

MEMORANDUM

To: Fray Crease
From: Matt Naftaly and Claire Kouba
Subject: *Hydrogeologic Conceptual Model to Fulfill Requirements in Section I of the Basin Boundary Modification Application for the Cuyama Valley Groundwater Basin*
Date: February 4, 2016
Attachment(s): Figures 1 and 2, reproduced from Everett et. al, 2013; Figure 3, reproduced from Sweetkind et. al; Figure D3; and Appendix K1.

The following Hydrogeologic Conceptual Model for the Cuyama Valley Groundwater Basin (Basin) is primarily based on a report completed by Everett et. al of the USGS in 2013. All italicized, indented text is a direct quotation from the Everett et. al 2013 report.

Much less is known about the proposed new Chalk Mountain Subbasin (Subbasin), as the area it covers has been studied far less than the main Cuyama basin. A separate section, Section 5, discusses known properties of the proposed Subbasin.

1. Principal Aquifer Units

The depth and thickness of the principal aquifer units vary considerably throughout the Cuyama Valley, due to thrust faulting and folding associated with compression, as well as changes in erosion and deposition rates over time.

As stated in the Everett et. al 2013 report:

Generalized lithologic characterization from the monitoring sites indicated the water-bearing units in the subsurface consist of unconsolidated to partly consolidated sand, gravel, silt, clay, and occasional cobbles within alluvial fan and stream deposits. Analysis of geophysical logs indicated alternating layers of finer- and coarser-grained material that range from less than 1 foot to more than 20 feet thick. On the basis of the geologic data collected, the principal water-bearing units beneath the monitoring-well sites were found to be composed of younger alluvium of Holocene age, older alluvium of Pleistocene age, and the Tertiary-Quaternary Morales Formation. At all three sites, the contact between the recent fill and younger alluvium is approximately 20 feet below land

surface... In terms of water-bearing properties, the geology of the Cuyama Valley can be generalized into four main units: (1) non-water-bearing rocks—the crystalline granitic rocks and all consolidated sedimentary rocks older than the Morales Formation, (2) the Morales Formation, (3) older alluvium of Pleistocene age, and (4) younger alluvium of Holocene age (Upson and Worts, 1951; Singer and Swarzenski, 1970).

Morales Formation

The Morales Formation (QTm, fig. 2) is a Pliocene- Pleistocene fluvial deposit that is up to 5,000 feet thick and consists of massive- to thick-bedded, partly consolidated deposits of clay, silt, sand, and gravel (Hill and others, 1958; Ellis and others, 1993).

The water-bearing properties of the Morales Formation are not well defined, but available data indicate that the hydraulic conductivity of the formation varies greatly both areally and with depth.

Wells perforated in the Morales Formation in the western part of the valley have specific capacities of 5–25 gpm per foot, whereas those in the north-central part of the valley have specific capacities of 25–50 gpm per foot (Singer and Swarzenski, 1970). Inspection of available geologic and geophysical logs indicated that the hydraulic conductivity of the Morales Formation decreases with depth.

Older (Pleistocene-age) Alluvium

Older alluvium (Qoa, fig. 2) consists of unconsolidated to partly consolidated sand, gravel, and boulders, with some clay (Vedder and Repenning, 1975; DeLong and others, 2008). The percentage of clay increases in the western part of the valley (Singer and Swarzenski, 1970; DeLong and others, 2008). Interpretation of geophysical logs from oil exploration wells indicated that this unit is typically 400 to 600 feet thick, but is as thick as 1,000 feet near the axis of Cuyama Valley (Schwing, 1984; Spitz, 1986). In the study area, older alluvium includes dissected alluvial fans, colluvial deposits, and sediments on multiple terraces and alluvial surfaces (Hill and others, 1958; DeLong and others, 2008). Older alluvial deposits are slightly deformed and are probably of late Pleistocene age, although in some places they could be Holocene (Vedder, 1968; DeLong and others, 2008).

Younger (Holocene) Alluvium

Younger alluvium (Qya, fig. 2) consists of unconsolidated sand, gravel, and boulders, with some clay deposited as alluvium in stream channels, floodplains, alluvial fans, and

stream terraces. The unit is mainly Holocene in age, but locally can be late Pleistocene in part. Active stream deposits consist of river-bed gravels of the Cuyama River and other active channels (Vedder and Repenning, 1975; DeLong and others, 2008).

2. Lateral boundaries of the proposed basin

The proposed basin is bounded to the north by the Morales fault, the Whiterock fault, and the Caliente Range. It is bounded to the west by the Russell fault and to the southwest by the South Cuyama fault and the Sierra Madre Range. The eastern end of the basin lies within the Los Padres National Forest; the southern and eastern portions of the basin boundary generally follow the outlines of surface outcrops of Pliocene and younger lithologies, which are surrounded by Miocene and older consolidated rocks (Figure 2).

The proposed basin was divided into nine zones by Everett et. al in the 2013 study, as outlined below.

The basin was divided into nine groundwater subregional hydrologic zones (fig. 1). These zones separate the aquifers into regions that are fault bounded and where the response to the use, movement, and consumption of water is similar in specific parts of the aquifers, but differs from the other zones. In this context, Cuyama Valley can be considered a collection of zones that are partially connected, but have different geologic boundaries, hydrologic features and hydraulic properties, water quality and age of groundwater, and dominant aquifers that respond to natural and anthropogenic stresses differently.

Three sections (the Northern, Northeast, and Southern Ventucopa Uplands) comprise the southeastern half of the basin, and are predominately located in Ventura County. Three sections (the Northwestern, Central, and Southern Sierra Madre Foothills) span the southern border of the northwestern half of the basin. Two sections (Western Basin and Caliente Northern-Main) span the majority of the northern border of the northwestern half of the basin. The final section (Southern-Main) is centrally located and comprises the majority of the flat portion of the Cuyama Valley.

Isotope data from water quality samples indicate that communication between zones is limited.

Differences in the stable-isotopic values of hydrogen and oxygen among groundwater samples indicated that water does not move freely between different formations or between different zones within the Cuyama Valley... Comparison of values from other

supply wells in the basin also supported restricted lateral flow between zones that could be controlled by the structural compartments of the basin.

Estimated carbon-14 ages for the other 20 sites ranged from 600 (CUI-03) to 38,300 (CUI-23) years before present (table 9). In general, the youngest water was found in wells in the Southern Ventucopa Uplands; this zone is a source of recharge for the Cuyama Valley and the presence of younger water is expected. The oldest water was found in wells in the Southern-Main, Northwestern Sierra Madre Foothills, and Central Sierra Madre Foothills zones.

Several faults within the basin may impede groundwater flow based on geologic, hydrologic, or indirect evidence. For example, though the Rehoboth fault was not visible from the surface, a lack of connectivity across it was inferred on the basis of water level changes in the west-central part of the valley. As such, the Rehoboth Farms fault constitutes an internal barrier to groundwater flow and is used as a boundary between two sub-areas of the basin (Figure 1). Additionally, in the recently revised Hydrologic Modeling Report (Hanson et. al, 2015), the major faults in the Cuyama Valley (including the Russell, Morales, South Cuyama, and Whiterock faults) are represented as no-flow groundwater boundaries along the outer edge of the alluvial basin for modelling purposes (Hanson et. al, 2015).

The thrust faults to the north and south of the northwestern half of the basin (the Whiterock, Morales and South Cuyama) are characterized by older, virtually non-water bearing lithology thrust over younger, water-bearing formations. Thus, though the younger sediments may extend further laterally than the surface faults suggest, the topographic (and thus drainage) divides of the Sierra Madre and Caliente Ranges (immediately outside the thrust fault boundaries) would constitute bounding features.

The Russell fault to the west is known to truncate older geologic formations which may be an indication of obstruction of water flow across it. The vast majority of agricultural land use and urban development in the basin has occurred to the east of the Russell fault. Finally, an area of standing moisture near the northwestern portion of the Russell fault may be an indication of upwelling of groundwater as it is forced to the surface against the Russell, Whiterock and/or Morales faults.

3. Recharge and discharge areas within the basin

Recharge in the Basin occurs through the Cuyama River, underflow, and surface percolation. Precipitation and associated recharge rates are higher in the Ventucopa Uplands than in the western portions of the basin:

Rainfall in the valley averaged about 8 inches annually, whereas the mountains to the south received between 12 and 19 inches.

Though some seasonal springs have been reported along the Graveyard Ridge fault, the Turkey Trap Ridge fault, and the Santa Barbara Canyon fault (Figure 2), the majority of the groundwater in the Cuyama Valley discharges from the basin through the Cuyama River, either as sub-surface flow through the alluvium in the defined channel, or as surface flow for periods during the wet season.

4. Definable bottom of the basin or subbasin

The definable bottom of the basin is the bottom of the Morales Formation, as that is the oldest water-bearing lithology present in the basin. The depth and thickness of the Morales Formation vary substantially, but in the vicinity of the valley floor the top of the Morales is generally encountered approximately 600 feet below ground surface, with a thickness ranging up to 5,000 feet (Sweetkind et. al, 2013).

Electric, sonic and density logs in the report by Sweetkind et. al, in 2013 provide some additional detail. In log 11106166 in the Northeast Ventucopa Uplands (Figures 2, 3), the base of the Morales was encountered at 750 feet bgs, while in log 08304142, in the Northwest Sierra Madre Foothills, the base of the Morales was encountered at 1,750 feet bgs.

5. Properties of the proposed new Chalk Mountain Subbasin

The proposed new subbasin is defined as the territory within the Bulletin 118 Cuyama Basin Boundary that falls to the west of the Russell fault (Figures 2 and D3).

The proposed Chalk Mountain subbasin extends from the Russell fault on the east side to the westernmost point of the basin defined in Bulletin 118, which falls within Aliso Canyon in the Los Padres National Forest. It is generally bounded to the north and south by the La Panza and South Cuyama Faults, respectively, though one small area appears to extend away from the main subbasin along the Whiterock fault (Figures K1-A and K1-B).

The principle aquifer units and definable bottom of the subbasin have not been extensively studied, but surface outcrops of older Quaternary sediments and the Morales Formation are present in the subbasin.

The lateral boundaries of the subbasin have not been extensively studied. The westernmost portion of the basin is made up of two long slender areas that appear to trace outcrops of Quaternary and Pliocene sediments that follow the La Panza and Whiterock faults (Figure K1-

Memorandum

Subject: Cuyama Valley Groundwater Basin Hydrogeologic Model

A). Topographic drainage patterns in these two westernmost areas suggest that precipitation in these areas would not recharge the subbasin, so at a later date, after additional study, the County may request a modification to eliminate these areas from the defined subbasin.

Other than the two westernmost areas, the lateral boundaries of the proposed subbasin follow the South Cuyama and La Panza faults (Figure K1-B).

References

Everett, R.R., Gibbs, D.R., Hanson, R.T., Sweetkind, D.S., Brandt, J.T., Falk, S.E. and Harich, C.R., 2013, *Geology, water-quality, hydrology, and geomechanics of the Cuyama Valley groundwater basin, California, 2008–12: U.S. Geological Survey Scientific Investigations Report 2013–5108*, 62 p.

Hanson, R.T., Flint, L.E., Faunt, C.C., Gibbs, D.R., and Schmid, W., 2015, *Hydrologic models and analysis of water availability in Cuyama Valley, California (ver. 1.1, May 2015): U.S. Geological Survey Scientific Investigations Report 2014–5150*, 150 p., <http://dx.doi.org/10.3133/sir20145150>.

Sweetkind, D.S., Bova, S.C., Langenheim, V.E., Shumaker, L.E., and Scheirer, D.S., 2013, *Digital tabulation of stratigraphic data from oil and gas wells in Cuyama Valley and surrounding areas, central California: U.S. Geological Survey Open-File Report 2013–1084*, 44 p., <http://pubs.usgs.gov/of/2013/1084/>.

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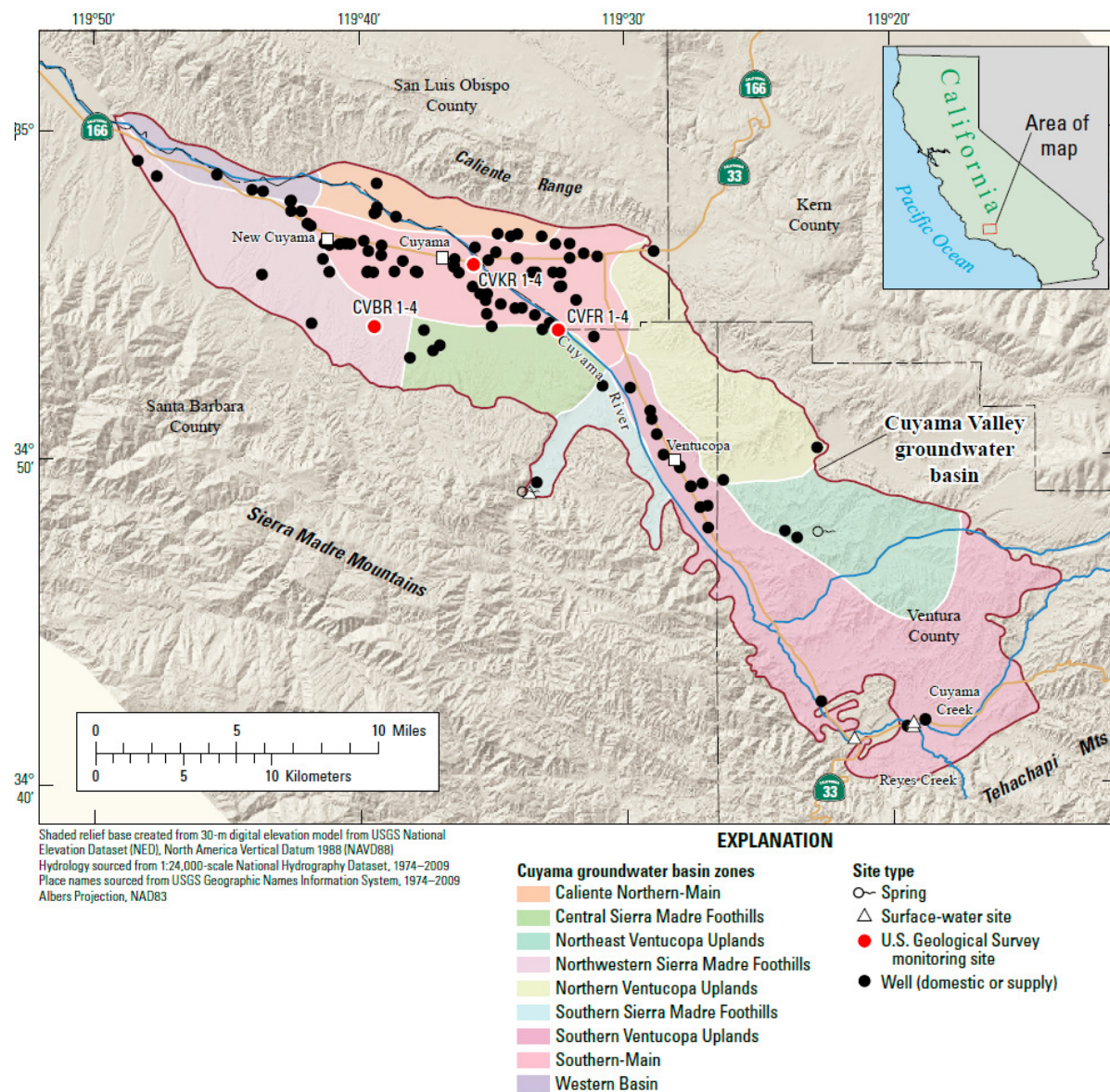


Figure 1. The location of Cuyama Valley, including multiple-well monitoring sites, selected domestic and supply wells, and hydrologic units, Cuyama Valley, Santa Barbara County, California.

Reproduced from Everett et. al, 2013.

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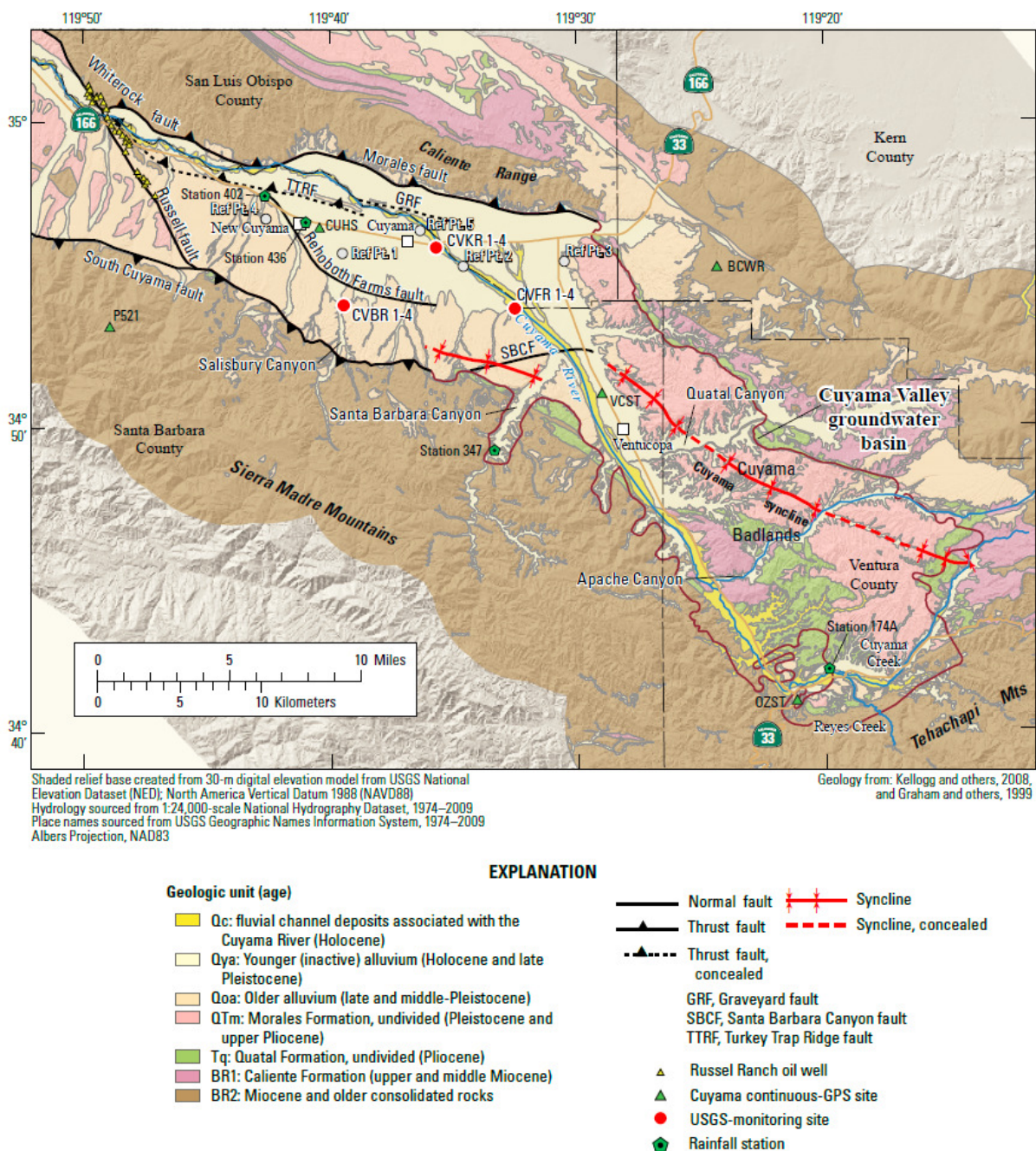


Figure 2. The location of Cuyama Valley, including multiple-well monitoring sites, selected domestic and supply wells, and hydrologic units, Cuyama Valley, Santa Barbara County, California.

Reproduced from Everett et. al, 2013

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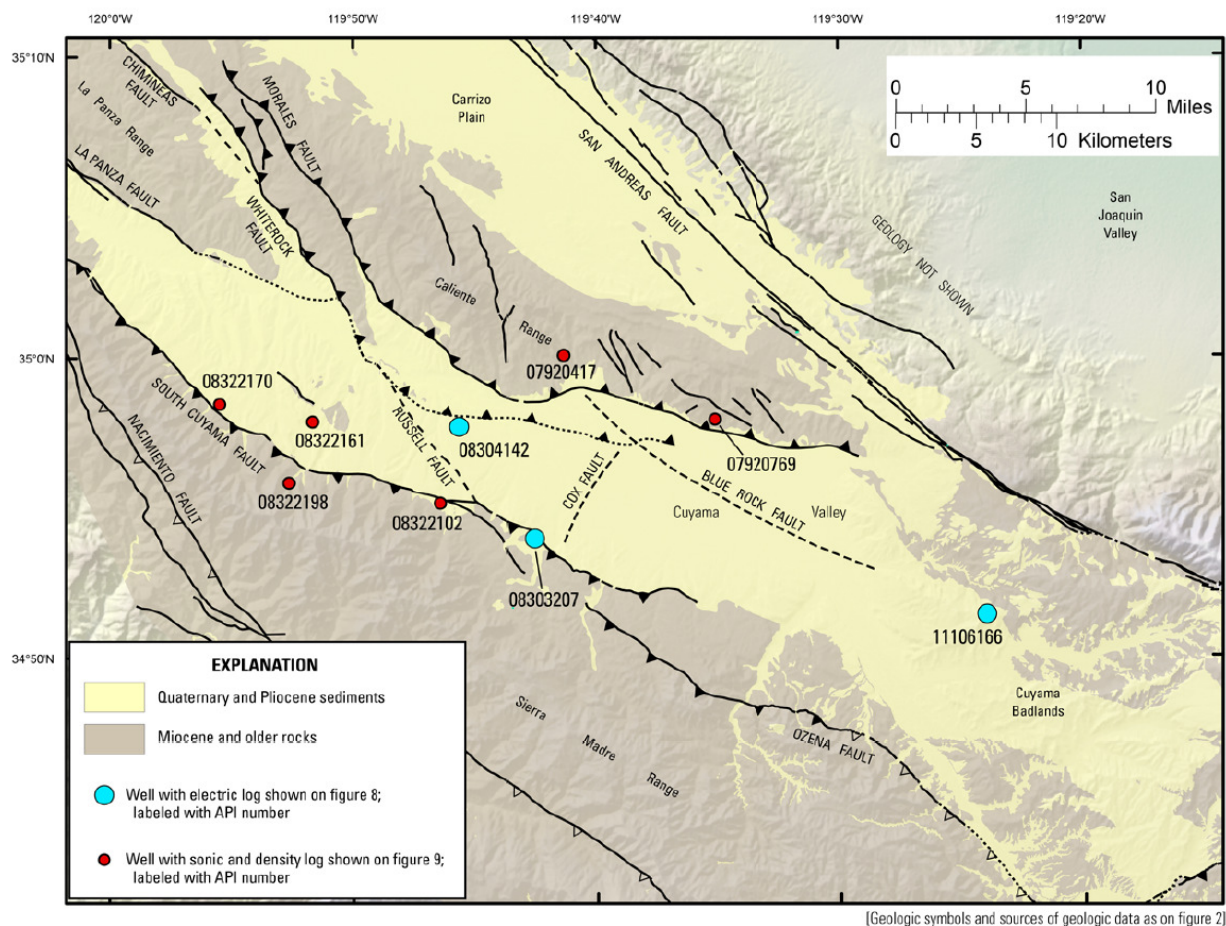
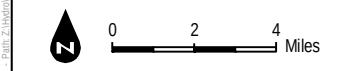
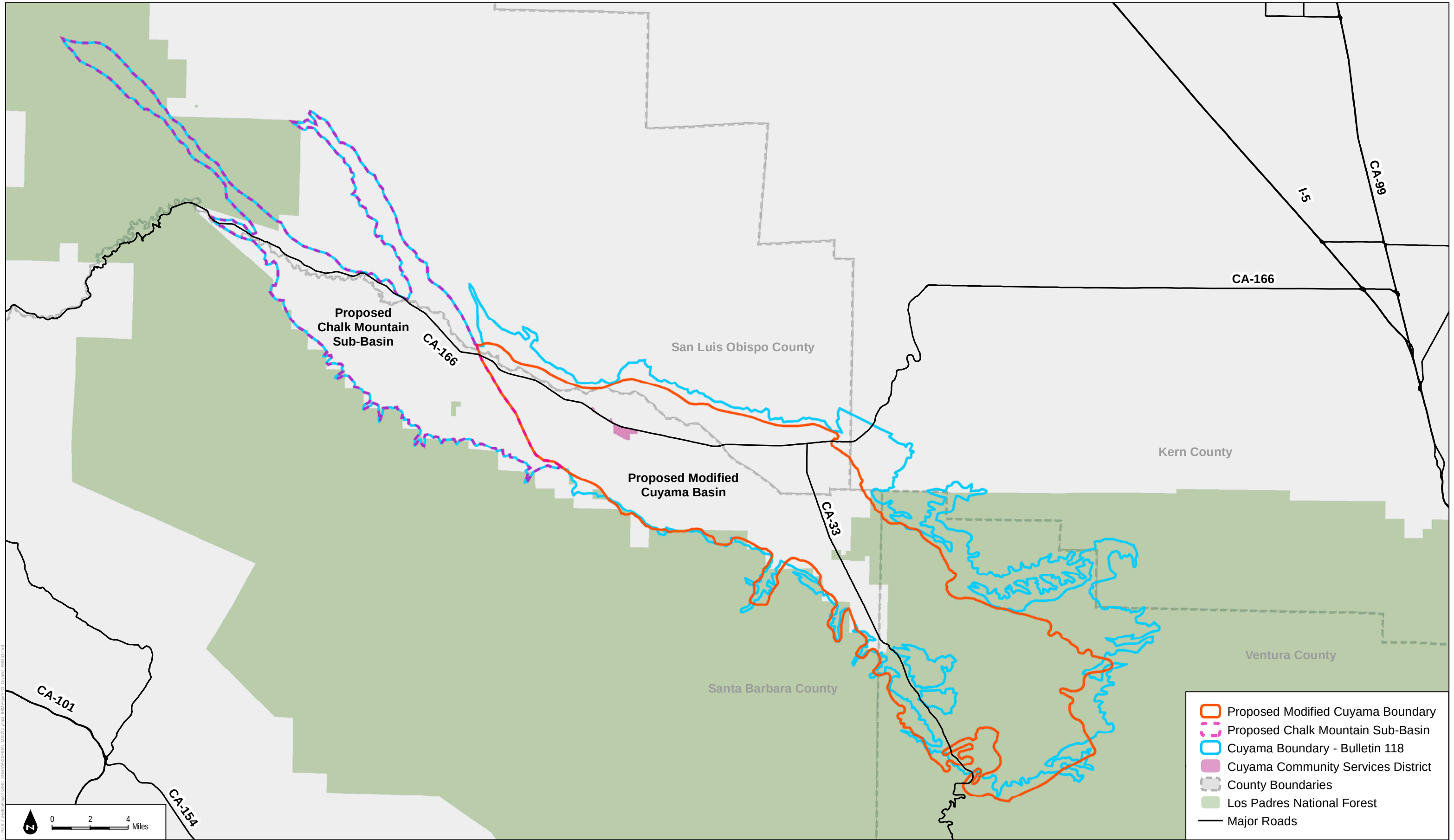


Figure 3. The location of Cuyama Valley, including multiple-well monitoring sites, selected domestic and supply wells, and hydrologic units, Cuyama Valley, Santa Barbara County, California.

Reproduced from Sweetkind et. al, 2013



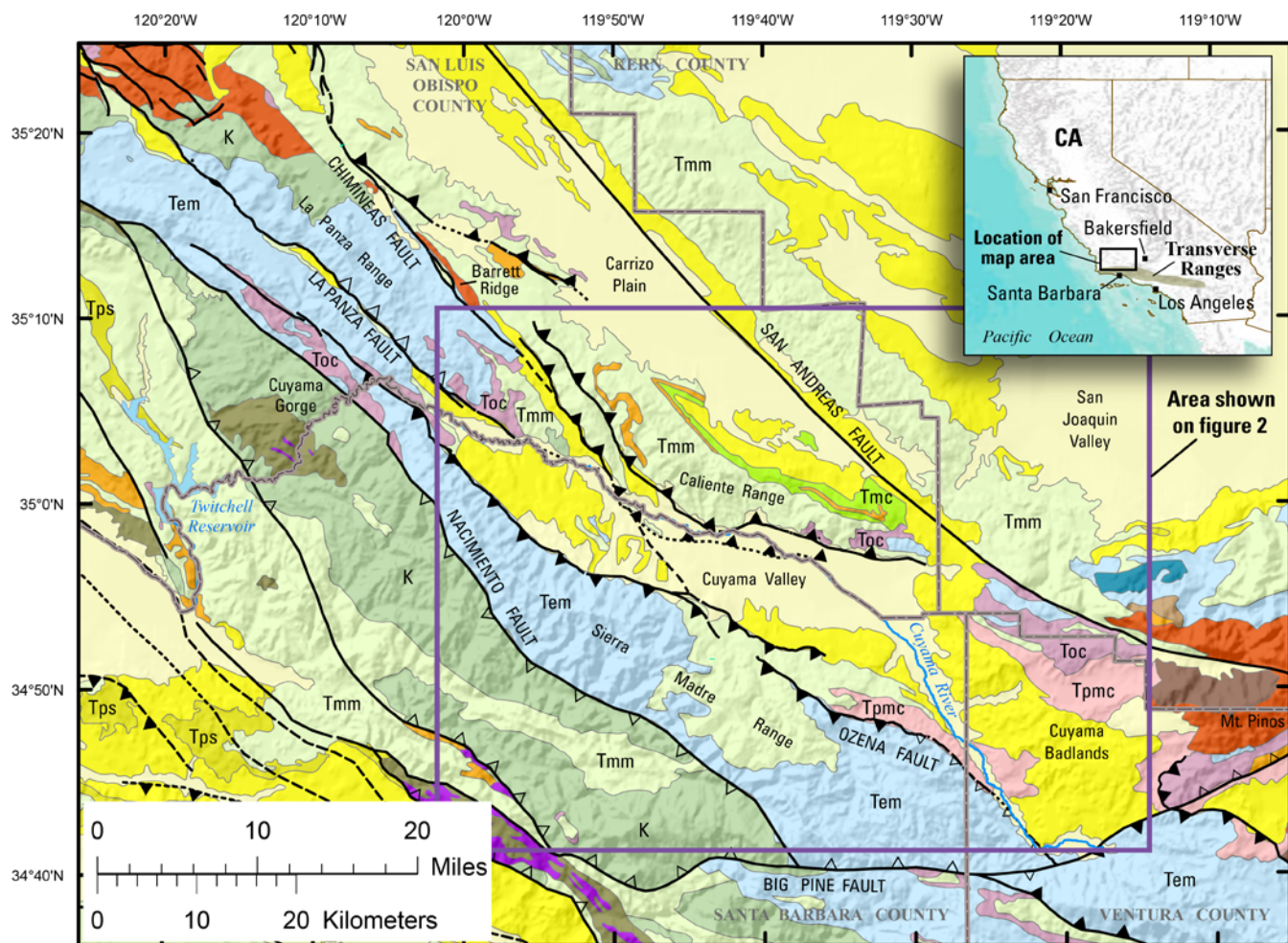
APPENDIX K1

Figures K1-A, K1-B, and K1-C

The following three figures are reproduced from Sweetkind et. al, 2013 and Everett et. al 2013 (full citations below). In this Basin Boundary Modification Application, Figure K1-A and K1-B refer to Figures 1 and 2, respectively, in Sweetkind et. al 2013; Figure K-1C refers to Figure 2 in Everett et. al 2013.

References

- Everett, R.R., Gibbs, D.R., Hanson, R.T., Sweetkind, D.S., Brandt, J.T., Falk, S.E. and Harich, C.R., 2013, *Geology, water-quality, hydrology, and geomechanics of the Cuyama Valley groundwater basin, California, 2008–12: U.S. Geological Survey Scientific Investigations Report 2013–5108*, 62 p.
- Sweetkind, D.S., Bova, S.C., Langenheim, V.E., Shumaker, L.E., and Scheirer, D.S., 2013, Digital tabulation of stratigraphic data from oil and gas wells in Cuyama Valley and surrounding areas, central California: U.S. Geological Survey Open-File Report 2013–1084, 44 p., <http://pubs.usgs.gov/of/2013/1084/>.



Shaded relief base created from 30-m digital elevation model from USGS National Elevation Dataset (NED); North American Vertical Datum 1983 (NAVD83). Hydrology sourced from 1:24,000-scale National Hydrography Dataset, 1974-2009. Place names sourced from USGS Geographic Names Information System, 1974-2009. Albers Projection, NAD83

Geology compiled from Saucedo and others (2000) and Kellogg and others (2008)

EXPLANATION

Quaternary sediments	Tem Eocene marine rocks	Fault, certain
Quaternary and Pliocene sediments	K Cretaceous marine rocks	Fault, inferred based on subsurface data
Tps Pliocene sediments	Mesozoic granitic rocks	Fault, concealed
Tpmc Pliocene and Miocene continental rocks	Mesozoic Franciscan Complex	Thrust fault, certain
Tertiary volcanic rocks	Serpentine within Franciscan Complex	Thrust fault, concealed
Tmc Miocene continental rocks	Mesozoic and Paleozoic ultramafic rocks	Reverse fault, certain
Tmm Miocene marine rocks	Paleoproterozoic granitic gneiss and Paleocene Pelona Schist	Reverse fault, concealed
Toc Oligocene continental rocks	Water	River
		County boundary

Figure 1. Generalized geologic map of the Cuyama Basin and surrounding region.

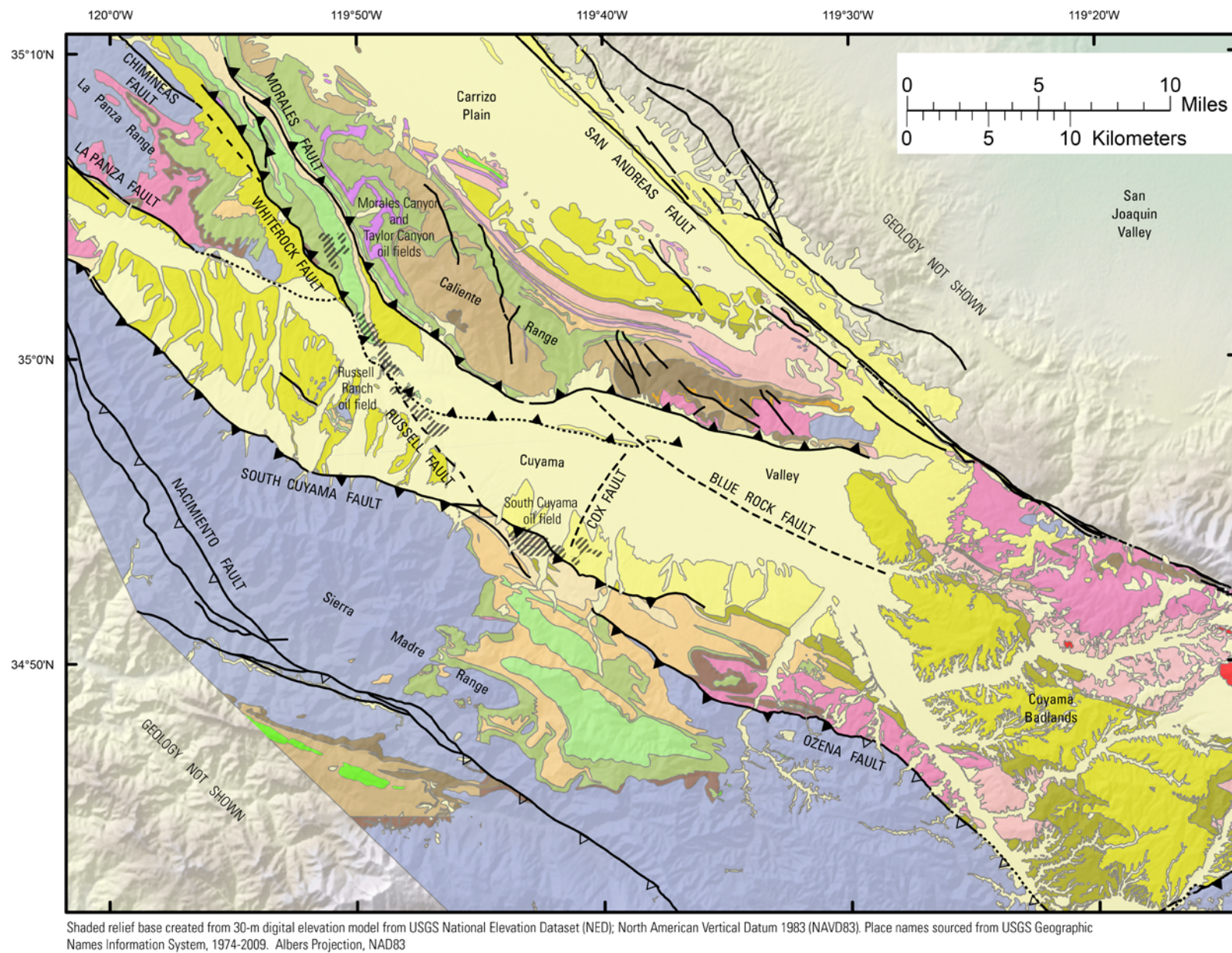


Figure 2. Geologic map of Cuyama Valley and surrounding ranges.

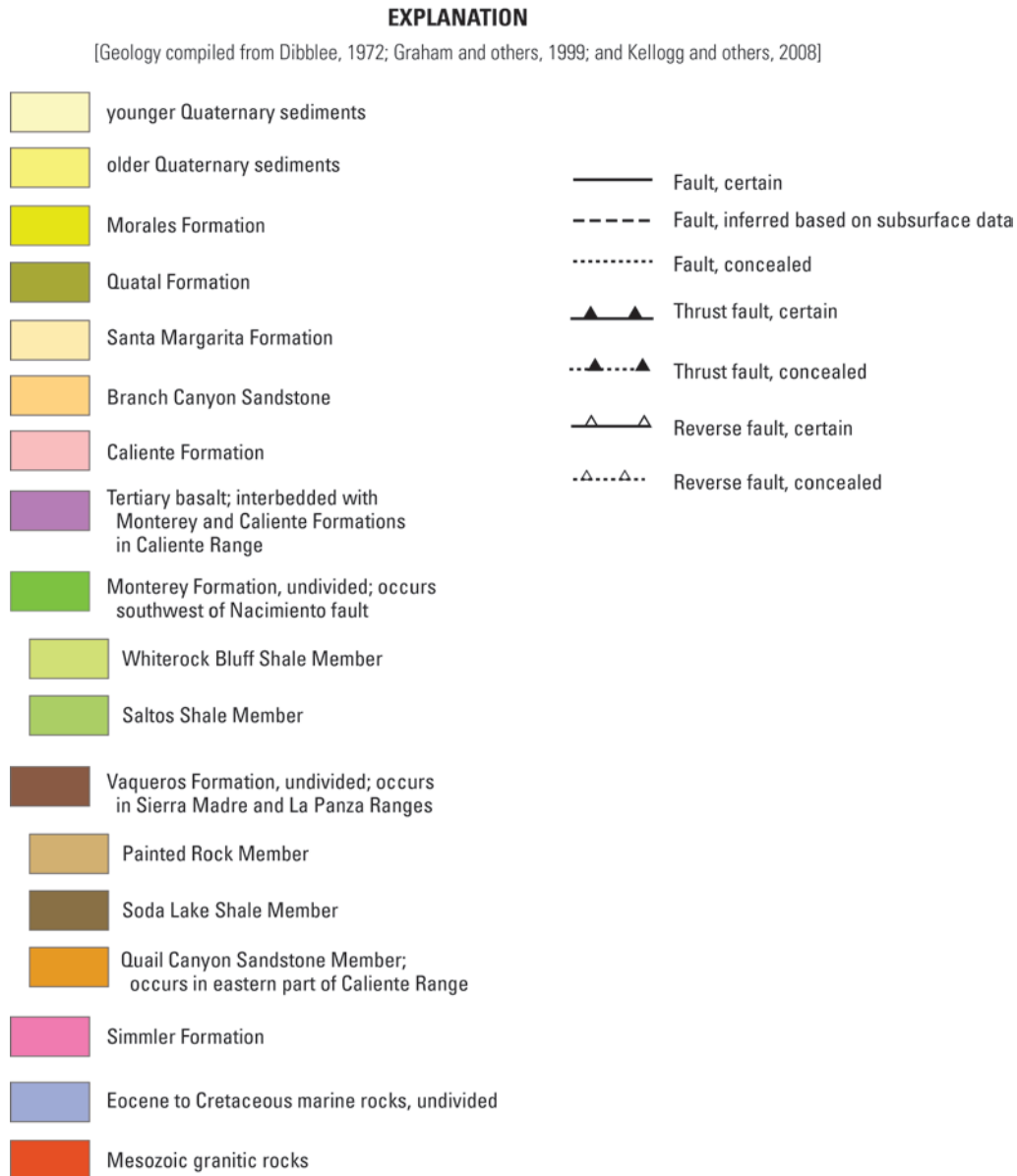
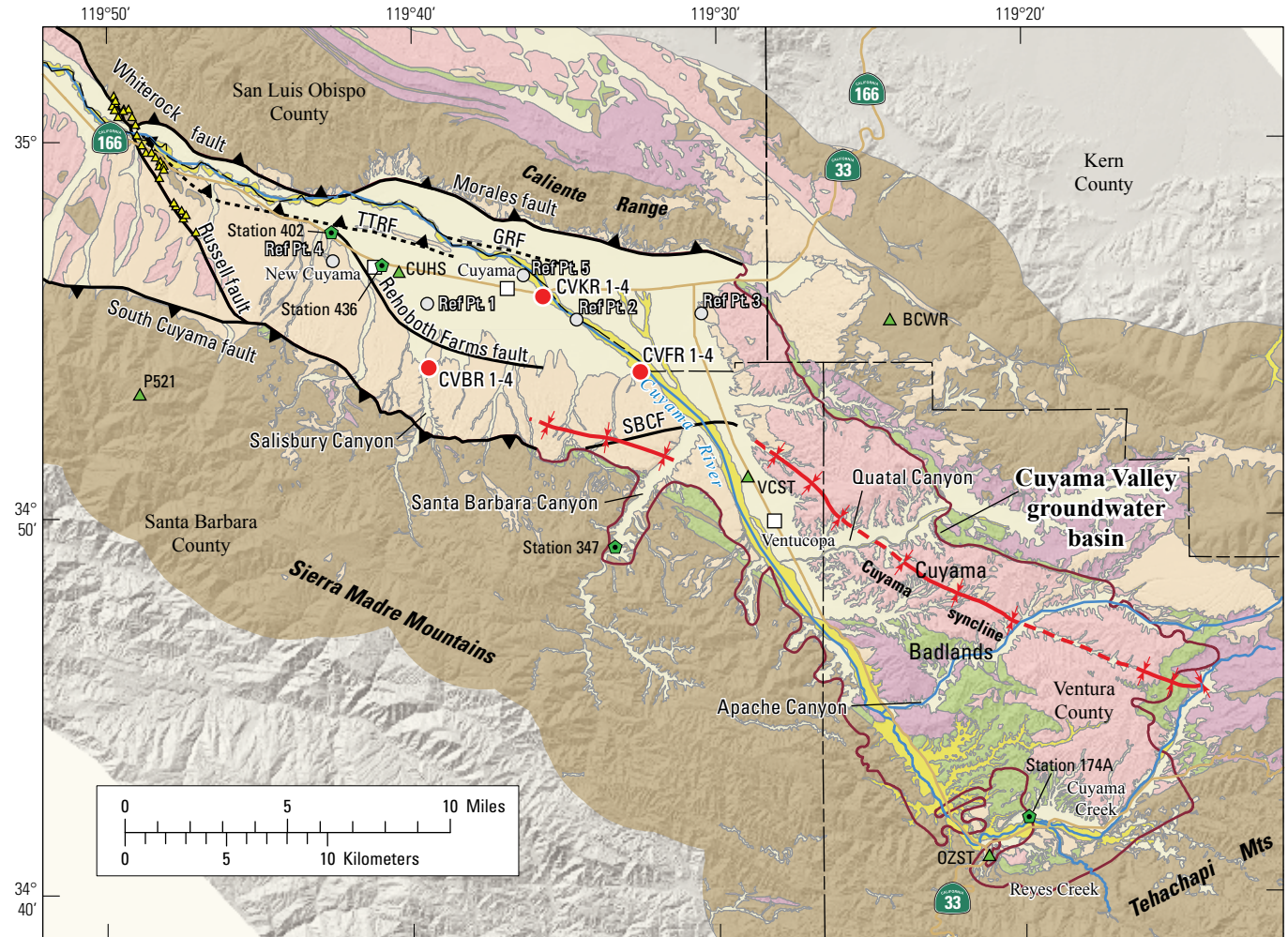


Figure 2—Continued. Geologic map of Cuyama Valley and surrounding ranges.

Geologic Setting

Stratigraphy

Cuyama Valley is underlain by a sequence of unconsolidated to partly consolidated nonmarine deposits including Pleistocene to Holocene alluvial and fluvial deposits and the underlying Pliocene and Pleistocene Morales Formation (Upson and Worts, 1951; Hill and others, 1958; Dibblee, 1982; DeLong and others, 2008; Kellogg and others, 2008). These deposits overlie an Upper Cretaceous to Neogene succession of consolidated marine and nonmarine sedimentary rocks, which themselves overlie crystalline granitic and gneissic rocks (Hill and others, 1958; Schwade and others, 1958; Lagoe, 1987) (figs. 2 and 3). This general stratigraphic succession is exposed in the La Panza Range and dips to the southeast towards Cuyama Valley (fig. 1).



Shaded relief base created from 30-m digital elevation model from USGS National Elevation Dataset (NED); North America Vertical Datum 1988 (NAVD88)
Hydrology sourced from 1:24,000-scale National Hydrography Dataset, 1974–2009
Place names sourced from USGS Geographic Names Information System, 1974–2009
Albers Projection, NAD83

Geology from: Kellogg and others, 2008, and Graham and others, 1999

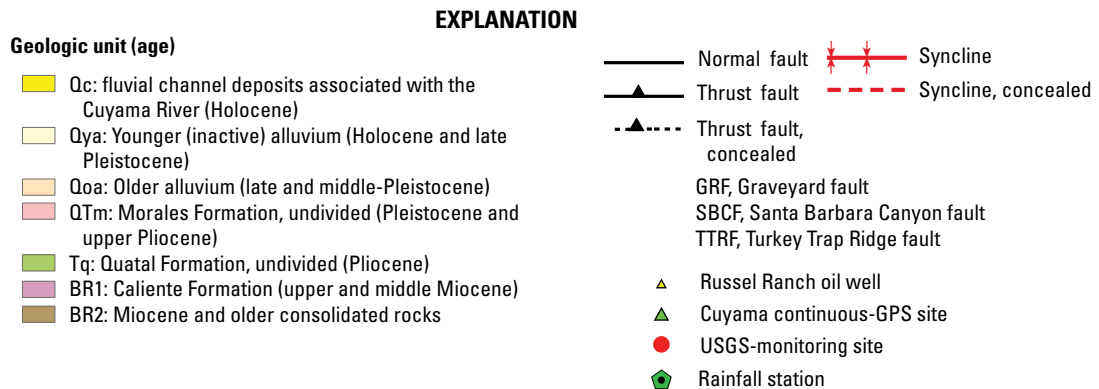


Figure 2. Geologic formation outcrops, faults, folds, InSAR reference points, continuously operating GPS stations, oil wells, and rainfall stations, Cuyama Valley, Santa Barbara County, California.