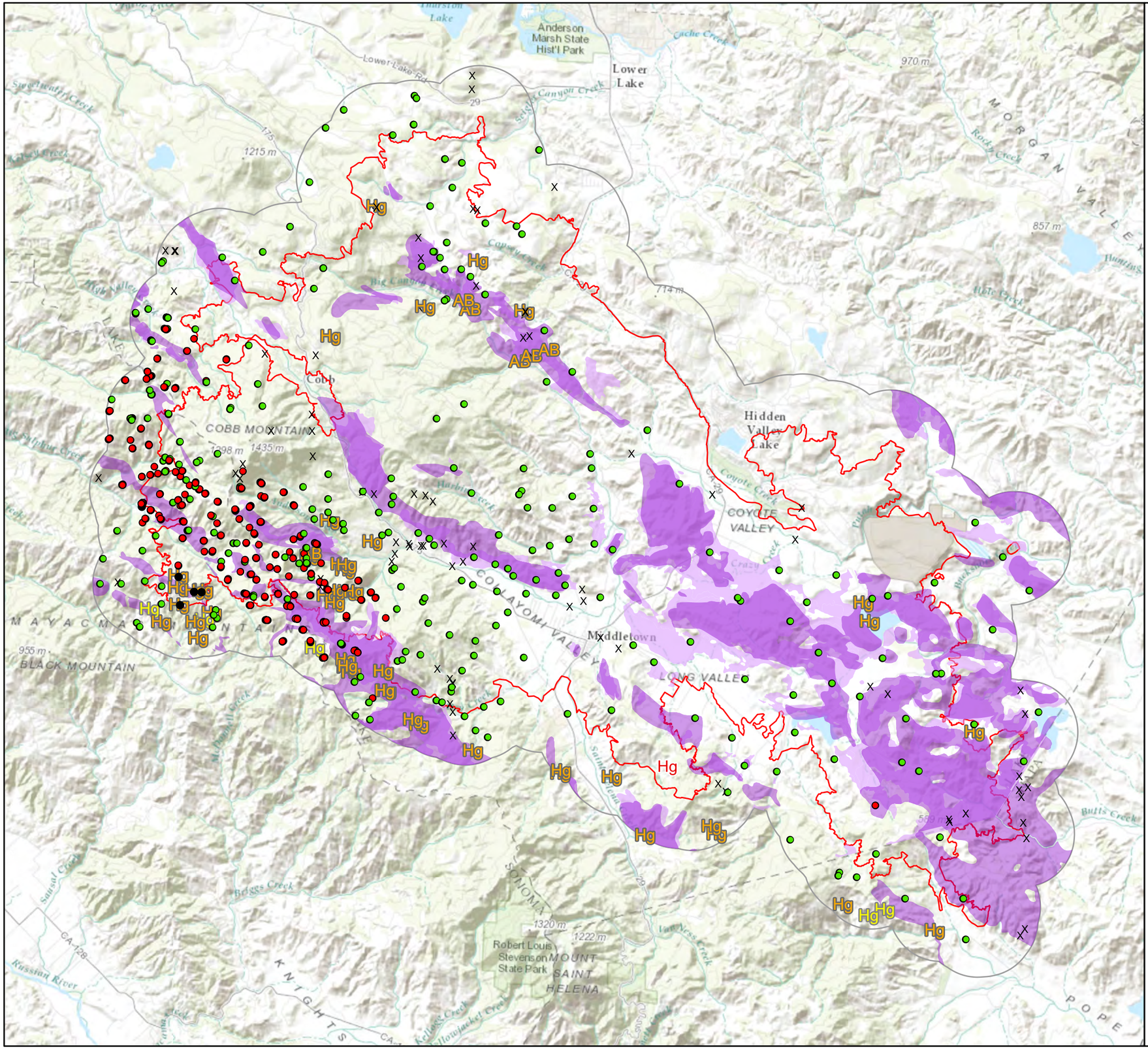
GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE CLEAR LAKE VOLCANICS, NORTHERN CALIFORNIA

By
B. C. Hearn, Jr., J. M. Donnelly-Nolan, and F. E. Goff

1995

Plate 4

Map of Hazardous Minerals Underlying 2015 Valley Fire



Potential Geologic Mineral Hazards
Valley Fire

Areas with Higher Potential for Naturally Occurring Asbestos

- Ultramafic rock
- Serpentine soils
- Ultramafic rock and serpentine soils

Mines

Mercury

- Hg — Mercury - Plant, Producer
- Hg — Mercury - Past Producer, Occurrence, Unknown
- Hg — Mercury - Prospect

Asbestos

- AB — Asbestos - Past Producer, Occurrence, Unknown, Null
- AB — Asbestos - Prospect

Other Mines

- x — Other commodities

Geothermal Wells

- Active, deserted, unknown
- Abandoned, cancelled, idle, proposed, suspended

Oil and Gas Seeps

- Oil and Gas Seeps - Sonoma and Napa Counties

- Valley Fire perimeter, 2015-09-22, 2243
- 1 mile buffer around fire perimeter

0 1 2 3 Miles

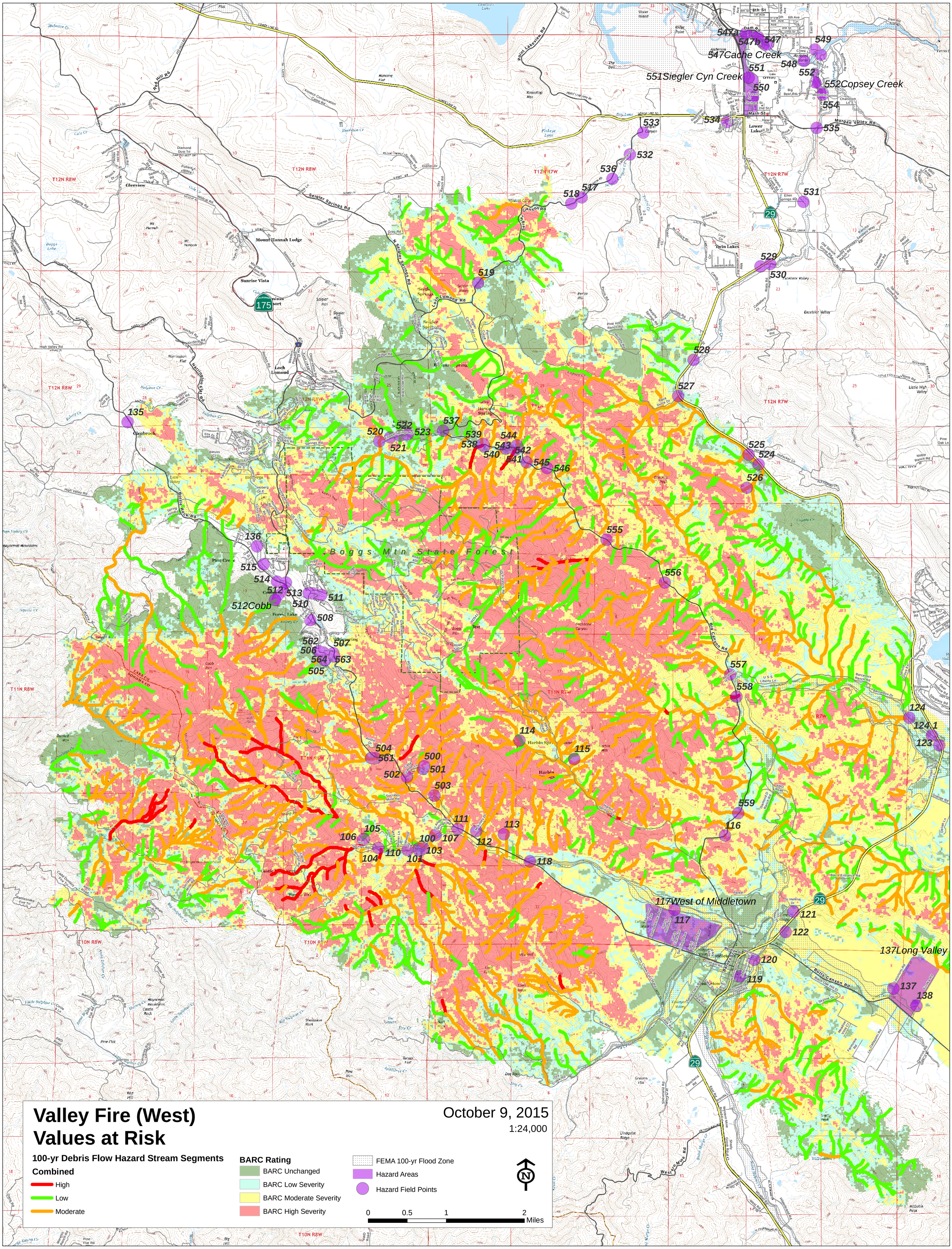
N

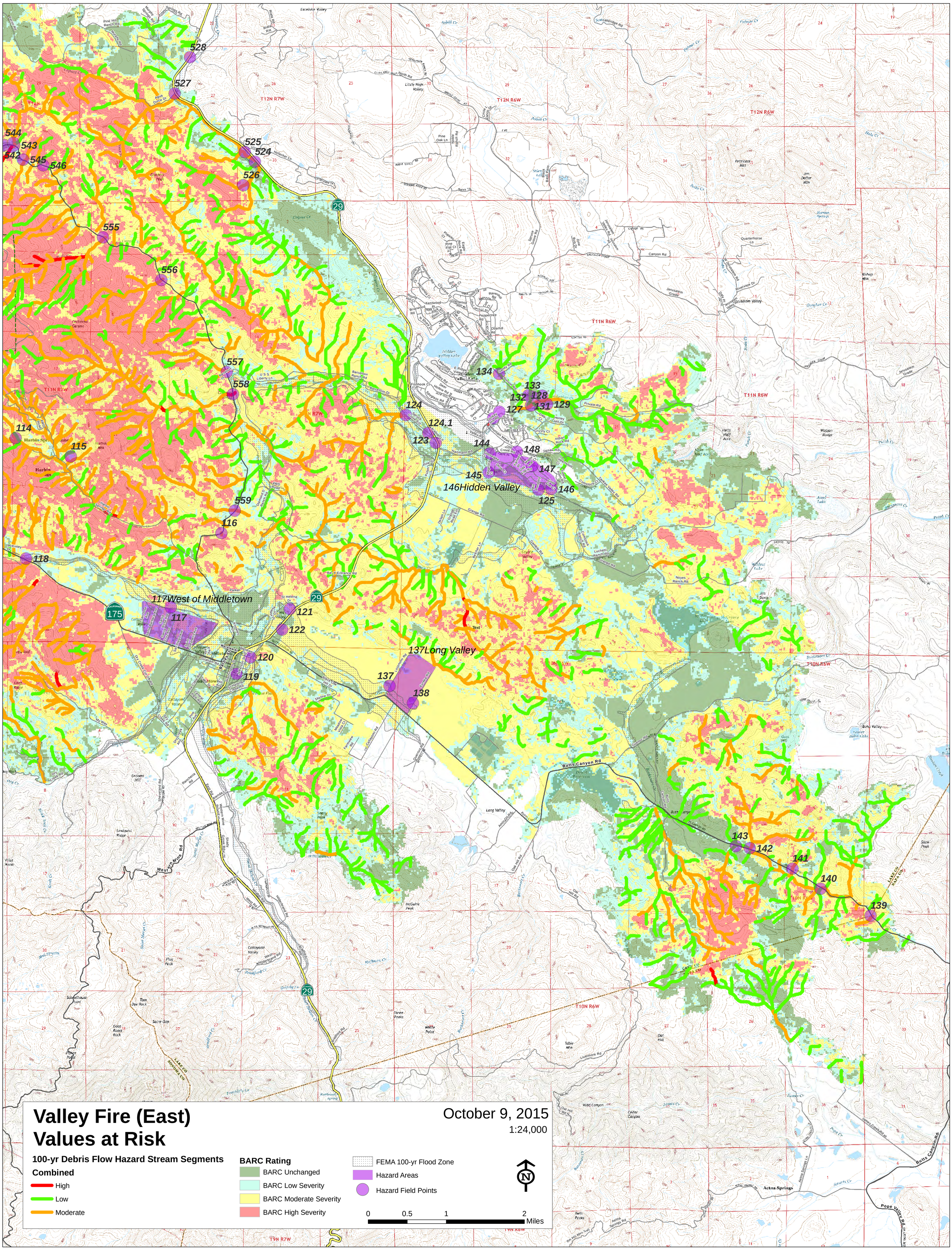
Sources: CGS, USGS, Lake Co AQMD

28 Sep 2015

Plate 5

Values at Risk


Valley Fire (West)
Values at Risk
October 9, 2015
1:24,000
100-yr Debris Flow Hazard Stream Segments
Combined
High
Low
Moderate
BARC Rating
BARC Unchanged
BARC Low Severity
BARC Moderate Severity
BARC High Severity
FEMA 100-yr Flood Zone
Hazard Areas
Hazard Field Points
0
0.5
1
2
Miles
547Cache Creek
551Siegler Cyn Creek
552Copsey Creek
512Cobb
117West of Middletown
137Long Valley
Boggs Mtn State Forest


Valley Fire (East)
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Hazard Areas
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1
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Miles
N
117West of Middletown
137Long Valley
146Hidden Valley
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